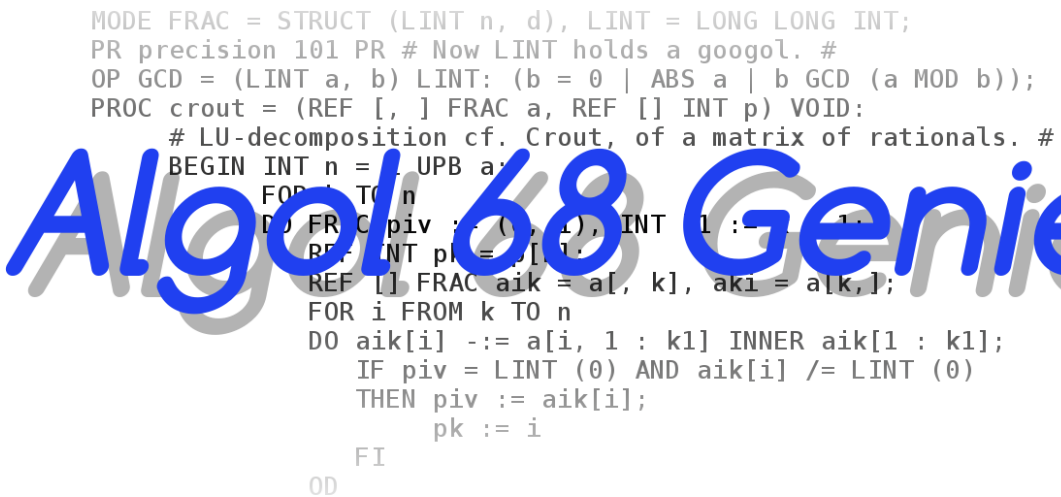
Learning



Algol 68 Genie

Algol 68 Genie 3.12

Edited by Marcel van der Veer

Learning Algol 68 Genie is a compilation of separate and independent documents or works, consisting of the following parts:

I. Informal introduction to Algol 68,

II. Programming with Algol 68 Genie,

III. Example programs,

IV. Algol 68 Revised Report,

V. Appendices

Edition from May 2026, typeset in LaTeX.

Table of contents

Preface

{Les inventions qui ne sont pas connues ont toujours plus de
censeurs que d'approbateurs.
Lettres dédicatoires à Monsieur le Chancelier. Blaise Pascal. }

Learning Algol 68 Genie is distributed with Algol 68 Genie, an open source Algol 68 hybrid compiler-interpreter that can be used for executing Algol 68 programs or scripts. Algol 68 Genie is a new implementation written from scratch, it is not a port of a vintage implementation. This publication corresponds to Algol 68 Genie Version 3.12. Algol 68 Genie implements practically full Algol 68 as defined by the Revised Report, and extends that language to make it particularly suited to scientific computations. This publication provides an informal introduction to Algol 68, a manual for Algol 68 Genie, and a LaTeX translation of the Revised Report on Algol 68. It describes how to use Algol 68 Genie, as well as its features and incompatibilities, and how to report bugs. Algol 68 Genie is open source software. The license for Algol 68 Genie is the GNU GPL {C}.

The development of Algol was an international platform for discussing programming languages, compiler - and program construction, et cetera, and stimulated computer science as an academic discipline in its own right. The preservation of Algol 68 is important from both an educational as well as a scientific-historical point of view. Algol 68 has been around for five decades, but some who rediscovered it in recent years, well aware of how the world has moved on, had a feeling best described as *plus ça change, plus c'est la même chose*. One of the reasons for this is that Algol 68 introduced a number of concepts that are now common, for example structured and united values, the possibility to define new types and operators on them, et cetera.

A more or less comprehensive list of reasons for the continuing interest in Algol 68 { and preservation of the language } would be:

- *Importance to the history of science.* As already indicated, the development of Algol played a role in establishing computer science as an academic discipline in its own right. Algol 68 was designed by a learned committee whose meeting accounts show that there was, at times vigorous, debate before Algol 68 was presented. The influence of Algol is still tangible since it is to this day referred to in teaching material, discussions and publications. Therefore, knowledge of Algol is required to understand the current status of computer science.

- *Academic interest.* People interested in the design and formal specification of programming languages, such as students of computer science, should at an appropriate moment study Algol 68 to understand the influence it had. Algol 68 lives on not only in the minds of people formed by it, but also in other programming languages, even though the orthogonality in the syntax, elegance and security has been mostly lost.
- *Practical interest.* Algol 68 has high expressive power that relieves you from having to write all kind of irrelevant technicalities inherent to programming in many other languages. For programmers, the world has of course moved on, but the reactions to Algol 68 Genie suggest that many people who have seriously programmed in Algol 68 in the past, only moved to other programming languages because the Algol 68 implementations they were using were phased out. Algol 68 is a beautiful means to denote algorithms and it still has its niche in programming small to medium sized applications for instance in the field of mathematics, or numerical applications in physics - or chemistry problems.

Though Algol 68 did not spread widely in its day, it introduced innovations that are relevant up to the present. Its expressive power, and its being oriented towards the needs of programmers instead of towards the needs of compiler writers, may explain why, since Algol 68 Genie became available under GPL, many appeared interested in an Algol 68 implementation, the majority of them being mathematicians or computer scientists. Some still run proprietary implementations. Due to this continuing interest in Algol 68 it is expected that people will be interested in having access to documentation on Algol 68, but nowadays most material is out of print. Even if one can get hold of a book on Algol 68, it will probably not describe Algol 68 Genie since this implementation is most likely younger than such book.

The formal defining document, the Algol 68 Revised Report, is also out of print but a LaTeX version comes with this publication. The Revised Report ranks among the difficult publications of computer science and is therefore not suited as an *informal* introduction. In fact, it has been said that at the time Algol 68 was presented some fifty years ago, the complexity of the Revised Report made some people who allegedly did not *use* Algol 68 believe that the language itself would be complex as well. That misconception has persisted up to this day - Algol 68 would be "difficult", "complex" or even "bloated". After reading this publication you will likely agree that Algol 68 is in fact a relatively lean language that is quite easy to use.

This publication consists of original Algol 68 Genie documentation and material from various free or open source publications {A.1} that have been edited and blended to form a consistent, new publication. This text is in the first place documentation for Algol 68 Genie; it is neither an introduction to programming nor a textbook for a course in computer science. Parts I through III are a comprehensive introduction into programming with Algol 68 Genie. Since Algol 68 is nowadays not commonly known and the Revised Report is terse, it is desirable to have an informal introduction in this documentation. I am aware that this creates some unevenness in the set-up and level of this publication, but if you

succeed in programming in Algol 68 using this text, then the objective of this publication is met.

Algol 68 Genie

The language described in Parts I through III of this publication is that implemented by Algol 68 Genie available from:

https://algol68genie.nl/

This page also posts a prebuilt `WIN64` binary for Microsoft Windows 11.

Prebuilt binaries are available from:

https://sourceforge.net/projects/algol68/

but also from for instance Debian (stable), Ubuntu (universe) or OpenBSD (ports) repositories.

Please consider joining the Algol 68 user group at LinkedIn:

https://www.linkedin.com/groups/2333923

Marcel van der Veer is author and maintainer of Algol 68 Genie. Algol 68 Genie implements practically all of Algol 68, and extends that language. To run the programs described in this publication you will need a computer with Linux or a compatible operating system, or Microsoft Windows 11. You will run `a68g` from the command line, hence from a terminal emulator on Linux, or for example `powershell` on Windows 11. Chapter 10 describes how you can install Algol 68 Genie on your system, and how you can use it.

Algol 68 Genie is open source software distributed under GNU GPL. This software is distributed in the hope that it will be useful, but **without any warranty**. Consult the GNU General Public License[1] for details. A copy of the license is in this publication.

Algol 68 Genie version 1 was an interpreter. It constructed a syntax tree for an Algol 68 program and the interpreter executed this syntax tree. As of version 2 and on Linux or compatible[2] operating systems, Algol 68 Genie can run in optimising mode, in which it employs a **unit** compiler that emits C code for many **units** involving operations on primitive modes `INT`, `REAL`,`BOOL`,`CHAR` and `BITS` and simple structures thereof such as `COMPLEX`. Execution time of such **units** by interpretation is dominated by interpreter overhead, which makes compilation of these units worthwhile. Generated C code is compiled and dynamically linked before it is executed by Algol 68 Genie. Technically, the compiler synthesizes per selected **unit** efficient routines compounding elemental interpreter routines needed to exe-

[1] See https://www.gnu.org/licenses/gpl.html.

[2] *Compatible* means here that the operating system must have a mechanism for dynamic linking that works the same as on Linux.

cute terminals in the syntax tree; compounding allows for instance common sub-expression elimination. Generated C code is compatible with the virtual stack-heap machine implemented by the interpreter proper, hence generated code has full access to `a68g`'s runtime library and the interpreter's debugger. Many runtime checks are disabled in optimising mode for the sake of efficiency. Therefore, it is recommended to only specify optimisation for programs that work correctly. Due to overhead, optimisation is not efficient for programs with short execution times, or *run-once* programs typical for programming course exercises.

Conventions in this publication

Algol 68 source code is typeset in fixed-space font like this:

```
#
Takeuchi's Tarai (or Tak) function. Moore proved its termination.
See mathworld.wolfram.com/TAKFunction.html
#

PROC tak = (INT i, j, k) INT:
  IF i <= j
  THEN j
  ELSE tak (tak (i - 1, j, k), tak (j - 1, k, i), tak (k - 1, i, j))
  FI;
```

Sometimes code is substituted with `...` when it would not be relevant to the explanation at hand, as in for instance:

```
PROC tak = (INT i, j, k) INT: ...
```

In this publication, `a68g` output is typeset as:

```
$ a68g hello.a68
Hello, world!
```

Throughout the text you will find references to other sections; for instance {1.1} refers to section 1.1 and {A} refers to appendix A. This publication contains references that are listed in the *Bibliography*. A format as [Mailloux 1978] means the entry referring to work of Mailloux, published in the year 1978. An indication `AB39.3.1` means ALGOL BULLETIN, volume 39, article 3.1. The ALGOL BULLETIN is still available on the internet. On various places in Parts I through III you will see references to the Revised Report in Part IV formatted as for example {26_{10}.1.1.A} referring you to chapter 26, section 1.1(.1), mark A, where the chapter number refers to Part IV, while its suffix refers to the chapter number in the original Revised Report.

Organisation of this publication

Part I. Informal introduction to Algol 68

- Chapter 1 *Preliminaries* gives a brief history of Algol 68 and introduces a notation for production rules.
- Chapter 2 *Basic concepts* introduces standard modes representing plain values (integers, reals, booleans and characters), as well as variables. This chapter also explains **formulas** involving **operands** of standard modes.
- Chapter 3 *Stowed and united modes* describes ordered sets of values like rows and structures, and also united modes. It explains how to extract sub rows from a row, how to select a diagonal in a matrix, et cetera. This chapter also shows how to group objects into structures. `STRING` and `COMPLEX` are introduced.
- Chapter 4 *Program structure* describes conditional and case constructs that let you control program flow depending on the value of boolean or integer conditions. It also describes loops.
- Chapter 5 *Procedures and operators* explains how to declare procedures and operators. This chapter brings together recursion and data structures and is a demonstration of Algol 68's expressive power. This chapter also describes partial parametrisation. `a68g` is one of the few Algol 68 implementations to implement partial parametrisation.
- Chapter 6 *Modes, contexts and coercions* explains which modes are well-formed, and which modes are equivalent. This chapter also summarises the "strengths" that different syntactic positions have and the mode coercions allowed in each one.
- Chapter 7 *Transput* is about transput which is an Algol 68 term for input-output. Formatted transput is described in this chapter.
- Chapter 8 *Context-free grammar* provides a reference for context-free Algol 68 Genie syntax. This in contrast to the Revised Report, which describes a context-sensitive syntax for Algol 68.

Part II. Programming with Algol 68 Genie

- Chapter 9 *Description of Algol 68 Genie* describes the Algol 68 Genie.
- Chapter 10 *Installing and using Algol 68 Genie* describes how to install the program on your computer and how to use it.
- Chapter 11 *Standard prelude and library prelude* is an extensive description of the standard prelude and library prelude. Standard Algol 68 predefines a plethora of

operators and procedures. Algol 68 Genie predefines many operators and procedures in addition to those required by the standard prelude, that form the library prelude. This chapter documents these extensions.

Part III. Example programs

- Chapter 12 *Example programs* lists a number of `a68g` **programs** to demonstrate the material covered in this publication.

Part IV. Revised report on Algol 68

- Chapters 13—28 constitute a LaTeX translation of the revised report on Algol 68. This report ranks among the difficult publications in computer science.

Part V. Appendices

- Appendix A *Bibliography* has references and suggestions for further reading.
- Appendix B *Reporting bugs* gives information on how and where to report bugs in Algol 68 Genie or in this publication.
- Appendix C *GNU General Public License* is a copy of `a68g`'s license.
- Appendix D *GNU Free Documentation License* is a copy of the license for parts I, II and IV of this publication.

Acknowledgements

{Were I to await perfection, my book would never be finished.
Tai T'ung, 13^{th} century. }

Thanks go to the following people who were kind enough to report bugs and obscurities, propose improvements, provide documentation, encourage me, or contribute in another way. In alphabetical order:

Mark Alford, Bruce Axtens, Maciej Barć, Ewan Bennett, Lennart Benschop, Andrey Bergman, Jaap Boender, Bart Botma, Colin Broughton, Brian Callahan, Paul Cartwright, Paul Cockshott, Barry Cook, Jürgen Dabel, Nikita Danilov, Huw Davies, Neville Dempsey, Koos Dering, Alexey Dokuchaev, Jón Fairbairn, Tomas Fasth, Sergey Fedorov, Jeremy Frey, Scott Gallaher, Boris Gärtner, Jeremy Gibbons, Oleg Girko, Mayer Goldberg, Shaun Greer, Dick Grune, Keith Halewood, Norman Hardy†, Chap Harrison, Jim Heifetz, Andrew Herbert, Chris Hermansen, Lex Herrendorf, Carlos Horný, Daniel James, Patrik Jansson, Helmut Jarausch, Trevor Jenkins, James Jones, Rob Jongschaap, Richard O'Keefe, Henk Keller[3]†, Wilhelm Kloke, Erwin Koning, Kees Koster†, Has van der Krieken, Ilya Kurdyukov, Jonathan Lane, Paul Leyland, Karolina Lindqvist, Charles Lindsey†, Patrick Linnane, Isobel Mailloux, Floris van Manen, José Marchesi, Neil Matthew, John Maybury, Paul McJones, Lionel Moisan, Sian Mountbatten, Robert Nix, Raymond Nijssen, Filon Oikonomou, Lawrence D'Oliveiro, France Pahlplatz, Jason Pandolfo, Janis Papanagnou, Lasse Hillerøe Petersen, Steven Pemberton, Charles Penman, Richard Pinch, Omar Polo, Ben Potter, Ivan Prpic, Hannu-Heiki Puupponen, Henk Robbers, Pedro Rodrigues de Almeida, Tom Rushworth, Alexej Saushev, Marc Schooldergang, Olaf Seibert, David Sherratt, Rubin Simons, Eli Soli, Doaitse Swierstra†, Philip Taylor, Chris Thomson, Valeriy Ushakov, Robert Uzgalis, Adam Vandenberg, Bruno Verlyck, Nacho Vidal García, Merijn Vogel, Eric Voss, Theo Vosse, Peter de Wachter, Andy Walker, Jim Watt, Glyn Webster, Ron Westdijk, Sam Wilmott, Lee Wittenberg, Thomas Wolff and Tom Zahm.

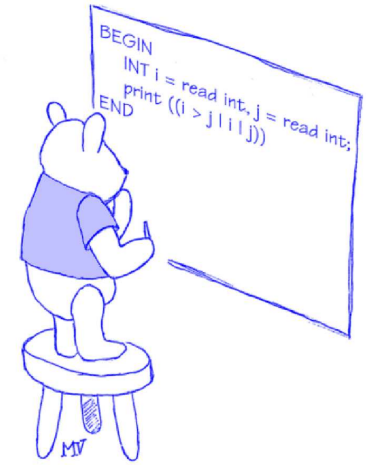
The Algol 68 Genie project would not be what it is without their help.

Marcel van der Veer
Uithoorn, May 2026

[3]Henk Keller encouraged me to distribute Algol 68 Genie as open source software.

Biography

Marcel van der Veer is the author, maintainer and copyright holder of Algol 68 Genie and its documentation. He holds a MSc in Chemistry from the University of Nijmegen and a PhD in Applied Physics from the University of Twente.



During his academic years, he worked with `ALGOL68C` and `FLACC` on IBM and compatible mainframes, and also with `ALGOL68RS` on large VAXen. Probably because chemists and physicists tend to take a pragmatic approach towards computer science, Marcel was undeterred to write his own Algol 68 implementation when Algol 68 compilers were phased out when computer facilities were decentralised in the 1990's — Algol 68 typically was a mainframe language.

Marcel started development of Algol 68 Genie in 1992, and decided to release it under GNU General Public License in 2001.

I

Informal introduction to Algol 68

1 Preliminaries

{Languages take such a time, and so do
all the things one wants to know about.
The Lost Road. John Tolkien. }

1.1 A brief history of programming languages

As to better understand the position of Algol 68 among today's plethora of programming languages, we should consider the development of modern programming languages.

In the period 1950-1960 a number of programming languages evolved, the descendants of which are still widely used. The most notable are Fortran by Backus et al., Lisp by McCarthy et al., Cobol by Hopper et al. and Algol 60 by a committee of European and American academics including Backus. Algol 60 was particularly influential in the design of later languages since it introduced nested block structure, lexical scope, and a syntax in Backus-Naur form (BNF). Nearly all subsequent programming languages have used a variant of BNF to describe context-free syntax.

At the time of the development of Algol 68, programming languages were required to serve two purposes. They should provide concepts and statements allowing a precise formal description of computing processes and facilitate communication between programmers, and they should provide a tool to solve small to medium-sized problems without specialist help. The context of Algol 68's development is perhaps adequately illustrated by a quote[1] from Edsger Dijkstra: *The intrinsic difficulty of the programming task has never been refuted . . . I vividly remember from the late 60's the tendency to blame the programming languages in use and to believe in all naivety that, once the proper way of communicating with the machines had been found, all programming ills would have been cured.*

The early procedural languages served above purposes required for them. However, the evolving need to build complex interactive systems asked for decomposition of a problem into "natural" components, resulting in object oriented programming languages starting

[1] Transcript from keynote delivered at the ACM 1984 South Central Regional Conference. Source: E. W. Dijkstra Archive - the manuscripts of Edsger W. Dijkstra; https://www.cs.utexas.edu/users/EWD/.

as early as the 1960's. The object oriented and procedural paradigms each have strengths and weaknesses and it is not always clear which paradigm is best suited to certain tasks, even large ones. In numerical and scientific computing for instance, the benefit of object oriented languages over procedural languages is controversial since in number crunching, efficiency is a top priority.

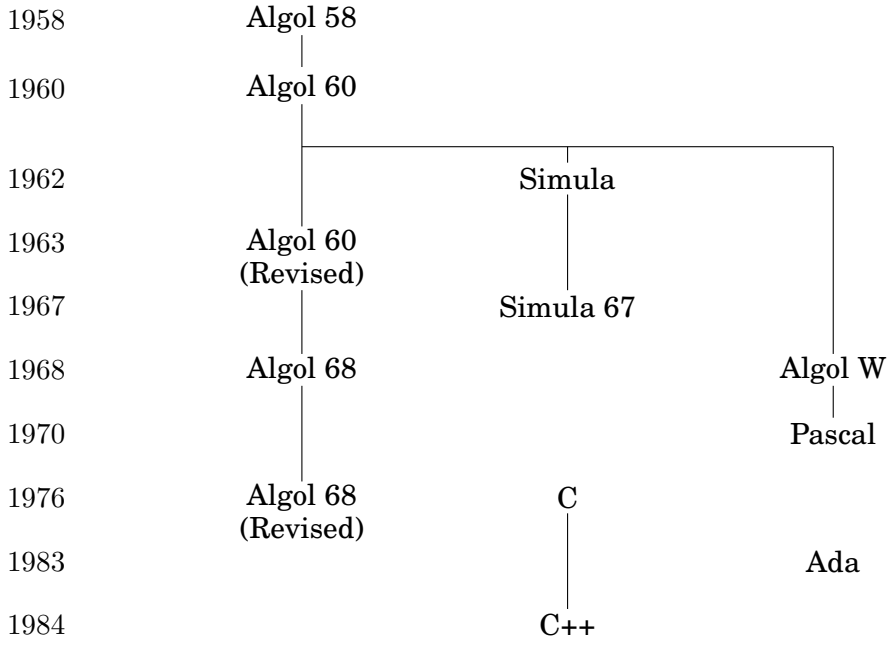
The period 1960 to 1980 produced most of the major language paradigms now in use. Algol 68 was conceived as a successor to Algol 60. Its syntax and semantics became even more orthogonal and were defined by a Van Wijngaarden grammar, a formalism designed specifically for this purpose. Simula by Nygaard and Dahl was a superset of Algol 60 supporting object oriented programming, while Smalltalk by Kay, Ingalls and Kaehler, was a newly designed object oriented language. C, the Unix system programming language, was developed by Ritchie and Thompson at Bell Laboratories between 1969 and 1973. Prolog by Colmerauer, Roussel, and Kowalski was the first logic programming language. ML by Milner built a polymorphic type system on top of Lisp, pioneering statically typed functional programming languages. Each of these languages spawned a family of descendants, and most modern languages count at least one of them in their ancestry. Other important languages that were developed in this period include Pascal, Forth, Scheme and SQL.

The decade 1980-1990 saw consolidation of imperative languages. Rather than introducing new paradigms, ideas from the 1970's were elaborated. C++ combined object oriented programming and system programming. The United States government standardised Ada as a system programming language for defense contractors. Mainly in Japan major efforts were spent investigating so-called fifth-generation programming languages that incorporated logic programming constructs. The functional languages community standardised ML and Lisp. Research in Miranda, a functional language with lazy evaluation, began to take hold in this decade. An important trend in 1980's language design was increased focus on programming large-scale systems through the use of modules, reflected in the development of Modula, Ada and ML. Although major new paradigms for imperative languages did not appear, many researchers elaborated on existing ideas, for example object oriented programming, and adapting them to new contexts, for example to distributed systems. Some other notable languages from the 1980's are Objective C and Perl.

During the 1990's recombination and maturation of existing ideas continued. An important motivation in this period was productivity. Many *rapid application development* (RAD) languages emerged, which usually were descendants of older, typically object oriented, languages that were equipped with an IDE and garbage collection. These languages included Object Pascal, Visual Basic, and Java. Java in particular received much attention. More radical and innovative were new scripting languages. These did not directly descend from other languages and featured new syntax and liberal incorporation of features. Many consider these scripting languages as more productive than RAD languages, though others will forward that scripting languages may make small programs simpler but large programs are more difficult to write and maintain. Nevertheless, scripting languages came to be the most prominent ones used in connection with the internet. Some important languages that were developed in the 1990's are Haskell, Python and PHP.

Some current trends in programming languages are mechanisms for security and reliability verification, alternative mechanisms for modularity, component-oriented software development, constructs to support concurrent and distributed programming, metaprogramming, and integration with databases. The 21^{th} century has to date seen the introduction of for example C#, Visual Basic.NET and Go.

Algol 68 can be placed in the history of programming languages more or less as in below diagram. Note that some languages like Euler are not mentioned in this diagram. Some claim that Ada is Algol 68's successor but many dispute that. Therefore Ada is mentioned in above diagram, but there is no line drawn from Algol 68 to Ada. An overview of the development of Algol, and implementations, can be found at Paul McJones's page {A}.



1.2 A brief history of Algol 68

Algol, *ALGOrithmic Language*, is a family of imperative computer programming languages which greatly influenced many other languages and became the *de facto* way algorithms were described in textbooks and academic works for almost three decades. The two specifications relevant to this publication are Algol 60, revised in 1963, and Algol 68, revised in 1976. Algol 58, originally known as IAL (*International Algebraic Language*), was an early member of the Algol family soon superseded by Algol 60. Algol 58 introduced a compound statement which was restricted to flow of control only and did not relate to lexical scope as do Algol 60's blocks.

Ideally, a programming language supports systematic expression of algorithms by offering appropriate control structures and data structures, and a precise, consistent formal definition to avoid surprises and portability issues resulting from obscure details that are left to the discretion of an implementation; for example the number of implementation-defined features in the C standard is notorious. Members of the Algol family (Algol 60 and Algol 68, Simula, Pascal and also Ada, et cetera) are considered reasonable approximations of such "ideal" languages, although all of them have strong points as well as disadvantages. Algol 68 offers appropriate means of abstraction and exemplary control structures that leads to a good understanding of programming. Its orthogonality results in an economic use of language constructs making it a beautiful means to write algorithms.

The design of Algol was firmly rooted in the *computing community*, a contemporary term for the small but growing international community of computer professionals and scientists. It formed an international platform for discussing programming languages, compiler construction, program construction, et cetera, and thus Algol had an important part in erecting computer science as an academic discipline in its own right. Algol 60 was designed by and for numerical mathematicians; in its day it was the *Lingua Franca* of computer science. The language introduced block structure with lexical scope and a concise BNF definition that were appreciated by people with a background in mathematics, but it lacked compilers and industrial support which gave the advantage to languages as Fortran and Cobol. To promote Algol, its application range had to be extended. IFIP[2] Working Group 2.1 *Algorithmic Languages and Calculi* (WG 2.1), that to this day has continuing responsibility for Algol 60 and Algol 68, assumed the task of developing a successor to Algol 60.

In the early 1960's WG 2.1 discussed this successor and in 1965 descriptions of a language Algol X based on these discussions were invited. This resulted in various language proposals by Wirth, Seegmüller and Van Wijngaarden[3] and other significant contributions by Hoare and Naur. Van Wijngaarden's paper *Orthogonal design and description of a formal language*[4] featured a new technique for language design and definition and formed the basis for what would develop into Algol 68. Many features found in Algol 68 were first proposed in ALGOL BULLETIN by the original authors of Algol 60 like Peter Naur, by new members of WG 2.1 like Tony Hoare and Niklaus Wirth, and by many others from the world-wide computing community.

[Koster 1996] gives a first hand account of the events leading to Algol 68. Algol 68 has had a large influence on the development of programming languages since it addressed many issues; for example orthogonality, a strong type system, procedures as types, memory

[2]IFIP, the International Federation for Information Processing is an umbrella organisation for national information processing organisations. It was established in 1960 under the auspices of UNESCO.

[3]Adriaan van Wijngaarden (1916 - 1987) is considered by many to be the founding father of computer science in the Netherlands. He was co-founder of IFIP and one of the designers of Algol 60 and later Algol 68. As leader of the Algol 68 committee, he made a profound contribution to the field of programming language design, definition and description.

[4]Available from [Karl Kleine's collection].

management, treatment of arrays, a rigorous description of syntax, and parallel processing, but also ideas that caused debate over the years such as context-sensitive coercions and quite complicated input-output formatting. After various meetings WG 2.1 had not reached unanimous consent. Algol 68 was eventually produced by members who wanted a new milestone in language design. Other members, notably Wirth and Hoare, wanted to shorten the development cycle by improving Algol 60, which eventually produced Algol W and later Pascal. Yet other members wrote a brief *minority report* outlining their view on a new language; many years later it was commented that no programming language developed since would have satisfied that vision.

Where Algol 60 syntax is in BNF form, Algol 68 syntax is described by a two-level W-grammar ('W' for Van Wijngaarden) that can define a context-sensitive grammar. Formally, in a context-sensitive grammar the left-hand - and right-hand side of a production rule may be surrounded by a context of terminal and nonterminal symbols. The concept of context-sensitive grammar was introduced by Chomsky in the 1950's to describe the syntax of natural language where a word may or may not be appropriate in a certain position, depending on context. Analogously, Algol 68 syntax can rigorously define syntactic restrictions; for example, demanding that **applied-identifiers** or operators be declared, or demanding that modes result in finite objects that require finite coercion, et cetera. To enforce such syntactic constrictions, a context-free syntax must be complemented with extra rules formulated in natural language to reject incorrect **programs**. This is less elegant, but defining documents for programming languages with a context-free grammar do look less complex than the Algol 68 (revised) report — compare the context-free Algol 68 Genie syntax in chapter 8 to the Revised Report syntax in Part IV.

Probably because of the formal character of the Revised Report, which requires study to comprehend, the misconception got hold that Algol 68 is a complex language, while in fact it is rather lean. [Koster 1996] states that the alleged obscurity of description is denied by virtually anyone who has studied it. Perhaps it only made the impression of being complex at the time of its introduction around 1970, since one may argue that the specification of many contemporary languages, including that of modern `C`, is more complex than that of Algol 68 [Henney 2018]. Algol 68 was defined in a formal document, first published in January 1969, and later published in Acta Informatica and also printed in Sigplan Notices. A Revised Report was issued in 1976; this publication includes a LaTeX translation. Algol 68 was the first major language for which a full formal definition was made before it was implemented. Though known to be terse, the Revised Report does contain humour *solis sacerdotibus* — to quote from [Koster 1996]: *The strict and sober syntax permits itself small puns, as well as a liberal use of portmanteau words. Transput is input or output. 'Stowed' is the word for structured or rowed. Hipping is the coercion for the hop, skip and jump.* `MOID` *is* `MODE` *or* `void`*. All metanotions ending on* `ETY` *have an empty production. Just reading aloud certain lines of the syntax, slightly raising the voice for capitalized words, conveys a feeling of heroic and pagan fun (...) Such lines cannot be read or written with a straight face.*

Algol 68 was designed for programmers, not for compiler writers, in a time when the field

of compiler construction was not as advanced as it is today. Implementation efforts based on formal methods generally failed; Algol 68's context-sensitive grammar required some invention to parse[5]; consider for instance `x (y, z)` that can be either a **call** or a **slice** depending on the mode of `x`, while `x` does not need to be declared before being applied. At the time of Algol 68's presentation compilers usually were made available on mainframes by computing centres, which may explain why Algol 68 was popular in locations rather than areas, for instance Amsterdam, Berlin or Cambridge. It appears that Algol 68 was relatively popular in the United Kingdom, where the `ALGOL68R` , `ALGOL68RS` and `ALGOL68C` compilers were developed. Hence Algol 68 compilers were few and initiatives to commercialise them were relatively unsuccessful; for instance the `FLACC` compiler sold just twenty-two copies[6]. In the end industry did not pick it up — the market for new universal programming languages evidently did not develop as hoped for during the decade in which the language was developed and implemented. Algol 68 was not widely used, though the influence it had on the development of computer science is noticeable to this day. Interestingly, two other members of the Algol family, Pascal and Ada, still have their niches but also did not spread as widely as some may have hoped.

1.3 Notation of syntax

In Part I, a method to describe Algol 68 Genie syntax is used that closely follows the notation in Part IV, the Algol 68 Revised Report {16_1.3.2.2}. However, the syntax rules in Part I are context-free rules, while the Revised Report describes a context-sensitive W-grammar. In the Revised Report, production rules are derived from hyper-rules and metaproduction rules by substitution of notions (generally, bold upper-case words). This substitution mechanism is adopted in Part I to introduce a context-free grammar and will be explained in this section. We will forego the difference between hyper-rules, metaproduction rules and production rules since Part I does not introduce a context-sensitive grammar. Following conventions from the Revised Report are adopted:

(i) A syntactic notion is a bold word, with optional hyphens or blank space, for example **integral-denotation**. A notion that is to be substituted, generally is a bold upper-case word, for instance **UNITED**. To improve legibility syntactic notions are provided with hyphens, however in production rules they are mostly provided with blanks. Typographical display features, such as blank space, hyphen, and change to a new line or new page, are of no significance (but see 25_9.4.d). For instance, **integral denotation** means the same as **integral-denotation** or **integraldenotation**.

(ii) To write a plural form of a syntactic notion, the letter **s** is appended to its singular form, for instance **identifiers**. Also, the initial letter of a lower-case syntactic notion

[5] Algol 68 Genie employs a multi-pass scheme to parse Algol 68 [Lindsey 1993] {10.9}.

[6] Source: Chris Thomson, formerly with Chion Corporation, on `comp.lang.misc` [1988].

may be capitalised, for instance **Formulas** that would follow the production rule for **formula**.

(iii) Within a production rule, a reference as for example **identifier {8.6.2}** means that the notion **identifier** is defined in section 8.6.2.

(iv) A rule for a syntactic notion consists of the following items, in order:

- an optional asterisk ;
  {If a notion is preceded by an optional asterisk, the notion is not used in other rules and is used as an abstraction for its alternatives, for example:
  ***operand: monadic operand; dyadic operand.**}
- a non-empty bold notion N ;
- a **colon-symbol** ;
- a non-empty sequence of alternatives for N separated by **semicolon-symbols**; within an alternative, a **comma-symbol** means "is followed by".
- a **point-symbol**.

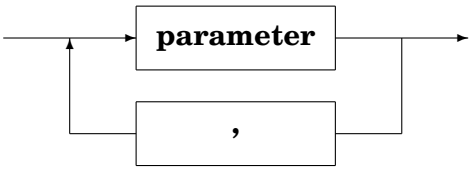
General production rules in Part I (but hyper-rules or metaproduction rules in the Revised Report), are:

- **EMPTY: .**
  This is the empty production.
- **NOTION list: NOTION; NOTION, comma {8.2} symbol, NOTION list.**
- **NOTION list proper: NOTION, comma {8.2} symbol, NOTION list.**
  A **list-proper** contains at least two **NOTIONs**.
- **NOTION option: NOTION; EMPTY.**
- **NOTION sequence: NOTION; NOTION, NOTION sequence.**
- **NOTION series: NOTION; NOTION, semicolon {8.2} symbol, NOTION series.**

For example, with above rules we can define **parameter-list-option** by substituting **NOTION** for **parameter-list** and **parameter** respectively to obtain:

- **parameter list option: parameter list; EMPTY.**
- **parameter list: parameter; parameter, comma {8.2} symbol, parameter-list.**

From this we see that a **parameter-list-option** is possibly empty, or possibly contains one **parameter** or multiple **parameters** separated by **comma-symbols**. Typically, in C and Pascal documentation, graphic syntax-diagrams are used to describe syntactic constructs; for instance a **parameter-list** would be depicted as:



Another example for a production rule is **MARKER frame**:

- **MARKER frame:**
  insertion option, replicator option, letter s {8.4} option, MARKER;

Viewing **MARKER** as a parameter, we can for instance deduce the production rule for a **letter-z-frame** by substituting **MARKER** for **z-frame**:

- **letter z frame:**
  insertion option, replicator option, letter s {8.4} option, letter z;

More common production rules encountered in Part I are:

- **length: long {8.2} symbol sequence; short {8.2} symbol sequence.**
- **qualifier: heap {8.2} symbol; new {8.2} symbol; loc {8.2} symbol.**
- **sign: plus {8.2} symbol, minus {8.2} symbol.**
- ***conditional clause: choice using boolean clause {8.9.1}.**
- ***case clause: choice using integral clause {8.9.1}.**
- ***conformity clause: choice using UNITED {16_1.5} clause {8.9.1}.**

As indicated earlier, in a context-sensitive grammar, the left-hand - and right-hand side of a production rule may be surrounded by a context of terminal and nonterminal symbols. This can be clearly recognised in the Revised Report. The Revised Report employs hyper-rules and metaproduction rules to construct context-sensitive grammars. For instance, unique declaration of all applied tags in a program (identifiers, operators, and so forth) is ensured via **LAYER**, **PROP** and related rules, while well-formed modes are constructed via **SAFE** and related rules. One way to view the matter is as follows: substituting hyper-rules and metaproduction rules to obtain production rules (which is the machinery of a two-level grammar) is an ingenious technique to generate a tailored context-sensitive grammar needed to parse a particular Algol 68 program. Since every correct particular Algol 68 program has its specific grammar to parse it, a universal Algol 68 grammar, being the set of all grammars for every possible correct Algol 68 program, would be infinite. With this in mind, Part IV of this publication is easier to comprehend. In Part I, being an informal introduction, a context-free grammar is presented and syntactic restrictions are written in natural language.

2 Basic concepts

{Lisp and Algol, are built around a kernel that
seems as natural as a branch of mathematics.
Metamagical Themas. Douglas Hofstadter. }

2.1 Introduction

The chapters in this part present example Algol 68 code that can be executed with Algol 68 Genie, `a68g` . You may want to install `a68g` on your computer to try these examples yourself. Chapter 10, *Installing and using Algol 68 Genie*, describes how to install `a68g` on your computer, and how to use it.

2.2 Displays

We start this informal introduction with a feature that contributes to the elegance of Algol 68 programs. It is important to understand that in Algol 68, every construct except for a declaration yields a value. Imagine a desk calculator where the result of the last operation is visible in the display. Algol 68 works in a similar way - there is a "display" by which the result of the last operation is made visible to the surrounding statements[1]. With this in mind, and if you have programmed before, you may understand next small program that reads whole numbers from the keyboard and echoes the factorial of each number to the screen:

```
OP FAC = (INT k) INT: # A new monadic operator yielding k!#
  IF k = 0
  THEN 1
  ELSE k * FAC (k - 1)
  FI;

WHILE INT n = read int; n >= 0
```

[1] In technical terms, the display is the top of the evaluation stack.

```
DO print ((n, "! = ", FAC n))
OD
```

In above example, the `THEN` and `ELSE` branches yield the result of their respective statements; in this case those values are yielded as the result of tail-recursive operator `FAC`. Also note the double-parenthesised call of `print`; the inner parenthesis form a **row-display**, which is a denotation for a row, in this case a row of printable values.

2.3 Modes and values

Two basic concepts in Algol 68 are *mode* and *value*. In other programming languages a *mode* is for instance called a *type*. At the time of development of Algol 68, two notable scientific-engineering programming languages in use were Fortran and Algol 60. At the time Fortran 66 let a programmer manipulate values of type `INTEGER`, `REAL`, `COMPLEX` and `LOGICAL`, and rows thereof. Algol 60 just offered the types `INTEGER`, `REAL`, `BOOLEAN` and rows thereof. On the other hand Lisp offered lists, a data structure at the time not yet supported by the former two languages, for example.

Algol 68 brought this to a next level by introducing next to basic modes `INT`, `REAL`, `BOOL` and `CHAR` (with obvious meaning) a mechanism to define other modes by compounding other modes into rows, structures, unions, and pointers. Moreover Algol 68 offers a method to define new operators that operate on values of plain or compounded modes. These features are common now in many programming languages, but around 1970 those were an innovation.

Values can be compounded to form text strings, complex numbers, rows and matrices etcetera. Text, which is a row of characters, is so common that this is the only compounded mode with a **denotation**, for instance `"denotation"`. Algol 68 provides the **collateral-clause** to write values for other compounded modes. In chapter 3 this is described in detail; in brief, a **collateral-clause** is a parenthesised comma-separated list written as either

`( ... )`

or

`BEGIN ... END`.

For example, the value of a complex number might be written as `(0.5, -0.5)` which represents the value $\frac{1}{2} - \frac{i}{2}$.

A typical use of a **collateral-clause** comes with procedure `print` that takes as single argument a row of a union of all printable modes. This causes the Algol 68 idiosyncrasy that

input-output statements working on multiple objects have double-parenthesised calls[2], for example

```
print (("Step ", n, " yields ", z, new line))
```

When printing a single object, the **collateral-clause** is not needed because Algol 68 will cast a value to a row where context both allows and requires it (see sections 6.5 and 6.4), so one can write

```
print (new line)
```

Algol 68 transput is described in chapter 7.

There must of course also be a way to write a 'constant' value for a mode, which in Algol 68 terminology is a **denotation**. Like any other language, Algol 68 has common **denotations** for all basic modes.

The symbols `INT`, `REAL`, `BOOL` and `CHAR` are examples of **mode-indicants** in Algol 68. A **mode-indicant** might be called a *type identifier* in other programming languages. A **mode-indicant** is a **declarer** that specifies a mode. **Mode-indicants** are written in capital letters and can be as long as you like though no intervening spaces are allowed; however `a68g` allows intervening underscores to be part of a **mode-indicant**.

In Algol 68 `VOID` indicates the absence of a value so has different status than a mode[3] though there is a single **denotation**: `EMPTY`.

2.4 Whole numbers

In Algol 68 whole numbers (integers) have mode `INT` and are elements of $\mathbb{Z}$, but not the other way round: not all elements of $\mathbb{Z}$ are integers since a computer is a finite object. The **identifier** max int from the **standard-prelude** {11.4} represents the largest representable integer on the platform on which a program runs:

```
$ a68g -p maxint
+9223372036854775807
```

or

```
$ a68g -p 'long max int'
+170141183460469231731687303715884105727
```

Note that within an **identifier** white space has no meaning so `max int` is the same **identifier** as `maxint`. Compare `max int` to the pre-defined constant `INT_MAX` in C. Sometimes

[2] Except in `ALGOL68C` that deviated from the input-ouput specification in this respect.
[3] In the Revised Report, "`MOID`" is "`MODE` or `void`".

one needs to work with integral values larger than `max int`. To that end Algol 68 Genie supports modes `LONG INT` and `LONG LONG INT`. In `a68g`, the range of `LONG LONG INT` is default circa twice the length of `LONG INT` but can be made arbitrarily large through the option **--precision** {10.6.4}. The respective maximum values for the three integer lengths available in `a68g` depend on the platform on which the program was built.

On platforms supporting sufficiently long types:

Identifier	Value	Remarks
`max int`	$2^{63} - 1$	
`long max int`	$2^{127} - 1$	
`long long max int`	$10^{70} - 1$	`a68g` library

On other platforms:

Identifier	Value	Remarks
`max int`	$2^{31} - 1$	
`long max int`	$10^{35} - 1$	`a68g` library
`long long max int`	$10^{70} - 1$	`a68g` library

As in any programming language, one writes the **denotation** for an integer in Algol 68 as a sequence of digits 0 to 9. Note that in Algol 68 an **integral-denotation** is unsigned; it is in $\mathbb{W}$, not in $\mathbb{Z}$. A **sign** is a **monadic-operator**, so if one writes -1 or $+1$ you will have written a **formula**, {2.7}. In standard Algol 68, a **denotation** for `LONG INT` must be preceded by the reserved word `LONG` and a **denotation** for `LONG LONG INT` must be preceded by the reserved words `LONG LONG`. The production rule for an **integral-denotation** is:

- **integral denotation:**
  length {1.3} option, digit {8.3} sequence.

For instance:

a) `6048000 • 6 048 000`

b) `LONG 266716800000 • LONG 266 716 800 000`

c) `LONG LONG 393006152591286105717362428713750622189273719742528036969898 7`

with value (c) being 3^{127}. Note that white space has no meaning in an **integral-denotation**. `a68g` relaxes the use of `LONG` prefixes when the context imposes a mode for a **denotation**, in which case a **denotation** of a lesser precision is automatically promoted to a **denotation** of the imposed mode.

2.5 Identifiers and identity declarations

Suppose one wants to use the value `8` in various parts of a program, then a symbolic reference to this value is practical. Algol 68 provides an **identity-declaration** that binds an **identifier** to a constant value. Similar constructions in other languages are `CONST` declarations in Pascal, `PARAMETER` statements in Fortran, or `#define` directives in the C preprocessor. The **identity-declaration** for the above mentioned integer would be:

```
INT measurements done = 8
```

In Algol 68, white space is only required when concatenating terms introduces ambiguity, so you could write:

```
INTmeasurementsdone=8
```

but it is of course common practice to add white space to improve clarity[4].

An **identity-declaration** is defined as:

- **identity declaration:**
  formal declarer {8.11}, identity definition list.
- **identity definition:**
  identifier {8.6.2}, equals {8.2} symbol, strong unit {8.9.5}.

A **mode-indicant** can be used as a **formal-declarer**. The **formal-declarer** cannot be `VOID`. The difference between a **formal-declarer** and an **actual-declarer** will be explained in chapter 3. An **identifier** is a sequence of one or more characters which starts with a lower-case letter and continues with lower-case letters or digits:

- **identifier:**
  letter {8.4};
  identifier, letter {8.4};
  identifier, digit {8.3};
  identifier, underscore {8.2} symbol sequence, identifier.

An **identifier** can be interrupted by spaces or tab characters, but those are ignored. Hence `maxint` is the same **identifier** as `max int`. `a68g` allows underscores in **identifiers**, but an underscore is part of the **identifier** unlike white space. Examples of valid **identifiers** are:

```
i • rate 2 pay • eigen value 3
```

The following are not **identifiers**:

[4] Also in other languages, like Fortran, white space has no meaning. Even so, programmers add white space to improve legibility, hardly anyone leaves it all out.

a) `3d vector`

b) `particle-energy`

c) `rootSymbolPointer`

Example (a) starts with a digit, (b) contains a character which is neither a letter nor a digit, and (c) contains capital letters. An **identifier** looks like a name in the sense of that word, but we do not use the term "name" because in Algol 68 the term "name" signifies a value refering to another one, such as a "variable".

The right hand side of the **equals-symbol** in an **identity-declaration** is a **unit** yielding a value. The **unit** can be any piece of program text which yields a value of the mode specified by the **mode-indicant**. A **denotation** is an example of a **unit**. Other **units** yielding integers are the routines[5] `read int`, `read long int` and `read long long int` that yield an integral value read from standard input; if you did not redirect input, this would be your keyboard. Since an **identity-declaration** is a not a **unit** and cannot yield a value, one cannot write:

```
INT i = INT j = 1
```

Instead one must write:

```
INT i = 1; INT j = i
```

There are two ways of declaring multiple **identifiers**. The first way is sequential declaration:

```
INT i = 1; INT j = read int
```

The **semicolon-symbol** "`;`" is called the **go-on-symbol**. One can in principle contract the above **declarations** as follows:

```
INT i = 1, j = read int
```

The **comma-symbol** separates the two **declarations**, but this does not mean that `i` is declared first, followed by `j`. It is up to `a68g` to determine which **declaration** is elaborated first; they could even be done in parallel. This is known as collateral elaboration, as opposed to sequential elaboration determined by the **go-on-symbol** (the **semicolon-symbol**). Therefore a risk of combining two **identity-declarations** as in:

```
INT one = 1, start = one
```

is that `start` is left undefined if `one = 1` is elaborated last. When `a68g` executes above **declaration**, it may or may not end in a runtime error since an uninitialised **identifier**, in casu `one` before it is associated with `1`, is being used.

[5] These **identifiers** come from `ALGOL68C`.

Actually, in Algol 68 all declarations of objects are an **identity-declaration** though abbreviations are allowed since programs would become verbose and terse. You will see this for instance when reading about **variable-declarations** and **procedure-declarations**.

2.6 Real numbers

The term "real number" here is a subtle misnomer since in the mathematical sense real numbers are not countable and computers cannot represent them exactly because a computer is a finite object. Hence in programming, real numbers are elements of $\mathbb{R}$, but not the other way round: not all elements of $\mathbb{R}$ are real numbers. The common way to treat real numbers are either as rational numbers with separate numerator and denominator, as fixed-point numbers which is a rational with a same denominator for all numbers, or as a floating-point number that stores with a fixed-point number an exponent for the denominator. Floating-point numbers are a compromise between range, precision and processing time. The optimum for that compromise varies with the application.

As in many programming languages, in Algol 68 real numbers are floating point numbers. The smallest `REAL` which `a68g` can handle is declared in the standard prelude as **identifier** `min real`. The largest `REAL` which `a68g` can handle is declared as **identifier** `max real` in the standard prelude. Compare these **identifiers** to their equivalents `DBL_MIN` and `DBL_MAX` in C. Also, there is an **identifier** `small real` that gives the smallest value that when added to 1.0, yields a value larger than 1.0, and thus is a measure of precision. As with integers, sometimes one needs to use real values with higher precision than offered by `REAL`. Algol 68 Genie supports modes `LONG REAL` and `LONG LONG REAL`. In `a68g` the precision of `LONG LONG REAL` is default circa twice that of `LONG REAL` but can be made arbitrarily large through the option **--precision** {10.6.4}. Below are the respective limiting values for the three real lengths available in `a68g`, which were chosen under the observation that most multi-precision applications require 20-60 significant digits.

On platforms supporting sufficiently long types:

Identifier	Value	Remarks
`max real`	$1.7976931\ldots \times 10^{308}$	
`long max real`	$1.1897314\ldots \times 10^{4932}$	
`long long max real`	1×10^{999999}	`a68g` library
`min real`	$2.2250738\ldots \times 10^{-308}$	
`long min real`	$3.3621031\ldots \times 10^{-4932}$	
`long long min real`	1×10^{-999999}	`a68g` library
`small real`	$2.2204460\ldots \times 10^{-16}$	
`long small real`	$1.9259299\ldots \times 10^{-34}$	
`long long small real`	1×10^{-63}	`a68g` library

On other platforms, `LONG REAL` is implemented in software:

Identifier	Value	Remarks
`max real`	$1.7976931\ldots \times 10^{308}$	
`long max real`	1×10^{999999}	`a68g` library
`long long max real`	1×10^{999999}	`a68g` library
`min real`	$2.2250738\ldots \times 10^{-308}$	
`long min real`	1×10^{-999999}	`a68g` library
`long long min real`	1×10^{-999999}	`a68g` library
`small real`	$2.2204460\cdots \times 10^{-16}$	
`long small real`	1×10^{-28}	`a68g` library
`long long small real`	1×10^{-63}	`a68g` library

A **real-denotation** consists of **digits** followed by at least either a fractional part **point-symbol, digit-sequence** or an **exponent-part**. The production rules for a **real-denotation** read:

- **real denotation:**
  length {1.3} option, digit {8.3} sequence, exponent part;
  length {1.3} option, digit {8.3} sequence option, point {8.2} symbol,
  digit {8.3} sequence, exponent part option.

- **exponent part:**
  letter e {8.4} symbol, sign option, digit {8.3} sequence.

As is common, `e` is the times ten to the power {8.2} symbol; for example `9e-9` means 9×10^{-9}. **Real-denotations** are unsigned, as are **integral-denotations**, but the exponent can be preceded by a **sign**[6]. In standard Algol 68, a **denotation** for `LONG REAL` must be preceded

[6] One of the minor difficulties with Algol 68 is that in `INT i = -9`, the - means the **monadic-operator**, which could have been user-defined, whereas in `REAL x = 1e-9`, the - is the mathematical minus-sign, even if the **monadic-operator** - has been re-defined.

by the reserved word LONG and a **denotation** for LONG LONG REAL must be preceded by the reserved words LONG LONG. Example **real-denotations** are:

a) .5 • 0.5 • 5.0e-1 • 5e-1

b) LONG 2.71828182845904523536028747

c) LONG LONG
0.70710678118654752440084436210484903928483593768847403658833986 9

with value (b) representing e and value (c) representing $\frac{1}{2}\sqrt{2}$. As with **integral-denotations**, a68g relaxes the use of LONG prefixes when the context imposes a mode for a **denotation**, in which case a **denotation** of a lesser precision is automatically promoted to a **denotation** of the imposed mode.

Example **identity-declarations** for values of mode REAL are:

```
REAL e = 2.718 281 828,
  electron charge = 1.6021e-19 # C #,
  cost per unit = 25.00 # Euro #
```

Since a68g admits the indicant DOUBLE for LONG REAL, you could also write:

```
DOUBLE pi times 2 = 2 * long pi
```

The value of π is declared in the a68g standard prelude as the **identifier** pi with three precisions:

- REAL pi = 3.14159265358979
- LONG REAL long pi = 3.14159265358979323846264338327950288419716939937510
- LONG LONG REAL long long pi =
  3.14159265358979323846264338327950288419716939937510582097494459

The length of LONG LONG modes can be made arbitrarily large through the option **--precision** {10.6.4}. So one can easily print a hundred digits of π through:

```
$ a68g -p "long long pi" --precision=100
+3.14159265358979323846264338327950288419716939937510582097494459230781640628620899862803482534211706798214808651328231e  +0
```

or Euler's number e, analoguously:

```
$ a68g -p "long long exp(1)" --precision=100
+2.71828182845904523536028747135266249775724709369995957496696762772407663035354759457138217852516642742746639193200306e  +0
```

It was mentioned above that in an **identity-declaration**, the **unit** must yield a value of the mode required by the **declarer**. Now consider this example **identity-declaration** where the **unit** yields a value of mode `INT`:

```
REAL z = read int
```

However, the mode required by the **declarer** is `REAL`. Depending on the context, in Algol 68 a value can change mode through a small set of implicit coercions. There are five contexts in Algol 68: *strong*, *firm*, *meek*, *weak* and *soft*. The right-hand side of an **identity-declaration** is a strong context. In a strong context, the mode of a **unit** is always imposed (in this case by the **formal-declarer** on the left-hand side). One of the strong coercions is widening that can for instance widen a value of mode `INT` to a value of mode `REAL`.

The procedure `print` will print a real argument, per default to standard output, as in:

```
print (pi) • print (LONG 1.732050807568877293527446342)
```

`a68g` implements the routines `read real`, `read long real` and `read long long real` that yield a real value read from standard input, so you may write:

```
REAL z = read real;
```

On a right-hand side of an **identity-declaration**, the strong context forces the routine `read real` to yield a real value by a coercion called deproceduring 6.5.1.

2.7 Formulas

Formulas, often called *expressions* in other programming languages, consist of **operators** working on **operands**. Operators are encapsulated algorithms that compute a value from their **operands**. In chapter 5, we will look at operators in more detail, as well as how to define new ones. Algol 68 provides a rich set of pre-defined operators in the standard prelude, described in chapter 11, and one can define more as needed. This chapter describes the operators in the **standard-prelude** which can take **operands** of mode `INT`, `REAL`, `BOOL` or `CHAR`. The syntax for a **formula** reads:

- **formula:**
  monadic operator {8.6.3} sequence, monadic operand;
  dyadic operand, dyadic operator {8.6.3}, dyadic operand.
- **monadic operand:**
  secondary {8.9.3};
- **dyadic operand:**
  monadic operator {8.6.3} sequence option, monadic operand;
  formula.

- ***operand: monadic operand; dyadic operand.**

Secondaries {8.9.3} are **operands** in **formulas**. Operators come in two forms: **monadic-operators** that take one operand and **dyadic-operators** that take two operands. **Operator-symbols** are written as a combination of one or more special symbols, or in upper-case letters like a **mode-indicant**. A **formula** can be the **unit** of an **identity-declaration**. Thus the following **identity-declarations** are both valid:

```
REAL x = read real + 1.0; REAL y = ABS sin (2 * pi * x)
```

White space is not significant in a **formula** as long as it has a unique meaning. However, an operator cannot contain white space, in contrast to an **identifier**. The reason for this is that in Algol 68, adjacent **identifiers** have no meaning but adjacent **operators** do.

A **monadic-operator** has only one **operand**, while a **dyadic-operator** has two **operands**. A **monadic-operator** precedes its **operand**. For example, the monadic minus - reverses the **sign** of its **operand**: `-k`. There is, likewise, a monadic + operator which returns its **operand**: `+k`. Hence **monadic-operators** - or + take an **operand** of mode `INT` and yield a value of mode `INT`. They can also take an **operand** of mode `REAL` in which case they will yield a value of mode `REAL`. The operator `ABS` takes an **operand** of mode `INT` and yields the absolute value of mode `INT`. For example, `ABS -1` yields 1. In the standard prelude is another definition of `ABS` that takes an **operand** of mode `REAL` yielding a value of mode `REAL`. When **monadic-operators** are combined, they are of course elaborated in right-to-left order. That is, in `ABS -1`, - acts on 1 to yield -1, and then `ABS` acts on -1 to yield 1. Another **monadic-operator** which takes an `INT` or `REAL` **operand** is `SIGN` which yields -1 if the **operand** is negative, 0 if it is zero, and $+1$ if it is positive. For modes that have multiple precisions, Algol 68 defines the **monadic-operator** `LENG` that will increase precision by one `LONG`, and the **monadic-operator** `SHORTEN` that will decrease precision by one `LONG`, for the **operand** value. Note that a runtime error may result in case the value of a longer precision cannot be represented in a shorter precision, though `REAL` values will be rounded.

It was mentioned that in a strong context, a value of mode `INT` can be coerced by widening to a value of mode `REAL`. But how do we convert a value of mode `REAL` to a value of mode `INT`? In Algol 68 this is impossible by implicit coercion. You must explicitly state how the conversion should take place. Algol 68 Genie offers monadic operators to convert a value of mode `REAL` to a value of mode `INT`. Operator `TRUNC` truncates the fraction from its `REAL` **operand**, yielding an `INT` value. `ROUND` rounds an **operand** of mode `REAL` to the nearest `INT` value. `ENTIER` or `FLOOR` yield the largest integer not larger than the `REAL` **operand**. `CEIL` yields the smallest integer not smaller than the `REAL` **operand**.

A basic **dyadic-operator** is addition, +; for instance:

```
print (read int + 1)
```

The plus operator + takes two **operands** of mode `INT` and yields a sum of mode `INT`. It is

also defined for two **operands** of mode REAL yielding a sum of mode REAL :

```
REAL x = read real + offset
```

As mentioned, the maximum integer which a68g can represent is max int and the maximum real is max real. Addition could give a sum which exceeds those two values, which is called overflow. Algol 68 leaves such case undefined, meaning that an implementation can choose what to do. a68g will give a runtime error in case of arithmetic overflow, for example:

```
1     (print (((1 + max int)
                  1
a68g: runtime error: 1: INT math error (numerical result out of
range) (detected in [] "SIMPLOUT" closed-clause starting at "("
in this line).
```

The dyadic minus operator for subtraction − also takes two **operands** of mode INT or two **operands** of mode REAL and will yield an INT or REAL difference respectively:

```
INT difference = a - b, REAL distance = end - begin
```

Since a **formula** yields a value of a particular mode, one can use it as an **operand** for another operator. For example:

```
INT sum = a + b + c
```

the order of elaboration being that **operands** are elaborated collaterally, and then the operators are applied from left-to-right in this particular example, since the two operators have the same priority. The times operator $\star$ performs arithmetic multiplication and takes INT **operands** yielding an INT product. For example:

```
INT product = 45 * 36
```

Likewise, $\star$ is also defined for multiplication of two values of mode REAL:

```
REAL pi 2 = 2.0 * pi
```

We already saw with + and − that a **formula** can be an **operand** in another **formula**:

```
INT factorial 6 = 2 * 3 * 4 * 5 * 6;
REAL interpolation = slope * x + intercept
```

In Algol 68, the common precedence of brackets over exponentiation, then division, then multiplication, and then addition and subtraction, applies and it is implemented by giving a priority to operators. The priority of multiplication is higher than the priority for addition or subtraction. The priority of the **dyadic-operators** + and − is 6, and the priority of the $\star$ operator is 7. For example, the value of the **formula** $2 + 3 * 4$ is 14. It is possible to change the priority of standard operators, but that does not make sense — **priority-declarations** are meant to define the priority of *new* **dyadic-operators** one introduces.

Every dyadic operator has a priority of between 1 and 9 inclusive, and **monadic-operators** bind more tightly than any **dyadic-operator**. One can of course force priorities by writing sub expressions in parentheses:

```
INT m = 1 + (2 * 3), # 7 #, n = (1 + 2) * 3 # 9 #
```

The parentheses in Algol 68 are short-hand for `BEGIN ... END` and indeed, you could write a clause in parentheses:

```
INT one ahead = 1 + (INT k; read (k); k)
```

Hence there is no special construct for *sub expressions in parenthesis* that one finds in many other programming languages. This is a consequence of Algol 68's famed orthogonality. There are many examples of orthogonality throughout this publication. Parentheses can be nested to any depth as long as `a68g` does not run out of stack space.

On the right-hand side of an **identity-declaration**, widening is allowed, so the following **declaration** is valid:

```
REAL a = 24 * -36
```

The **formula** is elaborated first, and the final `INT` result is widened[7] to `REAL`.

Algol 68 defines two **operator-symbols** for division of integers. The operator `%` takes **operands** of mode `INT` and yields a value of mode `INT`. It has the alternative representation `OVER`. The **formula** `7 % 3` yields 2, and the **formula** `-7 % 3` yields -2. The priority of `%` is 7, the same as multiplication.

The modulo operator `MOD` yields the remainder after integer division. `MOD` can alternatively be written as `%*` and its priority is 7, the same as division. Algol 68 defines `MOD` as follows: let $q \in \mathbb{Z}$ be the quotient of $a \in \mathbb{Z}$ and $b \in \mathbb{Z}, b \neq 0$ and $r \in \mathbb{W}$ the remainder, such that $a = q \times b + r; r < |b|$ then `a MOD b` yields r. Note that the result of `MOD` always is a non-negative number. Therefore the quotient q in the definition of `MOD` is not consistent with the definition of `OVER`; for example `7 MOD 3` yields 1 ($q = 2$), but `-7 MOD 3` yields 2 ($q = -3$).

Division of `REAL` numbers is performed by the operator `/` which takes two `REAL` **operands** and yields a `REAL` result; it has a priority of 7. For example, the **formula** `3.0 / 2.0` yields 1.5. As indicated above, the operator `/` is also defined for `INT` **operands**; for example `3 / 2` yields 1.5. There is no `REAL` version of `MOD`.

[7] An **operand** is in a firm context. In a firm context no widening is allowed, otherwise we could not decide whether to use integer addition or real addition when we add integer **operands**.

Algol 68 defines an exponentiation operator `**` or its equivalents `^` or `UP`. Its priority is 8. The mode of its left **operand** can be either `REAL` or `INT` but its right **operand**, the exponent, must have mode `INT`. If both its **operands** have the mode `INT`, the yield will have mode `INT` and in this case the right **operand** must not be negative; if the left **operand** is real the yield will have mode `REAL` and the right operand can be negative. Thus the **formula** `3 ** 4` yields 81 and `3.0 ** 4` yields 81.0. Exponentiation takes priority over division, multiplication and addition or subtraction. For example, the **formula** `3 * 2 ** 4` yields 48, not 1296. A common pitfall is the **formula** `-x ** 2` which yields x^2 in stead of $-(x^2)$. The monadic minus is elaborated first, followed by the exponentiation. This looks straightforward, but even experienced programmers tend to make this mistake every now and then. This particular example is not specific to Algol 68, for instance Fortran has the same peculiarity.

In the discussion above the arithmetic operators `+`, `-` and `*` have **operands** of identical modes:

$$\mathbb{Z} \times \mathbb{Z} \to \mathbb{Z} \bullet \mathbb{R} \times \mathbb{R} \to \mathbb{R}$$

In practice, one will frequently use **operands** of mixed modes. The **dyadic-operators** `+`, `-`, `*` and `/` (but not `%`) are also defined for mixed modes. That is, any combination of `REAL` and `INT` **operands** can be used:

$$\mathbb{Z} \times \mathbb{R} \to \mathbb{R} \bullet \mathbb{R} \times \mathbb{Z} \to \mathbb{R}$$

With mixed modes the yield is always `REAL`. Thus the following **formulas** are valid and yield a value of mode `REAL`:

```
small real + 1 • 2 * pi
```

The priority of the mixed-mode operators is unchanged since priority relates to the operator symbol rather than to the modes of **operands** or result.

2.8 Mathematical functions

Routines are the subject of chapter 5, however the routines `print`, `read` and others like `read int`, `read real`, `read bool` and `read char` were already mentioned. Like other languages, Algol 68 defines various mathematical functions that take real arguments and yield a real result. A runtime error occurs if either argument or result is out of range. Multi-precision versions for many of these routines are also pre-defined and are preceded by either `long` or `long long`, for instance `long sqrt` or `long long ln`. Algol 68 Genie provides many more functions than standard Algol 68. A complete list of available functions is in section 11.6.1 onwards.

2.9 Boolean values

The two values of mode BOOL have **denotations** TRUE and FALSE. The procedure print prints T for TRUE, and F for FALSE. Thus:

```
BOOL t = TRUE, f = FALSE;
print ((t, f));
```

produces TF on standard output. Boolean values are also read as T and F respectively. a68g implements procedure read bool that yields a boolean value read from standard input, so one can write:

```
BOOL answer = read bool;
```

A common **monadic-operator** for a BOOL **operand** is NOT, with alternative representations ^ or ~. Obviously, if the **operand** is TRUE, NOT yields FALSE, and if the **operand** is FALSE, NOT yields TRUE. The operator ODD, a relict from a distant past, yields TRUE if the integer **operand** is an odd number and FALSE if it is even. ABS converts its **operand** of mode BOOL and yields an integer result: ABS TRUE yields 1 and ABS FALSE yields 0.

Dyadic-operators with boolean result come in two kinds: those that take **operands** of mode BOOL, yielding TRUE or FALSE, and comparison operators {2.11} that take **operands** of other modes. Three **dyadic-operators** are declared in a68g's **standard-prelude** which take **operands** of mode BOOL. The operator AND, with alternative representation &, yields TRUE only if both its **operands** yield TRUE. The priority of AND is 3. The operator OR yields TRUE if at least one of its **operands** yields TRUE. The priority of OR is 2. The operator XOR yields TRUE if exactly one of its **operands** yields TRUE. It has no alternative representation. The priority of XOR is 3.

2.10 Characters and text

The mode of a character is CHAR. Algol 68 Genie recognises 1 + max abs char distinct values of mode CHAR, some of which cannot be written in **denotations**, for example control characters. A character is denoted by placing it between quote characters, for instance the **denotation** of lower-case a is "a". The quote character """ is doubled in its **denotation**. This convention works because adjacent **denotations** have no meaning in Algol 68 syntax. These are example **character-denotations**:

```
"M" ."m" ."0" .";" ."\" ."'" """" ." "
```

The procedure print will print a character value, and a68g implements procedure read char that yields a char value read from standard input. Example **identity-declarations** for values of mode CHAR are:

```
CHAR a = "A", z = read char, tilde = "~"
```

The space character is declared as the **identifier** `blank` in the **standard-prelude**. Note that there also is a predefined **identifier** `space`, but this is a routine that only advances the position in a file upon input or output, without operating on the character that was at the current position in the file.

For characters that have no denotation, the operator `REPR` can be used that converts an integral value into a character value, for instance:

```
CHAR null = REPR 0, bell = REPR 7
```

Values of modes `INT`, `REAL`, `BOOL` and `CHAR` are known as plain values in Algol 68. Chapter 3 describes that plain values can be organised in rows and in this way text is represented as a row of characters like vectors are rows of real numbers, et cetera. Texts are so common that every programming language has a text **denotation**: a quoted string literal. In chapter 3 you will read that in Algol 68 the row of character mode reads `[] CHAR`. We discuss `[] CHAR` briefly here just to introduce the **row-of-character-denotation** so we can print texts from our basic Algol 68 **programs**. The relevant production rules read:

- **row of character denotation:**
  quote {8.2} symbol, string item sequence, quote {8.2} symbol.
- **string item:**
  character;
  quote {8.2} symbol, quote {8.2} symbol.

A **row-of-character-denotation** is conventionally delimited by quote characters:

```
"row-of-character-denotation"
```

One can of course print **row-of-character-denotations**, so one can let a program print descriptive texts:

```
print ("Oops! Too few experiments performed");
```

In general, `a68g` will concatenate a source line ending in a backslash with the next line; this feature can be used in case a **denotation** must be continued on a next line:

```
print ("In general, a68g will concatenate \
a source line ending in a backslash with the next line;");
```

Algol 68 provides operators for character **operands**. There are two **monadic-operators** which involve the mode `CHAR`. The operator `ABS` takes a `CHAR` **operand** and yields the integer corresponding to that character. For example, `ABS "A"` yields 65 (if your platform uses ASCII encoding). The **identifier** `max abs char` is declared in the **standard-prelude** and will give you the maximum number in your encoding. Conversely, we can convert an integer to a character using the **monadic-operator** `REPR`; for instance `REPR 65` yields the

value "A". REPR accepts an integer in the range 0 to max abs char. REPR is of particular value in allowing access to control characters. **Dyadic-operators** + and * involve (repeated) concatenation of characters and are discussed in chapter 3.

2.11 Comparison operators

Values of modes INT, REAL, BOOL and CHAR can be compared to determine their relative ordering. Because the widening coercion is not allowed for **operands**, many extra comparison operators are declared in the **standard-prelude** that compare values of mixed modes such as REAL and INT. For example, the **boolean-formula**:

```
3 = 1.0 + 2
```

yields TRUE. Similarly:

```
1 + 1 = 1
```

yields FALSE. Note that the **equals-symbol** = can also be written as EQ. Likewise, the **formula**:

```
3500.0 EQ 3.5e3
```

should[8] yields TRUE. The negation of = is /= (not equal):

```
3 /= 2
```

yields TRUE, and:

```
TRUE /= TRUE
```

trivially yields FALSE. Alternative representations of /= are ~= and NE. The priority of both = and /= is 4. The comparison operators <, >, <= and >=can be used to compare values of modes INT, REAL and CHAR in the same way as = and /=. Alternative representations for these operators are LT and GT for < and > and LE and GE for <= and >= respectively. The priority of all these four comparison operators is 5. Characters are ordered by their absolute (integer) value. Hence if **identifiers** a and b are declared as having mode CHAR, then the **formula**:

```
a < b
```

will yield the same value as the comparison of integers:

```
ABS a < ABS b
```

[8]You should of course be cautious when comparing two REAL values for equality or inequality because of subtle rounding errors and finite precision of an object of mode REAL. For instance, 1.0 + small real / 2 = 1.0 will yield TRUE.

BOOL **formulas** yielding TRUE or FALSE can of course be combined. For example, to test whether x lies between 0 and 1 one writes:

```
x > 0 AND x < 1
```

The priorities of <, > and AND are defined such that parentheses are unnecessary in this case, but using parenthesis can improve legibility of code. More complicated BOOL **formulas** can be written:

```
cycle < 10 AND cmd /= "s" OR read bool
```

Because the priority of AND is higher than the priority of OR, AND in the above **formula** is elaborated first. Code clarity can always be improved using parentheses:

```
cycle < 10 AND (cmd /= "s" OR read bool)
```

2.12 Variables and assignation

Up to here we dealt with constants: **denotations** or values associated with an **identifier** through an **identity-declaration**. Practical **programs** require *variables*, for instance **identifiers** whose value *can* change. In Algol 68 parlance, a *name* is a value that *refers to* (points to) another value. A name is a value which refers to a location that stores a value. Obtaining the value from a name is called dereferencing, and changing the value at the referenced location is called **assignation**.

You may be tempted to think that a name is implemented as a pointer to a memory location, but names are handles rather than pointers. Algol 68 is a garbage-collected language, meaning that when memory fills a procedure is started to weed out stale names and to compact memory so new objects can be allocated again. Hence a name can change, but it will always point to the last value that was assigned to it.

The mode of a name is called a "reference mode", with "reference" having reserved word REF. For example, a name which refers to a value of mode REAL has mode REF REAL. Likewise, we can create names with modes:

```
REF INT • REF REAL • REF COMPLEX • REF BOOL
```

REF can precede any mode, except VOID which is not a mode.

Since names are values, REF can also precede the mode of a name - a pointer variable. Thus it is possible to construct modes such as:

```
REF INT • REF REF REAL • REF REF REF COMPLEX
```

Although one can write an arbitrary number of REFs, in practice one will not encounter more than four of them, which specify REF–REF–REF variables.

Names are created in Algol 68 using **generators**. There are two kinds of **generator**: local and global. Local **generators** generate space in the stack, while global **generators** generate space in the heap. The two differ in the dynamic lifetime of the name they generate. We have encountered the concepts of *range* and *reach*. Those are static concepts, as the program text defines the ranges and reaches. However, a value at runtime has a *dynamic* lifetime that in Algol 68 cannot always be correlated to a *static* range since **serial-clauses** yield a value, thereby exporting them out of a range. In Algol 68, the dynamic lifetime of a value is called its scope which is the largest **serial-clause** throughout which that value exists.

The scope of a plain value, like `1` or `TRUE`, and the scope of a global name, is the whole program. The scope of a local name is the smallest enclosing clause which contains its **generator** (which may be hidden by an abbreviated **variable-declaration**, vide infra). In general, values have *scope* and **identifiers** have *range*. In Algol 68 it is often, but not always, possible to check at compile time that names are not applied outside of their scopes. Since this check is not always possible at compile time, `a68g` applies dynamic scope checking at runtime.

The **generator** `LOC REAL` generates in the stack a local name of mode `REF REAL` which can refer to a value of mode `REAL`. One could write:

```
read (LOC REAL)
```

but the created name is anonymous *(sic)* since it is not associated with an **identifier**; when `read` terminates, the value is marooned since the name is no longer accessible.

Since Algol 68 is highly orthogonal, one can of course associate an **identifier** with a generated name by means of an **identity-declaration**:

```
REF REAL v = LOC REAL
```

A brief term for `v` is `REAL` *variable*. The **generator** `LOC REAL` generates a name of mode `REF REAL` although any **unit** yielding a value of mode `REF REAL` would do. After this **identity-declaration**, `v` refers to a local memory location that stores a value of mode `REAL`. One can for instance write:

```
read (v)
```

When `read` finishes, `v` refers to a value assigned to the name through the call to `read`.

Names can also be declared using a previously declared name on the right-hand side of the **identity-declaration**:

```
REAL w;
REF REAL v = w
```

The **identity-declaration** makes `v` the same name as `w`, they are each other's alias. An assignment to one changes the value of the other as well.

Declaring variables by means of an **identity-declaration** is verbose and yields rather pedantic code. The abbreviated **variable-declaration** will let you write:

```
REAL v
```

which means exactly the same as:

```
REF REAL v = LOC REAL
```

The production rules for a **variable-declaration** are:

- **variable declaration:**
  qualifier option, actual declarer {8.11}, variable definition list.
- **variable definition list:**
  identifier {8.6.2}, initialisation option.
- **initialisation: becomes {8.2} symbol, strong unit {8.9.5}.**

Thus the **declaration**

```
REF REAL x = LOC REAL;
```

can be written as:

```
LOC REAL x
```

or, most commonly, since `LOC` is the default:

```
REAL x
```

It is important to note that an **identity-declaration** cannot be mixed with a **variable-declaration**, so one cannot write:

```
REAL a := 0, b = 1
```

An abbreviated **declaration** needs an **actual-declarer** followed by the **identifier**. An **actual-declarer** contains information about the length of rows for instance, and is required when space is generated for an object, for instance in a **variable-declaration** or a **generator**. When no space is generated, **formal-declarers** are required, for instance in an **identity-declaration**. For `INT`, `REAL`, `BOOL` and `CHAR` the **formal-declarer** is the same as the **actual-declarer**.

Whereas `LOC` will generate local names, `HEAP` will generate global names. Global names have a scope as large as the program itself. The **generator** `HEAP REAL` generates a global name of mode `REF REAL` which can refer to a value of mode `REAL`, so we could write:

```
REF REAL v = HEAP REAL
```

or, abbreviated:

```
HEAP REAL v
```

`a68g` allows the symbol `NEW` as alternative for `HEAP`, hence we may also write:

```
REF REAL v = NEW REAL
```

Local names are allocated in the stack, and global names are allocated in the heap. As explained earlier, you should not assume that a global name is a *constant address* in memory. During execution of an Algol 68 program the heap fills with data, but after some time it will contain much data that is no longer accessible (temporary data, data from ranges that have ceased to exist, et cetera). Algol 68 employs a garbage collector that restores heap space by removing inaccessible data from the heap and compacting it. Heap compaction means that *addresses* are not constant, though of course the association between name and value remains unbroken when data is moved around. Note that even in the stack, data may be moved, although currently `a68g` only performs garbage collection of the heap.

An example **assignation** is:

```
v := rate * elapsed
```

An **assignation** consists of a left-hand-side **unit** that yields a name, the **becomes-symbol**, and a right-hand-side **unit** yields a value. The right-hand side of an **assignation** can be any **unit** which yields a value whose mode is the derefrenced mode of the name on the left-hand side. Note that **becomes-symbol** `:=` is not an operator. The production rules for an **assignation** are:

- **assignation: soft tertiary {8.9.4}, becomes-symbol, strong-unit.**

When an **identifier** for a name is declared, the name can *initialised* to refer to a value immediately:

```
REF REAL x = LOC REAL := pi, y = LOC REAL := 0
```

`LOC REAL` is a **unit** that here generates a name of mode `REF REAL`.

The right-hand side of an **assignation** is in a strong context so coercions as dereferencing and widening are allowed. Thus the **assignation**

```
LOC REAL := 0
```

results in `0` being widened to `0.0` before being assigned to the name yielded by the **generator**.

When we write

```
x := y
```

the left-hand-side yields a name, which will be implicitly dereferenced to yield a `REAL` value.

Every construct in Algol 68 yields a value except a **declaration**, that yields no value. We said earlier that the value of the left-hand side of an **assignation** is a name. In fact, the value of the whole of the **assignation** is the value of the left-hand side. Because this is a name, it can be used on the right-hand side of another **assignation**. For example:

```
x := y := 0
```

Since names are themselves values, a name may refer to a name. For example, suppose we declare:

```
INT j, k
```

then the mode of both `j` and `k` is `REF INT`. We could also declare:

```
REF INT j 2, k 2
```

so that `j 2` and `k 2` both have the mode `REF REF INT`. Now, according to the definition of an **assignation** {8.9.5}, it is allowed to write:

```
INT j, k;
REF INT j 2, k 2;
j 2 := j
```

because the **identifier** on the left has mode `REF REF INT` and the **identifier** on the right has mode `REF INT`. The potential pitfall in **assignations** to `REF` variables will be clear after coercions are discussed in a later chapter, but the idea can already be explained here: Algol 68 can adapt the number of `REF`s of the source of an **assignation** to the number of `REF`s of the destination, but not vice versa. Hence the **assignation** in:

```
INT j;
REF INT k := j;
k := 1
```

fails since the `INT` value 1 is not a value for a name of mode `REF REF INT`. A way around this will be discussed later - the **cast** {6.5}, that forces coercions where one needs them. The above **assignation** should be written forcing coercion of the destination to mode `REF INT`:

```
REF INT (k) := 1
```

with the effect that both `j` and `k` will be associated with the value 1.

2.13 The value NIL

In Algol 68 there is only one **denotation** for a name, which is `NIL` meaning *pointing to no value*. Compare this to `NULL` in C or `NIL` in Pascal. The mode of `NIL` depends on the

context. For example, consider:

```
REF INT k = NIL
```

then `NIL` has mode `REF INT`, in this context. Although `NIL` is a name, it points to no value and one cannot assign to it.

An **assignation** to `k` as declared above would cause a runtime error:

```
2     k := 0
      1
a68g: runtime error: 1: attempt to access NIL name of mode REF INT
(detected in particular program).
```

An application of `NIL` is in section 5.8 on lists and trees where `NIL` is used to terminate a list or (branches of) a tree.

2.14 Assignment combined with an operator

Consider the common **assignation** where the right-hand side is a simple **formula**.

```
a := a + 1
```

Assignations of this kind are so common that the standard-prelude declares operators to perform them. The above **assignation** can be written:

`a +:= 1` or `a PLUSAB 1`

which is read as *a plus-and-becomes one*. The left **operand** must be a name, and the right **operand** may be any **unit** yielding a value that can be assigned to that name. The yield of `+:=` is the value of the left **operand**, that is, the name. The operator `+:=` is defined for among others a left **operand** of mode `REF INT` or `REF REAL`. The `REF INT` version of the operator expects an integer right **operand**. There are two `REF REAL` versions for this operator, expecting a right **operand** of mode `INT` or `REAL` respectively. Analoguous operators are `-:=`, `*:=`, `/:=`, `%:=` and `%*:=` with obvious meaning. Their alternative representations are respectively `MINUSAB`, `TIMESAB`, `DIVAB`, `OVERAB` and `MODAB`. The operators `OVERAB` and `MODAB` are only declared for **operands** with modes `REF INT` and `INT`. The priority of all the operators combined with **assignation** is 1. Note that **operators** that perform **assignations** constitute a **formula**, not an **assignation**.

3 Stowed and united modes

3.1 Introduction

Stowed is a portmanteau for **st**ructured or r**owed**. We have dealt with plain values, that is, values with modes INT, REAL, BOOL or CHAR. This chapter introduces compounded modes: rows and structures. The first compounded mode introduced in this chapter is a row, which is an ordered set of elements of a same mode, like in any other programming language. For example, text is a string of characters and many of us use vectors and matrices which are one - and two dimensional rows respectively. The other compounded mode introduced in this chapter is a structure, which is an ordered set of objects not necessarily of a same mode. This chapter introduces the basic modes STRING and COMPLEX, together with the operations defined for them, and also modes BYTES and BITS will be introduced. Finally this chapter describes united modes, that can store in one object a value of different modes.

3.2 Rows and row displays

A row consists of a number of elements with a common mode which cannot be VOID. The mode of a row is written as the mode for each element preceded by square brackets, and is called *row of* followed by the name of the mode of each element, such as *row of int* or *row of bool*. As an example we write an **identity-declaration** for a row:

```
[] CHAR a = "tabula materna combusta est"
```

The mode on the left-hand-side is read *row of char*, which we will write throughout this publication as [] CHAR. The **unit** on the right-hand-side of the **equals-symbol** is in this case the **denotation** of a [] CHAR value. Note that we can use a **formal-declarer** in the **identity-relation** since a will just be an alias of "tabula materna combusta est", and the **denotation** has implicit **bounds** 1..27. If you want to declare a row variable, you need to supply **bounds**. The **declarer** must be an **actual-declarer**. For instance, you *must* write:

```
[1 : 27] CHAR a := "tabula materna combusta est"
```

even though the **bounds** are implicit in this specific example. The difference with an **identity-declaration** is the general situation that when a row is the source of an **assignation**, also when the source appears in a **variable-declaration**, the source is copied into the destination and the **bounds** of source and destination must match. The **bounds** must match since Algol 68 does not regenerate the destination row unless the row is flexible {3.6}. In an **identity-declaration** you only make an alias for a row descriptor, which does not involve copying a row. The maximum number of elements in a row is equal to `max int`.

Following is an **identity-declaration** for a name referring to a row:

```
REF [] INT i = LOC [1 : read int] INT
```

which can be abbreviated to a **variable-declaration**:

```
[1 : read int] INT i
```

There are two things to notice about the first **declaration**. First, the mode on the left-hand side is a **formal-declarer**. It says what the mode of the **identifier** is, but not what its **bounds** are. Second, the **generator** on the right-hand side is an **actual-declarer**. It specifies the **bounds** of the row to be generated. If the **lower-bound** is 1 it may be omitted, so the above **declaration** could also have been written:

```
REF [] INT i = LOC [read int] INT
```

This **declaration** can be abbreviated to a **variable-declaration**:

```
[read int] INT i
```

A dynamic name is one which can refer to a row whose **bounds** are determined at the time the **program** is elaborated. This means that one can declare names referring to rows of the size actually required, rather than some maximum size. The **bounds** of a row do not have to start from 1. You are free to choose the value of the **lower-bound**. In this **identity-declaration**:

```
REF [] INT i at 0 = HEAP [0 : 6] INT
```

or its equivalent **variable-declaration**:

```
HEAP [0 : 6] INT i
```

the **bounds** of the row will be `[0 : 6]`. The minimum value for a **lower-bound** is `-max int`. The maximum value for an **upper-bound** is `max int`. But remember that the maximum number of elements in a row is also `max int`, hence the following condition must be satisfied:

$$-max\ int \leq upper\ bound - lower\ bound + 1 \leq max\ int$$

The condition

$$upper\ bound - lower\ bound + 1 \leq 0$$

that occurs when you specify a **lower-bound** that exceeds the **upper-bound**, means that a row is empty; it has no elements. Such a row is called a flat row in Algol 68 jargon.

As said, `print` prints plain values. Actually, `print` takes as argument a row of values to be output, so it is valid to write:

```
[] INT i;
...
print ((i, new line))
```

which will print all elements of `i`. In case of multi-dimensional rows, elements are printed in row-order, that is, the rightmost **subscript** varies most frequently. This is the same order as C, but not as Fortran that stores in column-order. One can call `new line` and `new page` explicitly to ensure that the next value to be output will start at the beginning of the next line or page. With respect to rows, `read` behaves just like `print` in that a whole row can be read in one **call**. A difference between `read` and `print` is that the values for `read` must be names whereas `print` also accepts values. Note that if `read` is used to read a `[] CHAR` with fixed **bounds** as in:

```
REF [] CHAR sf = LOC [80] CHAR;
read (sf)
```

the number of characters specified by the **bounds** will be read, `new line` and `new page` being called as needed.

Only `[] CHAR` has a **denotation**. Values for other rows are denoted by a construct called a **row-display**. The production rule for a **row-display** reads:

- ***row display:**
  begin {8.2} symbol, unit {8.9.5} list proper option, end {8.2} symbol.

A **row-display** consists of none or two or more **units** separated by **comma-symbols** and enclosed by parentheses (or `BEGIN` and `END`). Also `[] CHAR` has a **row-display**:

```
[] CHAR a = ("a", "b", "c", "d")
```

which means the same as:

```
[] CHAR a = "abcd"
```

It is important to note that the **units** in the **row-display** could be quite complicated. Any **unit** yielding the a value of the mode of an element of the row is permitted. For example, here is another **declaration** for a row with mode `[] CHAR`:

```
[] CHAR a = (blank, (CHAR z; read (z); z), """")
```

In this **declaration** the number of elements is 3. The **lower-bound** of a **row-display** is always 1, so the **upper-bound** equals the number of elements in the **row-display**.

Since a **row-display** is only allowed in a strong context, such as the right-hand side of an **identity-declaration** or the source of an **assignation**, its constituent **units** are also in a strong context. Thus, the **units** in a **row-display** can for instance be widened as in:

```
[] REAL zero vector = (0, 0, 0)
```

An empty **row-display** can be used to yield a flat row, which is a row with no elements. We could initialise a line like so:

```
[] CHAR empty line = ()
```

In this particular case, the **denotation** for a flat `[] CHAR` can also be used:

```
[] CHAR empty line = ""
```

A row can have a single element but a **row-display** cannot have a single **unit** because such construct would coincide with a **closed-clause**. This causes ambiguity in the **uniting** coercion {6.5.2}. In this case and in a strong context, we write a single **unit** yielding a value of correct mode for the element, which is coerced to a row with a single element by the rowing coercion {6.5.4}. For example:

```
[] INT z = 0
```

yields a row with one element. A **closed-clause** could be used instead:

```
[] INT z = (0)
```

since a **closed-clause** is also a **unit** {8.9.1} but note that coercions move inside clauses — coercions are not applied to **enclosed-clauses** but to the terminal **units** contained therein. Again, a **row-display** can only be used in a strong context. It was mentioned that the context of an **operand** is firm, so a **row-display** cannot appear as **operand** in a **formula**. One can force an **operand** in a strong context by using a **cast** {6.5}, for example

```
[] INT (1, 2, 3)
```

Note that the **denotation** for a `[] CHAR` is not a **row-display** and does need a **cast** {6.5} to be used as an **operand** in a **formula**.

Imagine you want to **slice** {3.4} a **row-display**, then the **row-display** must be **cast** {6.5} since the context of the **primary** in a **slice** is weak. For example, the **slice**

```
[] PROC VOID (u, v, w) [@-1]
```

yields a row of three `PROC VOID` procedures declared elsewhere `u`, `v` and `w`, with bounds `[-1 : 1]` in stead of default bounds `[1 : 3]`.

3.3 Row dimensions

A row has dimensions. All the rows declared so far have one dimension, compare to the mathematical concept of a vector. The number of dimensions is a part of the mode. A two-dimensional row of integers, compare to the concept of a matrix, has mode

```
[, ] INT
```

read *row row of int*, while a 3-dimensional row of reals has mode

```
[,, ] REAL
```

which reads *row row row of real*. Note that the number of **comma-symbols** is always one less than the number of dimensions. In Algol 68, rows with any number of dimensions can be declared. To cater for more than one dimension, each of the **units** of a **row-display** can also be a **row-display**. The **row-display** for a row with mode `[, ] INT` could be:

```
((1, 2, 3),
 (4, 5, 6))
```

For two dimensions, it is convenient to talk of rows and columns. This is an **identity-declaration** using the previous row display:

```
[, ] INT e =
  ((1, 2, 3),
   (4, 5, 6))
```

The first row of `e` is yielded by the **row-display** $(1, 2, 3)$ and the second row is yielded by $(4, 5, 6)$. The first column of `e` is yielded by the **row-display** $(1, 4)$, the second column by $(2, 5)$, and the third column by $(3, 6)$. Note that the number of elements in each row is the same, and the number of elements in each column is also the same, but that the number of rows and columns do not need to be the same.

The mode of a row element can be any mode, including another row mode. For example:

```
[][] CHAR days = ("Monday","Tuesday","Wednesday",
  "Thursday","Friday","Saturday",
  "Sunday")
```

The mode here is read *row of row of* `CHAR`. This is another example using integers:

```
[][] INT trapezium = (1, (2, 3), (3, 4, 5))
```

Note that in a `[, ] MODE` object the number of columns is fixed, while `[] MODE` rows in a `[][] MODE` object can be of different length. A `[, ] MODE` object is therefore fundamentally different from a `[][] MODE` object.

3.4 Subscripts, slices and trims

Since a row is an ordered set of elements, each element of a row has one index, an integral value, associated with it for each dimension. These integers increase by 1 from the first to the last element in each dimension. For example, after the **declaration**:

```
[] INT odds = (1, 3, 5)
```

elements of `odds` can be accessed as `odds[1]` yielding 1, `odds[2]` yielding 3 and `odds[3]` yielding 5. The integers $1, 2, 3$ are called **subscripts** or **indexers**. Selecting elements from a row is called slicing. A construction as `odds[1]` is called a **slice**. Slicing binds more tightly than any operator, so a **slice** can be an **operand** in a **formula**. The related production rules read:

- **slice:**
  weak primary {8.9.2}, sub {8.2} symbol, indexer list, bus {8.2} symbol.
- **indexer:**
  subscript;
  trimmer.
- **trimmer:**
  lower index option,
  colon {8.2} symbol,
  upper index option,
  revised lower bound option.
- **subscript: meek integral unit {8.9.5}.**
- **lower index: meek integral unit {8.9.5}.**
- **upper index: meek integral unit {8.9.5}.**
- **revised lower bound:**
  at {8.2} symbol, meek integral unit {8.9.5}.

In the two-dimensional row:

```
[, ] INT v =
  ((1, 2, 3),
   (4, 5, 6),
   (7, 8, 9))
```

the **subscripts** for 1 are `[1, 1]`, those for 3 are `[1, 3]` and the **subscripts** for 9 are `[3, 3]`. A **slice** can also select a sub-row from a row. For example, after declaring `v` as above, we can write:

```
v[1, ]
```

which yields the row denoted by the **row-display** $(1, 2, 3)$. Note that the absence of an **indexer** implicitly selects all elements for that dimension. Vertical slicing is also possible, for instance:

```
v[,3]
```

yields $(3, 6, 9)$. The ability to make an alias for both rows and columns in a two-dimensional row is a notable property of Algol 68.

Since Algol 68 rows are dynamic, their size is not always fixed at compile-time. The **bounds** of a row can be interrogated using the operators `LWB` for the **lower-bound**, and `UPB` for the **upper-bound**. The **bounds** of the first, or only, dimension can be interrogated using the monadic form of these operators. When the row is multi-dimensional, the **bounds** are interrogated using the dyadic form of `LWB` and `UPB`: the left **operand** is the dimension being interrogated while the right **operand** is a **unit** yielding a row. The priority of the **dyadic-operators** is 8. For example:

```
[1 : 10, -5 : 5] INT r;
print (1 LWB r); # prints 1 #
print (1 UPB r); # prints 10 #
print (2 LWB r); # prints -5 #
print (2 UPB r); # prints 5 #
```

An extension of Algol 68 provided by `a68g` are the **monadic-operator** and **dyadic-operator** `ELEMS` that operate on any row. The dyadic version gives the number of elements in the specified dimension of a row, and the monadic version yields the total number of elements of a row. For example:

```
[1 : 10, -5 : 5] INT r;
print (1 ELEMS r); # prints +10 #
print (2 ELEMS r); # prints +11 #
print (ELEMS r) # prints +110 #
```

The **monadic-operator** returns the total number of elements while the **dyadic-operator** returns the number of elements in the specified dimension, if this is a valid dimension.

In a 3-dimensional row, both 2-dimensional and 1-dimensional **slices** can be produced. Given the **declaration**:

```
[, ] INT r =
  ((1, 2, 3, 4),
   (5, 6, 7, 8),
   (9, 10, 11, 12),
   (13, 14, 15, 16))
```

these are the yields of different **slices**:

1. `r[2, 2]` yields 6
2. `r[3, ]` yields $(9, 10, 11, 12)$
3. `r[, 2 UPB r]` yields $(4, 8, 12, 16)$
4. `r[3, 2]` yields 10
5. `r[2, ]` yields $(5, 6, 7, 8)$
6. `r[, 3]` yields $(3, 7, 11, 15)$

A **slice** can be used to change the **bounds** of a row using the `@` construction. For example, after the **declaration**:

```
[] CHAR digits = "0123456789"[@0]
```

the **bounds** of `digits` are `[0 : 9]`. Note that `@` can also be written `AT`.

If you slice a name, you want the sliced element to be a name as well, otherwise you could not assign to an element of the row. The important rule in Algol 68 is that if you slice an object of mode `REF [...] MODE`, the yield will be of mode `REF MODE`. So if you first write:

```
[1 : products] REAL price;
```

one can later write:

```
price[1] := 0;
```

since slicing a `[] REAL` variable yields a `REAL` variable. Again, if you slice an object of mode `[...] MODE`, the yield will be of mode `MODE`. If you slice an object of mode `REF [...] MODE`, the yield will be of mode `REF MODE`. But if you slice an object of mode `REF REF [...] MODE`, the yield will still be of mode `REF MODE`. This coercion is called weak dereferencing {6.5}.

A **trimmer** makes a **slice** select a sub-row from a row. A **trimmer** reads `first element : last element`. The positions `first element` and `last element` are **meek-integral-units**. If `first element` is omitted, the **lower-bound** for that dimension is taken, and if `last element` is omitted, the **upper-bound** for that dimension is taken. Omission of both **subscripts** yields all elements in the specific dimension. Trimming is particularly useful with values of mode `[] CHAR`. Given the **declaration**:

```
[] CHAR quote = "Habent sua fata libelli"
```

the **trimmers**:

```
quote[: 6]
quote[8 : 10]
quote[12 : 15]
```

yield the first three words. The **lower-bound** of a **trimmer** is 1 by default, but may be changed by the use of AT or @. The AT construction is called a **revised-lower-bound**. For example, quote[: 6] has **bounds** [1 : 6], but quote[: 6 AT 2] quote[: 6@2] has **bounds** [2 : 7]. a68g allows you to replace the **colon-symbol** : by .. in **bounds** and **trimmers**, which is the Pascal style. Hence in a68g next **trimmers** are identical:

```
quote[: 6] and quote[.. 6]
quote[8 : 10] and quote[8 .. 10]
quote[12 : 15] and quote[12 .. 15]
```

One can assign values to the elements of a row either individually or collectively. One can access an individual element of a row by subscripting that element. The rules of the language state that a subscripted element of a row name is itself a name. In fact, the elaboration of a **slice** of a row name creates a new name. Unless you store the new name by means of an **identity-declaration**, the new name will cease to exist after the above **assignation** has been elaborated.

There are two ways of assigning values collectively. First, this can be done with a **row-display** or a [] CHAR **denotation**. For example:

```
[1 : 5] INT first primes := (1, 3, 5, 7, 11);
```

Note that the **bounds** of both first primes and the **row-display** are [1 : 5]. In the **assignation** of a row, the **bounds** of the row on the right-hand side must match the **bounds** of the row name on the left-hand side. If they differ, a run time error is generated. The second way of assigning to the elements of a row collectively is to use as the source of the **assignation** any **unit** yielding a row of the correct mode with the required **bounds**.

3.5 Operators for rows

Rows of CHAR are so common that **dyadic-operators** are available implementing concatenation and comparison of text. The concatenation operator + is defined for all combinations of CHAR and [] CHAR. Thus, the **formula**:

```
"abc" + "d"
```

yields the value denoted by "abcd". The operator has a priority of 6, the same as addition; remember that all operators with the same symbol have the same priority in Algol 68. Multiplication, meaning repeated concatenation, of values of mode CHAR or [] CHAR is defined using the operator *. The operator takes a [] CHAR **operand** and a INT **operand**, and the yield has mode [] CHAR. For example, in the **declaration**:

```
[] CHAR word = 3 * "ab"
```

the **formula** yields `"abababab"`. The **formula** may also be written with the integer as the right-hand **operand** `"ab" * 3`. In both cases, the operator only makes sense with a positive integer.

The operators = and /= are also defined for **operands** of mode `[] CHAR`. Corresponding elements must be equal if the = operator is to yield `TRUE`. Thus:

```
"a" = "abc"
```

yields `FALSE`. Note that the **bounds** do not have to be the same:

```
([] CHAR a = "Rose"[@0], b = "Rose"; a = b)
```

yields `TRUE`. The negation of = is /= which test for inequality. So the **formula**:

```
"Algol" /= "Algol"
```

yields `FALSE`. Alternative representations of /= are ~=, ^= and `NE`. The ordering operators <, >, <= and >= can be used to compare values of mode `[] CHAR` in the same way as = and /=. For values of mode `[] CHAR`, ordering is alphabetic. The **formula**:

```
"abcd" > "abcc"
```

yields `TRUE`. Two values of mode `[] CHAR` of different length can be compared. For example, both:

```
"aaa" <= "aaab"
"aaa" <= "aaaa"
```

yield `TRUE`. Alternative representations for these operators are `LT` and `GT` for < and > and `LE` and `GE` for <= and >= respectively. Because the rowing coercion is not allowed for firm **operands** in **formulas**, the comparison operators are declared in the **standard-prelude** for mixed modes `CHAR` and `[] CHAR`.

Note that apart from values of mode `[] CHAR` and the interrogation operators `LWB`, `UPB`, no operators are defined in the Revised Report for rows. `a68g`, further to `ELEMS`, defines pseudo-operators for vectors and matrices (3.8) and provides operators to support linear algebra (11.10). Also, `a68g` defines the operator `ELEM` (11.5.12) to select a character from an object of mode `STRING` or `BYTES`, for compatibility with the vintage `ALGOL68C` compiler.

3.6 Flexible names and the mode STRING

In the previous section, we declared row names. The **bounds** of the row to which the name can refer are included in the **generator**. In subsequent **assignations**, the **bounds** of the new row to be assigned must be the same as the **bounds** given in the **generator**. In

Algol 68, it is possible to declare names which can refer to a row of any number of elements (including none) and, at a later time, can refer to row with a different number of elements. These are called flexible names. Consider this **identity-declaration** for a flexible name:

```
REF FLEX [] INT fn = LOC FLEX [1 : 0] INT
```

or, abbreviated:

```
FLEX [1 : 0] INT fn
```

There are several things to note about this **declaration**:

1. the mode of the name is not `REF [] INT`, but `REF FLEX [] INT`. `FLEX` means that the **bounds** of the row to which the name can refer can differ from one **assignation** to the next.
2. the **bounds** of the name generated at the time of the **declaration** are `[1 : 0]`. Since the **upper-bound** is less than the **lower-bound**, the row is said to be flat; it has no elements at the time of its **declaration**.

One can now assign rows of integers to `fn`:

```
fn := (1, 2, 3, 4)
```

The **bounds** of the row to which `fn` now refers are `[1 : 4]`. Again, we can write:

```
fn := (2, 3, 4)
```

Now the **bounds** of the row to which `fn` refers are `[1 : 3]`. One can even write:

```
fn := 7
```

in which the right-hand side will be rowed to yield a one-dimensional row with **bounds** `[1 : 1]`, and:

```
fn := ()
```

giving **bounds** of `[1 : 0]`.

If a flexible name is sliced, the resulting name is called a transient name because it can only exist while that flexible name is not deallocated. Therefore transient names have restricted use, the general rule being that a transient name cannot be stored for later reference. For example, consider the **declaration** and **assignation**:

```
REF FLEX [] CHAR c1 = LOC FLEX [1 : 0] CHAR := "abcdef";
```

Suppose now we could have the **declaration**:

```
REF [] CHAR lc1 = c1[2 : 4]; # Wrong! #
```

followed by this **assignation**:

```
c1 := "z";
```

Now `lc1` no longer refers to anything meaningful. Thus transient names cannot be stored: they cannot be linked to **identifiers**, nor used as **parameters** for a routine (whether operator or procedure). They can be the destination in an **assignation**, as in:

```
STRING s := "abcdefghijklmnopqrstuvwxyz";
s[2 : 7] := s[9 : 14]
```

where the name yielded by `s[9 : 14]` is immediately dereferenced. So the **assignation**:

```
s[2 : 7] := "abc"
```

would produce a run time error.

What has not been made apparent up to now is a problem arising from the ability that we can have rows of any mode except `VOID`, so also rows of rows, et cetera. Now consider the **declaration**:

```
FLEX [1 : 0][1 : 3] INT semiflex
```

Because the mode of `semiflex` is `REF FLEX [][] INT`, when it is subscripted, the mode of each element is `REF [] INT` with **bounds** `[1 : 3]`. Clearly, after the **declaration**, `semiflex` has no elements, so how would we know about dimensions of the `REF [] INT` sub-row of `semiflex`? According to the Revised Report a row must have a *ghost element*, inaccessible by subscripting, to preserve information on **bounds** in case no elements are present. This ghost element prohibits writing:

```
semiflex := LOC [1 : 4][1 : 4] INT
```

Algol 68 has been criticised for offering flexible rows, but not a simple way to extend an existing row with a number of elements while leaving the present elements untouched. This has to be achieved by declaring a new (larger) flexible row, assigning existing elements to it, and then copying back:

```
INT n = read int;
FLEX [n] INT u;
...
# Extend u by one element #
[UPB u + 1] INT v;
v[: UPB u] := u;
u := v
```

after which the row is extended with one yet uninitialised element.

The mode `STRING` is defined in the **standard-prelude** as `FLEX [1 : 0] CHAR`. That is, the **identity-declaration**:

```
REF STRING s = LOC STRING
```

has exactly the same effect as the **declaration**:

```
REF FLEX [] CHAR s = LOC FLEX [1 : 0] CHAR
```

You will notice that although the **mode-indicant** `STRING` appears on both sides of the **identity-declaration** for `s`, in the second **declaration** the **bounds** are omitted on the left-hand side (the mode is a formal-declarer) and kept on the right-hand side (the **actual-declarer**). Without getting into grammatical explanations, just accept that if you define a mode like `STRING`, whenever it is used on the left-hand side of an **identity-declaration** the compiler will ignore the **bounds** inherent in its definition. One can now write:

```
s := "String"
```

which gives **bounds** of `[1 : 6]` to `s`. One can **slice** that row to get a value with mode `REF CHAR` which can be used in a **formula**. Often, where `[] CHAR` appears, it may be safely replaced by `STRING`. This is because it is only names which are flexible so the flexibility of `STRING` is only available in `REF STRING` **declarations**.

When reading `STRING` values, reading will not go past the end of the current line[1]. If the reading position is already at the end of the line, the row will have no elements. When reading a `STRING`, `new line` must be called explicitly for transput to continue.

Two operators are defined in the **standard-prelude** which take an **operand** of mode `REF STRING`: `PLUSAB`, whose left **operand** has mode `REF STRING` and whose right **operand** has mode `STRING` or `CHAR`, and `PLUSTO`, whose left **operand** has mode `STRING` or `CHAR` and whose right **operand** has mode `REF STRING`. Using the concatenation operator `+`, their actions can be summarised as follows:

1. `a PLUSAB b` means `a := a + b`
2. `a PLUSTO b` means `b := a + b`

Thus `PLUSAB` concatenates `b` onto the end of `a`, and `PLUSTO` concatenates `a` to the beginning of `b`. Their alternative representations are `+:=` and `+=:` respectively. For example, if `a` refers to `"abc"` and `b` refers to `"def"`, after `a PLUSAB b`, `a` refers to `"abcdef"`, and after `a PLUSTO b`, `b` refers to `"abcdefdef"` (assuming the `PLUSAB` was elaborated first).

3.7 Vectors, matrices and tensors

Algol 68 Genie has extensions to support vectors, matrices and tensors provided they are represented as rows. Next section shows how to extract a transpose, or a diagonal from a matrix. Furthermore, `a68g` offer a basic vector and matrix interface operating on Algol 68 rows of mode:

[1] For details of string terminators see {7.7}.

```
[] REAL # vector #
[, ] REAL # matrix #
[] COMPLEX # complex vector #
[, ] COMPLEX # complex matrix #
```

This part of the library is described in section 11.10.

3.8 Torrix extensions

Algol 68 Genie implements pseudo-operators as described by [Torrix 1977]. These are of particular interest to vector - and matrix algebra. Original Torrix code implements these symbols as operators on one- and two-dimensional rows of real and complex numbers. The pseudo-operator implementation offered by `a68g` is more general as it works on one- and two-dimensional rows of any mode. The syntactic position of these pseudo-operator expressions is at the same level as a **formula**, which is a **tertiary** as described in chapter 8.

Next list compiles the definitions of these pseudo-operators. Note that all yield a descriptor. This means that the yield of the pseudo-operator refers to the same elements as the row operated on, only the indices are mapped. In the list below `a` is a two-dimensional row:

$$a = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{n2} & \dots & a_{mn} \end{pmatrix}$$

`u` is a one-dimensional row:

$$u = \begin{pmatrix} u_1 \\ u_2 \\ \vdots \\ u_n \end{pmatrix}$$

and `i`, `j` and `k` are integers. Next pseudo-operators are available:

1. `TRNSP` constructs for a matrix, without copying, a descriptor such that:

   ```
   (TRNSP a)[j, i] = a[i, j]
   ```

   for valid `i` and `j`.

2. `DIAG` constructs for a square matrix, without copying, a descriptor such that:

   ```
   (k DIAG a)[i] = a[i, i + k]
   ```

   for valid `i` and `k`. The monadic form of `DIAG` is equivalent to `0 DIAG ...` .

3. `COL` constructs, without copying, a descriptor such that:

```
(k COL u)[i, k] = u[i]
```

for valid `i` and `k`. The monadic form of `COL` is equivalent to `1 COL ...` .

4. `ROW` constructs, without copying, a descriptor such that:

```
(k ROW u)[k, i] = u[i]
```

for valid `i` and `k`. The monadic form of `ROW` is equivalent to `1 ROW ...` .

These pseudo-operators yield a new descriptor, but do no copy data. They give a new way to address the elements of an already existing one - or two dimensional row. For example, next code sets the diagonal elements of a matrix:

```
[3, 3] REAL matrix;
DIAG matrix := (1, 1, 1);
print (DIAG matrix)
```

This will print three ones as the result of the **assignation**. These pseudo-operators delivering new descriptors to existing data cannot be coded in standard Algol 68. There is an analogy with slicing a name. If you apply an above pseudo-operator to an object of mode `[...] MODE`, the yield will be of mode `[...] MODE`, but the number of dimensions will of course change. If you operate on an object of mode `REF [...] MODE`, the yield will be of mode `REF [...] MODE`. But if you operate on an object of mode `REF REF [...] MODE`, the yield will still be of mode `REF [...] MODE`. This coercion is called weak dereferencing {6.5}.

3.9 A note on brackets

Algol 68 allows square brackets, used when working with rows, to be replaced with parenthesis. `a68g` supports this feature so in stead of:

```
[3, 3] REAL matrix;
DIAG matrix := (1, 1, 1);
print ((DIAG matrix)[1])
```

you may write:

```
(3, 3) REAL matrix;
DIAG matrix := (1, 1, 1);
print ((DIAG matrix)(1))
```

as long as you close `[` with `]` and `(` with `)`.

3.10 Structured modes

We have seen how a number of individual values can be collected together to form a row whose mode was expressed as *row of mode*. The principal characteristic of rows is that all the elements have the same mode. Often the value of an object cannot be represented by a value of a single object of a standard mode. Think for instance of a book, that has an author, a title, year of publication, ISBN, et cetera. A structure is another way of grouping data elements where the individual parts may be of different modes. In general, accessing the elements of a row is determined at run time by the elaboration of a **slice**. In a structure, access to the individual parts, called fields, is determined at compile time. In some programming languages, structured modes are called *records*. The mode constructor `STRUCT` is used to create structured modes. This is a **identity-declaration** involving a structure:

```
STRUCT (INT index, STRING title) s = (1, "De bello gallico")
```

The mode of the structure is:

```
STRUCT (INT index, STRING title)
```

The terms `index` and `title` are called field selectors and are part of the mode. They are not actually **identifiers**, even though the production rule for **identifiers** applies to them. Their only use is to provide access to fields in a structured value. The expression to the right of the **equals-symbol** is called a **structure-display** that has this production rule:

- ***structure-display: strong-collateral-clause.**

Like **row-displays**, **structure-displays** can only appear in a strong context. A **structure-display** has two or more fields; allowing a single-field **structure-display** would introduce ambiguity in Algol 68 syntax. In a strong context, `a68g` can determine which mode is required and so it can tell whether a **row-display** or a **structure-display** has been provided. We could now declare another such structure:

```
STRUCT (INT index, STRING title) t = s
```

and `t` would have the same value as `s`.

One can write a structure **declaration** with different field selectors:

```
STRUCT (INT count, STRING title) ss =
  (1, "Reflexions sur la puissance motrice du feu")
```

which looks almost exactly like the first structure **declaration** above, except that the field selector `index` has been replaced with `count`. The structure `ss` has a different mode from `s` because not only must the constituent modes be the same, but the field selectors must also be identical.

Structure names can be declared:

```
REF STRUCT (INT index, STRING title) sn =
```

```
LOC STRUCT (INT index, STRING title)
```

Because the field selectors are part of the mode, they appear on both sides of the **declaration**. The abbreviated form is:

```
STRUCT (INT index, STRING title) sn
```

We could then write:

```
sn := s
```

in the usual way, but not:

```
sn := ss
```

The mode of a field can be any mode except `VOID`. For example, we can declare:

```
STRUCT (REAL x, REAL y, REAL z) vector
```

which can be abbreviated to:

```
STRUCT (REAL x, y, z) vector
```

and later on write an **assignation**:

```
vector := (0, 0, 0)
```

where the value `0` would be widened to `0.0` since the right hand side is in a strong context. A structure can also contain another structure:

```
STRUCT (STRING c, STRUCT (REAL x, y) point) ori = ("O", (0, 0))
```

In this case, the inner structure has the field selector `point` with field selectors `x` and `y`. If size of rows is relevant, as in **generators** and **variable-declarations**, the mode of a field selector is an **actual-declarer**. Otherwise, as in an **identity-declaration**, the mode is a **formal-declarer**.

The field selectors of a structured mode are used to extract the individual fields of a structure by means of a **selection** that has following production rule:

- **selection: identifier {8.6.2}, of-symbol, secondary {8.9.3}.**

For example, given this **declaration** for the structure `s`:

```
STRUCT (INT index, STRING title) s = (1, "De bello gallico")
```

we can select the first field of `s` using the **selection**:

```
index OF s
```

The mode of the **selection** is `INT` and its value is `1`. Note that the construct `OF` is not an

operator, as is its equivalent in C. The second field of `s` can be selected using the **selection**:

```
title OF s
```

whose mode is `STRING` with value `"De bello gallico"`. The field selectors cannot be used on their own: they can only be used in a **selection**. A **selection** binds more tightly than any operator, so a **selection** can be used as an **operand**. However, a **slice** or a **call** {5} binds more tightly than a **selection**. Consider the **formula**:

```
[inventory size] STRUCT (INT index, STRING title) inventory;
...
index OF inventory[1] + 1
```

then first `inventory[1]` is elaborated, then the **selection**, and finally the addition. Sometimes you need to write parenthesis — actually, an **enclosed-clause** — to ensure correct elaboration of a construct; consider for instance:

```
STRUCT ([inventory size] INT indices, STRING title) inventory;
...
(indices OF inventory)[1] + 1
```

Would you have written the last **unit** as

```
indices OF inventory[1] + 1
```

a runtime error would occur since this strictly means

```
(indices OF (inventory[1])) + 1
```

which involves slicing of the value `inventory` that is not a row in this case, and `a68g` will protest:

```
32    indices OF inventory[1] + 1
                  1
a68g: error: 1: REF STRUCT ([] INT indices, STRING title) identifier does
not yield a row or procedure (detected in particular-program).
```

The two fields of the structure:

```
STRUCT (STRING c, STRUCT (REAL x, y) point) ori
```

can be selected by writing:

```
c OF ori
point OF ori
```

and their modes are `STRING` and `STRUCT (REAL x, y)` respectively. Now the fields of the inner structure `point` of `ori` can be selected by writing:

```
x OF point OF ori
```

```
y OF point OF ori
```

and both **selections** have mode `REAL`. Note that nested **selection** proceeds from right-to-left.

If you want to assign to a field, the **selection** of that field must somehow yield a name. As with rows, Algol 68 applies the rule that a field selected from a name is itself a name. Consider for instance the structure name `sn` declared by:

```
STRUCT (INT index, STRING title) sn;
```

The mode of `sn` is:

```
REF STRUCT (INT index, STRING title)
```

This means that the mode of the **selection**:

```
index OF sn
```

must be `REF INT`, and the mode of the **selection**:

```
title OF sn
```

must be `REF STRING`. That is, the modes of the fields of a structure name get preceded by `REF`. Otherwise you would not be able to assign to a single field in a structured object. The important general rule is that if you select a field with mode `MODE` from an object with mode `STRUCT (...)`, then the yield will be of mode `MODE` as well. If you select a field with mode `MODE` from an object with mode `REF STRUCT (...)`, then the yield will be of mode `REF MODE`. But if you select a field with mode `MODE` from an object with mode `REF REF STRUCT (...)`, then the yield will still be of mode `REF MODE`. This coercion is called weak dereferencing {6.5}. Thus, instead of assigning a complete structure using a **structure-display**, one can assign values to individual fields. That is, the **assignation**:

```
sn := (2, "The republic")
```

is equivalent to the **assignations**:

```
index OF sn := 2;
title OF sn := "The republic"
```

except that the two **units** in the **structure-display** are separated by a **comma-symbol** and hence are elaborated collaterally.

Given the **declaration**:

```
STRUCT (CHAR mark, STRUCT (REAL x, y) point) ori;
```

the **selection**:

```
point OF ori
```

has mode `REF STRUCT (REAL x, y)`, and so you could assign directly to it:

```
point OF ori := (0, 0)
```

as well as to its fields:

```
x OF point OF ori := 0;
y OF point OF ori := 0
```

Structures are read or printed field-by-field from left to right if the modes of every field can be transput. For example, the following **program** fragment will print a complex number:

```
STRUCT (CHAR mark, STRUCT (REAL x, y) point) ori := ("O", (0, 0));
print ((ori, new line))
```

For details of how this works, see the remarks on straightening {7.10}.

If a structure contains rows, the structure **declaration** should only include required **bounds** if it is an **actual-declarer**. For example, we could declare:

```
STRUCT ([] CHAR forename, surname, title)
  lecturer = ("Albert", "Einstein", "Dr")
```

where the mode on the left is a **formal-declarer** (remember that the mode on the left-hand side of an **identity-declaration** is always a **formal-declarer**). When declaring a name, an **actual-declarer** precedes the **identifier**, and **bounds** must be included. A suitable **declaration** for a name which could refer to `lecturer` would be:

```
STRUCT ([7] CHAR forename, [6] CHAR surname, [3] CHAR title)
  new lecturer;
```

but we cannot assign `lecturer` to it. A better **declaration** would use `STRING`:

```
STRUCT (STRING forename, surname, title) person
```

in which case we could now write:

```
person := lecturer
```

Using field **selection**, we can write:

```
title OF person
```

which would have mode `REF STRING`. Thus, using field **selection**, we can assign to the individual fields of `person`:

```
surname OF person := "Schweitzer"
```

When slicing a field which is a row, it is necessary to remember that slicing binds more tightly than selecting {8}. Thus the first character of the surname of `person` would be

accessed by writing:

```
(surname OF person)[1]
```

which would have mode `REF CHAR`. The parentheses ensure that the **selection** is elaborated before the slicing. Similarly, the first five characters of the forename of `person` would be accessed as:

```
(forename OF person)[: 5]
```

with mode `REF [] CHAR`.

In the last section, we considered rows in structures. What happens if we have a row each of whose elements is a structure? If we had declared:

```
[10] STRUCT (REAL re, im) z
```

then the **selection** `re OF z` would yield a name with mode `REF [] REAL` and **bounds** `[1 : 10]`. Because `z` is a name, one can assign to it:

```
re OF z := (1, 2, 3, 4, 5, 6, 7, 8, 9, 10)
```

This extraction of a row of fields from a row of a structured value is called multiple **selection**. Multiple **selection** yields a new descriptor, so one could write aliases for the fields:

```
[10] COMPL z;
[] REAL x = re OF z, y = im OF z
```

but note that both `x` and `y` are aliases, so any **assignation** to either one would also affect `z`. To avoid this side effect, the rows should be copied by a **variable-declaration**:

```
[10] STRUCT (REAL re, im) z
[10] REAL x := re OF z, y := im OF z
```

after which both `x` and `y` contain the actual values of `z` but have no connection to `z` anymore. Selecting the field of a sliced row of structured elements is straightforward. Since the row is sliced before the field is selected, no parentheses are necessary. Thus the real part of the third `STRUCT (REAL re, im)` of `z` above is given by the expression:

```
re OF z[3]
```

3.11 Field selections

Algol 68 was one of the first languages to introduce structured values, and the production rule for a **selection**:

- **selection: identifier {8.6.2}, of-symbol, secondary {8.9.3}.**

nowadays appears a bit odd since this syntax evaluates from right-to-left while most other languages evaluate **selections** from left-to-right. Compare for instance the Algol 68 construction:

```
x OF point OF z
```

which in C or Pascal would read[2]:

```
z.point.x
```

`a68g` offers alternative syntax to the classic Algol 68 **selection**, called a **field-selection**, which is described by the production rule:

- **field selection:**
  weak primary {8.9.2}, sub {8.2} symbol, identifier {8.6.2} list, bus {8.2} symbol.

by which one can write above example in `a68g` as:

`z[point, x]` or `z(point, x)`

which is elaborated as if you would have written:

```
x OF point OF z
```

The **field-selection** is a **primary** and is very similar to a **call** (see 5.3) or a **slice**. Unlike a **selection**, a **field-selection** cannot perform multiple selection; if it could, then for example in a range containing the declaration `INT im, [3] COMPL z`, the **primary** `z[im]` would be ambiguous.

3.12 Mode declarations

Structure **declarations** are very common in Algol 68 **programs** because they are a convenient way of grouping disparate data elements, but writing out modes in every **declarer** is clumsy and error-prone. Using the **mode-declaration**, a new **mode-indicant** can be declared to indicate a mode. Relevant production rules are:

- **mode declaration:**
  mode {8.2} symbol, mode definition list.

- **mode definition:**
  mode indicant {8.6.1}, equals {8.2} symbol, actual declarer {8.11}.

[2]For convenience we ignore the distinction between the `.` and `->` operators.

An indicant can be an upper-case tag as `RECORD` or `VECTOR`. `a68g` accepts a tag that starts with an upper-case letter, optionally followed by upper-case letters or underscores. Since spaces are not allowed in an upper-case tag to avoid ambiguity, underscores can be used to improve legibility. The use of underscores in tags is not allowed in standard Algol 68. For example, the **mode-declaration**:

```
MODE VECTOR = STRUCT (REAL x, y, z)
```

or

```
MODE VECTOR = [1 : 3] REAL
```

makes `VECTOR` a synonym for the mode specification on the right-hand side of the **equals-symbol**, and new objects using `VECTOR` can be declared in the ordinary way:

```
VECTOR vec = (1, 2, 3);
VECTOR vn := vec;
[10] VECTOR va;
MODE TENSOR = STRUCT (VECTOR x, y, z)
```

The mode `STRING` is declared in the standard prelude as:

```
MODE STRING = FLEX [1 : 0] CHAR
```

Note that **bounds** are conveniently ignored when a newly declared **indicant** is used as a **formal-declarer**, for instance in an **identity-declaration**. Now consider this small **program** using matrix objects:

```
INT n;
MODE MATRIX = [n, n] REAL;
read (n);
MATRIX m;
```

In above **declaration** of mode `MATRIX`, the **bounds** will be elaborated at the **declaration** of any name of mode `MATRIX`. When `MATRIX` is used as a **formal-declarer**, the **bounds** are ignored and not evaluated.

Suppose you want a mode which refers to another mode which has not yet been declared before, and a second mode that refers to the first mode, for example:

```
MODE A = STRUCT (STRING title, REF B next),
  B = STRUCT (STRING name, REF A next)
```

This can for instance not be written in Pascal or C without using some sort of *forward declaration* in Pascal or *incomplete type* in C. In Algol 68, tags like **identifiers**, **indicants** or **operators** do not have to be declared before they are applied, so one can straightforwardly declare the two modes as listed above. The syntax of Algol 68 forces that a mode cannot give rise to (1) an infinitely large object or (2) endless coercion. Using a **mode-declaration**, you

might be tempted to declare a mode such as:

```
MODE CIRCULAR = STRUCT (INT i, CIRCULAR c) CO wrong! CO
```

but this is not allowed since a **declaration**:

```
CIRCULAR z;
```

would quickly consume all memory on your system and then complain that memory is exhausted. Next **declaration** will also give an infinitely large object:

```
MODE BINARY = [1 : 2] BINARY
```

and is therefore not allowed. However, there is nothing wrong with modes as:

```
MODE LIST = STRUCT (STRING s, REF LIST next)
```

because only a reference to itself is declared within the structure. Therefore `REF` shields a mode definition from its application.

3.13 Complex numbers

The **standard-prelude** contains the **mode-declaration**:

```
MODE COMPL = STRUCT (REAL re, im)
```

`a68g` considers the symbols `COMPL` and `COMPLEX` as equivalent.

Multi-precision **declarations** exist in `a68g`:

```
MODE LONG COMPL = STRUCT (LONG REAL re, im);
MODE LONG LONG COMPL = STRUCT (LONG LONG REAL re, im)
```

As with modes `INT` and `REAL`, the length of `LONG LONG` modes can be made arbitrarily large through the option **--precision** {10.6.4}. As described in the previous section, the indicant `COMPL` can be used wherever a mode is required. From the section on field **selection**, it is clear that in the **declarations**:

```
COMPL z = read complex;
COMPL w := z
```

the **selection**:

```
re OF z
```

yields a value of mode `REAL`, while the **selection**:

```
re OF w
```

yields a value of mode REF REAL. The predefined **monadic-operator** RE takes a COMPL **operand** and yields its re field with mode REAL. Likewise, the **monadic-operator** IM takes an **operand** of mode COMPL and yields its im field with mode REAL. Note that the **formula** RE w yields a value of mode REAL, not REF REAL, because RE is an operator whose single **operand** has mode COMPL. In the above expression, w will be dereferenced before RE is elaborated. Thus it is not valid to write:

```
RE w := 0
```

which should be written as:

```
re OF w := 0
```

In a strong strong context, a real number will be widened to a complex number. So, for example, in the following **identity-declaration**:

```
COMPL z = pi
```

z will have the same value as if it had been declared by:

```
COMPL z = (pi, 0)
```

Next to using a **row-display** to denote a complex number, the predefined **dyadic-operator** I can be used taking left- and right-**operands** of any combination of REAL and INT yielding a COMPL value. It has a priority of 9. For example −1 I 1 yields $i - 1$. Of course, there is a **declaration** for I that takes left- and right-**operands** of any combination of LONG REAL and LONG INT and yields a LONG COMPL value, and a **declaration** that takes left- and right-**operands** of any combination of LONG LONG REAL and LONG LONG INT and yields a LONG LONG COMPL value.

Many operators you need to manipulate complex numbers have been declared in the standard prelude. One can use the **monadic-operators** + and − which have also been declared for values of mode COMPL. For a complex number z, CONJ z yields RE z I − IM z. The operator ARG gives the argument of its **operand** in the interval $< -\pi, \pi]$. The **monadic-operator** ABS for a complex number is defined as:

```
OP ABS = (COMPL z) REAL: sqrt (RE z ** 2 + IM z ** 2)
```

Note that in the **formula** RE z ** 2, the operator RE is monadic and so is elaborated first. The **dyadic-operators** +, −, * and / are declared for all combinations of complex numbers, real numbers and integers, as are the comparison operators = and /=. The **dyadic-operator** ** is declared for a left hand **operand** of mode COMPL and a right hand **operand** of mode INT. The assignation operators TIMESAB, DIVAB, PLUSAB, and MINUSAB all take a left **operand** of mode REF COMPL and a right **operand** of modes INT, REAL or COMPL. In fact, a68g supplies **operator-declarations** for all combinations of **operand** precision, always resulting in a value with longest precision of either **operands**. a68g implements routines for complex arithmetic that circumvent unnecessary overflow when large real or imaginary values are used. Naive implementation of for example division or ABS can over-

flow while the result is perfectly representable.

Routines are the subject of a later chapter, however we have already introduced mathematical functions for real values. Algol 68 Genie extends the Revised Report requirements for the standard prelude by also defining mathematical functions for mode `COMPLEX`. Note that a runtime error occurs if either argument or result are out of range. Multi-precision versions of these routines are declared and are preceded by either `long` or `long long`, for instance `long complex sqrt` or `long long complex ln`. A complete list of available functions is in section 11.6.2.

3.14 Archaic modes BITS and BYTES

3.14.1 Mode BYTES

Mode `BYTES` is a compact representation of `[] CHAR`. It is a structure with an inaccessible field that stores a row of characters of fixed length in a compact way. A fixed-size object of mode `BYTES` may serve particular purposes (such as file names on a particular file system) but the mode appears of limited use - it was useful in a time when memories were small.

On modern hardware there is no reason to use an object of mode `BYTES` in stead of a `[] CHAR`. For reasons of compatibility with old **programs**, `a68` implements modes `BYTES` and `LONG BYTES`. Since these modes are of little practical use they are not extensively treated here and you are referred to chapter 11 that lists available operators and procedures for `BYTES` and `LONG BYTES`.

3.14.2 Mode BITS

Mode `BITS` is a compact representation for a `[] BOOL`. The `BOOL` values are represented as single bits. A `BITS` value is tradionally stored in a machine word. Alternatively a `BITS` value can be interpreted as a whole number in $\mathbb{W}$, comparable to an `unsigned` integer in C. The typical application of `BITS` is for masks, or to represent small sets where each bit is associated with a set member. The advantage of `BITS` is efficiency; compared to a `[] BOOL`, a `BITS` value uses less storage and offers parallel operation on bits for a number of operators. The number of bits in one machine word is given by the environment enquiry `bits width`; on modern hardware this value on `a68g` will be either 32 or 64.

It is important to note that in Algol 68 the most significant bit in a `BITS` value is bit 1 and the least significant bit is bit 32 (or bit 64). Nowadays this seems counter-intuitive, but imagine reading a `[] BOOL` from left to right; then the most significant bit is the first element in the row and therefore must be bit 1. Also, when Algol 68 was designed this was the way mainframes as the `IBM 370` or `PDP 10` stored data - the sign bit was bit 0, the most significant bit was bit 1, and the least significant bit was either bit 31 (32-bit

machines) or bit 35 (36 bit machines). Another language where bit 1 is the most significant bit, is PL/I.

Sometimes you want to use bits values with more bits than offered by BITS. Algol 68 Genie supports modes LONG BITS and before version 3 also LONG LONG BITS. The range of LONG LONG BITS is default circa twice the length of LONG BITS but can be made arbitrary large through the option precision {10.6.4}. Below are the respective bits widths for the three lengths available in a68g.

On platforms that support 64-bit integers and 128-bit floats:

Identifier	Value	Remarks
bits width	64	
long bits width	128	

On other platforms:

Identifier	Value	Remarks
bits width	64	
long bits width	116	a68g library
long long bits width	232	a68g library, variable

Algol 68 implements strong widening from a BITS value to a [] BOOL value. Default formatting in transput of a value of mode BITS is as a row of bool. A BITS value can also be denoted in four different ways using **denotations** written with radices of 2 (binary), 4, 8 (octal) or 16 (hexadecimal). The **denotations** in next **declaration**:

```
BITS a = 2r001011101101,
  b = 4r23231,
  c = 8r1355,
  d = 16r2ed
```

are all equivalent because they all denote the same value. Note that the radix precedes the letter r and is written in decimal. Recall that numbers can be written with spaces, or new lines, in the middle of the number; but one cannot put a **comment** in the middle of the number. In standard Algol 68, a **denotation** for LONG BITS must be preceded by the reserved word LONG and a **denotation** for LONG LONG BITS must be preceded by the reserved words LONG LONG. As with **integral-denotations** and **real-denotations**, a68g relaxes the use of prefixes when the context imposes a mode for a **denotation**, in which case a **denotation** of a lesser precision is automatically promoted to a **denotation** of the imposed mode.

3.14.3 Operators for BITS

There are many operators for BITS values. These are called bit-wise operators because their action on each bit is independent of the value of other bits. The **monadic-operator** BIN takes an INT **operand** and yields the equivalent value with mode BITS. The operator ABS converts a BITS value to its equivalent with mode INT. The NOT operator which you first met in chapter 2.7 for a Boolean value (section 2.9), takes a BITS **operand** and yields a BITS value where every bit in the **operand** is reversed, corresponding to forming a set of all members not present in the original set.

Three dyadic-operators taking two BITS **operands** are AND, OR (both of which you also met in chapter 2.7 for values of mode BOOL) and XOR. All three take two BITS **operands** and yield a BITS value. They are bit-wise operators with following action:

Left bit	Right bit	AND	OR	XOR
F	F	F	F	F
F	T	F	T	T
T	F	F	T	T
T	T	T	T	F

The priority of AND and XOR is 3 and the priority of OR is 2. The AND operator is particularly useful for either forming a set of common members from two **operand** sets. OR joins the two **operand** sets while XOR forms a set of members present in either **operand** set, but not both.

Other dyadic operators involve setting and extracting single bits in a BITS value, which corresponds to accessing individual set members. It is possible to extract a single bit as a Boolean value using the operator ELEM. For example, given the **declaration** BITS set and supposing we want the third bit (recall that the leftmost bit is bit-1), we could write the following **declaration**:

```
BOOL member 3 = 3 ELEM set
```

Thus, if the third bit is a binary 1, the **declaration** will give the value TRUE for bit 3. The priority of ELEM is 7. Operators SET and CLEAR yield a BITS value with the bit indicated by the left **operand** set or cleared in the BITS value yielded by the right **operand**. The priority of SET and CLEAR is 7.

Lastly, the **dyadic-operators** SHL and SHR shift a left hand BITS **operand** to the left, or to the right respectively, by the number of bits specified by their right hand INT **operand**. When shifting left (SHL), bits shifted beyond the most significant part of the word are lost. New bits shifted in from the right are always zero. When shifting right (SHR), the reverse happens. For SHL, if the number of bits to be shifted is negative, the BITS value is shifted to the right and likewise for SHR. UP and DOWN are synonyms for SHL and SHR respectively. The priorities of SHL and SHR are both 8.

The operators = and /= are defined for mode BITS with obvious meaning. Noteworthy are the operators <= and >= that for mode BITS are defined as follows:

`s <= t` is equivalent to `(s OR t) = t`
`s >= t` is equivalent to `t <= s`

This means that if objects of mode BITS are used to represent sets, that the **formula** `s <= t` tests whether `s` is a subset of `t`. Would you interpret BITS as unsigned integral values, then these operators have their obvious meaning of testing relative magnitude.

3.15 United modes

In computer science, a union is a data structure that stores one of several types of data in one object. Algol 68 implements tagged unions. A tagged union, also called a variant, variant record, discriminated union, or disjoint union, is a data structure used to hold a value that could take on several different, but fixed types. Only one of the types can be in use at any one time, and a tag field explicitly indicates which one is in use. `UNION` is used to create a united mode. For example `UNION (INT, STRING)` can either hold an `INT` value or a `STRING` value. Experience shows that united modes are not used very often in actual **programs**. One way of using unions is to save a little memory space when two values can be mapped onto each other, but this argument hardly holds any more considering the specifications of modern hardware. A good way to approach unions is:

1. to use them as an abstraction tool, when you want to explicitly express that an object can be of one of several modes. Transput is a good example of this, for instance:

   ```
   MODE NUMBER = UNION (INT, REAL,
     LONG INT, LONG REAL,
     LONG LONG INT, LONG LONG REAL);
   ```

   or think of a Lisp interpreter in Algol 68 where you could declare for example this:

   ```
   MODE VALUE = UNION (ATOM, LIST),
     ATOM = STRING,
     LIST = REF NODE,
     NODE = STRUCT (VALUE car, cdr);
   ```

   Also here, the union serves to provide abstraction.

2. to otherwise use a structure with a field for every mode you need.

Note that in a union, unlike structures, there are no field selectors. This is because a united mode does not consist of constituent parts. The order of the modes in the union is irrelevant, they are associative; so next unions are equivalent:

```
UNION (INT, STRING) • UNION (STRING, INT)
```

And above unions are equivalent to:

```
UNION (STRING, INT, STRING)
```

since identical modes within a union are absorbed. Like structured modes, united modes are often declared with the mode **declaration**. This is a suitable **declaration** of a united mode containing the constituent modes `STRING` and `INT`:

```
MODE CARDINAL = UNION (STRING, INT)
```

We could create another mode `NUMERAL` in two ways:

```
MODE NUMERAL = UNION (CARDINAL, REAL)
```

or the equivalent phrasing:

```
MODE NUMERAL = UNION (STRING, INT, REAL)
```

Using an above **declaration** for `CARDINAL`, we could declare:

```
CARDINAL u = (roman mood | "MMVIII" | 2008)
```

In this **identity-declaration**, the mode yielded by the right hand side is either `INT` or `STRING`, but the mode required is `UNION (STRING, INT)`. The value on the right-hand side is coerced to the required mode by a coercion called uniting which is available in firm and strong contexts. This means that operators which accept **operands** with united modes will also accept **operands** whose modes are any of the constituent modes. We will return to this in a further section. The united mode `CARDINAL` is a mode whose values either have mode `INT` or mode `STRING`. Any value of a united mode actually has a mode which is one of the constituent modes of the union. So there are no new values for a united mode. Because a united mode does not introduce new values, there are no **denotations** for united modes. **identifier** `u` as declared above identifies a value which is either an `INT` or a `STRING`. Later you will read how to determine the mode of the value currently contained in a united object using a **conformity-clause**. Any mode and also `VOID` can be a constituent mode of a united mode. Consider this united mode containing a procedure and `VOID`:

```
MODE OPTIONAL = UNION (PROC (REAL) REAL, VOID)
```

and a **declaration** applying it:

```
OPTIONAL function := EMPTY
```

indicating that `function` is initially undefined as it holds no `PROC (REAL) REAL` value. A limitation on constituent modes in a united mode is that none of the constituent modes may be firmly related (see section 5.6) and a united mode cannot appear in its own **declaration**. The following **declaration** is wrong because a value of one of the constituent modes can be deprocedured in a firm context to yield a value of the united mode:

```
MODE WRONG = UNION (PROC WRONG, INT)
```

Names for values with united modes are declared in exactly the same way as before. Look at this **declaration** for a name using a local **generator**:

```
REF UNION (BOOL, INT) un = LOC UNION (BOOL, INT)
```

The abbreviated **declaration** reads:

```
UNION (BOOL, INT) un
```

Hence objects of united modes can be declared in the same way as other objects.

4 Program structure

4.1 Introduction

This chapter describes the structure of an Algol 68 program (the **particular-program**). Formally, a program is an **enclosed-clause** of mode `VOID`, meaning that if this **enclosed-clause** yields for instance an integral value, that this value is discarded. There are seven types of **enclosed-clause**.

1. The simplest is the **closed-clause** which consists of a **serial-clause** enclosed in parentheses (or `BEGIN` and `END`).
2. **Collateral-clauses** are generally used as **row-displays** or structure displays: there must be at least two **units**. The **units** are elaborated collaterally. This means that the order is undefined and may well be in parallel.
3. A **parallel-clause** {4.12} is a **collateral-clause** preceded by `PAR`. The constituent **units** are executed in parallel.
4. The **loop-clause** {4.9} elaborates code iteratively.
5. The **conditional-clause** {4.3} elaborates code depending on a boolean value.
6. The **case-clause** {4.6} elaborates code depending on an integral value.
7. The **conformity-clause** {4.7} elaborates codedepending on the mode of a united value.

4.2 The closed clause

Algol 68 **programs** are free format: the meaning of a program is independent of its layout. This seems trivial but Algol 68 was presented at a time when languages as Fortran designed special meaning to characters at certain positions in a line. For example, you could write a complete though trivial Algol 68 program like so:

```
(print ("Hello world!"))
```

Note that the pair `BEGIN` and `END` can always be replaced by the pair `(` and `)`. This is another simple example program:

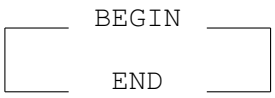
```
BEGIN INT m = read int;
  INT n = read int;
  print (("sum is", m + n))
END
```

Note that there is no **semicolon-symbol** before `END`. Unlike C where a **semicolon-symbol** is a statement terminator, in Algol 68 it is a phrase separator[1].

Examples of **units** are **formulas**, **assignations** etcetera. Chapter 8 will explain **units** and coercions in detail. **Units** and **declarations** are separated by the **go-on-symbol**, which is a **semicolon-symbol**. A sequence of at least one **unit** and if needed **declarations**, separated by **semicolon-symbols**, is called a **serial-clause**. A **serial-clause** yields the value of its last **unit**. Since a **serial-clause** yields a value but a **declaration** never does, a **serial-clause** cannot end in a **declaration**. In Algol 68, as in other block oriented languages as C and Pascal, the validity of **declarations** is limited to the "block" that contains them. Algol 68 uses the terms *range* and *reach* to explain the validity of **declarations**:

- a range is a validity area for **declarations**, for instance a **serial-clause**. A **declaration** in a range is not valid in its parent ranges, but it is valid in embedded ranges.
- a reach is a range excluding its embedded ranges. In Algol 68, looking for the **declaration** of a symbol (**identifier**, **mode-indicant**, operator et cetera) means searching inside-out through nested reaches. This is the same in languages as C or Pascal.

Declarations in a **serial-clause** have validity only in that **serial-clause** and in its embedded **serial-clauses**. The construct `BEGIN serial-clause END` contains a **serial-clause** and thus holds a range which is illustrated by this diagram:



Similar diagrams will be used in this publication to illustrate the hierarchy of ranges of more complicated constructs. The construct `BEGIN serial-clause END` is called a **closed-clause** in Algol 68.

The production rule for the **closed-clause** therefore reads:

- **closed clause:**
  begin {8.2} symbol, serial clause {8.8}, end {8.2} symbol.

[1] `a68g` is tolerant with respect to using the **semicolon-symbol** as phrase terminator. You will get a warning, but superfluous **semicolon-symbols** are ignored.

4.3 The conditional clause

The **conditional-clause** lets a **program** elaborate code depending on a BOOL value. This value must be yielded by a special **serial-clause** that cannot have **labels**: an **enquiry-clause**. This is a simple example of a **conditional-clause**:

```
IF REAL x = read real; x > 0
THEN print ((ln (x), new line))
ELSE stop
FI
```

If the BOOL **enquiry-clause** yields TRUE, the **serial-clause** following THEN is elaborated, otherwise the **serial-clause** following ELSE is elaborated. The symbol FI following the ELSE **serial-clause** is a closing parenthesis to IF. The ELSE part of a **conditional-clause** can be omitted. When the ELSE part is omitted, and the **conditional-clause** is expected to yield a value, an undefined value of the required mode will be yielded if the **enquiry-clause** yields FALSE. Actually, if the ELSE part is omitted then its **serial-clause** is regarded as consisting of the single **unit** SKIP. The use of IF with matching FI eliminates the dangling-else problem: to what IF does a nested ELSE belong in nested **conditional-clauses** when ELSE is optional? In for example Pascal and C such matters are decided by writing extra rules next to the syntax stating that any ELSE is related to the *closest* preceding IF. In Algol 68 such extra rules are not necessary. The production rules for the **conditional-clause** read:

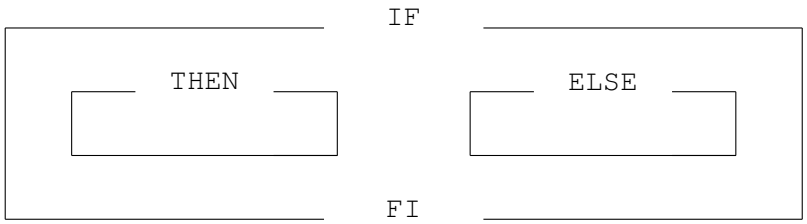
- ***conditional clause: choice using boolean clause.**
- **choice using boolean clause:**
  if {8.2} **symbol, meek boolean enquiry clause** {8.8}**,**
  then {8.2} **symbol, serial clause** {8.8}**,**
  elif part option,
  else part option,
  fi {8.2} **symbol.**
- **elif part:**
  elif {8.2} **symbol, meek boolean enquiry clause** {8.8}**,**
  then {8.2} **symbol, serial clause** {8.8}**,**
  elif part option.
- **else part:**
  else {8.2} **symbol, serial clause** {8.8}**.**

The **enquiry-clause** is in a meek context, meaning that only deproceduring and dereferencing {6.5} will be applied to the terminal **unit** of the **enquiry-clause**. For instance, if the terminal **unit** would be `read bool`, deproceduring will take place to make the routine yield a boolean value. The **enquiry-clause** on line 1 in above-mentioned example reads:

```
REAL x = read real;
x > 0
```

which obviously ends in a **unit** yielding a value of mode BOOL.

An **enquiry-clause** and a **serial-clause** may consist of at least one **unit** and possibly **declarations**. However, in a **conditional-clause** an **enquiry-clause** must end with a **unit** yielding BOOL. The hierarchy of ranges in **conditional-clauses** is illustrated by:



The range of any **declaration** in an **enquiry-clause** extends to the **serial-clauses** following THEN and ELSE. All **declarations** in the **conditional-clause** cease to exist when FI is encountered. This diagram also explains why an **enquiry-clause** cannot have **labels**: these **labels** would be visible from within constituent parts of the **conditional-clause**, and would let you jump back into the **if-part**. Note that this design of the **conditional-clause** allows you to write any **declaration** in the smallest range required, thus shielding them from other parts of the **program** that have no need for these **declarations**. This allows for a safe and clean programming style.

The **conditional-clause** can be written wherever a **unit** is permitted, so:

```
IF INT a = read int;
  a > 0
THEN print ((a, " is positive"))
ELSE print ((a, " is negative"))
FI
```

can also be written as:

```
INT a = read int;
print ((a, " is ", IF a >= 0 THEN "posi" ELSE "nega" FI, "tive"))
```

The value of each of the **serial-clauses** following THEN and ELSE in this case is [] CHAR, a **row-of-character**. The **conditional-clause** can appear as an **operand** in a **formula**. A short form for the **conditional-clause** is often used for this: IF and FI are replaced by (and) respectively, and THEN and ELSE are both replaced by a bar |. For example, assuming a **declaration** for x:

```
REAL abs = (x < 0.0 | - x | x)
```

which is equivalent to:

```
REAL abs = IF x < 0.0 THEN - x ELSE x FI
```

If you omit the **else-part**, Algol 68 Genie assumes that you wrote `ELSE SKIP`. For instance, in:

```
REAL quotient = (y /= 0.0 | x / y)
```

the quotient will have an undefined value in case $y = 0$. In such case, `SKIP` will yield an undefined value of the mode yielded by the `THEN` **serial-clause**, which is forced by the **formal-declarer** `REAL`. This is an example of balancing {8}. Formally, `SKIP` is an algorithm that performs no action, completes in finite time, and yields some value of the mode required by the context. You will note that `SKIP` can be useful when you would want to yield some undefined value.

Since the **enquiry-clause** is a special form of **serial-clause**, it can have any number of phrases before the `THEN` symbol. For example:

```
IF INT measurements;
  read (measurements);
  measurements < 10
THEN ...
FI
```

Conditional-clauses can be nested:

```
BOOL leap year =
  IF year MOD 400 = 0
  THEN TRUE
  ELSE IF year MOD 4 = 0
    THEN year MOD 100 /= 0
    ELSE FALSE
    FI
  FI
```

A construction `ELSE IF ... FI` can be contracted to `ELIF ...` which saves indentation:

```
BOOL leap year =
  IF year MOD 400 = 0
  THEN TRUE
  ELIF year MOD 4 = 0
  THEN year MOD 100 /= 0
  ELSE FALSE
  FI
```

Note that there is no contraction of `THEN IF` since that would leave undefined whether an eventual else part would be related to the first condition or to the second. In the abbreviated

form `|:` can be used instead of `ELIF`. For example, the above **identity-declaration** for `leap year` could be written:

```
BOOL leap year =
  (year MOD 400 = 0 | TRUE |: year MOD 4 = 0
  | year MOD 100 /= 0 | FALSE)
```

but this is generally not very legible. For better legibility it is recommended to alternate the long and brief form of the **conditional-clause**, for instance:

```
BOOL leap year =
  IF year MOD 400 = 0
  THEN TRUE
  ELSE (year MOD 4 = 0 | year MOD 100 /= 0 | FALSE)
  FI
```

4.4 Pseudo operators

Sometimes it is useful to include a **conditional-clause** in the `IF` part of a **conditional-clause**. In other words, a `BOOL` **enquiry-clause** can be a **conditional-clause** yielding a value of mode `BOOL`. This is an example with `a` and `b` declared with mode `BOOL` :

```
IF (a | b | TRUE)
THEN ...
ELSE ...
FI
```

As was mentioned in chapter 2.7, the **operands** of an operator are all elaborated before the operator is elaborated. Sometimes it is useful to refrain from further elaboration when the result of a **formula** can be determined from the value of a single **operand**. To that end `a68g` implements the pseudo-operator `THEF` (with synonyms `ANDF` and `ANDTH`) which although it looks like an operator, elaborates its right **operand** only if its left **operand** yields `TRUE`. Compare them with the operator `AND`. The **unit** `p THEF q` is equivalent to:

```
IF p THEN q ELSE FALSE FI
```

An example is the earlier used definition of `leap year`:

```
BOOL leap year =
  IF year MOD 400 = 0
  THEN TRUE
  ELSE year MOD 4 = 0
  THEF year MOD 100 /= 0
  FI
```

There is another pseudo-operator ELSF (with synonyms ORF and OREL) which is similar to the operator OR except that its right **operand** is only elaborated if its left **operand** yields FALSE. The **unit** p ELSF q is equivalent to:

```
IF p THEN TRUE ELSE q FI
```

These pseudo-operators are an a68g extension. Neither THEF nor ELSF are part of Algol 68. Compare them with && and || in C.

4.5 Identity relations

In the chapter on **formulas** we did not address operations on names. The reason for this is that Algol 68 only implements a test on name equality. One can check whether two names are the same, and if they are, they refer to the same value when the names are not NIL. One cannot manipulate addresses as one can in for instance C. Algol 68 does not prescribe how a name refers to a value, though in practice names involve memory addresses. You have already seen that a name generated by LOC is different from a name generated by HEAP since the latter can be modified by the garbage collector. In Algol 68 names are compared through a special construct, the **identity-relation**. For example:

```
u :=: v
```

yields TRUE if u is the same name as v or FALSE otherwise, and:

```
u :/=: v
```

yields TRUE if u is not the same name as v or FALSE otherwise. The symbols :=: and :/=: can be written as IS and ISNT respectively.

A pitfall in an **identity-relation** is that names must be compared at the proper level of dereferencing. The following artificial **program** demonstrates the potential difficulty:

```
BEGIN REF INT i := LOC INT, j := LOC INT, k := LOC INT;
  i := (read bool | j | k);
  print(i IS j)
END
```

Here the **identity-relation** i IS j always yields FALSE because i, j and k are different variables and thus are different names. What you actually want is to compare the *values* of these pointer variables, which in this case are themselves names. We intend to compare REF INT values, but actually test REF REF INT value equality. To compare the names that both i and j refer to, you should place at least one side in a **cast** {6.5}:

```
REF INT (i) IS j
```

This will ensure that the right-hand side (in this case) is dereferenced to yield a name of the same mode as the left-hand side.

The **identity-relation** is subject to balancing, a subject treated at length in chapter 8. The compiler places one side of the relation in a soft context and the other side in a strong context in such way that the modes on both sides are unique and matching. Balancing is certainly needed in the most common application of the **identity-relation**: comparison to `NIL`. Balancing makes `NIL` take the mode of the other name in the **identity-relation**. This however implies that the **identity-relation** `NIL IS NIL` gives a compile-time error since no unique mode can be established for the names:

```
$ a68g -p "NIL IS NIL"
1     (print ((NIL IS NIL)))
                1
a68g: error: 1: construct has no unique mode (detected in closed-clause
starting at "(" in this line).
```

4.6 The case clause

Often choices can be enumerated. Such situation can for example be handled by the following **conditional-clause**:

```
IF n = 1
THEN unit 1
ELIF n = 2
THEN unit 2
ELIF n = 3
THEN unit 3
ELSE unit 4
FI
```

This type of enumerated choice can be expressed more concisely using the **case-clause** in which the `BOOL` **enquiry-clause** is replaced by an `INT` **enquiry-clause**, for example:

```
CASE n
IN unit 1, unit 2, unit 3
OUT unit 4
ESAC
```

which could be abbreviated as:

```
(n | unit 1, unit 2, unit 3 | unit 4)
```

The **case-clause** can also be used to code tables. For instance, calendar computations give examples of **case-clauses**:

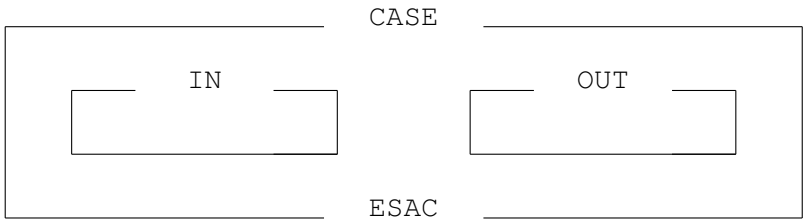
```
INT days =
  CASE month
  IN 31,
    IF IF year MOD 400 = 0
      THEN TRUE
      ELSE (year MOD 4 = 0 | year MOD 100 /= 0 | FALSE)
      FI
    THEN 29
    ELSE 28
    FI,
    31, 30, 31, 30, 31, 31, 30, 31, 30, 31
  ESAC
```

Note that **units** in the `IN` part are separated by **comma-symbols**. If you want more than one phrase for each **unit**, you must make that **unit** an **enclosed-clause**. If the `INT` **enquiry-clause** yields 1, `unit 1` is elaborated; if it yields 2, `unit 2` is elaborated and so on. If the value yielded is negative or zero, or exceeds the number of **units** in the `IN` part, the `OUT` part is elaborated. The `OUT` part is a **serial-clause**. Like the **conditional-clause**, if you omit the **out-part**, Algol 68 Genie assumes that you wrote `OUT SKIP`. The production rules for the **case-clause** read:

- ***case clause: choice using integral clause.**
- **choice using integral clause:**
  case {8.2} symbol, meek integral enquiry clause {8.8},
  in {8.2} symbol, unit {8.9.5} list proper,
  ouse part option,
  out part option
  esac {8.2} symbol.
- **ouse part:**
  ouse {8.2} symbol, meek integral enquiry clause {8.8},
  in {8.2} symbol, unit {8.9.5} list proper,
  ouse part option.
- **out part:**
  out {8.2} symbol, serial clause {8.8}.

The **case-clause** allows only for simple enumeration. Other languages offer constructs, like the `switch` statement in C, that allow for more complex enumeration schemes. In Algol 68, such complex schemes must be handled by a nested **conditional-clause**. The designers of Algol 68 apparently disliked syntactic sugar.

The hierarchy of ranges in **case-clauses** is illustrated by:



Sometimes the **out-part** consists of another **case-clause**. Just as with `ELIF` in a **conditional-clause**, `OUT CASE ... ESAC ESAC` can be replaced by `OUSE ... ESAC`.

4.7 The conformity clause

We will now discuss how a value can be extracted from a united mode since its constituent mode cannot be determined at compile-time. There is no de-uniting coercion in Algol 68 and the constituent mode of the value must be determined using a variant of the **case-clause** {4.6} which is called a **conformity-clause**. The production rules for the **conformity-clause** read:

- ***conformity clause: choice using UNITED {16_1.5} clause.**
- **choice using UNITED {16_1.5} clause:**
  case {8.2} symbol, meek UNITED {16_1.5} enquiry clause {8.8},
  in {8.2} symbol, specified unit list,
  conformity ouse part option,
  out part option,
  esac {8.2} symbol.
- **specified unit:**
  open {8.2} symbol, formal declarer {8.11}, identifier {8.6.2} option, close {8.2} symbol, colon {8.2} symbol, unit {8.9.5}.
  open {8.2} symbol, void {8.2} symbol, close {8.2} symbol, colon {8.2} symbol, unit {8.9.5}.
- **conformity ouse part:**
  ouse {8.2} symbol, meek UNITED {16_1.5} enquiry clause {8.8},
  in {8.2} symbol, specified unit list,
  conformity ouse part option.
- **out part:**
  out {8.2} symbol, serial clause {8.8}.

For our discussion, we return to the **declaration**:

```
MODE CARDINAL = UNION (STRING, INT);
CARDINAL u = (roman mood | "MMVIII" | 2008)
```

The constituent mode of `u` can be determined by:

```
CASE u
IN (INT): print ("decimal mood"),
  (STRING): print ("roman mood")
ESAC
```

If the constituent mode of `u` is `INT`, the first case will be selected. Note that the mode selector is enclosed in parentheses and followed by a **colon-symbol**. Above example could also have been written as:

```
CASE u
IN (STRING): print ("roman mood")
OUT print ("decimal mood")
ESAC
```

Usually, when we determine the mode of an united object with a **conformity-clause**, we also want to extract the value to operate on it. This can be done in this way:

```
CASE u
IN (INT i): print (("decimal mood: ", i)),
  (STRING s): print (("roman mood: ", s))
ESAC
```

In this example, the **declarer** and **identifier**, which is called the specifier, act as the left-hand side of an **identity-declaration**. The value can be used, but not changed as it is declared using an identity **declaration**, in the **unit** following the **semicolon-symbol**. A specifier can also select a united subset of a united mode. For example:

```
MODE ICS = UNION (INT, CHAR, STRING);


# Now define multiplication with an INT: #


OP * = (ICS a, INT b) ICS:
  CASE a
  IN (UNION (STRING, CHAR) ic):
      (ic | (CHAR c): c * b, (STRING s): s * b),
    (INT n): n * b
  ESAC
```

Note that **conformity-clauses** do not usually have an `OUT` clause. One usually defines a specific action by a **conformity-clause** on all possible modes at once.

4.8 Balancing

Enclosed-clauses such as **conditional-clauses**, **case-clauses** and **conformity-clauses** yield one of a number of **units**, and it is quite possible for the **units** to yield values of different modes. The principle of balancing allows the context of all these **units**, except one, to be promoted to strong, whatever the context of the **enclosed-clause**. The one that is not promoted to strong remains in the imposed context of the clause, is of course the one mode to which the promoted **units** can be strongly coerced. Balancing is also invoked for **identity-relations** {4.5}. Consider for example the **formula**:

```
1 + (a > 0 | 1 | 0.0)
```

where the context of the **conditional-clause** is firm hence widening is not allowed. Without balancing, the **conditional-clause** could yield a `REAL` or an `INT`. In this example, the principle of balancing would promote the context of the `INT` to strong and widen it to `REAL`. In a balanced clause, one of the yielded **units** remains in the context of the clause and all the others are in a strong context, irrespective of the actual context of the clause.

4.9 The loop clause

Often you need to iterate a group of actions a number of times. One mechanism for iteration in Algol 68 is the **loop-clause**:

```
TO n # We iterate n times #
DO # serial-clause to be iterated #
  ...
OD
```

Above construct is just one form of the **loop-clause**. Unlike a **conditional-clause** or **case-clause**, a **loop-clause** yields no value. The production rules for the **loop-clause** are:

- **loop clause:**
  for part option,
  from part option,
  by part option,
  to part option,
  while part option,
  do part.

- **for part:**
  for {8.2} **symbol, identifier** {8.6.2}**.**

- **from part:**
  from {8.2} symbol, meek integral unit {8.9.5}.
- **by part:**
  by {8.2} symbol, meek integral unit {8.9.5}.
- **to part:**
  to {8.2} symbol, meek integral unit {8.9.5};
  downto {8.2} symbol, meek integral unit {8.9.5}.
- **while part:**
  while {8.2} symbol, meek boolean enquiry clause {8.8}.
- **do part:**
  do {8.2} symbol, serial clause {8.8}, od {8.2} symbol;
  do {8.2} symbol, serial clause {8.8} option, until part, od {8.2} symbol.
- **until part:**
  until {8.2} symbol, meek boolean enquiry clause {8.8}.

Due to the many optional parts, the **loop-clause** has been compared by some to a Swiss army knife. The **loop-clause** can have a loop **identifier** counting the iterations, as is shown in the following example:

```
FOR i TO 10
DO print ((i, new line))
OD
```

Here i is a new `INT` **identifier**, a counting constant, that can be considered as implicitly declared by the **for-part**. Note that the mode of a loop **identifier** is not `REF INT` so one cannot perform an **assignation** to it. Above example will print the numbers 1 to 10. The range of a loop **identifier** is the **loop-clause** that defines it, except the **from-part**, **by-part** and **to-part**; since the **units** of the latter constructs are determined before iteration is started, they cannot depend on the value of the loop **identifier**. In a **to-part**, the **unit** following `TO` can be any **unit** yielding an integer. It is possible to modify the initial value of the loop **identifier** using a **from-part**, for example:

```
FOR n FROM -10 TO 10
DO print ((n, blank))
OD
```

This prints the numbers from -10 to $+10$ on standard output. The **unit** after `FROM` can be any **unit** which yields a value of mode `INT`. When the **from-part** is omitted, the default initial value of the loop **identifier** is 1. The value of the loop **identifier** is by default incremented by 1. The increment can be changed using a **by-part**. The **unit** after `BY` can be any **unit** which yields a value of mode `INT`. For example, to print the even numbers up to and including 10, you could write:

```
FOR n FROM 0 BY 2 TO 10
DO print ((n, new line))
OD
```

Compare this to its C equivalent:

```
{int n; for (n = 0; n <= 10; n += 2) {printf ("%d\n", n);}}
```

Next example demonstrates a **loop-clause** without a counting constant:

```
BEGIN STRING u := "Barbershop";
  TO UPB u + 1
  DO print ((u, new line));
    CHAR v = u[UPB u]; STRING w = u[1 : UPB u - 1];
    u[2 : UPB u] := w;
    u[1] := v
  OD
END
```

which produces:

```
$ a68g barbershop.a68
Barbershop
pBarbersho
opBarbersh
hopBarbers
shopBarber
rshopBarbe
ershopBarb
bershopBar
rbershopBa
arbershopB
Barbershop
```

The increment specified by a **by-part** can be negative, in which case the loop will count backwards. `a68g` offers the reserved word `DOWNTO` as an alternative to `TO`. `DOWNTO` originally is an `ALGOL68C` extension. `DOWNTO` will decrement, whereas `TO` will increment, the loop **identifier** by the amount stated by the (implicit) **by-part**; `BY n DOWNTO m` is equivalent to `BY -n TO m`. For example:

```
FOR k FROM 10 DOWNTO 1
DO print (k)
OD
```

If you omit a **to-part**, the loop will iterate indefinitely. There are of course applications for loops that iterate until a condition is met that does not depend on the loop **identifier** alone. Such condition can be programmed using the **while-part** of a loop. For example:

```
WHILE INT int;
  read (int);
  int > 0
DO print (int)
OD
```

In this example, no loop counter is needed and so the `FOR` part is omitted. `WHILE` is followed by an **enquiry-clause** yielding a `BOOL` value. An integer is read each time the loop is elaborated until a non-positive integer is read. The range of any **declarations** in the **enquiry-clause** extends to the `DO ... OD` loop. The **while-part** provides for a *pre-checked* loop. There are those who regret that Algol 68's definition did not include a *post-checked* loop. Apparently it was believed that a post-checked loop was not really necessary since it can be programmed as:

```
WHILE do what has to be done;
  condition
DO SKIP
OD
```

and as has been remarked before, the designers of Algol 68 apparently disliked syntactic sugar. Many think that the `DO SKIP OD` solution is not elegant. To accommodate this, `a68g` extends Algol 68 by offering a post-checked loop by allowing an optional **until-part** as final part of the `DO ... OD` construction:

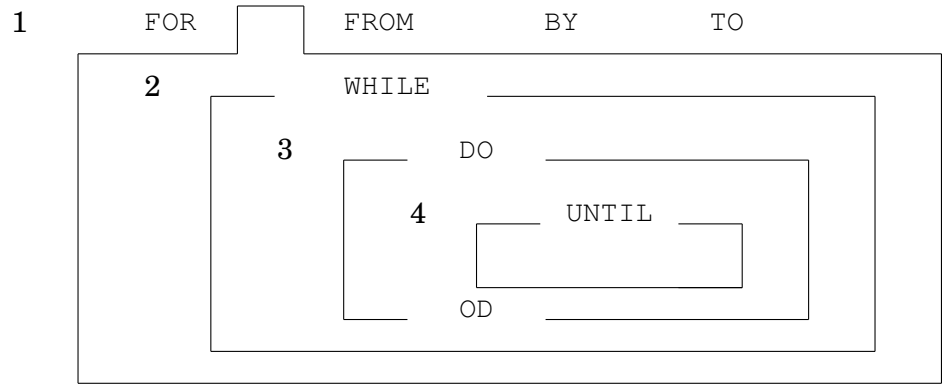
```
DO serial-clause-option
  UNTIL boolean-enquiry-clause
OD
```

A trivial example of a post-checked loop is:

```
DO UNTIL read char = "."
OD
```

which will skip characters from standard input until a `"."` is encountered which will disappear from the input as well.

The hierarchy of ranges in the **loop-clause** is illustrated by:



Again, note that the loop **identifier** is unknown in the **from-part**, **by-part** and **to-part**. Since the **units** of the latter constructs are determined before iteration is started, they cannot depend on the value of the loop **identifier**.

4.10 Order of evaluation

Take care in **assignations** that the effect of code does not depend on assumptions on the order of elaboration. The elaboration of left-hand-side destinations and right-hand-side sources is performed collaterally. After evaluating destinations and sources, **assignation** takes places from right-to-left. Since an **assignation** yields a value (specifically, a name), it can be used as an **operand** in a **formula**. However, an **assignation** is a **unit**, and a **unit** cannot be a direct **operand** (see chapter 8). The **assignation** must be packed in an **enclosed-clause** using parentheses, or `BEGIN` and `END`; for example:

```
2 * (a := a + 1)
```

In Algol 68, the **becomes-symbol** `:=` is not an operator, and an **assignation** cannot be a direct **operand**. The following rephrasing of above example applies `+:=` which *is* an operator:

```
2 * (a +:= 1)
```

Parentheses are still needed here as multiplication takes priority over `+:=`.

Now let us return to order of evaluation. In:

```
INT side sq = a ** 2 + b ** 2
```

the order of elaboration is that both terms are elaborated collaterally. Hence do not write code that yields a result that depends on the order of evaluation, for instance:

```
INT poly = a ** 2 + (a +:= 1)
```

which would yield either $a^2 + a + 1$ or $a^2 + 2a + 1$ or $a^2 + 3a + 2$ at the compiler's discretion[2]. Write this strictly as:

```
a +:= 1; INT poly = a * (a + 1)
```

4.11 Comments and pragmats

It is of course good practice to write **comments** in source code. **Comments** can be put almost anywhere, but not in the middle of symbols. A **comment** is ignored by `a68g`. A **comment** is delimited by one of the following pairs:

```
COMMENT ... COMMENT
CO ... CO
# ... #
```

where the ... represent the actual **comment**. If one starts a **comment** with `COMMENT` then you must also finish it with `COMMENT`, and likewise for the other **comment-symbols**. This is an example **comment** describing the purpose of a **program**:

```
COMMENT
  The determinant of the square matrix 'a' of order 'n' by the
  method of Crout with row interchanges: 'a' is replaced by its
  triangular decomposition, l * u, with all u[k, k] = 1.
  The vector 'p' gives as output the pivotal row indices; the k-th
  pivot is chosen in the k-th column of T such that
  ABS l[i, k] / row norm is maximal
COMMENT
...
```

It is of course recommended to indicate limitations of a piece of code:

```
  CO This only works for powers of two! CO
```

It is also common practice to "comment out" pieces of source code, as in:

```
  COMMENT
    print (i); # trivial check #
  COMMENT
```

This is an example of nested **comments**. Since in Algol 68 the symbol starting a **com-**

[2]This **formula** could fail completely if the **assignation** would be incomplete while multiplication started with an indeterminate value a. In C terms, the result is *undefined* rather than *unspecified*.

ment is equal to the symbol ending a **comment**, it is not possible to have proper nested **comments** in Algol 68. To have proper nested **comments**, Algol 68 Genie should be able to count how many **comments** are open, which is not possible if the embedding symbols are equal. Therefore, if the part of your **program** that you want to "comment out" already contains **comments**, you should ensure that the inner **comment** symbols are different from those of the outermost **comment**, because `a68g` only scans the outermost **comment** and ignores all text until the matching **comment** symbol[3].

A **pragmat** is a pragmatic remark that you can write in the source code. The Algol 68 definition {25_9.2} leaves it up to the implementation what such pragmatic remark should do, and in `a68g` pragmats let you insert command line options in the source code.

A pragmat is surrounded by one of the following pairs of delimiters:

```
PRAGMAT ... PRAGMAT
```

For instance, if you have a script that needs a lot of heap space you do not want to have to specify an option at the command line. Instead you write in the script:

```
#!/usr/local/a68g
PR heap=256M PR
```

The pragmat will execute the option at compile time as if you would have specified

```
--heap=256M
```

from the command line.

In `a68g`, by the use of pragmats you can textually include files in your source code; see section 10.7.2.

4.12 Parallel processing

Algol 68 supports parallel processing on platforms that support POSIX threads, such as Linux. Using the reserved word `PAR`, a **collateral-clause** becomes a **parallel-clause**, in which the synchronisation of actions is controlled using semaphores. In `a68g` the parallel actions are mapped to POSIX threads when available on the hosting operating system (and `a68g` must be built to support the **parallel-clause** {10.3.2}. Parallel **units** coordinate their actions by means of semaphores. A semaphore constitutes the classic method for restricting access to shared resources, such as shared stack and heap. It was invented by Edsger

[3]Compare this to Pascal where **comment** symbols are `{ ... }` or C where **comment** symbols are `/* ... */` making it possible to count how many **comments** are open; however not all implementations of those languages allow nested **comments**.

Dijkstra. Usually (and also in Algol 68) the term refers to a counting semaphore, since a binary semaphore is known as a mutex. A counting semaphore is a counter for a set of available resources, rather than a locked-unlocked flag of a single resource. Semaphores are the classic solution to preventing race conditions in the dining philosophers problem (a generic, abstract problem used for explaining issues with mutual exclusion), although they do not prevent resource deadlocks. Semaphores remain in common use in programming languages that do not support other forms of synchronisation. Semaphores are the primitive synchronisation mechanism in many operating systems. The trend in programming language development is towards more structured forms of synchronisation, such as monitors and channels. In addition to their inadequacies in dealing with (multi-resource) deadlocks, semaphores do not protect the programmer from easy mistakes like taking a semaphore that is already held by the same process, or forgetting to release a semaphore. It has been put forward that it is debatable whether a low-level feature as the semaphore is a proper feature for a high-level language as Algol 68. A semaphore in Algol 68 is an object of mode `SEMA`:

```
MODE SEMA = STRUCT (REF INT F)
```

Note that the field cannot be directly selected. For a semaphore, next operators are defined:

1. `OP LEVEL = (INT a) SEMA`
   Yields a semaphore whose value is `a`.
2. `OP LEVEL = (SEMA a) INT`
   Yields the level of `a`, that is, field `F OF a`.
3. `OP DOWN = (SEMA a) VOID`
   The level of `a` is decremented. If it reaches `0`, then the parallel **unit** that called this operator is hibernated until another parallel **unit** increments the level of `a` again.
4. `OP UP = (SEMA a) VOID`
   The level of `a` is incremented and all parallel **units** that were hibernated due to this semaphore being down are awakened.

Next classical example demonstrates the use of semaphores in Algol 68: producer-consumer-type parallel processes. In this simple example, production is incrementing an integer and consumption is decrementing it. Synchronisation is necessary to prevent both "production" and "consumption" from accessing the integer (the "resource") at the same time; hence the "consuming" action has to wait for the "producing" action to finish, and vice versa. This is done in line 2 by giving both actions a semaphore, the "producing" semaphore at level `1` so production can start, and the "consuming" semaphore at level `0` so it must initially wait for something being produced. Each parallel action starts by performing `DOWN` on its semaphore, then do its job, and then perform an `UP` on the semaphore of the other action.

```
BEGIN
  INT n := 0, SEMA consume = LEVEL 0, produce = LEVEL 1;
```

```
  PAR BEGIN # produce one #
    DO DOWN produce;
      print (n +:= 1);
      UP consume
    OD,
    # consume one #
    DO DOWN consume;
      print (n -:= 1);
      UP produce
    OD
  END
END
```

The `a68g` **parallel-clause** deviates from the standard Algol 68 **parallel-clause** when **parallel-clauses** are nested. `a68g` parallel **units** behave like threads with private stacks. Hence if parallel **units** modify a shared variable then this variable must be declared outside the outermost **parallel-clause**, and a **jump** out of a parallel **unit** can only be targeted at a **label** outside the outermost **parallel-clause**.

4.13 Jumps

Sometimes one cannot apply strict structural programming, for instance when one needs to abort a **serial-clause**. Like most other programming languages, Algol 68 allows to label **units** in **serial-clauses**. A **label** is an **identifier**, unique in its reach, followed by a **colon-symbol**. A **jump** to a **label** is invoked by writing the name of a **label** as a single **primary**, optionally preceeded by a **goto-symbol**:

```
stop
GOTO stop
GO TO stop
```

Actually, `stop` is a **label** defined at the last phrases of the standard environment. A jump to `stop` therefore ends program execution. Another example is the use of a **jump** in a transput event-routine:

```
on file end (standin, PROC (REF FILE f) BOOL: GO TO file empty)
```

There are restrictions on placing labels. After a **label** definition, one cannot write **declarations**. **Declarations** themselves cannot be labelled. **Labels** are not allowed in **enquiry-clauses** since you would be able to jump for instance from a **then-part** back into the **if-part**. **Declarations** are not allowed after a **label** definition since you would for instance be able to jump back to before a **declaration** and execute it again, facilitating dangling names and scope errors. The rule is that any **declaration** in a **serial-clause** must be seen at most once before that **serial-clause** ends. This means that after a **labelled-unit**, you

are free to use **enclosed-clauses** containing their private **declarations** since a **jump** out of a **serial-clause** effectively ends that **serial-clause**, and above rule is satisfied.

Jumps are like **skips**; they also yield an undefined object of the mode required by the context. But if the context expects a parameter-less procedure of mode `PROC VOID`, then a `PROC VOID` routine whose **unit** is that **jump** is yielded, instead of making the **jump**:

```
#!/usr/local/bin/a68g


# Commented text taken from:
C. H. Lindsey, A History of Algol 68,
ACM Sigplan Notices, Volume 28, No. 3 March 1993 #


# ... But worse! Van Wijngaarden was now able to exhibit his
pride and joy - his pseudo-switch [R8.2.7.2]. #
[] PROC VOID switch = (e1, e2, e3);


# or even #
LOC [1 : 3] PROC VOID switch var := (e1, e2, e3);
switch var[2] := e3;


# To my shame, I must admit that this still works, although implementations
tend not to support it. #


switch var[2];
print ("should not be here");
stop;
e3: e2: e1: print ("jumped correctly")
```

Put above code in a file *jump.a68*, make it executable with `chmod` and execute the file to find:

```
$ ./jump.a68
jumped correctly
```

which demonstrates that `a68g` implements proceduring to `PROC VOID`.

A completer, with reserved word `EXIT`, provides a completion point for a **serial-clause** but cannot occur in an **enquiry-clause**. A completer can be placed wherever a **semicolon-symbol** (the **go-on-symbol** `;`) can appear. A completer must be followed by a **label** definition or the **unit** following the completer could not be reached. This is an example of a completer in line 5:

```
BEGIN REAL x = read real;
  IF i < 0
```

```
  THEN GOTO negative
  FI;
  sqrt (i) EXIT
  negative:
  0
END
```

The example also illustrates why this is not a recommendable programming style. In fact, **jumps** have their use when it is required to jump out of nested clauses when something unexpected occurs from which recovery is not practical. Use of **jumps** should be confined to exceptions since they can make a **programs** illegible.

4.14 Assertions

Algol 68 Genie supports an extension called **assertions**. **Assertions** can be viewed in two ways. First, they provide a notation for invariants that can be used to code a proof of correctness together with an algorithm. Hardly anyone does this, but **assertions** make for debugging statements. The **assertion** syntax reads:

- **assertion: assert {8.2} symbol, meek boolean enclosed clause {8.9.1}.**

Under control of the pragmat items 'assertions' and 'noassertions', the `BOOL` **enclosed-clause** of an **assertion** is elaborated at runtime. If the **enclosed-clause** yields `TRUE` execution continues but if it yields `FALSE`, a runtime error is produced. For example:

```
OP FACULTY = (INT n) INT:
  IF ASSERT (n >= 0);
    n > 0
  THEN n * FACULTY (n - 1)
  ELSE 1
  FI
```

will produce a runtime error when `FACULTY` is called with a negative argument.

5 Procedures and operators

5.1 Introduction

A routine is a set of encapsulated actions which can be elaborated in other parts of the **program**. A traditional use for routines is to avoid duplicate code or to segment large programs, but there are of course many valid reasons to create a routine:

1. Reduce a program's complexity by hiding or abstracting information. For instance, hide the internal workings of a data structure. Hide how a set of equations is solved if the actual way in which it is solved is not relevant — use routines from a scientific library to do linear equations; the persons who wrote them are experts in linear algebra, while you probably are just interested in obtaining accurate results.
2. Avoid duplicate code, facilitating maintenance of that code, and also making central points to control the operation of code.
3. Use a routine as a **refinement**, a tool in top-down program construction introduced by N. Wirth. As an alternative to using routines as **refinements**, `a68g` offers a **refinement** preprocessor {8.13 and 10.7.3}.

In Algol 68, a routine is used in two ways:

1. As a procedure. The routine is invoked by parameter-less deproceduring {5.3} or by a **call** where an **actual-parameter-list** {5.3} is supplied to a routine.
2. As an operator. The routine is invoked by writing a **formula** {2.7}.

An Algol 68 routine is a value with a well-defined mode. The value of a routine is expressed as a **routine-text** which has following production rules:

- **routine text:**
  routine specification, colon {8.2} symbol, strong unit {8.9.5}.

- **routine specification:**
  parameter pack option, formal declarer {8.11}.
  parameter pack option, void {8.2} symbol.
- **parameter pack:**
  open {8.2} symbol, formal parameter list, close {8.2} symbol.
- **formal parameter: formal declarer {8.11}, identifier {8.6.2}.**

A **routine-text** is a **unit**.

Consider next example **routine-text** that sums the element of a row:

```
([] INT a) INT:
  BEGIN INT sum := 0;
    FOR i FROM LWB a TO UPB a
    DO sum +:= a[i] OD;
    sum
  END
```

In this example, the **routine-specification** is:

```
([] INT a) INT
```

which could be read as *with row of integer **parameter** yielding integer*. The mode of the routine `sum` is implicitly given by the **routine-specification** :

```
PROC ([] INT) INT
```

Above routine takes one **parameter** of mode `[] INT` and yields a value of mode `INT`. Often **parameters** can be written in a concise manner. Now consider the example **routine-specification**:

```
(REAL x, REAL y, REAL z) BOOL
```

A contraction of identifiers is possible in this case:

```
(REAL x, y, z) BOOL
```

A **routine-text** without its **routine-specification** is sometimes called a *body*. The body of the above **routine-text** is:

```
BEGIN INT sum := 0;
  FOR i FROM LWB a TO UPB a
  DO sum +:= a[i] OD;
  sum
END
```

The **routine-text** yields the sum of the individual elements of the **parameter** `a`. The body

of a **routine-text** is a **unit**. In this case, the body is an **closed-clause**. Since a **routine-text** is a value it can be associated with an **identifier** by means of an **identity-relation**:

```
PROC ([] INT) INT sum = ([] INT a) INT:
  BEGIN INT sum := 0;
    FOR i FROM LWB a TO UPB a
    DO sum +:= a[i] OD;
    sum
  END
```

Algol 68 allows not only for procedure constants, but also for procedure variables, so the next **declaration** is also valid:

```
PROC ([] INT) INT sum := ([] INT a) INT:
  BEGIN INT sum := 0;
    FOR i FROM LWB a TO UPB a
    DO sum +:= a[i] OD;
    sum
  END
```

Since in **procedure-declarations** the mode is stated on both sides of the **equals-symbol** or **becomes-symbol**, Algol 68 allows an abbreviation according these production rules:

- **procedure declaration:**
  proc {8.2} symbol, procedure definition list.
- **procedure definition: identifier {8.6.2}, equals {8.2} symbol, routine text.**
- **procedure variable declaration:**
  qualifier option, proc {8.2} symbol, procedure variable definition list.
- **procedure variable definition: identifier {8.6.2}, becomes {8.2} symbol, routine text.**

For example:

```
PROC sum = ([] INT a) INT:
  BEGIN INT sum := 0;
    FOR i FROM LWB a TO UPB a
    DO sum +:= a[i] OD;
    sum
  END
```

In the **routine-specification** of above routine, `[] INT a` is a **formal-parameter**. At the time the routine is declared, `a` does not identify a value and therefore the size of a row

parameter is irrelevant. That is why it is called a **formal-parameter**. It is only when the procedure is called that `a` will identify a value. According to the **routine-specification**, the routine must yield a value of mode `INT`. The context of the body of a routine is strong and the terminal **unit** of the **serial-clause** will be coerced. In this case, we have a value of mode `REF INT`, `sum`, which in a strong context will be coerced to a value of mode `INT` by dereferencing. Since **procedure-declarations** are **declarations** like any other, they can appear within other **procedure-declarations**. This is called nesting:

```
PROC print days = (DATE first, last) VOID:
  BEGIN
    PROC day of week = (DATE d) STRING:
      ...
    print ((week day (first), week day (last), new line))
  END
```

In this way one can hide details on the operation of the outer procedure if the inner procedure is not relevant outside the outer procedure.

5.2 Routine modes

The mode of a routine starts with the reserved word `PROC`, irrespective whether the routine is a procedure or an operator. A routine has zero or more **parameters**. The mode of the **parameters** may be any mode except `VOID` and the value yielded may be any mode including `VOID`. In the mode of a routine, **identifiers** are omitted. The modes written for the **parameters** and the yield are always **formal-declarers**, so no **bounds** are specified if the modes of the **parameters** or yield involve rows. Consider the **routine-specification**:

```
(REAL x, y, z) BOOL
```

The mode following from this **routine-specification** is:

```
PROC (REAL, REAL, REAL) BOOL
```

In section 3.12 it was remarked that a **mode-declaration** cannot lead to infinitely large objects or endless coercion. It was indicated that `REF` shields a **mode-indicant** from its **declaration** through a `STRUCT`. `PROC` also shields a **mode-indicant** from its **declaration** through a `STRUCT`. A **parameter-pack** shields a **mode-indicant** from its **declaration**. It is therefore possible to declare, for example:

```
MODE NODE = (STRING info, PROC NODE process)
```

or

```
MODE P = PROC (P) P # rather academic, but ok #
```

A routine must yield a value of some mode, but it is possible to discard that value using

the voiding coercion. The mode VOID has a single value denoted by EMPTY. VOID cannot be a **formal-declarer** of a **parameter** to a routine, so it is not allowed to write:

```
PROC (VOID) VOID # which is allowed in C #
```

though the effect of above (invalid) procedure can be obtained in Algol 68 by writing:

```
PROC VOID # a parameter-less procedure yielding VOID #
```

A routine, with or without **parameters**, can have a result mode VOID in case the routine performs actions but yields no value. In some languages like Fortran this is the distinction between a SUBROUTINE and a FUNCTION — the former only performs actions, the latter (also) yields a value.

In programming practice, because the context of the yield of a routine is strong and any resulting value is voided {6.5.5}, explicitly using EMPTY is almost always unnecessary. A FOR loop always yields EMPTY. A **semicolon-symbol** voids the **unit** that it terminates. **Declarations** yield no value, not even EMPTY. Therefore clauses cannot end in a **declaration**, as demonstrated by this a68g example:

```
$ a68g --exec 'PROC init = VOID: (INT i := 0)'
1     (PROC init = VOID: (INT i := 0))
      2                  1
a68g: syntax error: 1: clause does not yield a value.
a68g: syntax error: 2: clause does not yield a value.
```

5.3 Calls and parameters

Procedures can have no **parameters** at all; for example consider:

```
PROC report = VOID: print (("Now at point ", counter +:= 1));
```

A parameter-less procedure can be invoked by writing its **identifier**. A parameter-less procedure is invoked by the deproceduring coercion that is available in every context, even in a soft context such as the destination of an **assignation**. Deproceduring is a forced **call** of a parameter-less procedure. If the context requires the mode of the **identifier** itself, a routine without parameters is not invoked, as in:

```
PROC INT get int = read int # read int will not be invoked #
```

In case the context requires a value with mode that is the result mode of the routine, the routine without parameters is invoked, as in:

```
LONG INT k := read long int # read long int will be invoked #
```

where a PROC LONG INT is deprocedured to yield a LONG INT value. In case the context imposes voiding, a parameter-less routine is deprocedured and if it is not a PROC VOID

the value after deproceduring is discarded. To avoid unexpected behaviour, deproceduring is not used to coerce an **assignation**, a **generator** or a **cast** {6.5} to `VOID`. Hence if we consider:

```
PROC p = VOID: ...;
PROC VOID pp;
pp := p;
```

then voiding the **assignation** `pp := p` does not involve deproceduring `p` after the **assignation** is completed.

Parameters of procedures can have any mode, including procedures, except `VOID`. Unlike operators, procedures can have any number of **parameters**. A procedure with **parameters** is not implicitly called by deproceduring, but by writing a **call**. A **call** has these production rules:

- **call:**
  meek primary {8.9.2}, open {8.2} symbol, actual parameter list, close {8.2} symbol.
- **actual parameter:**
  strong unit {8.9.5} option.

In strict Algol 68, an **actual-parameter** is a **strong-unit** while in `a68g` it is a **strong-unit-option** because `a68g` allows for partial-parameterisation {5.10}. The most common example of a **call** is writing the **identifier** of a procedure followed by an argument list. The argument list consists of arguments separated by **comma-symbols**; the list is enclosed in parenthesis. For example, the procedure `sum` declared {5.1} can be invoked by a **call**:

```
print ((sum ((1, 2, 3, 4, 5, 6, 7, 8, 9, 10)), new line))
```

which will produce `55` on standard output. A **call** binds as tightly as a **slice**, that is, more tightly than a **selection** or a **formula**. This will be treated at length in chapter 8. Algol 68's allows you to write, instead of a procedure **identifier**, any **primary** (see chapter 8) that yields a procedure; for example:

```
r * (on x axis | cos | sin)(angle)
```

calls either `sin (angle)` or `cos (angle)` depending on the `BOOL` value of `on x axis`.

Algol 68's orthogonality allows you to write a **mode-declaration** involving a routine-mode, or declare a structure with a procedure field:

```
MODE METHOD = STRUCT (FUN f, CHAR name),
  FUN = PROC (REAL) REAL;
  METHOD sinus := (sin, "sin")
```

In the structure `sinus`, the procedure can be selected by:

```
f OF sinus • sinus[f]
```

which is a **selection** with mode `REF PROC (REAL) REAL`, which is a **procedure-variable**. A **procedure-variable** will be dereferenced before being called. Recall that a **call** binds as tightly as a **slice**, that is, more tightly than a **selection** or a **formula**. Hence if you want to call the procedure `f OF sinus`, you must enclose the **selection** in parentheses:

```
(f OF sinus)(pi) • sinus[f](pi)
```

Since a routine is a value, it is possible to declare values whose modes include a procedure mode, for example:

```
[] PROC (REAL) REAL trig = (sin, cos, tan)
```

after which you could write the **call** :

```
trig[read int](read real)
```

In standard Algol 68, a **call** of a routine must supply the same number of actual **parameters**, and in the same order, as there are formal **parameters** in the **procedure-declaration**. However, `a68g` offers an extension called partial parameterisation {5.10}.

Recall that in Algol 68, **bounds** are not part of a row mode. Since a **formal-parameter** which is a row has no **bounds** written in it, any row having that mode could be used as the **actual-parameter**. This means that if you need to know the **bounds** of the actual row, you will need to use operators interrogating **bounds** as `LWB`, `UPB` or `ELEMS`. An example is a **routine-text** which finds the smallest element in its row **parameter** `a`:

```
([] INT a) INT:
  (INT min := a[LWB a];
   FOR i FROM LWB a + 1 TO UPB a
   DO (a[i] < min | min := a[i])
   OD;
   min
  )
```

When a **parameter** is a name, the body of the routine can have an **assignation** which makes the name refer to a new value. For example:

```
(REF INT a) INT: a := 0
```

Note that the **unit** in this case is a single **unit** and so does not need to be enclosed.

If a flexible name is used as an **actual-parameter**, then the mode of the **formal-parameter** must include the mode constructor `FLEX`. For example:

```
(REF FLEX [] CHAR s) INT:
```

In this example, the mode of `s` could equivalently have been written as `REF STRING`.

You will have to be particularly careful when a **formal-parameter** of a procedure is a flexible name. A mechanism is in place in `a68g` to ensure that one cannot alter the **bounds** of a non-flexible row by aliasing it to a flexible row. This is particularly the case when passing names as **parameters** to procedures. For example, in a range that holds next **declarations**:

```
PROC x = (REF STRING s) VOID: ...,
PROC y = (REF [] CHAR c) VOID: ...;
```

these problems could occur:

```
x (LOC STRING); # OK #
x (LOC [10] CHAR); # Not OK, suppose x changes the bounds of s! #
y (LOC STRING); # OK #
y (LOC [10] CHAR); # OK #
```

`a68g` issues an error if it encounters a construct that might alter the **bounds** of a non-flexible row.

Parameters can be of any mode but `VOID`, so it is possible to pass procedures as **parameters**. Many procedures take a procedure as a **parameter**, for instance:

```
PROC series sum = (INT n, PROC (INT) REAL func) REAL:
  (LONG REAL s := 0;
   FOR i TO n
   DO s +:= LENG func (i)
   OD;
   SHORTEN s
  )
```

Note that the mode of the procedure **parameter** is a formal mode so no **identifier** is required for its `INT` **parameter** in the **routine-specification** of `sum`. In the **loop-clause**, the procedure is called with an **actual-parameter**. When a **parameter** must be a procedure, any **unit** yielding a routine-text can be supplied. For instance, a predeclared procedure **identifier** can be supplied, as in:

```
PROC rec = (INT a) REAL: 1 / a;
series sum (1000, rec)
```

or a **routine-text**:

```
series sum (1000, (INT a) REAL: 1 / a)
```

In this case, the routine text has mode `PROC (INT) REAL`, so it can be used in the **call** of `series sum`. Note also that, because the routine text is an **actual-parameter**, its **routine-specification** includes the **identifier** `a`. In fact, **routine-texts** can be used wherever a procedure is required, as long as the **routine-text** has the required mode. The

routine-text given in the **call** is on the right-hand side of the implied **identity-declaration** of the elaboration of the **parameter**.

5.4 Routines and scope

Since the yield of a routine can be a value of any mode, a routine can yield a name, but there is a restriction: the name yielded must have a scope larger than the body of the routine. This means that any names declared to be *local*, cannot be yielded by the routine. The reason for this is simple: when the routine terminates, it discards the local objects it generated, so any reference to those local object would point at something that no longer exists. It was mentioned that a new name can be generated using the **generator** `LOC`. Now look at this routine which should yield a name generated within its body:

```
(INT a) REF INT: LOC INT := a # wrong #
```

This routine is wrong because the scope of the name generated by `LOC INT` is limited to the body of the routine. `a68g` provides both compile-time and run-time scope checking, and will flag this error. There is a way of yielding a name declared in a routine. This is achieved using a global **generator**:

```
(INT a) REF INT: HEAP INT := a
```

In section 2.12 we saw that **identifiers** have range, but values have scope. The dynamic lifetime of a value is called its scope in Algol 68. A **routine-text** also is a value, but a potential scope problem arises when you write a routine that yields another routine. There is a danger that a routine gets exported to some place where the symbols that the exported routine applies, no longer exist. For example, next **declaration** is wrong:

```
MODE FUN = PROC (REAL) REAL;
MODE OPERATOR = PROC (FUN) FUN;
OPERATOR deriv = (FUN f) FUN: (REAL x) REAL: f (x) - f (x - 1);
```

the danger is that `f` may no longer exist when the routine yielded by `deriv` gets called, and `a68g` will warn you for the potential danger:

```
$ a68g examples/scope.a68 {-}{-}warnings
3     OPERATOR deriv = (FUN f) FUN: (REAL x) REAL: f (x) - f (x - 1);
                                                   1
a68g: warning: 1: PROC (REAL) REAL value from routine-text could
be exported out of its scope (detected in particular-program).
```

For this reason one cannot export a routine out of the ranges that hold all **declarations** (**identifiers**, operators, modes) that the exported routine applies. A routine is said to have thus a necessary environment outside of which the routine is meaningless.

5.5 Declaring new operators

An operator is called monadic when it takes one **operand**, or dyadic when it takes two **operands** in which case it also needs a priority. **Monadic-operators** have priority over any **dyadic-operator**. Operators are declared according these production rules:

- **brief operator declaration:**
  operator {8.2} symbol, brief operator definition list.
- **brief operator definition list:**
  operator {8.6.3}, equals {8.2} symbol, routine text.
- **operator declaration:**
  operator plan, operator definition list.
- **operator plan:**
  operator {8.2} symbol, routine specification.
- **operator definition list:**
  operator {8.6.3}, equals {8.2} symbol, strong unit {8.9.5}.

For example:

```
OP (INT) INT ABS = (INT a) INT: (a >= 0 | a | -a)
```

There are several points to note. The mode of the operator is `PROC (INT) INT`. That is, it takes a single **operand** of mode `INT` and yields a value of mode `INT`. The right-hand side of the **identity-declaration** is a routine text. Since the **routine-text** forces a mode for the operator, an abbreviated **brief-operator-declaration** can be used:

```
OP ABS = (INT a) INT: (a >= 0 | a | -a)
```

An operator symbol can be a tag as `ABS` or `REPR`. `a68g` accepts a tag that starts with an upper-case letter, optionally followed by upper-case letters or underscores. Since spaces are not allowed in an upper-case tag to avoid ambiguity, underscores can be used to improve legibility. The use of underscores is not allowed in standard Algol 68. Many of the operators described up to now are not words but composed of mathematical symbols as `+` or `**`. Since spaces have no meaning in between **operator-symbols** composed of mathematical symbols, rules apply to guarantee that any sequence of symbols has one unique meaning. To avoid ambiguity in parsing operator symbol sequences, operator characters are divided into **monads** and **nomads**, the latter group being inherently dyadic. Next rules force that for instance `1++-1` can only mean `(1) + (+(-2))`, and `1+>2` can only mean `(1) +> (2)` and not `(1) + (>2)`.

1. a **monadic-operator** symbol is a **monad**, optionally followed by a **nomad**.
2. a **dyadic-operator** symbol is either a **monad** or a **nomad**, optionally followed by a **nomad**.
3. an operator symbol consisting of **monads** or **nomads** may be followed by either `:=` or `=:`.
4. **monads** are `+`, `-`, `~`, `^` and `!`, `?`, `%` and `&`.
5. **nomads** are `<`, `>`, `/`, `=` and `*`. Again, a **monadic-operator** cannot start with a **nomad**.

Note that Algol 68 forbids **operator-symbols** that start with a double **monad**, such as `++`, `--` or `&&`, although **dyadic-operator** symbols starting with a double **nomad** (`**`, `»`, et cetera) are allowed. **Declarations** of operators using above rules are:

```
OP % = (BOOL b) BOOL: b AND read int > 0;
OP -:= = (REF CHAR c, d) INT: c := REPR (ABS c - ABS d)
```

The difference between **monadic-operators** and **dyadic-operators** is that the latter have a priority and take two **operands** in stead of one. Therefore the **routine-text** used for a **dyadic-operator** has two **formal-parameters**. The priority of a **dyadic-operator** is declared using the reserved word `PRIO`:

- **priority declaration:**
  prio {8.2} symbol, priority definition list.
- **priority definition list:**
  operator {8.6.3}, equals {8.2} symbol, priority digit

For example:

```
PRIO ** = 9, +=: = 1
```

The **declaration** of the priority of the operator uses a **priority-digit** in the range 1 to 9 on the right-hand side. Consecutive **priority-declarations** do not need to repeat the reserved word PRIO, but can be abbreviated in the usual way. The **priority-declaration** relates to the operator symbol, not to the modes of **operands** or result. Hence the same operator cannot have two different priorities in the same range, but there is no reason why an operator cannot have different priorities in different ranges.

5.6 Identification of operators

An obvious consequence of being able to declare operators with common **operator-symbols** as + or ELEM is that there can be more than one **declaration** of the same operator symbol. Think for instance of a + for integers, for reals, for complex values, et cetera. This is called operator overloading. How does Algol 68 Genie identify the operator to use when various definitions exist? As in identifying any **declaration**, Algol 68 Genie will first search the range in which it finds the application of that **declaration** (in this case, an operator symbol). If no such **declaration** is in that range, it will search the embedding range, and so on outwards until finally the standard prelude is searched. Suppose Algol 68 Genie finds a **declaration** with matching operator symbol and matching number of **operands**. How is it identified as the operator to be actually used? To answer that question we must know the coercions that apply to an **operand**. The syntactic position of an **operand** is a firm context. In a firm context we can have (repeated) dereferencing and deprocedured, followed by uniting. Uniting will be discussed in chapter 8. In determining which operator to use, Algol 68 Genie finds, in the smallest range enclosing the **formula**, that **operator-declaration** with correct number of **operands**, whose modes can be obtained from the **operands** in question using coercions allowed in a firm context. This way of identifying operators has an important consequence: if in a same range there could exist two **operator-declarations** taking the same number of **operands** of modes that can be coerced to each other by firm coercions (these modes are called firmly related) and Algol 68 Genie would have no way to choose between the two. This condition is therefore forbidden, it is not valid Algol 68. One cannot in the same range declare multiple operators whose **operands** are firmly related. For instance you could not declare in one range:

```
OP ? = (INT k) INT: k OVER 2;
OP ? = (REF INT k) BOOL: k IS NIL
```

since this would lead to ambiguous identification:

```
? 9
```

may identify the first **declaration** but:

```
INT k := read int;
? k
```

is ambiguous. The identification of **dyadic-operators** proceeds exactly as for **monadic-operators** except that the most recently declared priority in the same range is used to determine the order of elaboration of operators in a **formula**.

5.7 Recursion

An elegant property of Algol 68 procedures and operators is that they can call themselves. This is known as recursion. A paradigm of recursion is the Ackermann function which is a well-known recursive definition in mathematics. This is the Rózsa Péter version of 1935:

```
PROC ack = (INT m, n) INT:
  IF m = 0
  THEN n + 1
  ELSE (n = 0 | ack (m - 1, 1) | ack (m - 1, ack (m, n - 1)))
  FI;
```

The Ackermann function, conceived in 1928, is Turing computable, but not primitive recursive (id est, requires indefinite iteration) and was a counterexample to the belief in the early 1900's that every computable function would also be primitive recursive. This is a function only of interest in number theory, but it does find practical application in testing compilers for their ability to perform deep recursion well since it grows faster than an exponential or even multiple exponential function. For $m \geq 4$ results get spectacular, for example

$$A(4, n) = 2 \uparrow\uparrow (n + 3) - 3$$

where $2 \uparrow\uparrow k; k \geq 1$ denotes a tetration.

Next example is another illustration of a recursive procedure that calculates the number of ways to split an amount of money in coins of 2 Euro, 1 Euro, 50 ct, 20 ct, 10 ct and 5 ct. It applies back-tracking, which is constructing a tree of all possible combinations and cutting off impossible branches as early as possible:

```
PROC count = (INT rest, max) INT:
  IF rest = 0
  THEN 1 # Just right, valid combination found #
  ELIF rest < 0
  THEN 0 # Invalid combination, subtracted too much #
  ELSE INT combinations := 0;
    FOR i TO UPB values
    WHILE values[i] <= max
    DO combinations +:= count (rest - values[i], values[i])
    OD;
    combinations
```

```
  FI;


[] INT values = (5, 10, 20, 50, 100, 200), INT amount = 500 # cents #;
print (count (amount, amount))
```

5.7.1 Fast Fourier Transform

Some more points of interest to recursion will be illustrated by a non-trivial example which is a workhorse from numerical analysis: the Fast Fourier Transform or abbreviated, FFT. It can be easily proven that the k^{th} element of a discrete Fourier transform

$$F_k = \sum_{j=0}^{N-1} e^{2\pi ik/N} f_j$$

can be rewritten as the sum of two sub-transforms

$$F_k = F_{k,even} + e^{2\pi ik/N} F_{k,odd}$$

where $F_{k,even}$ is the transform of the even-numbered elements and $F_{k,odd}$ is the transform of the odd-numbered elements. This splitting of the transform can be applied recursively, meaning that transform $F_{k,even}$ and $F_{k,odd}$ can be obtained by calculating their sub-transforms et cetera, up until the point where the transform becomes trivial when there is just one element:

$$F_1 = f_1; N = 1$$

which is an identity. The advantage of binary splitting is that the complexity of a Fourier transform can be greatly reduced. A Fourier transform of length N requires N^2 operations. The binary splitting reduces that to $N \log_2 N$ operations. That is an immense improvement for large N, and many practical datasets are large. This is a naive but instructive implementation of the FFT[1]:

```
OP FFT = (REF [] COMPLEX f) VOID:
  IF # Unnormalised Fast Fourier Transform in recursive form:
       ELEMS f must be a power of 2 and LWB f must be zero. #
    INT length = ELEMS f;
    length = 1
  THEN # When the length is 1, the transform is an identity #
    SKIP
  ELSE INT middle = length OVER 2;
    # Calculate sub-transforms recursively #
```

[1] Note that this simple form of FFT involves a binary split in every sub-transform, and that therefore the number of elements in F must be a power of 2. Algorithms that lift this limitation of FFT are out of the scope of this text.

```
    [0 .. middle - 1] COMPLEX f even, f odd;
    FOR i FROM 0 TO middle - 1
    DO f even[i] := f[2 * i];
      f odd[i] := f[2 * i + 1]
    OD;
    (FFT f even, FFT f odd);
    # Calculate transform at this level #
    FOR k FROM 0 TO middle - 1
    DO REAL phi = 2 * pi * k / length;
      COMPLEX w = cos (phi) I sin (phi);
      f[k] := f even[k] + w * f odd[k];
      f[k + middle] := f even[k] - w * f odd[k]
    OD
  FI;
```

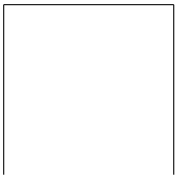
where `(FFT f even, FFT f odd)` is an example of a `VOID` **collateral-clause** {8.9.1}. Note that the routine does **assignations** to elements of its arguments that must therefore be of mode `REF [] COMPLEX`. When the **parameter** `f` holds a single element, the transform is an identity and the routine just returns. When the length of the **parameter** is a power of two, the transform is calculated by making a binary split into even and odd elements, which are then transformed recursively. Obviously, when the transformation is in progress, various **calls** to `FFT` are made, and every instant of `FFT` — which is called an incarnation of the routine — must wait for the sub-transform to finish, before it can continue. Hence various incarnations of a routine can exist at the same time; only the deepest (youngest) one being active, and the older ones awaiting completion of the younger ones. Algol 68 elaborates every new incarnation of a routine as if the called routine's body were *textually* and if applicable *recursively* inserted into the source code. Algol 68 is defined such that no incarnation can have access to locally defined tags in another incarnation. If such access is needed, such tag must be passed along as a **parameter** when calling a deeper incarnation. Hence every **declaration** in a routine is private to an incarnation; for instance, every incarnation of FFT has its own `f even` and `f odd` but also `length` et cetera.

5.7.2 Space-filling curves

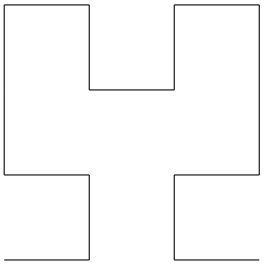
A beautiful demonstration of the elegance of recursion is the drawing of so-called space-filling curves. The mathematician Giuseppe Peano studied among many other subjects the projection of a square onto a line[2]. He considered a set of curves, constructed from straight line segments. The n^{th} member of the set is a continuous curve that passes all points in the square at a distance of at most 2^{-n}, a so-called Peano curve. There are various such sets and here we will demonstrate an algorithm due to A. van Wijngaarden that draws a particular solution that is known as a Hilbert-curve. Drawing the Hilbert-curve actually

[2] G. Peano. Sur une courbe, qui remplit toute une aire plaine. Math. Annln. (36) 157-160 [1890]

was an exercise in Algol 68 programming classes. The 0^{th} member of the curve is trivial, it is a point in the centre of the plane. The first member $n = 1$ starts at the bottom of the figure and end at its top, we call this orientation "up":



By successive clockwise rotation by 90 degrees we also get orientations "right", "down", and "left". The divide-and-conquer strategy in this problem is to divide the plane into four equal squares, and combine the four orientations to allow drawing a continuous curve by recursively applying our strategy. For example, we construct the orientation "up" of the second member $n = 2$ in a convenient way:

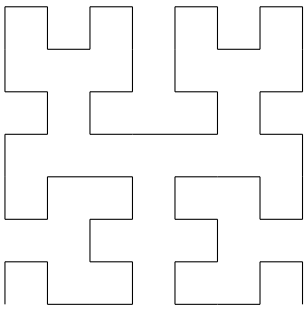


Above figures are drawn using next procedure for orientation "up":

```
PROC draw up = (INT n) VOID:
  IF n > 0
  THEN draw right (n - 1);
    line to ((x OF origin + d, y OF origin));
    draw up (n - 1);
    line to ((x OF origin, y OF origin + d));
    draw up (n - 1);
    line to ((x OF origin - d, y OF origin));
    draw left (n - 1)
  FI;
```

The routine composes orientation "up" of the n^{th} member of the curve by combining $(n-1)^{th}$

members of the curve until the member $n = 1$ gets drawn. One can now compose member $n = 3$ in an analogous way and see how it is composed of $n = 2$ members:



A complete **program** that was used to make above drawings is in example 12.7. It is left as an exercise to show that the Euclidean length of the Hilbert curve, member n, reads:

$$2^n - \frac{1}{2^n}$$

that is, grows exponentially.

5.7.3 Recursion versus iteration

An iterative routine is likely to be slightly faster in practice than a recursive equivalent because iterative routines do not have the **call** overhead of recursive routines. There are other types of problems whose solutions are inherently recursive, because they need to keep track of prior state. One example is tree traversal; others include the Ackermann function and divide-and-conquer algorithms such as quicksort. All of these algorithms can be implemented iteratively with the help of a stack, but the need for the stack arguably nullifies the advantages of the iterative solution. Another possible reason for choosing an iterative rather than a recursive algorithm is that in today's programming languages, the stack space available to a thread is often much less than the space available in the heap, and recursive algorithms tend to require more stack space than iterative algorithms.

5.8 Recursion and data structures

In mathematics and computer science, graph theory is the study of mathematical structures used to model pairwise relations between objects from a certain collection. A graph in this context refers to a collection of vertices or 'nodes' and a collection of edges that connect pairs of vertices. This is not the place to discuss topics in graph theory but it sets the background for this section. We will demonstrate how to handle data structures where nodes of a same mode refer to each other.

5.8.1 Linear lists

A linked list is a fundamental data structure, and can be used to implement other data structures. A linked list is a self-referring data structure because each node contains a pointer to another node of the same type. Practical examples are process queues or lists of free blocks in heap management. Linked lists permit insertion and removal of nodes at any point in the list, but do not allow random access. A linear list is a finite set in which the elements have the relation *is followed by*. We call it linear because each element has one successor. We could of course try to represent it by a row of elements:

```
MODE LIST = FLEX [1 : 0] ELEMENT
```

The principal benefit of a linked list over a row is that the order of the linked items may be different from the order that the data items are stored, allowing the list of items to be traversed in a different order. Also, inserting an element in a row is an expensive operation. An elegant representation is a self-referring data structure:

```
# Data structure and primitive operations: #

MODE NODE = STRUCT (ELEMENT info, LIST successor),
  LIST = REF NODE;

LIST empty list = NIL;

OP ELEM = (LIST list) REF ELEMENT: info OF list,
OP REST = (LIST list) REF LIST: successor OF list

# Note that REST yields a REF REF NODE, a pointer-variable #

OP EMPTY = (LIST list) BOOL: list IS empty list

OP ELEM = (INT n, LIST list) REF ELEMENT:
  IF EMPTY list OR n < 1
  THEN empty list # thus we mark an error condition #
  ELSE (n = 1 | ELEM list | (n - 1) ELEM list)
  FI;

PRIO ELEM = 9

# A routine to have a denotation for lists: #

PROC make list = ([] ELEMENT row) LIST:
  IF ELEMS row = 0
  THEN empty list
  ELSE HEAP NODE := (row[i], make list (row[LWB row + 1 : UPB row]))
  FI

# Operators to add an element to a list: #
```

```
# Add at the head #
OP + = (ELEMENT elem, LIST list) REF LIST:
  HEAP LIST := (elem, list)

# Add at the tail #
OP +:= = (REF LIST list, ELEMENT elem) VOID:
  IF EMPTY list
  THEN list := HEAP LIST := (elem, empty list)
  ELSE REST list +:= elem
  FI
```

Several different types of linked list exist:

1. singly-linked lists as discussed above, where each node points at its successor,
2. doubly-linked lists in which each node points to both predecessor and successor,
3. circularly-linked lists in which the last node points back at the first one which is especially useful when implementing buffers.

Linked lists sometimes have a special dummy or sentinel node at the beginning or at the end of the list, which is not used to store data. Its purpose is to simplify some operations, by ensuring that every node always has a previous and next node, and that every list (even an empty one) always has a first and last node. Lisp has such a design — the special value `nil` is used to mark the end of a proper singly-linked list; a list does not have to end in `nil`, in which case it is termed *improper*.

5.8.2 Trees

A binary tree is a data structure in which each node refers to two other nodes. Binary trees are commonly used to implement binary search trees and binary heaps. Next is the paradigm quicksort routine in Algol 68:

```
MODE NODE = STRUCT (INT k, TREE smaller, larger),
  TREE = REF NODE;
TREE empty tree = NIL;

PROC sort = (REF TREE root, INT k) VOID:
  IF root IS empty tree
  THEN root := HEAP NODE := (k, empty tree, empty tree)
  ELSE sort ((k < k OF root | smaller OF root | larger OF root), k)
  FI;

PROC write = (TREE root) VOID:
  IF root ISNT NIL
```

```
  THEN write (smaller OF root);
    print ((whole (k OF root, 0), " "));
    write (larger OF root)
  FI;

TREE root := empty tree;
WHILE INT n = read int;
  n > 0
DO sort (root, n)
OD;
write (root)
```

Compare the version above with next iterative version, which is the so-called triple-REF trick:

```
MODE NODE = STRUCT (INT v, REF NODE less, more);
REF NODE empty tree = NIL;

PROC sort = (INT v) VOID:
  BEGIN
    REF REF REF NODE place = LOC REF REF NODE := root;
    WHILE place ISNT empty tree
    DO place := (v < v OF place | less OF place | more OF place)
    OD;
    REF REF NODE (place) := HEAP NODE := (v, empty tree, empty tree)
  END;

PROC write = (TREE root) VOID:
  IF root ISNT NIL
  THEN write (smaller OF root);
    print ((whole (k OF root, 0), " "));
    write (larger OF root)
  FI;

REF REF NODE root = LOC REF NODE := empty tree;
WHILE INT n = read int;
  n > 0
DO sort (n)
OD;
write (root)
```

This is an example of an application of a `REF REF REF` object, that is, a pointer-to-pointer variable. **Program** 12.6 demonstrates building a decision tree in Algol 68. An elaborate example using lists is example **program** 27_{11}.10 which does **formula** manipulation.

5.9 Recursive mode declarations

A curiosity of Algol 68 that does not receive a lot of attention is that elaboration of some far-sought **mode-declarations** can generate recursive calls of code. This is possible since a tag can be applied before it is declared, so application in actual **bounds** of a rowed mode while it is being declared can make code in a **mode-declaration** recursive. This may lead to fuzzy code like this example:

```
MODE FAC = [1 : (n > 0 | m *:= n; n -:= 1; LOC FAC; n | 0)] INT;
INT m := 1, n := 10;
LOC FAC;
print ((m, n))
```

Such code actually runs under a68g:

```
$ a68g rec_mode.a68
   +3628800         +0
```

Using this type of recursion will be regarded as amusing by some, but most will agree that this is not a recommended programming style.

5.10 Partial parameterisation and currying

a68g offers partial parametrisation similar to C.H. Lindsey's proposal [Lindsey AB39.3.1] giving the imperative language Algol 68 a functional sub language [Koster 1996]. A formal description of this proposal can be found in this publication as an appendix to the Algol 68 Revised Report {21}. With a68g a **call** does not require that all arguments be specified. In case not all of the **actual-parameters** are specified, a **call** yields a routine (with identical body but with already specified arguments stored) that requires the unspecified **actual-parameters**. With Algol 68 Genie, when specification of all required **actual-parameters** is complete (complete closure) a procedure will actually be evaluated to yield its result. Partial parameterisation is closely related to currying, a transformation named after Haskell Curry. Currying is transforming a function $f : (x \times y) \rightarrow z$ into $f : (x) \rightarrow (y \rightarrow z)$. This transformation is for instance used in λ-calculus.

a68g does not save copies of the stack upon partial parameterisation, as happens for example in Lisp; the yield of a partially parameterised **call** in an environ E, cannot be newer in scope than E. Therefore stored **actual-parameters** cannot refer to objects in stack frames that no longer exist, and dynamic scope checking extends to stored **actual-parameters**. A routine may be parameterised in several stages. Upon each stage the yields of the new **actual-parameters** are stored inside the routine's locale and the scope of the routine becomes the newest of its original scope and the scopes of those yields. Following is an example of partial parameterisation:

```
# Raising a routine to a power #
MODE FUN = PROC (REAL) REAL;
PROC pow = (FUN f, INT n, REAL x) REAL: f (x) ** n;
OP ** = (FUN f, INT n) FUN: pow (f, n, );
# Example: sin (3 x) = 3 sin (x) - 4 sin ** 3 (x);
  This follows from DeMoivre's theorem. #
REAL x = read real;
print ((new line, sin (3 * x), 3 * sin (x) - 4 * (sin ** 3) (x)))
```

6 Modes, contexts and coercions

6.1 Introduction

Algol 68 only allows modes that define objects of finite size and that do not give rise to infinite coercion. This chapter describes which modes are well-formed in this respect. Also, in Algol 68 two modes are equivalent when they have an equivalent structure. The rules for structural equivalence are explained here.

Next, this chapter gives an overview of syntactic contexts and their allowed or applicable coercions. The mechanism of implicit coercions in Algol 68 has met critisism for being "overly complicated", but considering current state of affairs the mechanism is one of the few that gives a concise, logical definition of possible coercions per situation. The key two rules are:

1. There are five types of context of decreasing strength named strong, firm, meek, weak and soft.
2. There are six coercions named deproceduring or dereferencing, uniting, widening, rowing and voiding. With decreasing strength of the context, less of these coercions are either allowed or applicable. A strong context allows all coercions, a soft context allows only one of them.

6.2 Well-formed modes

It was already pointed out that not all possible **mode-declarations** are allowed in Algol 68. The syntax of Algol 68 forces that a mode cannot give rise to (1) an infinitely large object or (2) endless coercion. Now that the description of mode constructing elements is complete, we can give the rules for determining whether a mode is well-formed. There are two reasons why a mode might not be well-formed:

1. elaboration of a **declaration** using that mode would generate an infinitely large object:

```
MODE FRACTAL = [100] FRACTAL,
  LIST = STRUCT (INT index, LIST next)
```

2. coercion of that mode leads to an endless or ambiguous sequence of coercions:

```
MODE POINTER = REF POINTER,
  CELL = UNION (STRING content, REF CELL next)
```

All non-recursive **mode-declarations** are well-formed. It is only in recursive and mutually-recursive modes that we have to apply a test for well-formedness. Let us look at some examples of modes which are not well-formed. Consider the invalid **mode-declaration**:

```
MODE LIST = STRUCT (INT index, LIST next)
```

where field `LIST next` would expand to a further `STRUCT` and so on *ad infinitum*. However, if the mode within the `STRUCT` is shielded by `REF` or `PROC`, then the **mode-declaration** is valid since an object of such mode will be of finite size:

```
MODE LIST = STRUCT (INDEX index, REF LIST a)
```

Likewise, the **declaration**:

```
MODE LIST = STRUCT (INT index, PROC LIST action)
```

is well-formed because in any **declaration**, the second field is a procedure (or a name referring to such a procedure) which is not the original structure and so does not generate objects of infinite size. A `UNION` does not shield the mode as does a `STRUCT`. The **mode-declarations**:

```
MODE A = UNION (INT, REF A);
MODE B = STRUCT (UNION (CHAR, B) u, CHAR c)
```

are not well-formed. If we would have an object of mode `REF A` that would need coercion to `A` in a firm or strong context, the coercion could either be dereferencing or uniting, which is ambiguous. `B` again leads to objects of infinite size since `B` must be expanded to know the size of the union. All the above **declarations** have been recursive, but not mutually recursive. It is not possible to declare:

```
MODE A = STRUCT (B a, INT i),
  B = STRUCT (A a, CHAR i)
```

since the elaboration of **declarations** using either mode would generate an infinite object, so the modes are not well-formed. The following pair of **mode-declarations** are however well-formed since proper shielding is provided:

```
MODE A = STRUCT (REF B a, INT i),
  B = STRUCT (PROC A a, CHAR i)
```

6.2.1 Determination of well-formedness

In any mutually-recursive **mode-declarations**, or any recursive **mode-declaration**, to get from a particular mode on the left hand side of a **mode-declaration** to the same **mode-indicant** written on the right hand side of a **mode-declaration**, it is necessary to traverse various mode constructors. A `STRUCT` or `PROC` with **parameters** gets attribute *yang*. A `REF` or parameter-less `PROC` gets attribute *yin*. A `UNION` gets neither *yin* nor *yang*. Trace the path from the **mode-indicant** in question on the left-hand side of the **mode-declaration** until you arrive at the same **mode-indicant** on the right-hand side. If you have traversed at least one *yin* and at least one *yang*, the mode is well-formed — the definition is *properly shielded* from its application. Consider a recursive **mode-declaration**:

```
MODE LIST = STRUCT (INT index, LIST next)
```

To get from `LIST` on the left to `LIST` on the right, only *yang* is traversed thus `LIST` is not well-formed. In the **mode-declaration**:

```
MODE LIST = STRUCT (INDEX index, REF LIST next)
```

one traverses *yang* (`STRUCT`) and *yin* (`REF`), so `LIST` is well-formed. More examples are:

1. `MODE A = INT`
   is well-formed.

2. `MODE B = PROC (B) VOID`
   is well-formed.

3. `MODE B = PROC (B) B`
   is well-formed.

4. `MODE C = [3, 3] C`
   is not well-formed.

5. `MODE D = STRUCT (BOOL p, D m)`
   is not well-formed.

6. `MODE E = STRUCT (STRING s, REF E m)`
   is well-formed.

7. ```
   MODE A = STRUCT (REF B f),
     B = PROC (INT) A
   ```
   is well-formed.

8. ```
   MODE A = PROC (B) VOID,
     B = STRUCT (A a)
   ```
   is well-formed.

9.
```
MODE A = PROC (B) A,
MODE B = STRUCT (PROC C c, STRUCT (B b,INT i) d),
MODE C = UNION (A, B)
```
is not well-formed.

6.3 Equivalence of modes

In Algol 68, modes are equivalent if they have an equivalent structure. This principle is called structural equivalence. Compare this for example with Pascal where two objects are only of the same mode (type, in that language) when they are declared with the same type identifier. The rules for structural equivalence in Algol 68 are intuitive:

1. rows are of equivalent mode when the elements have equivalent modes. **Bounds** are not part of a mode.

2. structures are equivalent when fields in a same position have equivalent modes and identical field names. Field names are part of a mode.

3. procedures are equivalent when **parameters** in a same position have equivalent modes, and the result modes are equivalent,

4. unions are equivalent when for every constituent mode in one there is an equivalent constituent mode in the other.

For instance, these two modes are equivalent:

```
MODE COMPLEX = STRUCT (REAL re, im), PERPLEX = STRUCT (REAL re, im)
```

but these two are not equivalent:

```
MODE COMPLEX = STRUCT (REAL re, im), POLAR = STRUCT (REAL r, theta)
```

and these are equivalent:

```
MODE FUNC = UNION (COMPLEX, PROC (COMPLEX) PERPLEX),
  GUNC = UNION (PERPLEX, PROC (PERPLEX) COMPLEX)
```

As you are well aware by now, **mode-declarations** can get quite entangled. The algorithm that `a68g` uses to determine the equivalence of two modes, is to prove equivalence assuming that the two are equivalent. The latter assumption is necessary since in many cases a proof of equivalence eventually comes down to cyclic sub-proofs as $A = B$ *if and only if* $A = B$, and mentioned assumption resolves these situations. Structural equivalence has an important consequence when defining modes for unrelated quantities. For instance, one could write:

```
MODE WEIGHT = REAL, DISTANCE = REAL;
WEIGHT w = read real; DISTANCE r = read real;
print (w + r) # ? #
```

It makes of course no sense to add a `WEIGHT` to a `DISTANCE`, but since both are structurally equivalent, a `REAL`, it is impossible to set them apart in Algol 68. We could pack them in a structure:

```
MODE WEIGHT = STRUCT (REAL u), DISTANCE = STRUCT (REAL v);
```

but this is no more than a trick, for example used in **program** 27_{11}.10. In Algol 68 there is no simple way to abstract from a mode's representation, which is considered a weakness of the language.

6.4 Contexts

Below is a list of syntactic positions per strength and the coercions allowed in them. Next section discusses the coercions in detail.

1. Strong contexts
   (a) The actual **parameters** of **calls**
   (b) The **enclosed-clauses** of **casts**
   (c) The source **unit** of **assignations** (the destination imposes the mode)
   (d) The source **unit** of **identity-declarations** (the declarer imposes the mode)
   (e) The source **unit** of **variable-declarations** (the declarer imposes the mode)
   (f) The **units** of **routine-texts**
   (g) `VOID` **units** (the imposed mode is `VOID`)
   (h) Subordinated constituents of a balanced construct

   In a strong context, the mode that is expected from a construct is imposed by the context. Therefore all coercions are allowed to arrive at the imposed mode: deproceduring, dereferencing, uniting, widening, rowing and voiding. One can use a **cast** to force a strong context and thus force coercion to the mode specified by the cast. A **cast** consists of a **mode-indicant** followed by a **strong-enclosed-clause**. A **cast** forces a strong context for its **enclosed-clause**. It can for example be used to dereference exactly to the name required, as seen in paragraph 2.12, or it can be used to force the mode of a display when required, for instance `COMPLEX (1, 0)`.
2. Firm contexts
   (a) **Operands** of **formulas**

In a firm context widening and rowing are not allowed since this would lead to impossible situations as for instance not being able to write an operator for addition of `INT` operands when one for `REAL` operands also exists, or to write an operator for both scalars and vectors. Voiding does not apply in a firm context since operands cannot be of mode `VOID`.

3. Meek contexts

   (a) **Enquiry-clauses**

   (b) **Primaries** of **calls**

   (c) The **units** following `FROM`, `BY` and `TO` or `DOWNTO`

   (d) **Units** in **trimmers**, **subscripts** and **bounds**

   (e) **Enclosed-clause** of a **format-pattern**

   (f) **Enclosed-clause** of a **replicator**

   (g) Left-hand side integral **tertiary** of **stowed-functions**

   (h) The boolean **enclosed-clause** of an **assertion**

   A meek context allows dereferencing or deproceduring to a value of mode `INT` or `BOOL`. The other coercions simply do not apply in these contexts.

4. Weak contexts

   (a) **Primaries** of **slices**

   (b) **Secondaries** of **selections**

   (c) Right-hand side **tertiary** of a **stowed-function**

   A weak context allows dereferencing *all but the last reference*, or deproceduring. Allowing full dereferencing would forbid assignation to a row element. The other coercions do not apply in a weak context.

5. Soft contexts

   (a) The destination **tertiary** of **assignations**

   (b) One **tertiary** in an **identity-relation**, as to adapt it to the other **tertiary**.

   The soft context only allows deproceduring. Allowing dereferencing would mean that you could not assign to a `REF REF` name. The other coercions do not apply in a soft context.

6.5 Coercions

There are six coercions in Algol 68:

1. deproceduring or dereferencing
2. uniting
3. widening
4. rowing
5. voiding

These coercions can be chained top-to-bottom, as far as the context allows them. For example, first a sequence of deprocedurings or dereferencings may take place, then optionally uniting, then a possibly a sequence of widenings, after that if needed rowing and finally voiding can take place. So, for example, one can coerce `INT` to `[] REAL`, but one cannot coerce `REF INT` to `REF REAL` and one cannot coerce `[] INT` to `[] REAL`. At first sight, when a value will be voidened, all coercions before voiding seem unnecessary, but this section will show how to resolve the problem of voiding a `VOID` routine without parameters: whether to voiden by calling it or by discarding it.

6.5.1 Deproceduring or dereferencing

Deproceduring is the mechanism by which a parameter-less procedure is called. For example, a procedure having mode `PROC REAL`, when called yields a `REAL`. One can represent the coercion by:

$$\texttt{PROC REAL} \rightarrow \texttt{REAL}$$

The coercion can be applied repeatedly, for instance:

$$\texttt{PROC PROC REAL} \rightarrow \texttt{PROC REAL} \rightarrow \texttt{REAL}$$

Deproceduring only occurs with parameter-less procedures, and only if the context requires an object of the mode of the yield of the procedure in question.

Dereferencing is the process of moving from a name to the value to which it refers. That value can again be a name. For example, if we dereference `REF REAL`, the coercion can be represented by:

$$\texttt{REF REAL} \rightarrow \texttt{REAL}$$

As deproceduring, dereferencing can be applied repeatedly to produce for instance:

$$\texttt{REF REF REAL} \rightarrow \texttt{REF REAL} \rightarrow \texttt{REAL}$$

Dereferencing in a weak context is a variant of the dereferencing coercion in which any number of `REF`s can be removed except the final one. This can be represented by:

```
REF REF REAL → REF REAL
```

This coercion is only available in weak contexts and is needed in the **primary** of **slices** and the **secondary** of a **selection** to ensure that a **slice** or **selection** can yield a name — without this you would not be able to assign a value to an element of a row or to a field of a structure.

In strong, firm, meek and weak contexts dereferencing and deproceduring will be applied alternately if this leads of coercion of the source mode to the mode required by the context. For instance, in strong, firm and meek contexts we could have:

```
REF PROC REF REAL → PROC REF REAL → REF REAL → REAL
```

though in a weak context we would have:

```
REF PROC REF [] REAL → PROC REF [] REAL → REF [] REAL
```

6.5.2 Uniting

In this coercion, the mode of a value becomes a united mode. For example, if `I` were an operator with both **operands** of mode `UNION(INT, REAL)`, then in the **formula**:

```
0 I pi
```

both **operands** will be united to `UNION(INT, REAL)` before the operator is elaborated. These coercions can be represented by:

```
INT  }
REAL } → UNION(INT,REAL)
```

Uniting is available in firm contexts and also in strong contexts where it precedes rowing.

6.5.3 Widening

In a strong context, an integral value can be replaced by a real value and a real value replaced by a complex value, depending on the mode required. `a68g` implements next widenings:

1. `INT` → `REAL`
2. `INT` → `LONG INT`

3. `LONG INT` → `LONG REAL`
4. `LONG INT` → `LONG LONG INT`
5. `LONG LONG INT` → `LONG LONG REAL`
6. `REAL` → `COMPLEX`
7. `REAL` → `LONG REAL`
8. `LONG REAL` → `LONG COMPLEX`
9. `LONG REAL` → `LONG LONG REAL`
10. `LONG LONG REAL` → `LONG LONG COMPLEX`
11. `COMPLEX` → `LONG COMPLEX`
12. `LONG COMPLEX` → `LONG LONG COMPLEX`
13. `BITS` → `LONG BITS`
14. `LONG BITS` → `LONG LONG BITS`
15. `BITS` → `[] BOOL`
16. `LONG BITS` → `[] BOOL`
17. `LONG LONG BITS` → `[] BOOL`
18. `BYTES` → `[] CHAR`
19. `LONG BYTES` → `[] CHAR`

Widening can be repeated, for example

`INT` → `REAL` → `LONG REAL` → `LONG COMPLEX`

Widening is not available in **formulas** since **operands** are in a firm context. In a firm context, widening would lead to for instance not being able to write an operator for addition of `INT` operands when one for `REAL` operands also exists.

6.5.4 Rowing

In a strong context, a row can be constructed. The resulting row or added dimension always has one element with **bounds** $1 : 1$. There are two cases to consider:

1. Suppose we want to row an element of mode SOME to a row [] SOME. For example, if the required mode is [] INT, then the mode of an element is INT. In the **identity-declaration**:

   ```
   [] INT i = 0
   ```

   the value yielded by the right-hand side will be rowed and the coercion can be expressed as:

   INT → [] INT

   If the value given is a row mode, such as [] INT, then there are two possible rowings:

   (a) [] INT → [][] INT, or

   (b) [] INT → [,] INT
   (an extra dimension is added to the row)

2. If the row required is a name, then a name can be rowed. For example, if the value supplied is a name with mode REF SOME, then a name with mode REF [] SOME will be created. Likewise, a name of mode REF [] SOME can be rowed to a name with mode REF [,] SOME or with mode REF [][] SOME, depending on the mode required.

6.5.5 Voiding

In a strong context, a value can be discarded, either because the mode VOID is explicitly stated, as in a procedure yielding VOID, or because the context demands it, as in the case of a **semicolon-symbol** (the **go-on-symbol**). Voiding can be applied to any value that is not a (variable whose value is a) parameter-less routine. A parameter-less routine is deprocedured and if it is not a PROC VOID the value after deproceduring is discarded. To avoid unexpected behaviour, deproceduring is not used to coerce an **assignation**, a **generator** or a **cast** to VOID. Hence if we consider:

```
PROC p = VOID: ...;
PROC VOID pp;
pp := p;
```

then voiding the **assignation** pp := p does not involve deproceduring p after the **assignation** is completed.

7 Transput

7.1 Transput

Transput means *input and output*. At various points in this publication we have been reading data from standard input and writing data to standard output. These normally are your keyboard and screen, respectively. This chapter addresses the means whereby an Algol 68 **program** can obtain data from other devices and send data to devices other than the screen. Data transfer is called input-output in many other languages, but in Algol 68 it is called *transput*. We will use this term as a verb: we will use *to transput* meaning *to perform input or output*. This chapter describes transput as implemented by `a68g`. Though `a68g` transput preserves many characteristics of Algol 68 transput, there are differences. According to the Revised Report, Algol 68 discriminates *files* and *books*. A *file* described how to handle a *book* that represented a dataset having pages and lines, which in the 1970's was a convenient way to view data. Consider for instance a deck of punch cards as a dataset of as many lines as there are cards or a line printer as a dataset with pages and lines, or disk files organised as records of fixed or variable width. This way of viewing files has changed with Unix/Linux: here an important concept is a generalised mechanism for accessing a wide range of resources that are called *files*: documents, directories, devices, processes, network communications et cetera. This fundamental concept actually is twofold:

1. Every file is a stream of bytes.
2. The file system is a universal name-space.

Since `a68g` is developed for Unix/Linux we will not talk about books with pages and lines which is a deliberate deviation of the Revised Report. In `a68g`, we have files that are sequences of bytes[1]. An object of mode `FILE` is a file descriptor as in many other contemporary programming languages. As in Algol 68, `a68g` transput is event-driven. One can at forehand specify actions to be taken when certain events occur during transput. This relieves you of continuously checking all kind of conditions when reading or writing (such as: did you encounter end of file, can you actually write to this file, did a conversion error take place, et cetera). We shall be examining later the kinds of event that can occur during transput.

[1] File size is not necessarily limited, think for example of `/dev/null`.

7.2 Channels and files

Files have various properties. They usually have an identification string, the simplest example of which is a file name. Some files are read-only, some files are write-only and others permit both reading and writing. Some files allow you to browse, that is, they allow you to start anywhere in the file and read (or write) from that point on. `a68g` keeps track of the status of a file by means of a complicated structure of mode `FILE` which is declared in the standard prelude. There are four names of mode `REF FILE` declared in the standard prelude:

1) `stand in` is the standard input (normally the keyboard),

2) `stand out` is the standard output (normally a screen),

3) `stand error` is the standard error channel (normally a screen), and

4) `stand back` is a file that can both be read and written.

One cannot read from `stand out` or `stand error`, nor write to `stand in`. `a68g` opens above files at the start of the **program**. You normally have no need to close one of this standard files. A file is associated with a channel. In the early days of Algol 68 channels could be considered as a description of a device-driver, but nowadays such details are abstracted in the kernel. They are maintained in `a68g` since they specify access rights to a file and specify whether a file is used for drawing. The mode of a channel is `CHANNEL` which is declared in the standard prelude. In `a68g`, five principal channels are provided in the standard prelude:

1) `stand in channel`,

2) `stand out channel`,

3) `stand error channel`,

4) `stand back channel` and

5) `stand draw channel`.

The first is used for read-only files, the second and third are used for write-only files, and the fourth for files which permit both reading and writing. The fifth does not allow for reading and writing, but specifies that a file is used as a plotting device; it comes close to the device-driver specification mentioned earlier. The first four channels mentioned above are buffered.

7.3 United modes as arguments

One can now explain the **parameters** for `print` and `read` that accept parameters with all the modes needed. These routines takes as parameter a row of a united mode as in the two following **declarations**:

```
PROC print = ([] SIMPLOUT) VOID;

MODE SIMPLOUT = UNION (
  INT, REAL, BOOL, CHAR,
  [] INT, [] REAL, [] BOOL, [] CHAR,
  [, ] INT, [, ] REAL, [, ] BOOL, [, ] CHAR,
  ...
  ),

PROC read = ([] SIMPLIN) VOID;

MODE SIMPLIN = UNION (
  REF INT, REF REAL, REF BOOL, REF CHAR,
  REF [] INT, REF [] REAL, REF [] BOOL, REF [] CHAR,
  REF [, ] INT, REF [, ] REAL, REF [, ] BOOL, REF [, ] CHAR,
  ...
  ),
```

The mode `SIMPLIN` used by `read` is united from modes of names. Actually, the modes `SIMPLOUT` and `SIMPLIN` are more complicated than this (see chapters 9 and 11). To demonstrate the uniting coercion in a **call** of `print`, consider next example. If `a` has mode `REF INT`, `b` has mode `[] CHAR` and `c` has mode `PROC REAL`, then the **call**:

```
print ((a, b, c))
```

causes the following to happen:

1. `a` is dereferenced to mode `INT` and then united to mode `SIMPLOUT`.
2. `b` is united to mode `SIMPLOUT`.
3. `c` is deprocedured to produce a value of mode `REAL` and then united to mode `SIMPLOUT`.
4. The three elements are regarded as a **row-display** for a `[] SIMPLOUT`.
5. `print` is called with its single **parameter**.

`print` uses a **conformity-clause** (see next section) to extract the actual value from each element in the row. A curiosity is that although `read` and `print` take a united argument, one cannot read a united value, since united modes do not introduce new values. You have

to read a value of a constituent mode, which requires that the united value is initialised before `read` is attempted. For example, next code fails:

```
UNION (INT, REAL) number;
read (number);
```

An attempt at execution generates a runtime error:

```
2     read (number);
      1
a68g: runtime error: 1: attempt to use uninitialised
UNION (REAL, INT) value (detected in particular-program).
```

since at the time of the **call** to `read`, it is not yet known whether `number` holds an `INT` or a `REAL`. This can be arranged for instance by initialising `number`:

```
UNION (INT, REAL) number := 0.0;
read (number);
```

after which `read` will expect a `REAL` value from `standin`.

7.4 Transput and scope

Please note that it is rather easy to provoke a scope error in transput routines. As mentioned in section 2.12, the scope of a local name is the smallest enclosing clause which contains its **generator** (which may be hidden by an abbreviated **variable-declaration**) and the scope of a global name extends to the whole **program**. Some transput routines take a name, routine or format (vide infra) as argument, storing them in objects of mode `FILE` or `CHANNEL`. You must take care that these values still exist when you address such stored value in a later part of the **program**. For example, when you run next **program**:

```
FILE z;
STRING name = "test.data";


IF file is regular (name)
THEN VOID (open (z, name, standin channel))
ELSE associate (z, LOC STRING := "1")
FI;


INT k;
get (z, k);
print (k)
```

you will get next diagnostic in case file `test.data` does not exist:

```
6     ELSE associate (z, LOC STRING := "1")
           1
a68g: runtime error: 1: REF STRING value is exported out of its scope
no such file or directory) (detected in VOID conditional-clause starting
at "IF" in line 4).
```

The reason for this error is that `a68g` detects that `LOC STRING` may cease to exist before `z` ceases to exist. One can solve this for instance by writing `HEAP STRING`.

7.5 Reading files

Before one can read the contents of an existing file, you need to open the file. The **declaration** of the procedure `open` starts with:

```
PROC open = (REF FILE f, STRING idf, CHANNEL chan) INT
```

On Linux, the routine yields zero if the file is a regular file and non-zero otherwise. Example:

```
FILE inf;
STRING name = "results";


IF open (inf, name, stand in channel) /= 0
THEN print (("Cannot open ", results, new line))
FI
```

After a file has been opened, data can be read using the procedure `get`, the **declaration** of which starts with:

```
PROC get = (REF FILE f,
  [] UNION (INTYPE, PROC (REF FILE) VOID) items) VOID
```

The mode `INTYPE` is a united mode defined by the Revised Report {26_{10}.3.2.2} and encompasses all modes that can be read. `INTYPE` is processed by a process called straightening that converts any structure or row into a row of values of the constituent fields or elements. Allowed modes for latter elements in `a68g` are specified by the mode `SIMPLIN`:

```
MODE SIMPLIN = UNION (
  REF INT, REF REAL, REF COMPLEX,
  REF LONG INT, REF LONG REAL, REF LONG COMPLEX,
  REF LONG LONG INT, REF LONG LONG REAL, REF LONG LONG COMPLEX,
  REF BOOL,
  REF BITS, REF LONG BITS, REF LONG LONG BITS,
```

```
  REF CHAR, REF [] CHAR
)
```

This means that `get` can read directly any structure or row (or even rows of structures or rows) as long as its elements are in `SIMPLIN`. The `PROC (REF FILE) VOID` mode in `[] UNION (INTYPE, PROC (REF FILE) VOID)` lets you use routines like `new page` and `new line` as **parameters**. The **declaration** of `new line` starts with:

```
PROC new line = (REF FILE f) VOID
```

and one can call it from `get` if you want. On input, the rest of the current line is skipped and a new line is taken. The position in the file is at the start of the new line, just before the first character of that line. Consider next **program** fragment which opens a file and then reads the first line and makes a name of mode `REF STRING` to refer to it. After reading the string, `new line` is called explicitly:

```
FILE inf;
open (inf, "file", stand in channel);
STRING line;
get (inf, line);
new line (inf)
```

This could equally well have been written:

```
FILE inf;
open (inf, "file", stand in channel);
STRING line;
get (inf,(line, new line))
```

Of course one can declare own procedures with mode `PROC (REF FILE) VOID`. The procedure `read` which you have already encountered in this publication is declared as:

```
PROC read = ([] UNION (INTYPE, PROC (REF FILE) VOID) items) VOID
  get (stand in, items)
```

in the standard prelude. As one can see, it gets data from `stand in`.

`a68g` offers two routines familiar from C and Pascal that determine whether we are at the end of a line, or at the end of the file, while reading. Note that these routines are complementary to the event routines discussed in 7.8.

```
PROC end of line = (REF FILE file) BOOL
PROC eoln = (REF FILE file) BOOL
```

This routine yields `TRUE` if the file pointer of `file` is at the end of a line. One can advance the file pointer with `get (file, new line)` or `new line (file)`.

```
PROC end of file = (REF FILE file) BOOL
```

```
PROC eof = (REF FILE file) BOOL
```

This routine yields `TRUE` if the file pointer of `file` is at the end of the file. When you have finished reading data from a file, you should close the file by calling the procedure `close`. Its **declaration** starts with:

```
PROC close = (REF FILE f) VOID
```

7.6 Writing to files

One can use the `establish` procedure to create a new file. The **declaration** of `establish` starts with:

```
PROC establish = (REF FILE f, STRING idf, CHANNEL chann) INT
```

This **program** fragment creates a new file called `results`:

```
FILE outf;


IF establish (outf, "results", stand out channel) /= 0
THEN print (("Cannot establish file", new line));
  stop
FI
```

The procedure `establish` can fail if the disk you are writing to is full or you do not have write access (in a network, for example) in which case it will return a non-zero value. The procedure used to write data to a file is `put`. Its **declaration** starts with:

```
PROC put =
  (REF FILE f, [] UNION (OUTTYPE, PROC (REF FILE) VOID) items) VOID
```

The mode `OUTTYPE` is a united mode defined by the Revised Report {26_{10}.3.2.2} and encompasses all modes that can be printed. Like `INTYPE`, `OUTTYPE` is processed by straightening that converts any structure or row into a row of values of the constituent fields or elements. Allowed modes for latter elements in `a68g` are specified by the mode `SIMPLOUT`:

```
MODE SIMPLOUT = UNION (
  INT, REAL, COMPLEX,
  LONG INT, LONG REAL, LONG COMPLEX,
  LONG LONG INT, LONG LONG REAL, LONG LONG COMPLEX,
  BOOL,
  BITS, LONG BITS, LONG LONG BITS,
  CHAR, [] CHAR
)
```

Again, a `PROC (REF FILE) VOID` routine as `new line` and `new page` can be used as argument to `put` as in the following example:

```
FILE outf;
IF establish (outf, "newfile", stand out channel=) /= 0
THEN put (stand error, ("Cannot establish newfile"));
  stop
ELSE put (outf, ("Data for newfile", new line));
  close (outf)
FI
```

On output, the new line character is written to the file. `new page` behaves just like `new line` except that a form feed character is searched for on input, and written on output. When you have completed writing data to a file, you must close it with the procedure `close`. This is particularly important when writing files because the channel is buffered as explained above. Using `close` ensures that any remaining data in the buffer is flushed to the file. The procedure `print` directs output to `stand out`:

```
print (("Your name", new line))
```

which is equivalent to:

```
put (stand out, ("Your name", new line))
```

The procedure `write` is synonymous with `print`.

7.7 String terminators

A useful feature available for reading data is being able to specify when the reading of a string should terminate. Usually, this is set as the end of the line only. However, using the procedure `make term`, the string terminator can be a single character or any one of a set of characters. The **declaration** of `make term` starts with:

```
PROC make term = (REF FILE f, STRING term) VOID
```

so if you want to read a line word by word, defining a word as any sequence of non-space characters, one can make the string terminator a space by writing:

```
make term (inf, blank)
```

because `blank` (synonymous with `" "`) is rowed in the strong context of a **parameter** to `[] CHAR`. This will not remove the end-of-line as a terminator because the character `lf` is always added whatever characters you specify. You should remember that when a string is read, the string terminator is available for the next read — it has *not* been read by the previous read. Note that in `a68g` it is possible to inquire about the terminator string of a file by means of the routine:

```
PROC term = (REF FILE f) STRING
```

7.8 Events

The Revised Report implementation of Algol 68 transput is characterised by the use of events. Events are for instance end of file, or a conversion error. For each event, a file has a routine that is activated when its associated event occurs. `a68g` detects these events:

1. Reaching end of file.
2. Reaching end of line.
3. Reaching end of page.
4. Reaching end of format.
5. A file open error.
6. A value error.
7. A format error.
8. A transput error not caught by other events.

The default action when an event occurs depends on the event. For instance, end-of-line will per default provoke that `newline` is called after which transput continues, while end-of-file will provoke a runtime error. The default action can be replaced by a programmer-defined action.

7.8.1 File end

When the end of a file is detected, the default action is to generate a runtime error. A programmer-supplied action must be a procedure with mode `PROC (REF FILE) BOOL` The yield of this procedure should be `TRUE` if some action has been taken to remedy the end-of-file condition, in which case transput is resumed, or `FALSE` otherwise in which case the default action will be taken.

The **declaration** of the procedure `on logical file end` starts with:

```
PROC on logical file end =
  (REF FILE f, PROC (REF FILE) BOOL p) VOID
```

Algol 68 discerns {26_{10}.3.1.3} a *logical file end* and a *physical file end*. In `a68g` this difference is not implemented and `on file end`, `on logical file end` and `on physical`

`file end` are the same procedures. Next **program** will display the contents of its text input file and print a message at its end:

```
IF FILE inf; [] CHAR infn = "file";
  open (inf, infn, stand in channel) /= 0
THEN put (stand error, ("Cannot open ", infn, new line));
  stop
ELSE on logical file end
  (inf, (REF FILE f) BOOL:
    (write (("End of ", idf (f), new line));
    close (f);
    stop
    )
  );
  STRING line;
  DO get (inf, (line, new line));
    write ((line, new line))
  OD
FI
```

The anonymous procedure provided as the second **parameter** to `on logical file end` prints an informative message and closes the file. Note also that the `DO` loop simply repeats the reading of a line until the `logical file end` procedure is called by `get`. The procedure `idf` is described in section 7.15. You should be careful if you do transput on the **parameter** `REF FILE f` since you could get endless recursion in case such transput provokes the same event that the routine tried to handle. Also, because the `on logical file end` procedure stores its procedure **parameter** in its `REF FILE` **parameter**, you should be cautious when using `on logical file end` in limited ranges since a scope error may result. Any **unit** yielding an object of mode `PROC (REF FILE) BOOL` in a strong context is suitable as the second **parameter** of `on logical file end`. If you want to reset the action to the default action, use the **call** :

```
on logical file end (f, (REF FILE) BOOL: FALSE)
```

7.8.2 Line end and page end

These events are caused when while reading, the end of line or end of page is encountered. These conditions are events so one can provide a routine that for instance automatically counts the number of lines or pages read. The procedures `on line end` and `on page end` let you provide a procedure whose mode must be `PROC (REF FILE) BOOL`. If the programmer-supplied routine yields `TRUE`, transput continues, otherwise a `new line` in case of end of line, or `new page` in case of end of page, is executed and then transput resumes. Be careful when reading strings, since end of line and end of page characters are

string terminators. If you provide a routine that mends the line - or page end, be sure to call `new line` or `new page` before returning `TRUE`. In case of a default action, `new line` or `new page` must be called explicitly, for instance in the `read` procedure, otherwise you will read nothing but empty strings as you do not eliminate the terminator.

7.8.3 Format end

This event is caused when in formatted transput, the format gets exhausted. The procedure `on format end` lets you provide a procedure of mode `PROC (REF FILE) BOOL`. If the programmer-supplied routine yields `TRUE`, transput continues, otherwise the format that just ended is restarted and then transput resumes.

7.8.4 Open error

This event is caused when a file cannot be opened as required. For instance, you want to read a file that does not exist, or write to a read-only file. The procedure `on open error` lets you provide a procedure whose mode must be `PROC (REF FILE) BOOL`. If the programmer-supplied routine yields `TRUE`, the **program** continues, otherwise a runtime error occurs.

7.8.5 Value error

This event is caused when transputting a value that is not a valid representation of the mode of the object being transput. The procedure `on value error` lets the programmer provide a procedure whose mode must be `PROC (REF FILE) BOOL`. If you do transput on the file within the procedure ensure that a value error will not occur again. If the programmer-supplied routine yields `TRUE`, transput continues, otherwise a runtime error occurs.

7.8.6 Format error

This event is caused when an error occurs in a format, typically when patterns are provided without objects to transput. The procedure `on format error` lets the programmer provide a procedure whose mode must be `PROC (REF FILE) BOOL`. If the programmer-supplied routine yields `TRUE`, the **program** continues, otherwise a runtime error occurs.

7.8.7 Transput error

This event is caused when an error occurs in transput that is not covered by the other events, typically conversion errors (value out of range et cetera). The procedure `on transput error` lets the programmer provide a procedure whose mode must be `PROC (REF FILE) BOOL`. If the programmer-supplied routine yields `TRUE`, the **program** continues, otherwise a runtime error occurs.

7.9 Formatting routines

One of the problems of using the rather primitive facilities given so far for the output of real and integer numbers is that although they allow numbers to be printed in columns, the widths and precisions are fixed. It is necessary to have some means of controlling width and precision of printed values. The procedures `whole`, `fixed`, `float` and `real` provide these means. A specification of the routines in this section, as Algol 68 source code, is in 7.16.

The **declaration** of the procedure `whole` starts with:

```
PROC whole = (NUMBER v, INT width) STRING
```

and takes two **parameters**. The first is a real or integral value and the second is an integer which tells `whole` the width of the output number. If you pass a real number to `whole`, it calls the procedure `fixed` with **parameters** `width` and 0.

If $width = 0$, then the number is printed with the minimum possible width. A positive value for `width` will give numbers preceded by a "+" if positive and a "-" if negative. A negative value for `width` will provide a minus-sign for negative numbers but no plus-sign for positive numbers and the width will be `ABS width`. Note that where the integer is wider than the available space, the output field is filled with the character denoted by `error char` (which is declared in the standard prelude as the asterisk (⋆)).

The **declaration** of the procedure `fixed` starts with:

```
PROC fixed = (NUMBER v, INT width, after) STRING
```

and takes three **parameters**. The first two are the same as those for `whole` and the third specifies the number of decimal places required. The rules for `width` are the same as the rules for `width` for `whole`.

When you want to print numbers in scientific format, you should use `float` which takes four **parameters**. Its **declaration** starts with:

```
PROC float = (NUMBER v, INT width, after, exp) STRING
```

The first three are the same as the **parameters** for `fixed`, while the fourth is the width of the exponent field. Thus the **call** :

```
print (float (pi * 10, 8, 2, -2)
```

produces the output `+3.14e 1`. The **parameter** `exp` obeys the same rules, applied to the exponent, as `width`.

`a68g` implements a further routine `real` for formatting reals in a way closely related to `float`, declared as:

```
PROC real =
(NUMBER x, INT width, after, exp width, modifier) STRING
```

If `modifier` is a positive number, the resulting string will present `x` with its exponent a multiple of `modifier`. If $modifier = 1$, the returned string is identical to that returned by `float`. A common choice for `modifier` is 3 which returns the so-called engineers notation of `x`. If `modifier` is zero or negative, the resulting string will present `x` with `ABS modifier` digits before the **point-symbol** and its exponent adjusted accordingly; compare this to Fortran `nP` syntax.

7.10 Straightening

The term straightening is the process whereby a compounded mode is separated into its constituent modes, which are themselves straightened if required. For example, the mode:

```
STRUCT (INT a, CHAR b, UNION (REAL, STRING) u)
```

would be straightened into values of the following modes:

1. `INT`
2. `CHAR`
3. `UNION (REAL, STRING)`

The mode:

```
REF STRUCT (INT a, CHAR b, UNION (REAL, STRING) u)
```

would be straightened into a number of names having the modes:

1. `REF INT`
2. `REF CHAR`
3. `REF UNION (REAL, STRING)`

However, a value of mode COMPLEX is not straightened into two values both of mode REAL. Also, any row is separated into its constituent elements. For example:

```
[1 : 3] COMPLEX
```

will be straightened into three values of mode COMPLEX.

7.11 Default-format transput

In default-format transput, each primitive mode is written as follows:

1. CHAR
   Output a character to the current position in the file.
2. [] CHAR
   Output all the constituent characters to the file.
3. BOOL
   Output flip for TRUE or flop for FALSE to the file.
4. L BITS
   Output flip for each set bit and flop for each zero bit.
5. L INT
   Output the integer using the **call** :
   ```
   whole (i, L int width + 1)
   ```
   which will output the integral value in:
   ```
   L int width + 1
   ```
6. L REAL
   Output the real using the **call** :
   ```
   float (r, L real width + L exp width + 4,
     L real width - 1, L exp width + 1)
   ```
   which will output the real value in:
   ```
   L real width + L exp width + 4
   ```
   positions preceded by a **sign**.
7. L COMPLEX
   The complex value is output as two real numbers.
8. PROC (REF FILE) VOID
   An lf character is output if the routine is newline and an ff character if the routine is new page. User-defined routines with this mode can be used.

In default-format transput, each primitive mode is read as follows:

1. `REF CHAR`
   Characters `c`, `c < blank` are skipped and the first character `c ≥ blank` is assigned to the name. If a `REF [] CHAR` is given, then the above action occurs for each of the required characters of the row.

2. `REF STRING`
   All characters, including any control characters, are assigned to the name until any character in the character set specified by the `string term` field of `f` is encountered (but this is not read).

3. `REF BOOL`
   The next non-white-space character is read and, if it is `flip`, `TRUE` is assigned, or if it is `flop`, `FALSE` is assigned.

4. `REF L BITS`
   The action for `REF BOOL` is repeated for each bit in the name.

5. `REF L INT`
   White space is skipped until a **sign** or a digit is encountered. Reading of decimal digits continues until a character which is not a decimal digit is encountered.

6. `REF L REAL`
   A real number consists of 3 parts:

   (a) an optional **sign** possibly followed by spaces

   (b) an optional integral part

   (c) a `"."` followed by a fractional part

   (d) an optional exponent preceded by a character in the set `"Ee"`. The exponent may have a **sign**. Absence of a **sign** is taken to mean a positive exponent

7. `REF L COMPLEX`
   Two real numbers are read from the file. The first number is regarded as the real part and the second the imaginary part.

7.12 Formatted transput

Formatted transput gives the programmer a high degree of control over the transput of values. If you program in Fortran or in C then the concept of formatted transput is not strange to you. Algol 68 implements a similar mechanism but in its own orthogonal way.

A format is a description of how values should be transput. A format in Algol 68 is a value of mode `FORMAT`. The standard prelude defines the mode `FORMAT` as a structure the fields

of which are inaccessible. One can have format identities, format variables, procedures yielding formats et cetera. There are however no pre-defined operators for objects of mode FORMAT. One can define them but since the fields are inaccessible there is little sense in passing a format as **operand**. In a68g, formats behave like anonymous routines and follow the scope rules of routine-texts. Formats are associated with files by including them in the **parameter-list** of routines putf and getf. There are (of course) related routines printf and readf that perform putf on standout, or getf on standin, respectively. These routines have respective **routine-specifications**:

```
PROC putf = (REF FILE f, [] UNION (OUTTYPE,
  PROC (REF FILE) VOID, FORMAT) items) VOID

PROC getf = (REF FILE f, [] UNION (INTYPE,
  PROC (REF FILE) VOID, FORMAT) items) VOID

PROC printf =
  ([] UNION (OUTTYPE, PROC (REF FILE) VOID, FORMAT) items) VOID

PROC readf =
  ([] UNION (INTYPE, PROC (REF FILE) VOID, FORMAT) items) VOID
```

7.12.1 Format texts

In this section we will introduce formatted transput by describing the constituting constructs. In Fortran, a format is defined by a format statement like:

```
      WRITE (6, 10) N, RESULT
   10 FORMAT (/1X, 'RESULT', 1X, I3, '=', 1X, F9.5)
```

In Algol 68, a format has a pseudo **denotation** that is called a **format-text**, for instance:

```
$l, 1x, "Result", 1x, 2zd, "=", 1x, g (9.5)$
```

and you could write

```
FORMAT my format = $l, 1x, "Result", 1x, 2zd, "=", 1x, g (9.5)$;
FORMAT variable format := my format
```

but typically a **format-text** is used as a **parameter** to transput routines:

```
printf (($l, 1x, "Result", 1x, 2zd, "=", 1x, g (9.5)$, n, result))
```

A **format-text** has these general syntax elements:

- **format text:**
  formatter {8.2} symbol, picture list, formatter {8.2} symbol.

- **MARKER frame:**
  insertion option, replicator option, letter s {8.4} option, MARKER;

A **format-text** is a list of pictures; each picture representing an individual item to be transput:

- **picture:**
  insertion;
  pattern;
  collection;
  replicator collection.

Before describing other elements, a **replicator** is a static or dynamic specification of how often a subsequent construct should be repeated:

- **replicator:**
  integral denotation;
  letter n {8.4} symbol, meek integral enclosed clause {8.9.1}.

Examples of replicators are:

- `6 # Repeat six times #`
- `n (k + 1) # Repeat k + 1 times #`
- `n (read int) # Repeat as many times as you type #`

A **replicator** should not be less than zero. The Revised Report {26_{10}.3.4.1.dd} states that a negative **replicator** should be treated as if it were zero, but `a68g` assumes that a negative **replicator** means that something went wrong and will give a runtime error. A collection is simply a way to group a list of pictures, typically used when a **replicator** must be applied to it:

- **collection:**
  open {8.2} symbol, picture list, close {8.2} symbol.

Insertions give you control over new lines, new pages, spaces forward, or lets you insert string literals:

- **insertion: insertion item list.**

- **insertion item:**
  replicator option, letter k {8.4} symbol;
  performs as many spaces forward as its **replicator** indicates.
  replicator option, letter l {8.4} symbol;
  performs a new line; it calls `new line`.
  replicator option, letter p {8.4} symbol;
  performs a new page, it calls `new page`.
  replicator option, letter x {8.4} symbol;
  performs a space; it calls `space`.
  replicator option, letter q {8.4} symbol;
  performs a space; it calls `space`.
  replicator option, row of character denotation.
  Specifies a sequence of strings to be taken literally.

Examples:

- `20k`
- `3l"Answer"`
- `n (k + 1)x`
- `"Algol 68"`

Using insertions, we can for instance draw a sine-curve to standard output:

```
INT n = 24;
FOR i TO n
DO REAL x = 2 * pi * (i - 0.5) / n;
  printf ($l, n (40 - ROUND (30 * sin (x)))k, "*"$)
OD
```

Patterns specify how to:

1. transput a value of a standard mode.
2. direct transput depending on a boolean - or integer expression.
3. execute an embedded format.

`a68g` implements these patterns:

- **pattern:**
  general pattern;
  integral pattern;

real pattern;
complex pattern;
bits pattern;
string pattern;
boolean pattern;
choice pattern;
c style pattern;
format pattern.

These are standard Algol 68 patterns, except for the **c-style-pattern**, which is an `a68g` extension.

7.12.2 C-style patterns

If you are a C or C++ programmer you will be familiar with C format string placeholders. `a68g` offers a notation closely resembling C format string placeholders called **c-style-patterns**. These are an extension to standard Algol 68 **patterns**. Applicable production rules are:

- **c style pattern:**
  percent {8.2} symbol,
  minus {8.2} symbol option,
  plus {8.2} symbol option,
  width option,
  precision option,
  c type.
- **width: replicator.**
- **precision: point {8.2} symbol, replicator.**
- **c type:**
  letter b {8.4} symbol,
  letter c {8.4} symbol,
  letter d {8.4} symbol,
  letter e {8.4} symbol,
  letter f {8.4} symbol,
  letter g {8.4} symbol,
  letter i {8.4} symbol,
  letter o {8.4} symbol,
  letter s {8.4} symbol,
  letter x {8.4} symbol.

Example **c-style-patterns** are:

- `%-80s`
- `%+23.15f`
- `%d`
- `%n(bits width)b`

The **minus-symbol** specifies that the resulting string representation of the transput value will be left-justified instead of right-justified. The **plus-symbol** specifies that a sign must be printed for positive integer or real values. **Width** specifies the width of the string representation of the transput value. If you omit **width** then a default value is chosen. **Precision** applies to real values; if you omit this field then a default value is chosen. Note that fields which are not applicable to the mode of the value being transput are simply ignored; no diagnostic will be issued. The letter **c-type** determines the mode of the transput value:

`b` binary transput of a value of mode `L BITS`.

`c` transput of a value of mode `CHAR`.

`d` transput of a value of mode `L INT`.

`e` transput of a value of mode `L REAL` in scientific format.

`f` transput of a value of mode `L REAL` in fixed format.

`g` transput of a value of mode `L REAL` in `e` or `f` format, whichever is more appropriate.

`i` transput of a value of mode `L INT`.

`o` octal transput of a value of mode `L BITS`.

`s` transput of a value of mode `[] CHAR` or `STRING`.

`x` hexadecimal transput of a value of mode `L BITS`.

On reading a `STRING` or `[] CHAR` value, with omitted **width** field, string terminators as set by `make term` are obeyed. If you specify **width**, then exactly that number of characters is read, irrespective of terminators set by `make term`.

7.12.3 General patterns

The **general-pattern** performs transput following default formatting:

- **general pattern:**
  letter g {8.4} symbol, strong row of integer enclosed clause {8.9.1};
  letter h {8.4} symbol, strong row of integer enclosed clause {8.9.1};

Any standard mode can be transput with "g" or "h" when the **strong-row-of-integer-enclosed-clause** is absent; default formatting is used which is the formatting that default-format routines `read`, `get`, `out` or `print` would apply. In case of an integer or real value to transput, the length of the strong-row-of-integer determines the formatting to be applied. In case of letter "g" we get:

- element `(i).whole (..., i)` is called.
- elements `(i, j).fixed (..., i, j)` is called.
- elements `(i, j, k).float (..., i, j, k)` is called.

In case of letter "h" we always get scientific notation. Let `K` be `1` + the value `exp with` for the length of the integer or real value to transput, then we have this behaviour for "h":

- element `(i).real (..., i, i + K + 4, K, 3)` is called. Since this gives `i` decimals before the exponent is adjusted to be a multiple of 3, we get $i + 1$ digits in engineers notation and the width is automatically adjusted.
- elements `(i, j).real (..., i, i + K + 4, K, j)` is called. If you want to print a number with exactly `i` decimals, you specify `h (i, 1)` and the width is automatically adjusted.
- elements `(i, j, k).real (..., i, j, K, k)` is called. This prints as much digits as will fit in a width `i`, including `j` decimals, and the exponent is adjusted to be a multiple of `k`.
- elements `(i, j, k, l).real (..., i, j, k, l)` is called. This gives you full control of the routine `real` as no defaults are applied.

7.12.4 Integral patterns

An **integral-pattern** transputs integral values and consists of an optional **sign-mould** that lets you decide how to transput a **sign**, followed by an integer-mould that specifies how to transput each individual digit. We will meet elements here that are called frames: "s", "z" and "d". Frame "s" means that the next frame will be suppressed, "z" means to print a non-zero digit or a space otherwise, and "d" means to print a digit. Hence the **sign-mould** determines how to put a **sign**, would you want one.

- **integral pattern: sign mould option, integer mould.**
- **sign mould: integer mould option, sign.**
- **integer mould: digit marker sequence, insertion option.**

- **digit marker:**
  letter z frame;
  letter d frame.

Frames + and – are sign-frames; + forces a **sign** to be put, but a – only puts a minus if the number is negative. Example **sign-moulds** are:

- `+`
- `–`
- `zzz–`
- `3z–`

If you specify **letter-z-frames** before the **sign** "+" or "-" then the **sign** will shift left one digit for every non-zero digit that is begin put. In `a68g`, when a **sign** is shifted in a **sign-mould**, any character output by literal insertions in that **sign-mould** is replaced with a space as well, starting from the first **letter-z-frame** until the **sign** is put. The insertions let you put all kind of literals in between digits. For example:

- `4d # transputs 9 as "0009", error on negative #`
- `zzz-d # transputs -9 as " -9" #`
- `3z-d # transputs -9 as " -9" #`
- `3z","2z-d # transputs 100000 as " 100,000" #`
- `3d"-"3d"-"4d # transputs 5551234567 as 555-123-4567 #`

7.12.5 Real patterns

A **real-pattern** follows the same logic as an **integral-pattern**. **Sign-moulds** are optional, and the exponent-part is optional. The **decimal-point-frame** and the **exponent-frame** "e" are suppressible by preceding them with "s"; this can for instance be used to replace the standard exponent character by an insertion of choice.

- **real pattern:**
  sign mould option, integer mould option, letter s {8.4} symbol option, point {8.2} symbol,
  insertion option, integer mould, exponent frame option;
  sign mould option, integer mould, letter s {8.4} symbol option, point {8.2} symbol,
  insertion option, integer mould option, exponent frame option;
  sign mould option, integer mould, exponent frame;

- **exponent frame:**
  letter s {8.4} symbol option, letter e {8.4} symbol, insertion option, sign mould option, integer mould.

Examples:

- `d.3d # transputs pi as "3.142" #`
- `d.3dez-d # transputs 0.3333 as "3.333e -1" #`
- `ds.","3dse"^"z-d # transputs 0.3333 as "3,333^-1" #`

7.12.6 Complex patterns

A **complex-pattern** consists of a **real-pattern** for the real part and a **real-pattern** for the imaginary part of the value. The **plus-i-times-frame** "i" is suppressible and can thus be replaced by an insertion.

- **complex pattern:**
  real pattern, letter s {8.4} symbol option, letter i {8.4} symbol, insertion option, real pattern.

Examples:

- `-d.3di-d.3d # transputs f.i. 0.000i-1.000 #`
- `-d.3dsi-d.3d, "j" # transputs f.i. 0.000-1.000j #`

7.12.7 Bits patterns

A **bits-pattern** has no **sign-mould**, since a `BITS` value is unsigned. In `a68g` the radix is specified by a **replicator** by which it can be dynamic.

- **bits pattern:**
  replicator, letter r {8.4} symbol, integer mould.

Examples:

- `2r7zd # binary 8-bit byte with trailing zero-bit suppression #`
- `16r8d # hexadecimal 32 bit word #`

7.12.8 String patterns

The **string-pattern** transputs an object of modes `STRING`, `CHAR` and `[] CHAR`. The **letter-a-frames** can be suppressed.

- **string-pattern: letter-a-frame-sequence, insertion-option.**

Examples:

- `printf (($7a$, "Algol68")) # prints "Algol68" #`
- `printf (($5a"-"2a$, "Algol68")) # prints "Algol-68" #`
- `printf (($5a2sa$, "Algol68")) # prints "Algol" #`

7.12.9 Boolean patterns

The boolean-expression transputs a `BOOL` value.

- **boolean pattern:**
  letter b {8.4} symbol;
  letter b {8.4} symbol, open {8.2} symbol, row of character denotation,
  comma {8.2} symbol, row of character denotation, close {8.2} symbol.

If you just want the standard "T" or "F" transput, do not specify the **row-of-character-denotations**. If you do specify those, a **boolean-pattern** is the **format-text** equivalent of a **conditional-clause**. Example:

- `printf ($b ("true", "not true")$, read bool)`

7.12.10 Choice patterns

A **choice-pattern** transputs a row-of-character-denotation depending on an integral value. It is the **format-text** equivalent of an case-clause.

- **choice pattern:**
  letter c {8.4} symbol, open {8.2} symbol, row of character denotation list,
  close {8.2} symbol.

Examples:

- `printf ($c ("one", "two", "three")$, read int)`

The Revised Report specification of getting using an **integral-choice-pattern** has the peculiarity that when two literals start with the same sequence of characters, the longer literal should appear first in the list. `a68g` makes no such demand, and will select the correct literal from the list whatever their order.

7.12.11 Format patterns

The **format-pattern** lets you dynamically choose the format you want to employ.

- **format pattern:**
  letter f {8.4} symbol, meek format enclosed clause {8.9.1}.

This is an example where a format may be selected dynamically:

- `f (um | (INT): $g (0)$, (REAL): $g (0, 4)$)`

The effect of a **format-pattern** is that is temporarily supersedes the active format for the file at hand. When this temporary format ends, the original format continues without invoking an format-end event.

7.13 Binary files

Files that are not meant to be read by you can be in a compact binary form. These files are called binary files or unformatted files. Many large files will be stored in this form. Algol 68 allows you to read and write the same values to binary files as are allowed for text files. The difference between transput on binary files is that instead of using the procedures `put` and `get`, you use the procedures `put bin` and `get bin`. The modes accepted by these procedures are identical with those accepted by `put` and `get` respectively. Values of mode `[] CHAR` or `REF STRING` can be written by `put bin`, and read by `get bin`, but note that the string terminator set using the procedure `make term` is ignored — on binary output, `a68g` first writes the number of characters that will be printed and consequently on binary input, `a68g` first reads the number of characters that will be read. Note that the procedure `read bin` is equivalent to `get bin (stand back, ...)` and the procedure `write bin` is equivalent to `put bin (standback, ...)`.

7.14 Using a string as a file

In a program, you may want to manipulate data in text format. Therefore you would need to convert data to text, or vice versa. Program languages typically have routines for this. Algol 68 transput routines also convert data to text, so it stands to reason to utilise those. To enable this, Algol 68 allows a file to be associated with an object of mode `STRING`. You associate a string with a files using the routine `associate` which is declared as:

```
PROC associate = (REF FILE, REF STRING) VOID
```

On putting, the string is dynamically lengthened and output is added at the end of the string. Attempted getting outside the string provokes an end of file condition. When a file that is associated with a string is reset, getting restarts from the start of the associated string. Next code fragment illustrates the use of `associate` in transput:

```
[n] COMPL u, v;
# code to give values to elements in u #
FILE in, out,
STRING z;
# convert data to text #
associate (out, z);
putf (out, u);
close (out);
# convert text to data #
associate (in, z);
getf (in, v);
close (in);
```

Next to above standard approach, Algol 68 Genie offers procedures by which you can read and write using a string instead of a file. These compound a series of calls to Algol 68 transput routines as in above example. These routines are described in section 11.14.7.

7.15 Other transput procedures

The **declaration** of the procedure `idf` starts with:

```
PROC idf = (REF FILE f) STRING
```

and yields the identification of the file handled by the file `f`. There are two other ways of closing a file. One is `scratch` and the other is `lock`:

```
PROC scratch = (REF FILE f) VOID
PROC lock = (REF FILE f) VOID
```

The procedure `scratch` deletes the file once it is closed. It is often used with temporary files. The procedure `lock` closes its file and then locks it so that it cannot be opened without some system action. It is possible to reset, or rewind, a file, to let the next transput operation start from the beginning of a file. The procedure provided for this purpose is `reset`. Its **declaration** starts with:

```
PROC reset = (REF FILE f) VOID
```

One possible use of this procedure is to output data to a file, then use `reset` followed by `get` to read the data from the file. `a68g` allows the alternative spelling `rewind`. Whether a file supports `reset` can be interrogated by using:

```
PROC reset possible = (REF FILE f) BOOL
```

This routine yields `TRUE` when `f` can be reset, or `FALSE` otherwise. `a68g` allows the alternative spelling `rewind possible`. In `a68g` there is also a procedure `set` that attempts to set the file pointer to a position other than the beginning of the file as done by `reset`:

```
PROC set = (REF FILE f, INT n) INT
```

This routine deviates from the standard Algol 68 definition. In `a68g`, `set` attempts to move the file pointer of `f` by `n` character positions with respect to the current position. If the file pointer would as a result of this move get outside the file, it is not changed and the routine set by `on file end` is called. If this routine returns `FALSE`, and end-of-file runtime error is produced. The routine returns an `INT` value representing system-dependent information on this repositioning. Whether a file allows setting, can be interrogated with set possible:

```
PROC set possible = (REF FILE f) BOOL
```

which does what its name suggests — yield `TRUE` when `f` can be set, or `FALSE` otherwise. Related to `set` are the routines `space` and `backspace`:

```
PROC space = (REF FILE f) VOID
```

The procedure advances the file pointer in file `f` by one character. It does *not* read or write a blank.

```
PROC backspace = (REF FILE f) VOID
```

The procedure attempts to retract the file pointer in file `f` by one character. It actually executes

```
VOID (set (f, -1))
```

and thus is subject to the properties of the routine `set`.

7.16 Appendix. Formatting routines

Next listing is a specification of `whole`, `fixed`, `float` and `real` implemented by `a68g`. It closely follows the Revised Report definition (26_{10}.3.2.1), that however does not define the routine `real`.

```
# Actual implementation also includes LONG and LONG LONG modes #
MODE NUMBER = UNION (INT, REAL);
CHAR error char = "*";

# REM is not the same as MOD #
OP REM = (INT i, j) INT: (i - j * (i OVER j));
PRIO REM = 7;

PROC whole = (NUMBER v, INT width) STRING:
  CASE v IN
    (INT x):
    (INT length := ABS width - (x < 0 OR width > 0 | 1 | 0),
      INT n := ABS x;
      IF width = 0 THEN
        INT m := n; length := 0;
        WHILE m OVERAB 10; length +:= 1; m /= 0
        DO SKIP OD
      FI;
      STRING s := sub whole (n, length);
      IF length = 0 OR char in string (error char, LOC INT, s)
      THEN ABS width * error char
      ELSE
        (x < 0 | "-" |: width > 0 | "+" | "") PLUSTO s;
        (width /= 0 | (ABS width - UPB s) * " " PLUSTO s);
        s
      FI),
    (REAL x): fixed (x, width, 0)
  ESAC;

PROC fixed = (NUMBER v, INT width, after) STRING:
  CASE v IN
    (REAL x):
    IF INT length := ABS width - (x < 0 OR width > 0 | 1 | 0);
      after >= 0 AND (length > after OR width = 0)
    THEN REAL y = ABS x;
      IF width = 0
      THEN length := (after = 0 | 1 | 0);
        WHILE y + .5 * .1 ^ after > 10 ^ length
        DO length +:= 1 OD;
        length +:= (after = 0 | 0 | after + 1)
      FI;
      STRING s := sub fixed (y, length, after);
      IF NOT char in string (error char, LOC INT, s)
```

```
      THEN (length > UPB s AND y < 1.0 | "0" PLUSTO s);
          (x < 0 | "-" |: width > 0 | "+" | "") PLUSTO s;
          (width /= 0 | (ABS width - UPB s) * " " PLUSTO s);
          s
      ELIF after > 0
      THEN fixed (v, width, after - 1)
      ELSE ABS width * error char
      FI
    ELSE ABS width * error char
    FI,
    (INT x): fixed (REAL(x), width, after)
  ESAC;

PROC real = (NUMBER v, INT width, after, exp, modifier) STRING:
  CASE v IN
    (REAL x):
    IF INT before = ABS width - ABS exp -
        (after /= 0 | after + 1 | 0) - 2;
      INT mod aft := after;
      SIGN before + SIGN after > 0
    THEN STRING s, REAL y := ABS x, INT p := 0;
      standardize (y, before, after, p);
      IF modifier > 0
      THEN WHILE p REM modifier  = 0
        DO y *:= 10;
          p -:= 1;
          IF mod aft > 0
          THEN mod aft -:= 1
          FI
        OD
      ELSE WHILE y < 10.0 ^ (- modifier - 1)
        DO y *:= 10;
          p -:= 1;
          IF mod aft > 0
          THEN mod aft -:= 1
          FI
        OD;
        WHILE y > 10.0 ^ - modifier
        DO y /:= 10;
          p +:= 1;
          IF mod aft > 0
          THEN mod aft +:= 1
          FI
        OD
      FI;
      s := fixed (SIGN x * y,
        SIGN width * (ABS width - ABS exp - 1), mod aft) +
        "E" + whole (p, exp);
      IF exp = 0 OR char in string (error char, LOC INT, s)
      THEN float (x, width,
```

```
        (mod aft /= 0 | mod aft - 1 | 0),
        (exp > 0 | exp + 1 | exp - 1))
      ELSE s
      FI
    ELSE ABS width * error char
    FI,
    (INT x): float (REAL(x), width, after, exp)
  ESAC;

PROC float = (NUMBER v, INT width, after, exp) STRING:
  real (v, width, after, exp, 1);

PROC sub whole = (NUMBER v, INT width) STRING:
  CASE v IN
    (INT x):
    BEGIN STRING s, INT n := x;
      WHILE dig char (n MOD 10) PLUSTO s;
        n OVERAB 10; n /= 0
      DO SKIP OD;
      (UPB s > width | width * error char | s)
    END
  ESAC;

PROC sub fixed = (NUMBER v, INT width, after) STRING:
  CASE v IN
    (REAL x):
    BEGIN STRING s, INT before := 0;
      REAL y := x + .5 * .1 ^ after;
      PROC choose dig = (REF REAL y) CHAR:
        dig char ((INT c := ENTIER (y *:= 10.0);
          (c > 9 | c := 9); y -:= c; c));
      WHILE y >= 10.0 ^ before DO before +:= 1 OD;
      y /:= 10.0 ^ before;
      TO before DO s PLUSAB choose dig (y) OD;
      (after > 0 | s PLUSAB ".");
      TO after DO s PLUSAB choose dig (y) OD;
      (UPB s > width | width * errorchar | s)
    END
  ESAC;

PROC standardize = (REF REAL y, INT before, after, REF INT p) VOID:
  BEGIN
    REAL g = 10.0 ^ before, REAL h := g * .1;
    WHILE y >= g DO y *:= .1; p +:= 1 OD;
    (y /= 0.0 | WHILE y < h DO y *:= 10.0; p -:= 1 OD);
    (y + .5 * .1 ^ after >= g | y := h; p +:= 1)
  END;

PROC dig char = (INT x) CHAR: "0123456789abcdef" [x + 1];

SKIP
```

8 Context-free grammar

{There are writings which are lovable although ungrammatical,
and there are other writings which are extremely grammatical,
but are disgusting.
This is something that I cannot explain to superficial persons.
On Flowers and Women. Chang Ch'ao. }

8.1 Introduction

This chapter is a reference for Algol 68 Genie context-free syntax. The advantage of presenting a context-free syntax is that the backbone of constructions can be explained briefly. The disadvantage is that a context-free grammar cannot reject **programs** that are semantically incorrect, for instance those that apply undeclared symbols. The two-level Algol 68 syntax is described in the Revised Report in Part IV. In this informal introduction to Algol 68, a method from Van Wijngaarden is used to write context-free production rules that is explained in section {1.3}.

8.2 Reserved symbols

Algol 68, like other programming languages, reserves several symbols. One cannot redefine reserved uppercase symbols by **declarations**. Next symbols are reserved in `a68g`:

Symbol	Representation
andf symbol	ANDF
andth symbol	ANDTH
assert symbol	ASSERT
assign symbol	ASSIGN
at symbol	AT
begin symbol	BEGIN
becomes symbol	:=
bits symbol	BITS
bool symbol	BOOL
bus symbol	]
by symbol	BY
bytes symbol	BYTES
case symbol	CASE
channel symbol	CHANNEL
char symbol	CHAR
class symbol	CLASS
close symbol	)
code symbol	CODE
col symbol	COL
comment symbol	COMMENT
complex symbol	COMPLEX
compl symbol	COMPL
diag symbol	DIAG
do symbol	DO
downto symbol	DOWNTO
edoc symbol	EDOC
elif symbol	ELIF
else symbol	ELSE
elsf symbol	ELSF
empty symbol	EMPTY
end symbol	END
environ symbol	ENVIRON
equals symbol	=
esac symbol	ESAC
exit symbol	EXIT
false symbol	FALSE
file symbol	FILE
fi symbol	FI
flex symbol	FLEX
format symbol	FORMAT
formatter symbol	$
for symbol	FOR

Symbol	Representation
from symbol	FROM
go symbol	GO
goto symbol	GOTO
heap symbol	HEAP
if symbol	IF
in symbol	IN
int symbol	INT
isnt symbol	ISNT
is symbol	IS
loc symbol	LOC
long symbol	LONG
mode symbol	MODE
new symbol	NEW
nil symbol	NIL
od symbol	OD
of symbol	OF
op symbol	OP
open	(
orel symbol	OREL
orf symbol	ORF
ouse symbol	OUSE
out symbol	OUT
par symbol	PAR
pipe symbol	PIPE
pragmat symbol	PRAGMAT
prio symbol	PRIO
proc symbol	PROC
real symbol	REAL
ref symbol	REF
row symbol	ROW
sema symbol	SEMA
short symbol	SHORT
skip symbol	SKIP
sound symbol	SOUND
string symbol	STRING
struct symbol	STRUCT
sub symbol	[
thef symbol	THEF
then symbol	THEN
to symbol	TO
trnsp symbol	TRNSP

Symbol	Representation
true symbol	TRUE
underscore symbol	_
union symbol	UNION
until symbol	UNTIL
void symbol	VOID
while symbol	WHILE

8.3 Digit symbols

- **digit:**
  digit 0 symbol; digit 1 symbol; digit 2 symbol;
  digit 3 symbol; digit 4 symbol; digit 5 symbol;
  digit 6 symbol; digit 7 symbol; digit 8 symbol;
  digit 9 symbol.

Symbol	Representation	Symbol	Representation
digit 0 symbol	0	**digit 5 symbol**	5
digit 1 symbol	1	**digit 6 symbol**	6
digit 2 symbol	2	**digit 7 symbol**	7
digit 3 symbol	3	**digit 8 symbol**	8
digit 4 symbol	4	**digit 9 symbol**	9

8.4 Letter symbols

- **letter:**
  letter a symbol; letter b symbol; letter c symbol;
  letter d symbol; letter e symbol; letter f symbol;
  letter g symbol; letter h symbol; letter i symbol;
  letter j symbol; letter k symbol; letter l symbol;
  letter m symbol; letter n symbol; letter o symbol;
  letter p symbol; letter q symbol; letter r symbol;
  letter s symbol; letter t symbol; letter u symbol;
  letter v symbol; letter w symbol; letter x symbol;
  letter y symbol; letter z symbol.

Symbol	Representation		
letter a symbol	a	**letter n symbol**	n
letter b symbol	b	**letter o symbol**	o
letter c symbol	c	**letter p symbol**	p
letter d symbol	d	**letter q symbol**	q
letter e symbol	e	**letter r symbol**	r
letter f symbol	f	**letter s symbol**	s
letter g symbol	g	**letter t symbol**	t
letter h symbol	h	**letter u symbol**	u
letter i symbol	i	**letter v symbol**	v
letter j symbol	j	**letter w symbol**	w
letter k symbol	k	**letter x symbol**	x
letter l symbol	l	**letter y symbol**	y
letter m symbol	m	**letter z symbol**	z

8.5 Bold letter symbols

- **bold letter:**
  bold letter a symbol; bold letter b symbol;
  bold letter c symbol; bold letter d symbol;
  bold letter e symbol; bold letter f symbol;
  bold letter g symbol; bold letter h symbol;
  bold letter i symbol; bold letter j symbol;
  bold letter k symbol; bold letter l symbol;
  bold letter m symbol; bold letter n symbol;
  bold letter o symbol; bold letter p symbol;
  bold letter q symbol; bold letter r symbol;
  bold letter s symbol; bold letter t symbol;
  bold letter u symbol; bold letter v symbol;
  bold letter w symbol; bold letter x symbol;
  bold letter y symbol; bold letter z symbol.

Symbol	Representation	Symbol	Representation
bold letter a symbol	A	**bold letter n symbol**	N
bold letter b symbol	B	**bold letter o symbol**	O
bold letter c symbol	C	**bold letter p symbol**	P
bold letter d symbol	D	**bold letter q symbol**	Q
bold letter e symbol	E	**bold letter r symbol**	R
bold letter f symbol	F	**bold letter s symbol**	S
bold letter g symbol	G	**bold letter t symbol**	T
bold letter h symbol	H	**bold letter u symbol**	U
bold letter i symbol	I	**bold letter v symbol**	V
bold letter j symbol	J	**bold letter w symbol**	W
bold letter k symbol	K	**bold letter x symbol**	X
bold letter l symbol	L	**bold letter y symbol**	Y
bold letter m symbol	M	**bold letter z symbol**	Z

8.6 Tags

Tags are the symbols for **identifiers**, **mode-indicants** and **operators**.

8.6.1 Mode indicant tags

- **mode indicant:**
  bold letter {8.5};
  mode indicant, bold letter {8.5};
  mode indicant, underscore {8.2} symbol sequence, mode indicant.

8.6.2 Identifier tags

- **identifier:**
  letter {8.4};
  identifier, letter {8.4};
  identifier, digit {8.3};
  identifier, underscore {8.2} symbol sequence, identifier.

- **label:**
  identifier, colon {8.2} symbol.

8.6.3 Operator tags

Note that white space cannot be written within an operator symbol.

- **operator:**
  monadic operator;
  dyadic operator.
- **monadic operator:**
  bold operator;
  monad, nomad option, becomes option.
- **dyadic operator:**
  bold operator;
  monad, nomad option, becomes option;
  nomad, nomad option, becomes option.
  - **bold operator:**
    bold letter {8.5};
    bold operator, bold letter {8.5};
    bold operator, underscore {8.2} symbol sequence, bold operator.
- **becomes:**
  becomes {8.2} symbol option;
  assigns to {8.2} symbol option.

8.7 Particular program

A **particular-program** is the actual application, embedded in the standard environ.

- **particular program:**
  label sequence option, enclosed clause {8.9.1}.

8.8 Clauses

Serial-clauses and **enquiry-clauses** describe how **declarations** and **units** are put in sequence. Algol 68 requires clauses to yield a value. As **declarations** yield no value, **serial-clauses** and **enquiry-clauses** cannot end in a **declaration**. `EXIT` leaves a serial-clause, yielding the value of the preceding **unit**. If the **unit** following `EXIT` would not be labelled, it could never be reached. In a **serial-clause** there cannot be **labelled-units** before **declarations** to prevent re-entering **declarations** once they have been executed.

- **serial clause:**
  initialiser series option,
  labelled unit series.

- **labelled unit:**
  unit {8.9.5};
  label, unit {8.9.5};
  unit {8.9.5}, exit {8.2} symbol, label, unit {8.9.5}.

- **initialiser:**
  unit {8.9.5};
  declaration list.

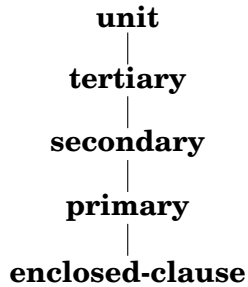
- ***phrase: declaration; unit {8.9.5}.**

{An **enquiry-clause** yields a value to direct the **conditional-clause**, **case-clause**, **conformity-clause**, **while-part** or **until-part** in a **loop-clause**. An **enquiry-clause** contains no **labels**, so one cannot for instance jump back to the **enquiry-clause** at `IF` from the **serial-clause** at `THEN`.}

- **enquiry clause:**
  initialiser series option,
  unit {8.9.5} series.

8.9 Units

Units are orthogonal; for instance an **enclosed-clause** can be an **operand** in a **formula**. The constituent constructs of phrases are **primaries**, **secondaries**, **tertiaries** and **units**. **Units** are arranged in this hierarchy:



where each class includes the lower class. For example, all **primaries** are **secondaries**, but not vice versa. This hierarchy of **units** prevents writing ambiguous **programs**; it specifies for example that:

```
z[k] := z[k] + 1
```

can only mean:

```
((z)[(k)]) := (((z)[(k)]) + (1))
```

or that:

```
ref OF ori OF z :=: NIL
```

can only mean:

```
(ref OF (ori OF (z))) :=: (NIL)
```

8.9.1 Enclosed clauses

Enclosed-clauses provide structure for a **particular-program**. There are seven types of **enclosed-clause**.

1. The simplest is the **closed-clause** which consists of a **serial-clause** enclosed in parentheses (or `BEGIN` and `END`).
2. **Collateral-clauses** are generally used as **row-displays** or structure displays: there must be at least two **units**. The **units** are elaborated collaterally. This means that the order is undefined and may well be in parallel.
3. A **parallel-clause** {4.12} is a **collateral-clause** preceded by `PAR`. The constituent **units** are executed in parallel.
4. The **loop-clause** {4.9}.
5. The **conditional-clause** {4.3}.
6. The **case-clause** {4.6}.
7. The **conformity-clause** {4.7}.

It should be noted that the **enquiry-clause** in a **conditional-clause**, **case-clause** or **loop-clause** is in a meek context whatever the context of the clause. Thus, the context of the clause is passed on only to the terminal **unit** in the `THEN`, `ELSE`, `IN` or `OUT` **serial-clauses**.

- **enclosed clause:**
  closed clause,
  collateral clause,
  parallel clause,

choice using boolean clause,
choice using integral clause,
choice using UNITED {16_1.5} clause,
loop clause.

- **closed clause:**
  begin {8.2} symbol, serial clause {8.8}, end {8.2} symbol.

- **collateral clause:**
  begin {8.2} symbol, unit {8.9.5} list proper, end {8.2} symbol.

- ***row display:**
  begin {8.2} symbol, unit {8.9.5} list proper option, end {8.2} symbol.

- ***structure display: strong collateral clause.**

In a **parallel-clause** {4.12} the elaboration of **units** can be synchronised using semaphores. Section 4.12 discusses the `a68g` implementation of the **parallel-clause**.

- **parallel clause:**
  par {8.2} symbol, begin {8.2} symbol, unit {8.9.5} list, end {8.2} symbol.

- ***conditional clause: choice using boolean clause.**

- **choice using boolean clause:**
  if {8.2} symbol, meek boolean enquiry clause {8.8},
  then {8.2} symbol, serial clause {8.8},
  elif part option,
  else part option,
  fi {8.2} symbol.

- **elif part:**
  elif {8.2} symbol, meek boolean enquiry clause {8.8},
  then {8.2} symbol, serial clause {8.8},
  elif part option.

- **else part:**
  else {8.2} symbol, serial clause {8.8}.

- ***case clause: choice using integral clause.**

- **choice using integral clause:**
  case {8.2} symbol, meek integral enquiry clause {8.8},
  in {8.2} symbol, unit {8.9.5} list proper,

ouse part option,
out part option
esac {8.2} symbol.

- **ouse part:**
  ouse {8.2} symbol, meek integral enquiry clause {8.8},
  in {8.2} symbol, unit {8.9.5} list proper,
  ouse part option.

- **out part:**
  out {8.2} symbol, serial clause {8.8}.

- ***conformity clause: choice using UNITED {16_1.5} clause.**

- **choice using UNITED {16_1.5} clause:**
  case {8.2} symbol, meek UNITED {16_1.5} enquiry clause {8.8},
  in {8.2} symbol, specified unit list,
  conformity ouse part option,
  out part option,
  esac {8.2} symbol.

- **specified unit:**
  open {8.2} symbol, formal declarer {8.11}, identifier {8.6.2} option, close {8.2} symbol, colon {8.2} symbol, unit {8.9.5}.
  open {8.2} symbol, void {8.2} symbol, close {8.2} symbol, colon {8.2} symbol, unit {8.9.5}.

- **conformity ouse part:**
  ouse {8.2} symbol, meek UNITED {16_1.5} enquiry clause {8.8},
  in {8.2} symbol, specified unit list,
  conformity ouse part option.

- **loop clause:**
  for part option,
  from part option,
  by part option,
  to part option,
  while part option,
  do part.

- **for part:**
  for {8.2} symbol, identifier {8.6.2}.

- **from part:**
  from {8.2} symbol, meek integral unit {8.9.5}.

- **by part:**
  by {8.2} **symbol, meek integral unit** {8.9.5}**.**

- **to part:**
  to {8.2} **symbol, meek integral unit** {8.9.5}**;**
  downto {8.2} **symbol, meek integral unit** {8.9.5}**.**

- **while part:**
  while {8.2} **symbol, meek boolean enquiry clause** {8.8}**.**

- **do part:**
  do {8.2} **symbol, serial clause** {8.8}**, od** {8.2} **symbol;**
  do {8.2} **symbol, serial clause** {8.8} **option, until part, od** {8.2} **symbol.**

- **until part:**
  until {8.2} **symbol, meek boolean enquiry clause** {8.8}**.**

8.9.2 Primaries

Primaries are **denotations**, **applied-identifiers**, **casts**, **calls**, **format-texts**, **enclosed-clauses** and **slices**. **Applied-identifiers** are **identifiers** being used in a context, rather than in their **declarations** where they are defining **identifiers**. **Routine-texts** are not **primaries**, though **format-texts** are.

- **primary:**
  enclosed clause {8.9.1}**,**
  identifier {8.6.2}**,**
  specification,
  cast,
  format text,
  denotation.

- **specification:**
  call,
  slice,
  field selection.

Calls were discussed in section 5.3. A **call** invokes a procedure, but can be partially parameterised: partial parameterisation adds arguments to a procedure 's locale; when the locale is complete the procedure is called, otherwise currying takes place. In section 6.4, it was mentioned that the **primary** of a **call** is in a meek context. This applies even if the **call** itself is in a strong context.

- **call:**
  meek primary, open {8.2} symbol, actual parameter list, close {8.2} symbol.

- **actual parameter:**
  strong unit {8.9.5} option.

A **slice** selects an element or a sub-row from a rowed value {3.4}. The context of the **primary** of the **slice** is weak. This means that if the primary yields a name, then the slice will yield a name. **Collateral-clauses** used as **row-displays** can only be used in a strong context. Where necessary, a strong context can be created by means of a **cast**. The context of **units** in **subscripts** and **trimmers** is meek.

- **slice:**
  weak primary, sub {8.2} symbol, indexer list, bus {8.2} symbol.
- **indexer:**
  subscript;
  trimmer.
- **trimmer:**
  lower index option,
  colon {8.2} symbol,
  upper index option,
  revised lower bound option.
- **subscript: meek integral unit {8.9.5}.**
- **lower index: meek integral unit {8.9.5}.**
- **upper index: meek integral unit {8.9.5}.**
- **revised lower bound:**
  at {8.2} symbol, meek integral unit {8.9.5}.

Field-selections are an `a68g` extension described in section 3.11.

- **field selection:**
  weak primary, sub {8.2} symbol, identifier {8.6.2} list, bus {8.2} symbol.

- **cast:**
  formal declarer {8.11}, strong enclosed clause {8.9.1}.

- **denotation:**
  integral denotation;

real denotation;
boolean denotation;
bits denotation;
character denotation;
row of character denotation;
void denotation.

- **integral denotation:**
  length {1.3} option, digit {8.3} sequence.
- **real denotation:**
  length {1.3} option, digit {8.3} sequence, exponent part;
  length {1.3} option, digit {8.3} sequence option, point {8.2} symbol, digit {8.3} sequence, exponent part option.
- **exponent part:**
  letter e {8.4} symbol, sign option, digit {8.3} sequence.
- **boolean denotation:**
  true {8.2} symbol;
  false {8.2} symbol.
- **bits denotation:**
  length {1.3} option, bits digit {8.3} sequence;
  bits digit {8.3} sequence
- **character denotation:**
  quote {8.2} symbol, string item, quote {8.2} symbol.
- **string item:**
  character;
  quote {8.2} symbol, quote {8.2} symbol.
- **row of character denotation:**
  quote {8.2} symbol, string item sequence, quote {8.2} symbol.
- **void denotation:**
  empty {8.2} symbol.

8.9.2.1 Formats

Format-texts are discussed in section 7.12.

- **format text:**
  formatter {8.2} symbol, picture list, formatter {8.2} symbol.

- **replicator:**
  integral denotation;
  letter n {8.4} symbol, meek integral enclosed clause {8.9.1}.

- **MARKER frame:**
  insertion option, replicator option, letter s {8.4} option, MARKER;

- **picture:**
  insertion;
  pattern;
  collection;
  replicator collection.

- **collection:**
  open {8.2} symbol, picture list, close {8.2} symbol.

- **insertion: insertion item list.**

- **insertion item:**
  replicator option, letter k {8.4} symbol;
  replicator option, letter l {8.4} symbol;
  replicator option, letter p {8.4} symbol;
  replicator option, letter x {8.4} symbol;
  replicator option, letter q {8.4} symbol;
  replicator option, row of character denotation.

- **pattern:**
  general pattern;
  integral pattern;
  real pattern;
  complex pattern;
  bits pattern;
  string pattern;
  boolean pattern;
  choice pattern;
  format pattern.
  c style pattern.

- **general pattern:**
  letter g {8.4} symbol, strong row of integer enclosed clause {8.9.1};
  letter h {8.4} symbol, strong row of integer enclosed clause {8.9.1};

- **integral pattern: sign mould option, integer mould.**

- **sign mould: integer mould option, sign.**

- **integer mould: digit marker sequence, insertion option.**

- **digit marker:**
  letter z frame;
  letter d frame.

- **real pattern:**
  sign mould option, integer mould option, letter s {8.4} symbol option, point {8.2} symbol,
  insertion option, integer mould, exponent frame option;
  sign mould option, integer mould, letter s {8.4} symbol option, point {8.2} symbol,
  insertion option, integer mould option, exponent frame option;
  sign mould option, integer mould, exponent frame;

- **exponent frame:**
  letter s {8.4} symbol option, letter e {8.4} symbol, insertion option,
  sign mould option, integer mould.

- **complex pattern:**
  real pattern, letter s {8.4} symbol option, letter i {8.4} symbol, insertion option, real pattern.

- **complex pattern:**
  real pattern, letter s {8.4} symbol option, letter i {8.4} symbol, insertion option, real pattern.

- **bits pattern:**
  replicator, letter r {8.4} symbol, integer mould.

- **string pattern: letter a frame sequence, insertion option.**

- **boolean pattern:**
  letter b {8.4} symbol;
  letter b {8.4} symbol, open {8.2} symbol, row of character denotation,
  comma {8.2} symbol, row of character denotation, close {8.2} symbol.

- **choice pattern:**
  letter c {8.4} symbol, open {8.2} symbol, row of character denotation list, close {8.2} symbol.

- **format pattern:**
  letter f {8.4} symbol, meek format enclosed clause {8.9.1}.

- **c style pattern:**
  percent {8.2} symbol,
  minus {8.2} symbol option,
  plus {8.2} symbol option,
  width option,
  precision option,
  c type.

- **width: replicator.**

- **precision: point {8.2} symbol, replicator.**

- **c type:**
  letter b {8.4} symbol,
  letter c {8.4} symbol,
  letter d {8.4} symbol,
  letter e {8.4} symbol,
  letter f {8.4} symbol,
  letter g {8.4} symbol,
  letter i {8.4} symbol,
  letter o {8.4} symbol,
  letter s {8.4} symbol,
  letter x {8.4} symbol.

8.9.3 Secondaries

- **secondary:**
  primary {8.9.2};
  selection;
  generator.

Selections are described in section 3.10.

- **selection: identifier {8.6.2}, of-symbol, secondary.**

Generators are introduced in section 2.12.

- **generator: qualifier, actual-declarer {8.11}.**

8.9.4 Tertiaries

- **tertiary:**
  secondary {8.9.3};
  nihil;
  formula;
  stowed function.

`NIL` is introduced in section 2.13.

- **nihil: nil {8.2} symbol.**

Formulas are covered in section 2.7.

- **formula:**
  monadic operator {8.6.3} sequence, monadic operand;
  dyadic operand, dyadic operator {8.6.3}, dyadic operand.
- **monadic operand:**
  secondary {8.9.3};
- **dyadic operand:**
  monadic operator {8.6.3} sequence option, monadic operand;
  formula.
- ***operand: monadic operand; dyadic operand.**

Stowed-functions are described in section 3.8.

- **stowed function:**
  monadic stowed {8.2} symbol, weak tertiary,
  meek integral tertiary, dyadic stowed {8.2} symbol, weak tertiary.
- **monadic stowed {8.2} symbol:**
  diag {8.2} symbol, trnsp {8.2} symbol, row {8.2} symbol, col {8.2} symbol.
- **dyadic stowed {8.2} symbol:**
  diag {8.2} symbol, row {8.2} symbol, col {8.2} symbol.

8.9.5 Units

- **unit:**
  tertiary {8.9.4};

assignation;
routine text;
identity relation;
jump;
skip;
assertion;
conditional function;
code clause.

Assignations are discussed in section 2.12.

- **assignation: soft tertiary {8.9.4}, becomes-symbol, strong-unit.**

The **identity-relation** is introduced in section 4.5.

- **identity relation:**
  soft tertiary {8.9.4}, is {8.2} symbol, soft tertiary {8.9.4};
  soft tertiary {8.9.4}, isnt {8.2} symbol, soft tertiary {8.9.4};

For a description of **jumps** see 4.13.

- **jump: goto {8.2} symbol option, identifier {8.6.2}.**

{A **skip** is indicated by the reserved word `SKIP`. This construct terminates and yields an undefined value of the mode required by the context, and can therefore only occur in a strong context. It is particularly useful in cases were the result is undefined:

```
OP INVERSE = (MATRIX m) MATRIX:
  IF DET m = 0 THEN SKIP ELSE ... FI
```

If the determinant of a matrix is zero, no unique inverse exists and the operator yields an undefined matrix.}

- **skip: skip {8.2} symbol.**

Assertions are described in section 4.14.

- **assertion: assert {8.2} symbol, meek boolean enclosed clause {8.9.1}.**

Conditional-functions are discussed in {4.4}.

- **conditional function:**
  meek boolean tertiary {8.9.4}, conditional {8.2} symbol, meek boolean tertiary {8.9.4}.

- **conditional {8.2} symbol:**
  thef {8.2} symbol; andf {8.2} symbol; andth {8.2} symbol;
  elsf {8.2} symbol; orf {8.2} symbol; orel {8.2} symbol.

Routine-texts were discussed in chapter 5.

- **routine text:**
  routine specification, colon {8.2} symbol, strong unit.

- **routine specification:**
  parameter pack option, formal declarer {8.11}.
  parameter pack option, void {8.2} symbol.
- **parameter pack:**
  open {8.2} symbol, formal parameter list, close {8.2} symbol.
- **formal parameter: formal declarer {8.11}, identifier {8.6.2}.**

{A **code-clause** is meant to directly insert C code into an object file generated by the plugin compiler {9.1.1}. This construct yields a value of the mode required by the context, and can therefore only occur in a strong context. The **row-of-character-denotations** are inserted consecutively in the object file.}

- **code clause:**
  code {8.2} symbol, row of character denotation list, edoc {8.2} symbol.

8.10 Declarations

Declarations introduce new tags, or specify the priority of an operator.

- **declaration:**
  mode declaration;
  identity declaration;
  variable declaration;
  procedure declaration;
  procedure variable declaration;
  operator declaration;
  priority declaration.

- **mode declaration:**
  mode {8.2} symbol, mode definition list.

- **mode definition:**
  mode indicant {8.6.1}, equals {8.2} symbol, actual declarer {8.11}.

- **identity declaration:**
  formal declarer {8.11}, identity definition list.

- **identity definition:**
  identifier {8.6.2}, equals {8.2} symbol, strong unit {8.9.5}.

- **variable declaration:**
  qualifier option, actual declarer {8.11}, variable definition list.

- **variable definition list:**
  identifier {8.6.2}, initialisation option.

- **initialisation: becomes {8.2} symbol, strong unit {8.9.5}.**

- **procedure declaration:**
  proc {8.2} symbol, procedure definition list.

- **procedure definition: identifier {8.6.2}, equals {8.2} symbol, routine text.**

- **procedure variable declaration:**
  qualifier option, proc {8.2} symbol, procedure variable definition list.

- **procedure variable definition: identifier {8.6.2}, becomes {8.2} symbol, routine text.**

- **brief operator declaration:**
  operator {8.2} symbol, brief operator definition list.

- **brief operator definition list:**
  operator {8.6.3}, equals {8.2} symbol, routine text.

- **operator declaration:**
  operator plan, operator definition list.

- **operator plan:**
  operator {8.2} symbol, parameter pack, formal declarer {8.11}.

- **operator definition list:**
  operator {8.6.3}, equals {8.2} symbol, strong unit {8.9.5}.

- **priority declaration:**
  prio {8.2} symbol, priority definition list.

- **priority definition list:**
  operator {8.6.3}, equals {8.2} symbol, priority digit

- **priority digit:**
  digit 1 symbol;
  digit 2 symbol;
  digit 3 symbol;
  digit 4 symbol;
  digit 5 symbol;
  digit 6 symbol;
  digit 7 symbol;
  digit 8 symbol;
  digit 9 symbol.

8.11 Declarers

Declarers specify modes. The context determines whether a mode is formal, virtual, or actual. Formal or virtual **declarers** are needed where the size of rows is irrelevant. **Actual-declarers** are needed where the size of rows must be known, for instance when allocating memory for rows.

- **VICTAL: virtual; actual; formal.**

- **VICTAL declarer:**
  length {1.3} option, primitive declarer;
  mode indicant;
  ref {8.2} symbol, virtual declarer;
  sub {8.2} symbol, VICTAL bounds list, bus {8.2} symbol, VICTAL declarer;
  flex {8.2} symbol, sub {8.2} symbol, VICTAL bounds list, bus {8.2} symbol, VICTAL declarer,
  struct {8.2} symbol, open {8.2} symbol, VICTAL declarer identifier {8.6.2} list, close {8.2} symbol;
  union {8.2} symbol, open {8.2} symbol, united declarer list, close {8.2} symbol;
  proc {8.2} symbol, formal declarer pack option, formal declarer;
  proc {8.2} symbol, formal declarer pack option, void {8.2} symbol.

- **formal declarer pack:**
  open {8.2} symbol, formal declarer list, close {8.2} symbol.

- **united declarer: formal declarer; void {8.2} symbol.**
- **formal bounds: colon {8.2} symbol option.**
- **virtual bounds: colon {8.2} symbol option.**
- **actual bounds: lower bound option, upper bound.**
- **lower bound: meek integral unit {8.9.5}, colon {8.2} symbol.**
- **upper bound: meek integral unit {8.9.5}.**

8.12 Pragments

Pragments are either **pragmats** or **comments** {4.11}. In `a68g`, **pragmats** contain preprocessor directives, or set options from within a **program**.

- **pragment: pragmat; comment.**
- **pragmat:**
  pragmat {8.2} symbol, pragmat item sequence, pragmat {8.2} symbol.
- **comment:**
  comment symbol character sequence comment {8.2} symbol.

8.13 Refinements

A low-level tool for top-down program construction is the **refinement** preprocessor. **Refinements** are not a part of Algol 68 syntax, but are superimposed on top of it. Note that **refinements** interfere somewhat with **labels**.

- **refined program: paragraph, point {8.2} symbol, refinement definition sequence.**
- **refinement definition: identifier {8.6.2}, colon {8.2} symbol, paragraph, point {8.2} symbol.**
- **paragraph: character sequence.**

8.14 Private production rules

`a68g` uses a number of private production rules. These are not used for the description of syntax in this text. You may however encounter them in `a68g` diagnostics.

- ***if-part: if {8.2} symbol, meek boolean enquiry clause {8.8}.**
- ***then-part: then {8.2} symbol, serial clause {8.8},**
- ***case-in-part: in {8.2} symbol, unit {8.9.5} list proper.**
- ***conformity-in-part: in {8.2} symbol, specified unit {8.9.1} list.**

II

Programming with Algol 68 Genie

9 Description of Algol 68 Genie

{**Genie**, *noun*.

A spirit from Arabian folklore, capable of granting wishes when summoned.}

9.1 Algol 68 Genie

Algol 68 Genie implements almost all of Algol 68, and extends[1] that language. Algol 68 Genie (`a68g`) is open source software distributed under GNU GPL. This software is distributed in the hope that it will be useful, but **without any warranty**. Consult the GNU General Public License[2] for details. A copy of the license is in this publication.

An interpreter is a program that executes code written in a programming language. While interpretation and compilation are the two principal means for implementing programming languages, these are not fully distinct categories. An interpreter may be a program that either (1) executes source code directly, (2) translates source code into some intermediate representation which is executed or (3) executes stored code from a compiler which is part of the interpreter system. Perl, Python, MATLAB, and Ruby are examples of type (2), while UCSD Pascal and Java and `a68g`[3] are type (3). After successful parsing of an entire source **program**, `a68g` will interpret the syntax tree that serves as an intermediate **program** representation. The **unit** compiler may construct routines by which Algol 68 Genie can efficiently execute selected **units**. Algol 68 Genie employs a multi-pass scheme to parse Algol 68 [Lindsey 1993] {10.9}. The interpreter proper performs many runtime checks[4]:

1. Assigning to, or dereferencing of, `NIL`.
2. Using uninitialised values.
3. Invalid **operands** to standard prelude operators and procedures.

[1] One can disable most extensions using the `strict` option, see section 10.6.4.
[2] See `https://www.gnu.org/licenses/gpl.html`.
[3] If you specify `optimise a68g` is type (3), otherwise it is type (2).
[4] In this respect `a68g` resembles `FLACC` [Mailloux 1978].

4. **Bounds** check when manipulating rows.

5. Overflow of arithmetic modes.

6. *Dangling references*, that are names that refer to deallocated memory.

9.1.1 The Algol 68 Genie unit compiler

On Linux or compatible (with respect to the dynamic linking mechanism) operating systems, Algol 68 Genie can run in optimising mode, in which it employs a **unit** compiler that emits C code for many **units** involving operations on primitive modes `INT`, `REAL`,`BOOL`,`CHAR` and `BITS` and simple structures thereof such as `COMPLEX`. Execution time of such **units** by interpretation is dominated by interpreter overhead, which makes compilation of these units worthwhile.

Generated C code is compiled and dynamically linked before it is executed by Algol 68 Genie. Technically, the compiler synthesizes per selected **unit** efficient routines compounding the elemental routines needed to execute terminals in the syntax tree which allows for instance common sub-expression elimination. Generated C code is compatible with the virtual stack-heap machine implemented by the interpreter proper, hence generated code has full access to `a68g`'s runtime library and the interpreter's debugger. Note that this scheme involves *ahead of time* compilation, the **unit** compiler is not a *just in time* compiler as used in for example Java implementations.

The **unit** compiler omits many runtime checks for the sake of efficiency. Therefore, it is not recommended to specify option `optimise` or `compile` while your program is still in development, and to use it only for programs that work correctly.

Your mileage will vary depending on your source code; expect a speed increase ranging from *hardly noticeable* to *ten times as fast*. Optimisation generally is not efficient for programs with short execution times, or *run-once* programs typical for programming course exercises.

The **unit** compiler requires `gcc` or `clang` as back-end for code generation and the `libdl` library, as dynamic linker loader. If you use the option `compile` to generate shell scripts from Algol 68 programs, also `GNU tar` and `sed` are required. On platforms where the **unit** compiler cannot run, the Algol 68 Genie interpreter executes the intermediate syntax-tree.

9.1.2 Features of Algol 68 Genie

1. Precision of numeric modes {2.4, 2.6, 3.13 and 3.14}:

   (a) Implementation of `LONG INT`, `LONG REAL`, `LONG COMPLEX` and `LONG BITS` with roughly doubled precision with respect to `INT`, `REAL`, `COMPLEX` and `BITS`.

(b) Implementation of multi-precision arithmetic through `LONG LONG INT`, `LONG LONG REAL`, `LONG LONG COMPLEX` and `LONG LONG BITS` which are modes with user defined precision which is set by an option.

2. On systems that support them, Linux extensions that allow e.g. for executing child processes that communicate through pipes, matching regular expressions or fetching web page contents, {11.18}.

3. Procedures for drawing using the GNU Plotting Utilities {11.18}.

4. Various extra numerical procedures, many of which from the GNU Scientific Library.

5. Basic linear algebra and Fourier transform procedures from the GNU Scientific Library {11.10, 11.10 and 11.11}.

6. Support for WAVE/PCM sound format {11.23}.

7. Support for PostgreSQL, an open source relational database management system, enabling client applications in Algol 68 {11.22}.

8. **Format-texts**, straightening and formatted transput. Transput routines work generically on files, (dynamic) strings and Unix pipes {7.12}.

9. **Parallel-clause** on platforms that support POSIX threads {4.12}.

10. Implementation of C.H. Lindsey's partial parameterisation proposal, giving Algol 68 a functional sub language [Koster 1996] {5.10}.

11. A simple **refinement** preprocessor to facilitate top-down **program** construction {10.7.3}.

12. Symbol `NEW` as alternative for symbol `HEAP`.

13. **Field-selections** as alternative syntax for **selections**, see 3.11.

14. Implementation of pseudo-operators `ANDF` and `ORF` (or their respective alternatives `THEF`, `ANDTH` and `OREL`, `ELSF` {4.4}.

15. Implementation of pseudo-operators `TRNSP`, `DIAG`, `COL` and `ROW` as described by [Torrix 1977] {3.8}.

16. Implementation of `DOWNTO` with comparable function as `TO` in **loop-clauses**; `DOWNTO` decreases, whereas `TO` increases, the loop counter by the value of the (implicit) by-part {4.9}.

17. Implementation of a post-checked loop. A do-part may enclose a **serial-clause** followed by an optional **until-part**, or just enclose an **until-part**. This is an alternative to the paradigm Algol 68 post-check loop `WHILE ... DO SKIP OD`. An until-part consists of the reserved word `UNTIL` followed by a meek-boolean-enquiry-clause. The **loop-clause** terminates when the **enquiry-clause** yields `TRUE` {4.9}.

18. Implementation of monadic- and **dyadic-operator** `ELEMS` that operate on any row. The **monadic-operator** returns the total number of elements while the **dyadic-operator** returns the number of elements in the specified dimension, if this is a valid dimension {3.4}.

19. When option **--brackets** is specified, `(...)`, `[...]` and `{...}` are equivalent to the parser and any pair can be used where Algol 68 requires open-symbols and close-symbols. This allows for clearer coding when parenthesis are nested. If `brackets` is not specified, `(...)` is an alternative for `[...]` in **bounds** and **indexers**, which is traditional Algol 68 syntax.

20. Implementation of operators `SET` and `CLEAR` for mode `BITS`.

21. The parser allows for **colon-symbols**, used in **bounds** and **indexers**, to be replaced by `..` which is the Pascal style.

22. Upper stropping is the default, quote stropping is optional.

9.1.3 Deviations from the Revised Report language

1. The important difference with the Revised Report transput model is that Algol 68 Genie transput does not operate on `FLEX [] FLEX [] FLEX [] CHAR`, but on `FLEX [] CHAR`. This maps better onto operating systems as Unix or Linux.

2. Algol 68 Genie does not initialise values to `SKIP` and uninitialised values provoke a runtime error. This is believed to be a safe approach since many program errors result from using uninitialised values.

3. The Algol 68 Genie parallel-clause deviates from the standard Algol 68 **parallel-clause** {4.12} when **parallel-clauses** are nested. Algol 68 Genie's parallel **units** behave like threads with private stacks. Hence if parallel **units** modify a shared variable then this variable must be declared outside the outermost parallel-clause, and a **jump** out of a parallel **unit** can only be targeted at a **label** outside the outermost **parallel-clause** {4.12}.

4. It is not possible to declare in a `[WHILE ...] DO ... [UNTIL ...] OD` part an **identifier** with equal spelling as the loop **identifier**.

5. If the context of a **jump** expects a parameter-less procedure of mode `PROC VOID`, then a `PROC VOID` routine whose **unit** is that **jump** is yielded instead of making the **jump**. In standard Algol 68, this proceduring will take place if the context expects a parameter-less procedure, while Algol 68 Genie limits this to `PROC VOID`.

6. Algol 68 Genie maps a **declarer** whose length is not implemented onto the most appropriate length available {17_2.1.3.1}. Algol 68 Genie considers mapped modes equivalent to the modes they are mapped onto, while standard Algol 68 would still set them apart. Routines or operators for not-implemented lengths are mapped accordingly.

7. At runtime, Algol 68 Genie does not make a copy of row parameters. Hence a procedure body could contrive a way to alter the original row. This is an obvious trade-off between efficiency of row handling and implementing the revised language to the letter. `ALGOL68RS` had the same shortcoming, but not `ALGOL68C`.

9.1.4 Deviations from the proposed language extensions

1. Algol 68 Genie evaluates a routine once a value is obtained for all actual parameters. It is therefore not possible to obtain a parameter-less procedure from a procedure with a single parameter. Hence
   `REAL e = exp(1)`
   is obviously allowed, but
   `PROC REAL e = exp(1)`
   is not allowed.

9.2 Algol 68 Genie transput

`a68g` transput deviates from the Revised Report specification, as described below. For an overview of implemented procedures refer to the standard prelude reference.

9.2.1 Features of Algol 68 Genie transput

1. Transput procedures operate generically on files, strings and Linux pipes.
2. Implementation of a procedure `real` that extends the functionality of `float`.
3. `a68g` implements `ALGOL68C` routines as `read int` and `print int` but not routines as `get int` and `put int`.
4. There are two extra procedures to examine a file: `idf` and `term`.
5. If a file does not exist upon calling open, the default action will be to create it on the file system.
6. If a file exists upon calling establish, the event handler set by on open error will be invoked.
7. `a68g` can write to file stand error with associated channel stand error channel. This file is linked to the standard error stream that is usually directed at the console.
8. Insertions can be any combination of alignments and literals.

9. The argument for a **general-pattern** is an **enclosed-clause** yielding `[] INT` (which is a superset of the Revised Report specification.

10. Extended **general-pattern** `h` for transputting real values.

11. The radix for a **bits-pattern** can be 2 . . . 16. The radix can be dynamic.

12. Implementation of C-style format placeholders.

13. The Revised Report specification of getting using an **integral-choice-pattern** has the peculiarity that when two literals start with the same sequence of characters, the longer literal should appear first in the list. `a68g` makes no such demand, and will select the correct literal from the list whatever their order in the list.

9.2.2 Deviations from standard Algol 68 transput

1. The important difference with the Revised Report transput model is that `a68g` transput does not operate on a `FLEX [] FLEX [] FLEX [] CHAR`, but on a `FLEX [] CHAR`. This maps better onto operating systems as Unix/Linux.

2. `establish` does not take arguments specifying the size of a file.

3. Getting and putting a file is essentially sequential. Only `reset` can intervene with sequential processing.

4. `a68g` does not currently permit switching between read mood and write mood unless the file is `reset` first (and the file was opened with `standback channel`). Whether a file is in read mood or write mood is determined by the first actual transput operation (`put` or `get`) on a file after opening it.

5. Since `a68g` transput operates on a `FLEX [] CHAR`, routine `associate` is associates a file to a `REF STRING` object. On putting, the string is dynamically lengthened and output is added at the end of the string. Attempted getting outside the string provokes an end of file condition, and the event routine set by `on file end` is invoked. When a file that is associated with a string is reset, getting restarts from the start of the associated string.

6. Since an end on file event handler cannot move the file pointer to a good position (reset also resets a file's read mood and write mood), encountering end of file terminates getting of a `STRING` value. Conform the Revised Report, getting of a `STRING` value will resume if the end of line event handler or the end of page handler returns `TRUE`.

7. There is no event routine `on char error mended`. Attempted conversion of an invalid value for a required mode, or attempted transput of a value that cannot be converted by the current format-pattern, evokes the event routine set by `on value error`.

8. When all arguments in a **call** of `readf`, `printf`, `writef`, `getf` or `putf` are processed, the format associated with the corresponding file is purged - that is, remaining insertions are processed and the format is discarded. If a **pattern** is encountered while purging, then there was no associated argument and the event routine set by on format error is called. When this event routine returns `FALSE` (the default routine always returns `FALSE`) a runtime error will be produced.

9. According to {26_{10}.3.3.1}, formatless output prints an intervening space before the value of a `L INT`, `L REAL` or `L COMPL` value, when not at the beginning of the line. Also, the imaginary part of a `L COMPL` value is prefixed by the "plus i times" symbol "⊥". Algol 68 Genie neither prints those intervening characters in formatless output, nor expects a "plus i times" symbol in formatless input {26_{10}.3.3.2}.

10. `SIMPLIN` and `SIMPLOUT` are generic for both formatted and unformatted transput. Therefore `SIMPLIN` and `SIMPLOUT` include both mode `FORMAT` and `PROC (REF FILE) VOID`. If a transput procedure encounters a value whose transput is not defined by that procedure, a runtime error occurs.

11. Insertion `x` has the same effect as insertion `q`; both call space.

12. When a **sign** is shifted in a **sign-mould**, any character output by literal insertions in that **sign-mould** is replaced with a space as well, starting from the first **letter-z-frame** until the **sign** is put.

13. When printing using a **pattern**, a **letter-z-frame** behaves as a **letter-d-frame** once a non-zero digit has been printed, and in a fractional part of a real number a **letter-z-frame** always behaves as a **letter-d-frame**.

14. When getting a literal insertion, `space` is performed for every character in that literal. It is not checked whether read characters actually match the literal.

15. Routine `set` moves with respect to the current file pointer.

10 Installing and using Algol 68 Genie

10.1 Installing Algol 68 Genie on Windows 11

The Algol 68 Genie project web page provides a prebuilt `WIN64` binary for Microsoft Windows 11. This binary is cross-compiled on Linux for 64-bit Windows. The binary is linked against GNU plotutils, the GNU Scientific Library, and R mathlib. Unzip this file, enter the distribution directory and execute `a68g.exe` from `powershell`. The executable is in the `bin` sub-directory. The distribution directory also contains `a68g` source files, and selected Algol 68 test programs, in the sub-directory `src`.

10.2 Installing from prebuilt binaries

On the internet you can find various prebuilt binaries for Algol 68 Genie. These binaries are available for various systems, for instance Debian, Ubuntu, Fedora, Arch Linux and BSD variants including macOS. If those binaries suit you, you can install `a68g` following the instructions provided by the respective repositories.

10.3 Installing Algol 68 Genie from source

This section describes into detail how to compile and install `a68g` on a Linux or FreeBSD system.

You will need to download the latest version of Algol 68 Genie from:
https://algol68genie.nl/

In this section we assume that the latest version is packed in a file called:

```
algol68g-3.12.2.tgz
```

which is a gzipped tar-archive.

10.3.1 Optional libraries

If installed on your system, `a68g` can use several libraries to extend its functionality. The `configure` script checks for shared libraries and necessary includes. If necessary files are not detected then `a68g` builds without support for absent libraries.

1. The quadmath library is needed for 128-bit floats.

   Without quadmath, `a68g` reverts to its own multiprecision library to implement `LONG` modes. The quadmath library comes with `gcc`. Therefore `gcc` is preferred for building `a68g`, since for instance `clang` does not have this library. Note that FreeBSD disables hardware support for 128-bit floats.

2. GNU Scientific Library extends the `a68g` prelude.

   On Debian, install the library like so:

   ```
   sudo apt install libgsl-dev
   ```

   See https://www.gnu.org/software/gsl/.

3. GNU plotutils allows drawing from Algol 68. Specifically, `a68g` links to the library `libplot`.
   See https://www.gnu.org/software/plotutils/.

   On Debian, install `libplot` like so:

   ```
   sudo apt install libplot-dev
   ```

4. R mathlib provides support for many statistical routines. See https://www.r-project.org.

   On Debian, install R mathlib like so:

   ```
   sudo apt install r-mathlib
   ```

5. GNU MPFR provides extra `LONG LONG REAL` support, meant as reference material for `a68g` development. See https://mpfr.org/.
   Note that GNU MPFR needs GNU MP, which is typically installed as a GNU MPFR dependency. On Debian, install both libraries like so:

   ```
   sudo apt install libgmp-dev libmpfr-dev
   ```

6. PostgreSQL for writing PostgreSQL database client applications.
   See https://www.postgresql.org/.

   On Debian, install this library like so:

   ```
   sudo apt install libpq-dev
   ```

7. CURL for HTTP client or HTTPS client applications.
   See https://curl.se/libcurl/.

On Debian, there are several CURL libraries available, but either of the next two should work:

```
sudo apt install libcurl4-gnutls-dev
```

or

```
sudo apt install libcurl4-openssl-dev
```

10.3.2 Generic installation

Algol 68 Genie follows the GNU build system. The package will be configured automatically for your platform by a configuration script, conveniently named `configure`. This script generates a `Makefile` using `autoconf` and `automake`. The generated `Makefile` is used by `make` to compile and install the package on your system. You will need some tools that are present on most Linux systems. Note that Algol 68 Genie prefers `gcc` as `C` compiler. For a generic installation, you can follow next instructions. For a customised build, follow instructions in the file `INSTALL` in the distribution.

Step 1: Unpacking the distribution

Unpack the distribution by typing:

```
tar -xzf algol68g-3.12.2.tgz
```

Make the distribution directory the working directory by typing:

```
cd algol68g-3.12.2
```

Step 2: Configuring

In the distribution directory type:

```
./configure
```

You will now see information scrolling by. On Linux, you would for example see:

```
[ ... ]
checking platform... linux
[ ... ]
configure: algol68g-3.12.2 by Marcel van der Veer <algol68g@algol68genie.nl>
configure:
configure: C compiler is gcc
configure:
configure: Building with long modes
configure: Building with parallel clause
configure: Building with GNU MPFR
configure: Building with R mathlib
configure: Building with GNU Scientific Library
configure: Building with curses
```

```
configure: Building with GNU plotutils
configure: Building with PostgreSQL
configure: Building with curl
configure: Building plugin compiler
configure:
configure: Now enter 'make', optionally followed by 'make check'.
configure: Enter 'make install' to install a68g for all users.
configure: Consult the README file for more information.
[ ... ]
```

On FreeBSD, output may look like this:

```
[ ... ]
checking platform... freebsd
[ ... ]
configure:
configure: algol68g-3.12.2 by Marcel van der Veer <algol68g@algol68genie.nl>
configure:
configure: C compiler is clang
configure:
configure: Building with parallel clause
configure: Building with curses
configure: Building plugin compiler
configure:
configure: Now enter 'make', optionally followed by 'make check'.
configure: Enter 'make install' to install a68g for all users.
configure: Consult the README file for more information.
[ ... ]
```

Note on FreeBSD the absence of the line

```
configure: Building with long modes
```

FreeBSD disables hardware support for 128-bit floats altogether. On other platforms, absence for long mode support will typically be a consequence of `a68g` depending on quadmath, which is a `gcc` library, not provided by `clang`.

Now you have a `Makefile`, which will be used by `make` to build `a68g`.

The configure script accepts various options. For an overview of options, type:

```
./configure --help
```

Some users will want to install in other directories than the default ones. To this end one could for example specify:

```
./configure --prefix=$HOME
```

in case one would like to install in the home directory. The GNU build system and `a68g`

expect you to organise your file system in a specific manner - if you specify `--prefix=dir` targets for installation are:

- `dir/bin` for `a68g`,
- `dir/include/algol68g` for `a68g.h` and `a68g-config.h`,
- `dir/share/man` for the manual page `a68g.1`.

The default GNU building system setting is `--prefix=/usr/local`, hence default install directories are:

- `/usr/local/bin` for `a68g`,
- `/usr/local/include/algol68g` for `a68g.h` and `a68g-config.h`,
- `/usr/local/share/man` for the manual page `a68g.1`.

The `--help` option also lists configuration options specific for Algol 68 Genie:

1. `enable-arch=cpu`
   If using `gcc`, enable emitting architecture-tuned assembly code. (default is "no")
2. `enable-generic`
   This will build `a68g` with version `2` functionality. Version `2` was the last version providing variable `LONG LONG BITS` precision. Note that in `a68g` version `2`, `INT` is a 32-bit object, `LONG` modes are implemented in software, and some routines described in this manual are not available.
3. `enable-int-4-real-8`
   Enable 4-byte `INT` and 8-byte `REAL`. This is a fall-back for vintage platforms (default is "no").
4. `enable-int-8-real-16`
   If supported, enable 8-byte `INT`, 8-byte `REAL` and 16-byte `LONG REAL`. For instance, `i386` platforms already supports this option. This option takes precedence over "enable-int-4-real-8" (default is "yes").
5. `enable-compiler`
   Enable plugin compiler (default is "yes").
6. `enable-mpfr`
   If installed, enable GNU MPFR (default is "yes").
7. `enable-gsl`
   If installed, enable GNU Scientific Library (default is "yes").

8. `enable-parallel`
   Enable Algol 68 parallel-clause (default is "yes").
9. `enable-mathlib`
   If available, enable R mathlib library (default is "yes").
10. `enable-pic=option`
    If using `gcc`, enable option to generate position-independent code (PIC). Absence of PIC capabilities switches off the plugin compiler. (default is "-fPIC")
11. `enable-curses`
    If available, enable curses library (default is "yes").
12. `enable-plotutils`
    If installed, enable GNU plotting utilities (default is "yes").
13. `enable-postgresql`
    If installed, enable PostgreSQL (default is "yes").
14. `enable-readline`
    If available, enable readline library (default is "yes").

You do not need to specify those options; you can safely stick to the defaults. But if you would want an interpreter-only version of `a68g`, you specify:

```
./configure --enable-compiler=no
```

or, equivalently:

```
./configure --disable-compiler
```

This disables the plugin compiler altogether. If you are not interested in Algol 68's **parallel-clause** {4.12}, you specify:

```
./configure --disable-parallel
```

Step 3: Building

Now that you have a `Makefile`, type:

```
make
```

Again a lot of output will scroll by. You might see some inconsequential warning messages, for instance on possible clobbering by `longjmp`. When `make` finishes, the executable `a68g` will be in the present working directory. To check that the executable is built correctly, type:

```
make check
```

Again, output will scroll by which will look much like:

```
make check-TESTS
make[1]: Entering directory `./a68g'
...
================================
All 37 tests behaved as expected
================================
make[1]: Leaving directory `./a68g'
```

The final message is reassuring - you can install the executable. To install the executable, include files and the manual page, you need write access to the direcory you want to install in. If you specified for instance `--prefix=$HOME`, you will have write-access, but if you install in the default directory `/usr/local`, you have to be super-user, i.e. user `root`. To install you type:

```
make install
```

To remove binaries used for building, type:

```
make clean
```

Finally, if you want to undo installation, type:

```
make uninstall
```

Step 4: Starting Algol 68 Genie

When you install `a68g` in the present working directory, you may want to include the current directory in your `PATH` variable. Otherwise you will need to indicate the current directory by typing `./a68g` as in the following examples. On Linux you can expect:

```
$./a68g --version
Algol 68 Genie 3.12.2
Copyright 2001-2026 Marcel van der Veer <algol68g@algol68genie.nl>.

This is free software covered by the GNU General Public License.
There is ABSOLUTELY NO WARRANTY for Algol 68 Genie;
not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
See the GNU General Public License for more details.

Please report bugs to Marcel van der Veer <algol68g@algol68genie.nl>.

With hardware support for long modes
With plugin-compilation support
With parallel-clause support
With PostgreSQL support
With curl 8.14.1
With GNU MP 6.3.0
With GNU MPFR 4.2.2
With mathlib from R 4.5.3
```

```
With GNU Scientific Library 2.8
With GNU plotutils 4.4
With ncurses 6.5
GNU libc version glibc 2.41
GNU libpthread version NPTL 2.41
Build level 3.2224 gcc May 21 2026
```

If instead of above version statement you get a message as:

```
a68g: error in loading shared libraries
libgsl.so.0: cannot open shared object file:
No such file or directory
```

or:

```
psql: error in loading shared libraries
libpq.so.5.15: cannot open shared object file:
No such file or directory
```

then your shared library search path was not properly set for the GNU Scientific Library or PostgreSQL's `libpq` library, respectively. The method to set the shared library search path varies between platforms, but the most widely used method is to set the environment variable `LD_LIBRARY_PATH`. In Bourne shells (`sh`, `ksh`, `bash`, `zsh`) you would use:

```
LD_LIBRARY_PATH=/usr/local/lib:/usr/local/pgsql/lib:$LD_LIBRARY_PATH
export LD_LIBRARY_PATH
```

while in `csh` or `tcsh` you would use:

```
setenv LD_LIBRARY_PATH /usr/local/lib:/usr/local/pgsql/lib:$LD_LIBRARY_PATH
```

You should put these commands into a shell start-up file such as:

`/etc/profile`, or

`~/.bash_profile`.

When in doubt, refer to the manual pages of your system.

10.4 Synopsis

To start `a68g` from the command-line you would use:

```
a68g [options] filename
```

If `a68g` cannot open `filename`, it will try opening with extensions `.a68`, `.a68g`, `.algol68` or `.algol68g` respectively. Alternatively, under Linux an Algol 68 source file can be made a script by entering:

```
#! [/usr/local/bin/]a68g [option]
```

as the *first* line in the script file. Note that shells as `bash` only pass a single option to `a68g` in a script; other options can be entered on the command line. After making the script executable by typing:

```
chmod +x filename
```

the script can be started from the command line by typing:

```
filename [options]
```

For compatibility with other Algol 68 implementations, `a68g` accepts that you terminate the first line of a script with `#` as in:

```
#! [/usr/local/bin/]a68g [option] #
```

In this way, above line will appear to another implementation as a comment. If you want to pass command line arguments to a script, you should use option `--script` as in next example:

```
$ cat my_script
#! ./a68g --script #

FOR i TO a68g argc
DO printf(($lg(0)x"""g"""$, i, a68g argv(i)))
OD

$ ./my_script a b c

1 "./a68g"
2 "a"
3 "b"
4 "c"
```

The first three arguments in above example are the typical action of a shell like `bash`. From the fourth argument on, the actual command line arguments follow. Option `--script` prevents that these are processed as `a68g` options, and you can have your script handle them as you see fit. Would you want to pass options to `a68g` using option `--script`, these have to be passed as **pragmat-items**.

For programs for which you expect a long run time, and that you consider fit to run without many of the runtime checks that Algol 68 Genie offers, you can enable the **unit** compiler by typing:

```
a68g --optimise [options] filename
```

or alternatively,

```
a68g -O [options] filename
```

After successful compilation you will have a file with name `filename` with its extension changed for `.so`. Consider for example a program that will give you the Whetstone rating, which is a vintage measure of floating-point performance of your platform and programming language:

```
$ ./a68g whetstone.a68
 0.49   20.5
```

which means that we needed 0.49 seconds giving a rating of 20.5 MWhets on this particular platform. Now we try optimisation:

```
$ ./a68g -O whetstone.a68
 0.05  220.0
```

showing that the **unit** compiler significantly improves the runtime of this program; this because the Whetstone rating involves many basic operations on primitive modes, which is the forte of the **unit** compiler. If you use the **unit** compiler, and wish to run a same program another time without recompiling generated C code, you have two options:

1. One can request to skip the code generation and compilation phase by typing:

   ```
   a68g --rerun [options] filename
   ```

   For example:

   ```
   $ ./a68g --rerun whetstone.a68
    0.05  220.0
   ```

   Note that `a68g` uses a time stamp to determine whether previously compiled code can still be used. Even when using option `rerun`, a C file will be emitted, since Algol 68 Genie needs to reconstruct the names of the symbols to resolve.

2. On Linux, you can request `a68g` to build a shell script for your program by typing:

   ```
   a68g --compile [options] filename
   ```

   or, briefly

   ```
   a68g -c [options] filename
   ```

   The shell script will be named `filename` stripped from its extension. One can in a later stage run this shell script. For example:

   ```
   $ ./a68g -c whetstone.a68
   $ ./whetstone
    0.05  220.0
   ```

Command line options passed to the script are not processed by a68g, but can be processed by your script instead. Would you want to pass options to a68g using this scheme, then these have to be passed as **pragmat-items**.

If you inspect the shell script you will find little intelligible information. The script consists of a call to a68g followed by a compressed source code fork and compressed binary fork. Thus the shell script can place diagnostics in the original source code, also when the original source file is no longer available. The shell script checks whether it executes the same a68g version that was used to build it. The shell script is a pseudo-executable; it is independent of the original source file, but still depends on a68g.

On Linux, Algol 68 Genie recognises below environment variables. If they are undefined, a68g assumes default values for them:

A68G_STANDIN
The value will be the name of the file to which stand in will be redirected.

A68G_STANDOUT
The value will be the name of the file to which stand out will be redirected.

A68G_STANDERROR
The value will be the name of the file to which stand error will be redirected.

A68G_OPTIONS
The value will be tokenised and processed as options. These options will supersede options set in file .a68grc (vide infra).

10.5 Diagnostics

This section discusses how a68g specifies its diagnostics. Algol 68 Genie checks for many events and since some diagnostics are synthesized it is not possible to provide a finite list of a68g's diagnostics. Diagnostics would typically be presented like this:

```
7            REF [] INT q2 = p[3,];
                             1    2
a68g: warning: 1: tag "q2" is not used (detected in VOID closed-clause
starting at "BEGIN" in line 1).
a68g: error: 2: attempt at storing a transient name (detected in VOID
closed-clause starting at "BEGIN" in line 1).
```

If possible, a68g writes the offending line and indicates by means of single-digit markers the positions where diagnostics have been issued. Note that the source of the error will often only be *near* that marker. Then a list follows of diagnostics issued for that line. As is usual in the Linux world, the first element of a diagnostic is the name of the program giving

the diagnostic, in casu `a68g`. If the error occurs in an included source file, the included source file's name will be the next element. If the source is contained in a single file then the source file name is not stated. Then follows the marker that indicates the position in the line where the diagnostic was issued. Finally a descriptive message is written.

Diagnostics come in different levels of severity. A *notice* will not impede execution of a **program**, but is a remark on your code. For instance

```
106           ABS diff < 100 ANDF exp (- diff) > random
              1
a68g: notice: 1: construct is an extension.
```

indicates that this phrase contains an extension (here, `ANDF`) so this **program** may not be portable. Notices are suppressed when you specify the `--no-notices` option.

A *warning* will not impede execution of a **program**, but it will draw your attention to a potential runtime issue; for instance:

```
$ ./a68g hidden --warnings
46          ELSE (b :=: one | a | HEAP TRIPLE := (a, to, b))
                                                        1
a68g: warning: 1: potential scope violation from FORM uniting,
      in TRIPLE collateral-clause starting at "(" in this line.
```

Since a warning does not impede execution, `a68g` suppresses many of them unless you specify the `--warnings` option at the command line. Some warnings cannot be suppressed, for instance when a construct is most likely not what you intended, like implicitly voiding a **formula**.

An *error* impedes successful compilation and execution of a **program**. Some condition was encountered that you must fix before execution could take place. For instance:

```
2     IN (UNION (INT, BOOL)): SKIP,
         1
a68g: error: 1: UNION (BOOL, INT) is neither component nor subset of
UNION (CHAR, BOOL) (detected in conformity-clause starting at "CASE"
in line 1).
```

or:

```
38        matvec (1, 10, bool, ca, aa);
          1
a68g: error: 1: REF BOOL cannot be coerced to INT in a
strong-argument (detected in closed-clause starting at "("
in line 3).
```

obviously are errors that need fixing before successful compilation and execution.

A syntax error is given when an error has been made in syntax according to chapter 8. Such diagnostic is typically issued by the parser. In case of a syntax error, a68g tries to give additional information in an attempt to help you localising and diagnosing the exact error. For instance, in:

```
103           CASE v
              1
a68g: syntax error: 1: incorrect parenthesis nesting; encountered
end-symbol in line 152 but expected esac-symbol; check for "END"
without matching "BEGIN" and "CASE" without matching "ESAC".
```

a **case-clause** was terminated with END so a68g straightforwardly suggests to check for a missing BEGIN or a missing or misspelled ESAC. In next example:

```
317   OP * = (VEC,v  REAL r) VEC: r * v;
              1
a68g: syntax error: 1: construct beginning with "(" in line 317
followed by a declarer and then ",", "v", a parameter-list, ")" is
not a valid parameter-pack.
```

the parser explains that it wanted to parse a parameter-pack but it could not complete that since a **declarer** was followed by a **comma-symbol**. Clearly VEC,r should have been written VEC r,. These synthetic explanations can get quite verbose, as in:

```
385   proc set pixel = (ICON i, PT p, COLOR c) VOID:
                       1
a68g: syntax error: 1: construct beginning with a serial-clause
starting in line 5 followed by "=" in line 385 and then a
routine-text, ";" in line 386, "procsetpixelrgb" in line 387, "=", a
routine-text, ";" in line 388 et cetera is not a valid serial-clause.
```

which indicates that things looked all-right up to line 385, but then a **serial-clause** was equated to a routine-text which is odd. You will be quick to note that a missing PROC symbol was incorrectly spelled in lower-case, and the same will have happened in line 387.

When your **program** is being executed, a *runtime error* can occur indicating that some condition arose that made continuation of execution either impossible or undesirable. A typical example is:

```
8         CASE CASE n
               1
a68g: runtime error: 1: REF [] INT value from united value is exported
out of its scope (detected in VOID conformity-clause starting at
 "CASE" in this line).
```

but if any information can be obtained from runtime support about *what* went wrong, it will be included in the diagnostic as in:

```
41          get (standin, (x, space, y, space, number, new line));
            1
a68g: runtime error: 1: cannot open ".txt" for getting (no such
file or directory) (detected in VOID loop-clause starting at "TO"
in line 38).
```

which means that the file name that you specified with `open` does not exist now that you decided to read from it — it indeed seems you only wrote an extension. Note that you can intercept a runtime error by specifying option `--monitor` or `--debug` by which the monitor will be entered when a runtime error occurs, so you can inspect what went wrong {10.8}.

`a68g` limits the number of diagnostics it issues, since it is believed that there is no point in generating many diagnostics that might be related to an earlier one. Since `a68g` compiles in several passes, each traversing the source from begin to end, it is possible that a diagnostic announcing suppression of further ones appears in the middle of other diagnostics. Also, to make diagnostics more intelligible, `a68g` attempts to substitute modes for indicants that are declared for them. Therefore you could expect for a single **program**:

```
38          HEAP CALL := (name, parameter);
                          1
a68g: warning: 1: REF FUNCTION value from identifier could be
exported out of its scope (detected in CALL collateral-clause
starting at "(" in this line).
41          HEAP FUNCTION := (bound var, body);
                             1
a68g: warning: 1: further warning diagnostics suppressed
(detected in FUNCTION collateral-clause starting at "(" in this
line).
199                      is const (f)
                         1
a68g: warning: 1: construct is an extension.
208                   THEN IF is const (f)
                             1
a68g: warning: 1: construct is an extension.
217                        THEN make dyadic (g, times, f);
                                                       1
a68g: warning: 1: skipped superfluous semi-symbol.
```

10.6 Options

Options are passed to `a68g` either from the file `.a68grc` in the working directory, the environment variable:

`A68G_OPTIONS`

or the command-line, or through pragmats. Precedence is as follows: pragmats supersede command-line options, command-line options supersede options from:

`A68G_OPTIONS`

that supersede options in:

`.a68grc`

Options have syntax **–option [[=] value[suffix]]**. Option names are not case sensitive, but option arguments are. Note that option syntax is a superset of Linux standards since `a68g` was initially written on other operating systems than Linux and had to maintain a degree of compatibility with option syntax of all of them. Listing options, tracing options and `--pragmat`, `--no-pragmat`, take their effect when they are encountered in a left-to-right pass of the **program** text, and can thus be used to generate a cross reference for a particular part of the user **program**. In integral arguments, a suffix k, M or G is accepted to specify multiplication by 10^3, 10^6 or 10^9 respectively. The suffix is case-insensitive.

10.6.1 One-liners

• **--print unit** | **-p unit**

Prints value yielded by the specified Algol 68 **unit**. In this way `a68g` can execute one-liners from the command-line. The one-liner is written in a file `.a68g.x` either in `$HOME/.a68g/` or in the working directory.

Example: `a68g -p "sqrt (2 * pi)"`

• **--execute unit**, **-x unit**

Executes specified Algol 68 **unit**. In this way `a68g` can execute one-liners from the command-line. The one-liner is written in file `.a68g.x` in the working directory.

Example: `a68g --exec 'printf (($lh$, 4 * atan (-1)))'`

10.6.2 Memory size

Algol 68 relieves the programmer from managing memory, hence `a68g` manages allocation and de-allocation of heap space. However, if memory size were not bounded, `a68g` might claim all available memory before the garbage collector is called. Since this could impede overall system performance, memory size is bounded.

• **--storage** *number*

Expands the default segment sizes *number* times.

• **--heap** *number*

Sets heap size to *number* bytes. This is the size of the block that will actually hold data, not handles. At runtime `a68g` will use the heap to store temporary arrays, so even a **program** that has no heap **generators** requires heap space, and can invoke the garbage collector.

Example: `PR heap=32M PR`

• **--handles** *number*

Sets handle space size to *number* bytes. This is the size of the block that holds handles that point to data in the heap. A reference to the heap does not point to the heap, but to a handle as to make it possible for the garbage collector to compact the heap.

Example: `PR handles=2M PR`

• **--frame** *number*

Sets frame stack size to *number* bytes. A deeply recursive **program** with many local variables may require a large frame stack space.

Example: `PR frame=1M PR`

• **--stack** *number*

Sets expression stack size to *number* bytes. A deeply recursive **program** may require a large expression stack space.

Example: `PR stack=512k PR`

• **--overhead** *number*

Sets the overhead, which is a safety margin, for the expression stack and the frame stack to *number* bytes. Since stacks grow by relatively small amounts at a time, Algol 68 Genie checks stack sizes only where recursion may set in. It is checked whether stacks have grown into the overhead. For example, if the frame stack size is 512 kB and the overhead is set to 128 kB, Algol 68 Genie will signal an imminent stack overflow when the frame stack pointer exceeds $512 - 128 = 384$ kB. When the overhead is set to a too small value, a segment violation may occur.

Example: `PR overhead=64k PR`

10.6.3 Listing options

• **--extensive**

Generates an extensive listing, including source listing, syntax tree, cross reference, generated C code et cetera. This listing can be quite bulky.

• **--listing**

Generates concise listing.

• **--moids**

Generates overview of moids in listing file.

• **--prelude-listing**

Generates a listing of preludes.

• **--object, --no-object**

Switches listing of object C code in listing file. This requires **--optimise**.

• **--source, --no-source**

Switches listing of source lines in listing file.

• **--statistics**

Generates statistics in listing file.

• **--tree**, **--no-tree**

Generates syntax tree listing in listing file. This option can make the listing file bulky, so use considerately.

• **--unused**

Generates an overview of unused tags in the listing file.

• **--xref**, **--no-xref**

Switches generating a cross reference in the listing file.

10.6.4 Compiler-interpreter options

• **--optimise**, **--optimize**, **--no-optimise**, **--no-optimize**

Enables or disables the **unit** compiler which emits C code for many **units**, and then compiles and dynamically links this code before it is executed by Algol 68 Genie. This option omits many runtime checks. Option **--optimise** is equivalent to option **-O0**. On some platforms, the plugin compiler is disabled.

• **-O0**, **-Og**, **-O1**, **-O2**, **-O3**

Invokes **--optimise** but selects a specific optimisation level for the compilation of generated code. The plugin compiler actions depend on the optimisation level, where `-O3` enables

most optimisations. The option is also passed to the `C` compiler as optimiser option. Option **--optimise** is equivalent to option **-O0**.

• **--compile**, **--no-compile**

This option works on Linux. Enables, or disables, generation of a shell script for your program. The shell script will have the name `filename` stripped from its extension. The shell script stores the source code and the generated shared library, in a compressed manner. One can in a later stage run this shell script. Command line options passed to the script are not processed by `a68g`, but can be processed by your script instead.

• **--rerun**

Run using the shared library generated by a previous run. See also option **--optimise**.

• **--monitor | --debug**

Start the **program** in the monitor. You will have to start **program** execution manually. Also, upon encountering a runtime error, instead of terminating execution, the monitor will be entered.

• **--assertions**, **--no-assertions**

Switches elaboration of assertions.

• **--backtrace**, **--no-backtrace**

Switches stack back tracing in case of a runtime error.

• **--breakpoint**, **--no-breakpoint**

Switches setting of breakpoints on following **program** lines.

• **--trace**, **--no-trace**

Switches tracing of a **program**.

• **--precision** *number*

Sets precision for `LONG LONG` modes to *number* significant digits. The precision cannot be less than the precision of `LONG` modes. Algorithms for extended precision in `a68g` are not really suited for precisions larger than about a thousand digits. State of the art in the field offers more efficient algorithms than implemented here.

• **--restart**, **--no-restart**

Switch restarting system calls at interrupt. Algol 68 Genie is interrupted at a regular interval, for instance to check the execution time limit, when it is set with **--time-limit**. In principle, this in turn interrupts system calls performing transput, that consequently also have an implicit time limit. This option restarts such system calls automatically, and are

not interrupted in turn. This is the default behaviour of `a68g`. As a consequence, unresponsive devices may let `a68g` appear to 'hang'. In such case, **--no-restart** will time out hanging transput operations.

• **--time-limit** *number*

On Linux, interrupts Algol 68 Genie after *number* seconds; a *time limit exceeded* runtime error will be given. This can be useful to detect endless loops. Trivial example:

```
$ a68g --time-limit=1 --exec 'DO SKIP OD'
1      (DO SKIP OD)
        1
a68g: runtime error: 1: time limit exceeded (detected in
VOID loop-clause starting at "DO" in this line).
```

10.6.5 Miscellaneous options

• **--apropos**, **--help**, **--info** [*string*]

Prints info on options if *string* is omitted, or prints info on *string* otherwise.

• **--upper-stropping**, **--quote-stropping**

Sets the stropping regime. Upper stropping is the default. Quote stropping is implemented to let `a68g` scan vintage source code.

• **--brackets**

Enables non-traditional use of brackets. This option makes `{ ... }` and `[ ... ]` equivalent to `( ... )` for the parser.

• **--check** | **--no-run**

Check syntax only, interpreter does not start.

• **--clock**

Report process time for Algol 68 program execution. This time does not include time needed to compile the program. Note that the reported value is not the elapsed time on a wall clock.

• **--run**

Overrides **--norun**.

• **--exit** | **--**

Ignore further options from command line or current pragmat. This option is usually provided under Linux to allow source file names to have a name beginning with a minus-sign.

• **--script**

This option takes the next option as source file name, and prevents that further options are processed as `a68g` options, so you can have a script handle them as you see fit. Would you want to pass further options to be processed by `a68g`, then these have to be passed as **pragmat-items**. This option is particularly suited for writing scripts.

• **--file** | **-f** *string*

Accept argument *string* as generic filename. This option serves to pass filenames that through their spelling would conflict with shell syntax.

• **--pedantic**

Equivalent to **--warning --portcheck**.

• **--portcheck**, **--no-portcheck**

Enable or suppress portability warning messages.

• **--strict**

Ignores most `a68g` extensions to Algol 68 syntax as described by the Revised Report. This option implies **--portcheck**, and `a68g` will not reserve words `ANDF`, `ANDTH`, `CLASS`, `CODE`, `COL`, `DIAG`, `DOWNTO`, `EDOC`, `ELSF`, `ENVIRON`, `NEW`, `OREL`, `ORF`, `ROW`, `THEF`, `TRNSP` and `UNTIL`.

• **--warnings**, **--no-warnings**

Enable warning messages or suppresses warning messages. A warning generally signals a potential problem at runtime. For instance, a possible scope violation generates a warning.

• **--notices**, **--no-notices**

Enable notice messages. A notice is a remark on source code. For instance, not applying a declared tag generates a notice instead of a warning.

• **--pragmats**, **--no-pragmats**

Switches elaboration of pragmat items. When disabled, pragmat items are ignored, except for option **pragmats**.

• **--reductions**

Prints reductions made by the parser. This option was originally meant for parser debugging but can be quite instructive (and very verbose).

• **--verbose**

Informs on actions.

• **--version**

States the version of the running copy of `a68g`.

10.7 The preprocessor

`a68g` has a basic preprocessor. Currently, the preprocessor supports these features:

1. concatenation of lines,
2. inclusion of files,
3. **refinement** preprocessor,
4. switching the preprocessor on or off.

10.7.1 Concatenation of lines

Concatenation of lines is similar to what the C preprocessor does. Any line that ends in a backslash ('\') will be concatenated with the line following it. For example:

```
STRING s := "spanning two \
lines"
```

will become:

```
STRING s := "spanning two lines"
```

Using a backslash as an escape character causes no interference with Algol 68 source text since when using upper stropping, a backslash is an unworthy character; when using quote stropping a backslash is a times-ten-symbol, but a real-denotation cannot span end-of-line hence no interference occurs.

Note that when you make use of line concatenation, diagnostics in a concatenated line may be placed in an earlier source line than its actual line in the original source text. In order to preserve line numbering as much as possible, a line is emptied but not deleted if it is joined with a preceding one. This shows in the listing file as emptied lines.

10.7.2 Inclusion of files

In `a68g`, by the use of pragmats you can textually include files in your source. The inclusion directive reads:

```
PR read "filename" PR
```

or:

```
PR include "filename" PR
```

The file with name filename is inserted textually before the line that holds the file inclusion directive. In this way tokens remain in their original lines, which will give more accurate placement of diagnostics. It is therefore recommended that a file inclusion directive be the only text on the line it is in. A file will only be inserted once, on attempted multiple inclusion the file is ignored. Attempted multiple inclusion may for example result from specifying, in an included file, an inclusion directive for an already included file.

10.7.3 The refinement preprocessor

Algol 68 Genie is equipped with a basic **refinement** preprocessor, which allows programming through stepwise **refinement** as taught in [Koster 1978, 1981]. A similar preprocessor was actually used in computer science classes at the University of Nijmegen as a front-end for `FLACC`. The idea is to facilitate **program** construction by elaborating the description of the solution to a problem as ever more detailed steps until the description of the solution is complete. (See also Wirth's well known lecture).

Refinement syntax can be found in the syntax summary. **Refinements** cannot be recursive, nor can their definitions be nested. Also, refinement definitions must be unique, and a **refinement** can only be applied once (**refinements** are not procedures). `a68g` will check whether a **program** looks like a stepwise refined **program**. The **refinement** preprocessor is transparent to **programs** that are not stepwise refined.

10.7.4 Switching the preprocessor on or off

It is possible to switch the preprocessor on or off. The preprocessor is per default switched on. If switched off, it will no longer process preprocessor items embedded in pragmats, except for switching the preprocessor on again. Concatenation of lines takes place even if the preprocessor is switched off.

```
PR preprocessor PR
```

Switches the preprocessor on if it is switched off.

```
PR nopreprocessor PR
```

Switches the preprocessor off if it is switched on.

10.8 The monitor

The a68g interpreter has a monitor for debugging of a running **program**. The monitor is invoked when a68g receives signal SIGINT (which usually comes from typing CTRL-C), when standard procedures debug or break are called, or when a runtime error occurs while option monitor or debug is in effect. Breakpoints can be indicated a priori through **pragmats** as well.

Following shows an example where the monitor is invoked by typing CTRL-C:

```
$ a68g buggy
^C
121   WHILE n ~= 0 DO
            _
Terminate a68g (yes|no): n
This is the main thread
(a68g)
```

The prompt (a68g) tells you that the monitor is awaiting a command. Next section describes the commands that the monitor can process.

10.8.1 Monitor commands

As with options, monitor command names are not case sensitive, but arguments are. In the list below, upper-case letters denote letters mandatory for recognition. Currently, the monitor recognises next commands:

1. **apropos** *string*
   help *string*
   info *string* Prints info on monitor commands if *string* is omitted, or prints info on *string* otherwise.

2. **breakpoint** *n* **[if** *expression* **]** Set breakpoints on **units** in line *n*. If you supply *expression* then interruption will only take place if *expression* yields TRUE. If *expression* is incorrect, it is ignored. Algol 68 Genie only breaks in **serial-clauses**, **collateral-clauses** and **enquiry-clauses**, in **unit-lists** in **in-parts** of **integer-clauses** or **conformity-clauses**, and sources in **declarations**. Note that a breakpoint expression is a nice debugging tool, but it slows down execution a lot.

3. **breakpoint watch [** *expression* **]** Sets the watchpoint expression, or clears it if *expression* is not specified. Interruption will take place whenever *expression* yields

TRUE. If *expression* is incorrect, it is ignored. Algol 68 Genie only breaks in **serial-clauses**, **collateral-clauses** and **enquiry-clauses**, in **unit-lists** in **in-parts** of **integer-clauses** or **conformity-clauses**, and sources in **declarations**. Note that a watchpoint expression is a nice debugging tool, but it slows down execution a lot.

4. **breakpoint** n **clear** Clears breakpoints on **units** in line n.

5. **breakpoint [** *list* **]** Lists all breakpoints and the watchpoint expression.

6. **breakpoint clear [all]** Clears all breakpoints and the watchpoint expression.

7. **breakpoint clear watchpoint** Clears the watchpoint expression.

8. **breakpoint clear breakpoints** Clears all breakpoints.

9. **bt** n Print n frames in the stack following the dynamic link (Back Trace) (default $n = 3$).

10. **calls** n Print n frames in the **call** stack (default $n = 3$).

11. **continue**
resume Continue execution.

12. **do** *command*
exec *command* Pass *command* to the shell and print the return code.

13. **evaluate** *expression*
x *expression* Evaluate *expression* and show its result. For a description of monitor expressions see next section.

14. **examine** n Print value of all **identifiers** named n in the **call** stack.

15. **exit**
hx
quit Terminates a68g.

16. **frame** n Select stack frame n as the current stack frame. If n is not specified, print the current stack frame. If $n = 0$ is specified, the current stack frame will be the top one in the frame stack.

17. **heap** n Print contents of the heap with address not greater than n.

18. **ht** Halts typing to standard output.

19. **link** n Print n frames in the stack, following the static link (default $n = 3$). This will give generally give a shorter back trace than `stack` since the static link links to the frame embedding (a) the actual lexical level or (b) the incarnations of the active procedure, while the dynamic link just points at the previous lexical level (and thus walks through all incarnations of a recursive procedure and all ranges of clauses).

20. **rerun**
    restart Restarts the Algol 68 **program** without resetting breakpoints.

21. **reset** Restarts the Algol 68 **program** and resets breakpoints.

22. **rt** Resumes typing to standard output.

23. **list** n m If m is omitted, show n lines around the interrupted line (default $n = 10$). If n and m are supplied, show lines n up to m.

24. **next** Resume execution until the next **unit** (that can be a breakpoint) is reached; do not enter routine-texts.

25. **step** Resume execution until the next **unit** (that can be a breakpoint) is reached.

26. **finish**
    out Resume execution until the next **unit** (that can be a breakpoint) is reached, *after* the current procedure incarnation will have finished. You typically use this to leave a procedure and to stop in the caller.

27. **until** n Resume execution until the first **unit** (that can be a breakpoint) is reached, on line number n.

28. **prompt** n Set prompt to n. Default prompt is $n = (a68g)$.

29. **sizes** Show sizes of various memory segments.

30. **stack** n Print n frames in the stack following the dynamic link (default $n = 3$).

31. **where** Show the line where interruption took place.
    xref n Give detailed information on source line n.

10.8.2 Monitor expressions

Monitor expressions provide basic means to do arithmetic in the monitor, and to change stored values. Monitor expression syntax is similar to Algol 68 syntax. Important points are:

1. Expressions, **assignation** sources, and **assignation** destinations, are strictly evaluated from left to right.
2. Actual assignation is done from right to left:

```
(a68g) x a[1] := 0
(REF INT) refers to heap (892000)
(INT) +0
(a68g) x a[2] := a[1] := 1
(REF INT) refers to heap (892016)
(INT) +1
```

   Note that the result of the evaluation of an expression is preceded by the mode of that result.

3. Only procedures and operators from standard environ can be called, and operator priorities are taken from standard environ.
4. **Operands** are **denotations**, **identifiers**, **closed-clauses**, **calls** and **slices**. **Casts** are also **operands** but can only be made to mode `[LONG][LONG] REAL` or to a (multiple) reference to an indicant:

```
(a68g) x REAL (1)
(REAL) +1.00000000000000E  +0
(a68g) x REF TREE (k) IS NIL
(BOOL) F
(a68g) x REF TREE (k) := NIL
(REF REF STRUCT (INT f, REF SELF next)) refers to heap (600000)
(REF STRUCT (INT f, REF SELF next)) NIL
```

5. Slicing does not support **trimmers**. Only `[` and `]` are allowed as brackets for **indexers**.

6. **Selections** are allowed, but not multiple **selections**:

```
(a68g) x im OF z
(REF LONG REAL) refers to frame (80)
(LONG REAL) +3.14159265358979323846264338327950 29
```

7. Dereferencing is the only coercion in arithmetic. Names can be compared through `IS` and `ISNT`, and `NIL` is supplied, but there is no soft coercion of **operands**.

10.9 Algol 68 Genie internals

This section explains, without going into all detail, how `a68g` executes a **program**. Algol 68 Genie employs a multi-pass scheme to parse Algol 68 [Lindsey 1993]:

1. The *tokeniser*. The source file is tokenised, and if needed a **refinement** preprocessor elaborates a stepwise refined **program**. The result is a linear list of tokens that is input for the parser, that will transform the linear list into a syntax tree. `a68g` tokenises all symbols before the parser is invoked. This means that scanning does not use information from the parser. The scanner does some rudimentary parsing: **format-texts** can have **enclosed-clauses** in them, so information is recorded in a stack as to know what is being scanned. Also, the **refinement** preprocessor implements a (trivial) grammar.

2. The *parser*. First, parentheses are checked to see whether they match. Then a top-down parser determines the basic-block structure of the **program** so symbol tables can be set up that the bottom-up parser will consult as you can define things before they are applied. After that the bottom-up parser parses without knowing about modes while parsing and reducing. It can therefore not exchange `[ ... ]` with `( ... )` as is allowed by the Revised Report. This is solved by treating **calls** and **slices** as equivalent for the moment and letting the mode checker sort it out later. This is a Mailloux-type parser [Mailloux 1968], in the sense that it scans a range for **declarations** — **identifiers**, **operator-symbols** and operator priorities — before it starts parsing, and thus allows for tags to be applied before they are declared.

3. The *mode checker*. The modes in the **program** are collected. Derived modes are calculated. Well-formedness is checked and structural equivalence is resolved. Then the modes of constructs are checked and coercions are inserted.

4. The *static-scope checker*. This pass checks whether you export names out of their scopes. Some cases cannot be detected by a static-scope checker, therefore Algol 68 Genie applies dynamic-scope checking.

5. The *plugin compiler*. This is an optional phase. The plugin compiler emits C code for many **units** and has this code compiled by `gcc`, after which the dynamic linker loader will make this code available to Algol 68 Genie.

6. The *interpreter*. The interpreter executes the syntax tree that results from the previous passes.

10.10 Limitations and bugs

Next `a68g` issues are known:

1. If you specify option `--optimise` and find a possible bug, use the default `--no-optimise` to check whether you get a runtime error from the interpreter proper. The plugin compiler omits many runtime checks, making a faulty Algol 68 program behave erratically.

2. Algol 68 Genie offers optional checking of the system stack. When this check is not activated, or on systems where this check would not work, the following may result in a segment violation (and possibly a core dump):

   (a) Deep recursion or garbage collection of deeply recursive data structures.

   (b) Using **jumps** to move between incarnations of recursive procedures.

3. When the stack overhead {10.6.2} is set to a too small value, a segment violation may occur.

4. Algorithms for extended precision (`LONG LONG` arithmetic modes) are not really suited for precisions larger than about a thousand digits. State of the art in the field offers more efficient algorithms than implemented here.

5. Overflow- and underflow checks on `REAL` and `COMPLEX` operations require IEEE-754 compatibility. Many processor types, notably ix86's and PowerPC processors, are IEEE-754 compatible.

6. A garbage collector cannot solve all memory allocation issues. It is therefore possible to get an unexpected "out of memory" diagnostic. Two options in such case are:

   (a) Increase heap size.

   (b) Call standard prelude routine `sweep heap` or `preemptive sweep` at strategic positions in the **program**.

7. There are some `libplot` related issues. Algol 68 Genie cannot work around these problems in `libplot`:

(a) In some versions of `libplot`, pseudo-gif plotters produce garbled graphics when more than 256 different colours are specified.

(b) Some platforms cannot give proper `libplot` support for all plotter types. Linux with the X window system lets `libplot` implement all plotters but for example the `WIN64` executable provided for `a68g` will give runtime errors as `X plotter missing` or `postscript plotter missing` due to an incomplete `libplot` library for that platform. On other platforms it is possible that a plotter produces garbage or gives a message as `output stream jammed`.

(c) In some versions of `libplot`, X plotters do not flush after every plotting operation. It may happen that a plotting operation does not show until `close` is called for that plotter (after closing, an X plotter window stays on the screen (as a forked process) until you type `"q"` while it has focus, or click in it).

11 Standard prelude and library prelude

11.1 The standard environ

An Algol 68 **program** run with `a68g` is embedded in the next environ:

```
BEGIN
  COMMENT
  Here the standard-prelude and library-prelude are included.
  COMMENT
  PR include "standard prelude" PR
  PR include "library prelude" PR
  BEGIN
    MODE DOUBLE = LONG REAL;
    start: commence:
    BEGIN
        COMMENT
        Here your program "program.a68" is embedded.
        COMMENT
        PR include "program.a68" PR
    END;
    stop: abort: halt: SKIP
  END
END
```

A consequence of this standard-environ is that an `a68g` **program** does not need to be an **enclosed-clause**; a **serial-clause** suffices.

11.2 The standard prelude

Next sections up to and including the section on transput describe the facilities in the standard prelude supplied with `a68g`.

11.3 Standard modes

Many of the modes available in the standard prelude are built from the standard modes of the language which are all defined in the Revised Report:

1. `VOID`
   This mode has one value: `EMPTY`. It is used as the yield of routines, in **casts** and in unions.

2. `INT`
   In `a68g`, these precisions are available:

   (a) `INT`

   (b) `LONG INT`

   (c) `LONG LONG INT`

3. `REAL`
   In `a68g`, these precisions are available:

   (a) `REAL`

   (b) `LONG REAL`

   (c) `LONG LONG REAL`

4. `BOOL`
   This mode has two values, `TRUE` and `FALSE`.

5. `CHAR`
   This mode is used for most character operations.

6. `STRING`
   This mode is defined as:

   ```
   MODE STRING = FLEX [1 : 0] CHAR
   ```

7. `COMPLEX, COMPL`
   This is not a primitive mode because it is a structure with two fields:

   ```
   MODE COMPLEX = STRUCT (REAL re, im)
   ```

   However, the widening coercion will convert a `REAL` value into a `COMPLEX` value, and transput routines will not straighten a `COMPLEX` - or `REF COMPLEX` value. Like `REAL`s, the following precisions are available in `a68g`:

   (a) `COMPLEX`

   (b) `LONG COMPLEX`

   (c) `LONG LONG COMPLEX`

8. BITS
   This mode is equivalent to a computer word regarded as a group of bits (binary digits) numbered 1 to bits width. These precisions are available in a68g :

   (a) BITS

   (b) LONG BITS

   (c) LONG LONG BITS

9. BYTES
   This mode stores a row-of-character in a single value. These precisions are available in a68g:

   (a) BYTES

   (b) LONG BYTES

10. SEMA
    Semaphores are used to synchronise parallel actions. This mode is defined as:

    ```
    MODE SEMA = STRUCT (REF INT F)
    ```

    Note that the field cannot be directly selected.

11. CHANNEL
    Channels describe the properties of a FILE.

12. FILE
    A FILE structure holds status of transputting to or from a specific stream of bytes.

13. FORMAT
    Holds an internal representation of **format-texts** and their elaboration.

14. PIPE
    Pipes describe software pipelines with which an output stream can be directly connected to an input stream. This is a Unix feature that is available under Linux.

15. SOUND
    Sounds hold sound values which can be manipulated with a68g.

11.4 Environment enquiries

Algol 68 was the first programming language to contain **declarations** which enable a programmer to determine the characteristics of the implementation. The enquiries are divided into a number of different groups.

11.4.1 Enquiries about precisions

Any number of `LONG` or `SHORT` can be given in the mode specification of numbers, but only a few such modes are distinguishable in any implementation. The following environment enquiries tell which modes are distinguishable:

1. `INT int lengths`
   1+ the number of extra lengths of integers.
2. `INT int shorths`
   1+ the number of short lengths of integers.
3. `INT real lengths`
   1+ the number of extra lengths of real numbers.
4. `INT real shorths`
   1+ the number of short lengths of real numbers.
5. `INT bits lengths`
   1+ the number of extra lengths of `BITS`.
6. `INT bits shorths`
   1+ the number of short lengths of `BITS`.
7. `INT bytes lengths`
   1+ the number of extra lengths of `BYTES`.
8. `INT bytes shorths`
   1+ the number of short lengths of `BYTES`.

11.4.2 Characteristics of modes

1. `INT max int`
   The maximum value of mode `INT`.
2. `LONG INT long max int`
   The maximum value of mode `LONG INT`.
3. `LONG LONG INT long long max int`
   The maximum value of mode `LONG INT`.
4. `REAL max real`
   The largest real value.
5. `REAL min real`
   The smallest real value.

6. `REAL small real`
   The smallest real which, when added to 1.0, gives a sum larger than 1.0.

7. `LONG REAL long max real`
   The largest long real value.

8. `LONG REAL long min real`
   The smallest long real value.

9. `LONG REAL long small real`
   The smallest long real which, when added to 1.0, gives a sum larger than 1.0.

10. `LONG LONG REAL long long max real`
    The largest long long real value.

11. `LONG LONG REAL long long min real`
    The smallest long long real value.

12. `LONG LONG REAL long long small real`
    The smallest long long real which, when added to 1.0, gives a sum larger than 1.0.

13. `INT int width`
    The maximum number of decimal digits expressible by an integer.

14. `INT long int width`
    The maximum number of decimal digits expressible by a long integer.

15. `INT long long int width`
    The maximum number of decimal digits expressible by a long long integer.

16. `INT bits width`
    The number of bits required to hold a value of mode `BITS`.

17. `INT long bits width`
    The number of bits required to hold a value of mode `LONG BITS`.

18. `INT long long bits width`
    The number of bits required to hold a value of mode `LONG LONG BITS`.

19. `INT bytes width`
    The number of bytes required to hold a value of mode `BYTES`.

20. `INT long bytes width`
    The number of bytes required to hold a value of mode `LONG BYTES`.

21. `INT real width`
    The maximum number of significant decimal digits in a real.

22. `INT exp width`
    The maximum number of decimal digits in the exponent of a real.

23. `INT long real width`
    The maximum number of significant decimal digits in a long real.

24. `INT long exp width`
    The maximum number of decimal digits in the exponent of a long real.

25. `INT long long real width`
    The maximum number of significant decimal digits in a long real.

26. `INT long long exp width`
    The maximum number of decimal digits in the exponent of a long long real.

11.4.3 Mathematical constants

1. `REAL pi`
   The value 3.14159265358979.

2. `LONG REAL long pi`
   The value 3.14159265358979323846264338327.

3. `LONG LONG REAL long long pi`
   The value 3.14159265358979323846264338327950288419716939937510582097494459 at default precision.

The long values of π are calculated using an AGM due to Borwein and Borwein[1]:

$$\begin{aligned} x_0 &= \sqrt{2} \\ \pi_0 &= 2+\sqrt{2} \\ y_0 &= \sqrt{\sqrt{2}} \end{aligned}$$

$$\begin{aligned} x_{i+1} &= \frac{1}{2}\Big(\sqrt{x_i}+\frac{1}{\sqrt{x_i}}\Big) \\ \pi_{i+1} &= \pi_i\Big(\frac{1+x_i}{1+y_i}\Big) \\ y_{i+1} &= \frac{y_i\sqrt{x_i}+\frac{1}{\sqrt{x_i}}}{1+y_i} \end{aligned}$$

The number π equals the limit π_∞.

11.4.4 Character set enquiries

[1] J.M. Borwein and P.B. Borwein. *Pi and the AGM: A study in analytical number theory and computational complexity*. Wiley [1987]).

The absolute value of Algol 68 characters range from `0` to the value of `max abs char`. Furthermore, the operator `REPR` will convert any `INT` up to `max abs char` to a character. What character is represented by `REPR 225` will depend on the character set used by the displaying device.

1. `INT max abs char`
   The largest positive integer which can be represented as a character.

2. `CHAR blank`
   This is the space character `" "`.

3. `CHAR error char`
   The character used by formatting routines to represent invalid values. Its value is `"*"`.

4. `CHAR flip`
   This character is used to represent `TRUE` in transput. Its value is `"T"`.

5. `CHAR flop`
   This character is used to represent `FALSE` in transput. Its value is `"F"`.

6. `CHAR null char`
   This is the null character, `REPR 0`.

7. `CHAR eof char`
   A system dependent value representing an end of file marker.

11.5 Standard operators

The number of distinct operators is vastly increased by the availability of `SHORT` and `LONG` modes. Thus it is imperative that some kind of shorthand be used to describe the operators. Following the subsection on the method of description are sections devoted to operators with classes of **operands**. The end of this section contains tables of all the operators.

11.5.1 Method of description

Where an operator has **operands** and yield which may include `LONG` or `SHORT`, the mode is written using `L`. For example:

```
OP + = (L INT, L INT) L INT:
```

is shorthand for the following operators:

```
OP + = (INT, INT) INT:
OP + = (LONG INT, LONG INT) LONG INT:
OP + = (LONG LONG INT, LONG LONG INT) LONG LONG INT:
```

Ensure that wherever L is replaced by SHORTs or LONGs, it should be replaced by the same number of SHORTs or LONGs throughout the definition of that operator. This is known as "consistent substitution". Note that any number of SHORTs or LONGs can be given in the mode of any value whose mode accepts such constructs (INT, REAL, COMPLEX and BITS), but the only modes which can be distinguished are those specified by the environment enquiries in section 11.4.1. a68g maps a **declarer** whose length is not implemented onto the most appropriate length available {17_2.1.3.1}. Routines or operators for unimplemented lengths are mapped accordingly. a68g considers mapped modes equivalent to the modes they are mapped onto, while standard Algol 68 would still set them apart.

11.5.2 Operator synonyms

Algol 68 provides a plethora of operators, and in some cases also synonyms for operators. In the listings further on in this chapter, only one synonym will be defined per operator. This is a list of synonyms for **operator-symbols** implemented in a68g:

1. AND for &
2. ^ for **
3. ~ for NOT
4. ~= for /=
5. ^= for /=
6. I for +*
7. EQ for =
8. NE for /=
9. LE for <=
10. LT for <
11. GE for >=
12. GT for >
13. OVER for %
14. MOD for %*

15. PLUSAB for +:=
16. MINUSAB for -:=
17. TIMESAB for *:=
18. DIVAB for /:=
19. OVERAB for %:=
20. MODAB for %*:=
21. PLUSTO for +=

11.5.3 Standard priorities

The priority of an operator is independent of the mode of the **operands** or result. The standard prelude sets next priorities for operators:

1. +:=, -:=, *:=, /:=, %:=, %*:=, +=
2. OR
3. AND, XOR
4. =, /=
5. <, <=, >=, >
6. -, +
7. *, /, %, %*, ELEM
8. **, UP, DOWN, SHL, SHR, LWB, UPB
9. +*, I

These priorities can be changed by PRIO in your **program**, but this easily leads to incomprehensible**programs**. Use PRIO for your own **dyadic-operators**.

11.5.4 Operators with row operands

Both monadic and dyadic forms are available. We will use the mode ROW to denote the mode of any row.

1. Monadic.
   `OP LWB = (ROW r) INT`
   `OP UPB = (ROW r) INT`
   Yield the **lower-bound** or **upper-bound** for the first dimension of `r`.
   `OP ELEMS = (ROW r) INT`
   Yields the number of elements, in all dimensions, of `r`.
2. Dyadic.
   `OP LWB = (INT n, ROW r) INT`
   `OP UPB = (INT n, ROW r) INT`
   Yield the **lower-bound** or **upper-bound** of the `n`-th dimension of `r`.
   `OP ELEMS = (INT n, ROW r) INT`
   Yields the number of elements in the `n`-th dimension of `r`.

11.5.5 Operators with boolean operands

1. `OP ABS = (BOOL a) INT`
   `ABS TRUE` yields a non-zero number and `ABS FALSE` yields zero.
2. `OP AND = (BOOL a, b) BOOL`
   Logical `AND`.
3. `OP OR = (BOOL a, b) BOOL`
   Logical inclusive `OR`.
4. `OP XOR = (BOOL a, b) BOOL`
   Logical exclusive OR, `XOR`.
5. `OP NOT = (BOOL a) BOOL`
   Logical `NOT`: yields `TRUE` if `a` is `FALSE` and yields `FALSE` if `a` is `TRUE`.
6. `OP = = (BOOL a, b) BOOL`
   `TRUE` if `a` equals `b` and `FALSE` otherwise.
7. `OP /= = (BOOL a, b) BOOL`
   `TRUE` if `a` not equal to `b` and `FALSE` otherwise.

11.5.6 Operators with integral operands

The shorthands in section 11.5.9 apply.

1. `OP + = (L INT a) L INT`
   The identity operator.

2. `OP - = (L INT a) L INT`
   The negation operator.

3. `OP ABS = (L INT a) L INT`
   The absolute value: `(a < 0 | - a | a)`.

4. `OP SIGN = (L INT a) INT`
   Yields -1 for a negative **operand**, $+1$ for a positive **operand** and 0 for a zero **operand**.

5. `OP ODD = (L INT a) BOOL`
   Yields `TRUE` if the **operand** is odd and `FALSE` if it is even. This is a relic of times long past.

6. `OP LENG = (L INT a) LONG L INT`
   Converts its **operand** to the next longer precision.

7. `OP SHORTEN = (LONG L INT a) L INT`
   Converts its **operand** to the next shorter precision. If `a` exceeds `l max int` for the next shorter precision, a runtime error occurs.

1. `OP + = (L INT a, L INT b) L INT`
   Integer addition: $a + b$.

2. `OP - = (L INT a, L INT b) L INT`
   Integer subtraction: $a - b$.

3. `OP * = (L INT a, L INT b) L INT`
   Integer multiplication: $a \times b$.

4. `OP / = (L INT a, L INT b) L REAL`
   Integer fractional division. Even if the quotient is a whole number (for example, $6/3$), the yield always has mode `L REAL`.

5. `OP % = (L INT a, L INT b) L INT`
   Integer division.

6. `OP %* = (L INT a, L INT b) L INT`
   Integer modulo, which always yields a non-negative result {2.7}.

7. `OP ** = (L INT a, INT b) L INT`
   Computes a^b for $b \geq 0$.

8. `OP +* = (L INT a, L INT b) L COMPLEX`
   Joins two integers into a complex number $a + bi$ of the same precision.

9. `OP = = (L INT a, L INT b) BOOL`
   Integer equality: $a = b$.

10. `OP /= = (L INT a, L INT b) BOOL`
    Integer inequality: $a \neq b$.

11. `OP < = (L INT a, L INT b) BOOL`
    Integer "less than" $a < b$.

12. `OP <= = (L INT a, L INT b) BOOL`
    Integer "not greater than" $a \leq b$.

13. `OP >= = (L INT a, L INT b) BOOL`
    Integer "not less than": $a \geq b$.

14. `OP > = (L INT a, L INT b) BOOL`
    Integer "greater than": $a > b$.

11.5.7 Operators with real operands

The shorthands in section 11.5.9 apply.

1. `OP + = (L REAL a) L REAL`
   Real identity, $+a$.

2. `OP - = (L REAL a) L REAL`
   Real negation, $-a$.

3. `OP ABS = (L REAL a) L REAL`
   The absolute value $|a|$.

4. `OP FRAC = (L REAL a) L REAL`
   The fraction of a, `a - TRUNC a`.

5. `OP SIGN = (L REAL a) INT`
   Yields -1 for negative a, $+1$ for positive a and 0 when $a = 0$.

6. `OP TRUNC = (L REAL a) L INT`
   `OP FIX = (L REAL a) L INT`
   The integral part of a.

7. `OP ROUND = (L REAL a) L INT`
   Round a to the nearest integer.

8. `OP FLOOR = (L REAL a) L INT`
   `OP ENTIER = (L REAL a) L INT`
   The largest integer not larger than a.

9. `OP CEIL = (L REAL a) L INT`
   The smallest integer not smaller than a.

10. `OP LENG = (L REAL a) LONG L REAL`
    Convert a to the next longer precision.

11. `OP SHORTEN = (LONG L REAL a) L REAL`
    Converts a to the next shorter precision. If a value exceeds `l max real` for the next shorter precision, a runtime error occurs. The mantissa will be rounded.

1. `OP + = (L REAL a, L REAL b) L REAL`
   Real addition $a + b$.

2. `OP - = (L REAL a, L REAL b) L REAL`
   Real subtraction $a - b$.

3. `OP * = (L REAL a, L REAL b) L REAL`
   Real multiplication $a \times b$.

4. `OP / = (L REAL a, L REAL b) L REAL`
   Real division a/b.

5. `OP +* = (L REAL a, L REAL b) L COMPLEX`
   Joins two reals into a complex number $a + bi$ of the same precision.

6. `OP = = (L REAL a, L REAL b) BOOL`
   Real equality: $a = b$.

7. `OP /= = (L REAL a, L REAL b) BOOL`
   Real inequality: $a \neq b$.

8. `OP < = (L REAL a, L REAL b) BOOL`
   Real "less than": $a < b$.

9. `OP <= = (L REAL a, L REAL b) BOOL`
   Real "not greater than": $a \leq b$.

10. `OP >= = (L REAL a, L REAL b) BOOL`
    Real "not less than": $a \geq b$.

11. `OP > = (L REAL a, L REAL b)BOOL`
    Real "greater than": $a > b$.

11.5.8 Operators with complex operands

Algol 68 Genie offers a rich set of operators and routines for complex numbers. The shorthands in section 11.5.9 apply.

1. `OP RE = (L COMPLEX a) L REAL`
   Yields the real component: `re OF a`.

2. `OP IM = (L COMPLEX a) L REAL`
   Yields the imaginary component: `im OF a`.

3. `OP ABS = (L COMPLEX a) L REAL`
   Yields the absolute value (a magnitude) of its argument.

4. `OP ARG = (L COMPLEX a) L REAL`
   Yields the argument of the complex number.

5. `OP CONJ = (L COMPLEX a) L COMPLEX`
   Yields the conjugate complex number.

6. `OP + = (L COMPLEX a) L COMPLEX`
   Complex identity.

7. `OP - = (L COMPLEX a) L COMPLEX`
   Complex negation.

8. `OP LENG = (L COMPLEX a) LONG L COMPLEX`
   Converts its **operand** to the next longer precision.

9. `OP SHORTEN = (LONG L COMPLEX a) L COMPLEX`
   Converts its **operand** to the next shorter precision. If either of the components of the complex number exceeds `l max real` for the next shorter precision, a runtime error occurs.

1. `OP + = (L COMPLEX a, L COMPLEX b) L COMPLEX`

   Complex addition for both components $a + b$.

2. `OP - = (L COMPLEX a, L COMPLEX b) L COMPLEX`

   Complex subtraction for both components $a - b$.

3. `OP * = (L COMPLEX a, L COMPLEX b) L COMPLEX`
   Complex multiplication $a * b$.

4. `OP / = (L COMPLEX a, L COMPLEX b) L COMPLEX`
   Complex division a/b.

5. `OP = = (L COMPLEX a, L COMPLEX b) BOOL`
   Complex equality $a = b$.

6. `OP /= = (L COMPLEX a, L COMPLEX b) BOOL`
   Complex inequality $a \neq b$.

11.5.9 Operators with mixed operands

The shorthands in section 11.5.9 apply. Extra shorthands are used, as follows:

1. The shorthand `P` stands for `+`, `-`, `*` or `/`.
2. The shorthand `R` stands for `<`, `<=`, `=`, `/=`, `>=`, `>`, or `LT`, `LE`, `EQ`, `NE`, `GE`, `GT`.
3. The shorthand `E` stands for `=` `/=`, or `EQ` or `NE`.

1. `OP P = (L INT a, L REAL b) L REAL`
2. `OP P = (L REAL a, L INT b) L REAL`
3. `OP P = (L INT a, L COMPLEX b) L COMPLEX`
4. `OP P = (L COMPLEX a, L INT b) L COMPLEX`
5. `OP P = (L REAL a, L COMPLEX b) L COMPLEX`
6. `OP P = (L COMPLEX a, L REAL b) L COMPLEX`
7. `OP R = (L INT a, L REAL b) BOOL`
8. `OP R = (L REAL a, L INT b) BOOL`
9. `OP E = (L INT a, L COMPLEX b) BOOL`
10. `OP E = (L COMPLEX a, L INT b) BOOL`
11. `OP E = (L REAL a, L COMPLEX b) BOOL`
12. `OP E = (L COMPLEX a, L REAL b) BOOL`
13. `OP ** = (L REAL a, INT b) L REAL`
14. `OP ** = (L COMPLEX a, INT b) L COMPLEX`
15. `OP +* = (L INT a, L REAL b) L COMPLEX`
16. `OP +* = (L REAL a, L INT b) L COMPLEX`

11.5.10 Operators with BITS operands

The shorthands in section 11.5.9 apply.

1. `OP BIN = (L INT a) L BITS`
   Mode conversion.
2. `OP ABS = (L BITS a) L INT`
   Mode conversion.
3. `OP NOT = (L BITS a) L BITS`
   Yields the bits obtained by inverting each bit in the **operand**.
4. `OP LENG = (L BITS a) LONG L BITS`
   Converts a bits value to the next longer precision by adding zero bits to the more significant end.
5. `OP SHORTEN = (LONG L BITS a) L BITS`
   Converts a bits value to a value of the next shorter precision.

1. `OP AND = (L BITS a, L BITS b) L BITS`
   The logical "AND" of corresponding binary digits in `a` and `b`.
2. `OP OR = (L BITS a, L BITS b) L BITS`
   The logical "OR" of corresponding binary digits in `a` and `b`.
3. `OP SHL = (L BITS a, INT b) L BITS`
   The left **operand** shifted left by the number of bits specified by the right **operand**. New bits shifted in are zero. If the right **operand** is negative, shifting is to the right.
4. `OP SHR = (L BITS a, INT b) L BITS`
   The left **operand** shifted right by the number of bits specified by the right **operand**. New bits shifted in are zero. If the right **operand** is negative, shifting is to the left.
5. `OP ELEM = (INT a, L BITS b) BOOL`
   Yields `TRUE` if bit `a` is set, and `FALSE` if it is not set.
6. `OP = = (L BITS a, L BITS b) BOOL`
   Logical equality $a = b$.
7. `OP /= = (L BITS a, L BITS b) BOOL`
   Logical inequality $a \neq b$.
8. `OP <= = (L BITS a, L BITS b) BOOL`
   Yields `TRUE` `a` is a subset of `b` or `FALSE` otherwise: `(a OR b) = b`
9. `OP >= = (L BITS a, L BITS b) BOOL`
   Yields `TRUE` `b` is a subset of `a` or `FALSE` otherwise: `(a OR b) = a`

11.5.11 Operators with character operands

The shorthands in section 11.5.9 apply.

1. `OP ABS = (CHAR a) INT`
   The integer equivalent of a character.

2. `OP REPR = (INT a) CHAR`
   The character representation of an integer. The **operand** should be in the range `0 ... max abs char`.

3. `OP + = (CHAR a, CHAR b) STRING`
   The character `b` is appended to the character `a` (concatenation).

4. `OP E = (CHAR a, CHAR b) BOOL`
   Equality or inequality of characters.

5. `OP R = (CHAR a, CHAR b) BOOL`
   Relative ordering of characters.

11.5.12 Operators with string operands

The shorthands in section 11.5.9 apply.

1. `OP ELEM = (INT a, STRING b) CHAR`
   Yields `b[a]`. This is an `ALGOL68C` operator.

2. `OP + = (STRING a, STRING b) STRING`
   String `b` is appended to string `a` (concatenation).

3. `OP + = (CHAR a, STRING b) STRING`
   String `b` is appended to character `a`.

4. `OP + = (STRING a, CHAR b) STRING`
   Character `b` is appended to string `a`.

5. `OP * = (INT a, STRING b) STRING`
   Yields `a` times string `b`, concatenated.

6. `OP * = (STRING a, INT b) STRING`
   Yields `b` times string `a`, concatenated.

7. `OP * = (INT a, CHAR b) STRING`
   Yields `a` times character `b`, concatenated.

8. `OP * = (CHAR a, INT b) STRING`
   Yields `b` times character `a`, concatenated.

9. `OP E = (STRING a, STRING b) BOOL`
   `OP E = (CHAR a, STRING b) BOOL`
   `OP E = (STRING a, CHAR b) BOOL`
   Equality or inequality of characters and strings.

10. `OP R = (STRING a, STRING b) BOOL`
    `OP R = (CHAR a, STRING b) BOOL`
    `OP R = (STRING a, CHAR b) BOOL`
    Alphabetic ordering of strings.

11.5.13 Operators with bytes operands

The shorthands in section 11.5.9 apply.

1. `OP LENG = (BYTES a) LONG BYTES`
   Converts a bytes value to longer width by padding null characters.

2. `OP SHORTEN = (LONG BYTES a) L BYTES`
   Converts a value to normal width.

3. `OP ELEM = (INT a, L BYTES b) CHAR`
   Yields the a^{th} character in `b`.

4. `OP + = (L BYTES a, L BYTES b) BYTES`
   Concatenation $a + b$

5. `OP E = (L BYTES a, L BYTES b) BOOL`
   Equality or inequality of byte strings.

6. `OP R = (L BYTES a, L BYTES b) BOOL`
   Alphabetic ordering of byte strings.

11.5.14 Operators combined with assignation

The shorthands in section 11.5.9 apply.

1. `+:=`
   The operator is a shorthand for `a := a + b`.

Left **operand**	Right **operand**	Result
REF L INT	L INT	REF L INT
REF L REAL	L INT	REF L REAL
REF L COMPLEX	L INT	REF L COMPLEX
REF L REAL	L REAL	REF L REAL
REF L COMPLEX	L REAL	REF L COMPLEX
REF L COMPLEX	L COMPLEX	REF L COMPLEX
REF STRING	CHAR	REF STRING
REF STRING	STRING	REF STRING
REF L BYTES	L BYTES	REF L BYTES

2. `+=:`
   The operator is a shorthand for `b := a + b`.

Left **operand**	Right **operand**	Result
STRING	REF STRING	REF STRING
CHAR	REF STRING	REF STRING
L BYTES	REF L BYTES	REF L BYTES

3. `-:=`
   The operator is a shorthand for `a := a - b`.

Left **operand**	Right **operand**	Result
REF L INT	L INT	REF L INT
REF L REAL	L INT	REF L REAL
REF L COMPLEX	L INT	REF L COMPLEX
REF L REAL	L REAL	REF L REAL
REF L COMPLEX	L REAL	REF L COMPLEX
REF L COMPLEX	L COMPLEX	REF L COMPLEX

4. `*:=`
   The operator is a shorthand for `a := a * b`.

Left **operand**	Right **operand**	Result
REF L INT	L INT	REF L INT
REF L REAL	L INT	REF L REAL
REF L COMPLEX	L INT	REF L COMPLEX
REF L REAL	L REAL	REF L REAL
REF L COMPLEX	L REAL	REF L COMPLEX
REF L COMPLEX	L COMPLEX	REF L COMPLEX
REF STRING	INT	REF STRING

5. `/:=`
   The operator is a shorthand for `a := a / b`.

Left **operand**	Right **operand**	Result
REF L REAL	L INT	REF L REAL
REF L REAL	L REAL	REF L REAL
REF L COMPLEX	L INT	REF L COMPLEX
REF L COMPLEX	L REAL	REF L COMPLEX
REF L COMPLEX	L COMPLEX	REF L COMPLEX

6. `OP %:= = (REF L INT a, L INT b) REF L INT`
   The operator is a shorthand for `a := a % b`.

7. `OP %*:= = (REF L INT a, L INT b) REF L INT`
   The operator is a shorthand for `a := a %* b`.

11.5.15 Synchronisation operators

`a68g` implements the **parallel-clause** {4.12} on platforms that support POSIX threads.

1. `OP LEVEL = (INT a) SEMA`
   Yields a semaphore whose value is `a`.

2. `OP LEVEL = (SEMA a) INT`
   Yields the level of `a`, that is filed `F OF a`.

3. `OP DOWN = (SEMA a) VOID`
   The level of `a` is decremented. If it reaches `0`, then the parallel **unit** that called this operator is hibernated until another parallel **unit** increments the level of `a` again.

4. `OP UP = (SEMA a) VOID`
   The level of `a` is incremented and all parallel **units** that were hibernated due to this semaphore being down are awakened.

11.6 Standard procedures

The shorthand `L` is used to simplify the list of procedures. Many routines are available in a default `a68g` build, while some require `a68g` be linked to an optional library. See section 10.3.1 for building `a68g` with optional libraries.

11.6.1 Procedures for real numbers

1. `PROC L sqrt = (L REAL x) L REAL`
   Compute the square root.

2. `PROC L curt = (L REAL x) L REAL`
   `PROC L cbrt = (L REAL x) L REAL`
   Compute the cube root.

3. `PROC L exp = (L REAL x) L REAL`
   Comput the exponential e^x.

4. `PROC L ln = (L REAL x) L REAL`
   Compute the natural logarithm.

5. `PROC L log = (L REAL x) L REAL`
   Compute the logarithm to base 10.

6. `PROC L sin = (L REAL x) L REAL`
   `PROC L cos = (L REAL x) L REAL`
   `PROC L tan = (L REAL x) L REAL`
   `PROC L csc = (L REAL x) L REAL`
   `PROC L sec = (L REAL x) L REAL`
   `PROC L cot = (L REAL x) L REAL`
   Compute the sine, cosine, tangent, cosecant, secant and cotangent in radians.

7. `PROC L arcsin = (L REAL x) L REAL`
   `PROC L arccos = (L REAL x) L REAL`
   `PROC L arctan = (L REAL x) L REAL`
   `PROC L arccsc = (L REAL x) L REAL`
   `PROC L arcsec = (L REAL x) L REAL`
   `PROC L arccot = (L REAL x) L REAL`
   Compute the inverse sine, cosine, tangent, cosecant, secant and cotangent in radians.

8. `PROC L arctan2 = (L REAL x, y) L REAL`
   Compute the angle whose tangent is y/x. The angle will be in range $[-\pi, \pi]$.

9. `PROC L sinh = (L REAL x) L REAL`
   `PROC L cosh = (L REAL x) L REAL`
   `PROC L tanh = (L REAL x) L REAL`
   Compute the hyperbolic sine, cosine or tangent.

10. `PROC L arcsinh = (L REAL x) L REAL`
    `PROC L arccosh = (L REAL x) L REAL`
    `PROC L arctanh = (L REAL x) L REAL`
    Compute the inverse hyperbolic sine, cosine or tangent.

11. `PROC L sin dg = (L REAL x) L REAL`
    `PROC L cos dg = (L REAL x) L REAL`
    `PROC L tan dg = (L REAL x) L REAL`
    Compute the sine, cosine and tangent in degrees.

12. `PROC L arcsin dg = (L REAL x) L REAL`
    `PROC L arccos dg = (L REAL x) L REAL`
    `PROC L arctan dg = (L REAL x) L REAL`
    Compute the inverse sine, cosine or tangent in degrees.

13. `PROC L arctan2 dg = (L REAL x, y) L REAL`
    Compute the angle whose tangent is y/x. The angle will be in range $[-180, 180]$.

14. `PROC L sin pi = (L REAL x) L REAL`
    `PROC L cos pi = (L REAL x) L REAL`
    `PROC L tan pi = (L REAL x) L REAL`
    Compute the sine, cosine and tangent of $x\pi$ yielding exact results where possible.

11.6.2 Procedures for complex numbers

The shorthand `L` is used to simplify the list of procedures.

1. `PROC L complex sqrt = (L COMPLEX z) L COMPLEX`
   Compute the square root.

2. `PROC L complex exp = (L COMPLEX z) L COMPLEX`
   Compute the exponential e^z.

3. `PROC L complex ln = (L COMPLEX z) L COMPLEX`
   Compute the natural logarithm.

4. `PROC L complex sin = (L COMPLEX z) L COMPLEX`
   `PROC L complex cos = (L COMPLEX z) L COMPLEX`
   `PROC L complex tan = (L COMPLEX z)L COMPLEX`
   Compute the sine, cosine or tangent.

5. `PROC L complex arcsin = (L COMPLEX z) L COMPLEX`
   `PROC L complex arccos = (L COMPLEX z) L COMPLEX`
   `PROC L complex arctan = (L COMPLEX z)L COMPLEX`
   Compute the inverse sine, cosine or tangent.

6. `PROC L complex sinh = (L COMPLEX z) L COMPLEX`
   `PROC L complex cosh = (L COMPLEX z) L COMPLEX`
   `PROC L complex tanh = (L COMPLEX z) L COMPLEX`
   Compute the hyperbolic sine, cosine or tangent.

7. `PROC L complex arcsinh = (L COMPLEX z) L COMPLEX`
   `PROC L complex arccosh = (L COMPLEX z) L COMPLEX`
   `PROC L complex arctanh = (L COMPLEX z) L COMPLEX`
   Compute the inverse hyperbolic sine, cosine or tangent.

11.6.3 Infinity

Algol 68 Genie behaves as other vintage programming languages in that non-numeric conditions as *infinity* or *undefined (Not a Number)* result in runtime errors. Nonetheless, routines as `gamma inc g` can take ∞ as argument. Therefore below procedures are implemented, to facilitate routines that can handle them.

1. `PROC infinity = L REAL`
   `PROC inf = REAL`
   Yields an internal representation of $+\infty$.
2. `PROC minus infinity = L REAL`
   `PROC min inf = REAL`
   Yields an internal representation of $-\infty$.

11.6.4 Error, Gamma, Beta and related functions

Routines for the incomplete gamma function listed below employ algorithms from a recent paper by Abergel and Moisan[2].

1. `PROC L erf = (L REAL x) L REAL`
   Compute the error function.
2. `PROC L erfc = (L REAL x) L REAL`
   Compute the complementary error function.
3. `PROC L inverf = (L REAL x) L REAL`
   Compute the inverse Gauss error function.
4. `PROC L inverfc = (L REAL x) L REAL`
   Compute the inverse complementary Gauss error function.
5. `PROC L gamma = (L REAL) L REAL`
   Compute the Gamma function.
6. `PROC L ln gamma = (L REAL x) L REAL`
   Compute the natural logarithm of the Gamma function.
7. `PROC L gamma inc = (L REAL p, x) L REAL`
   Compute the upper incomplete Gamma function.
8. `PROC gamma inc f = (REAL p, x) REAL`
   Compute the incomplete Gamma function as special case $I^{p;1}_{x;\infty}$ using `gamma inc g`.

[2] Rémy Abergel, Lionel Moisan. Fast and accurate evaluation of a generalized incomplete gamma function. 2019. hal-01329669v2.

9. `PROC L gamma inc g = (L REAL p, x, y, mu) L REAL`
   Compute a generalised incomplete Gamma function.

$$I_{x,y}^{p,\mu} = \int_x^y ds\, s^{p-1} e^{-\mu\, s}$$

   where $0 \leq x \leq y$, $p > 0$ and $\mu \neq 0$. Both x and y accept ∞. This routine strives to be accurate in the case of $x \approx y$.

10. `PROC gamma inc gf = (REAL p, x) REAL`
    Compute a generalised incomplete Gamma function $G(p, x)$.

$$x \leq p \quad G(p,x) = e^{x-p\ln|x|} \int_0^{|x|} ds\, s^{p-1} e^{\frac{|x|}{x}\, s}$$

$$x > p \quad G(p,x) = e^{x-p\ln x} \int_x^{\infty} ds\, s^{p-1} e^{-s}$$

11. `PROC L beta = (L REAL x) L REAL`
    Compute the complete Beta function.

12. `PROC L ln beta = (L REAL x) L REAL`
    Compute the natural logarithm of the complete Beta function.

13. `PROC L beta inc = (L REAL a, b, x) L REAL`
    Compute the ratio of the incomplete Beta function to the complete Beta function.

14. `PROC fact = (INT n) REAL`
    Compute the factorial function.

15. `PROC ln fact = (INT n) REAL`
    Compute the natural logarithm of the factorial function.

16. `PROC choose = (REAL n, m) REAL`
    Compute the combinatorial factor `n!/(m!(n-m)!)`.

17. `PROC ln choose = (REAL n, m) REAL`
    Compute the natural logarithm of combinatorial factor `n!/(m!(n-m)!)`.

11.7 Statistical procedures from R mathlib

Algol 68 Genie has bindings for R mathlib, the stand-alone math library from the R project. Section 10.3.1 explains how to build `a68g` with this library. This way `a68g` can provide a number of statistical routines from the R statistical package. Original R routine names are prefixed with letter `r` to avoid name space conflicts.

1. `PROC r digamma = (REAL x) REAL`
   Compute the derivative of the Gamma function.

2. `PROC r trigamma = (REAL x) REAL`
   Compute the second derivative of the Gamma function.

3. `PROC r tetragamma = (REAL x) REAL`
   Compute the third derivative of the Gamma function.

4. `PROC r pentagamma = (REAL x) REAL`
   Compute the fourth derivative of the Gamma function.

5. `PROC r psigamma = (REAL x, REAL n) REAL`
   Compute the n-th derivative of the digamma function.

For the respective distributions, routines starting with `'d'` give the probability at argument `'x'`, routines starting with `'p'` give the cumulative probability upto argument `'x'`, routines starting with `'q'` are the respective inverses of routines starting with `'p'`, and routines starting with `'r'` yield a random variate. For more detailed descriptions of the R routines please refer to R documentation.

1. ```
   PROC r dchisq = (REAL x, df, BOOL give log) REAL
   PROC r pchisq = (REAL x, df, BOOL lower tail, give log) REAL
   PROC r qchisq = (REAL p, df, BOOL lower tail, log p) REAL
   PROC r rchisq = (REAL df) REAL
   ```
   Chi-square distribution.

2. ```
   PROC r dexp = (REAL x, scale, BOOL give log) REAL
   PROC r pexp = (REAL x, scale, BOOL lower tail, give log) REAL
   PROC r qexp = (REAL p, scale, BOOL lower tail, log p) REAL
   PROC r rexp = (REAL scale) REAL
   ```
   Exponential distribution.

3. ```
   PROC r dgeom = (REAL x, p, BOOL give log) REAL
   PROC r pgeom = (REAL x, p, BOOL lower tail, give log) REAL
   PROC r qgeom = (REAL p, p, BOOL lower tail, log p) REAL
   PROC r rgeom = (REAL p) REAL
   ```
   Geometrical distribution.

4. ```
   PROC r dpois = (REAL x, lambda, BOOL give log) REAL
   PROC r ppois = (REAL x, lambda, BOOL lower tail, give log) REAL
   PROC r qpois = (REAL p, lambda, BOOL lower tail, log p) REAL
   PROC r rpois = (REAL lambda) REAL
   ```
   Poisson distribution.

5.
```
PROC r dt = (REAL x, n, BOOL give log) REAL
PROC r pt = (REAL x, n, BOOL lower tail, give log) REAL
PROC r qt = (REAL p, n, BOOL lower tail, log p) REAL
PROC r rt = (REAL n) REAL
```
Student-t distribution.

6.
```
PROC r dbeta = (REAL x, a, b, BOOL give log) REAL
PROC r pbeta = (REAL x, a, b, BOOL lower tail, give log) REAL
PROC r qbeta = (REAL p, a, b, BOOL lower tail, log p) REAL
PROC r rbeta = (REAL a, b) REAL
```
Beta distribution.

7.
```
PROC r dbinom = (REAL x, n, p, BOOL give log) REAL
PROC r pbinom = (REAL x, n, p, BOOL lower tail, give log) REAL
PROC r qbinom = (REAL p, n, p, BOOL lower tail, log p) REAL
PROC r rbinom = (REAL n, p) REAL
```
Binomial distribution.

8.
```
PROC r dnchisq = (REAL x, df, ncp, BOOL give log) REAL
PROC r pnchisq = (REAL x, df, ncp, BOOL lower tail, give log) REAL

PROC r qnchisq = (REAL p, df, ncp, BOOL lower tail, log p) REAL
PROC r rnchisq = (REAL df, ncp) REAL
```
Non-central chi squared distribution.

9.
```
PROC r dcauchy = (REAL x, location, scale, BOOL give log) REAL
PROC r pcauchy =
(REAL x, location, scale, BOOL lower tail, give log) REAL
PROC r qcauchy =
(REAL p, location, scale, BOOL lower tail, log p) REAL
PROC r rcauchy = (REAL location, scale) REAL
```
Cauchy distribution.

10.
```
PROC r df = (REAL x, n1, n2, BOOL give log) REAL
PROC r pf = (REAL x, n1, n2, BOOL lower tail, give log) REAL
PROC r qf = (REAL p, n1, n2, BOOL lower tail, log p) REAL
PROC r rf = (REAL n1, n2) REAL
```
F distribution.

11.
```
PROC r dlogis = (REAL x, location, scale, BOOL give log) REAL
PROC r plogis =
(REAL x, location, scale, BOOL lower tail, give log) REAL
PROC r qlogis =
(REAL p, location, scale, BOOL lower tail, log p) REAL
PROC r rlogis = (REAL location, scale) REAL
```
Logistic distribution.

12.
```
PROC r dlnorm = (REAL x, logmean, logsd, BOOL give log) REAL
PROC r plnorm =
(REAL x, logmean, logsd, BOOL lower tail, give log) REAL
PROC r qlnorm =
(REAL p, logmean, logsd, BOOL lower tail, log p) REAL
PROC r rlnorm = (REAL logmean, logsd) REAL
```
Log-normal distribution.

13.
```
PROC r dnbinom = (REAL x, size, prob, BOOL give log) REAL
PROC r pnbinom =
(REAL x, size, prob, BOOL lower tail, give log) REAL
PROC r qnbinom =
(REAL p, size, prob, BOOL lower tail, log p) REAL
PROC r rnbinom = (REAL size, prob) REAL
```
Negative binomial distribution.

14.
```
PROC r dnt = (REAL x, df, delta, BOOL give log) REAL
PROC r pnt = (REAL x, df, delta, BOOL lower tail, give log) REAL
PROC r qnt = (REAL p, df, delta, BOOL lower tail, log p) REAL
```
Non-central t distribution.

15.
```
PROC r dnorm = (REAL x, mu, sigma, BOOL give log) REAL
PROC r pnorm = (REAL x, mu, sigma, BOOL lower tail, give log) REAL

PROC r qnorm = (REAL p, mu, sigma, BOOL lower tail, log p) REAL
PROC r rnorm = (REAL mu, sigma) REAL
```
Normal distribution.

16.
```
PROC r dunif = (REAL x, a, b, BOOL give log) REAL
PROC r punif = (REAL x, a, b, BOOL lower tail, give log) REAL
PROC r qunif = (REAL p, a, b, BOOL lower tail, log p) REAL
PROC r runif = (REAL a, b) REAL
```
Uniform distribution.

17.
```
PROC r dweibull = (REAL x, shape, scale, BOOL give log) REAL
PROC r pweibull =
(REAL x, shape, scale, BOOL lower tail, give log) REAL
PROC r qweibull =
(REAL p, shape, scale, BOOL lower tail, log p) REAL
PROC r rweibull = (REAL shape, scale) REAL
```
Weibull distribution.

18.
```
PROC r dnf = (REAL x, n1, n2, ncp, BOOL give log) REAL
PROC r pnf = (REAL x, n1, n2, ncp, BOOL lower tail, give log) REAL
```

```
PROC r qnf = (REAL p, n1, n2, ncp, BOOL lower tail, log p) REAL
```
Non-central F distribution.

19. ```
    PROC r dhyper = (REAL x, nr, nb, n, BOOL give log) REAL
    PROC r phyper = (REAL x, nr, nb, n, BOOL lower tail, give log) REAL

    PROC r qhyper = (REAL p, nr, nb, n, BOOL lower tail, log p) REAL
    PROC r rhyper = (REAL nr, nb, n) REAL
    ```
    Hyper-geometric distribution.

20. ```
    PROC r ptukey =
    (REAL x, groups, df, treatments, BOOL lower tail, give log) REAL
    PROC r qtukey =
    (REAL p, groups, df, treatments, BOOL lower tail, log p) REAL
    ```
    Studentized range distribution.

21. ```
    PROC r dwilcox = (REAL x, m, n, BOOL give log) REAL
    PROC r pwilcox = (REAL x, m, n, BOOL lower tail, give log) REAL
    PROC r qwilcox = (REAL p, m, n, BOOL lower tail, log p) REAL
    PROC r rwilcox = (REAL m, n) REAL
    ```
    Wilcoxon distribution.

22. ```
    PROC r dsignrank = (REAL x, n, BOOL give log) REAL
    PROC r psignrank = (REAL x, n, BOOL lower tail, give log) REAL
    PROC r qsignrank = (REAL p, n, BOOL lower tail, log p) REAL
    PROC r rsignrank = (REAL n) REAL
    ```
    Wilcoxon signed rank distribution.

11.8 Functions from the GNU Scientific Library

Next routines require the GNU Scientific Library (GSL). Section 10.3.1 explains how to build `a68g` with this library. For more detailed information on those routines please refer to GSL documentation. Below routines have an equivalent in SLATEC. GSL aims to be a modern version of SLATEC.

1. ```
   PROC airy ai = (REAL x) REAL
   ```
   Compute the Airy function.

2. ```
   PROC airy ai scaled = (REAL x) REAL
   ```
   Compute Airy function for a negative argument and an exponentially scaled Airy function for a non-negative argument.

3. ```
   PROC airy bi = (REAL x) REAL
   ```
   Compute the Bairy function.
   ```

4. `PROC airy bi scaled = (REAL x) REAL`
   Compute the Bairy function for a negative argument and an exponentially scaled Bairy function for a non-negative argument.

5. `PROC bessel in0 = (REAL x) REAL`
   Compute the hyperbolic Bessel function of the first kind of order 0.

6. `PROC bessel in0 scaled = (REAL x) REAL`
   Compute the exponentially scaled modified hyperbolic Bessel function of the first kind of order 0.

7. `PROC bessel in1 = (REAL x) REAL`
   Compute the hyperbolic Bessel function of the first kind of order 1.

8. `PROC bessel in1 scaled = (REAL x) REAL`
   Compute the exponentially scaled modified hyperbolic Bessel function of the first kind of order 1.

9. `PROC bessel jn0 = (REAL x) REAL`
   Compute the Bessel function of the first kind of order 0.

10. `PROC bessel jn1 = (REAL x) REAL`
    Compute the Bessel function of the first kind of order 1.

11. `PROC bessel kn0 = (REAL x) REAL`
    Compute the exponentially scaled modified (hyperbolic) Bessel function of the third kind of order 0.

12. `PROC bessel kn0 scaled = (REAL x) REAL`
    Compute the exponentially scaled modified hyperbolic Bessel function of the third kind of order 0.

13. `PROC bessel kn1 = (REAL x) REAL`
    Compute the exponentially scaled modified (hyperbolic) Bessel function of the third kind of order 0.

14. `PROC bessel kn1 scaled = (REAL x) REAL`
    Compute the exponentially scaled modified hyperbolic Bessel function of the third kind of order 1.

15. `PROC bessel yn0 = (REAL x) REAL`
    Compute the Bessel function of the first kind of order 0.

16. `PROC bessel yn1 = (REAL x) REAL`
    Compute the Bessel function of the first kind of order 1.

17. `PROC dawson = (REAL x) REAL`
    Compute Dawson's function.

18. `PROC expint e1 = (REAL x) REAL`
    Compute the exponential integral `E1(x)`.

19. `PROC expint ei = (REAL x) REAL`
    Compute the exponential integral `Ei(x)`.

20. `PROC exprel = (REAL x) REAL`
    Compute the relative error exponential `(exp(x)-1)/x`.

21. `PROC digamma = (REAL x) REAL`
    Compute the Psi (or Digamma) function.

22. `PROC poch = (REAL a, x) REAL`
    Compute a generalisation of Pochhammer's symbol.

Other bindings to GSL routines in `a68g` are listed below. For more detailed information on those routines please refer to GSL documentation.

1. ```
   PROC airy ai deriv = (REAL x) REAL
   PROC airy ai deriv scaled = (REAL x) REAL
   PROC airy bi deriv = (REAL x) REAL
   PROC airy bi deriv scaled = (REAL x) REAL
   PROC airy zero ai deriv = (INT s) REAL
   PROC airy zero ai = (INT s) REAL
   PROC airy zero bi deriv = (INT s) REAL
   PROC airy zero bi = (INT s) REAL
   ```

2. ```
   PROC angle restrict pos = (REAL theta) REAL
   PROC angle restrict symm = (REAL theta) REAL
   ```

3. ```
   PROC atanint = (REAL x) REAL
   ```

4. ```
   PROC bessel il0 scaled = (REAL x) REAL
   PROC bessel il1 scaled = (REAL x) REAL
   PROC bessel il2 scaled = (REAL x) REAL
   PROC bessel il scaled = (INT l, REAL x) REAL
   ```

5. ```
   PROC bessel in = (INT n, REAL x) REAL
   PROC bessel in scaled = (INT n, REAL x) REAL
   PROC bessel inu = (REAL nu, x) REAL
   PROC bessel inu scaled = (REAL nu, x) REAL
   ```

6. ```
   PROC bessel jl0 = (REAL x) REAL
   PROC bessel jl1 = (REAL x) REAL
   PROC bessel jl2 = (REAL x) REAL
   ```

7.
```
PROC bessel jl = (INT l, REAL x) REAL
PROC bessel jn = (INT n, REAL x) REAL
PROC bessel jnu = (REAL nu, REAL x) REAL
```

8.
```
PROC bessel kl0 scaled = (REAL x) REAL
PROC bessel kl1 scaled = (REAL x) REAL
PROC bessel kl2 scaled = (REAL x) REAL
PROC bessel kl scaled = (INT l, REAL x) REAL
```

9.
```
PROC bessel kn = (INT n, REAL x) REAL
PROC bessel kn scaled = (INT n, REAL x) REAL
PROC bessel knu = (REAL nu, x) REAL
PROC bessel knu scaled = (REAL nu, x) REAL
PROC bessel ln knu = (REAL nu, x) REAL
```

10.
```
PROC bessel yl0 = (REAL x) REAL
PROC bessel yl1 = (REAL x) REAL
PROC bessel yl2 = (REAL x) REAL
PROC bessel yl = (INT l, REAL x) REAL
```

11.
```
PROC bessel yn = (INT n, REAL x) REAL
PROC bessel ynu = (REAL nu, x) REAL
```

12.
```
PROC bessel zero jnu0 = (INT s) REAL
PROC bessel zero jnu1 = (INT s) REAL
PROC bessel zero jnu = (INT s, REAL nu) REAL
```

13.
```
PROC chi = (REAL x) REAL
```

14.
```
PROC ci = (REAL x) REAL
```

15.
```
PROC clausen = (REAL x) REAL
```

16.
```
PROC conicalp 0 = (REAL lambda, x) REAL
PROC conicalp 1 = (REAL lambda, x) REAL
PROC conicalp cyl reg = (INT n, REAL lambda, x) REAL
PROC conicalp half = (REAL lambda, x) REAL
PROC conicalp mhalf = (REAL lambda, x) REAL
PROC conicalp sph reg = (INT n, REAL lambda, x) REAL
```

17.
```
PROC debye 1 = (REAL x) REAL
PROC debye 2 = (REAL x) REAL
PROC debye 3 = (REAL x) REAL
PROC debye 4 = (REAL x) REAL
PROC debye 5 = (REAL x) REAL
PROC debye 6 = (REAL x) REAL
```

18.
```
PROC dilog = (REAL x) REAL
```

19.
```
PROC double fact = (INT n) REAL
```

20.
```
PROC ellint d = (REAL phi, k) REAL
PROC ellint e comp = (REAL k) REAL
PROC ellint e = (REAL phi, k) REAL
PROC ellint f = (REAL phi, k) REAL
PROC ellint k comp = (REAL k) REAL
PROC ellint p comp = (REAL k, n) REAL
PROC ellint p = (REAL phi, k, n) REAL
PROC ellint rc = (REAL x, y) REAL
PROC ellint rd = (REAL x, y, z) REAL
PROC ellint rf = (REAL x, y, z) REAL
PROC ellint rj = (REAL x, y, z, p) REAL
```

21.
```
PROC eta int = (INT n) REAL
PROC eta = (REAL s) REAL
```

22.
```
PROC expint 3 = (REAL x) REAL
PROC expint e2 = (REAL x) REAL
PROC expint en = (INT n, REAL x) REAL
PROC expm1 = (REAL x) REAL
PROC exprel2 = (REAL x) REAL
PROC exprel n = (INT l, REAL x) REAL
```

23.
```
PROC fermi dirac 0 = (REAL x) REAL
PROC fermi dirac 1 = (REAL x) REAL
PROC fermi dirac 2 = (REAL x) REAL
PROC fermi dirac 3 half = (REAL x) REAL
PROC fermi dirac half = (REAL x) REAL
PROC fermi dirac inc0 = (REAL x, b) REAL
PROC fermi dirac int = (INT n, REAL x) REAL
PROC fermi dirac m1 = (REAL x) REAL
PROC fermi dirac m half = (REAL x) REAL
```

24.
```
PROC gamma inc p = (REAL a, x) REAL
PROC gamma inc q = (REAL a, x) REAL
PROC gamma inv = (REAL x) REAL
PROC gamma star = (REAL x) REAL
```

25.
```
PROC gegenpoly 1 = (REAL lambda, x) REAL
PROC gegenpoly 2 = (REAL lambda, x) REAL
PROC gegenpoly 3 = (REAL lambda, x) REAL
PROC gegenpoly n = (INT n, REAL lambda, x) REAL
```

26.
```
PROC hermite func = (INT n, REAL x) REAL
```

27.
```
PROC hypot = (REAL x) REAL
```

28. `PROC hzeta = (REAL s, q) REAL`

29. ```
    PROC laguerre 1 = (REAL a, x) REAL
    PROC laguerre 2 = (REAL a, x) REAL
    PROC laguerre 3 = (REAL a, x) REAL
    PROC laguerre n = (INT n, REAL a, x) REAL
    ```

30. ```
    PROC lambert w0 = (REAL x) REAL
    PROC lambert wm1 = (REAL x) REAL
    ```

31. ```
    PROC legendre h3d 0 = (REAL lambda, x) REAL
    PROC legendre h3d 1 = (REAL lambda, x) REAL
    PROC legendre h3d = (INT l, REAL lambda, x) REAL
    PROC legendre p1 = (REAL x) REAL
    PROC legendre p2 = (REAL x) REAL
    PROC legendre p3 = (REAL x) REAL
    PROC legendre pl = (INT l, REAL x) REAL
    PROC legendre q0 = (REAL x) REAL
    PROC legendre q1 = (REAL x) REAL
    PROC legendre ql = (INT l, REAL x) REAL
    ```

32. `PROC ln cosh = (REAL x) REAL`

33. `PROC ln double fact = (INT n) REAL`

34. `PROC ln fact = (INT n) REAL`

35. `PROC ln poch = (REAL a, x) REAL`

36. `PROC ln sinh = (REAL x) REAL`

37. `PROC ln 1plusxmx = (REAL x) REAL`

38. `PROC ln 1plusx = (REAL x) REAL`

39. `PROC ln abs = (REAL x) REAL`

40. `PROC pochrel = (REAL a, x) REAL`

41. ```
    PROC psi 1 = (INT n) REAL
    PROC psi 1piy = (INT n) REAL
    PROC psi 1 = (REAL x) REAL
    PROC psi int = (INT n) REAL
    PROC psi = (INT n) REAL
    PROC psi n = (INT n, REAL x) REAL
    ```

42. `PROC shi = (REAL x) REAL`

43. `PROC sinc = (REAL x) REAL`

44. `PROC si = (REAL x) REAL`

45. `PROC synchrotron 1 = (REAL x) REAL`
    `PROC synchrotron 2 = (REAL x) REAL`

46. `PROC taylor coeff = (INT n, REAL x) REAL`

47. `PROC transport 2 = (REAL x) REAL`
    `PROC transport 3 = (REAL x) REAL`
    `PROC transport 4 = (REAL x) REAL`
    `PROC transport 5 = (REAL x) REAL`

48. `PROC zeta int = (INT n) REAL`
    `PROC zetam1 int = (INT n) REAL`
    `PROC zetam1 = (REAL s) REAL`
    `PROC zeta = (REAL s) REAL`

11.9 Random-number generator

`a68g` implements a Tausworthe generator that has a period of order 2^{113}. The code is reused from the GNU Scientific Library.

1. `PROC first random = (INT seed) VOID`
   Initialises the random number generator using `seed`.

2. `PROC L next random = L REAL`
   Generates the next random number. The result will be in $[0 \ldots 1>$.

11.10 Linear algebra

Next routines require that `a68g` is linked to the GNU Scientific Library. Section 10.3.1 explains how to build `a68g` with this library. These routines provide a simple vector and matrix interface to Algol 68 rows of mode:

```
[] REAL # vector #
[, ] REAL # matrix #
[] COMPLEX # complex vector #
[, ] COMPLEX # complex matrix #
```

These routines complement the **stowed-functions** described in section 3.8.

This section also describes routines for solving linear algebraic equations. Routines in this chapter convert Algol 68 rows to objects compatible with vector- and matrix formats used

by BLAS routines. However, they are always passed to GSL routines. These are intended for linear equations where simple algorithms are acceptable.

11.10.1 Monadic-operators

1. `OP + = ([] REAL u) [] REAL`

   `OP + = ([, ] REAL u) [, ] REAL`

   `OP + = ([] COMPLEX u) [] COMPLEX`

   `OP + = ([, ] COMPLEX u) [, ] COMPLEX`

   Evaluate $+u$.

2. `OP - = ([] REAL u) [] REAL`

   `OP - = ([, ] REAL u) [, ] REAL`

   `OP - = ([] COMPLEX u) [] COMPLEX`

   `OP - = ([, ] COMPLEX u) [, ] COMPLEX`

   Evaluate $-u$.

3. `OP NORM = ([] REAL u) REAL`

   `OP NORM = ([] COMPLEX u) REAL`

   Euclidean norm of vector `u`.

4. `OP TRACE = ([, ] REAL u) REAL`

   `OP TRACE = ([, ] COMPLEX u) COMPLEX`

   Trace (sum of diagonal elements) of square matrix `u`.

5. `OP T = ([, ] REAL u) [, ] REAL`

   `OP T = ([, ] COMPLEX u) [, ] COMPLEX`

   Transpose of matrix `u`. Note that operator `T` yields a copy of the transpose of its argument, whereas pseudo-operator `TRNSP` yields a descriptor without copying its argument.

6. `OP DET = ([, ] REAL u) REAL`

   `OP DET = ([, ] COMPLEX u) COMPLEX`

   Determinant of square matrix `u` by LU decomposition.

7. `OP INV = ([, ] REAL u) [, ] REAL`

   `OP INV = ([, ] COMPLEX u) [, ] COMPLEX`

   Inverse of square matrix `u` by LU decomposition.

11.10.2 Dyadic-operators

1. `OP = = ([] REAL u, v) BOOL`

   `OP = = ([, ] REAL u, v) BOOL`

   `OP = = ([] COMPLEX u, v) BOOL`

   `OP = = ([, ] COMPLEX u, v) BOOL`

   Evaluate whether `u` equals `v`.

2. `OP /= = ([] REAL u, v) BOOL`

   `OP /= = ([, ] REAL u, v) BOOL`

   `OP /= = ([] COMPLEX u, v) BOOL`

   `OP /= = ([, ] COMPLEX u, v) BOOL`

   Evaluate whether `u` does not equal `v`.

3. `OP DYAD = ([] REAL u, v) [, ] REAL`

   `OP DYAD = ([] COMPLEX u, v) [, ] COMPLEX`

   Dyadic (or tensor) product of `u` and `v`. The priority of `DYAD` is 3. This means that (assuming standard priorities) addition, subtraction, multiplication and division have priority over a dyadic product:

   ```
   r + dr DYAD t * r
   ```

   is equivalent to

   ```
   (r + dr) DYAD (t * r).
   ```

4. `OP + = ([] REAL u, v) [] REAL`

   `OP + = ([, ] REAL u, v) [, ] REAL`

   `OP + = ([] COMPLEX u, v) [] COMPLEX`

   `OP + = ([, ] COMPLEX u, v) [, ] COMPLEX`

   Evaluate $u + v$.

5. `OP +:= ([] REAL u, v) [] REAL`

   `OP +:= ([, ] REAL u, v) [, ] REAL`

   `OP +:= ([] COMPLEX u, v) [] COMPLEX`

   `OP +:= ([, ] COMPLEX u, v) [, ] COMPLEX`

   Evaluate `u := u + v`.

6. `OP - = ([] REAL u, v) [] REAL`

   `OP - = ([, ] REAL u, v) [, ] REAL`

   `OP - = ([] COMPLEX u, v) [] COMPLEX`

```
OP - = ([, ] COMPLEX u, v) [, ] COMPLEX
```

Evaluate $u - v$.

7.
```
OP -:= ([] REAL u, v) [] REAL
OP -:= ([, ] REAL u, v) [, ] REAL
OP -:= ([] COMPLEX u, v) [] COMPLEX
OP -:= ([, ] COMPLEX u, v) [, ] COMPLEX
```

Evaluate `u := u - v`.

8.
```
OP * = ([] REAL u, REAL v) [] REAL
OP * = ([, ] REAL u, REAL v) [, ] REAL
OP * = ([] COMPLEX u, COMPLEX v) [] COMPLEX
OP * = ([, ] COMPLEX u, COMPLEX v) [, ] COMPLEX
```

Scaling of `u` by a scalar `v`: $u \times v$.

9.
```
OP * = (REAL u, [] REAL v) [] REAL
OP * = (REAL u, [, ] REAL v) [, ] REAL
OP * = (COMPLEX u, [] COMPLEX v) [] COMPLEX
OP * = (COMPLEX u, [, ] COMPLEX v) [, ] COMPLEX
```

Scaling of `u` by a scalar `v`: $u \times v$.

10.
```
OP * = ([, ] REAL u, [] REAL v) [] REAL
OP * = ([, ] COMPLEX u, [] COMPLEX v) [] COMPLEX
```

Matrix-vector product $u \cdot v$.

11.
```
OP * = ([] REAL u, [, ] REAL v) [] REAL
OP * = ([] COMPLEX u, [, ] COMPLEX v) [] COMPLEX
```

Vector-matrix product $u \cdot v$, that equals $v^T \cdot u$.

12.
```
OP * = ([] REAL u, v) REAL
OP * = ([] COMPLEX u, v) COMPLEX
```

Inner product of $u \cdot v$.

13.
```
OP * = ([, ] REAL u, [, ] REAL v) [, ] REAL
OP * = ([, ] COMPLEX u, [, ] COMPLEX v) [, ] COMPLEX
```

Matrix-matrix product $u \cdot v$.

14. `OP *:= = (REF [] REAL u, REAL v) REF [] REAL`
    `OP *:= = (REF [, ] REAL u, REAL v) REF [, ] REAL`
    `OP *:= = (REF [] COMPLEX u, COMPLEX v) REF [] COMPLEX`
    `OP *:= = (REF [, ] COMPLEX u, COMPLEX v) REF [, ] COMPLEX`
    Scaling by a scalar `u := u * v`.

15. `OP / = ([] REAL u, REAL v) [] REAL`
    `OP / = ([, ] REAL u, REAL v) [, ] REAL`
    `OP / = ([] COMPLEX u, COMPLEX v) [] COMPLEX`
    `OP / = ([, ] COMPLEX u, COMPLEX v) [, ] COMPLEX`
    Scaling by a scalar u/v.

16. `OP /:= = (REF [] REAL u, REAL v) REF [] REAL`
    `OP /:= = (REF [, ] REAL u, REAL v) REF [, ] REAL`
    `OP /:= = (REF [] COMPLEX u, COMPLEX v) REF [] COMPLEX`
    `OP /:= = (REF [, ] COMPLEX u, COMPLEX v) REF [, ] COMPLEX`
    Evaluate `u := u / v`.

11.10.3 LU decomposition through Gaussian elimination

A square matrix has an *LU* decomposition into upper and lower triangular matrices

$$P \cdot A = L \cdot U$$

where A is a square matrix, P is a permutation matrix, L is a unit lower triangular matrix and U is an upper triangular matrix. For square matrices this decomposition can be used to convert the linear equation $A \cdot x = b$ into a pair of triangular equations

$$L \cdot y = P \cdot b, U \cdot x = y$$

which can be solved by forward- and back-substitution.

The algorithm that GSL uses in *LU* decomposition is Gaussian elimination with partial pivoting. Advantages of *LU* decomposition are that it works for any square matrix and will efficiently produce all solutions for a linear equation. A disadvantage of *LU* decomposition is that that it cannot find approximate (least-square) solutions in case of singular or ill-conditioned matrices, that are better solved by a singular value decomposition.

1. `PROC lu decomp =`
   `([, ] REAL a, REF [] INT p, REF INT sign) [, ] REAL`

```
PROC complex lu decomp =
([, ] COMPLEX a, REF [] INT p, REF INT sign) [, ] COMPLEX
```

These routines factorise the square matrix `a` into the *LU* decomposition $P \cdot A = L \cdot U$. The diagonal and upper triangular part of the returned matrix contain U. The lower triangular part of the returned matrix holds L. Diagonal elements of L are unity, and are not stored. Permutation matrix P is encoded in the permutation `p`. The **sign** of the permutation is given by `sign`. It has the value $(-1)^n$, where `n` is the number of row interchanges in the permutation.

2. `PROC lu solve = ([, ] REAL a, lu, [] INT p, [] REAL b) [] REAL`

   ```
   PROC complex lu solve =
   ([, ] COMPLEX a, lu, [] INT p, [] COMPLEX b) [] COMPLEX
   ```

   These routines solve the equation $A \cdot x = b$ and apply an iterative improvement to `x`, using the *LU* decomposition of `a` into `lu`, `p` as calculated by `[complex] lu decomp`.

3. `PROC lu inv = ([, ] REAL lu, [] INT p) [, ] REAL`

   `PROC complex lu inv = ([, ] COMPLEX lu, [] INT p) [, ] COMPLEX`

   These routines yield the inverse of a matrix from its *LU* decomposition `lu`, `p` as calculated by `[complex] lu decomp`. The inverse is computed by solving $A \cdot A^{-1} = 1$. It is not recommended to use the inverse matrix to solve a linear equation $A \cdot x = b$ by applying $x = A^{-1} \cdot b$; use `[complex] lu solve` for better precision instead.

4. `PROC lu det = ([, ] REAL lu, INT sign) REAL`

   `PROC complex lu det = ([, ] COMPLEX lu, INT sign) COMPLEX`

   These routines yield the determinant of a matrix from its *LU* decomposition `lu`, `sign` as calculated by `[complex] lu decomp`. The determinant is computed as the product of the diagonal elements of U and the **sign** of the row permutation `sign`.

11.10.4 Singular value decomposition

A $M \times N$ matrix A has a singular value decomposition in the product of a $M \times N$ orthogonal matrix U, a $N \times N$ diagonal matrix S and the transpose of a $N \times N$ orthogonal square matrix V, such that

$$A = U \cdot S \cdot V^T$$

The singular values S_{ii} are zero or positive, off-diagonal elements are zero.

Singular value decomposition has many practical applications. The ratio of the largest to the smallest singular value is called the condition number; a high ratio means that the equation is ill conditioned. Zero singular values indicate a singular matrix A, the number of non-zero singular values is the rank of A. Small singular values should be edited by choosing a suitable tolerance since finite numerical precision may result in a singular value to be close to, but no equal to, zero.

1. `PROC svd decomp = ([, ] REAL a, REF [, ] REAL v, REF [] REAL s) [, ] REAL`

   This routine factorises a $M \times N$ matrix A into the singular value decomposition for $M \geq N$. The routine yields U. The diagonal elements of singular value matrix S are stored in vector `s`. The singular values are non-negative and form a non-increasing sequence from s_1 to s_N. Matrix `v` contains on completion the elements of V in un-transposed form. To form the product

   $$U \cdot S \cdot V^T$$

   it is necessary to take the transpose of V. This routine uses the Golub-Reinsch SVD algorithm.

2. `PROC svd solve = ([, ] REAL u, [] REAL s, [, ] REAL v, [] REAL b) [] REAL`

   This routine solves the system $A \cdot x = b$ using the singular value decomposition u, s, v of A computed by `svd decomp`. Only non-zero singular values are used in calculating the solution. The parts of the solution corresponding to singular values of zero are ignored. Other singular values can be edited out by setting them to zero before calling this routine. In the overdetermined case where A has more rows than columns the routine returns solution `x` which minimises $||A \cdot x - b||^2$.

For example:

```
INT n = read int;
[n, n] REAL a, v, u, [n] REAL b, s, sol;
svd decomp (a, v, s, u);
sol := svd solve (v, s, u, b);
```

11.10.5 QR decomposition

A $M \times N$ matrix A has a decomposition into the product of an orthogonal $M \times M$ square matrix Q, where $Q^T \cdot Q = I$, and an $M \times N$ right-triangular matrix R, such that $A = Q \cdot R$. A linear equation $A \cdot x = b$ can be converted to the triangular equation $R \cdot x = Q^T \cdot b$, which can be solved by back-substitution.

QR decomposition can be used to determine an orthonormal basis for a set of vectors since the first N columns of Q form an orthonormal basis for the range of A.

1. `PROC qr decomp = ([, ] REAL a, REF [] REAL t) [, ] REAL` This routine factorises the $M \times N$ matrix `a` into the QR decomposition $A = Q \cdot R$. The diagonal and upper triangular part of the returned matrix contain matrix R. The vector `t` and the

columns of the lower triangular part of matrix `a` contain the Householder coefficients and Householder vectors which encode the orthogonal matrix Q. Vector `t` must have length $min(M, N)$. The algorithm used to perform the decomposition is Householder QR (Golub and Van Loan, *Matrix Computations*, Algorithm 5.2.1).

2. `PROC qr solve ([, ] REAL a, [] REAL t, [] REAL b) [] REAL` This routine solves the square system $A \cdot x = b$ using the QR decomposition of A into a, t computed by `qr decomp`. The least-squares solution for rectangular equations can be found using `qr ls solve`.

3. `PROC qr ls solve ([, ] REAL a, [] REAL t, [] REAL b) [] REAL` This routine finds the least squares solution to the overdetermined system $A \cdot x = b$ where $M \times N$ matrix A has more rows than columns, id est $M > N$. The least squares solution minimises the Euclidean norm of the residual $||A \cdot x - b||^2$. The routine uses the QR decomposition of A into a, t computed by `qr decomp`.

For example:

```
INT m = read int, n = read int;
[m, n] REAL a, qr, [(m < n | m | n)] REAL t, [n] REAL b, sol;
qr := qr decomp (a, t);
sol := qr solve (qr, t, b);
```

11.10.6 Cholesky decomposition

A symmetric, positive definite square matrix A has a Cholesky decomposition into a product of a lower triangular matrix L and its transpose $L^T, A = L \cdot L^T$. This is sometimes referred to as taking the square root of a matrix. The Cholesky decomposition can only be carried out when all the eigen values of the matrix are positive. This decomposition can be used to convert the linear system $A \cdot x = b$ into a pair of triangular equations $L \cdot y = b$, $L^T \cdot x = y$, which can be solved by forward and back-substitution.

1. `PROC cholesky decomp = ([, ] REAL a) [, ] REAL`

   This routine factorises the positive-definite symmetric square matrix `a` into the Cholesky decomposition $A = L \cdot L^T$. The diagonal and lower triangular part of the returned matrix contain matrix L. The upper triangular part of the input matrix contains L^T, the diagonal terms being identical for both L and L^T. If the matrix is not positive-definite then the decomposition will fail.

2. `PROC cholesky solve = ([, ] REAL a, [] REAL b) [] REAL`

   This routine solves the system $A \cdot x = b$ using the Cholesky decomposition of A into matrix `a` computed by `cholesky decomp`.

11.11 Fourier transform

This section describes mixed-radix discrete fast Fourier transform (FFT) algorithms for complex data. Next routines require that `a68g` is linked to the GNU Scientific Library. The forward transform (to the time domain) is defined by

$$F_k = \sum_{j=0}^{N-1} e^{-2\pi ik/N} f_j$$

while the inverse transform (to the frequency domain) is defined by

$$f_k = \frac{1}{N} \sum_{j=0}^{N-1} e^{2\pi ik/N} F_j$$

and the backward transform is an unscaled inverse transform defined by

$$f_k = \sum_{j=0}^{N-1} e^{2\pi ik/N} F_j$$

The mixed-radix procedures work for FFTs of any length. They are a reimplementation of Paul Swarztrauber's FFTPACK library.

The mixed-radix algorithm is based on sub-transform modules - highly optimised small length FFTs which are combined to create larger FFTs. There are efficient modules for factors of 2, 3, 4, 5, 6 and 7. The modules for the composite factors of 4 and 6 are faster than combining the modules for 2×2 and 2×3.

For factors which are not implemented as modules there is a general module which uses Singleton's method. Lengths which use the general module will still be factorised as much as possible. For example, a length of 143 will be factorised into 11×13. Large prime factors, e.g. 99991, should be avoided because of the $\mathcal{O}(n^2)$ complexity of the general module. The procedure `prime factors` can be used to detect inefficiencies in computing a FFT.

For physical applications it is important to note that the index appearing in the discrete Fourier transform (DFT) does not correspond directly to a physical frequency. If the time-step of the DFT reads `dt` then the frequency-domain includes both positive and negative frequencies, ranging from $-1/(2dt)$ to $+1/(2dt)$. The positive frequencies are stored from the beginning of the row up to the middle, and the negative frequencies are stored backwards from the end of the row. When N is even, next frequency table holds:

Index	Time	Frequency
1	0	0
2	dt	$1/(Ndt)$
...	...	...
$N/2$	$(N/2-1)dt$	$(N/2-1)/(Ndt)$
$N/2+1$	$(N/2)dt$	$\pm 1/(2dt)$
$N/2+2$	$(N/2+1)dt$	$-(N/2-1)/(Ndt)$
...	...	...
$N-1$	$(N-2)dt$	$-2/(Ndt)$
N	$(N-1)dt$	$-1/(Ndt)$

When the length N of the row is even, the location $N/2+1$ contains the most positive and negative frequencies $\pm 1/(2dt)$ that are equivalent. If N is odd, this central value does not appear, but the general structure of above table still applies.

1. `PROC prime factors = (INT n) [] INT`

   Factorises argument `n` and yields the factors as a row of integral values. This routine can be used to determine whether the Fourier transform of a row of length `n` can be calculated in an efficient way.

2. `PROC fft complex forward = ([] COMPLEX) [] COMPLEX`

   `PROC fft complex backward = ([] COMPLEX) [] COMPLEX`

   `PROC fft complex inverse = ([] COMPLEX) [] COMPLEX`

   `PROC fft forward = ([] REAL) [] COMPLEX`

   `PROC fft backward = ([] COMPLEX) [] REAL`

   `PROC fft inverse = ([] COMPLEX) [] REAL`

   These procedures compute forward, backward (i.e., an unscaled inverse) and inverse FFTs, using a mixed radix decimation-in-frequency algorithm. There is no restriction on the length of the argument rows. Efficient modules are provided for sub transforms of length 2, 3, 4, 5, 6 and 7. Any remaining factors are computed with a slow, $\mathcal{O}(N^2)$, module.

11.12 Laplace transform

Next routine requires the GNU Scientific Library. The Laplace transform $F(s)$ of a real-valued function $f(t)$ is defined by

$$F(s) = \int_0^\infty dt\, f(t)\, e^{-st}$$

`a68g` can calculate this transform:

1. `PROC laplace = (PROC (REAL) REAL f, REAL s, REF REAL error) REAL`

   This procedure computes the Laplace transform of f at value s. Argument $error$ must be set to the desired error in the integral at forehand. If $error$ is positive, it is taken as an absolute error. If $error$ is negative, its absolute value is passed as a relative error. Upon return, $error$ contains the estimated *absolute* error in the calculated integral. Routine `laplace` calls a GSL function to compute an integral over the semi-infinite interval $[0, \infty]$ by mapping onto the semi-open interval $[0, 1]$ using the transformation

$$\int_0^\infty dt\, g(t) = \int_0^1 du\, g\left(\frac{1-u}{u}\right)\frac{1}{u^2}$$

   For example:

```
PROC exp nx = (INT n, REAL x) REAL: exp (-n * x);


FOR n TO 3
DO print (("exp (-", whole (n, 0), "t)", new line));
  FOR k TO 10
  DO REAL error := 1e-12;
    print ((laplace (exp nx (n, ), k, error), blank, error,
      blank, 1 / (n + k), new line))
  OD
OD;
```

11.13 Constants

This paragraph describes physical constants such as the speed of light or the gravitational constant. The constants are available in the MKSA system (meter-kilograms-seconds-ampere) and the CGS system (centimetre-grams-seconds).

11.13.1 Fundamental constants

1. `REAL mksa speed of light` • `REAL cgs speed of light`
   Speed of light in vacuum, c.

2. `REAL mksa vacuum permeability`
   Permeability of vacuum μ_0.

3. `REAL mksa vacuum permittivity`
   Permittivity of free space ϵ_0.

4. `REAL num avogadro`
   Avogadro's number N_a.

5. `REAL mksa faraday` • `REAL cgs faraday`
   Molar charge of one Faraday.

6. `REAL mksa boltzmann` • `REAL cgs boltzmann`
   Boltzmann's constant k_B.

7. `REAL mksa molar gas` • `REAL cgs molar gas`
   Molar gas constant R.

8. `REAL mksa standard gas volume` • `REAL cgs standard gas volume`
   Standard gas volume V_0.

9. `REAL mksa planck constant` • `REAL cgs planck constant`
   Planck constant h.

10. `REAL mksa planck constant bar` • `REAL cgs planck constant bar`
    Planck constant $\hbar = h/(2\pi)$.

11. `REAL mksa gauss` • `REAL cgs gauss`
    Magnetic field strength of one Gauss.

11.13.2 Length and velocity

1. `REAL mksa micron` • `REAL cgs micron`
   Length of one micron.

2. `REAL mksa hectare` • `REAL cgs hectare`
   Area of one hectare.

3. `REAL mksa miles per hour` • `REAL cgs miles per hour`
   Speed of one mile per hour.

4. `REAL mksa kilometres per hour` • `REAL cgs kilometres per hour`
   Speed of one kilometre per hour.

11.13.3 Astronomy and astrophysics

1. `REAL mksa astronomical unit` • `REAL cgs astronomical unit`
   Length of one astronomical unit au.

2. `REAL mksa gravitational constant` •
   `REAL cgs gravitational constant`
   Gravitational constant G.

3. `REAL mksa light year` • `REAL cgs light year`
   Distance of one light-year ly.

4. `REAL mksa parsec` • `REAL cgs parsec`
   Distance of one parsec pc.

5. `REAL mksa grav accel` • `REAL cgs grav accel`
   Gravitational acceleration on Earth g.

6. `REAL mksa solar mass` • `REAL cgs solar mass`
   Mass of the Sun.

11.13.4 Atomic and nuclear physics

1. `REAL mksa electron charge` • `REAL cgs electron charge`
   Charge of an electron e.

2. `REAL mksa electron volt` • `REAL cgs electron volt`
   Energy of one electron volt eV.

3. `REAL mksa unified atomic mass` • `REAL cgs unified atomic mass`
   Unified atomic mass amu.

4. `REAL mksa mass electron` • `REAL cgs mass electron`
   Mass of an electron m_e.

5. `REAL mksa mass muon` • `REAL cgs mass muon`
   Mass of a muon m_μ.

6. `REAL mksa mass proton` • `REAL cgs mass proton`
   Mass of a proton m_p.

7. `REAL mksa mass neutron` • `REAL cgs mass neutron`
   Mass of a neutron m_n.

8. `REAL num fine structure`
   Electromagnetic fine structure constant, α.

9. `REAL mksa rydberg` • `REAL cgs rydberg`
   The Rydberg constant Ry in units of energy. This is related to the Rydberg inverse wavelength R by $Ry = hcr$.

10. `REAL mksa bohr radius` • `REAL cgs bohr radius`
    Bohr radius a_0.

11. `REAL mksa angstrom` • `REAL cgs angstrom`
    Length of one Ångstrom.

12. `REAL mksa barn` • `REAL cgs barn`
    Area of one barn.

13. `REAL mksa bohr magneton` • `REAL cgs bohr magneton`
    Bohr magneton μ_b.

14. `REAL mksa nuclear magneton` • `REAL cgs nuclear magneton`
    Nuclear magneton μ_n.

15. `REAL mksa electron magnetic moment` •
    `REAL cgs electron magnetic moment`
    Absolute value of the magnetic moment of an electron μ_e. The physical magnetic moment of an electron is negative.

16. `REAL mksa proton magnetic moment` •
    `REAL cgs proton magnetic moment`
    Magnetic moment of a proton μ_p.

11.13.5 Time

1. `REAL mksa minute` • `REAL cgs minute`
   Number of seconds in one minute.

2. `REAL mksa hour` • `REAL cgs hour`
   Number of seconds in one hour.

3. `REAL mksa day` • `REAL cgs day`
   Number of seconds in one day.

4. `REAL mksa week` • `REAL cgs week`
   Number of seconds in one week.

11.13.6 Imperial units

1. `REAL mksa inch` • `REAL cgs inch`
   Length of one inch.

2. `REAL mksa foot` • `REAL cgs foot`
   Length of one foot.

3. `REAL mksa yard` • `REAL cgs yard`
   Length of one yard.

4. `REAL mksa mile` • `REAL cgs mile`
   Length of one mile.

5. `REAL mksa mil` • `REAL cgs mil`
   Length of one mil (1/1000th of an inch).

11.13.7 Nautical units

1. `REAL mksa nautical mile` • `REAL cgs nautical mile`
   Length of one nautical mile.
2. `REAL mksa fathom` • `REAL cgs fathom`
   Length of one fathom.
3. `REAL mksa knot` • `REAL cgs knot`
   Speed of one knot.

11.13.8 Volume

1. `REAL mksa acre` • `REAL cgs acre`
   Area of one acre.
2. `REAL mksa liter` • `REAL cgs liter`
   Volume of one liter.
3. `REAL mksa us gallon` • `REAL cgs us gallon`
   Volume of one us gallon.
4. `REAL mksa canadian gallon` • `REAL cgs canadian gallon`
   Volume of one canadian gallon.
5. `REAL mksa uk gallon` • `REAL cgs uk gallon`
   Volume of one uk gallon.
6. `REAL mksa quart` • `REAL cgs quart`
   Volume of one quart.
7. `REAL mksa pint` • `REAL cgs pint`
   Volume of one pint.

11.13.9 Mass and weight

1. `REAL mksa pound mass` • `REAL cgs pound mass`
   Mass of one pound.
2. `REAL mksa ounce mass` • `REAL cgs ounce mass`
   Mass of one ounce.

3. `REAL mksa ton • REAL cgs ton`
   Mass of one ton.

4. `REAL mksa metric ton • REAL cgs metric ton`
   Mass of one metric ton (1000 kg).

5. `REAL mksa uk ton • REAL cgs uk ton`
   Mass of one uk ton.

6. `REAL mksa troy ounce • REAL cgs troy ounce`
   Mass of one troy ounce.

7. `REAL mksa carat • REAL cgs carat`
   Mass of one carat.

8. `REAL mksa gram force • REAL cgs gram force`
   Force of one gram weight.

9. `REAL mksa pound force • REAL cgs pound force`
   Force of one pound weight.

10. `REAL mksa kilopound force • REAL cgs kilopound force`
    Force of one kilopound weight.

11. `REAL mksa poundal • REAL cgs poundal`
    Force of one poundal.

11.13.10 Thermal energy and power

1. `REAL mksa calorie • REAL cgs calorie`
   Energy of one Calorie.

2. `REAL mksa btu • REAL cgs btu`
   Energy of one British Thermal Unit.

3. `REAL mksa therm • REAL cgs therm`
   Energy of one therm.

4. `REAL mksa horsepower • REAL cgs horsepower`
   Power of one horsepower.

11.13.11 Pressure

1. `REAL mksa bar • REAL cgs bar`
   Pressure of one Bar.

2. `REAL mksa std atmosphere • REAL cgs std atmosphere`
   Pressure of one standard atmosphere.

3. `REAL mksa torr • REAL cgs torr`
   Pressure of one Torricelli.

4. `REAL mksa meter of mercury • REAL cgs meter of mercury`
   Pressure of one meter of mercury.

5. `REAL mksa inch of mercury • REAL cgs inch of mercury`
   Pressure of one inch of mercury.

6. `REAL mksa inch of water • REAL cgs inch of water`
   Pressure of one inch of water.

7. `REAL mksa psi • REAL cgs psi`
   pressure of one pound per square inch.

11.13.12 Viscosity

1. `REAL mksa poise • REAL cgs poise`
   Dynamic viscosity of one Poise.

2. `REAL mksa stokes • REAL cgs stokes`
   Kinematic viscosity of one Stokes.

11.13.13 Light and illumination

1. `REAL mksa stilb • REAL cgs stilb`
   Luminance of one stilb.

2. `REAL mksa lumen • REAL cgs lumen`
   Luminous flux of one lumen.

3. `REAL mksa lux • REAL cgs lux`
   Illuminance of one lux.

4. `REAL mksa phot • REAL cgs phot`
   Illuminance of one phot.

5. `REAL mksa footcandle • REAL cgs footcandle`
   Illuminance of one footcandle.

6. `REAL mksa lambert • REAL cgs lambert`
   Luminance of one lambert.

7. `REAL mksa footlambert` • `REAL cgs footlambert`
   Luminance of one footlambert.

11.13.14 Radioactivity

1. `REAL mksa curie` • `REAL cgs curie`
   Activity of one Curie.

2. `REAL mksa roentgen` • `REAL cgs roentgen`
   Exposure of one Röntgen.

3. `REAL mksa rad` • `REAL cgs rad`
   Absorbed dose of one Rad.

11.13.15 Force and energy

1. `REAL mksa newton` • `REAL cgs newton`
   SI unit of force, one Newton.

2. `REAL mksa dyne` • `REAL cgs dyne`
   Force of one Dyne.

3. `REAL mksa joule` • `REAL cgs joule`
   SI unit of energy, one Joule.

4. `REAL mksa erg` • `REAL cgs erg`
   Energy of one Erg.

11.13.16 Prefixes

1. `REAL num yotta` 10^{24}

2. `REAL num zetta` 10^{21}

3. `REAL num exa` 10^{18}

4. `REAL num peta` 10^{15}

5. `REAL num tera` 10^{12}

6. `REAL num giga` 10^{9}

7. `REAL num mega` 10^{6}

8. `REAL num kilo` 10^{3}
9. `REAL num milli` 10^{-3}
10. `REAL num micro` 10^{-6}
11. `REAL num nano` 10^{-9}
12. `REAL num pico` 10^{-12}
13. `REAL num femto` 10^{-15}
14. `REAL num atto` 10^{-18}
15. `REAL num zepto` 10^{-21}
16. `REAL num yocto` 10^{-24}

11.13.17 Printer units

1. `REAL mksa point` • `REAL cgs point`
   Length of one printer's point $1/72$".
2. `REAL mksa texpoint` • `REAL cgs texpoint`
   Length of one TEX point $1/72.27$".

11.14 Transput

An introduction to Algol 68 transput is in chapter 7. The function of this section is to document all the transput **declarations** so that you can use it for reference purposes.

11.14.1 Transput modes

Only two modes are available:

1. `FILE`
   A structure containing details of a file.
2. `CHANNEL`
   A structure whose fields are routines returning truth values which determine the available methods of access to a file.

11.14.2 Standard channels

`a68g` initialises four channels at start-up:

1. `CHANNEL stand in channel`
2. `CHANNEL stand out channel`
3. `CHANNEL stand back channel`
4. `CHANNEL stand error channel`

These four channels have similar properties because they use the same access procedures. The standard input channel is `stand in channel`. Files on this channel have the following properties:

stand in channel	
reset possible	FALSE
set possible	FALSE
get possible	TRUE
put possible	FALSE
bin possible	FALSE

The `stand out channel` is the standard output channel. Files on this channel have the following properties:

stand out channel	
reset possible	FALSE
set possible	FALSE
get possible	FALSE
put possible	TRUE
bin possible	FALSE

The `stand back channel` is the standard input/output channel. Files on this channel have the following properties:

stand back channel	
reset possible	TRUE
set possible	TRUE
get possible	TRUE
put possible	TRUE
bin possible	TRUE

The `stand error channel` is the standard error output channel. Files on this channel have the following properties:

stand out channel	
reset possible	`FALSE`
set possible	`FALSE`
get possible	`FALSE`
put possible	`TRUE`
bin possible	`FALSE`

11.14.3 Standard files

Four standard files are provided:

1. `REF FILE stand in`
   On Linux this file is opened on `stdin` with `stand in channel`.
2. `REF FILE stand out`
   On Linux this file is opened on `stdout` with `stand out channel`.
3. `REF FILE stand error`
   On Linux this file is opened on `stderror` with `stand error channel`.
4. `REF FILE stand back`
   If this file is used, a temporary file will be established on the file system.

11.14.4 Opening files

These procedures are available for opening files:

1. `PROC establish = (REF FILE f, STRING n, CHANNEL c) INT`
   Establishes a new file `f` with file name `n` and channel `c`. If the file already exists, an `on open error` event occurs. The procedure yields zero on success, otherwise an integer denoting an error.
2. `PROC open = (REF FILE f, STRING n, CHANNEL c) INT`
   Open a file `f` with file name `n` and channel `c`. On Linux, the routine yields zero if the file is a regular file and non-zero otherwise. If the file does not exists, it will be created when the file is actually written to.
3. `PROC append = (REF FILE f, STRING n, CHANNEL c) INT`
   Open a file `f` with file name `n` and channel `c`. When written to, append to the end of the file, original contents are left untouched. On Linux, the routine yields zero if

the file is a regular file and non-zero otherwise. If the file does not exists, it will be created when the file is actually written to.

4. `PROC create = (REF FILE f, CHANNEL c) INT`
   Creates a temporary file (on Linux with a unique identification in the directory `/tmp`) using the given channel `c`.

5. `PROC associate = (REF FILE f, REF STRING s) VOID`
   Associates file `f` with string `s`. Note that the Revised Report specifies a `REF [][][] CHAR` argument where `a68g` specifies a `REF STRING` argument. On putting, the string is dynamically lengthened and output is added at the end of the string. Attempted getting outside the string provokes an end of file condition, and on file end is invoked. When a file that is associated with a string is reset, getting restarts from the start of the associated string.

11.14.5 Closing files

Three procedures are provided.

1. `PROC close = (REF FILE f) VOID`
   This is the common procedure for closing a file. The procedure checks whether the file is open.

2. `PROC lock = (REF FILE f) VOID`
   The Algol 68 Revised Report requires `lock` to close the file in such a manner that some system action is required before it can be reopened. `a68g` closes the file and then removes all access permissions.

3. `PROC scratch = (REF FILE f)VOID`
   The file is closed and then deleted from the file system.

11.14.6 Transput routines

The procedures in this section are responsible for the transput of actual values. Firstly, default-format transput is covered and then binary transput. In each section, the shorthand `L` is used for the various precisions of numbers and bits values.

Default-format transput

1. `PROC put = (REF FILE f,`
   `[] UNION (OUTTYPE, PROC (REF FILE) VOID) items) VOID`
   Writes `items` to file `f` using default formatting.

2. `PROC print =`
   `([] UNION (OUTTYPE, PROC (REF FILE) VOID) items) VOID`
   Writes `items` to file standout using default formatting.

3. `PROC get = (REF FILE f,`
   `[] UNION (INTYPE, PROC (REF FILE) VOID) items) VOID`
   Reads `items` from file `f` using default formatting.

4. `PROC read =`
   `([] UNION (INTYPE, PROC (REF FILE) VOID) items) VOID`
   Reads `items` from file standin using default formatting.

Formatted transput

1. `PROC putf = (REF FILE f, [] UNION (OUTTYPE,`
   `PROC (REF FILE) VOID, FORMAT) items) VOID`
   Writes `items` to file `f` using formatted transput.

2. `PROC printf = ([] UNION (OUTTYPE,`
   `PROC (REF FILE) VOID, FORMAT) items) VOID`
   Writes `items` to file standout using formatted transput.

3. `PROC getf = (REF FILE f, [] UNION (INTYPE,`
   `PROC (REF FILE) VOID, FORMAT) items) VOID`
   Reads `items` from file `f` using formatted transput.

4. `PROC readf = ([] UNION (INTYPE,`
   `PROC (REF FILE) VOID, FORMAT) items) VOID`
   Reads `items` from file standin using formatted transput.

Binary transput

Binary transput performs no conversion, storing data in a compact form in files.

1. `PROC write bin = ([] OUTTYPE items) VOID`
   This is equivalent to `put bin (stand back, items)`.

2. `PROC put bin =`
   `(REF FILE f, [] OUTTYPE items) VOID`
   This procedure outputs data in binary form.

3. `PROC read bin = ([] SIMPLIN items) VOID`
   This procedure is equivalent to:

   ```
   get bin (stand back, items)
   ```

4. `PROC get bin = (REF FILE f, [] INTYPE items) VOID`
   This procedure reads data in binary form.

It should also be noted that the procedure `make term`, although usually used with default-format transput, can also be used with binary transput for reading a `STRING`.

11.14.7 Using strings as files

1. `PROC puts = (REF STRING s, [] UNION (OUTTYPE, PROC (REF FILE) VOID) items) VOID`
   Write `items` to string `s` using unformatted transput.

2. `PROC gets = (REF STRING s, [] UNION (INTYPE, PROC (REF FILE) VOID) items) VOID`
   Read `items` from string `s` using unformatted transput.

3. `PROC putsf = (REF STRING s, [] UNION (OUTTYPE, PROC (REF FILE) VOID, FORMAT) items) VOID`
   Write `items` to string `s` using formatted transput.

4. `PROC getsf = (REF STRING s, [] UNION (INTYPE, PROC (REF FILE) VOID, FORMAT) items) VOID`
   Read `items` from string `s` using formatted transput.

5. `PROC string = (REF STRING s, [] UNION (OUTTYPE, PROC (REF FILE) VOID) items) REF STRING`
   Write `items` to string `s` using unformatted transput and return `s`.

6. `PROC stringf = (REF STRING s, [] UNION (OUTTYPE, PROC (REF FILE) VOID, FORMAT) items) REF STRING`
   Write `items` to string `s` using formatted transput and return `s`.

For example:

```
STRING z := string (LOC STRING, ("sum =", read int + read int))
```

11.14.8 Interrogating files

A number of procedures are available for interrogating the properties of files:

1. `PROC bin possible = (REF FILE f) BOOL`
   Yields `TRUE` if binary transput is possible.

2. `PROC put possible = (REF FILE f) BOOL`
   Yields `TRUE` if data can be sent to the file.

3. `PROC get possible = (REF FILE f) BOOL`
   Yields `TRUE` if data can be got from the file.

4. `PROC set possible = (REF FILE f) BOOL`
   Yields `TRUE` if the position in the file for further transput can be set.

5. `PROC reset possible = (REF FILE f) BOOL`
   `PROC rewind possible = (REF FILE f) BOOL`
   Yields `TRUE` if the position in the file for further transput can be reset. The spelling `rewind possible` is an `a68g` extension.

6. `PROC compressible = (REF FILE f) BOOL`
   Yields `TRUE` if the file is compressible. This is a dummy routine supplied for backwards compatibility since `a68g` sets the compressible field of all channels to `TRUE`.

7. `PROC reidf possible = (REF FILE f) BOOL`
   Yields `TRUE` if the identification of the file can be changed.

8. `PROC idf = (REF FILE f) STRING`
   Yields the identification string of `f`, if it is set.

9. `PROC term = (REF FILE file) STRING`
   Yields the terminator string of `f`, if it is set.

11.14.9 File properties

1. `PROC make term=(REF FILE f, STRING term) VOID`
   Makes `term` the current string terminator.

11.14.10 Event routines

For each routine, the default behaviour will be described. In each case, if the user routine yields `FALSE`, the default action will be elaborated. If it yields `TRUE`, the action depends on the event.

1. ```
   PROC on file end =
   (REF FILE f, PROC (REF FILE) BOOL p) VOID
   PROC on logical file end =
   (REF FILE f, PROC (REF FILE) BOOL p) VOID
   PROC on physical file end =
   ```
   ```

```
(REF FILE f, PROC (REF FILE) BOOL p) VOID
```
These procedure let you provide a routine to be called when end of file is reached on file `f`. The default action on file end is to produce a runtime error.

2.
```
PROC on format end =
(REF FILE f, PROC (REF FILE) BOOL p) VOID
```
Format end events are caused when in formatted transput, the format gets exhausted. The procedure `on format end` lets you provide a procedure of mode `PROC (REF FILE) BOOL`. If the programmer-supplied routine yields `TRUE`, transput simply continues, otherwise the format that just ended is restarted and transput resumes.

3.
```
PROC on line end =
(REF FILE f, PROC (REF FILE) BOOL p) VOID
PROC on page end =
(REF FILE f, PROC (REF FILE) BOOL p) VOID
```
Line end and page end events are caused when while reading, the end of line or end of page is encountered. These are events so you can provide a routine that for instance automatically counts the number of lines or pages read. The procedures `on line end` and `on page end` let the programmer provide a procedure whose mode must be `PROC (REF FILE) BOOL`. If the programmer-supplied routine yields `TRUE`, transput continues, otherwise a `new line` in case of end of line, or `new page` in case of end of page, is executed and then transput resumes.

   Be careful when reading strings, since end of line and end of page are string terminators! If you provide a routine that mends the line - or page end, be sure to call `new line` or `new page` before returning `TRUE`. In case of a default action, `new line` or `new page` must be called explicitly, for instance in the `read` procedure, otherwise you will read nothing but empty strings as you do not eliminate the terminator.

4.
```
PROC on open error =
(REF FILE f, PROC (REF FILE) BOOL p) VOID
```
Open error events are caused when a file cannot be opened as required. For instance, you want to read a file that does not exist, or write to a read-only file. The procedure `on open error` lets the programmer provide a procedure whose mode must be `PROC (REF FILE) BOOL`. If the programmer-supplied routine yields `TRUE`, the **program** continues, otherwise a runtime error occurs.

5.
```
PROC on value error =
(REF FILE f, PROC (REF FILE) BOOL p) VOID
```
Value error events are caused when transputting a value that is not a valid representation of the mode of the object being transput. The procedure `on value error` lets the programmer provide a procedure whose mode must be `PROC (REF FILE) BOOL`. If you do transput on the file within the procedure ensure that a value error will not occur again! If the programmer-supplied routine yields `TRUE`, transput continues, otherwise a runtime error occurs.

6. `PROC on format error =`
   `(REF FILE f, PROC (REF FILE) BOOL p) VOID`
   Format error events are caused when an error occurs in a format, typically when patterns are provided without objects to transput. The procedure `on format error` lets the programmer provide a procedure whose mode must be `PROC (REF FILE) BOOL`. If the programmer-supplied routine yields `TRUE`, the **program** continues, otherwise a runtime error occurs.

7. `PROC on transput error =`
   `(REF FILE f, PROC (REF FILE) BOOL p) VOID`
   This event is caused when an error occurs in transput that is not covered by the other events, typically conversion errors (value out of range et cetera). The procedure `on transput error` lets the programmer provide a procedure with mode `PROC (REF FILE) BOOL`. If the programmer-supplied routine yields `TRUE`, the **program** continues, otherwise a runtime error occurs.

11.14.11 Formatting routines

There are four procedures for conversion of numbers to strings. The procedures `whole`, `fixed` and `float` will return a string of `error char`s if the number to be converted cannot be represented in the given width.

1. `PROC whole = (NUMBER v, INT width) STRING`
   The procedure converts integral values. Leading zeros are replaced by spaces and a **sign** is included if $width > 0$. If `width` is zero, the shortest possible string is yielded. If a real number is supplied for the **parameter** `v`, then the **call** `fixed (v, width, 0)` is elaborated.

2. `PROC fixed = (NUMBER v, INT width, after) STRING`
   The procedure converts real numbers to fixed point form, that is, without an exponent. The total number of characters in the converted value is given by the **parameter** `width` whose **sign** controls the presence of a **sign** in the converted value as for `whole`. The **parameter** `after` specifies the number of required digits after the **point-symbol**. From the values of `width` and `after`, the number of digits in front of the **point-symbol** can be calculated. If the space left in front of the **point-symbol** is insufficient to contain the integral part of the value being converted, digits after the **point-symbol** are sacrificed.

3. `PROC float = (NUMBER v, INT width, after, exp) STRING`
   The procedure converts reals to floating-point form ("scientific notation"). The total number of characters in the converted value is given by the **parameter** `width` whose **sign** controls the presence of a **sign** in the converted value as for `whole`. Likewise, the **sign** of `exp` controls the presence of a preceding **sign** for the exponent. If `exp` is

zero, then the exponent is expressed in a string of minimum length. In this case, the value of `width` must not be zero. Note that `float` always leaves a position for the **sign**. If there is no **sign**, a blank is produced instead. The values of `width`, `after` and `exp` determine how many digits are available before the decimal point and, therefore, the value of the exponent. The latter value has to fit into the width specified by `exp` and so, if it cannot fit, decimal places are sacrificed one by one until either it fits or there are no more decimal places (and no **point-symbol**). If it still doesn't fit, digits before the decimal place are also sacrificed. If no space for digits remains, the whole string is filled with `error char`.

4. `PROC real =`
   `(NUMBER x, INT width, after, exp width, modifier) STRING`
   Converts `x` to a `STRING` representation. If `modifier` is a positive number, the resulting string will present `x` with its exponent a multiple of `modifier`. If $modifier = 1$, the returned string is identical to that returned by `float`. A common choice for `modifier` is 3 which returns the so-called engineers notation of `x`. If $modifier \leq 0$, the resulting string will present `x` with `ABS modifier` digits before the **point-symbol** and its exponent adjusted accordingly; compare this to Fortran `nP` syntax.

11.14.12 Miscellaneous transput routines

1. `PROC end of line = (REF FILE file) BOOL`
   `PROC eoln = (REF FILE file) BOOL`
   This routine yields `TRUE` if the file pointer of `file` is at the end of a line, or `FALSE` if it is not. One can advance the file pointer with `get (file, new line)` or `new line (file)`.

2. `PROC end of file = (REF FILE file) BOOL`
   `PROC eof = (REF FILE file) BOOL`
   This routine yields `TRUE` if the file pointer of `file` is at the end of the file, or `FALSE` if it is not.

3. `PROC set = (REF FILE f, INT n) INT`
   This routine deviates from the standard Algol 68 definition. It attempts to move the file pointer by `n` character positions with respect to the current position. If the file pointer would as a result of this move get outside the file, it is not changed and the routine set by `on file end` is called. If this routine returns `FALSE`, and end-of-file runtime error is produced. The routine returns an `INT` value representing system-dependent information on this repositioning.

4. `PROC reset = (REF FILE f) VOID`
   `PROC rewind = (REF FILE f) VOID`
   Resets the file to the state it was in directly after `open`, `create` or `establish`.

Default event-routines are installed and the file pointer is reset. The spelling `rewind` is an `a68g` extension.

5. `PROC space = (REF FILE f) VOID`
   The procedure advances the file pointer in file `f` by one character. It does *not* read or write a blank.

6. `PROC backspace = (REF FILE f) VOID`
   The procedure attempts to retract the file pointer in file `f` by one character. It executes:

   ```
   VOID (set (f, -1))
   ```

7. `PROC new line = (REF FILE f) VOID`
   On input, `new line` skips any remaining characters on the current line and positions the file pointer at the beginning of the next line. This means that all characters on input are skipped until a linefeed character is read. On output, the routine writes a linefeed character.

8. `PROC new page = (REF FILE f) VOID`
   On input, `new page` skips any remaining characters on the current page and positions the file pointer at the beginning of the next page. This means that all characters on input are skipped until a form feed character is read. On output, a form feed character is written.

11.15 The library prelude

`a68g` supplies many routines, operators and constants, not described by the Revised Report, for linear algebra, Fourier transforms, Laplace transforms, drawing and plotting, PCM sounds and PostgreSQL database support. Many of these routines require optional libraries; if these libraries are not present on your system, `a68g` will not support library prelude elements that require them.

11.16 `ALGOL68C`-style transput procedures

For compatibility with `ALGOL68C`, `a68g` offers a number of transput procedures.

Following routines read an object of the resulting mode of the respective routine from `stand in`:

1. `PROC read int = INT`

2. `PROC read long int = LONG INT`

3. `PROC read long long int = LONG LONG INT`
4. `PROC read real = REAL`
5. `PROC read long real = LONG REAL`
6. `PROC read long long real = LONG LONG REAL`
7. `PROC read complex = COMPLEX`
8. `PROC read long complex = LONG COMPLEX`
9. `PROC read long long complex = LONG LONG COMPLEX`
10. `PROC read bool = BOOL`
11. `PROC read bits = BITS`
12. `PROC read long bits = LONG BITS`
13. `PROC read long long bits = LONG LONG BITS`
14. `PROC read char = CHAR`
15. `PROC read string = STRING`

Following routines read an object of the resulting mode of the respective routine from file *f*:

1. `PROC get int = (REF FILE f) INT`
2. `PROC get long int = (REF FILE f) LONG INT`
3. `PROC get long long int = (REF FILE f) LONG LONG INT`
4. `PROC get real = (REF FILE f) REAL`
5. `PROC get long real = (REF FILE f) LONG REAL`
6. `PROC get long long real = (REF FILE f) LONG LONG REAL`
7. `PROC get complex = (REF FILE f) COMPLEX`
8. `PROC get long complex = (REF FILE f) LONG COMPLEX`
9. `PROC get long long complex = (REF FILE f) LONG LONG COMPLEX`
10. `PROC get bool = (REF FILE f) BOOL`
11. `PROC get bits = (REF FILE f) BITS`

12. `PROC get long bits = (REF FILE f) LONG BITS`
13. `PROC get long long bits = (REF FILE f) LONG LONG BITS`
14. `PROC get char = (REF FILE f) CHAR`
15. `PROC get string = (REF FILE f) STRING`

Following routines write an object of the **parameter** mode of the respective routine to `stand out`:

1. `PROC print int = (INT k) VOID`
2. `PROC print long int = (LONG INT k) VOID`
3. `PROC print long long int = (LONG LONG INT k) VOID`
4. `PROC print real = (REAL x) VOID`
5. `PROC print long real = (LONG REAL x) VOID`
6. `PROC print long long real = (LONG LONG REAL x) VOID`
7. `PROC print complex = (COMPLEX c) VOID`
8. `PROC print long complex = (LONG COMPLEX c) VOID`
9. `PROC print long long complex = (LONG LONG COMPLEX c) VOID`
10. `PROC print bool = (BOOL b) VOID`
11. `PROC print bits = (BITS b) VOID`
12. `PROC print long bits = (LONG BITS b) VOID`
13. `PROC print long long bits = (LONG LONG BITS b) VOID`
14. `PROC print char = (CHAR c) VOID`
15. `PROC print string = (STRING s) VOID`

Following routines write an object of the **parameter** mode of the respective routine to file *f*:

1. `PROC put int = (REF FILE f, INT k) VOID`
2. `PROC put long int = (REF FILE f, LONG INT k) VOID`
3. `PROC put long long int = (REF FILE f, LONG LONG INT k) VOID`

4. `PROC put real = (REF FILE f, REAL x) VOID`
5. `PROC put long real = (REF FILE f, LONG REAL x) VOID`
6. `PROC put long long real = (REF FILE f, LONG LONG REAL x) VOID`
7. `PROC put complex = (REF FILE f, COMPLEX c) VOID`
8. `PROC put long complex = (REF FILE f, LONG COMPLEX c) VOID`
9. `PROC put long long complex = (REF FILE f, LONG LONG COMPLEX c) VOID`

10. `PROC put bool = (REF FILE f, BOOL b) VOID`
11. `PROC put bits = (REF FILE f, BITS b) VOID`
12. `PROC put long bits = (REF FILE f, LONG BITS b) VOID`
13. `PROC put long long bits = (REF FILE f, LONG LONG BITS b) VOID`
14. `PROC put char = (REF FILE f, CHAR c) VOID`
15. `PROC put string = (REF FILE f, STRING s) VOID`

11.17 Drawing and plotting

On systems that have installed the GNU Plotting Utilities, `a68g` can be linked with the `libplot` library to extend the standard prelude. Section 10.3.1 explains how to build `a68g` with this library. This section contains a list of routines supported by the current revision of `a68g`.

The GNU Plotting Utilities offer a number of routines for drawing 2-D graphics. This allows for drawing in an X window, postscript format, pseudo graphical interface format (pseudo-gif) and portable any-map format (pnm) from Algol 68. Note that `a68g` is not a full Algol 68 binding for `libplot`.

A plotter (window, postscript file, et cetera) can be considered as a stream to which plotting commands are written. Therefore `a68g` considers plotters to be objects of mode `REF FILE`. This seems consistent with the design of Algol 68 transput since a file is associated with a channel that describes the device, and therefore can be considered as a description of a device driver.

A plotter must be opened and closed, just like any file. To specify the file to be a drawing device, `stand draw channel` is declared, that yields `TRUE` when inspected by `draw possible`. To specify details on the plotter type and page size, the procedure `draw device` has to be called. A sample **program** is given below:

```
# 'window' is an X window with 600x400 pixels #
FILE window;
open (window, "Hello!", stand draw channel);
draw device (window, "X", "600x400");
# 'draw erase' makes the window appear on the screen #
draw erase (window);
# Goto pixel 0.25x600, 0.5x400 #
draw move (window, 0.25, 0.5);
# Colour will be 100% red, 0% green, 0% blue #
draw colour (window, 1, 0, 0);
# Write an aligned text #
draw text (window, "c", "c", "Hello world!");
# Flush the drawing command buffer -
only needed for real-time plotters like X #
draw show (window);
# Give audience a chance to read the message #
VOID (read char);
# Make the window disappear from the screen #
close (window);
```

11.17.1 Setting up a graphics device

1. `PROC draw device =`
   `(REF FILE file, STRING type, STRING params) BOOL`

   `PROC make device =`
   `(REF FILE file, STRING type, STRING params) BOOL`

   Set **parameters** for plotter `file`. **Parameter** `type` sets the plotter type. `a68g` supports `"X"` for X Window System, `"ps"` for postscript, `"gif"` for pseudo graphical interface format and `"pnm"` for portable any-map format. `X` plotters in `a68g` are only available with Linux. `X` plotters write graphics to an X Window System display rather than to an output stream. A runtime error results if the plotter could not be opened, so `file` must be open prior to calling `make device`. Argument `params` is interpreted as an image size. For X, gif and pnm the syntax reads `x pixelsxy pixels`, for instance `"500x500"`. For postscript, image size is the size of the page on which the graphics display will be positioned. Any ISO page size in the range `"a0"` - `"a4"` or ANSI page size in the range `"a"` - `"e"` may be specified. Recognised aliases are `"letter"` for `"a"` and `"tabloid"` for `"b"`. Other valid page sizes are `"legal"`, `"ledger"` and `"b5"`. The graphics display will be a square region centred on the specified page and occupying its full width, with allowance being made for margins. This routine returns `TRUE` if it succeeds.

   Note that some platforms cannot give `libplot` proper support for all plotters. Linux with the X window system lets `libplot` implement all plotters but for example the

`WIN64` binary would have problems with X and postscript plotters. On other platforms it is possible that a plotter produces garbage or gives a message as `output stream jammed`. Algol 68 Genie does not work around this deficiency.

2. `PROC draw erase = (REF FILE file) VOID`

   Begins the next frame of a multi-frame page, by clearing all previously plotted objects from the graphics display, and filling it with the background colour (if any).

3. `PROC draw show = (REF FILE file) VOID`

   Flushes all pending plotting commands to the display device. This is useful only if the currently selected plotter does real-time plotting, since it may be used to ensure that all previously plotted objects have been sent to the display and are visible to the user. It has no effect on plotters that do not do real-time plotting.

4. `PROC draw move = (REF FILE file, REAL x, y) VOID`

   The graphics cursor is moved to (x, y). The values of `x` and `y` are fractions $0 \ldots 1$ of the page size in respectively the `x` and `y` directions.

5. `PROC draw aspect = (REF FILE file) REAL`

   Yields the aspect ratio $ysize/xsize$.

6. `PROC draw fill style = (REF FILE file, INT level) VOID`

   Sets the fill fraction for all subsequently drawn objects. A value of $level = 0$ indicates that objects should be unfilled, or transparent. This is the default. A value in the range $16r0001 \ldots 16rffff$, indicates that objects should be filled. A value of 1 signifies complete filling; the fill colour will be the colour specified by calling `draw colour`. If $level = 16rffff$, the fill colour will be white. Values $16r0002 \ldots 16rfffe$ represent a proportional saturation level, for instance $16r8000$ denotes a saturation of 0.5.

7. `PROC draw linestyle = (REF FILE file, [] CHAR style) VOID`

   Sets the line style for all lines subsequently drawn on the graphics display. The supported line styles are `"solid"`, `"dotted"`, `"dotdashed"`, `"shortdashed"`, `"longdashed"`, `"dotdotdashed"`, `"dotdotdotdashed"`, and `"disconnected"`. The first seven correspond to the following dash patterns:

```
"solid"           ----------------------
"dotted"          - - - - - - - - -
"dotdashed"       --- - --- - --- -
"shortdashed"     --- --- --- ---
"longdashed"      ----- ----- -----
"dotdotdashed"    --- - - --- - -
"dotdotdotdashed" --- - - - --- - - -
```

   In the preceding patterns, each hyphen stands for one line thickness. This is the case for sufficiently thick lines, at least. So for sufficiently thick lines, the distance

over which a dash pattern repeats is scaled proportionately to the line thickness. The "disconnected" line style is special. A "disconnected" path is rendered as a set of filled circles, each of which has diameter equal to the nominal line thickness. One of these circles is centred on each of the juncture points of the path (i.e., the endpoints of the line segments or arcs from which it is constructed). Circles with "disconnected" line style are invisible. Disconnected circles are not filled. All line styles are supported by all plotters.

8. `PROC draw linewidth = (REF FILE file, REAL thickness) VOID`

   Sets the thickness of all lines subsequently drawn on the graphics display. The value of `thickness` is a fraction $0 \ldots 1$ of the page size in the `y` direction. A negative value resets the thickness to the default. For plotters that produce bitmaps, i.e., X plotters, and pnm plotters, it is zero. By convention, a zero-thickness line is the thinnest line that can be drawn.

11.17.2 Specifying colours

In some versions of `libplot`, pseudo-gif plotters produce garbled graphics when more than 256 different colours are specified. Algol 68 Genie does not work around this problem in `libplot`.

1. ```
   PROC draw background colour =
   (REF FILE file, REAL red, green, blue) VOID

   PROC draw background color =
   (REF FILE file, REAL red, green, blue) VOID
   ```

   Sets the background colour for plotter `file` its graphics display, using fractional intensities in a 48-bit RGB colour model. The arguments `red`, `green` and `blue` specify the red, green and blue intensities of the background colour. Each is a real value in the range $0 \ldots 1$. The choice $0, 0, 0$ signifies black, and the choice $1, 1, 1$ signifies white. This procedure affects only plotters that produce bitmaps, i. e., X plotters and pnm plotters. Its effect is that when the draw erase procedure is called for this plotter, its display will be filled with the specified colour.

2. ```
   PROC draw background colour name =
   (REF FILE file, STRING name) VOID

   PROC draw background color name =
   (REF FILE file, STRING name) VOID
   ```

   Sets the background colour for plotter `file` its graphics display. Argument `name` is a case insensitive string. Accepted names are essentially those supported by the X Window System.

3. `PROC draw colour = (REF FILE file, REAL red, green, blue) VOID`

   `PROC draw color = (REF FILE file, REAL red, green, blue) VOID`

   Sets the foreground colour for plotter `file` its graphics display, using fractional intensities in a 48-bit RGB colour model. The arguments `red`, `green` and `blue` specify the red, green and blue intensities of the background colour. Each is a real value in the range $0 \ldots 1$. The choice $0, 0, 0$ signifies black, and the choice $1, 1, 1$ signifies white.

4. `PROC draw colour name = (REF FILE file, STRING name) VOID`

   `PROC draw color name = (REF FILE file, STRING name) VOID`

   Sets the foreground colour for plotter `file` its graphics display. Argument `name` is a case insensitive string. Accepted names are essentially those supported by the X Window System.

11.17.3 Drawing objects

1. `PROC draw point = (REF FILE file, REAL x, y) VOID`

   The arguments specify the co-ordinates (x, y) of a point that will be drawn. The graphics cursor is moved to (x, y). The values of `x` and `y` are fractions $0 \ldots 1$ of the page size in respectively the `x` and `y` directions.

2. `PROC draw line = (REF FILE file, REAL x, y) VOID`

   The arguments specify the co-ordinates (x, y) of a line that will be drawn starting from the current graphics cursor. The graphics cursor is moved to (x, y). The values of `x` and `y` are fractions $0 \ldots 1$ of the page size in respectively the `x` and `y` directions.

3. `PROC draw rect = (REF FILE file, REAL x, y) VOID`

   The arguments specify the corner coordinates (x, y) of a rectangle that will be drawn starting from the diagonally opposing corner represented by the current graphics cursor. The graphics cursor is moved to (x, y). The values of `x` and `y` are fractions $0 \ldots 1$ of the page size in respectively the `x` and `y` directions.

4. `PROC draw circle = (REF FILE file, REAL x, y, r) VOID`

   The three arguments specifying the centre (x, y) and radius `r` of a circle that is drawn. The graphics cursor is moved to (x, y). The values of `x` and `y` are fractions $0 \ldots 1$ of the page size in respectively the `x` and `y` directions. The value of `r` is a fraction $0 \ldots 1$ of the page size in the `y` direction.

In some versions of `libplot`, X plotters do not flush after every plotting operation. It may happen that a plotting operation does not show until `close` is called for that plotter. After closing, an X plotter window stays on the screen (as a forked process) until you type `"q"`

while it has focus, or click in it. If you click the close-button of such window, you will get an error message like

```
XIO: fatal IO error 11 (Resource temporarily unavailable) on
X server ":0.0" after 198525 requests (198525 known processed) with 0
events remaining.
```

Algol 68 Genie does not work around this buffering mechanism in `libplot`.

Note that `libplot` plots its primitives without applying anti-aliasing. Example 11.17.5 demonstrates how to draw an anti-aliased circle using a method from X. Wu:

11.17.4 Drawing text

1. `PROC draw text =`
   `(REF FILE file, CHAR h justify, v justify, [] CHAR s) VOID`

   The justified string `s` is drawn according to the specified justifications. If `h justify` is equal to `"l"`, `"c"`, or `"r"`, then the string will be drawn with left, centre or right justification, relative to the current graphics cursor position. If `v justify` is equal to `"b"`, `"x"`, `"c"`, or `"t"`, then the bottom, baseline, centre or top of the string will be placed even with the current graphics cursor position. The graphics cursor is moved to the right end of the string if left justification is specified, and to the left end if right justification is specified. The string may contain escape sequences of various sorts {see "Text string format and escape sequences" in the plotutils manual}, though it should not contain line feeds or carriage returns; in fact it should include only printable characters. The string may be plotted at a non-zero angle, if `draw text angle` has been called.

2. `PROC draw text angle = (REF FILE file, INT angle) VOID`

   Argument `angle` specifies the angle in degrees counter clockwise from the `x` (horizontal) axis in the user coordinate system, for text strings subsequently drawn on the graphics display. The default angle is zero. The font for plotting strings is fully specified by calling `draw font name`, `draw font size`, and `draw text angle`.

3. `PROC draw font name = (REF FILE file, [] CHAR name) VOID`

   The case-insensitive string `name` specifies the name of the font to be used for all text strings subsequently drawn on the graphics display. The font for plotting strings is fully specified by calling `draw font name`, `draw font size`, and `draw text angle`. The default font name depends on the type of plotter. It is `"Helvetica"` for X plotters, for pnm it is `"HersheySerif"`. If the argument `name` is NIL or an empty string, or the font is not available, the default font name will be used. Which fonts are available also depends on the type of plotter; for a list of all available fonts {see "Available text fonts" in the plotutils manual}.

4. `PROC draw font size = (REF FILE file, INT size) VOID`

   Argument `size` is interpreted as the size, in the user coordinate system, of the font to be used for all text strings subsequently drawn on the graphics display. A negative value for `size` sets the size to the default, which depends on the type of plotter. Typically, the default font size is $1/50$ times the size (minimum dimension) of the display. The font for plotting strings is fully specified by calling `draw font name`, `draw font size`, and `draw text angle`.

11.17.5 Example. Anti-aliasing in drawing

This example draws an anti-aliased circle using the Wu algorithm.

```
FILE f;
INT resolution = 1000;
open (f, "circle.pnm", stand draw channel);
make device (f, "pnm", whole (resolution, 0) + "x" + whole (resolution, 0));

PROC circle anti aliased = (INT x0, y0, r) VOID:
(# This is the Wu algorithm.#
  REAL rgb r = 0.5, rgb g = .5, rgb b = .5, alpha = 0.6;
  PROC point = (INT x, x0, y, y0) VOID:
    draw point (f, (x + x0) / resolution, (y + y0) / resolution);
    draw point (f, (y + x0) / resolution, (x + y0) / resolution);
    draw point (f, (x0 - x) / resolution, (y + y0) / resolution);
    draw point (f, (x0 - y) / resolution, (x + y0) / resolution);
    draw point (f, (x + x0) / resolution, (-y + y0) / resolution);
    draw point (f, (y + x0) / resolution, (-x + y0) / resolution);
    draw point (f, (x0 - x) / resolution, (-y + y0) / resolution);
    draw point (f, (x0 - y) / resolution, (-x + y0) / resolution)
  );
  FOR x FROM 0 TO r
  WHILE REAL y = sqrt (r * r - x * x);
    INT y1 = ENTIER y;
    x <= y
  DO IF y1 = y
    THEN draw colour (f, alpha * rgb r, alpha * rgb g, alpha * rgb b);
      point (x, x0, y1, y0)
    ELSE REAL d0 = ABS (y1 - y) * alpha;
      draw colour (f, d0 * rgb r, d0 * rgb g, d0 * rgb b);
      point (x, x0, y1 + 1, y0)
    FI;
    FOR y2 FROM y1 DOWNTO 0
    DO REAL d = (1 - alpha) * sqrt (r * r - x * x - y2 * y2) / r + alpha;
      draw colour (f, d * rgb r, d * rgb g, d * rgb b);
      point (x, x0, y2, y0)
    OD
```

```
  OD
);

circle anti aliased (resolution % 2, resolution % 2, resolution % 3);
close (f)
```

11.18 Linux extensions

`a68g` maps to Linux as to provide basic means with which a **program** can

1. access command line arguments,
2. access directory - and file information,
3. access environment variables,
4. access system error information,
5. start child processes and communicate with them by means of pipes. `a68g` transput procedures as `getf` or `putf` operate on pipes,
6. send a request to a HTTP server, fetch web page contents, and match regular expressions in a string.

11.19 Miscellaneous definitions

1. `MODE PIPE = STRUCT (REF FILE read, write, INT pid)`
   Used to set up communication between processes. See for instance `execve child pipe`.
2. `PROC utc time = [] INT`
   Returns UTC calendar time, or an empty row if the function fails. Respective array elements are year, month, day, hours, minutes, seconds, day of week and daylight-saving-time flag.
3. `PROC local time = [] INT`
   Returns local calendar time, or an empty row if the function fails. Respective array elements are year, month, day, hours, minutes, seconds, day of week and daylight-saving-time flag.
4. `PROC argc = INT`
   Returns the number of command-line arguments consistent with procedure `argv`.

5. `PROC argv = (INT k) STRING`
   Returns command-line argument `k` or an empty string when `k` is not valid. It is comparable to the C routine `argv`, but note that the first argument has index $k = 1$, and not for example $k = 0$ as in the C language. The first argument will be the name of the interpreter, typically `a68g` preceeded by a path name.

6. `PROC a68g argc = INT`
   Returns the number of command-line arguments consistent with procedure `a68g argv`. See the procedure `a68g argv` to understand which arguments are considered command-line arguments.

7. `PROC a68g argv = (INT k) STRING`
   Returns command-line argument `k` or an empty string when `k` is not valid. Note that the first argument has index $k = 1$, and not for example $k = 0$ as in the C language. The first argument will be the name of the interpreter, typically `a68g` preceeded by a path name. If the program is not run as a script, next arguments $k > 1$ are the ones following the options **--** or **--exit**. If the program is run as a script, next arguments $k > 1$ are the ones following the filename of the script on the command-line.

8. `PROC rows = INT`
   Returns the number of rows in the current terminal.

9. `PROC columns = INT`
   Returns the number of columns in the current terminal.

10. `PROC get env = (STRING var) STRING`
    Returns the value of environment variable `var`.

For accessing system error information through `errno` next routines are available:

1. `PROC reset errno = VOID`
   Resets the global error variable `errno`.

2. `PROC errno = INT` Returns the global error variable `errno`.

3. `PROC strerror = (INT errno) STRING`
   Returns a string describing the error code passed as `errno`.

11.19.1 File system

1. `PROC file is block device = (STRING file) BOOL`
   Returns whether `file` is a block device. If the file does not exists or if an error occurs, `FALSE` is returned and `errno` is set.

2. `PROC file is char device = (STRING file) BOOL`
   Returns whether `file` is a character device. If the file does not exists or if an error occurs, `FALSE` is returned and `errno` is set.

3. `PROC file is directory = (STRING file) BOOL`
   Returns whether `file` is a directory. If the file does not exists or if an error occurs, `FALSE` is returned and `errno` is set.

4. `PROC file is regular = (STRING file) BOOL`
   Returns whether `file` is a regular file. If the file does not exists or if an error occurs, `FALSE` is returned and `errno` is set.

5. `PROC file is fifo = (STRING file) BOOL`
   Returns whether `file` is a first-in-first-out file, for instance a pipe. If the file does not exists or if an error occurs, `FALSE` is returned and `errno` is set.

6. `PROC file is link = (STRING file) BOOL`
   Returns whether `file` is a first-in-first-out file, for instance a pipe. If the file does not exists or if an error occurs, `FALSE` is returned and `errno` is set.

7. `PROC file mode = (STRING file) BITS`
   Yields file mode of file `file`. If the file does not exists or if an error occurs, `2r0` is returned and `errno` is set.

8. `PROC get pwd = STRING`
   Returns the current working directory.

9. `PROC set pwd = (STRING dir) INT`
   Sets the current working directory to `dir`, which must be a valid directory name.

10. `PROC get directory = (STRING dir) [] STRING`
    Retrieves the file names from directory `dir`, which must be a valid directory name. Note that the order of entries in the returned `[] STRING` is arbitrary. Example:

```
PROC ls = (STRING dir name) VOID:
  IF is directory (dir name)
  THEN printf (($lg$, SORT get directory (dir name)))
  ELSE print (("'", dir name, "' is not a directory"))
  FI
```

11. `PROC abend = (STRING error) VOID`

    Issues at the call a runtime error with text *error*.

12. `PROC L bits pack = ([] BOOL a) L BITS`
    This routine packs `a` into a value of mode `L BITS`. In case `a` has more elements than `L bits width`, a runtime error occurs. In case `a` has less elements than `L bits width`, the result will be aligned to the right and be padded with `F` bits to the left. For example:

```
$ a68g -p "bitspack ((TRUE, FALSE, TRUE, TRUE, FALSE))"
FFFFFFFFFFFFFFFFFFFFFFFFFFFFTFTTF
```

Only when `a` has `L bits width` elements, this relation holds:

```
a[i] = i ELEM L bits pack (a)
```

13. `PROC L bytes pack = (STRING text) L BYTES`

    This routine converts `text` to a `L BYTES` representation. In case `text` has more elements than `L bytes width`, a runtime error occurs. In case the argument has less elements than `L bytes width`, the result is padded with `null char`s. The result of the routine is such that this relation holds:

    ```
    text[i] = i ELEM L bytes pack (text)
    ```

14. `PROC char in string = (CHAR c, REF INT p, STRING t) BOOL`

    If found, assigns position (counting from `LWB t`) of first occurrence of `c` in `t` to `p` if `p` is not `NIL`. Returns whether `c` is found.

15. `PROC last char in string = (CHAR c, REF INT p, STRING t) BOOL`

    If found, assigns position (counting from `LWB t`) of last occurrence of `c` in text to `p` if `p` is not `NIL`. Returns whether `c` is found.

16. `PROC string in string = (STRING c, REF INT p, STRING t) BOOL`

    If found, assigns position (counting from `LWB t`) of first occurrence of `c` in `t` to `p` if `p` is not `NIL`. Returns whether `c` is found.

17. `OP SORT = ([] STRING row) [] STRING`

    Yields a copy of `row`, with elements sorted in ascending order. `SORT` employs a quick-sort algorithm.

18. `PROC is alnum = (CHAR c) BOOL`

    Checks whether `c` is an alphanumeric character; it is equivalent to:

    ```
    is alpha (c) OR is digit (c)
    ```

19. `PROC is alpha = (CHAR c) BOOL`

    Checks whether `c` is an alphabetic character; it is equivalent to:

    ```
    is upper (c) OR is lower (c)
    ```

    In some locales, there may be additional characters for which this routine holds.

20. `PROC is cntrl = (CHAR c) BOOL`

    Checks whether `c` is a control character.

21. `PROC is digit = (CHAR c) BOOL`

    Checks whether `c` is a digit (0 through 9).

22. `PROC is graph = (CHAR c) BOOL`

    Checks whether `c` is a printable character except space

23. `PROC is lower = (CHAR c) BOOL`

    Checks whether `c` is a lower-case character.

24. `PROC is print = (CHAR c) BOOL`

    Checks whether `c` is a printable character including space.

25. `PROC is punct = (CHAR c) BOOL`

    Checks whether `c` is a printable character which is not a space or an alphanumeric character.

26. `PROC is space = (CHAR c) BOOL`

    Checks whether `c` is white-space characters. In the C and POSIX locales, these are space, form-feed, newline, carriage return, horizontal tab, and vertical tab.

27. `PROC is upper = (CHAR c) BOOL`

    Checks whether c is an upper-case letter.

28. `PROC is xdigit = (CHAR c) BOOL`

    Checks whether `c` is a hexadecimal digit, that is, one of $0123456789abcdefABCDEF$.

29. `PROC to lower = (CHAR c) CHAR`

    Converts the letter `c` to lower-case, if possible.

30. `PROC to upper = (CHAR c) CHAR`

    Converts the letter c to upper-case, if possible.

31. `PROC system = (STRING command) INT`

    Passes the string command to the operating system for execution. The operating system is expected to return an integral value that will be returned by system.

32. `PROC break = VOID`

    Raises SIGINT, after which `a68g` will stop in its monitor routine. The monitor may be entered on a **unit** executed after the actual **call** to break; see details on breakpoints. To enter the monitor immediately, call `debug` or `monitor`.

33. `PROC debug = VOID`
    `PROC monitor = VOID`

    `a68g` will stop in its monitor routine immediately.

34. `PROC evaluate = (STRING expression) STRING`

    Evaluate expression in the monitor and returning the resulting value as a string.

35. `PROC program idf = STRING`

    Returns the name of the source file.

36. `PROC seconds = REAL`
    `PROC clock = REAL`
    `PROC cpu time = REAL`

    Return process time in seconds since interpreter started. This is different from elapsed wall clock time.

37. `PROC wall seconds = REAL`
    `PROC wall clock = REAL`
    `PROC wall time = REAL`

    On Linux systems, return elapsed wall clock time in seconds since interpreter started.

38. `PROC sweep heap = VOID`
    `PROC gc heap = VOID`

    Invokes the garbage collector immediately. Sometimes Algol 68 Genie cannot sweep the heap when memory is required, for instance when copying stowed objects. In rare occasions this may lead to a **program** running out of memory. Calling this routine just before the position where the **program** ran out of memory might help to keep it running. Otherwise (or, alternatively) a larger heap size should be given to the **program**.

39. `PROC preemptive sweep = VOID`
    `PROC preemptive sweep heap = VOID`
    `PROC preemptive gc = VOID`
    `PROC preemptive gc heap = VOID`

    Invokes the garbage collector if the heap is "sufficiently full". Sometimes Algol 68 Genie cannot sweep the heap when memory is required, for instance when copying stowed objects. In rare occasions this may lead to a **program** running out of memory. Calling this routine just before the position where the **program** ran out of memory might help to keep it running. Otherwise (or, alternatively) a larger heap size should be given to the **program**.

40. `PROC on gc event = (PROC VOID f) VOID`

    Calls *f* when a successful garbage collection is completed. Under circumstances the garbage collector cannot sweep the heap. Such idle sweep will be counted, but *f* will not be invoked to avoid possible infinite recursion.

41. `PROC garbage = LONG INT`

    Returns the number of bytes recovered by the garbage collector.

42. `PROC collections = INT`

    Returns the number of times the garbage collector was invoked.

43. `PROC collect seconds = REAL`

    Returns an estimate of the time used by the garbage collector.

44. `PROC system stack size = INT`

    Returns the size of the system stack.

45. `PROC system stack pointer = INT`

    Returns the (approximate) value of the system stack pointer.

46. `PROC stack pointer = INT`

    Returns the value of the evaluation stack pointer. (Note: this is an Algol 68 stack, not the system stack)

11.19.2 Processes

1. `PROC fork = INT`
   Creates a child process that differs from the parent process only in its `PID` and `PPID`, and that resource utilisations are set to zero. File locks and pending signals are not inherited. Under Linux, fork is implemented using copy-on-write pages, so the only penalty incurred by fork is the time and memory required to duplicate the parent's page tables, and to create a unique task structure for the child. On success, the `PID` of the child process is returned in the parent's thread of execution, and a `0` is returned in the child's thread of execution. On failure, a -1 will be returned in the parent's context, no child process will be created, and `errno` will be set appropriately.

2. `PROC wait pid = (INT pid) INT`
   Waits until child process `pid` ends. Returns the process ID of the child `pid` whose status has been reported. If no child has exited `0` is returned. If an error occurs, -1 is returned.

3. `PROC execve =`
   `(STRING filename, [] STRING argv, [] STRING envp) INT`
   Executes `filename` that must be either a binary executable, or a script starting with a line of the form:

   ```
   #! interpreter [argv]
   ```

   In the latter case, *interpreter* must a valid path-name for an executable which is not itself a script, which will be invoked as `interpreter [arg] filename`. Argument `argv` is a row of argument strings that is passed to the new program. Argument `envp` is a row of strings, with elements conventionally of the form `KEY=VALUE`, which are

passed as environment to the new program. The argument vector and environment can be accessed by the called program's `main` function, when it is defined as:

```
int main (int argc, char *argv[], char *envp[])
```

The procedure does not return on success, and the text, data, bss, and stack of the calling process are overwritten by that of the program loaded. The program invoked inherits the calling process's `PID`, and any open file descriptors that are not set to close on exec. Signals pending on the calling process are cleared. Any signals set to be caught by the calling process are reset to their default behaviour. The `SIGCHLD` signal (when set to `SIG_IGN`) may or may not be reset to `SIG_DFL`.

4. `PROC execve child = (STRING filename, [] STRING argv, [] STRING envp) INT`
   Executes a command in a child process. Algol 68 Genie is not superseded by the new process. For details on arguments see `execve`.

5. `PROC execve output = (STRING filename, [] STRING argv, [] STRING envp, REF STRING output) INT`
   Executes a command in a child process. Algol 68 Genie is not superseded by the new process. For details on arguments see `execve`. Output written to `stdout` by the child process is collected in a string which is assigned to `output` unless `output` is `NIL`. The routine yields the return code of the child process on success or -1 on failure. Next code fragment shows how to execute a command in the shell and retrieve output from both `stdout` and `stderr`:

```
PROC get output = (STRING cmd) VOID:
  IF STRING sh cmd = " " + cmd + " ;  2>&1";
    STRING output;
    execve output ("/bin/sh", ("sh", "-c", sh cmd),
      "", output) >= 0
  THEN print (output)
  FI;


get output ("ps | grep a68g")
```

6. `PROC execve child pipe = (STRING filename, [] STRING argv, [] STRING envp) PIPE`
   Executes a command in a child process. Algol 68 Genie is not superseded by the new process. For details on arguments see `execve`. The child process redirects standard input and standard output to the pipe that is delivered to the parent process. Therefore, the parent can write to the `write` field of the pipe, and this data can be read by the child from standard input. The child can write to standard output, and this data can be read by the parent process from the `read` field of the pipe. The files in the pipe are opened. The channels assigned to the read - and write end of the pipe are `standin channel` and `standout channel`, respectively. This procedure calls

`execve` in the child process, for a description of the arguments refer to that procedure. For example:

```
PROC eop handler = (REF FILE f) BOOL:
  BEGIN put (stand error, ("end of pipe", new line));
    GO TO end
  END;

PIPE p = execve child pipe ("/bin/cat", ("cat", program idf), "");

IF pid OF p < 0
THEN put (stand error, ("pipe not valid: ", strerror (errno)));
  stop
FI;

on logical file end (read OF p, eop handler);

DO STRING line;
  get (read OF p, (line, newline));
  put (stand out, ("From pipe: """, line, """", newline))
OD;

end:
close (read OF p);
close (write OF p)
```

11.19.3 Fetching web page contents

1. `PROC https content = (REF STRING content, STRING domain, STRING path, INT port) INT`
   Gets content from web page specified by `domain` and `path`, and stores it in `content`. Both `domain` and `path` must be properly `MIME` encoded. The routine connects to server `domain` using CURL. The `port` parameter is currently not used. The procedure returns `0` on success or an appropriate number indicating status otherwise. For example:

   ```
   STRING reply;
   https content (reply, "www.gnu.org", "/index.html", 0);
   print ((reply, new line))
   ```

   prints the contents from `https://www.gnu.org/index.html`.

2. `PROC https time out = (INT connect time, transfer time) VOID`
   Set time limits for connecting to, and transferring data from, a web site. Values are in seconds.

Next legacy routines are kept for backward compatibility.

1. `PROC http content =`
   `(REF STRING content, STRING domain, STRING path, INT port) INT`
   Gets content from web page specified by `domain` and `path`, and stores it in `content`. Both `domain` and `path` must be properly `MIME` encoded. The routine connects to server `domain` using TCP and sends a straightforward `GET` request for `path` using HTTP 1.0, and reads the reply from the server. If port number `port` is 0 the default port number (80) will be used. The procedure returns 0 on success or an appropriate number indicating status otherwise. For example:

```
PROC good page = (REF STRING page) BOOL:
  IF grep in string ("^HTTP/[0-9.]* 200", page, NIL, NIL) = 0
  THEN TRUE
  ELSE IF INT start, end;
      grep in string ("^HTTP/[0-9.]* [0-9]+ [a-zA-Z ]*", page,
        start, end) = 0
    THEN print (page[start : end])
    ELSE print ("unknown error retrieving page")
    FI;
    FALSE
  FI;

IF STRING reply;
  INT rc =
    http content (reply, "www.gnu.org", "/", 0);
  rc = 0 AND good page (reply)
THEN print (reply)
ELSE print (strerror (rc))
FI
```

2. `PROC http time out = (INT connect time, transfer time) VOID`
   Set time limits for connecting to, and transferring data from, a web site. Values are in seconds.

11.20 Regular expressions in string manipulation

1. `PROC grep in string =`
   `(STRING pattern, string, REF INT start, end) INT`

Matches `pattern` with `string` and assigns first character position (counting from `LWB string`) and last character position of the widest leftmost matching sub string to `start` and `end` when they are not `NIL`. The routine yields `0` on match, `1` on no-match, `2` on out-of-memory error and `3` on other errors. If the string contains `newline character`, it is considered as end-of-line ("$") and the following character is considered as start-of-line ("^"). Compare this function with AWK function `match`.

2. `PROC grep in substring =`
   `(STRING pattern, string, REF INT start, end) INT`
   As `grep in string`, but does not match the start-of-line meta-character "^".

3. `PROC sub in string =`
   `(STRING pattern, replacement, REF STRING string) INT`
   Matches `pattern` with `string` and replaces the widest leftmost matching sub string with
   `replacement`. The routine yields `0` on match, `1` on no-match, `2` on out-of-memory error and `3` on other errors. If the string contains `newline character`, it is considered as end-of-line ("$") and the following character is considered as start-of-line ("^"). Compare this function with AWK function `sub`.

`grep in string`, `grep in substring` and `sub in string` employ extended POSIX syntax for regular expressions. Traditional Unix regular expression syntax is obsoleted by POSIX (but is still widely used for the purposes of backwards compatibility). POSIX extended regular expressions are similar to traditional Unix regular expressions. Most characters are treated as literals that match themselves: "a" matches "a", "(bc" matches "(bc", et cetera. Meta characters "(", ")", "[", "]", "", "", ".", "*", "?", "+", "^" and "$" are used as special symbols that have to be marked by a preceding "ẅhen they are to be matched literally.

11.20.1 Definition of meta characters

1. .
   Matches any single character.

2. `*`
   Matches the preceding expression zero or more times. For example, "[xyz]*" matches "", "x", "y", "zx", "zyx", and so on.

3. `+`
   Matches the preceding expression one or more times - "ba+" matches "ba", "baa", "baaa" et cetera.

4. `?`
   Matches the preceding expression zero or one times - "ba?" matches "b" or "ba".

5. `{x, y }` Matches the preceding expression at least `x` and not more than `y` times. For example, "a{3, 5 }" matches "aaa", "aaaa" or "aaaaa". Note that this is not implemented on all platforms.

6. `|`
The choice (or set union) operator: match either the expression before or the expression after the operator - "abc|def" matches "abc" or "def".

7. `[ ]`
Matches characters that contained within [ ]. For example, [abc] matches "a", "b", or "c", and [a-z] matches any lower-case letter. These can be mixed: [abcq-z] matches a, b, c, q, r, s, t, u, v, w, x, y, z, and so does [a-cq-z]. A "-" character is a literal only if it is the first or last character within the brackets: [abc-] or [-abc]. To match an "[" or "]" character, put the closing bracket first in the enclosing square brackets: [][ab] matches "]", "[", "a" or "b".

8. `[^]`
Matches a single character that is not contained within [ ]. For example, [^abc] matches any character other than "a", "b", or "c". [^a-z] matches any single character that is not a lower-case letter. As with [ ], these can be mixed.

9. `^`
Matches start of the line.

10. `$`
Matches end of the line.

11. `( )`
Matches a sub-expression. A sub-expression followed by "*" is invalid on most platforms.

Since many ranges of characters depend on the chosen locale setting (e.g., in some settings letters are organised as `abc ... yzABC ... YZ` while in some others as `aAbBcC ... yYzZ`) the POSIX standard defines categories of characters as shown in the following table:

Category	Compare to	Matches
`[:upper:]`	`[A-Z]`	Upper-case letters
`[:lower:]`	`[a-z]`	Lower-case letters
`[:alpha:]`	`[A-Za-z]`	Upper- and lower-case letters
`[:alnum:]`	`[A-Za-z0-9]`	Digits, upper- and lower-case letters
`[:digit:]`	`[0-9]`	Digits
`[:xdigit:]`	`[0-9A-Fa-f]`	Hexadecimal digits
`[:punct:]`	`[.,!?:...]`	Punctuation marks
`[:blank:]`	`[ \t ]`	Space and Tab
`[:space:]`	`[ \t \n \r \f \v]`	Typographical display features
`[:cntrl:]`	—	Control characters
`[:graph:]`	`[^ \t \n \r \f \v]`	Printed characters
`[:print:]`	`[^ \t \n \r \f \v]`	Printed characters and space

Examples:

1. `".at"` matches any three-character string ending with `at`,
2. `"[hc]at"` matches `hat` and `cat`,
3. `"[^]at"` matches any three-character string ending with `at` and not beginning with `b`,
4. `"^[hc]at"` matches `hat` and `cat` but only at the beginning of a line,
5. `"[hc]at$"` matches `hat` and `cat` but only at the end of a line,
6. `"[hc]+at"` matches with "hat", "cat", "hhat", "chat", "hcat", "ccchat" et cetera,
7. `"[hc]?at"` matches "hat", "cat" and "at",
8. `"([cC]at)([dD]og)"|` matches "cat", "Cat", "dog" and "Dog",
9. `[[:upper:]ab]` matches upper-case letters and "a", "b".

11.21 Curses support

On systems that have installed the curses library, and most systems do, `a68g` can link with that library to extend the standard prelude. Curses support is very basic.

1. `PROC curses start = VOID`
   Starts curses support.
2. `PROC curses end = VOID`
   Stops curses support.

3. `PROC curses clear = VOID`
   Clears the screen.

4. `PROC curses refresh = VOID`
   Refreshes the screen (by writing all changes since the last **call** to this routine).

5. `PROC curses getchar = CHAR`
   Check if a key was pressed on the keyboard. If so, the routine returns the corresponding character, if not, on Unix it returns `null char`.

6. `PROC curses putchar = (CHAR ch) VOID`
   Writes `ch` at the current cursor position, and advances the cursor. If the advance is at the right margin, the cursor automatically wraps to the beginning of the next line. If the next line is off the screen, a runtime error occurs.

7. `PROC curses move = (INT line, column) VOID`
   Sets the cursor position to `line` and `column`. A runtime error occurs if you move the cursor off screen.

8. `PROC curses lines = INT`
   This function returns the number of lines on the screen. The line numbers on the screen are $0 \ldots curses\ lines - 1$. A runtime error occurs if you move the cursor off screen.

9. `PROC curses columns = INT`
   This function returns the number of columns on the screen. The column numbers on the screen are $0 \ldots curses\ columns - 1$. A runtime error occurs if you move the cursor off screen.

11.22 PostgreSQL support

PostgreSQL (https://www.postgresql.org) is an object-relational database management system (ORDBMS) based on POSTGRES, Version 4.2, developed at the University of California at Berkeley computer science Department. PostgreSQL is an open source descendant of this original Berkeley code. It supports a large part of the SQL standard and offers many modern features. PostgreSQL uses a client/server model. A PostgreSQL session consists of the following cooperating processes (programs)

1. A server process, which manages the database files, accepts connections to the database from client applications, and performs actions on the database on behalf of the clients. The database server program is called postmaster.

2. The user's client (front-end) application that wants to perform database operations. Client applications can be very diverse in nature: a client could be a text-oriented

tool, a graphical application, a web server that accesses the database to display web pages, or a specialised database maintenance tool.

As is typical of client/server applications, the client and the server can be on different hosts. In that case they communicate over a TCP/IP network connection. You should keep this in mind, because the files that can be accessed on a client machine might not be accessible (or might only be accessible using a different file name) on the database server machine.

The PostgreSQL server can handle multiple concurrent connections from clients. For that purpose it starts ("forks") a new process for each connection. From that point on, the client and the new server process communicate without intervention by the original postmaster process. Thus, the postmaster is always running, waiting for client connections, whereas client and associated server processes come and go.

The routines in this section enable basic client interactions from Algol 68 with a PostgreSQL back end server. These routines allow client programs to pass queries to a PostgreSQL back end server and to receive the results of these queries.

Algol 68 Genie uses `libpq`, the C application programmer's interface to PostgreSQL (version 8.1.4 or compatible). The `libpq` library is also used in other PostgreSQL application interfaces, including those for C++, Perl, Python, Tcl and ECPG. An example application is in 11.22.5.

Connection to a database server is established through a `REF FILE` variable. String results are communicated through a `REF STRING` buffer that is associated with the `REF FILE` variable upon establishing a connection with a PostgreSQL server. This allows for easy mode conversion of text-formatted data from tables using `get`. Currently, Algol 68 Genie does not support retrieving data in binary format.

Next routines return 0 or positive on success, -1 when no connection was established, -2 when no result was available, or -3 on other errors.

11.22.1 Connecting to a server

1. `PROC pq connect db =`
   `(REF FILE f, STRING conninfo, REF STRING buffer) INT`
   Connect to a PostgreSQL back end server and open a new database connection in a way specified by `conninfo`, associate the connection with file `f` and associate `buffer` with file `f`.

   The passed string can be empty to use all default parameters, or it can contain one or more parameter settings separated by white space. Each parameter setting is in the form keyword = value. Spaces around the equal **sign** are optional. To write an empty value or a value containing spaces, surround it with single quotes, e.g., keyword =

'a value'. Single quotes and backslashes within the value must be escaped with a backslash, i.e., `\'` and `\\`.

The currently recognised parameter keywords are:

`host`
Name of host to connect to. If this begins with a slash, it specifies Unix-domain communication rather than TCP/IP communication; the value is the name of the directory in which the socket file is stored. The default behaviour when host is not specified is to connect to a Unix-domain socket in /tmp (or whatever socket directory was specified when PostgreSQL was built). On machines without Unix-domain sockets, the default is to connect to localhost.

`hostaddr`
Numeric IP address of host to connect to. This should be in the standard IPv4 address format, e.g., `172.28.40.9`. If your machine supports IPv6, you can also use those addresses. TCP/IP communication is always used when a non-empty string is specified for this parameter. Using hostaddr instead of host allows the application to avoid a host name look-up, which may be important in applications with time constraints. However, Kerberos authentication requires the host name. The following therefore applies: If host is specified without hostaddr, a host name lookup occurs. If hostaddr is specified without host, the value for hostaddr gives the remote address. When Kerberos is used, a reverse name query occurs to obtain the host name for Kerberos. If both host and hostaddr are specified, the value for hostaddr gives the remote address; the value for host is ignored, unless Kerberos is used, in which case that value is used for Kerberos authentication. (Note that authentication is likely to fail if `libpq` is passed a host name that is not the name of the machine at hostaddr.) Also, host rather than hostaddr is used to identify the connection in `/.pgpass`. Without either a host name or host address, `libpq` will connect using a local Unix-domain socket; or on machines without Unix-domain sockets, it will attempt to connect to localhost.

`port`
Port number to connect to at the server host, or socket file name extension for Unix-domain connections.

`dbname`
The database name. Defaults to be the same as the user name.

`user`
PostgreSQL user name to connect as. Defaults to be the same as the operating system name of the user running the application.

`password`
Password to be used if the server demands password authentication.

`connect_timeout`
Maximum wait for connection, in seconds (write as a decimal integer string). Zero or

not specified means wait indefinitely. It is not recommended to use a time-out of less than 2 seconds.

options
Command-line options to be sent to the server.

sslmode
This option determines whether or with what priority an SSL connection will be negotiated with the server. There are four modes: disable will attempt only an unencrypted SSL connection; allow will negotiate, trying first a non-SSL connection, then if that fails, trying an SSL connection; prefer (the default) will negotiate, trying first an SSL connection, then if that fails, trying a regular non-SSL connection; require will try only an SSL connection. If PostgreSQL is compiled without SSL support, using option require will cause an error, while options allow and prefer will be accepted but libpq will not in fact attempt an SSL connection.

requiressl
This option is deprecated in favour of the sslmode setting. If set to 1, an SSL connection to the server is required (this is equivalent to sslmode require). libpq will then refuse to connect if the server does not accept an SSL connection. If set to 0 (default), libpq will negotiate the connection type with the server (equivalent to sslmode prefer). This option is only available if PostgreSQL is compiled with SSL support.

krbsrvname
Kerberos service name to use when authenticating with Kerberos 5. This must match the service name specified in the server configuration for Kerberos authentication to succeed.

service
Service name to use for additional parameters. It specifies a service name in
pg_service.conf
that holds additional connection parameters. This allows applications to specify only a service name so connection parameters can be centrally maintained. See
share/pg_service.conf.sample
in the installation directory for information on how to set up the file. If any parameter is unspecified, then the corresponding environment variable is checked. If the environment variable is not set either, then the indicated built-in defaults are used. The following environment variables can be used to select default connection parameter values, which will be used by PQconnectdb if no value is directly specified by the calling code. These are useful to avoid hard-coding database connection information into simple client applications, for example.

PGHOST
PGHOST sets the database server name. If this begins with a slash, it specifies Unix-domain communication rather than TCP/IP communication; the value is then the name of the directory in which the socket file is stored (in a default installation setup this would be /tmp).

PGHOSTADDR
PGHOSTADDR specifies the numeric IP address of the database server. This can be set instead of or in addition to PGHOST to avoid DNS lookup overhead. See the documentation of these parameters, under PQconnectdb above, for details on their interaction. When neither PGHOST nor PGHOSTADDR is set, the default behaviour is to connect using a local Unix-domain socket; or on machines without Unix-domain sockets, libpq will attempt to connect to localhost.

PGPORT
PGPORT sets the TCP port number or Unix-domain socket file extension for communicating with the PostgreSQL server.

PGDATABASE
PGDATABASE sets the PostgreSQL database name.

PGUSER
PGUSER sets the user name used to connect to the database.

PGPASSWORD
PGPASSWORD sets the password used if the server demands password authentication. Use of this environment variable is not recommended for security reasons (some operating systems allow non-root users to see process environment variables via ps); instead consider using the /.pgpass file.

PGPASSFILE
PGPASSFILE specifies the name of the password file to use for lookups. If not set, it defaults to /.pgpass.

PGSERVICE
PGSERVICE sets the service name to be looked up in pg_service.conf. This offers a shorthand way of setting all the parameters.

PGREALM
PGREALM sets the Kerberos realm to use with PostgreSQL, if it is different from the local realm. If PGREALM is set, libpq applications will attempt authentication with servers for this realm and use separate ticket files to avoid conflicts with local ticket files. This environment variable is only used if Kerberos authentication is selected by the server.

PGOPTIONS
PGOPTIONS sets additional run-time options for the PostgreSQL server.

PGSSLMODE
PGSSLMODE determines whether and with what priority an SSL connection will be negotiated with the server. There are four modes: disable will attempt only an unencrypted SSL connection; allow will negotiate, trying first a non-SSL connection, then if that fails, trying an SSL connection; prefer (the default) will negotiate, trying first an SSL connection, then if that fails, trying a regular non-SSL connection; require will try only an SSL connection. If PostgreSQL is compiled without SSL support, us-

ing option require will cause an error, while options allow and prefer will be accepted but libpq will not in fact attempt an SSL connection.

PGREQUIRESSL
PGREQUIRESSL sets whether or not the connection must be made over SSL. If set to 1, libpq will refuse to connect if the server does not accept an SSL connection (equivalent to sslmode prefer). This option is deprecated in favour of the sslmode setting, and is only available if PostgreSQL is compiled with SSL support.

PGKRBSRVNAME
PGKRBSRVNAME sets the Kerberos service name to use when authenticating with Kerberos 5.

PGCONNECT_TIMEOUT
PGCONNECT_TIMEOUT sets the maximum number of seconds that libpq will wait when attempting to connect to the PostgreSQL server. If unset or set to zero, libpq will wait indefinitely. It is not recommended to set the time-out to less than 2 seconds.

2. PROC pq finish = (REF FILE f) INT
Closes the connection to the server. Also frees memory used. Note that even if the server connection attempt fails, the application should call pq finish to free memory used. The connection must not be used again after pq finish has been called.

3. PROC pq reset = (REF FILE f) INT
Resets the communication channel to the server. This function will close the connection to the server and attempt to re-establish a new connection to the same server, using all the same parameters previously used. This may be useful for error recovery if a working connection is lost.

4. PROC pq parameter status = (REF FILE f, STRING parameter) INT
Assigns current parameter value to the string associated with f. Certain parameter values are reported by the server automatically at connection start-up or whenever their values change. pq parameter status can be used to interrogate these settings. It returns the current value of a parameter if known, or an empty string if the parameter is not known.

Parameters reported as of the current release include
server_version,
server_encoding,
client_encoding,
is_superuser,
session_authorization,
DateStyle,
TimeZone,
integer_datetimes, and
standard_conforming_strings.

Note that
server_version,

`server_encoding` and
`integer_datetimes`
cannot change after start-up.

Pre-3.0-protocol servers do not report parameter settings, but `libpq` includes logic to obtain values for `server_version` and `client_encoding` anyway. Note that on a pre-3.0 connection, changing `client_encoding` via `SET` after connection start-up will not be reflected by `pq parameter status`.

If no value for `standard_conforming_strings` is reported, applications may assume it is `false`, that is, backslashes are treated as escapes in string literals. Also, the presence of this parameter may be taken as an indication that the escape string syntax (`E'...'`) is accepted.

11.22.2 Sending queries and retrieving results

1. `PROC pq exec = (REF FILE f, STRING query) INT`
   Submits a command to the server and waits for the result. A zero result will generally be returned except in out-of-memory conditions or serious errors such as inability to send the command to the server. If a zero result is returned, it should be treated like a fatal error. Use `pq error message` to get more information about such errors.

   It is allowed to include multiple SQL commands (separated by **semicolon-symbols**) in the command string. Multiple queries sent in a single `pq exec` call are processed in a single transaction, unless there are explicit BEGIN/COMMIT commands included in the query string to divide it into multiple transactions. Note however that the returned PGresult structure describes only the result of the last command executed from the string. Should one of the commands fail, processing of the string stops with it and the returned PGresult describes the error condition.

2. `PROC pq ntuples = (REF FILE f) INT`
   Returns the number of rows (tuples) in the query result.

3. `PROC pq nfields = (REF FILE f) INT`
   Returns the number of columns (fields) in each row of the query result.

4. `PROC pq fname = (REF FILE f, INT index) INT`
   Returns the column name associated with the given column number. Column numbers start at `1` (which deviates from the `libpq` convention, where `0` subscripts the first element).

5. `PROC pq fnumber = (REF FILE f, INT index) INT`
   Returns the column number associated with the given column name. Column numbers start at `1` (which deviates from the `libpq` convention, where `0` subscripts the first element). The given name is treated like an **identifier** in an SQL command, that is, it is down-cased unless quoted.

6. `PROC pq fformat = (REF FILE f, INT index) INT`
   Returns the format code indicating the format of the given column. Column numbers start at `1` (which deviates from the `libpq` convention, where `0` subscripts the first element). Format code zero indicates textual data representation, while format code one indicates binary representation. (Other codes are reserved for future definition.) Column numbers start at `1` (which deviates from the `libpq` convention, where `0` subscripts the first element).

7. `PROC pq get is null = (REF FILE f, INT row, column) INT`
   Tests a field for a null value. Row and column numbers start at `1` (which deviates from the `libpq` convention, where `0` subscripts the first element). This function returns `1` if the field is null and `0` if it contains a non-null value.

8. `PROC pq get value = (REF FILE f, INT row, column) INT`
   Assigns a single field value (in text format) of one row to the string associated with `f`. Row and column numbers start at `1` (which deviates from the `libpq` convention, where `0` subscripts the first element).

   Currently, `pq get value` does not support retrieving data in binary format.

   An empty string is returned if the field value is null.

   File `f` is reset, hence after a **call** to `pq get value`, conversion of text data to other data types than row-of-character can be easily accomplished using `get`.

9. `PROC pq cmd status = (REF FILE f) INT`
   Assigns the command status tag of the last SQL command sent to `f` to the string associated with `f`. Commonly this is just the name of the command, but it may include additional data such as the number of rows processed.

10. `PROC pq cmd tuples = (REF FILE f) INT`
    Assigns the number of rows affected by the last SQL command sent to `f` to the string associated with `f`, following the execution of an `INSERT`, `UPDATE`, `DELETE`, `MOVE`, or `FETCH` phrase.

11.22.3 Connection status information

1. `PROC pq error message = (REF FILE f) INT`
   Assigns the error message most recently generated by an operation on the connection to the string associated with `f`.

2. `PROC pq result error message = (REF FILE f) INT`
   Assigns the error message associated with the command (or an empty string if there was no error) to the string associated with `f`. Immediately following a `pq exec call`, `pq error message` (on the connection) will return the same string as `pq result error message` (on the result). However, a query result will retain its error

message until destroyed, whereas the connection's error message will change when subsequent operations are done.

3. `PROC pq db = (REF FILE f) INT`
   Assigns the database name of the connection to the string associated with `f`.

4. `PROC pq user = (REF FILE f) INT`
   Assigns the user name of the connection to the string associated with `f`.

5. `PROC pq pass (REF FILE f) INT`
   Assigns the password of the connection to the string associated with `f`.

6. `PROC pq host = (REF FILE f) INT`
   Assigns the server host name to the string associated with `f`.

7. `PROC pq port = (REF FILE f) INT`
   Assigns the port of the connection to the string associated with `f`.

8. `PROC pq options = (REF FILE f) INT`
   Assigns the command-line options passed in the connection request to the string associated with `f`.

9. `PROC pq protocol version = (REF FILE f) INT`
   Returns the front-end/back-end protocol being used. Applications may wish to use this to determine whether certain features are supported. Currently, the possible values are 2 (2.0 protocol), 3 (3.0 protocol), or zero (connection bad). This will not change after connection start-up is complete, but it could theoretically change during a connection reset. The 3.0 protocol will normally be used when communicating with PostgreSQL 7.4 or later servers; pre-7.4 servers support only protocol 2.0. (Protocol 1.0 is obsolete and not supported by libpq.)

10. `PROC pq server version = (REF FILE f) INT`
    Returns an integer representing the back end version. Applications may use this to determine the version of the database server they are connected to. The number is formed by converting the major, minor, and revision numbers into two-decimal-digit numbers and appending them together. For example, version 7.4.2 will be returned as 70402, and version 8.1 will be returned as 80100 (leading zeroes are not shown). Zero is returned if the connection is bad

11. `PROC pq socket = (REF FILE f) INT`
    Obtains the file descriptor number of the connection socket to the server. A valid descriptor will be greater than or equal to 0; a result of -1 indicates that no server connection is currently open. (This will not change during normal operation, but could change during connection set-up or reset.)

12. `PROC pq back end pid = (REF FILE f) INT`
    Returns the process ID (PID) of the backed server process handling this connection.

The back end PID is useful for debugging purposes and for comparison to NOTIFY messages (which include the PID of the notifying back end process). Note that the PID belongs to a process executing on the database server host, `not` the local host.

11.22.4 Behaviour in threaded programs

`libpq` is re-entrant and thread-safe if the configure command-line option

`--enable-thread-safety`

was used when the PostgreSQL distribution was built.

One restriction is that no two threads attempt to manipulate the same PGconn object at the same time. In particular, one cannot issue concurrent commands from different threads through the same connection object. If you need to run concurrent commands, use multiple connections. PGresult objects are read-only after creation, and so can be passed around freely between threads.

In Algol 68 Genie, this means that in a parallel-clause, two concurrent **units** should not manipulate a same `FILE` variable that is used to hold a connection to a database. Use multiple `FILE` variables to set up multiple connections.

For more information please refer to the PostgreSQL documentation.

11.22.5 Example. Accessing a PostgreSQL database

This example assumes a database `mydb` owned by postgres user `marcel` and a table `weather` constructed following the example in the PostgreSQL 8.1 manual, chapter 2.

```
FILE z; # Holds the connection #
STRING str; # The string associated with 'z' to do IO with the server #


# Connect to the server #
IF pq connectdb (z, "dbname=mydb user=marcel", str)  = 0
THEN print ((pq result error message (z); str));
  exit
ELSE printf (($"protocol="g (0)x"server="g (0)x"socket="g (0)x"pid="g (0)l$,
  pq protocol version (z),
  pq server version (z),
  pq socket (z),
  pq back end pid (z)))
FI;

# Get the complete table #
IF pq exec (z, "SELECT * FROM weather")  = 0
```

```
THEN print ((pq result error message (z); str));
  exit
FI;

printf (($"tuples="g (0)x"fields="g (0)l$,
  pq ntuples (z), pq nfields (z)));

# Print column names #
FOR i TO pq nfields (z)
DO IF pq fname (z, i) = 0
  THEN print ((str, blank))
  FI
OD;
newline (standout);

# Print row entries #
FOR i TO pq ntuples (z)
DO FOR k TO pq nfields (z)
  DO IF pq getisnull (z, i, k)  = 0
    THEN print ("(null)")
    ELIF pq getvalue (z, i, k) = 0
    THEN print ((str, blank))
    ELSE print ("error")
    FI
  OD;
  newline (standout)
OD;

# Print average high temperature, convert mode as a demo #
IF pq exec (z, "SELECT avg (temp_hi) FROM weather")  = 0
THEN print ((pq result error message (z); str));
  exit
FI;
printf (($"tuples="g (0)x"fields="g (0)/$, pq ntuples (z), pq nfields (z)));
IF pq getisnull (z, 1, 1)  = 0
THEN print ("(null)")
ELIF pq getvalue (z, 1, 1) = 0
THEN print ((REAL avg temp hi; get (z, avg temp hi); avg temp hi))
ELSE print ("error")
FI;

# Close connection to the server #
exit:
pq finish (z)
```

11.23 PCM Sounds

Algol 68 Genie has basic support for manipulating sounds. In a68g, SOUND values can be generated, read and written and the sampled sound data can be accessed and altered. One can for example write an application to concatenate sound files, or to filter a sound using Fourier transforms {11.23.4}. Currently Algol 68 Genie supports linearly encoded PCM (for example used for CD audio). Should you wish to manipulate sound data in another format, then one option is to convert formats using a tool as for instance *SoX*.

11.23.1 Data structure and routines

a68g allows the **declaration** of values of mode SOUND that will contain a sound. The standard prelude contains a **declaration**:

```
MODE SOUND = STRUCT ( ... );
```

with structured fields that cannot be directly accessed. The actual sample data is stored in the heap. a68g takes care of proper copying of sample data in case of assignation of SOUND values, or manipulation of stowed objects containing SOUND values, et cetera. Currently next routines are declared for values of mode SOUND:

1. `PROC new sound = (INT resolution, rate, channels, samples) SOUND`

   Returns a sound value where resolution is the number of bits per sample (8, 16, ...), rate is the sample rate, channels is the number of channels (1 for mono, 2 for stereo) and samples is the number of samples per channel.

2. `OP RESOLUTION = (SOUND s) INT`

   Returns the number of bits in a sample of s.

3. `OP CHANNELS = (SOUND s) INT`

   Returns the number of channels of s.

4. `OP RATE = (SOUND s) INT`

   Returns the sample rate (as samples per second per channel) of s. Common values are 8000, 11025, 22050 or 44100.

5. `OP SAMPLES = (SOUND s) INT`

   Returns the number of samples per channel of s.

6. `PROC get sound = (SOUND s, INT channel, sample) INT`

   Returns the sample indexed by channel and sample of s. Note that under RIFF, samples with size up to 8 bits are normally unsigned while samples of larger size are signed.

7. `PROC set sound = (SOUND s, INT channel, sample, value) INT`

Sets the sample indexed by `channel` and `sample` of `s` to `value`. Note that under RIFF, samples with size up to `8` bits are normally unsigned while samples of larger size are signed.

11.23.2 Transput of Sound values

`SOUND` values can be read and written using standard prelude transput routines. Formatted transput of `SOUND` values is undefined. Currently, Algol 68 Genie supports transput of files according to the RIFF PCM/WAVE format specification. Note that chunks other than `WAVE`, `fmt` or `data` are stripped upon reading, and do not appear upon writing.

An example of transput of a `SOUND` value is:

```
SOUND s;
FILE in, out;
open (in, "source.wav", standback channel);
open (out, "destination.wav", standback channel);
get bin (in, s);
put bin (out, s);
close (in);
close (out);
```

11.23.3 Playing sounds

Playing a sound depends on actual hardware details of a platform. Therefore, Algol 68 Genie does not have a standard procedure to play `SOUND` values. It is however possible to write a procedure to play a sound in Algol 68 Genie, making use of its extensions to print to pipes and to fork, as is demonstrated in next example that makes a `SOUND` value to be played by the `play` program that comes with *SoX*:

```
PR heap=256M PR # ... to play BIG audio tracks #
PROC play sound = (SOUND s) VOID:
  IF PIPE p = execve child pipe ("/usr/bin/play",
      ("play", "-t", "wav", "-q", "-"), "");
    pid OF p < 0
  THEN put (stand error, ("pipe not valid: ", strerror (errno)));
  ELSE put (write OF p, s); # put must wait for play to empty pipe #
    close (read OF p);
    close (write OF p)
  FI;

print ("File: ");
STRING name = read string;
open (standin, name + ".wav", standin channel);
```

```
SOUND s;
read (s);
close (standin);
play sound (s)
```

11.23.4 Example. Filter for Sound values

Next application demonstrates how to program applications manipulating sound values. This particular example filters a sound by Fourier-transformation using routines described in section 11.23:

```
COMMENT
Band-pass filter for a sound file on a second-per-second basis using FFT.
Limitations:
(1) sound duration must be a whole number of seconds
(2) sample rate must be even
COMMENT

# Get the sound file #
SOUND w, FILE in, out;
print ((newline, "File: "));
STRING fn = read string;
open (in, fn + ".wav", standback channel);
get bin (in, w);
close (in);
print ((newline, "rate=", RATE w));
print ((newline, "samples=", SAMPLES w));
print ((newline, "bits=", RESOLUTION w));
print ((newline, "channels=", CHANNELS w));
INT secs = SAMPLES w OVER RATE w;
print ((newline, "duration=", secs));
# If next number is large, FFT is inefficient #
print ((newline, "prime factors=", UPB prime factors (RATE w)));
# Get filter parameters #
print ((newline, "low frequency: "));
REAL low f = read real;
print ((newline, "high frequency: "));
REAL high f = read real;
# Apply a band filter.
Not the most efficient code, but obvious #
FOR i TO secs
DO print ((newline, i, collections, garbage));
  FOR j TO CHANNELS w
  DO # Get data for this second #
```

```
    [RATE w] REAL samples;
    FOR k TO RATE w
    DO samples[k] := get sound (w, j, (i - 1) * RATE w + k)
    OD;
    # Forward transform to determine spectrum #
    [RATE w] COMPLEX spectrum := fft forward (samples);
    # Apply filter.
      Simplifications apply since the FFT is over one second,
      hence N*dt=1 and the frequencies are whole numbers #
    FOR m TO RATE w OVER 2 + 1
    DO # f2 is the corresponding negative frequency with f1 #
      INT f1 = m, f2 = (f1 = 1 | 1 | RATE w - f1 + 2);
      IF f1 < low f OR f1 > high f
      THEN spectrum[f1] := spectrum[f2] := 0
      FI
    OD;
    # Restore sample data for this second #
    samples := fft inverse (spectrum);
    FOR k TO RATE w
    DO set sound (w, j, (i - 1) * RATE w + k, ENTIER samples[k])
    OD
  OD
OD;
# Put the filtered sound file #
open (out, fn + ".fft.wav", standback channel);
put bin (out, w);
close (out)
```

III

Example Algol 68 programs

12 Example programs

12.1 Hamming numbers

Hamming numbers are of the form $2^i \times 3^j \times 5^k$. This program generates them in a trivial iterative way but keeps the series needed to generate the numbers as short as possible using flexible rows; on the downside, it spends considerable time on garbage collection.

```
PR precision=100 PR
MODE SERIES = FLEX [1 : 0] UNT; # Initially, no elements #
MODE UNT = LONG LONG INT; # A 100-digit unsigned integer #
OP LAST = (SERIES h) UNT: h[UPB h]; # Last element of a series #

PROC hamming number = (INT n) UNT: # The n-th Hamming number #
  CASE n
  IN 1, 2, 3, 4, 5, 6, 8, 9, 10, 12 # First 10 in a table #
  OUT SERIES h := 1, # Series, initially one element #
    UNT m2 := 2, m3 := 3, m5 := 5, # Multipliers #
    INT i := 1, j := 1, k := 1; # Counters #
    TO n - 1
    DO OP MIN = (INT i, j) INT: (i < j | i | j),
      MIN = (UNT i, j) UNT: (i < j | i | j);
      PRIO MIN = 9;
      OP +:= = (REF SERIES s, UNT elem) VOID:
        # Extend a series by one element, only keep the elements you need #
        (INT lwb = i MIN j MIN k, upb = UPB s;
        REF SERIES new s = NEW FLEX [lwb : upb + 1] UNT;
        (new s[lwb : upb] := s[lwb : upb], new s[upb + 1] := elem);
        s := new s
        );
      # Determine the n-th hamming number iteratively #
      h +:= m2 MIN m3 MIN m5;
      (LAST h = m2 | m2 := 2 * h[i +:= 1]);
      (LAST h = m3 | m3 := 3 * h[j +:= 1]);
      (LAST h = m5 | m5 := 5 * h[k +:= 1])
    OD;
    LAST h
  ESAC;
```

```
FOR k TO 20
DO print ((whole (hamming number (k), 0), blank))
OD;
print ((newline, whole (hamming number (1 691), 0)));
print ((newline, whole (hamming number (1 000 000), 0)))
```

Sample output:

```
1 2 3 4 5 6 8 9 10 12 15 16 18 20 24 25 27 30 32 36
2125764000
519312780448388736089589843750000000000000000000000000000000000000000000000
000000000
```

12.2 Roman numbers

The Roman numeral system is decimal but not positional and is related to the Etruscan number system. The letters derive from earlier non-alphabetical symbols.

```
BEGIN # Conversion decimal to Roman notation #
  OP ROMAN = (INT number) STRING:
    BEGIN INT n:= number, STRING sum,
      [] STRUCT (INT value, STRING r) table =
        ((1000, "M"), (900, "CM"), (500, "D"), (400, "CD"),
        (100, "C"), (90, "XC"), (50, "L"), (40, "XL"),
        (10, "X"), (9, "IX"), (5, "V"), (4, "IV"), (1, "I"));
      FOR i TO UPB table
      DO INT v = value OF table[i], STRING r = r OF table[i];
        WHILE v <= n
        DO (sum +:= r, n -:= v)
        OD
      OD;
      sum
    END,
  OP DECIMAL = (STRING text) INT:
    IF ELEMS text = 0
    THEN 0
    ELSE
      OP ABS = (CHAR s) INT:
        CASE INT p;
          VOID (char in string (s, p, "IVXLCDM"));
          p
        IN 1, 5, 10, 50, 100, 500, 1000
        ESAC,
```

```
      INT v, maxv := 0, maxp;
      FOR p TO UPB text
      DO IF (v := ABS text[p]) > maxv
        THEN maxp := p;
          maxv := v
        FI
      OD;
      maxv - DECIMAL text[: maxp - 1] + DECIMAL text[maxp + 1:]
    FI;
  print(ROMAN 1968); # MCMLXVIII #
  print(DECIMAL "MMXIII") # 2013 #
END
```

12.3 Hilbert matrix using fractions

In linear algebra, a Hilbert matrix is a square matrix having unit fraction entries:

$$H_{ij} = \frac{1}{i+j-1}$$

Hilbert matrices are canonical examples of ill-conditioned matrices, making them notoriously difficult to use in numerical computation. In this example we tackle these difficulties by using multi-precision fractions to calculate the exact determinant of Hilbert matrices.

```
COMMENT
An application for multi-precision LONG LONG INT.
A fraction has positive denominator; the nominator holds the sign.
COMMENT

MODE FRAC = STRUCT (NUM nom, den), NUM = LONG LONG INT;
OP N = (FRAC u) NUM: nom OF u,
  D = (FRAC u) NUM: den OF u;
FRAC zero = 0 DIV 1, one = 1 DIV 1;

PR precision=101 PR # NUM can hold a googol! #

OP DIV = (NUM n, d) FRAC:
  IF d = 0
  THEN print ("Zero denominator"); stop
  ELSE NUM gcd = ABS n GCD ABS d;
    (SIGN n * SIGN d * ABS n OVER gcd, ABS d OVER gcd)
  FI;

OP DIV = (INT n, d) FRAC: NUM (n) DIV NUM (d);
PRIO DIV = 2;

OP GCD = (NUM a, b) NUM:
  IF b = 0
```

```
  THEN ABS a
  ELSE b GCD (a MOD b)
  FI;
PRIO GCD = 8;

# Basic operators for fractions. #


OP - = (FRAC u) FRAC: - N u DIV D u;
OP + = (FRAC u, v) FRAC:
  N u * D v + N v * D u DIV D u * D v;
OP - = (FRAC u, v) FRAC: u + - v;
OP * = (FRAC u, v) FRAC: N u * N v DIV D u * D v;
OP / = (FRAC u, v) FRAC: u * (D v DIV N v);
OP +:= = (REF FRAC u, FRAC v) REF FRAC: u := u + v;
OP -:= = (REF FRAC u, FRAC v) REF FRAC: u := u - v;
OP *:= = (REF FRAC u, FRAC v) REF FRAC: u := u * v;
OP /:= = (REF FRAC u, FRAC v) REF FRAC: u := u / v;
OP = = (FRAC u, v) BOOL: N u = N v ANDF D u = D v;
OP /= = (FRAC u, v) BOOL: NOT (u = v);

# Matrix algebra. #
OP INNER = ([] FRAC u, v) FRAC:
  # Inner product of two arrays of rationals #
  BEGIN FRAC s := zero;
    FOR i TO UPB u
    DO s +:= u[i] * v[i]
    OD;
    s
  END;
PRIO INNER = 8;

PROC lu decomposition = (REF [, ] FRAC a, REF [] INT p) VOID:
  # LU-decomposition cf. Crout, of a matrix of rationals. #
  BEGIN INT n = 1 UPB a;
    FOR k TO n
    DO FRAC piv := zero, INT k1 := k - 1;
      REF INT pk = p[k];
      REF [] FRAC aik = a[, k], aki = a[k,];
      FOR i FROM k TO n
      DO aik[i] -:= a[i, 1 : k1] INNER aik[1 : k1];
        IF piv = zero
        THEF aik[i] /= zero
        THEN piv := aik[i];
          pk := i
        FI
      OD;
      IF piv = zero
      THEN print ((new line, "Singular matrix")); stop
      FI;
```

```
      IF pk /= k
      THEN FOR i TO n
        DO FRAC r = aki[i];
          aki[i] := a[pk, i];
          a[pk, i] := -r
        OD
      FI;
      FOR i FROM k + 1 TO n
      DO aki[i] -:=
        aki[1 : k1] INNER a[1 : k1, i] /:= piv
      OD
    OD
  END;

PROC determinant = ([, ] FRAC a) FRAC:
  # Determinant of a decomposed matrix is its trace. #
  BEGIN FRAC d := one;
    FOR i TO 1 UPB a
    DO d *:= a[i, i]
    OD;
    d
  END;

# Table of required results. #
[] NUM table = BEGIN
  1,
  12,
  2 160,
  6 048 000,
  266 716 800 000,
  186 313 420 339 200 000,
  2 067 909 047 925 770 649 600 000,
  365 356 847 125 734 485 878 112 256 000 000,
  1 028 781 784 378 569 697 887 052 962 909 388 800 000 000
  46 206 893 947 914 691 316 295 628 839 036 278 726 983 680 000 000 000
END;

# Compute determinant of Hilbert matrix of increasing rank. #
FOR n TO UPB table
DO [1 : n, 1 : n] FRAC a;
  FOR i TO n
  DO a[i, i] := 1 DIV 2 * i - 1;
    FOR j FROM i + 1 TO n
    DO a[i, j] := a[j, i] := 1 DIV i + j - 1
    OD
  OD;
  lu decomposition (a, LOC [1 : n] INT);
  FRAC det = determinant (a);
  print (("Rank ", whole (n, 0), ", determinant ",
```

```
    whole (N det, 0), " / ", whole (D det, 0),
    IF N det = 1 AND D det = table[n]
    THEN ", ok"
    ELSE ", not ok"
    FI, new line))
OD
```

12.4 Parallel sieve of Erathostenes

This is a gratuitously parallel implementation of the sieve of Eratosthenes after a program contributed by Lawrence D'Oliveiro; the number of primes it can output is limited only by the number of threads `a68g` can create.

```
MODE SIEVER = STRUCT (SEMA full, empty, REF INT n);
PROC make siever = SIEVER: (LEVEL 0, LEVEL 1, NEW INT);

PROC start siever = (SIEVER s, INT n) VOID:
  (n MOD 2 /= 0 | DOWN empty OF s; n OF s := n; UP full OF s);

PROC next unmarked = (SIEVER s) INT:
  (DOWN full OF s; INT n = n OF s; UP empty OF s; n);

PROC sieve = (SIEVER current) VOID:
  (INT n = next unmarked (current);
  print ((whole (n, -int width), new line));
  SIEVER new = make siever;
  PAR (
    DO IF INT i = next unmarked (current);
      i MOD n /= 0
      THEN start siever (new, i)
      FI
    OD,
    sieve (new)
  )
);

SIEVER first = make siever;
INT n := 1;

PAR (DO n PLUSAB 1; start siever (first, n) OD, sieve (first))
```

12.5 Mastermind code breaker

Mastermind is a simple code-breaking board game for two players. The modern game with coloured pegs was devised in 1970 but the game resembles an earlier pencil and paper game called *bulls and cows* that may date back a century or more. The program guesses the pattern you think of, in both order and color. It demonstrates the use of a flexible row. Peg colour is replaced by a small integral value. After each guess, you rate the score with a series of "w"s and "b"s stating how many pegs are of the right colour, and also how many pegs are in the correct position.

```
# This breaks a code of 'pegs' unique digits that you think of. #
INT pegs = 4, max digit = 6;

MODE LIST = FLEX [1 : 0] COMBINATION,
  COMBINATION = [pegs] DIGIT,
  DIGIT = INT;

OP +:= = (REF LIST u, COMBINATION v) REF LIST:
  # Add one combination to a list. #
  (sweep heap;
  [UPB u + 1] COMBINATION w;
  w[: UPB u] := u;
  w[UPB w] := v;
  u := w
  );

PROC gen = (REF COMBINATION part, INT peg) VOID:
  # Generate all unique [max digit!/(max digit-pegs)!] combinations. #
  IF peg > pegs
  THEN all combs +:= part
  ELSE FOR i TO max digit
    DO IF BOOL unique := TRUE;
        FOR j TO peg - 1 WHILE unique
        DO unique := part[j]  = i
        OD;
        unique
      THEN part[peg] := i;
        gen (part, peg + 1)
      FI
    OD
  FI;

LIST all combs;
gen (LOC COMBINATION, 1);

PROC break code = (LIST sieved) VOID:
  # Present a trial and sieve the list with entered score. #
  CASE UPB sieved + 1
  IN printf ($"Inconsistent scores"$),
```

```
    printf (($"Solution is "4(d)$, sieved[1]))
  OUT printf (($g (0), " solutions in set; Guess is "4(d)": "$,
    UPB sieved, sieved[1]));
    # Read the score as a sequence of "w" and "b" #
    INT col ok := 0, pos ok := 0, STRING z := "";
    WHILE z = ""
    DO read ((z, new line))
    OD;
    FOR i TO UPB z
    DO (z[i] = "w" | col ok |: z[i] = "b" | pos ok) +:= 1
    OD;
    (pos ok = pegs | stop);
    # Survivors are combinations with score as entered. #
    LIST survivors;
    FOR i FROM 2 TO UPB sieved
    DO INT col ok i := 0, pos ok i := 0;
      FOR u TO pegs
      DO FOR v TO pegs
        DO IF sieved[1][u] = sieved[i][v]
          THEN (u = v | pos ok i | col ok i) +:= 1
          FI
        OD
      OD;
      IF col ok = col ok i AND pos ok = pos ok i
      THEN survivors +:= sieved[i]
      FI
    OD;
    break code (survivors)
  ESAC;

printf (($"This breaks a unique code of ", g (0),
  " digits in range 1 ... ", g (0),
  " that you think of.", 2l,
  "Enter score as a series of w (hite) and b (lack)", l,
  "for instance www, wbw or bbbb.", 2l
  $, pegs, max digit));

break code (all combs)
```

12.6 Decision tree

This program builds a library of objects together with a question distinguishing each object, while it guesses an object you have in mind using that library. This was a popular programming exercise among students in the 1980's.

```
ENTRY library := get reply ("give an initial object");
DO guess object (library);
```

```
  UNTIL NOT ask ("again")
OD;

# Data structure and access operators #
MODE ENTRY = UNION (STRING, FORK),
  FORK = STRUCT (STRING text, REF ENTRY has, hasnt);

OP TEXT = (FORK d) STRING: text OF d,
  HAS = (FORK d) REF ENTRY: has OF d,
  HASNT = (FORK d) REF ENTRY: hasnt OF d;
PROC new fork = (STRING text, ENTRY has, hasnt) FORK:
  (HEAP STRING := text, HEAP ENTRY := has, HEAP ENTRY := hasnt);

# Guessing and extending library #

PROC guess object = (REF ENTRY sub lib) VOID:
  # How to guess an object #
  CASE sub lib
  IN (STRING s): (ask (s) | SKIP | sub lib := learn (s)),
    (FORK d): guess object ((ask (TEXT d) | HAS d | HASNT d))
  ESAC;

PROC learn = (STRING guess) ENTRY:
  # Introduce new entry in library #
  IF STRING object = get reply ("what is the object"),
      question = get reply ("give a question to distinguish "
        + object);
    ask ("does " + question + " apply to " + object)
  THEN new fork (question, object, guess)
  ELSE new fork (question, guess, object)
  FI;

# Interaction #


PROC get reply = (STRING prompt) STRING:
  BEGIN STRING s;
    printf (($gl$, prompt));
    readf (($gl$, s));
    s
  END;

PROC ask = (STRING question) BOOL:
  IF STRING s = get reply (question);
    UPB s > 0
  THEN s[1] = "y" ORF s[1] = "Y"
  ELSE ask (question)
  FI;

SKIP
```

12.7 Peano curve

This is the complete algorithm as discussed in 5.7.2. This program writes instructions to draw a Hilbert curve (a particular Peano curve) from a picture-environment in LaTeX.

```
INT points = 384;

PROC draw member = (INT n) VOID:
  BEGIN INT d = points OVER (2 ^ n);
    MODE POINT = STRUCT (INT x, y);
    POINT origin := (d OVER 2, d OVER 2);
    print (("\begin{picture}(", whole (points, 0), ", ",
      whole(points, 0), ")", newline));
    go right (n);
    print (("\end{picture}"));

    PROC line to = (POINT end) VOID:
      (POINT vector = (x OF end - x OF origin, y OF end - y OF origin);
      print (("\put (", whole (x OF origin, 0), ", ",
        whole (y OF origin, 0), ")",
        "\line (", whole (SIGN x OF vector, 0), ", ",
        whole (SIGN y OF vector, 0), ")",
        whole (ENTIER sqrt (x OF vector ^ 2 +
        y OF vector ^ 2), 0), "", newline));
      origin := end
      );

    PROC go up = (INT n) VOID:
      IF n > 0
      THEN go right (n - 1);
        line to ((x OF origin + d, y OF origin));
        go up (n - 1);
        line to ((x OF origin, y OF origin + d));
        go up (n - 1);
        line to ((x OF origin - d, y OF origin));
        go left (n - 1)
      FI;

    PROC go down = (INT n) VOID:
      IF n > 0
      THEN go left (n - 1);
        line to ((x OF origin - d, y OF origin));
        go down (n - 1);
        line to ((x OF origin, y OF origin - d));
        go down (n - 1);
        line to ((x OF origin + d, y OF origin));
        go right (n - 1)
      FI;

    PROC go left = (INT n) VOID:
```

```
      IF n > 0
      THEN go down (n - 1);
        line to ((x OF origin, y OF origin - d));
        go left (n - 1);
        line to ((x OF origin - d, y OF origin));
        go left (n - 1);
        line to ((x OF origin, y OF origin + d));
        go up (n - 1)
      FI;

    PROC go right = (INT n) VOID:
      IF n > 0
      THEN go up (n - 1);
        line to ((x OF origin, y OF origin + d));
        go right (n - 1);
        line to ((x OF origin + d, y OF origin));
        go right (n - 1);
        line to ((x OF origin, y OF origin - d));
        go down (n - 1)
      FI;
    SKIP
  END;

draw member (5)
```

12.8 Fibonacci grammar

This example computes Fibonacci numbers by counting the number of derivations of the "Fibonacci grammar":

```
  fib: "a"; "a", fib; "aa", fib.
```

The purpose for this is to illustrate the use of procedure closures which we call continuations. We use this to generate a recursive descent with backup parser following a simple translation from grammar rules to procedures. This program was contributed by Eric Voss and simplified by Erwin Koning.

```
MODE CONT = PROC (INT) VOID;

PROC grammar fib = (INT i, CONT q) VOID:
  BEGIN terminal (i, "a", q);
    terminal (i, "a", (INT j) VOID: grammar fib (j, q));
    terminal (i, "aa", (INT j) VOID: grammar fib (j, q))
  END;

PROC terminal = (INT i, STRING a, CONT q) VOID:
  IF INT u = i + UPB a;
    u <= UPB sentence
```

```
  THEN q (u)
  FI;

STRING sentence;
FOR k TO 10
DO sentence := k * "a";
  INT nr derivations := 0;
  grammar fib (0, (INT j) VOID: (j = UPB sentence | nr derivations +:= 1));
  print (("Fibonacci number ", UPB sentence, " = ", nr derivations,
    new line))
OD
```

IV

Revised report on Algol 68

Revised Report on the Algorithmic Language

Algol 68

Edited by
A. van Wijngaarden, B.J. Mailloux, J.E.L. Peck, C.H.A. Koster,
M. Sintzoff, C.H. Lindsey, L.G.T. Meertens and R.G. Fisker

The Revised Report on Algol 68 has been previously published as:

- Mathematical Centre Tracts **50** Mathematisch Centrum Amsterdam [1976].
- Acta Informatica **5** 1-236 [1976].
- SIGPLAN Notices **12**(5) 1-70 [1977].
- Springer-Verlag, ISBN 3-540-07592-5, ISBN 0-387-07592-5 [1976].

13

About this translation

This is a translation {16_1.1.5} of the Algol 68 Revised Report into LaTeX, for distribution with Algol 68 Genie, an open source Algol 68 compiler-interpreter. Many people are (still) interested in an Algol 68 implementation; hence it is expected that there are also people interested in having access to the formal defining document, the Algol 68 Revised Report, which is since long out of print. It is believed that this LaTeX translation may well meet this need and enable people to study the formal description of Algol 68. The Revised Report ranks among the difficult publications in computer science, and section 1.3 in Part I of this publication may serve as a brief introduction for readers unfamiliar with this report.

Since the translation is a part of *Learning Algol 68 Genie*, chapter numbering differs from that of the original report and therefore cross-references have also been renumbered. Chapter numbers in cross-references are appended with the corresponding chapter number in the original Revised Report: for instance 25_9.4.d refers to chapter 25 in this translation, but to chapter 9 in the original Revised Report. In cross-referencing {16_1.1.3.4.f} a final 1 is omitted as is done in the original Revised Report, but since LaTeX does not support 10 to appear as A in cross-references, the substitution of 10 for A is not maintained in this translation, and points are not omitted as to improve legibility of cross-references. For instance, a cross-reference {A341A} in the original Revised Report will appear as {26_{10}.3.4.1.A} in this translation.

Lay-out may differ in places from that of the original publication. The name *ALGOL 68* was replaced by *Algol 68* since the latter is the preferred way of writing the name these days. Code examples in this translation adopt upper-stropping for bold symbols since this has been the predominant notation in actual Algol 68 programming over the years; for instance the **bold-begin-symbol** {16_1.3.3.d} is typeset as `BEGIN` in this translation. This translation contains comments which are not part of the original text and are contained in footnotes, for instance errata from ALGOL BULLETIN as well as a-posteriori comments or -remarks.

14 Acknowledgments

{Habent sua fata libelli.
De litteris. Terentianus Maurus. }

Working Group 2.1 on ALGOL of the International Federation for Information Processing has discussed the development of "Algol X", a successor to Algol 60 [3] since 1963. At its meeting in Princeton in May 1965, WG 2.1 invited written descriptions of the language based on the previous discussions. At the meeting in St Pierre de Chartreuse near Grenoble in October 1965, three reports describing more or less complete languages were amongst the contributions, by Niklaus Wirth [8], Gerhard Seegmüller [6], and Aad van Wijngaarden [9]. In [6] and [8], the descriptional technique of [3] was used, whereas [9] featured a new technique for language design and definition. Other significant contributions available were papers by Tony Hoare [2] and Peter Naur [4, 5].

At subsequent meetings between April 1966 and December 1968, held in Kootwijk near Amsterdam, Warsaw, Zandvoort near Amsterdam, Tirrenia near Pisa and North Berwick near Edinburgh, a number of successive approximations to a final report, commencing with [10] and followed by a series numbered MR 88, MR 92, MR 93, MR 95, MR 99 and MR 100, were submitted by a team working in Amsterdam, consisting first of A. van Wijngaarden and Barry Mailloux, later reinforced by John Peck, and finally by Kees Koster. Versions were used during courses on the language held at various centres, and the experience gained in explaining the language to skilled audiences and the reactions of the students influenced the succeeding versions. The final version, MR 101 [11], was adopted by the Working Group on December 20^{th} 1968 in Munich, and was subsequently approved for publication by the General Assembly of IFIP. Since that time, it has been published in Numerische Mathematik [12], and translations have been made into Russian [13], into German [14], into French [15], and into Bulgarian [16]. An "Informal Introduction", for the benefit of the uninitiated reader, was also prepared at the request of the Working Group [18].

The original authors acknowledged with pleasure and thanks the wholehearted cooperation, support, interest, criticism and violent objections from members of WG 2.1 and many other people interested in Algol. At the risk of embarrassing omissions, special mention should be made of Jan Garwick, Jack Merner, Peter Ingerman and Manfred Paul for [1], the Brussels group consisting of M. Sintzoff, P. Branquart, J. Lewi and P. Wodon for numerous brainstorms, A.J.M. van Gils of Apeldoorn, G. Goos and his group at Munich, also

for [7], G.S. Tseytin of Leningrad, and L.G.L.T. Meertens and J.W. de Bakker of Amsterdam. An occasional choice of a, not inherently meaningful, identifier in the sequel may compensate for not mentioning more names in this section.

Since the publication of the Original Report, much discussion has taken place in the Working Group concerning the further development of the language. This has been influenced by the experience of many people who saw disadvantages in the original proposals and suggested revised or extended features. Amongst these must be mentioned especially: I.R. Currie, Susan G. Bond, J.D. Morison and D. Jenkins of Malvern (see in [17]), in whose dialect of Algol 68 many features of this Revision may already be found; P. Branquart, J.P. Cardinael and J. Lewi of Brussels, who exposed many weaknesses (see in [17]); Ursula Hill, H. Woessner and H. Scheidig of Munich, who discovered some unpleasant consequences: the contributors to the Rapport d'Evaluation [19]: and the many people who served on the Working Group subcommittees on Maintenance and Improvements (convened by M. Sintzoff) and on Transput (convened by C.H. Lindsey). During the later stages of the revision, much helpful advice was given by H. Boom of Edmonton, W. Freeman of York, W.J. Hansen of Vancouver, Mary Zosel of Livermore, N. Yoneda of Tokyo, M. Rain of Trondheim, L. Ammeraal, D. Grune, H. van Vliet and R. van Vliet of Amsterdam, G. van der Mey of Delft, and A.A. Baehrs and A.F. Rar of Novosibirsk. The editors of this revision also wish to acknowledge that the wholehearted cooperation, support, interest, criticism and violent objections on the part of the members of WG 2.1 have continued unabated during this time.

[1] J.V. Garwick, J.M. Merner, P.Z. Ingerman and M. Paul, Report of the ALGOL-X - I-O Subcommittee, WG 2.1 Working Paper, July 1966.

[2] C.A.R. Hoare, Record Handling, WG 2.1 Working Paper, October 1965; also AB.21.3.6. November 1965.

[3] P. Naur (Editor), Revised report on the Algorithmic Language ALGOL 60, Regnecentralen, Copenhagen, 1962, and elsewhere.

[4] P. Naur, Proposals for a new language, AB.18.3.9, October 1964.

[5] P. Naur, Proposals for introduction on aims, WG 2.1 Working Paper, October 1965.

[6] G. Seegmüller, A proposal for a basis for a Report on a Successor to ALGOL 60. Bavarian Acad. Sci., Munich, October 1965.

[7] G. Goos, H. Scheidig, G. Seegmueller and H. Walther, Another proposal for ALGOL 67. Bavarian Acad. Sci., Munich, May 1967.

[8] N. Wirth, A Proposal for a Report on a Successor of ALGOL 60, Mathematisch Centrum, Amsterdam, MR 75, October 1965.

[9] A. van Wijngaarden, Orthogonal Design and Description of a Formal Language, Mathematisch Centrum, Amsterdam, MR 76, October 1965.

[10] A. van Wijngaarden and B.J. Mailloux, A Draft Proposal for the Algorithmic Language ALGOL X, WG 2.1 Working Paper, October 1966.

[11] A. van Wijngaarden (Editor), B.J. Mailloux, J.E.L. Peck and C.H.A. Koster, Report on the Algorithmic Language ALGOL 68, Mathematisch Centrum. Amsterdam, MR 101, February 1969.

[12] idem, Numerische Mathematik, Vol. 14, pp. 79-218. 1969.

[13] Soobshchenie ob algoritmicheskom yazyke ALGOL 68, translation into Russian by A.A. Baehrs, A.P. Ershov, L.L. Zmievskaya and A.F. Rar. Kybernetica, Kiev, Part 6 of 1969 and Part 1 of 1970.

[14] Bericht ueber die Algorithmische Sprache ALGOL 68, translation into German by I.O. Kerner, Akademie-Verlag, Berlin, 1972.

[15] Définition du Langage Algorithmique ALGOL 68, translation into French by J. Buffet, P. Arnal, A. Quéré (Eds.), Hermann, Paris, 1972.

[16] Algoritmichniyat yezik ALGOL 68, translation into Bulgarian by D. Toshkov and St. Buchvarov, Nauka i Yzkustvo, Sofia, 1971.

[17] J.E.L. Peck (Ed.), ALGOL 68 Implementation (proceedings of the IFIP working conference held in Munich in 1970), North Holland Publishing Company, 1971.

[18] C.H. Lindsey and S.G. van der Meulen, Informal introduction to ALGOL 68, North Holland Publishing Company 1971.

[19] J.C. Boussard and J.J. Duby (Eds.), Rapport d'Evaluation ALGOL 68, Revue d'Informatique et de Recherche Opérationelle, B2, Paris, 1970.

15 Introduction

15.1 Aims and principles of design

a) In designing the Algorithmic Language Algol 68, Working Group 2.1 on ALGOL of the International Federation for Information Processing expresses its belief in the value of a common programming language serving many people in many countries.

b) Algol 68 is designed to communicate algorithms, to execute them efficiently on a variety of different computers, and to aid in teaching them to students.

c) This present Revision of the language is made in response to the directive of the parent committee, IFIP TC 2, to the Working Group to "keep continually under review experience obtained as a consequence of this original publication, so that it may institute such corrections and revisions to the Report as become desirable". In deciding to bring forward this Revision at the present time, the Working Group has tried to keep in balance the need to accumulate the maximum amount of experience of the problems which arose in the language originally defined, as opposed to the needs of the many teams at present engaged in implementation, for whom an early and simple resolution of those problems is imperative.

d) Although the language as now revised differs in many ways from that defined originally, no attempt has been made to introduce extensive new features and, it is believed, the revised language is still clearly recognizable as "Algol 68". The Working Group has decided that this present revision should be "the final definition of the language Algol 68", and the hope is expressed that it will be possible for implementations at present in preparation to be brought into line with this standard.

e) The Working Group may, from time to time, define sublanguages and extended capabilities, by means of Addenda to this Report, but these will always be built on the language here defined as a firm foundation. Moreover, variants more in conformity with natural languages other than English may be developed. To coordinate these activities, and to maintain contact with implementers and users, a Subcommittee on Algol 68 Support has been established by the Working Group.

f) The members of the Group, influenced by several years of experience with Algol 60 and other programming languages, have always accepted the following as their aims:

15.1.1 Completeness and clarity of description

The Group wishes to contribute to the solution of the problems of describing a language clearly and completely. The method adopted in this Report is based upon a formalized two-level grammar, with the semantics expressed in natural language, but making use of some carefully and precisely defined terms and concepts. It is recognized, however, that this method may be difficult for the uninitiated reader.

15.1.2 Orthogonal design

The number of independent primitive concepts has been minimized in order that the language be easy to describe, to learn, and to implement. On the other hand, these concepts have been applied "orthogonally" in order to maximize the expressive power of the language while trying to avoid deleterious superfluities.

15.1.3 Security

Algol 68 has been designed in such a way that most syntactical and many other errors can be detected easily before they lead to calamitous results. Furthermore, the opportunities for making such errors are greatly restricted.

15.1.4 Efficiency

Algol 68 allows the programmer to specify programs which can be run efficiently on present-day computers and yet do not require sophisticated and time-consuming optimization features of a compiler; see, e.g., 27_{11}.7.

15.1.4.1 Static mode checking

The syntax of Algol 68 is such that no mode checking during run time is necessary, except when the programmer declares a **UNITED-variable** and then, in a **conformity-clause**, explicitly demands a check on its mode.

15.1.4.2 Mode-independent parsing

The syntax of Algol 68 is such that the parsing of a program can be performed independently of the modes of its constituents. Moreover, it can be determined in a finite number of steps whether an arbitrary given sequence of symbols is a program.

15.1.4.3 Independent compilation

The syntax of Algol 68 is such that the main-line programs and procedures can be compiled independently of one another without loss of object-program efficiency provided that, during each independent compilation, specification of the mode of all nonlocal quantities is provided: see the remarks after 17_2.2.2.c.

15.1.4.4 Loop optimization

Iterative processes are formulated in Algol 68 in such a way that straightforward application of well-known optimization techniques yields large gains during run time without excessive increase of compilation time.

15.1.4.5 Representations

Representations of Algol 68 symbols have been chosen so that the language may be implemented on computers with a minimal character set. At the same time implementers may take advantage of a larger character set, if it is available.

15.2 Comparison with Algol 60

a) Algol 68 is a language of wider applicability and power than Algol 60. Although influenced by the lessons learned from Algol 60, Algol 68 has not been designed as an expansion of Algol 60 but rather as a completely new language based on new insight into the essential, fundamental concepts of computing and a new description technique.

b) The result is that the successful features of Algol 60 reappear in Algol 68 but as special cases of more general constructions, along with completely new features. It is, therefore, difficult to isolate differences between the two languages: however, the following sections are intended to give insight into some of the more striking differences.

15.2.1 Values in Algol 68

a) Whereas Algol 60 has values of the types **integer**, **real** and **Boolean**, Algol 68 features an infinity of "modes", i.e., generalizations of the concept "type".

b) Each plain value is either arithmetic, i.e., of **'integral'** or **'real'** mode and then it is of one of several sizes, or it is of **'boolean'** or **'character'** or **'void'** mode. Machine words, considered as sequences of bits or of bytes, may also be handled.

c) In Algol 60, values can be composed into arrays, whereas in Algol 68, in addition to such "multiple" values, also "structured" values, composed of values of possibly different modes, are defined and manipulated. An example of a multiple value is the character array, which corresponds approximately to the Algol 60 string; examples of structured values are complex numbers and symbolic formulae.

d) In Algol 68 the concept of a "name" is introduced, i.e., a value which is said to "refer to" another value; such a name-value pair corresponds to the Algol 60 variable. However, a name may take the value position in a name-value pair, and thus chains of indirect addresses can be built up.

e) The Algol 60 concept of procedure body is generalized in Algol 68 to the concept of "routine", which includes also the formal parameters, and which is itself a value and therefore can be manipulated like any other value.

f) In contrast with plain values, the significance of a name or routine is, in general, dependent upon the existence of the storage cells referred to or accessed. Therefore, the use of names and routines is subject to some restrictions related to their "scope". However, the syntax of Algol 68 is such that in many cases the check on scope can be made at compile time, including all cases where no use is made of features whose expressive power transcends that of Algol 60.

15.2.2 Declarations in Algol 68

a) Whereas Algol 60 has type declarations, array declarations, switch declarations and procedure declarations, Algol 68 features the **identity-declaration** whose expressive power includes all of these, and more. The **identity-declaration**, although theoretically sufficient in itself, is augmented by the **variable-declaration** for the convenience of the user.

b) Moreover, in Algol 68, a **mode-declaration** permits the construction of a new mode from already existing ones. In particular, the modes of multiple values and of structured values may be defined in this way; in addition, a union of modes may be defined, allowing each value referred to by a given name to be of any one of the uniting modes.

c) Finally, in Algol 68, a **priority-declaration** and an **operation-declaration** permit the introduction of new **operators**, the definition of their operation and the extension of the class of operands of, and the revision of the meaning of, already established operators.

15.2.3 Dynamic storage allocation in Algol 68

Whereas Algol 60 (apart from "own dynamic arrays") implies a "stack"-oriented storage-allocation regime, sufficient to cope with objects having nested lifetimes (an object created before another object being guaranteed not to become inaccessible before that second one),

Algol 68 provides, in addition, the ability to create and manipulate objects whose lifetimes are not so restricted. This ability implies the use of an additional area of storage, the "heap", in which garbage-collection techniques must be used.

15.2.4 Collateral elaboration in Algol 68

Whereas, in Algol 60, statements are "executed consecutively", in Algol 68, **phrases** are "elaborated serially" or "collaterally". This latter facility is conducive to more efficient object programs under many circumstances, since it allows discretion to the implementer to choose, in many cases, the order of elaboration of certain constructs or even, in some cases, whether they are to be elaborated at all. Thus the user who expects his "side effects" to take place in any well determined manner will receive no support from this Report. Facilities for parallel programming, though restricted to the essentials in view of the none-too-advanced state of the art, have been introduced.

15.2.5 Standard declarations in Algol 68

The Algol 60 standard functions are all included in Algol 68 along with many other standard declarations. Amongst these are "environment enquiries", which make it possible to determine certain properties of an implementation, and "transput" declarations, which make it possible, at run time, to obtain data from and to deliver results to external media.

15.2.6 Some particular constructions in Algol 68

a) The Algol 60 concepts of block, compound statement and parenthesized expression are unified in Algol 68 into the **serial-clause**. A **serial-clause** may be an **expression** and yield a value. Similarly, the Algol 68 **assignation**, which is a generalization of the Algol 60 assignment statement, may be an **expression** and, as such, also yield a value.

b) The Algol 60 concept of subscripting is generalized to the Algol 68 concept of "indexing", which allows the selection not only of a single element of an array but also of subarrays with the same or any smaller dimensionality and with possibly altered bounds.

c) Algol 68 provides **row-displays** and **structure-displays**, which serve to compose the multiple and structured values mentioned in 15_0.2.1.c from other, simpler, values.

d) The Algol 60 for statement is modified into a more concise and efficient **loop-clause**.

e) The Algol 60 conditional expression and conditional statement, unified into a **conditional-clause**, are improved by requiring them to end with a closing symbol whereby the two

alternative clauses admit the same syntactic possibilities. Moreover, the **conditional-clause** is generalized into a **case-clause**, which allows the efficient selection from an arbitrary number of clauses depending on the value of an **integral-expression**, and a **conformity-clause**, which allows a selection depending upon the actual mode of a value.

f) Some less successful Algol 60 concepts, such as own quantities and integer labels, have not been included in Algol 68, and some concepts, like designational expressions and switches, do not appear as such in Algol 68 but their expressive power is included in other, more general, constructions.

15.2.7 Comparison with the language defined in 1968

The more significant changes to the language are indicated in the sections which follow. The revised language will be described in a new edition of the "Informal Introduction to Algol 68" by C.H. Lindsey and S.G. van der Meulen, which accompanied the original Report.

15.2.8 Casts and routine texts

Routines without parameters used to be constructed out of a **cast** in which the **cast-of-symbol** (:) appeared. This construct is now one of the forms of the new **routine-text**, which provides for procedures both with and without parameters. A new form of the **cast** has been provided which may be used in contexts previously not possible. Moreover, both **void-casts** and **procedure-PARAMETY-yielding-void-routine-texts** must now contain an explicit **void-symbol**.

15.2.9 Extended ranges

The new **range** which is established by the **enquiry-clause** of a **choice-clause** (which encompasses the old **conditional-** and **case-clauses**) or of a **while-part** now extends into the controlled **serial-clause** or **do-part**.

15.2.10 Conformity clauses

The **conformity-relation** and the **case-conformity** which was obtained by extension from it are now replaced by a new **conformity-clause**, which is a further example of the **choice-clause** mentioned above.

15.2.11 Modes of multiple values

A new class of modes is introduced, for multiple values whose elements are themselves multiple values. Thus one may now write the **declarer** [ ] **string**.

Moreover, multiple values no longer have "states" to distinguish their flexibility. Instead, flexibility is now a property of those names which refer to multiple values whose size may change, such names having distinctive modes of the form **'reference to flexible ROWS of MODE'**.

15.2.12 Identification of operators

Not only may two **operators**, related to each other by the modes of their operands, not be declared in the same **range**, as before, but now, if two such **operators** be declared in different reaches, any attempt to identify from the inner reach the one in the outer reach will fail. This gives some benefit to the implementer and removes a source of possible confusion to the user.

15.2.13 Representations

The manner in which **symbols** for newly defined **mode-indications** and **operators** are to be represented is now more closely defined. Thus it is clear that the implementer is to provide a special alphabet of bold-faced, or "stropped", marks from which **symbols** such as **person** may be made, and it is also clear that **operators** such as » are to be allowed.

15.2.14 Standard prelude

In order to ease the problems of implementers who might wish to provide variants of the language suitable for environments where English is not spoken, there are no longer any **field-selectors** known to the user in the **standard-prelude**, with the exception of re and im of the mode COMPL. The **identifiers** and other **indicators** declared in the **standard-prelude** could, of course, easily be defined again in some **library-prelude**, but this would not have been possible in the case of **field-selectors**.

15.2.15 Line length in transput

The lines (and the pages also) of the "book" used during transput may now, at the discretion of the implementer, be of varying lengths. This models more closely the actual behaviour of most operating systems and of devices such as teleprinters and paper-tape readers.

15.2.16 Internal transput

The transput routines, in addition to sending data to or from external media, may now be associated with **row-of-character-variables** declared by the user.

15.2.17 Elaboration of formats

The dynamic **replicators** contained in **format-texts** are now elaborated as and when they are encountered during the formatted transput process. This should give an effect more natural to the user, and is easier to implement.

15.2.18 Features removed

Certain features, such as proceduring, gommas and formal bounds, have not been included in the revision.

15.3 Changes in the method of description

In response to the directive from the Working Group "to make its study easier for the uninitiated reader", the Editors of this revision have rewritten the original Report almost entirely, using the same basic descriptional technique, but applying it in new ways. It is their hope that less "initiation" will now be necessary.

The more significant changes in the descriptional technique are indicated below.

15.3.1 Two-level grammar

a) While the syntax is still described by a two-level grammar of the type now widely known by the name "Van Wijngaarden", new techniques for using such grammars have been applied. In particular, the entire identification process is now described in the syntax using the metanotion "**NEST**", whose terminal metaproductions are capable of describing, and of passing on to the descendent constructs, all the declared information which is available at any particular node of the production tree.

b) In addition, extensive use is made of "predicates". These are notions which are deliberately made to yield blind alleys when certain conditions are not met, and which yield empty terminal productions otherwise. They have enabled the number of syntax rules to be reduced in many cases, while at the same time making the grammar easier to follow by reducing the number of places where a continuation of a given rule might be found.

It has thus been possible to remove all the "context conditions" contained in the original Report.

15.3.2 Modes

a) In the original Report, modes were protonotions of possibly infinite length. It was assumed that, knowing how an infinite mode had been obtained, it was decidable whether or not it was the same as some other infinite mode. However, counterexamples have come to light where this was not so. Therefore, it has been decided to remove all infinities from the process of producing a finite **program** and, indeed, this can now be done in a finite number of moves.

b) A mode, essentially, has to represent a potentially infinite tree. To describe it as a protonotion of finite length requires the use of markers **'MU definition'**s and pointers back to those markers **'MU application'**s within the protonotion. However, a given infinite tree can be "spelled" in many ways by this method, and therefore a mode becomes an equivalence class comprised of all those equivalent spellings of that tree. The equivalence is defined in the syntax using the predicates mentioned earlier.

15.3.3 Extensions

The need for many of the extensions given in the original Report had been removed by language changes. Some of the remainder had been a considerable source of confusion and surprises. The opportunity has therefore been taken to remove the extension as a descriptional mechanism, all the former extensions now being specified directly in the syntax.

15.3.4 Semantics

a) In order to remove some rather repetitious phrases from the semantics, certain technical terms have been revised and others introduced. The grammar, instead of producing a terminal production directly, now does so by way of a production tree. The semantics is explained in terms of production trees. Paranotions, which designate constructs, may now contain metanotions and "hypernotions" have been introduced in order to designate protonotions.

b) A model of the hypothetical computer much more closely related to a real one has been introduced. The elaboration of each construct is now presumed to take place in an "environ" and, when a new **range** is entered (and, in particular, when a routine is called), a new "locale" is added to the environ. The locale corresponds to the new **range** and, if recursive procedure calls arise, then there exist many locales corresponding to one same routine.

This supersedes the method of "textual substitution" used before, and one consequence of this is that the concept of "protection" is no longer required.

c) The concept of an "instance" of a value is no longer used. This simplifies certain portions of the semantics where, formerly, a "new instance" had to be taken, the effects of which were not always clear to see.

15.3.5 Translations

The original Report has been translated into various natural languages. The translators were not always able to adhere strictly to the descriptional method, and so the opportunity has been taken to define more clearly and more liberally certain descriptional features which caused difficulties (see 16_1.1.5).

{True wisdom knows it must comprise
some nonsense as a compromise,
lest fools should fail to find it wise.
Grooks, Piet Hein. }

{Revised Report } Part I

Preliminary definitions

16 Language and metalanguage

16.1 The method of description

16.2 Introduction

a) Algol 68 is a language in which algorithms may be formulated for computers, i.e., for automata or for human beings. It is defined by this Report in four stages, the "syntax" {b}, the "semantics" {c}, the "representations" {d} and the "standard environment" {e}.

b) The syntax is a mechanism whereby all the constructs of the language may be produced. This mechanism proceeds as follows:

(i) A set of "hyper-rules" and a set of "metaproduction rules" are given {16_1.1.3.4, 16_1.1.3.3}, from which "production rules" may be derived:

(ii) A "construct in the strict language" is a "production tree" {16_1.1.3.2.f} which may be produced by the application of a subset of those production rules; this production tree contains static information {i.e., information known at "compile time"} concerning that construct: it is composed of a hierarchy of descendent production trees, terminating at the lowest level in the "**symbols**"; with each production tree is associated a "nest" of properties, declared in the levels above, which is passed on to the nests of its descendents;

(iii) A "**program** in the strict language" is a production tree for the notion **'program'** {17_2.2.1.a}. It must also satisfy the "environment condition" {26_{10}.1.2}.

c) The semantics ascribes a "meaning" {17_2.1.4.1.a} to each construct {i.e. to each production tree} by defining the effect (which may, however, be "undefined") of its "elaboration" {17_2.1.4.1}. This proceeds as follows:

(i) A dynamic {i.e., run-time} tree of active "actions" is set up {17_2.1.4}; typically, an action is the elaboration of some production tree T in an "environ" consistent with the nest of T, and it may bring about the elaboration of descendents of T in suitable newly created descendent environs;

(ii) The meaning of a **program** in the strict language is the effect of its elaboration in the empty "primal environ".

d) A **program** in the strict language must be represented in some "representation language" {25_9.3.a} chosen by the implementer. In most cases this will be the official "reference language".

(i) A **program** in a representation language is obtained by replacing the **symbols** of a **program** in the strict language by certain typographical marks {25_9.3}.

(ii) Even the reference language allows considerable discretion to the implementer {25_9.4.a, b, c}. A restricted form of the reference language in which such freedom has not been exercised may be termed the "canonical form" of the language, and it is expected that this form will be used in algorithms intended for publication.

(iii) The meaning of a **program** in a representation language is the same as that of the **program** {in the strict language} from which it was obtained.

e) An algorithm is expressed by means of a **particular-program**, which is considered to be embedded, together with the standard environment, in a **program-text** {26_{10}.1.1.a}. The meaning of a **particular-program** {in the strict or a representation language} is the meaning of the **program** "akin" to that **program-text** {26_{10}.1.2.a}.

16.3 Pragmatics

{Merely corroborative detail, intended to
give artistic verisimilitude to an otherwise
bald and unconvincing narrative.
Mikado, W.S. Gilbert. }

Scattered throughout this Report are "pragmatic" remarks included between the braces "{" and "}". These are not part of the definition of the language but serve to help the reader to understand the intentions and implications of the definitions and to find corresponding sections or rules.

{Some of the pragmatic remarks contain examples written in the reference language. In these examples, **applied-indicators** occur out of context from their **defining-indicators**. Unless otherwise specified, these occurrences identify those in the **standard-** or **particular-preludes** and the **particular-postlude** (26_{10}.2, 26_{10}.3, 26_{10}.5) (e.g. see 26_{10}.2.3.12.a for `pi`, 26_{10}.5.1.b for `random` and 26_{10}.5.2.a for `stop`), or those in:

```
INT i, j, k, m, n; REAL a, b, x, y; BOOL p, q, overflow; CHAR c; FORMAT f;
  BYTES r; STRING s; BITS t; COMPL w, z; REF REAL xx, yy;
```

```
    UNION (INT, REAL) uir;
  PROC VOID task1, task2;


[1 : n] REAL x1, y1; FLEX [1 : n] REAL a1; [1 : m, 1 : n] REAL x2;
  [1 : n, 1 : n] REAL y2; [1 : n] INT i1; [1 : m, 1 : n ] INT i2;
  [1 : n] COMPL z1;


PROC x or y = REF REAL: IF random < .5 THEN x ELSE y FI;
PROC ncos = (INT i) REAL: cos (2 × pi × i / n);
PROC nsin = (INT i) REAL: sin (2 × pi × i / n);
PROC finish = VOID: GO TO stop;


MODE BOOK = STRUCT (STRING text, REF BOOK next);
BOOK draft;


princeton: grenoble: st pierre de chartreuse: kootwijk: warsaw:
  zandvoort: amsterdam: tirrenia: north berwick: munich:
  finish.
}
```

16.3.1 The syntax of the strict language

16.3.1.1 Protonotions

a) In the definition of the syntax of the strict language, a formal grammar is used in which certain syntactic marks appear. These may be classified as follows:

(i) "small syntactic marks", written, in this Report, as
"**a**", "**b**", "**c**", "**d**", "**e**", "**f**", "**g**", "**h**", "**i**", "**j**", "**k**", "**l**", "**m**", "**n**", "**o**", "**p**", "**q**", "**r**", "**s**", "**t**", "**u**", "**v**", "**w**", "**x**", "**y**", "**z**", "(", ")";

(ii) "large syntactic marks", written, in this Report, as
"**A**", "**B**", "**C**", "**D**", "**E**", "**F**", "**G**", "**H**", "**I**", "**J**", "**K**", "**L**", "**M**", "**N**", "**O**", "**P**", "**Q**", "**R**", "**S**", "**T**", "**U**", "**V**", "**W**", "**X**", "**Y**", "**Z**", "**0**", "**1**", "**2**", "**3**", "**4**", "**5**", "**6**", "**7**", "**8**", "**9**";

(iii) "other syntactic marks", written, in this Report, as
"**.**" ("point"), "**,**" ("comma"), "**:**" ("colon"), "**;**" ("semicolon"), "’" ("apostrophe"), "**-**" ("hyphen") and "*" ("asterisk").

{Note that these marks are in another type font than that of the marks in this sentence.}

b) A "protonotion" is a possibly empty sequence of small syntactic marks.

c) A "notion" is a {nonempty} protonotion for which a production rule can be derived {16_1.1.3.2.a, 16_1.1.3.4.d}.

d) A "metanotion" is a {nonempty} sequence of large syntactic marks for which a metaproduction rule is given or created {16_1.1.3.3.a}.

e) A "hypernotion" is a possibly empty sequence each of whose elements either is a small syntactic mark or is a metanotion.

{Thus the class of protonotions {b} is a subclass of the class of hypernotions. Hypernotions are used in metaproduction rules (16_1.1.3.3), in hyper-rules (16_1.1.3.4), as paranotions (16_1.1.4.2) and, in their own right, to "designate" certain classes of protonotions {16_1.1.4.1}.}

{A "paranotion" is a hypernotion to which certain special conventions and interpretations apply, as detailed in 16_1.1.4.2.}

f) A "symbol" is a protonotion ending with **'symbol'**. {Note that the paranotion **symbol** {25_9.1.1.h} designates a particular occurrence of such a protonotion.}

{Examples:

b) **'variable point'**

c) **'variable point numeral'** {24_8.1.2.1.b}

d) "**INTREAL**" {16_1.2.1.C}

e) **'reference to INTREAL'**

f) **'letter a symbol'**.

}

Note that the protonotion **'twas brillig and the slithy toves'** is neither a symbol nor a notion, in that it does not end with **'symbol'** and no production rule can be derived for it. Likewise, "**LEWIS**" and "**CAROLL**" are not metanotions in that no metaproduction rules are given for them.

g) In order to distinguish the various usages in the text of this Report of the terms defined above, the following conventions are adopted:

(i) No distinguishing marks {quotes, apostrophes or hyphens} are used in production rules, metaproduction rules or hyper-rules;

(ii) Metanotions, and hypernotions which stand for themselves {i.e., which do not designate protonotions}, are enclosed in quotes;

(iii) Paranotions are not enclosed in anything {but, as an aid to the reader, are provided with hyphens where, otherwise, they would have been provided with blanks};

(iv) All other hypernotions {including protonotions} not covered above are enclosed in apostrophes {in order to indicate that they designate some protonotion, as defined in 16_1.1.4.1.a};

(v) Typographical display features, such as blank space, hyphen, and change to a new line or new page, are of no significance (but see also 25_9.4.d).

{Examples:

(i) **LEAP :: local ; heap ; primal.** is a metaproduction rule ;

(ii) "**INTREAL**" is a metanotion and designates nothing but itself;

(iii) **reference-to-INTREAL-identifier**, which is not enclosed in apostrophes but is provided with hyphens, is a paranotion designating a construct {16_1.1.4.2.a};

(iv) **'variable point'** is both a hypernotion and a protonotion; regarded as a hypernotion, it designates itself regarded as a protonotion;

(v) **'reference to real'** means the same as **'referencetoreal'**.

}

16.3.1.2 Production rules and production trees

a) The {derived} "production rules" {b} of the language are those production rules which can be derived from the "hyper-rules" {16_1.1.3.4}, together with those specified informally in 24_8.1.4.1.d and 25_9.2.1.d.

b) A "production rule" consists of the following items, in order:

- an optional asterisk;
- a nonempty protonotion N;
- a colon;
- a nonempty sequence of "alternatives" separated by semicolons;
- a point.

It is said to be a production rule "for" {the notion {16_1.1.3.1.c}} N. {The optional asterisk, if present, signifies that the notion is not used in other production rules, but is provided to facilitate discussion in the semantics. It also signifies that that notion may be used as an "abstraction" {16_1.1.4.2.b} of one of its alternatives.}

c) An "alternative" is a nonempty sequence of "members" separated by commas.

d) A "member" is either

(i) a notion {and may then be said to be productive, or nonterminal},

(ii) a symbol {which is terminal},

(iii) empty, or

(iv) some other protonotion {for which no production rule can be derived}, which is then said to be a "blind alley". {For example, the member **'reference to real denotation'** (derived from the hyper-rule 24_8.0.1.a) is a blind alley.}

{Examples:
b) **exponent part : times ten to the power choice, power of ten.** {24_8.1.2.1.g} •
times ten to the power choice :
times ten to the power symbol ;
letter e symbol {24_8.1.2.1.h}
c) **times ten to the power choice, power of ten** •
times ten to the power symbol •
letter e symbol
d) **times ten to the power choice** •
power of ten •
times ten to the power symbol •
letter e symbol }

e) A "construct in the strict language" is any "production tree" {f} that may be "produced" from a production rule of the language.

f) A "production tree" T for a notion N, which is termed the "original" of T, is "produced" as follows:

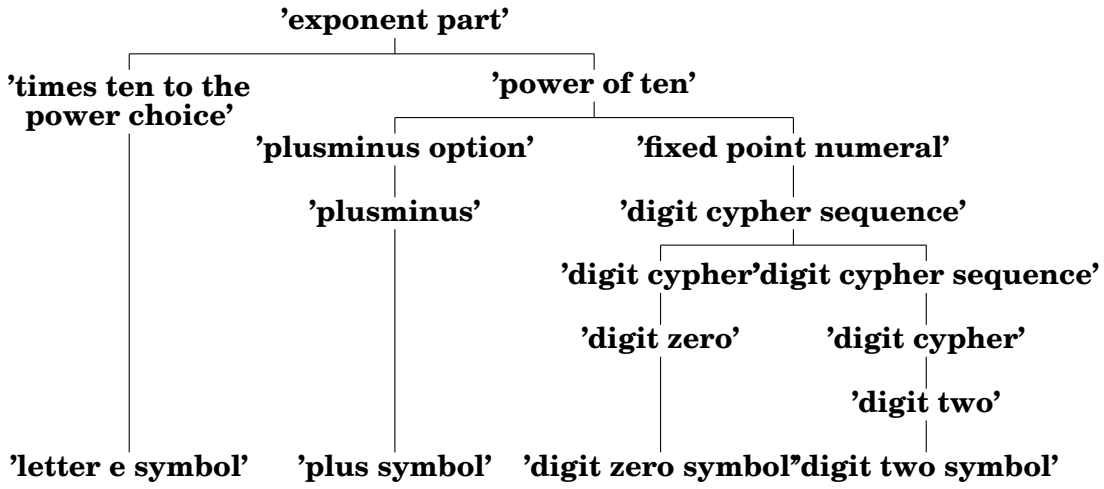
- let P be some {derived} production rule for N;
- a copy is taken of N;
- a sequence of production trees, the "direct descendents" of T, one produced for each nonempty member of some alternative A of P, is attached to the copy; the order of the sequence is the order of those members within A;
- the copy of the original, together with the attached direct descendents, comprise the production tree T.

A "production tree" for a symbol consists of a copy of that symbol {i.e., it consists of a **symbol**}.

The "terminal production" of a production tree T is a sequence consisting of the terminal productions of the direct descendents of T, taken in order.

The "terminal production" of a production tree consisting only of a **symbol** is that **symbol**.

{Example:



}

{The terminal production of this tree is the sequence of **symbols** at the bottom of the tree. In the reference language, its representation would be `e+02`.}

A "terminal production" of a notion is the terminal production of some production tree for that notion {thus there are many other terminal productions of **'exponent part'** besides the one shown}.

{The syntax of the strict language has been chosen in such a way that a given sequence of **symbols** which is a terminal production of some notion is so by virtue of a unique production tree, or by a set of production trees which differ only in such a way that the result of their elaboration is the same (e.g., production trees derived from rules 18_3.2.1.e (balancing), 16_1.3.1.d,e (predicates) and 22_6.7.1.a,b (choice of spelling of the mode of a **coercend** to be voided); see also 17_2.2.2.a).

Therefore, in practice, terminal productions (or representations thereof) are used, in this Report and elsewhere, in place of production trees. Nevertheless, it is really the production trees in terms of which the elaboration of programs is defined by the semantics of this Report, which is concerned with explaining the meaning of those constructs whose originals are the notion **'program'**.}

g) A production tree P is a "descendent" of a production tree Q if it is a direct descendent {f} either of Q or of a descendent of Q. Q is said to "contain" its descendents and those

descendents are said to be "smaller" than Q. {For example, the production tree

'plusminus option'
|
'plusminus'
|
'plus symbol'

occurs as a descendent in (and is contained within and is smaller than) the production tree for **'exponent part'** given above.}

h) A "visible" ("invisible") production tree is one whose terminal production is not (is) empty.

i) A descendent {g} U of a production tree T is "before" ("after") a descendent V of T if the terminal production {f} of U is before (after) that of V in the terminal production of T. The {partial} ordering of the descendents of T thus defined is termed the "textual order". {In the example production tree for **'exponent part'** {f}, the production tree whose original is **'plusminus'** is before that whose original is **'digit two'**.}

j) A descendent A of a production tree "follows" ("precedes") another descendent B in some textual order if A is after (before) B in that textual order, and there exists no visible {h} descendent C which comes between A and B. {Thus "immediately" following (preceding) is implied.}

k) A production tree A is "akin" to a production tree B if the terminal production {f} of A is identical to the terminal production of B.

16.3.1.3 Metaproduction rules and simple substitution

{The metaproduction rules of the language form a set of context-free grammars defining a "metalanguage".}

a) The "metaproduction rules" {b} of the language are those given in the sections of this Report whose heading begins with "Syntax", " Metasyntax" or "Metaproduction rules", together with those obtained as follows:

- for each given metaproduction rule, whose metanotion is M say, additional rules are created each of which consists of a copy of M followed by one of the large syntactic marks "**0**", "**1**", "**2**", "**3**", "**4**", "**5**", "**6**", "**7**", "**8**" or "**9**", followed by two colons, another copy of that M and a point.

{Thus, the metaproduction rule "**MODE1 :: MODE.**" is to be added.}

b) A "metaproduction rule" consists of the following items, in order:

- an optional asterisk;
- a nonempty sequence M of large syntactic marks;
- two colons;
- a nonempty sequence of hypernotions {16_1.1.3.1.e} separated by semicolons;
- a point.

It is said to be a metaproduction rule "for" {the metanotion {16_1.1.3.1.d}} M.

{The asterisk, if present, signifies that the metanotion is not used in other metaproduction rules or in hyper-rules, but is provided to facilitate discussion in the semantics.}

{Examples:

INTREAL :: SIZETY integral ; SIZETY real. (1.2.1.C) •
SIZETY :: long LONGSETY ; short SHORTSETY ; EMPTY. (1.2.1.D) }

c) A "terminal metaproduction" of a metanotion M is any protonotion which is a "simple substitute" {d} for one of the hypernotions {on the right hand side} of the metaproduction rule for M.

d) A protonotion P is a "simple substitute" for a hypernotion H if a copy of H can be transformed into a copy of P by replacing each metanotion M in the copy by some terminal metaproduction of M.

{Thus two possible terminal metaproductions {c} of "**INTREAL**" are **'integral'** and **'long long real'**. This is because the hypernotions **'SIZETY integral'** and **'SIZETY real'** (the hypernotions of the metaproduction rule for "**INTREAL**") may, upon simple substitution {d}, give rise to **'integral'** and **'long long real'**, which, in turn, is because **''** (the empty protonotion) and **'long long'** are terminal metaproductions of "**SIZETY**".}

{The metanotions used in this Report have been so chosen that no concatenation of one or more of them gives the same sequence of large syntactic marks as any other such concatenation. Thus a source of possible ambiguity has been avoided.

Although the recursive nature of some of the metaproduction rules makes it possible to produce terminal metaproductions of arbitrary length, the length of the terminal metaproductions necessarily involved in the production of any given **program** is finite.}

16.3.1.4 Hyper-rules and consistent substitution

a) The hyper-rules {b} of the language are those given in the sections of this Report whose heading begins with "Syntax".

b) A "hyper-rule" consists of the following items, in order:

- an optional asterisk ;
- a nonempty hypernotion H ;
- a colon ;
- a nonempty sequence of "hyperalternatives" separated by semicolons ;
- a point.

It is said to be a hyper-rule "for" {the hypernotion {16_1.1.3.1.e}} H.

c) A "hyperalternative" is a nonempty sequence of hypernotions separated by commas.

{Examples:
b) **NOTION sequence : NOTION ; NOTION, NOTION sequence.** {16_1.3.3.b}
c) **NOTION, NOTION sequence** }

d) A production rule PR {16_1.1.3.2.b} is derived from a hyper-rule HR if a copy of HR can be transformed into a copy of PR by replacing the set of all the hypernotions in the copy by a "consistent substitute" {e} for that set.

e) A set of {one or more} protonotions PP is a "consistent substitute" for a corresponding set of hypernotions HH if a copy of HH can be transformed into a copy of PP by means of the following step:

Step : If the copy contains one or more metanotions then, for some terminal metaproduction T of one such metanotion M, each occurrence of M in the copy is replaced by a copy of T and the Step is taken again.

{See 16_1.1.4.1.a for another application of consistent substitution.}

{Applying this derivation process to the hyper-rule given above {c} may give rise to

- **digit cypher sequence :**
  digit cypher ; digit cypher, digit cypher sequence.

which is therefore a production rule of the language. Note that

- **digit cypher sequence :**
  digit cypher ; digit cypher, letter b sequence.

is not a production rule of the language, since the replacement of the metanotion "**NOTION**" by one of its terminal metaproductions must be consistent throughout.}

{Since some metanotions have an infinite number of terminal metaproductions, the number of production rules which may be derived is infinite. The language is, however, so designed

that, for the production of any **program** of finite length, only a finite number of those production rules is needed.}

{f) The rules under Syntax are provided with "cross-references" to be interpreted as follows.

Each hypernotion H of a hyperalternative of a hyper-rule A is followed by a reference to those hyper-rules B whose derived production rules are for notions which could be substituted for that H. Likewise, the hypernotions of each hyper-rule B are followed by a reference back to A. Alternatively, if H is to be replaced by a symbol, then it is followed by a reference to its representation in section 25_9.4.1 . Moreover, in some cases, it is more convenient to give a **cross-reference** to one metaproduction rule rather than to many hyper-rules, and in these cases the missing cross-references will be found in the metaproduction rule.

Such a reference is, in principle, the section number followed by a letter indicating the line where the rule or representation appears, with the following conventions:

(i) the references whose section number is that of the section in which they appear are given first and their section number is omitted; e.g., "24_8.2.1.a" appears as "a" in section "24_8.2.1";

(ii) a final 1 is omitted; e.g., "24_8.2.1.a" appears as "24_8.2.a" elsewhere and "26_{10}.3.4.1.1.i" appears as "26_{10}.3.4.1.i";[1]

(iii) a section number which is the same as that of the preceding reference is omitted; e.g., "24_8.2.a, 24_8.2.b, 24_8.2.c" appears as "24_8.2.a,b,c";

(iv) the presence of a blind alley derived from that hypernotion is indicated by "**-**"; e.g., in 24_8.0.1.a after "**MOID denotation**", since "**MOID**" may be replaced by, for example, **'reference to real'**, but **'reference to real denotation'** is not a notion.}

16.3.2 The semantics

The "meaning" of **programs** {17_2.2.1.a} in the strict language is defined in the semantics by means of sentences {in somewhat formalized natural language} which specify the "actions" to be carried out during the "elaboration" {17_2.1.4.1} of those **programs**. The meaning of a **program** in a representation language is the same as the meaning of the **program** in the strict language it represents {25_9.3}.

[1] in the original Revised Report this read: *all points and a final* 1 *are omitted, and* 10 *appears as* A*; e.g., "8.2.1.a" appears as "82a" elsewhere and "10.3.4.1.1.i" appears as "A341i";*. LaTeX does not support 10 to appear as A in references, thus the substitution of 10 for A is not maintained in this translation. Also, points are not omitted in this translation as to improve legibility of cross-references

{The semantics makes extensive use of hypernotions and paranotions in order to "designate", respectively, protonotions and constructs. The word "designate" should be understood in the sense that the word "flamingo" may "designate" any animal of the family *Phoenicopteridae*.}

16.3.2.1 Hypernotions, designation and envelopment

{Hypernotions, when enclosed between apostrophes, are used to "designate" protonotions belonging to certain classes; e.g., **'LEAP'** designates any of the protonotions **'local'**, **'primal'** and **'heap'**.}

a) Hypernotions standing in the text of this Report, except those in hyper-rules {16_1.1.3.4.b} or metaproduction rules {16_1.1.3.3.b} "designate" any protonotions which may be consistently substituted {16_1.1.3.4.e} for them, the consistent substitution being applied over all the hypernotions contained in each complete sub-section of the text (a sub-section being one of the lettered sub-divisions, if any, or else the whole, of a numbered section).

{Thus **'QUALITY TAX'** is a hypernotion designating protonotions such as **'integral letter i'**, **'real letter x'**, etc. If, in some particular discussion, it in fact designates **'integral letter i'**, then all occurrences of "**QUALITY**" in that subsection must, over the span of that discussion, designate **'integral'** and all occurrences of "**TAX**" must designate **'letter i'**. It may then be deduced from subsection 19_4.8.2.a that in order, for example, to "ascribe to an **integral-defining-indicator-with-letter-i**", it is **'integral letter i'** that must be "made to access V inside the locale".}

Occasionally, where the context clearly so demands, consistent substitution may be applied over less than a section. {For example, in the introduction to section 17_2.1.1.2, there are several occurrences of "**'MOID'**", of which two are stated to designate specific (and different) protonotions spelled out in full, and of which others occur in the plural form "**'MOID'**s", which is clearly intended to designate a set of different members of the class of terminal metaproductions of "**MOID**".}

b) If a protonotion (a hypernotion) P consists of the concatenation of the protonotions (hypernotions) A, B and C, where A and C are possibly empty, then P "contains" B at the position {in P} determined by the length of A. {Thus, **'abcdefcdgh'** contains **'cd'** at its third and seventh positions.}

c) A protonotion $P1$ "envelops" a protonotion $P2$ as specifically designated by a hypernotion $H2$ if $P2$, or some equivalent {17_2.1.1.2.a} of it, is contained {b} at some position within $P1$ but not, at that position, within any different {intermediate} protonotion $P3$ also contained in $P1$ such that $H2$ could also designate $P3$.

{Thus the **'MODE'** enveloped by **'reference to real closed clause'** is **'reference to real'** rather than **'real'**; moreover, the mode {17_2.1.1.2.b} specified by `STRUCT (REAL a, STRUCT (BOOL b, CHAR c) d)` envelops **'FIELD'** just twice.}

16.3.2.2 Paranotions

{In order to facilitate discussion, in this Report, of constructs with specified originals, the concept of a "paranotion" is introduced. A paranotion is a noun that designates constructs {16_1.1.3.2.e}; its meaning is not necessarily that found in a dictionary but can be construed from the rules which follow.}

a) A "paranotion" P is a hypernotion {not between apostrophes} which is used, in the text of this Report, to "designate" any construct whose original O satisfies the following:

- P, regarded as a hypernotion {i.e., as if it had been enclosed in apostrophes}, designates {16_1.1.4.1.a} an "abstraction" {b} of O.

{For example, the paranotion "**fixed-point-numeral**" could designate the construct represented by `02`, since, had it been in apostrophes, it would have designated an abstraction of the notion **'fixed point numeral'**, which is the original of that construct. However, that same representation could also be described as a **digit-cypher-sequence**, and as such it would be a direct descendent of that **fixed-point-numeral**.}

{As an aid to the reader in distinguishing them from other hypernotions, paranotions are not enclosed between apostrophes and are provided with hyphens where, otherwise, they would have been provided with blanks.}

The meaning of a paranotion to which the small syntactic mark "**s**" has been appended is the same as if the letter "s" {which is in the same type font as the marks in this sentence} had been appended instead. {Thus the **fixed-point-numeral** `02` may be said to contain two **digit-cyphers**, rather than two **digit-cypher**s.} Moreover, the "**s**" may be inserted elsewhere than at the end if no ambiguity arises {e.g., "**sources-for-MODINE**" means the same as "**source-for-MODINEs**"}.

An initial small syntactic mark of a paranotion is often replaced by the corresponding large syntactic mark (in order to improve readability, as at the start of a sentence) without change of meaning {; e.g., "**Identifier**" means the same as "**identifier**"}.

b) A protonotion $P2$ is an "abstraction" of a protonotion $P1$ if

(i) $P2$ is an abstraction of a notion whose production rule begins with an asterisk and of which $P1$ is an alternative

> {e.g., **'trimscript'** {20_5.3.2.1.h} is an abstraction of any of the notions designated by **'NEST trimmer'**, **'NEST subscript'** and **'NEST revised lower bound option'**}, or

(ii) $P1$ envelops a protonotion $P3$ which is designated by one of the "elidible hypernotions" listed in section c below, and $P2$ is an abstraction of the protonotion consisting of $P1$ without that enveloped $P3$

{e.g., **'choice using boolean start'** is an abstraction of the notions **'choice using boolean brief start'** and **'choice using boolean bold start'** (by elision of a **'STYLE'** from 25_9.1.1.a)}, or

(iii) $P2$ is equivalent to {17_2.1.1.2.a}$P1$

{e.g., **'bold begin symbol'** is an abstraction of **'bold begin symbol'**} .

{For an example invoking all three rules, it may be observed that **'union of real integral mode defining indicator'** is an abstraction of some **'union of integral real mode NEST defining identifier with letter a'** {19_4.8.1.a}. Note, however, that **'choice using union of integral real mode brief start'** is not an abstraction of the notion **'choice using union of integral real boolean mode brief start'**, because the **'boolean'** that has apparently been elided is not an enveloped **'MOID'** of that notion.}

c) The "elidible hypernotions" mentioned in section b above are the following:

"**STYLE**" • "**TALLY**" • "**LEAP**" • "**DEFIED**" • "**VICTAL**" • "**SORT**" • "**MOID**" • "**NEST**" • "**REFETY routine**" • "**label**" • "**with TAX**" • "**with DECSETY LABSETY**" • "**of DECSETY LABSETY**" • "**defining LAYER**".

{Which one of several possible notions or symbols is the original of a construct designated by a given paranotion will be apparent from the context in which that paranotion appears. For example, when speaking of the **formal-declarer** of an **identity-declaration**, if the **identity-declaration** is one whose terminal production {16_1.1.3.2.f} happens to be `REF REAL x = LOC REAL`, then the original of that **formal-declarer** is some notion designated by **'formal reference to real NEST declarer'**.}

{Since a paranotion designates a construct, all technical terms which are defined for constructs can be used with paranotions without formality.}

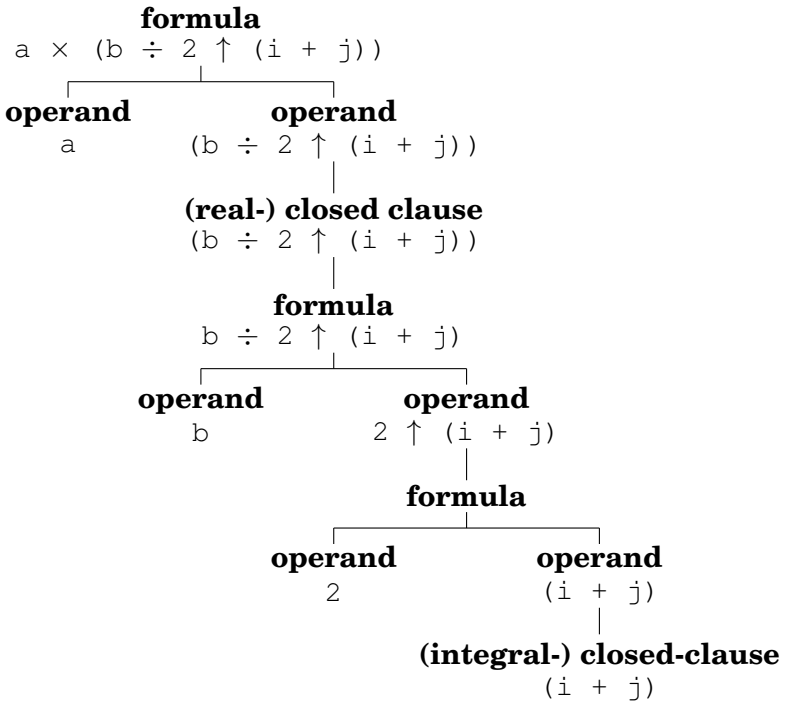
d) If two paranotions P and Q designate, respectively, two constructs S and T, and if S is a descendent of T, then P is termed a "constituent" of Q unless there exists some {intermediate construct} U such that

(i) S is a descendent of U,

(ii) U is a descendent of T, and

(iii) either P or Q could {equally well} designate U.

{Hence `a` ($S1$) is a constituent **operand** of the **formula** `a × (b ÷ 2 ↑ (i + j))` (T), but `b` ($S2$) is not, since it is a descendent of an intermediate **formula** `b ÷ 2 ↑ (i + j)` (U), which is itself descended from T. Likewise, `b ÷ 2 ↑ (i + j)` is a constituent **closed-clause** of the **formula** T, but the **closed-clause** `(i + j)` is not, because it is descended from an intermediate **closed-clause**. However, `(i + j)` is a constituent **integral-closed-clause** of T, because the intermediate **closed-clause** is, in fact, a **real-closed-clause**.



}

16.3.2.3 Undefined

a) If something is left "undefined" or is said to be "undefined", then this means that it is not defined by this Report alone and that, for its definition, information from outside this Report has to be taken into account.

{A distinction must be drawn between the yielding of an undefined value (whereupon elaboration continues with possibly unpredictable results) and the complete undefinedness of the further elaboration. The action to be taken in this latter case is at the discretion of the implementer, and may be some form of continuation (but not necessarily the same as any other implementer's continuation), or some form of interruption {17_2.1.4.3.h} brought about by some run-time check.}

b) If some condition is "required" to be satisfied during some elaboration then, if it is not so satisfied, the further elaboration is undefined.

c) A "meaningful" **program** is a **program** {17_2.2.1.a} whose elaboration is defined by this Report.

{Whether all **programs**, only **particular-programs**, only meaningful **programs**, or even

only meaningful **particular-programs** are "Algol 68" **programs** is a matter for individual taste.}

16.4 Translations and variants

a) The definitive version D of this Report is written in English. A translation T of this Report into some other language is an acceptable translation if:

- T defines the same set of production trees as D, except that
  - (i) the originals contained in each production tree of T may be different protonotions obtained by some uniform translation of the corresponding originals contained in the corresponding production tree of D, and
  - (ii) descendents of those production trees need not be the same if their originals are predicates {16_1.3.2};
- T defines the meaning {17_2.1.4.1.a} of each of its **programs** to be the same as that of the corresponding **program** defined by D;
- T defines the same reference language 25_9.4 and the same standard environment 26_{10} as D;
- T preserves, under another mode of expression, the meaning of each section of D except that:

(i) different syntactic marks {16_1.1.3.1.a} may be used {with a correspondingly different metaproduction rule for "**ALPHA**" {16_1.3.1.B}} ;

(ii) the method of derivation of the production rules {16_1.1.3.4} and their interpretation {16_1.1.3.2} may be changed to suit the peculiarities of the particular natural language {; e.g., in a highly inflected natural language, it may be necessary to introduce some inflections into the hypernotions, for which changes such as the following might be required:

1) additional means for the creation of extra metaproduction rules {16_1.1.3.3.a};
2) a more elaborate definition of "consistent substitute" {16_1.1.3.4.e};
3) a more elaborate definition of "equivalence" between protonotions {17_2.1.1.2.a};
1) different inflections for paranotions {16_1.1.4.2.a};

}

(iii) some pragmatic remarks {16_1.1.2} may be changed.

b) A version of this Report may, additionally, define a "variant of Algol 68" by providing:

(i) additional or alternative representations in the reference language {25_9.4},

(ii) additional or alternative rules for the notion **'character glyph'** {24_8.1.4.1.c} and for the metanotions "**ABC**" {25_9.4.2.1.L} and "**STOP**" {26_{10}.1.1.B},

(iii) additional or alternative declarations in the standard environment which must, however, have the same meaning as the ones provided in D;

provided always that such additional or alternative items are delineated in the text in such a way that the original language, as defined in D, is still defined therein.

16.5 General metaproduction rules

{The reader may find it helpful to note that a metanotion ending in "**ETY**" always has "**EMPTY**" as one of the hypernotions on its right-hand side.}

16.5.1 Metaproduction rules of modes

A) **MODE :: PLAIN ; STOWED ; REF to MODE ; PROCEDURE ; UNITED ; MU definition of MODE ; MU application.**

B) **PLAIN :: INTREAL ; boolean ; character.**

C) **INTREAL :: SIZETY integral ; SIZETY real.**

D) **SIZETY :: long LONGSETY ; short SHORTSETY ; EMPTY.**

E) **LONGSETY :: long LONGSETY ; EMPTY.**

F) **SHORTSETY :: short SHORTSETY ; EMPTY.**

G) **EMPTY :: .**

H) **STOWED :: structured with FIELDS mode ; FLEXETY ROWS of MODE.**

I) **FIELDS :: FIELD ; FIELDS FIELD.**

J) **FIELD :: MODE field TAG**{25_9.4.2.A} **.**

K) **FLEXETY :: flexible ; EMPTY.**

L) **ROWS :: row ; ROWS row.**

M) **REF :: reference ; transient reference.**

N) **PROCEDURE :: procedure PARAMETY yielding MOID.**

O) **PARAMETY :: with PARAMETERS ; EMPTY.**

P) **PARAMETERS :: PARAMETER ; PARAMETERS PARAMETER.**

Q) **PARAMETER :: MODE parameter.**

R) **MOID :: MODE ; void.**

S) **UNITED :: union of MOODS mode.**

T) **MOODS :: MOOD ; MOODS MOOD.**

U) **MOOD :: PLAIN ; STOWED ; reference to MODE ; PROCEDURE ; void.**

V) **MU :: muTALLY.**

W) **TALLY :: i ; TALLY i.**

{The metaproduction rule for "**TAG**" is given in section 25_9.4.2.1. It suffices for the present that it produces an arbitrarily large number of terminal metaproductions.}

16.5.2 Metaproduction rules associated with phrases and coercion

A) **ENCLOSED :: closed ; collateral ; parallel ; CHOICE**{18_3.4.A} **; loop.**

B) **SOME :: SORT MOID NEST.**

C) **SORT :: strong ; firm ; meek ; weak ; soft.**

16.5.3 Metaproduction rules associated with nests

A) **NEST :: LAYER ; NEST LAYER.**

B) **LAYER :: new DECSETY LABSETY.**

C) **DECSETY :: DECS ; EMPTY.**

D) **DECS :: DEC ; DECS DEC.**

E) **DEC ::**
MODE TAG{25_9.4.2.A} **;**
priority PRIO TAD{25_9.4.2.F} **;**
MOID TALLY TAB{25_9.4.2.D} **;**
DUO TAD{25_9.4.2.F} **;**
MONO TAM{25_9.4.2.K} **.**

F) **PRIO :: i ; ii ; iii ; iii i ; iii ii ; iii iii ; iii iii i ; iii iii ii ; iii iii iii.**

G) **MONO :: procedure with PARAMETER yielding MOID.**

H) **DUO :: procedure with PARAMETER1 PARAMETER2 yielding MOID.**

I) **LABSETY :: LABS ; EMPTY.**

J) **LABS :: LAB ; LABS LAB.**

K) **LAB :: label TAG**{25_9.4.2.A} **.**

{The metaproduction rules for "**TAB**", "**TAD**" and "**TAM**" are given in section 25_9.4.2.1. It suffices for the present that each of them produces an arbitrarily large number of terminal metaproductions, none of which is a terminal metaproduction of "**TAG**".}

{"Well, 'slithy' means 'lithe and slimy'. ...
You see it's like a portmanteau - there are
two meanings packed up into one word."
Through the Looking Glass, Lewis Carroll. }

16.6 General hyper-rules

{Predicates are used in the syntax to enforce certain restrictions on the production trees, such as that each **applied-indicator** should identify a uniquely determined **defining-indicator**. A more modest use is to reduce the number of hyper-rules by grouping several similar cases as alternatives in one rule. In these cases predicates are used to test which alternative applies.}

16.6.1 Syntax of general predicates

A) **NOTION :: ALPHA ; NOTION ALPHA.**

B) **ALPHA :: a ; b ; c ; d ; e ; f ; g ; h ; i ; j ; k ; l ; m ; n ; o ; p ; q ; r ; s ; t ; u ; v ; w ; x ; y ; z.**

C) **NOTETY :: NOTION ; EMPTY.**

D) **THING :: NOTION ; (NOTETY1) NOTETY2 ; THING (NOTETY1) NOTETY2.**

E) **WHETHER :: where ; unless.**

a) **where true : EMPTY.**

b) **unless false : EMPTY.**

c) **where THING1 and THING2 : where THING1, where THING2.**

d) **where THING1 or THING2 : where THING1 ; where THING2.**

e) **unless THING1 and THING2 : unless THING1 ; unless THING2.**

f) **unless THING1 or THING2 : unless THING1, unless THING2.**

g) **WHETHER (NOTETY1) is (NOTETY2) :**
WHETHER (NOTETY1) begins with (NOTETY2){h,i,j}
and (NOTETY2) begins with (NOTETY1){h,i,j}**.**

h) **WHETHER (EMPTY) begins with (NOTION)**{g,j} **: WHETHER false**{b,-}**.**

i) **WHETHER (NOTETY) begins with (EMPTY)**{g,j} **: WHETHER true**{a,-}**.**

j) **WHETHER (ALPHA1 NOTETY1) begins with (ALPHA2 NOTETY2)**{g,j,m} **:**
WHETHER (ALPHA1) coincides with (ALPHA2) in
(abcdefghijklmnopqrstuvwxyz){k,l,-}
and (NOTETY1) begins with (NOTETY2){h,i,j}**.**

k) **where (ALPHA) coincides with (ALPHA) in (NOTION)**{j} **: where true {a}.**

l) **unless (ALPHA1) coincides with (ALPHA2) in (NOTION)**{j} **:**
where (NOTION) contains (ALPHA1 NOTETY ALPHA2){m}
or (NOTION) contains (ALPHA2 NOTETY ALPHA1){m}**.**

m) **WHETHER (ALPHA NOTETY) contains (NOTION)**{l,m} **:**
WHETHER (ALPHA NOTETY) begins with (NOTION){j}
or (NOTETY) contains (NOTION){m,n}**.**

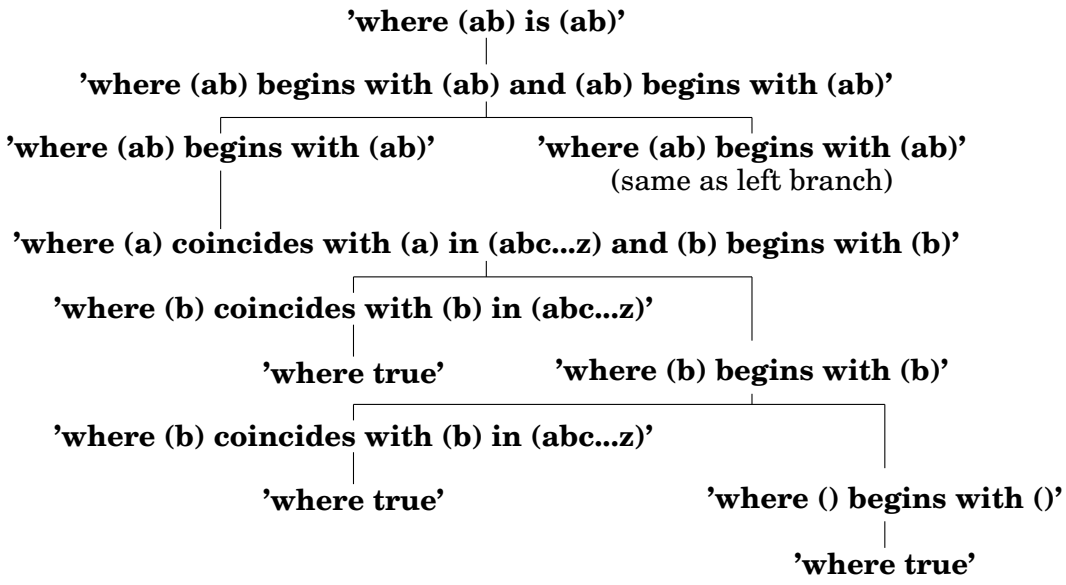
n) **WHETHER (EMPTY) contains (NOTION)**{m} **: WHETHER false**{b,-}**.**

{The small syntactic marks "(" and ")" are used to ensure, in a simple way, the unambiguous application of these predicates.}

16.6.2 The holding of predicates

A "predicate" is a protonotion which begins with **'where'** or **'unless'** {unified into **'WHETHER'**}. For a predicate P, either one or more production trees may be produced {16_1.1.3.2.f} {all of which are then invisible}, in which case P "holds", or no production tree may be produced {since each attempt to produce one runs into blind alleys}, and then P "does not hold".

{For example, the predicate **'where (ab) is (ab)'** holds. Its production tree may be depicted thus:



}

If a predicate holds, then its production tree always terminates via **'where true'** or **'unless false'**. If it does not hold, then, in general, the blind alleys are **'where false'** and **'unless true'**. Although almost all the hyper-rules concerned are for hypernotions beginning with "**WHETHER**" and so provide, each time, production rules for pairs of predicates such as **'where THING1'** and **'unless THING1'**, this does not mean that in each such case one of the pair must hold. For example, **'where digit four counts iii'** {19_4.3.1.c} does not hold, but no care has been taken to make **'unless digit four counts iii'** hold either, since there is no application for it in this Report.

In the semantics, no meaning is ascribed to constructs whose originals are predicates. They serve purely syntactical purposes.}

16.6.3 Syntax of general constructions

A) **STYLE :: brief ; bold ; style TALLY.**

a) **NOTION option : NOTION ; EMPTY.**

b) **NOTION sequence**{b} **: NOTION ; NOTION, NOTION sequence**{b}**.**

c) **NOTION list**{c} **: NOTION ; NOTION, and also**{25_9.4.f} **token, NOTION list**{c}**.**

d) **NOTETY STYLE pack :**
STYLE begin{25_9.4.f,-} **token, NOTETY, STYLE end**{25_9.4.f,-} **token.**

e) **NOTION STYLE bracket :**
STYLE sub{25_9.4.f,-} **token, NOTION, STYLE bus**{25_9.4.f,-} **token.**

f) **THING1 or alternatively THING2 : THING1 ; THING2.**

{It follows from this syntax that production rules such as

digit cypher sequence : digit cypher ;
digit cypher, digit cypher sequence.

(which was used in the production of the example in 16_1.1.3.2.f, but for which no more explicit hyper-rule is given) are immediately available. Thus the number of hyper-rules actually written in this Report has been reduced and those that remain have, hopefully, been made more readable, since these general constructions are so worded as to suggest what their productions should be.

For this reason, cross-references (16_1.1.3.4.f) to these rules have been replaced by more helpful references; e.g. in 24_8.1.1.1.b, instead of "**digit cypher sequence** {16_1.3.3.b}", the more helpful "**digit cypher** {c}**sequence**" is given. Likewise, references within the general constructions themselves have been restricted to a bare minimum.}

17 The computer and the program

The meaning of a **program** in the strict language is explained in terms of a hypothetical computer which performs the set of actions {17_2.1.4} which constitute the elaboration {17_2.1.4.1} of that **program**. The computer deals with a set of "objects" {17_2.1.1}.

17.1 Terminology

{"When *I* use a word," Humpty Dumpty said, in rather a
scornful tone, "it means just what I choose it to mean
- neither more nor less."
Through the Looking Glass, Lewis Carroll. }

17.1.1 Objects

An "object" is a construct {16_1.1.3.2.e}, a "value" {17_2.1.1.1.a}, a "locale" {17_2.1.1.1.b}, an "environ" {17_2.1.1.1.c} or a "scene" {17_2.1.1.1.d}.

{Constructs may be classified as "external objects", since they correspond to the text of the **program**, which, in a more realistic computer, would be compiled into some internal form in which it could operate upon the "internal objects", namely the values, the locales, the environs and the scenes. However, the hypothetical computer has no need of a compilation phase, it being presumed able to examine the **program** and all of its descendent constructs at the same time as it is manipulating the internal objects.}

17.1.1.1 Values, locales, environs and scenes

a) A "value" is a "plain value" {17_2.1.3.1}, a "name" {17_2.1.3.2}, a "stowed value" (i.e., a "structured value" {17_2.1.3.3} or a "multiple value" {17_2.1.3.4}) or a "routine" {17_2.1.3.5}.

{For example, a real number is a plain value. A special font is used for values appearing in the text of this Report, thus: `3.14`, `true`. This is not to be confused with the italic and bold

fonts used for constructs. This same special font is also used for letters designating such things as constructs and protonotions.}

b) A "locale" {is an internal object which} corresponds to some **'DECSETY LABSETY'** {16_1.2.3.C,I}. A "vacant locale" is one for which that **'DECSETY LABSETY'** is **'EMPTY'**.

{Each **'QUALITY TAX'** {19_4.8.1.F, G} enveloped by that **'DECSETY LABSETY'** corresponds to a **QUALITY-defining-indicator-with-TAX** {i.e., to an **identifier**, **operator** or **mode-indication**} declared in the construct whose elaboration caused that locale to be created. Such a **'QUALITY TAX'** may be made to "access" a value or a scene "inside" that locale {17_2.1.2.c}

A locale may be thought of as a number of storage cells, into which such accessed objects are placed.}

{The terminal metaproductions of the metanotions "**DEC**", "**LAB**" and "**FIELD**" (or of the more frequently used "**PROP**", which includes them all) are all of the form **'QUALITY TAX'**. These "properties" are used in the syntax and semantics concerned with nests and locales in order to associate, in a particular situation, some quality with that **'TAX'**.}

c) An "environ" is either empty, or is composed of an environ and a locale.

{Hence, each environ is derived from a series of other environs, stemming ultimately from the empty "primal environ" in which the **program** is elaborated {17_2.2.2.a}.}

d) A "scene" S is an object which is composed of a construct C {16_1.1.3.2.e} and an environ E. C is said to be the construct, and E the environ, "of" S.

{Scenes may be accessed inside locales {17_2.1.2.c} by **'LAB'**s or **'DEC'**s arising from **label-identifiers** or from **mode-indications**, and they may also be values {17_2.1.3.5}.}

17.1.1.2 Modes

{Each value has an attribute, termed its "mode", which defines how that value relates to other values and which actions may be applied to it. This attribute is described, or "spelled", by means of some **'MOID'** {16_1.2.1.R} (thus there is a mode spelled **'real'**, and there is a mode spelled **'structured with real field letter r letter e real field letter i letter m mode'**). Since it is intended that the modes specified by the **mode-indications** `A` and `B` in

```
MODE A = STRUCT (REF A b),
MODE B = STRUCT (REF STRUCT (REF B b) b)
```

should in fact be the same mode, it is necessary that both the **'MOID'**

> **'mui definition of structured with reference to mui application field letter b mode'**

and the **'MOID'**

'muii definition of structured with reference to structured with reference to muii application field letter b mode field letter b mode'

(and indeed many others) should be alternative spellings of that same mode. Similarly, the mode specified by the **declarer** `UNION (INT, REAL)` may be spelled as either **'union of integral real mode'** or **'union of real integral mode'**. All those **'MOID'**s which are spellings of one same mode are said to be "equivalent to" one another {a}.

Certain **'MOID'**s, such as **'reference to muiii application'**, **'reference to muiiii definition of reference to muiiii application'**, **'union of real reference to real mode'**, and **'structured with integral field letter a real field letter a mode'**, are ill formed {23_7.4, 19_4.7.1.f, 19_4.8.1.c} and do not spell any mode.

Although for most practical purposes a "mode" can be regarded as simply a **'MOID'**, its rigorous definition therefore involves the whole class of **'MOID'**s, equivalent to each other, any of which could describe it.}

a) **'MOID1'** {16_1.2.1.R} is "equivalent to" **'MOID2'** if the predicate **'where MOID1 equivalent MOID2'** {23_7.3.1.a} holds {16_1.3.2}.

{A well formed **'MOID'** is always equivalent to itself: **'union of integral real mode'** is equivalent to **'union of real integral mode'**.}

A protonotion P is "equivalent to" a protonotion Q if it is possible to transform a copy Pc of P into at copy Qc of Q in the following step:

Step: If Pc is not identical to Qc, then some **'MOID1'** contained in Pc, but not within any {larger} **'MOID2'** contained in Pc, is replaced by some equivalent **'MOID'**, and the Step is taken again.

{Thus **'union of integral real mode identifier'** is equivalent to **'union of real integral mode identifier'**.}

b) A "mode" is a class C of **'MOID'**s such that each member of C is equivalent {a} to each other member of C and also to itself {in order to ensure well formedness}, but not to any **'MOID1'** which is not a member of C.

{However, it is possible (except when equivalence of modes is specifically under discussion) to discuss a mode as if it were simply a terminal metaproduction of "**MOID**", by virtue of the abbreviation to be given in 17_2.1.5.f .}

c) Each value is of one specific mode.

{For example, the mode of the value `3.14` is **'real'**. However, there are no values whose mode begins with **'union of'**, **'transient reference to'** or **'flexible ROWS of'** (see 17_2.1.3.6).}

17.1.1.3 Scopes

{A value V may "refer to" {17_2.1.2.e}, or be composed from {17_2.1.1.1.d} another internal object O (e.g., a name may refer to a value; a routine, which is a scene, is composed, in part, from an environ). Now the lifetime of the storage cells containing {17_2.1.3.2.a} or implied by {17_2.1.1.1.b} O may be limited (in order that they may be recovered after a certain time), and therefore it must not be possible to preserve V beyond that lifetime, for otherwise an attempt to reach some no-longer-existent storage cell via V might still be made. This restriction is expressed by saying that, if V is to be "assigned" {20_5.2.1.2.b} to some name W, then the "scope" of W must not be "older" than the scope of V. Thus, the scope of V is a measure of the age of those storage cells, and hence of their lifetime.}

a) Each value has one specific "scope" {which depends upon its mode or upon the manner of its creation; the scope of a value is defined to be the same as that of some environ}.

b) Each environ has one specific "scope". {The scope of each environ is "newer" {17_2.1.2.f} than that of the environ from which it is composed {17_2.1.1.1.c}.}

{The scope of an environ is not to be confused with the scopes of the values accessed inside its locale. Rather, the scope of an environ is used when defining the scope of scenes for which it is necessary {23_7.2.2.c} or of the yields of generators for which it is "local" {20_5.2.3.2.b}. The scope of an environ is defined relative {17_2.1.2.f} to the scope of some other environ, so that hierarchies of scopes are created depending ultimately upon the scope of the primal environ {17_2.2.2.a}.}

17.1.2 Relationships

a) Relationships either are "permanent", i.e., independent of the **program** and of its elaboration, or actions may cause them to "hold" or to cease to hold. Relationships may also be "transitive"; i.e., if "*" is such a relationship and A*B and B*C hold, then A*C holds also.

b) "To be the yield of" is a relationship between a value and an action, viz., the elaboration of a scene. This relationship is made to hold upon the completion of that elaboration {17_2.1.4.1.b}.

c) "To access" is a relationship between a **'PROP'** {19_4.8.1.E} and a value or a scene V which may hold "inside" some specified locale L {whose **'DECSETY LABSETY'** envelops **'PROP'**} . This relationship is made to hold when **'PROP'** is "made to access" V inside L {18_3.5.2.Step 4, 19_4.8.2.a} and it then holds also between any **'PROP1'** equivalent to {17_2.1.1.2.a} **'PROP'** and V inside L.

d) The permanent relationships between values are: "to be of the same mode as" {17_2.1.1.2.c}, "to be smaller than", "to be widenable to", "to be lengthenable to" {17_2.1.3.1.e} and "to be equivalent to" {17_2.1.3.1.g}. If one of these relationships is defined at all for a given pair

of values, then it either holds or does not hold permanently. These relationships are all transitive.

e) "To refer to" is a relationship between a "name" {17_2.1.3.2.a} N and some other value. This relationship is made to hold when N is "made to refer to" that value and ceases to hold when N is made to refer to some other value.

f) There are three transitive relationships between scopes, viz., a scope A {17_2.1.1.3} may be either "newer than", or "the same as" or "older than" a scope B. If A is newer than B, then B is older than A and vice-versa. If A is the same as B, then A is neither newer nor older than B {but the converse is not necessarily true, since the relationship is not defined at all for some pairs of scopes}.

g) "To be a subname of" is a relationship between a name and a "stowed name" {17_2.1.3.2.b}. This relationship is made to hold when that stowed name is "endowed with subnames" {17_2.1.3.3.e, 17_2.1.3.4.g} or when it is "generated" {17_2.1.3.4.j, l}, and it continues to hold until that stowed name is endowed with a different set of subnames.

17.1.3 Values

17.1.3.1 Plain values

a) A plain value is either an "arithmetic value", i.e., an "integer" or a "real number", or is a "truth value" {f}, a "character" {g} or a "void value" {h}.

b) An arithmetic value has a "size", i.e., an integer characterizing the degree of discrimination with which it is kept in the computer.

c) The mode of an integer or of a real number of size n is, respectively, some **'SIZETY integral'** or **'SIZETY real'** where, if n is positive (zero, negative), that **'SIZETY'** is n times **'long'** (is empty, is $-n$ times **'short'**).

d) The number of integers or of real numbers of a given size that can be distinguished increases (decreases) with that size until a certain size is reached, viz., the "number of extra lengths" (minus the "number of extra shorths") of integers or of real numbers, respectively, {26_{10}.2.1.a, b, d, e} after which it is constant.

{Taking Three as the subject to reason about -
A convenient number to state - }

e) For the purpose of explaining the meaning of the widening coercion and of the **operators** declared in the **standard-prelude**, the following properties of arithmetic values are assumed:

- for each pair of integers or of real numbers of the same size, the relationship "to be smaller than" is defined with its usual mathematical meaning {26_{10}.2.3.3.a, 26_{10}.2.3.4.a};

- for each pair of integers of the same size, a third distinguishable integer of that size may exist, the first integer "minus" the other {26_{10}.2.3.3.g};

{We add Seven, and Ten, and then multiply out
By One Thousand diminished by Eight. }

- for each pair of real numbers of the same size, three distinguishable real numbers of that size may exist, the first real number "minus" ("times", "divided by") the other one {26_{10}.2.3.4.g, l, m};

  in the foregoing, the terms "minus", "times" and "divided by" have their usual mathematical meaning but, in the case of real numbers, their results are obtained "in the sense of numerical analysis", i.e., by performing those operations on numbers which may deviate slightly from the given ones {; this deviation is left undefined in this Report};

{The result we proceed to divide, as you see,
By Nine Hundred and Ninety and Two }

- each integer of a given size is "widenable to" a real number close to it and of that same size {22_6.5};

- each integer (real number) of a given size can be "lengthened to" an integer (real number) close to it whose size is greater by one {26_{10}.2.3.3.q, 26_{10}.2.3.4.n}.

f) A "truth value" is either "`true`" or "`false`". Its mode is **'boolean'**.

{Then subtract Seventeen, and the answer must be
Exactly and perfectly true.
The Hunting of the Snark, Lewis Carroll. }

g) Each "character" is "equivalent" to a nonnegative integer of size zero, its "integral equivalent" {26_{10}.2.1.n}; this relationship is defined only to the extent that different characters have different integral equivalents, and that there exists a "largest integral equivalent" {26_{10}.2.1.p}. The mode of a character is **'character'**.

h) The only "void value" is "`empty`". Its mode is **'void'**.

{The elaboration of a construct yields a void value when no more useful result is needed. Since the syntax does not provide for **void-variables**, **void-identity-declarations** or

void-parameters, the programmer cannot make use of void values, except those arising from uniting {22_6.4}.}

i) The scope of a plain value is the scope of the primal environ {17_2.2.2.a}.

17.1.3.2 Names

{What's in a name? that which we call a rose
By any other name would smell as sweet.
Romeo and Juliet, William Shakespeare. }

a) A "name" is a value which can be "made to refer to" {d, 20_5.2.3.2.a, 20_5.2.1.2.b} some other value, or which can be "nil" {and then refers to no value}; moreover, for each mode beginning with **'reference to'**, there is exactly one nil name of that mode.

A name may be "newly created" {by the elaboration of a **generator** {20_5.2.3.2} or a **rowed-to-FORM** {22_6.6.2}, when a stowed name is endowed with subnames {17_2.1.3.3.e, 17_2.1.3.4.g} and, possibly, when a name is "generated" {17_2.1.3.4.j, l} }. The name so created is different from all names already in existence.

{A name may be thought of as the address of the storage cell or cells, in the computer, used to contain the value referred to. The creation of a name implies the reservation of storage space to hold that value.}

b) The mode of a name N is some **'reference to MODE'** and any value which is referred to by N must be "acceptable to" {17_2.1.3.6.d} that **'MODE'**. If **'MODE'** is some **'STOWED'**, then N is said to be a "stowed name".

c) The scope of a name is the scope of some specific environ {usually the "local environ" {20_5.2.3.2.b} of some **generator**} . The scope of a name which is nil is the scope of the primal environ {17_2.2.2.a}.

d) If N is a stowed name referring to a structured (multiple) value V {17_2.1.3.3, 17_2.1.3.4}, and if a subname {17_2.1.2.g} of N selected {17_2.1.3.3.e, 17_2.1.3.4.g} by a **'TAG'** (an index) I is made to refer to a {new} value X, then N is made to refer to a structured (multiple) value which is the same as V except for its field (element) selected by I which is {now made to be} X.

{For the mode of a subname, see 17_2.1.3.3.d and 17_2.1.3.4.f.}

17.1.3.3 Structured values

a) A "structured value" is composed of a sequence of other values, its "fields", each of which is "selected" {b} by a specific **'TAG'** {25_9.4.2.1.A}. {For the selection of a field by a **field-**

selector, see 17_2.1.5.g .}

{The ordering of the fields of a structured value is utilized in the semantics of **structure-displays** {18_3.3.2.b} and **format-texts** {26_{10}.3.4}, and in straightening {26_{10}.3.2.3.c}.}

b) The mode of a structured value V is some **'structured with FIELDS mode'**. If the n-th **'FIELD'** enveloped by that **'FIELDS'** is some **'MODE field TAG'**, then the n-th field of V is "selected" by **'TAG'** and is acceptable to {17_2.1.3.6.d} **'MODE'**.

c) The scope of a structured value is the newest of the scopes of its fields.

d) If the mode of a name N {referring to a structured value} is some **'reference to structured with FIELDS mode'**, and if the predicate **'where MODE field TAG resides in FIELDS'** holds {23_7.2.1.b, c}, then the mode of the subname of N selected {e} by **'TAG'** is **'reference to MODE'**.

e) When a name N which refers to a structured value V is "endowed with subnames" {e, 17_2.1.3.4.g, 19_4.4.2.b, 20_5.2.3.2.a}, then,

For each **'TAG'** selecting a field F in V,

- a new subname M is created of the same scope as N;
- M is made to refer to F;
- M is said to be the name "selected" by **'TAG'** in N;
- if M is a stowed name {17_2.1.3.2.b}, then it is itself endowed with subnames {e, 17_2.1.3.4.g}.

17.1.3.4 Multiple values

a) A "multiple value" {of n dimensions} is composed of a "descriptor" and a sequence of other values, its "elements", each of which may be "selected" by a specific n-tuple of integers, its "index".

b) The "descriptor" is of the form
$((l_1, u_1), (l_2, u_2), ..., (l_n, u_n))$
where each $(l_i, u_i), i = 1, ..., n$, is a "bound pair" of integers in which l_i is the i^{th} "lower bound" and u_i is the i^{th} "upper bound".

c) If for any $i, i = 1, ..., n, u_i < l_i$, then the descriptor is said to be "flat" and there is one element, termed a "ghost element" {, and not selected by any index; see also {20_5.2.1.2.b} } ; otherwise, the number of elements is $(u_1 - l_1 + 1) \times (u_2 - l_2 + 1) \times ... \times (u_n - l_n + 1)$ and each is selected by a specific index $(r_1, ..., r_n)$ where $l_i \leq r_i \leq u_i, i = 1, ..., n$.

d) The mode of a multiple value V is some **'ROWS of MODE'**, where that **'ROWS'** is composed of as many times **'row'** as there are bound pairs in the descriptor of V and where each element of V is acceptable to {17_2.1.3.6.d} that **'MODE'**.

{For example, given `[ ] UNION (INT, REAL) ruir = (1, 2.0)`, the mode of the yield of `ruir` is **'row of union of integral real mode'**, the mode of its first element is **'integral'** and that of its second element is **'real'**.}

e) The scope of a multiple value is the newest of the scopes of its elements, if its descriptor is not flat, and, otherwise, is the scope of the primal environ {17_2.2.2.a}.

f) A multiple value, of mode **'ROWS of MODE'**, may be referred to either by a "flexible" name of mode **'reference to flexible ROWS of MODE1'**, or by a "fixed" name of mode **'reference to ROWS of MODE1'** where {in either case} **'MODE1'** "deflexes" {17_2.1.3.6.b} to **'MODE'**.

{The difference implies a possible difference in the method whereby the value is stored in the computer. The flexible case must allow a multiple value with different bounds to be assigned {20_5.2.1.2.b} to that name, whereas the fixed case can rely on the fact that those bounds will remain fixed during the lifetime of that name. Note that the "flexibility" is a property of the name; the underlying multiple value is the same value in both cases.}

If the mode of a name N {referring to a multiple value} is some **'reference to FLEXETY ROWS of MODE'**, then the mode of each subname of N is **'reference to MODE'**.

g) When a name N which refers to a multiple value V is "endowed with subnames" {g, 17_2.1.3.3.e, 19_4.4.2.b, 20_5.2.1.2.b, 20_5.2.3.2.a}, then,
For each index selecting an element E of V,

- a new subname M is created of the same scope as N;
- M is made to refer to E;
- M is said to be the name "selected" by that index in N;
- if M is a stowed name {17_2.1.3.2.b}, then it is itself endowed with subnames {g, 17_2.1.3.3.e}.

{In addition to the selection of an element {a} or a name {g} by means of an index, it is also possible to select a value, or to generate a new name referring to such a value, by means of a trim {h, i, j} or a **'TAG'** {k, l}. Both indexes and trims are used in the elaboration of **slices** {20_5.3.2.2}.}

h) A "trim" is an n-tuple, each element of which is either an integer {corresponding to a **subscript**} or a triplet (l, u, d) {corresponding to a **trimmer** or a **revised-lower-bound-option**}, such that at least one of those elements is a triplet {if all the elements are integers, then the n-tuple is an index {a}}. Each element of such a triplet is either an integer or is "*absent*".

{A trim (or an index) is yielded by the elaboration of an **indexer** {20_5.3.2.2.b}.}

i) The multiple value W {of m dimensions} "selected" by a trim T in a multiple value V {of n dimensions, $1 \leq$ m $\leq$ n} is determined as follows:

- Let T be composed of integers and triplets $T_i, i = 1, ...n$, of which m are actually triplets; let the j^{th} triplet be $(l_j, u_j, d_j), j = 1, ...m$;
- W is composed of

(i) a descriptor $((l_1 - d_1, u_1 - d_1), (l_2 - d_2, u_2 - d_2), ..., (l_m - d_m, u_m - d_m))$;

(ii) elements of V, where the element, if any, selected in W by an index $(w_1, ..., w_m)$ {$l_j - d_j \leq w_j \leq u_j - d_j$} is that selected in V by the index $(v_1, ..., v_n)$ determined as follows:

For i = 1, ..., n,

Case A: T_i is an integer:

- $v_i = T_i$;

Case B: T_i is the j^{th} triplet (l_j, u_j, d_j) of T:

- $v_i = w_j + d_j$.

j) The name M "generated" by a trim T from a name N which refers to a multiple value V is a {fixed} name, of the same scope as N, {not necessarily newly created} which refers to the multiple value W selected {i} by T in V. Each subname of M, as selected by an index I_W, is one of the {already existing} subnames of N, as selected by an index I_V, where each I_V is determined from T and the corresponding I_W using the method given in the previous sub-section.

k) The multiple value W "selected" by a **'TAG'** in a multiple value V {each of whose elements is a structured value} is composed of

(i) the descriptor of V, and

(ii) the fields selected by **'TAG'** in the elements of V, where the element, if any, selected in W by an index I is the field selected by **'TAG'** in the element of V selected by I.

l) The name M "generated" by a **'TAG'** from a name N which refers to a multiple value V {each of whose elements is a structured value} is a {fixed} name, of the same scope as N, {not necessarily newly created} which refers to the multiple value selected {k} by **'TAG'** in V. Each subname of M selected by an index I is the {already existing} name selected {17_2.1.3.3.e} by **'TAG'** in the subname of N selected {g} by I.

17.1.3.5 Routines

a) A "routine" is a scene {17_2.1.1.1.d} composed of a **routine-text** {20_5.4.1.1.a,b} together with an environ {17_2.1.1.1.c}.

{A routine may be "called" {20_5.4.3.2.b}, whereupon the **unit** of its **routine-text** is elaborated.}

b) The mode of a routine composed of a **PROCEDURE-routine-text** is **'PROCEDURE'**.

c) The scope of a routine is the scope of its environ.

17.1.3.6 Acceptability of values

a) {There are no values whose mode begins with **'union of'**. There exist names whose modes begin with **'reference to union of'**, e.g., `u` in `UNION (INT, REAL) u;` . Here, however, `u`, whose mode is **'reference to union of integral real mode'**, refers either to a value whose mode is **'integral'** or to a value whose mode is **'real'**. It is possible to discover which of these situations obtains, at a given moment, by means of a **conformity-clause** {18_3.4.1.q}.}

The mode **'MOID'** is "united from" the mode **'MOOD'** if **'MOID'** is some **'union of MOODSETY1 MOOD MOODSETY2 mode'**.

b) {There are no values whose mode begins with **'flexible'**. There exist flexible names whose modes begin with **'reference to flexible'**, e.g., `a1` in `FLEX [1: n] REAL a1;` . Here `a1`, whose mode is **'reference to flexible row of real'**, refers to a multiple value whose mode is **'row of real'** (see also 17_2.1.3.4.f). In general, there exist values only for those modes obtainable by "deflexing".}

The mode **'MOID1'** "deflexes" to the mode **'MOID2'** if the predicate **'where MOID1 deflexes to MOID2'** holds {19_4.7.1.a, b, c}.

{The deflexing process obtains **'MOID2'** by removing all **'flexible'**s contained at positions in **'MOID1'** where they are not also contained in any **'REF to MOID3'**. Thus

'structured with flexible row of character field letter a mode',
which is not the mode of any value, deflexes to

'structured with row of character field letter a mode'
which is therefore the mode of a value referable to by a flexible name of mode

'reference to structured with flexible row of character field letter a mode'.
This mode is already the mode of a name and therefore it cannot be deflexed any further.}

c) {There are no names whose mode begins with **'transient reference to'**.

The yield of a **transient-reference-to-MODE-FORM** is a "transient name" of mode **'reference to MODE'**, but, there being no **transient-reference-to-MODE-declarators** in the language {19_4.6.1}, the syntax ensures that transient names can never be assigned, ascribed or yielded by the calling of a routine.

E.g., `xx := a1[i]` is not an **assignation** because `xx` is not a **reference-to-transient-reference-to-real-identifier**. Transient names originate from the slicing, multiple selection or rowing of a flexible name.}

d) A value of mode $M1$ is "acceptable to" a mode $M2$ if

(i) $M1$ is the same as $M2$, or

(ii) $M2$ is united {a} from $M1$ {thus the mode specified by `UNION (REAL, INT)` accepts values whose mode is that specified by either `REAL` or `INT`}, or

(iii) $M2$ deflexes {b} to $M1$ {thus the mode **'flexible row of real'** (a mode of which there are no values) accepts values such as the yield of the **actual-declarer** `FLEX [1 : n] REAL` which is a value of mode **'row of real'**}, or

(iv) $M1$ is some **'reference to MODE'** and $M2$ is **'transient reference to MODE'** {thus the mode **'transient reference to real'** accepts values (such as the yield of `a1 [i]`) whose mode is **'reference to real'**} .

{See 17_2.1.4.1.b for the acceptability of the yield of a scene.}

17.1.4 Actions

{Suit the action to the word,
the word to the action.
Hamlet, William Shakespeare. }

17.1.4.1 Elaboration

a) The "elaboration" of certain scenes {those whose constructs are designated by certain paranotions} is specified in the sections of this Report headed "Semantics", which describe the sequence of "actions" which are to be carried out during the elaboration of each such scene.

{Examples of actions which may be specified are:

- the causing to hold of relationships,

- the creation of new names, and
- the elaboration of other scenes.}

The "meaning" of a scene is the effect of the actions carried out during its elaboration. Any of these actions or any combination thereof may be replaced by any action or combination which causes the same effect.

b) The elaboration of a scene S may "yield" a value. If the construct of S is a **MOID-NOTION**, then that value is, unless otherwise specified, {of such a mode that it is} acceptable to {17_2.1.3.6.d} **'MOID'**.

{This rule makes it possible, in the semantics, to discuss yields without explicitly prescribing their modes.}

c) If the elaboration of some construct A in some environ E is not otherwise specified in the semantics of this Report, and if B is the only direct descendent of A which needs elaboration {see below}, then the elaboration of A in E consists of the elaboration of B in E and the yield, if any, of A is the yield, if any, of B {; this automatic elaboration is termed the "pre-elaboration" of A in E} .

A construct needs no elaboration if it is invisible {16_1.1.3.2.h}, if it is a **symbol** {25_9.1.1.h}, or if its elaboration is not otherwise specified in the semantics of this Report and none of its direct descendents needs elaboration.

{Thus the elaboration of the **reference-to-real-closed-clause** {18_3.1.1.a} `(x := 3.14)` is (and yields the same value as) the elaboration of its constituent **reference-to-real-serial-clause** {18_3.2.1.a} `x := 3.14`.}

17.1.4.2 Serial and collateral actions

a) An action may be "inseparable", "serial" or "collateral". A serial or collateral action consists of one or more other actions, termed its "direct actions". An inseparable action does not consist of other actions {; what actions are inseparable is left undefined by this Report}.

b) A "descendent action" of another action B is a direct action either of B, or of a descendent action of B.

c) An action A is the "direct parent" of an action B if B is a direct action {a} of A.

d) The direct actions of a serial action S take place one after the other; i.e., the completion {17_2.1.4.3.c, d} of a direct action of S is followed by the initiation {17_2.1.4.3.b, c} of the next direct action, if any, of S. {The elaboration of a scene, being in general composed of a sequence of actions, is a serial action.}

e) The direct actions of a collateral action are merged in time; i.e., one of its descendent inseparable actions which, at that moment, is "active" {17_2.1.4.3.a} is chosen and carried out, upon the completion {17_2.1.4.3.c} of which another such action is chosen, and so on {until all are completed}.

If two actions {collateral with each other} have been said to be "incompatible with" {26_{10}.2.4} each other, then {they shall not be merged; i.e.,} no descendent inseparable action of the one shall (then the one {if it is already inseparable} shall not) be chosen if, at that moment, the other is active and one or more, but not all, of its descendent inseparable actions have already been completed; otherwise, the method of choice is left undefined in this Report.

f) If one or more scenes are to be "elaborated collaterally", then this elaboration is the collateral action consisting of the {merged} elaboration of those scenes.

17.1.4.3 Initiation, completion and termination

a) An action is either "active" or "inactive".

An action becomes active when it is "initiated" {b, c} or "resumed" {g} and it becomes inactive when it is "completed" {c, d}, "terminated" {e}, "halted" {f} or "interrupted" {h}.

b) When a serial action is "initiated", then the first of its direct actions is initiated. When a collateral action is "initiated", then all of its direct actions are initiated.

c) When an inseparable action is "initiated", it may then be carried out {see 17_2.1.4.2.e}, whereupon it is "completed".

d) A serial action is "completed" when its last direct action has been completed. A collateral action is "completed" when all of its direct actions have been completed.

e) When an action A {whether serial or collateral} is "terminated", then all of its direct actions {and hence all of its descendent actions} are terminated {whereupon another action may be initiated in its place}. {Termination of an action is brought about by the elaboration of a **jump** {20_5.4.4.2}.}

f) When an action is "halted", then all of its active direct actions {and hence all of its active descendent actions} are halted. {An action may be halted during a "calling" of the routine yielded by the **operator** DOWN {26_{10}.2.4.d}, whereupon it may subsequently be resumed during a calling of the routine yielded by the **operator** UP {26_{10}.2.4.e}.}

If, at any time, some action is halted and it is not descended from a "process" of a "parallel action" {26_{10}.2.4} of whose other process (es) there still exist descended active inseparable actions, then the further elaboration is undefined. {Thus it is not defined that the elaboration of the **collateral-clause** in

```
BEGIN SEMA sergei = LEVEL 0;
  (PAR BEGIN (DOWN sergei; print (pokrovsky)), SKIP END,
```

```
    (read (pokrovsky); UP sergei))
  END
```
will ever be completed.}

g) When an action A is "resumed", then those of its direct actions which had been halted consequent upon the halting of A are resumed.

h) An action may be "interrupted" by an event {e.g., "overflow"} not specified by the semantics of this Report but caused by the computer if its limitations {17_2.2.2.b} do not permit satisfactory elaboration. When an action is interrupted, then all of its direct actions, and possibly its direct parent also, are interrupted. {Whether, after an interruption, that action is resumed, some other action is initiated or the elaboration of the **program** ends, is left undefined by this Report.}

{The effect of the definitions given above is as follows:
During the elaboration of a **program** {17_2.2.2.a} the elaboration of its **closed-clause** in the empty primal environ is active. At any given moment, the elaboration of one scene may have called for the elaboration of some other scene or of several other scenes collaterally. If and when the elaboration of that other scene or scenes has been completed, the next step of the elaboration of the original scene is taken, and so on until it, in turn, is completed.

It will be seen that all this is analogous to the calling of one subroutine by another; upon the completion of the execution of the called subroutine, the execution of the calling subroutine is continued; the semantic rules given in this Report for the elaboration of the various paranotions correspond to the texts of the subroutines; the semantic rules may even, in suitable circumstances, invoke themselves recursively (but with a different construct or in a different environ on each occasion).

Thus there exists, at each moment, a tree of active actions descended {17_2.1.4.2.b} from the elaboration of the **program**.}

17.1.4.4 Abbreviations

{In order to avoid some long and turgid phrases which would otherwise have been necessary in the Semantics, certain abbreviations are used freely throughout the text of this Report.}

a) The phrase "the A of B", where A and B are paranotions, stands for "the A which is a direct descendent {16_1.1.3.2.f} of B".

{This permits the abbreviation of "direct descendent of" to "of" or "its", e.g., in the **assignation** {20_5.2.1.1.a} `i := 1`, `i` is "its" **destination** (or `i` is the, or a, **destination** "of" the **assignation** `i := 1`), whereas `i` is not a **destination** of the **serial-clause** `i := 1; j := 2` (although it is a constituent **destination** {16_1.1.4.2.d} of it).}

b) The phrase "C in E", where C is a construct and E is an environ, stands for "the scene composed {17_2.1.1.1.d} of C and E". It is sometimes even further shortened to just "C" when it is clear which environ is meant.

{Since the process of elaboration {17_2.1.4.1.a} may be applied only to scenes, this abbreviation appears most frequently in forms such as "A **loop-clause** C, in an environ $E1$, is elaborated ... " {18_3.5.2} and "An **assignation** A is elaborated ... " (20_5.2.1.2.a, where it is the elaboration of A in any appropriate environ that is being discussed).}

c) The phrase "the yield of S", where S is a scene whose elaboration is not explicitly prescribed, stands for "the yield obtained by initiating the elaboration of S and awaiting its completion".

{Thus the sentence {18_3.2.2.c} :

> "W is the yield of that **unit**;"

(which also makes use of the abbreviation defined in b above) is to be interpreted as meaning:

> "W is the yield obtained upon the completion of the elaboration, hereby initiated, of the scene composed of that **unit** and the environ under discussion;" .

}

d) The phrase "the yields of $S_1, ..., S_n$", where $S_1, ..., S_n$ are scenes whose elaboration is not explicitly prescribed, stands for "the yields obtained by initiating the collateral elaboration {17_2.1.4.2.f} of $S_1, ..., S_n$ and awaiting its completion {which implies the completion of the elaboration on them all} ".

If some or all of $S_1, ..., S_n$ are described as being, in some environ, certain constituents of some construct, then their yields are to be considered as being taken in the textual order {16_1.1.3.2.i} of those constituents within that construct.

{Thus the sentence {18_3.3.2.b} :

> "let $V_1, ..., V_m$ be the {collateral} yields of the constituent **units** of C;"

is to be interpreted as meaning:

> "let $V_1, ..., V_m$ be the respective yields obtained upon the completion of the collateral elaboration, hereby initiated, of the scenes composed of the constituent **units** of C, considered in their textual order, together with the environ in which C was being elaborated;" .

}

e) The phrase "if A is B", where A and B are hypernotions, stands for "if A is equivalent {17_2.1.1.2.a} to B".

{Thus, in "Case C: **'CHOICE'** is some **'choice using UNITED'**" {18_3.4.2.b}, it matters not whether **'CHOICE'** happens to begin with **'choice using union of'** or with some **'choice using MU definition of union of'**.}

f) The phrase "the mode is A", where A is a hypernotion, stands for "the mode {is a class of **'MOID'**s which} includes A".

{This permits such shortened forms as "the mode is some **'structured with FIELDS mode'**", "the mode begins with **'union of'**", and "the mode envelops a **'FIELD'**"; in general, a mode may be specified by quoting just one of the **'MOID'**s included in it.}

g) The phrase "the value selected (generated) by the **field-selector** F" stands for "if F is a **field-selector-with-TAG** {19_4.8.1.f}, then the value selected {17_2.1.3.3.a, e, 17_2.1.3.4.k} (generated {17_2.1.3.4.l}) by that **'TAG'**".

17.2 The program

17.2.1 Syntax

a) **program : strong void new closed clause** {18_3.1.a} **.** {See also 26_{10}.1 .}

17.2.2 Semantics

{"I can explain all the poems that ever were invented -
and a good many that haven't been invented just yet."
Through the Looking-glass, Lewis Carroll. }

a) The elaboration of a **program** is the elaboration of its **strong-void-new-closed-clause** in an empty environ {17_2.1.1.1.c} termed the "primal environ".

{Although the purpose of this Report is to define the meaning of a **particular-program** (26_{10}.1.1.g), that meaning is established only by first defining the meaning of a **program** in which that **particular-program** is embedded (26_{10}.1.2).}

{In this Report, the syntax says which sequences of symbols are terminal productions of **'program'**, and the semantics which actions are performed by the computer when elaborating a program. Both syntax and semantics are recursive. Though certain sequences

of symbols may be terminal productions of **'program'** in more than one way (see also 16_1.1.3.2.f), this syntactic ambiguity does not lead to a semantic ambiguity.}

b) In Algol 68, a specific syntax for constructs is provided which, together with its recursive definition, makes it possible to describe and to distinguish between arbitrarily large production trees, to distinguish between arbitrarily many different values of a given mode (except certain modes like **'boolean'** and **'void'**) and to distinguish between arbitrarily many modes, which allows arbitrarily many objects to exist within the computer and which allows the elaboration of a **program** to involve an arbitrarily large, not necessarily finite, number of actions. This is not meant to imply that the notation of the objects in the computer is that used in this Report nor that it has the same possibilities. It is not assumed that these two notations are the same nor even that a one-to-one correspondence exists between them; in fact, the set of different notations of objects of a given category may be finite. It is not assumed that the computer can handle arbitrary amounts of presented information. It is not assumed that the speed of the computer is sufficient to elaborate a given **program** within a prescribed lapse of time, nor that the number of objects and relationships that can be established is sufficient to elaborate it at all.

c) A model of the hypothetical computer, using a physical machine, is said to be an "implementation" of Algol 68 if it does not restrict the use of the language in other respects than those mentioned above. Furthermore, if a language A is defined whose **particular-programs** are also **particular-programs** of a language B, and if each such **particular-program** for which a meaning is defined in A has the same defined meaning in B, then A is said to be a "sublanguage" of B, and B a "superlanguage" of A.

{Thus a sublanguage of Algol 68 might be defined by omitting some part of the syntax, by omitting some part of the **standard-prelude**, and/or by leaving undefined something which is defined in this Report, so as to enable more efficient solutions to certain classes of problem or to permit implementation on smaller machines.

Likewise, a superlanguage of Algol 68 might be defined by additions to the syntax, semantics or **standard-prelude**, so as to improve efficiency (by allowing the user to provide additional information) or to permit the solution of problems not readily amenable to Algol 68.}

A model is said to be an implementation of a sublanguage if it does not restrict the use of the sublanguage in other respects than those mentioned above.

{See 25_9.3.c for the term "implementation of the reference language".}

{A sequence of **symbols** which is not a **particular-program** but can be turned into one by deleting or inserting a certain number of **symbols** and not a smaller number could be regarded as a **particular-program** with that number of syntactical errors. Any **particular-program** that can be obtained by deleting or inserting that number of symbols may be termed a "possibly intended" **particular-program**. Whether a **particular-program** or one of the possibly intended **particular-programs** has the effect its author in fact in-

tended it to have is a matter which falls outside this Report.}

{In an implementation, the **particular-program** may be "compiled", i.e., translated into an "object program" in the code of the physical machine. Under certain circumstances, it may be advantageous to compile parts of the **particular-program** independently, e.g., parts which are common to several **particular-programs**. If such a part contains **applied-indicators** which identify **defining-indicators** not contained in that part, then compilation into an efficient object program may be assured by preceding the part by a sequence of **declarations** containing those **defining-indicators**.}

{The definition of specific sublanguages and also the specification of actions not definable by any **program** (e.g., compilation or initiation of the elaboration) is not given in this Report. See, however, 25_9.2 for the suggested use of **pragmats** to control such actions.}

{Revised Report } Part II

Fundamental Constructions

{This part presents the essential structure of **programs**:

- the general rules for constructing them;
- the ways of defining **indicators** and their properties, at each new level of construction;
- the constructs available for programming primitive actions.}

18 Clauses

{Clauses provide

- a hierarchical structure for **programs**,
- the introduction of new **ranges** of definitions,
- serial or collateral composition, parallelism, choices and loops.}

18.0.1 Syntax

a) ***phrase : SOME unit** {18_3.2.d} **;**
NEST declaration of DECS {19_4.1.a} **.**

b) ***SORT MODE expression : SORT MODE NEST UNIT** {20_5.A} **.**

c) ***statement : strong void NEST UNIT** {20_5.A} **.**

d) ***MOID constant :**
MOID NEST DEFIED identifier with TAG {19_4.8.a, b} **;**
MOID NEST denoter {24_8.0.a} **.**

e) ***MODE variable :**
reference to MODE NEST DEFIED identifier with TAG {19_4.3.a, b} **.**

f) ***NEST range :**
SOID NEST serial clause defining LAYER {18_3.2.a} **;**
SOID NEST chooser CHOICE STYLE clause {18_3.4.b} **;**
SOID NEST case part of choice using UNITED {18_3.4.i} **;**
NEST STYLE repeating part with DEC {18_3.5.e} **;**
NEST STYLE while do part {18_3.5.f} **;**
PROCEDURE NEST routine text {20_5.4.1.a, b} **.**

{**NEST-ranges** arise in the definition of "identification" {23_7.2.2.b}.}

18.0.2 Semantics

A "nest" is a **'NEST'**. The nest "of" a construct is the **'NEST'** enveloped by the original of that construct, but not by any **'defining LAYER'** contained in that original.

{The nest of a construct carries a record of all the **declarations** forming the environment in which that construct is to be interpreted.

Those constructs which are contained in a **range** R, but not in any smaller **range** contained within R, may be said to comprise a "reach". All constructs in a given reach have the same nest, which is that of the immediately surrounding reach with the addition of one extra **'LAYER'**. The syntax ensures {18_3.2.1.b, 18_3.4.1.i, j, k, 18_3.5.1.e, 20_5.4.1.1.b} that each **'PROP'** {19_4.8.1.E} or "property" in the extra **'LAYER'** is matched by a **defining-indicator** {19_4.8.1.a} contained in a **definition** in that reach.}

18.1 Closed clauses

{**Closed-clauses** are usually used to construct **units** from **serial-clauses** as, e.g.,
`(REAL x; read (x); x)` in
`(REAL x; read (x); x) + 3.14.`}

18.1.1 Syntax

A) **SOID :: SORT MOID.**

B) **PACK :: STYLE pack.**

a) **SOID NEST closed clause** {17_2.2.a, 20_5.D, 20_5.5.1.a, 26_{10}.3.4.1.h, 26_{10}.3.4.9.a} **:**
SOID NEST serial clause defining LAYER {18_3.2.a} **PACK.**
{**LAYER :: new DECSETY LABSETY.**}

{Example

a) `BEGIN x := 1; y := 2 END`}

{The yield of a **closed-clause** is that of its constituent **serial-clause**, by way of pre-elaboration {17_2.1.4.1.c}.}

18.2 Serial clauses

{The purposes of **serial-clauses** are

- the construction of new **ranges** of definitions, and
- the serial composition of actions.

A **serial-clause** consists of a possibly empty sequence of unlabelled **phrases**, the last of which, if any, is a **declaration**, followed by a sequence of possibly labelled **units**. The **phrases** and the **units** are separated by **go-on-tokens**, viz., semicolons. Some of the **units** may instead be separated by **completers**, viz., `EXIT`s; after a **completer**, the next **unit** must be labelled so that it can be reached. The value of the final **unit**, or of a **unit** preceding an `EXIT`, determines the value of the **serial-clause**.

For example, the following **serial-clause** yields `true` if and only if the vector `a` contains the integer 8:

```
INT n; read (n);
[1 : n] INT a; read (a);
FOR i TO n DO IF a [i] = 8 THEN GOTO success FI OD;
FALSE EXIT
success: TRUE.}
```

18.2.1 Syntax

a) **SOID NEST serial clause defining new PROPSETY** {18_3.1.a, 18_3.4.f, l, 18_3.5.h} **:**
SOID NEST new PROPSETY series with PROPSETY {b}**.**
{Here **PROPSETY :: DECSETY LABSETY.**}

b) **SOID NEST series with PROPSETY** {a, b, 18_3.4.c} **:**
strong void NEST unit {d}**, go on** {25_9.4.f} **token,**
SOID NEST series with PROPSETY {b}**;**
where (PROPSETY) is (DECS DECSETY LABSETY),
NEST declaration of DECS {19_4.1.a} **, go on** {25_9.4.f} **token,**
SOID NEST series with DECSETY LABSETY {b}**;**
where (PROPSETY) is (LAB LABSETY),
NEST label definition of LAB {c}**,**
SOID NEST series with LABSETY {b}**;**
where (PROPSETY) is (LAB LABSETY) and SOID balances SOID1 and SOID2 {e}**,**
SOID1 NEST unit {d}**, completion** {25_9.4.f} **token,**
NEST label definition of LAB {c}**,**

SOID2 NEST series with LABSETY {b}**;**
where (PROPSETY) is (EMPTY),
SOID NEST unit {d}**.**

c) **NEST label definition of label TAG** {b} **:**
label NEST defining identifier with TAG {19_4.8.a} **, label** {25_9.4.f} **token.**

d) **SOME unit** {b, 18_3.3.b, g, 18_3.4.i, 18_3.5.d, 19_4.6.m, n, 20_5.2.1.c, 20_5.3.2.e, 20_5.4.1.a, b, 20_5.4.3.c, 26_{10}.3.4.10.b, c, d} **:**
SOME UNIT {20_5A, -}**.**

e) **WHETHER SORT MOID balances SORT1 MOID1 and SORT2 MOID2** {b, 18_3.3.b, 18_3.4.d, h} **:**
WHETHER SORT balances SORT1 and SORT2 {f} **and MOID balances MOID1 and MOID2** {g}**.**

f) **WHETHER SORT balances SORT1 and SORT2** {e, 20_5.2.2.a} **:**
where (SORT1) is (strong), WHETHER (SORT2) is (SORT);
where (SORT2) is (strong), WHETHER (SORT1) is (SORT).

g) **WHETHER MOID balances MOID1 and MOID2** {e} **:**
where (MOID1) is (MOID2), WHETHER (MOID) is (MOID1) ;
where (MOID1) is (transient MOID2), WHETHER (MOID) is (MOID1) ;
where (MOID2) is (transient MOID1), WHETHER (MOID) is (MOID2).

h) ***SOID unitary clause : SOID NEST unit** {d}**.**

i) ***establishing clause :**
SOID NEST serial clause defining LAYER {18_3.2.a} **;**
MODE NEST enquiry clause defining LAYER {18_3.4.c} **.**

{Examples:

b)
```
read (x1); REAL s := 0;
  sum: FOR i TO n DO (x1[i] >0 | s +:= x1[i] | nonpos) OD EXIT
  nonpos: print (s) •
REAL s := 0;
  sum: FOR i TO n DO (x1[i] >0 | s +:= x1[i] | nonpos) OD EXIT
  nonpos: print (s) •
sum: FOR i TO n DO (x1[i] >0 | s +:= x1[i] | nonpos) OD EXIT
  nonpos: print (s) •
FOR i TO n DO (x1[i] >0 | s +:= x1[i] | nonpos) OD EXIT
  nonpos: print (s) •
print (s)
```

c) `sum:`

d) `print (s)` }

{Often, a **series** must be "balanced" {18_3.2.1.e}. For remarks concerning balancing, see 18_3.4.1 .}

18.2.2 Semantics

a) The yield of a **serial-clause**, in an environ E, is the yield of the elaboration of its **series**, or of any **series** elaborated "in its place" {20_5.4.4.2}, in the environ "established" {b} around E according to that **serial-clause**; it is required that the yield be not newer in scope than E.

b) The environ E "established"

- upon an environ, $E1$, possibly not specified, {which determines its scope, }
- around an environ $E2$ {which determines its composition},
- according to a **NOTION-defining-new-PROPSETY** C, possibly absent, {which prescribes its locale, }
- with values $V_1, ..., V_n$, possibly absent, {which are possibly to be ascribed, }

is determined as follows:
• if $E1$ is not specified, then let $E1$ be $E2$;
• E is newer in scope than $E1$ and is composed of $E2$ and a new locale corresponding to **'PROPSETY'**, if C is present, and to **'EMPTY'** otherwise;

Case A: C is an **establishing-clause**:
For each constituent **mode-definition** M, if any, of C,

- the scene composed of
  (i) the **actual-declarer** of M, and
  (ii) the environ necessary for {23_7.2.2.c} that **actual-declarer** in E,
  is ascribed in E to the **mode-indication** of M;

For each constituent **label-definition** L, if any, of C,

- the scene composed of
  (i) the **series** of which L is a direct descendent, and

(ii) the environ E,

is ascribed in E to the **label-identifier** of L:

If each **'PROP'** enveloped by **'PROPSETY'** is some **'DYADIC TAD'** or **'label TAG'**, then E is said to be "nonlocal" {see 20_5.2.3.2.b} ;

Case B: C is a **declarative**, a **for-part** or a **specification**: For $i = 1...n$, where n is the number of **'DEC'**s enveloped by **'PROPSETY'**,
• V_i is ascribed {19_4.8.2.a} in E to the i^{th} constituent **defining-identifier**, if any, of C and, otherwise {in the case of an invisible **for-part**}, to an **integral-defining-indicator-with-letter-aleph**;
If C is a **for-part** or a **specification**,
then E is nonlocal.
{Other cases, i.e., when C is absent:
• E is local (see 20_5.2.3.2.b), but not further defined. }

c) The yield W of a **series** C is determined as follows:
If C contains a direct descendent **unit** which is not followed by a **go-on-token**, then

- W is the yield of that **unit**;

otherwise,

- the **declaration** or the **unit**, if any, of C is elaborated;
- W is the yield of the **series** of C.

{See also 20_5.4.4.2.Case A .}

18.3 Collateral and parallel clauses

{**Collateral-clauses** allow an arbitrary merging of streams of actions. **Parallel-clauses** provide, moreover, levels of coordination for the synchronization {26_{10}.2.4} of that merging.

A **collateral-** or **parallel-clause** consists of a sequence of **units** separated by **and-also-symbols** (viz., ", "), and is enclosed by parentheses or by a `BEGIN-END` pair; a **parallel-clause** begins moreover with `PAR`.

Collateral-clauses, but not **parallel-clauses**, may yield stowed values composed from the yields of the constituent **units**.

Examples of **collateral-clauses** yielding stowed values:

```
[] INT q = (1, 4, 9, 16, 25);
STRUCT (INT price, STRING category) bike := (150, "sport").
```

Example of a **parallel-clause** which synchronizes eating and speaking:.

```
PROC VOID eat, speak; SEMA mouth = LEVEL 1;
PAR BEGIN
  DO
    DOWN mouth;
    eat;
    UP mouth
  OD,
  DO
    DOWN mouth;
    speak;
    UP mouth
  OD
END.}
```

18.3.1 Syntax

a) **strong void NEST collateral clause** {20_5.D, 20_5.5.1.a} **:**
strong void NEST joined portrait {b} **PACK.**

b) **SOID NEST joined portrait** {a, b, c, d, 18_3.4.g} **:**
where SOID balances SOID1 and SOID2 {18_3.2.e} **,**
SOID1 NEST unit {18_3.2.d} 1**, and also** {25_9.4.f} **token,**
SOID2 NEST unit {18_3.2.d}
or alternatively SOID2 NEST joined portrait {b}**.**

c) **strong void NEST parallel clause** {20_5.D, 20_5.5.1.a} **:**
parallel {25_9.4.f} **token, strong void NEST joined portrait** {b} **PACK.**

d) **strong ROWS of MODE NEST collateral clause** {20_5.D, 20_5.5.1.a} **:**
where (ROWS) is (row),
strong MODE NEST joined portrait {b} **PACK ;**
where (ROWS) is (row ROWS1),
strong ROWS1 of MODE NEST joined portrait {b} **PACK ;**
EMPTY PACK.

e) **strong structured with FIELDS FIELD mode NEST collateral clause** {20_5.D, 20_5.5.1.a} **:**
NEST FIELDS FIELD portrait {f} **PACK.**

f) **NEST FIELDS FIELD portrait** {e, f} **:**
NEST FIELDS portrait {f, g}**, and also** {25_9.4.f} **token,**
NEST FIELD portrait {g}**.**
{**FIELD :: MODE field TAG.**}

g) **NEST MODE field TAG portrait** {f} **: strong MODE NEST unit** {18_3.2.d} **.**

h) ***structure display :**
strong structured with FIELDS FIELD mode NEST collateral clause {e}**.**

i) ***row display : strong ROWS of MODE NEST collateral clause** {d}**.**

j) ***display : strong STOWED NEST collateral clause** {d, e}**.**

k) ***vacuum : EMPTY PACK.**

{Examples:

a) `(x := 1, y := 2)`

b) `x := 1, y := 2`

c) `x := 1, y := 2`

d) `(1, 2)` (in `[] REAL (1, 2)`)

e) `(1, 2)` (in `COMPL (1, 2)`)

f) `1, 2`

g) `1` }

{**Structure-displays** must contain at least two **FIELD-portraits**, for, otherwise, in the reach of
`MODE M = STRUCT (REF M m); M nobuo, yoneda;`,
the **assignation** `nobuo := (yoneda)` would be syntactically ambiguous and could produce different effects; however, `m OF nobuo := yoneda` is unambiguous.

Row-displays contain zero, two or more constituent **units**. It is also possible to present a single value as a multiple value, e.g., `[1 : 1] INT v := 123`, but this uses a coercion known as rowing {22_6.6}.}

18.3.2 Semantics

a) The elaboration of a **void-collateral-clause** or **void-parallel-clause** consists of the collateral elaboration of its constituent **units** and yields `empty`.

b) The yield W of a **STOWED-collateral-clause** C is determined as follows:
If the direct descendent of C is a **vacuum**,
then

{**'STOWED'** is some **'ROWS of MODE'** and} each bound pair in the descriptor of W is (1, 0) {and it has one ghost element whose value is irrelevant};

otherwise,

- let $V_1, ..., V_m$ be the {collateral} yields of the constituent **units** of C;

Case A: **'STOWED'** is some **'structured with FIELDS mode'**:

- the fields of W, taken in order, are $V_1, ..., V_m$;

Case B: **'STOWED'** is some **'row of MODE1'**:

- W is composed of

(i) a descriptor $((1, m))$,

(ii) $V_1, ..., V_m$;

For $i = 1...m$,

- the element selected by the index (i) in W is V_i;

Case C: **'STOWED'** is some **'row ROWS of MODE2'**:

- it is required that the descriptors of $V_1, ..., V_m$ be identical;
- let the descriptor of {say} V_1 be $((l_1, u_1), ..., (l_n, u_n))$;
- W is composed of

(i) a descriptor $((1, m), (l_1, u_1), ..., (l_n, u_n))$;

(ii) the elements of $V_1, ..., V_m$;

For $i = 1...m$,

the element selected by an index $(i, i_1, ..., i_n)$ in W is that selected by $(i_1, ..., i_n)$ in V_i.

{Note that in `[„ ] CHAR block = ("abc", "def")`, the descriptor of the three-dimensional yield W will be $((1, 2), (1, 1), (1, 3))$, since the **units** `"abc"` and `"def"` are first rowed {22_6.6}, so that V_1 and V_2 have descriptors $((1, 1), (1, 3))$.}

18.4 Choice clauses

{**Choice-clauses** enable a dynamic choice to be made among different paths in a computation. The choice among the alternatives (the **in-CHOICE-** and the **out-CHOICE-clause**) is determined by the success or failure of a test on a truth value, on an integer or on a mode. The value under test is computed by an **enquiry-clause** before the choice is made.

A **choice-using-boolean-clause** (or **conditional-clause**) is of the form
`(x >0 | x | 0)` in the "brief" style, or
`IF x >0 THEN x ELSE 0 FI` in the "bold" style;
`x >0` is the **enquiry-clause**, `THEN x` is the **in-CHOICE-clause** and `ELSE 0` is the **out-CHOICE-clause**; all three may have the syntactical structure of a **series**, because all **choice-clauses** are well closed. A **choice-using-boolean-clause** may also be reduced to
`(x <0 | x := - x)` or
`IF x <0 THEN x := - x FI`;
the omitted **out-CHOICE-clause** is then understood to be an `ELSE SKIP`. On the other hand, the choice can be reiterated by writing
`(x >0 | 1 + x |: x <0 | 1 - x | 1)` or
`IF x >0 THEN 1 + x ELIF x <0 THEN 1 - x ELSE 1 FI`,
and so on; this is to be understood as
`(x >0 | 1 + x | (x <0 | 1 - x | 1))`.

CASE-clauses, which define choices depending on an integer or on a mode, are different in that the **in-CASE-clause** is further decomposed into **units**. The general pattern is
`(-- | --, ..., -- | --)` or
`CASE -- IN --, ..., -- OUT -- ESAC`.
The choice may also be reiterated by use of `OUSE`.

In a **choice-using-integral-clause** (or **case-clause**), the parts are simply **units** and there must be at least two of them; the choice among the **units** follows their textual ordering.
Example:

```
PROC VOID work, relax, enjoy;
CASE INT day; read (day); day
IN work, work, work, work, work, relax, enjoy
OUT print ((day, "is not in the week"))
ESAC.
```

In a **choice-using-UNITED-clause** (or **conformity-clause**), which tests modes, each **case-part-of-CHOICE** is of the form `(DECLARER identifier): unit` or `(DECLARER): unit`. The mode specified by the **declarer** is compared with the mode of the value under test; the **identifier**, if present, is available inside the **unit** to access that value, with the full security of syntactical mode checking. The **'UNITED'** mode provides the required freedom for the mode of the value under test; moreover, that **'UNITED'** mode must contain

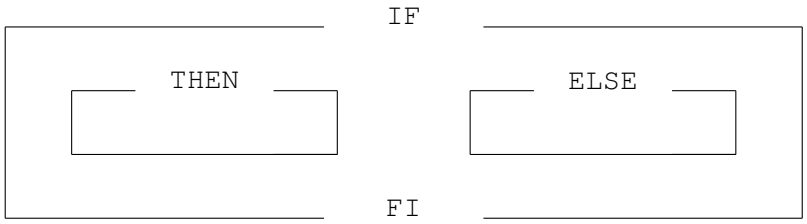
the mode of each **specification** for, otherwise, the corresponding **case-part-of-CHOICE** could never be chosen.

Example:

```
MODE BOY = STRUCT (INT age, REAL weight),
MODE GIRL = STRUCT (INT age, REAL beauty);
PROC UNION (BOY, GIRL) newborn;
CASE newborn IN
  (BOY john): print (weight OF john),
  (GIRL mary): print (beauty OF mary)
ESAC. }
```

{The flowers that bloom in the spring,
Tra la,
Have nothing to do with the case.
Mikado, W.S. Gilbert. }

{The hierarchy of **ranges** in **conditional-clauses** is illustrated by



and similarly for the other kinds of choice. Thus the nest and the environ of the **enquiry-clause** remain valid over the **in-CHOICE-clause** and the **out-CHOICE-clause**. However, no transfer back from the **in-** or **out-CHOICE-clause** into the **enquiry-clause** is possible, since the latter can contain no **label-definitions** (except within a **closed-clause** contained within it).}

18.4.1 Syntax

A) **CHOICE :: choice using boolean ; CASE.**

B) **CASE :: choice using integral ; choice using UNITED.**

a) **SOID NEST1 CHOICE clause** {20_5.D, 20_5.5.1.a, 26_{10}.3.4.1.h, 26_{10}.3.4.9.a} **:**
CHOICE STYLE start {25_9.1.a, -}**,**
SOID NEST1 chooser CHOICE STYLE clause {b}**,**
CHOICE STYLE finish {25_9.1.e, -}**.**

b) **SOID NEST1 chooser choice using MODE STYLE clause** {a, l} **:**
MODE NEST1 enquiry clause defining LAYER2 {c, -}**,**
SOID NEST1 LAYER2 alternate choice using MODE STYLE clause {d}**.**

c) **MODE NEST1 enquiry clause defining new DECSETY2** {b, 18_3.5.g} **:**
meek MODE NEST1 new DECSETY2 series with DECSETY2 {18_3.2.b} **.**

d) **SOID NEST2 alternate CHOICE STYLE clause** {b} **:**
SOID NEST2 in CHOICE STYLE clause {e}**;**
where SOID balances SOID1 and SOID2 {18_3.2.e} **,**
SOID1 NEST2 in CHOICE STYLE clause {e}**,**
SOID2 NEST2 out CHOICE STYLE clause {l}**.**

e) **SOID NEST2 in CHOICE STYLE clause** {d} **:**
CHOICE STYLE in {25_9.1.b, -}**, SOID NEST2 in part of CHOICE** {f, g, h}**.**

f) **SOID NEST2 in part of choice using boolean** {e} **:**
SOID NEST2 serial clause defining LAYER3 {18_3.2.a} **.**

g) **SOID NEST2 in part of choice using integral** {e} **:**
SOID NEST2 joined portrait {18_3.3.b} **.**

h) **SOID NEST2 in part of choice using UNITED** {e, h} **:**
SOID NEST2 case part of choice using UNITED {i}**;**
where SOID balances SOID1 and SOID2 {18_3.2.e} **,**
SOID1 NEST2 case part of choice using UNITED {i}**, and also** {25_9.4.f} **token,**
SOID2 NEST2 in part of choice using UNITED {h}**.**

i) **SOID NEST2 case part of choice using UNITED** {h} **:**
MOID NEST2 LAYER3 specification defining LAYER3 {j, k, -}**,**
where MOID unites to UNITED {22_6.4.b} **,**
SOID NEST2 LAYER3 unit {18_3.2.d} **.**
{Here**LAYER :: new MODE TAG ; new EMPTY.**}

j) **MODE NEST3 specification defining new MODE TAG3** {i} **:**
NEST3 declarative defining new MODE TAG3 {20_5.4.1.e} **brief pack,**
colon {25_9.4.f} **token.**

k) **MOID NEST3 specification defining new EMPTY** {i} **:**
formal MOID NEST3 declarer {19_4.6.b} **brief pack,**
colon {25_9.4.f} **token.**

l) **SOID NEST2 out CHOICE STYLE clause** {d} **:**
CHOICE STYLE out {25_9.1.d, -}**,**
SOID NEST2 serial clause defining LAYER3 {18_3.2.a} **;**
CHOICE STYLE again {25_9.1.c, -}**,**

SOID NEST2 chooser CHOICE2 STYLE clause {b}**,**
where CHOICE2 may follow CHOICE {m}**.**

m) **WHETHER choice using MODE2 may follow choice using MODE1** {l} **:**
where (MODE1) is (MOOD), WHETHER (MODE2) is (MODE1) ;
where (MODE1) begins with (union of),
WHETHER (MODE2) begins with (union of).

n) ***SOME choice clause : SOME CHOICE clause {a}.**

o) ***SOME conditional clause : SOME choice using boolean clause {a}.**

p) ***SOME case clause : SOME choice using integral clause {a}.**

q) ***SOME conformity clause : SOME choice using UNITED clause {a}.**

{Examples:

a) `(x > 0 | x | 0) •`
`CASE i IN princeton, grenoble OUT finish ESAC •`
`CASE uir IN (INT i): print (i), (REAL): print ("no") ESAC`

b) `x > 0 | x | 0`

c) `x > 0 • i • uir`

d) `| x • |x | 0`

e) `| x •`
`IN princeton, grenoble •`
`IN (INT i): print (i), (REAL): print ("no")`

f) `x`

g) `princeton, grenoble`

h) `(INT i): print (i), (REAL): print ("no")`

i) `(INT i): print (i)`

j) `(INT i):`

k) `(REAL):`

l) `OUT finish • |: x < 0 | -x | 0 }`

{I would to God they would either conform,
or be more wise, and not be catched!
Diary. 7 Aug. 1664, Samuel Pepys. }

{Rule d illustrates why **'SORT MOID'**s should be "balanced". If an **alternate-CHOICE-clause** is, say, firm, then at least its **in-CHOICE-clause** or its **out-CHOICE-clause** must be firm, while the other may be strong. For example, in

```
(p | x | SKIP) + (p | SKIP | y),
```

the **conditional-clause** `(p | x | SKIP)` is balanced by making `| x` firm and `| SKIP` strong whereas `(p | SKIP | y)` is balanced by making `| SKIP` strong and `| y` firm. The counterexample

```
(p | SKIP | SKIP) + y
```

illustrates that not both may be strong, for otherwise the **operator** + could not be identified.}

18.4.2 Semantics

a) The yield W of a **chooser-CHOICE-clause** C, in an environ $E1$, is determined as follows:
• let $E2$ be the environ established {18_3.2.2.b} around $E1$ according to the **enquiry-clause** of C;
• let V be the yield, in $E2$, of that **enquiry-clause**;
• W is the yield of the scene "chosen" {b} by V from C in $E2$; it is required that W be not newer in scope than $E1$.

b) The scene S "chosen" by a value V from a **MOID-chooser-CHOICE-clause** C, in an environ $E2$, is determined as follows: Case A: **'CHOICE'** is **'choice using boolean'** and V is `true`:

- S is the constituent **in-CHOICE-clause** of C, in $E2$;

Case B: **'CHOICE'** is **'choice using integral'** and $1 \leq V \leq n$, where n is the number of constituent **units** of the constituent **in-part-of-CHOICE** of C:

- S is the V^{th} such **unit**, in $E2$;

Case C: **'CHOICE'** is some **'choice using UNITED'** and V is acceptable to {17_2.1.3.6.d} the **'MOID2'** of some constituent **MOID2-specification** D of C {; if there exists more than one such constituent **specification**, it is not defined which one is chosen as D} ;

- S is the **unit** following that D, in an environ established {nonlocally {18_3.2.2.b} } around $E2$, according to D, with V;

Other Cases {when the **enquiry-clause** has been unsuccessful} :

If C contains a constituent **out-CHOICE-clause** O,

then S is O in $E2$;

otherwise, S is a **MOID-skip** in $E2$.

18.5 Loop clauses

{**Loop-clauses** are used for repeating dynamically one same sequence of instructions. The number of repetitions is controlled by a finite sequence of equidistant integers, by a condition to be tested each time, or by both.

Example 1:

```
INT fac := 1;
FOR i FROM n BY −1 TO 1
DO fac ×:= i OD.
```

Example 2:

```
INT a, b; read ((a, b)) PR ASSERT a ≥ 0 ∧ b >0 PR;
INT q := 0, r := a;
WHILE r ≥ b PR ASSERT a = b × q + r ∧ 0 ≤ r PR
DO (q +:= 1, r −:= b) OD
PR ASSERT a = b × q + r ∧ 0 ≤ r ∧ r <b PR
```

(see 25_9.2 for an explanation of the **pragmats**).

The controlled **identifier**, e.g., `i` in Example 1, is defined over the **repeating-part**. Definitions introduced in the **while-part** are also valid over the **do-part**.

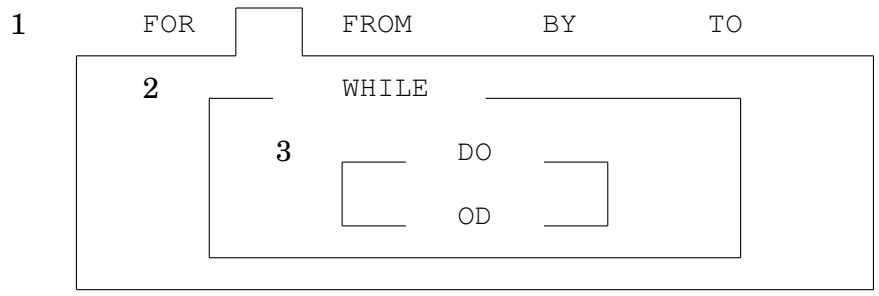
If the controlled **identifier** is not applied in the **repeating-part**, then the **for-part** may be omitted. A **from-part** `FROM 1` may be omitted; similarly, `BY 1` may be omitted. The **to-part** may be omitted if no test on the final value of the control-integer is required. A **while-part** `WHILE TRUE` may be omitted. For example,

```
FOR i FROM 1 BY 1 TO n WHILE TRUE DO print ("a") OD
```

may be written

```
TO n DO print ("a") OD.
```

The hierarchy of **ranges** is illustrated by:



}

18.5.1 Syntax

A) **FROBYT :: from ; by ; to.**

a) **strong void NEST1 loop clause** {20_5.D, 20_5.5.1.a} **:**
NEST1 STYLE for part defining new integral TAG2 {b}**,**
NEST1 STYLE intervals {c}**,**
NEST1 STYLE repeating part with integral TAG2 {e}**.**

b) **NEST1 STYLE for part defining new integral TAG2 {a} :**
STYLE for {25_9.4.g, -} **token,**
integral NEST1 new integral TAG2 defining identifier with TAG2 {19_4.8.a}
;
where (TAG2) is (letter aleph), EMPTY.

c) **NEST1 STYLE intervals {a} :**
NEST1 STYLE from part {d} **option,**
NEST1 STYLE by part {d} **option,**
NEST1 STYLE to part {d} **option.**

d) **NEST1 STYLE FROBYT part** {c} **:**
STYLE FROBYT {25_9.4.g, -} **token, meek integral NEST1 unit** {18_3.2.d} **.**

e) **NEST1 STYLE repeating part with DEC2** {a} **:**
NEST1 new DEC2 STYLE while do part {f}**;**
NEST1 new DEC2 STYLE do part {h}**.**

f) **NEST2 STYLE while do part** {e} **:**
NEST2 STYLE while part defining LAYER3 {g}**,**
NEST2 LAYER3 STYLE do part {h}**.**

g) **NEST2 STYLE while part defining LAYER3** {f} **:**
STYLE while {25_9.4.g, -} **token, boolean NEST2 enquiry clause defining LAYER3** {18_3.4.c, -}**.**

h) **NEST3 STYLE do part** {e, f} **:**
STYLE do {25_9.4.g, -} **token,**
strong void NEST3 serial clause defining LAYER4 {18_3.2.a} **,**
STYLE od {$25_9$4g, -} **token.**

{Examples:

a) `FOR i WHILE i <n DO task1 OD •`
`TO n DO task1; task2 OD`

b) `FOR i`

c) `FROM -5 TO +5`

d) `FROM -5`

e) `WHILE i <n DO task1 OD • DO task1; task2 OD`

f) `WHILE i <n DO task 1; task2 OD`

g) `WHILE i <n`

h) `DO task1; task2 OD` }

18.5.2 Semantics

A **loop-clause** C, in an environ $E1$, is elaborated in the following Steps:
Step 1: All the constituent **FROBYT-parts**, if any, of C are elaborated collaterally in $E1$;

- let f be the yield of the constituent **from-part**, if any, of C, and be 1 otherwise;
- let b be the yield of the constituent **by-part**, if any, of C, and be 1 otherwise;
- let t be the yield of the constituent **to-part**, if any, of C, and be $absent$ otherwise;
- let $E2$ be the environ established {nonlocally {18_3.2.2.b} } around $E1$, according to the **for-part-defining-new-integral-TAG2** of C, and with the integer f;

Step 2: Let i be the integer accessed {17_2.1.2.c} by **'integral TAG2'** inside the locale of $E2$;

If t is not $absent$,

then

If $b > 0$ and $i > t$ or if $b < 0$ and $i < t$,

then C in $E1$ {is completed and} yields `empty`;

{otherwise, Step 3 is taken; }

Step 3: Let an environ $E3$ and a truth value w be determined as follows:

Case A: C does not contain a constituent **while-part**:

- $E3$ is $E2$;
- w is `true`;

Case B: C contains a constituent **while-part** P:

- $E3$ is established {perhaps nonlocally {18_3.2.2.b} } around $E2$ according to the **enquiry-clause** of P;
- w is the yield in $E3$ of that **enquiry-clause**;

Step 4: If w is `true`, then

- the constituent **do-part** of C is elaborated in $E3$;
- **'integral TAG2'** is made to access $i + b$ inside the locale of $E2$;[1]
- Step 2 is taken again; otherwise,
- C in $E1$ {is completed and} yields `empty`.

{The **loop-clause**

```
FOR i FROM u1 BY u2 TO u3 WHILE condition DO action OD
```

is thus equivalent to the following **void-closed-clause**:

```
BEGIN INT f:= u1, INT b = u2, t = u3;
  step2:
    IF (b > 0 ∧ f ≤ t) ∨ (b < 0 ∧ f ≥ t) ∨ b = 0
    THEN INT i = f;
      IF condition
      THEN action; f +:= b; GO TO step2
      FI
    FI
END.
```

This equivalence might not hold, of course, if the **loop-clause** contains **local-generators**, or if some of the **operators** above do not identify those in the standard environment {26_{10}.}

[1] Note the possibility of overflow even in case TAG2 and intervals are empty.

19 Declarations, declarers and indicators

{Declarations serve

- to announce new **indicators**, e.g., **identifiers**,
- to define their modes or priorities, and
- to ascribe values to those **indicators** and to initialize **variables**.}

19.1 Declarations

19.1.1 Syntax

A) **COMMON :: mode ; priority ; MODINE identity ;**
reference to MODINE variable ; MODINE operation ; PARAMETER ; MODE FIELDS.
{**MODINE :: MODE ; routine.**}

a) **NEST declaration of DECS** {a, 18_3.2.b} **:**
NEST COMMON declaration of DECS {19_4.2.a, 19_4.3.a, 19_4.4.a, e, 19_4.5.a, -}**;**
where (DECS) is (DECS1 DECS2),
NEST COMMON declaration of DECS1 {19_4.2.a, 19_4.3.a, 19_4.4.a, e, 19_4.5.a, -}**,**
and also {94f} **token, NEST declaration of DECS2 {a}.**

b) **NEST COMMON joined definition of PROPS PROP**
{b, 19_4.2.a, 19_4.3.a, 19_4.4.a, e, 19_4.5.a, 19_4.6.e, 20_5.4.1.e} **:**
NEST COMMON joined definition of PROPS {b, c}**, and also** {94f} **token,**
NEST COMMON joined definition of PROP {c}**.**

c) **NEST COMMON joined definition of PROP**
{b, 19_4.2.a, 19_4.3.a, 19_4.4.a, e, 19_4.5.a, 19_4.6.e, 20_5.4.1e} **:**

NEST COMMON definition of PROP
{19_4.2.b, 19_4.3.b, 19_4.4.c, f, 19_4.5.c, 19_4.6.f, 20_5.4.1.f, -}**.**

d) ***definition of PROP : NEST COMMON definition of PROP**
{19_4.2.b, 19_4.3.b, 19_4.4.c, f, 19_4.5.c, 19_4.6.f, 20_5.4.1.f} **;**
NEST label definition of PROP {18_3.2.c} **.**

{Examples:

a) `MODE R = REF REAL, S = CHAR • PRIO ∨ = 2, ∧ = 3 • INT m = 4096 •`
`REAL x, y •`
`OP ∨ = (BOOL a, b) BOOL : (a | TRUE | b)`

b) `R = REF REAL, S = CHAR • ∨ = 2, ∧ = 3 • m = 4096 • x, y •`
`∨ = (BOOL a, b) BOOL : (a | TRUE | b)`

c) `R = REF REAL • ∨ = 2 • m = 4096 • x •`
`∨ = (BOOL a, b) BOOL : (a | TRUE | b)` }

19.1.2 Semantics

The elaboration of a **declaration** consists of the collateral elaboration of its **COMMON-declaration** and of its **declaration**, if any. {Thus, all the **COMMON-declarations** separated by **and-also-tokens** are elaborated collaterally.}

19.2 Mode declarations

{**Mode-declarations** provide the **defining-mode-indications**, which act as abbreviations for **declarers** constructed from the more primitive ones, or from other **declarers**, or even from themselves.

For example,
`MODE ARRAY = [m, n] REAL`, and
`MODE BOOK = STRUCT (STRING text, REF BOOK next)`

In the latter example, the **applied-mode-indication** `BOOK` is not only a convenient abbreviation, but is essential to the **declaration**.}

19.2.1 Syntax

a) **NEST mode declaration of DECS** {19_4.1.a} **:**
mode {25_9.4.d} **token, NEST mode joined definition of DECS** {19_4.1.b, c} **.**

b) **NEST mode definition of MOID TALLY TAB** {41c} **:**
where (TAB) is (bold TAG) or (NEST) is (new LAYER),
MOID TALLY NEST defining mode indication with TAB {19_4.8.a} **,**
is defined as {25_9.4.d} **token,**
actual MOID TALLY NEST declarer {c}**.**

c) **actual MOID TALLY1 NEST declarer** {b} **:**
where (TALLY1) is (i),
actual MOID NEST declarator {19_4.6.c, d, g, h, o, s, -}**;**
where (TALLY1) is (TALLY2 i),
MOID TALLY2 NEST applied mode indication with TAB2 {19_4.8.b} **.**

{Examples:

a) `MODE R = REF REAL, S = CHAR`

b) `R = REF REAL`

c) `REF REAL • CHAR` }

{The use of **'TALLY'** excludes circular chains of **mode-definitions** such as `MODE A = B, B = A`.

Defining-mode-indications-with-SIZETY-STANDARD may be declared only in the **standard-prelude**, where the nest is of the form "**new LAYER**" {26_{10}.1.1.b}.}

19.2.2 Semantics

The elaboration of a **mode-declaration** {involves no action, yields no value and} is completed.

19.3 Priority declarations

{**Priority-declarations** are used to specify the priority of **operators**. Priorities from 1 to 9 are available.

Since **monadic-operators** have effectively only one priority-level, which is higher than that of all **dyadic-operators**, **monadic-operators** do not require **priority-declarations**.}

19.3.1 Syntax

a) **NEST priority declaration of DECS** {19_4.1.a} **:**
priority {25_9.4.d} **token,**
NEST priority joined definition of DECS {19_4.1.b, c} **.**

b) **NEST priority definition of priority PRIO TAD** {19_4.1.c} **:**
priority PRIO NEST defining operator with TAD {19_4.8.a} **,**
is defined as {25_9.4.d} **token, DIGIT** {25_9.4.b} **token,**
where DIGIT counts PRIO {c, d}**.**
DIGIT :: digit zero; digit one; digit two; digit three; digit four;
digit five; digit six; digit seven; digit eight; digit nine.

c) **WHETHER DIGIT1 counts PRIO i** {b, c} **:**
WHETHER DIGIT2 counts PRIO {c, d}**,**
where (digit one digit two digit three digit four digit five digit six
digit seven digit eight digit nine) contains (DIGIT2 DIGIT1).

d) **WHETHER digit one counts i** {b, c} **: WHETHER true.**

{Examples:

a) `PRIO ∨ = 2, ∧ = 3`

b) `∨ = 2 }`

19.3.2 Semantics

The elaboration of a **priority-declaration** {involves no action, yields no value and} is completed.

19.4 Identifier declarations

{**Identifier-declarations** provide **MODE-defining-identifiers**, by means of either **identity-definitions** or **variable-definitions**.
Examples:

```
REAL pi = 3.1416 • REAL scan := 0.05.
```

The latter example, which is a **variable-declaration**, may be considered as an equivalent form of the **identity-declaration**

```
REF REAL scan = LOC REAL := 0.05.
```

The elaboration of **identifier-declarations** causes values to be ascribed to their **identifiers**; in the examples given above, 3.1416 is ascribed to `pi` and a new local name which refers to 0.05 is ascribed to `scan`.}

19.4.1 Syntax

A) **MODINE :: MODE ; routine.**

B) **LEAP :: local ; heap ; primal.**

a) **NEST MODINE identity declaration of DECS** {19_4.1.a}
: formal MODINE NEST declarer {b, 19_4.6.b} **,**
NEST MODINE identity joined definition of DECS {19_4.1.b, c} **.**

b) **VICTAL routine NEST declarer** {a, 20_5.2.3.b} **:**
procedure {25_9.4.d} **token.**

c) **NEST MODINE identity definition of MODE TAG** {19_4.1.c} **:**
MODE NEST defining identifier with TAG {19_4.8.a} **,**
is defined as {25_9.4.d} **token,**
MODE NEST source for MODINE {d}**.**

d) **MODE NEST source for MODINE** {c, f, 19_4.5.c} **:**
where (MODINE) is (MODE),
MODE NEST source {20_5.2.1.c} **;**
where (MODINE) is (routine),
MODE NEST routine text {20_5.4.1.a, b, -}**.**

e) **NEST reference to MODINE variable declaration of DECS** {19_4.1.a} **:**
reference to MODINE NEST LEAP sample generator {20_5.2.3.b} **,**
NEST reference to MODINE variable joined definition of DECS {19_4.1.b, c}
.

f) **NEST reference to MODINE variable definition of reference to MODE TAG** {19_4.1.c} **:**
reference to MODE NEST defining identifier with TAG {19_4.8.a} **,**
becomes {25_9.4.c} **token,**
MODE NEST source for MODINE {d}**;**
where (MODINE) is (MODE),
reference to MODE NEST defining identifier with TAG {19_4.8.a} **.**

g) ***identifier declaration :**
NEST MODINE identity declaration of DECS {a} **;**
NEST reference to MODINE variable declaration of DECS {e}**.**

{Examples:

a) `INT m = 4096 • PROC r10 = REAL: random × 10`

b) `PROC`

c) `m = 4096`

d) `4096 • REAL: random × 10`

e) `REAL x, y • PROC pp := REAL: random × 10`

f) `pp := REAL: random × 10 • x }`

19.4.2 Semantics

a) An **identity-declaration** D is elaborated as follows:
• the constituent **sources-for-MODINE** of D are elaborated collaterally;
For each constituent **identity-definition** $D1$ of D,

- the yield V of the **source-for-MODINE** of $D1$ is ascribed {19_4.8.2.a} to the **defining-identifier** of $D1$.

b) A **variable-declaration** D is elaborated as follows:
• the **sample-generator** {20_5.2.3.1.b} G of D and all the **sources-for-MODINE**, if any, of the constituent **variable-definitions** of D are elaborated collaterally;
For each constituent **variable-definition-of-reference-to-MODE-TAG** $D1$ of D,

- let $W1$ be a "variant" {c}, for **'MODE'**, of the value referred to by the yield N of G;
- let $N1$ be a newly created name equal in scope to N and referring to $W1$;
- if $N1$ is a stowed name {17_2.1.3.2.b}, then $N1$ is endowed with subnames {17_2.1.3.3.e, 17_2.1.3.4.g};
- $N1$ is ascribed {19_4.8.2.a} to the **defining-identifier** of $D1$;
- the yield of the **source-for-MODINE**, if any, of $D1$ is assigned {20_5.2.1.2.b} to $N1$.

{An **actual-declarer** which is common to a number of **variable-definitions** is elaborated only once. For example, the elaboration of

```
INT m := 10; [1 : m +:= 1] INT p, q; print (m)
```

causes 11 to be printed, and not 12; moreover, two new local names referring to multiple values with descriptor $((1, 11))$, and undefined elements, are ascribed to `p` and to `q`.}

c) A "variant" of a value V, for a mode M, is a value W acceptable to {17_2.1.3.6.d} M, and determined as follows:
Case A: M is some **'structured with FIELDS mode'**:

For each **'MODE field TAG'** enveloped by **'FIELDS'**,

- the field selected by **'TAG'** in W is a variant, for **'MODE'**, of the field selected by **'TAG'** in V;

Case B: M is some **'FLEXETY ROWS of MODE1'**:

- the descriptor of W is that of V;
- each element of W is a variant, for **'MODE1'**, of some element of V;

Other Cases:

- W is any value acceptable to M.

d) The yield of an **actual-routine-declarer** is some routine {whose mode is of no relevance}.

19.5 Operation declarations

{**Operation-declarations** provide **defining-operators**.
Example:

```
OP MC = (REAL a, b) REAL: (3 × a < b | a | b).
```

Unlike the case with, e.g., **identifier-declarations**, more than one **operation-declaration** involving the same **TAO-token** may occur in the same reach; e.g., the previous example may very well be in the same reach as

```
OP MC = (COMPL carthy, john) COMPL: (random < .5 | carthy | john);
```

the **operator** `MC` is then said to be "overloaded".}

19.5.1 Syntax

A) **PRAM :: DUO ; MONO.**

B) **TAO :: TAD ; TAM.**

a) **NEST MODINE operation declaration of DECS** {19_4.1.a} **:**
operator {25_9.4.d} **token, formal MODINE NEST plan** {b, 19_4.6.p, -}**,**
NEST MODINE operation joined definition of DECS {19_4.1.b, c} **.**

b) **formal routine NEST plan {a} : EMPTY.**

c) **NEST MODINE operation definition of PRAM TAO** {41c} **:**
PRAM NEST defining operator with TAO {19_4.8.a} **,**
is defined as {25_9.4.d} **token,**
PRAM NEST source for MODINE {19_4.4.d} **.**

{Examples:

a) `OP \/ = (BOOL a, b) BOOL: (a | TRUE | b)`

c) `\/ = (BOOL a, b) BOOL: (a | TRUE | b)` }

19.5.2 Semantics

a) The elaboration of an **operation-declaration** consists of the collateral elaboration of its constituent **operation-definitions**.

b) An **operation-definition** is elaborated by ascribing {19_4.8.2.a} the routine yielded by its **source-for-MODINE** to its **defining-operator**.

19.6 Declarers

{**Declarers** specify modes. A **declarer** is either a **declarator**, which explicitly constructs a mode, or an **applied-mode-indication**, which stands for some **declarator** by way of a **mode-declaration**. Declarators are built from `VOID`, `INT`, `REAL`, `BOOL` and `CHAR` {26_{10}.2.2}, with the assistance of other **symbols** such as `REF`, `STRUCT`, `[ ]`, `PROC`, and `UNION`. For example, `PROC (REAL)BOOL` specifies the mode **'procedure with real parameter yielding boolean'**.

Actual-declarers, used typically in **generators**, require the presence of bounds. **Formal-declarers**, used typically in **formal-parameters** and **casts**, are without bounds. The **declarer** following a `ref` is always **'virtual'**; it may then specify a **'flexible ROWS of MODE'**, because flexibility is a property of names. Since **actual-declarers** follow an implicit **'reference to'** in **generators**, they may also specify **'flexible ROWS of MODE'**.}

19.6.1 Syntax

A) **VICTAL :: VIRACT ; formal.**

B) **VIRACT :: virtual ; actual.**

C) **MOIDS :: MOID ; MOIDS MOID.**

a) **VIRACT MOID NEST declarer** {c, e, g, h, 20_5.2.3.a, b} **:**
VIRACT MOID NEST declarator {c, d, g, h, o, s, -}**;**
MOID TALLY NEST applied mode indication with TAB {19_4.8.b, -}**.**

b) **formal MOID NEST declarer** {e, h, p, r, u, 18_3.4.k, 19_4.4.a, 20_5.4.1.a, b, e, 20_5.5.1.a} **:**
where MOID deflexes to MOID {19_4.7.a, b, c, -}**,**
formal MOID NEST declarator {c, d, h, o, s, -}**;**
MOID1 TALLY NEST applied mode indication with TAB {19_4.8.b, -}**,**
where MOID1 deflexes to MOID {19_4.7.a, b, c, -}**.**

c) **VICTAL reference to MODE NEST declarator** {a, b, 19_4.2.c} **:**
reference to {94d} **token, virtual MODE NEST declarer {a}.**

d) **VICTAL structured with FIELDS mode NEST declarator** {a, b, 19_4.2.c} **:**
structure {25_9.4.d} **token, VICTAL FIELDS NEST portrayer of FIELDS** {e} **brief pack.**

e) **VICTAL FIELDS NEST portrayer of FIELDS1** {d, e} **:**
VICTAL MODE NEST declarer {a, b} **,**
NEST MODE FIELDS joined definition of FIELDS1 {19_4.1.b, c} **;**
where (FIELDS1) is (FIELDS2 FIELDS3),
VICTAL MODE NEST declarer {a, b} **,**
NEST MODE FIELDS joined definition of FIELDS2 {19_4.1.b, c} **,**
and also {25_9.4.f} **token,**
VICTAL FIELDS NEST portrayer of FIELDS3 {e}**.**

f) **NEST MODE FIELDS definition of MODE field TAG** {19_4.1.c} **:**
MODE field FIELDS defining field selector with TAG {19_4.8.c} **.**

g) **VIRACT flexible ROWS of MODE NEST declarator** {a, 42c} **:**
flexible {25_9.4.d} **token, VIRACT ROWS of MODE NEST declarer {a}.**

h) **VICTAL ROWS of MODE NEST declarator** {a, b, 19_4.2.c} **:**
VICTAL ROWS NEST rower {i, j, k, l} **STYLE bracket,**
VICTAL MODE NEST declarer {a, b}**.**

i) **VICTAL row ROWS NEST rower** {h, i} **:**
VICTAL row NEST rower {j, k, l}**, and also** {94f} **token,**
VICTAL ROWS NEST rower {i, j, k, l}**.**

j) **actual row NEST rower** {h, i} **:**
NEST lower bound {m}**, up to** {25_9.4.f} **token, NEST upper bound** {n}**;**
NEST upper bound {n}**.**

k) **virtual row NEST rower** {h, i}**: up to** {25_9.4.f} **token option.**

l) **formal row NEST rower** {h, i}**: up to** {25_9.4.f} **token option.**

m) **NEST lower bound** {j, 20_5.3.2.f, g} **: meek integral NEST unit** {18_3.2.d} **.**

n) **NEST upper bound** {j, 20_5.3.2.f} **: meek integral NEST unit** {18_3.2.d} **.**

o) **VICTAL PROCEDURE NEST declarator** {a, b, 19_4.2.c} **:**
procedure {25_9.4.d} **token, formal PROCEDURE NEST plan** {p}**.**

p) **formal procedure PARAMETY yielding MOID NEST plan** {o, 19_4.5.a} **:**
where (PARAMETY) is (EMPTY),
formal MOID NEST declarer {b}**;**
where (PARAMETY) is (with PARAMETERS),
PARAMETERS NEST joined declarer {q, r}
brief pack, formal MOID NEST declarer {b}**.**

q) **PARAMETERS PARAMETER NEST joined declarer** {p, q} **:**
PARAMETERS NEST joined declarer {q, r}**, and also** {94f} **token,**
PARAMETER NEST joined declarer {r}**.**

r) **MODE parameter NEST joined declarer** {p, q} **: formal MODE NEST declarer** {b}**.**

s) **VICTAL union of MOODS1 MOOD1 mode NEST declarator** {a, b, 19_4.2.c} **:**
unless EMPTY with MOODS1 MOOD1 incestuous {19_4.7.f} **,**
union of {25_9.4.d} **token,**
MOIDS NEST joined declarer {t, u} **brief pack,**
where MOIDS ravels to MOODS2 {19_4.7.g}
and safe MOODS1 MOOD1 subset of safe MOODS2 {23_7.3.l}
and safe MOODS2 subset of safe MOODS1 MOOD1 {23_7.3.l, m} **.**

t) **MOIDS MOID NEST joined declarer** {s, t} **:**
MOIDS NEST joined declarer {t, u}**, and also** {25_9.4.f} **token,**
MOID NEST joined declarer {u}**.**

u) **MOID NEST joined declarer** {s, t} **: formal MOID NEST declarer** {b}**.**

{Examples:

a) `[1 : n] REAL • PERSON`

b) `[] REAL • STRING`

c) `REF REAL`

d) `STRUCT (INT age, REF PERSON father, son)`

e) `REF PERSON father, son • INT age, REF PERSON father, son`

f) `age`

g) `FLEX [1 : n] REAL`

h) `[1 : m, 1 : n] REAL`

i) `1 : m, 1 : n`

j) `1 : n`

k) `:`

l) `:`

m) `1`

n) `n`

o) `PROC (BOOL, BOOL) BOOL`

p) `(BOOL, BOOL) BOOL q) BOOL, BOOL`

r) `BOOL s) UNION (INT, CHAR)`

t) `INT, CHAR`

u) `INT` }

{For **actual-MOID-TALLY-declarers**, see 19_4.2.1.c ; for **actual-routine-declarers**, see 19_4.4.1.b . There are no **declarers** specifying modes such as **'union of integral union of integral real mode mode'** or **'union of integral real integral mode'**. The **declarers** `UNION (INT, UNION (INT, REAL))` and `UNION (INT, REAL, INT)` may indeed be written, but in both cases the mode specified is **'union of integral real mode'** (which can as well be spelled **'union of real integral mode'**).}

19.6.2 Semantics

a) The yield W of an **actual-MODE-declarer** D, in an environ E, is determined as follows: If **'MODE'** is some **'STOWED'**, then

- let $D1$ in $E1$ be "developed" {c} from D in E;
- W is the yield of {the **declarator**} $D1$ in an environ established {locally, see 18_3.2.2.b} upon E and around $E1$;

otherwise,

- W is any value {acceptable to **'MODE'**} .

b) The yield W of an **actual-STOWED-declarator** D is determined as follows:
Case A: **'STOWED'** is some **'structured with FIELDS mode'**:

- the constituent **declarers** of D are elaborated collaterally;
- each field of W is a variant {19_4.4.2.c}

(i) of the yield of the last constituent **MODE-declarer** of D occurring before the constituent **defining-field-selector** of D selecting {17_2.1.5.g} that field,

(ii) for that **'MODE'**;

Case B: **'STOWED'** is some **'ROWS of MODE'**:

- all the constituent **lower-bounds** and **upper-bounds** of D and the **declarer** $D1$ of D are elaborated collaterally;
  For $i = 1...n$, where n is the number of **'row'**s contained in **'ROWS'**,
  - let l_i be the yield of the **lower-bound**, if any, of the i^{th} constituent **row-rower** of D, and be 1 otherwise;
  - let u_i be the yield of the **upper-bound** of that **row-rower**;
- W is composed of

(i) a descriptor $((l_1, u_1), ..., (l_n, u_n))$,

(ii) variants of the yield of $D1$, for **'MODE'**;

Case C: **'STOWED'** is some **'flexible ROWS of MODE'**:

- W is the yield of the **declarer** of D.

c) The scene S "developed from" an **actual-STOWED-declarer** D in an environ E is determined as follows:
If the visible direct descendent $D1$ of D is a **mode-indication**,
then

- S is the scene developed from that yielded by $D1$ in E;

otherwise {D1 is a **declarator**},

- S is composed of $D1$ and E.

d) A given **MOID-declarer** "specifies" the mode **'MOID'**.

19.7 Relationships between modes

{Some modes must be deflexed because the mode of a value may not be flexible {17_2.1.3.6.b}. Incestuous unions must be prevented in order to avoid ambiguities. A set of **'UNITED'**s and **'MOODS'**s may be ravelled by replacing all those **'UNITED'**s by their component **'MOODS'**s.}

19.7.1 Syntax

A) **NONSTOWED :: PLAIN ; REF to MODE ; PROCEDURE ; UNITED ; void.**

B) **MOODSETY :: MOODS ; EMPTY.**

C) **MOIDSETY :: MOIDS ; EMPTY.**

a) **WHETHER NONSTOWED deflexes to NONSTOWED**
{b, e, 19_4.6.b, 20_5.2.1.c, 22_6.2.a, 23_7.1.n} **:**
WHETHER true.

b) **WHETHER FLEXETY ROWS of MODE1 deflexes to ROWS of MODE2**
{b, e, 19_4.6.b, 20_5.2.1.c, 22_6.2.a, 23_7.1.n} **:**
WHETHER MODE1 deflexes to MODE2 {a, b, c, -}**.**

c) **WHETHER structured with FIELDS1 mode deflexes to structured with FIELDS2 mode**
{b, e, 19_4.6.b, 20_5.2.1c, 22_6.2.a, 23_7.1.n} **:**
WHETHER FIELDS1 deflexes to FIELDS2 {d, e, -}**.**

d) **WHETHER FIELDS1 FIELD1 deflexes to FIELDS2 FIELD2** {c, d} **:**
WHETHER FIELDS1 deflexes to FIELDS2 {d, e, -}
and FIELD1 deflexes to FIELD2 {e, -}**.**

e) **WHETHER MODE1 field TAG deflexes to MODE2 field TAG** {c, d} **:**
WHETHER MODE1 deflexes to MODE2 {a, b, c, -}**.**

f) **WHETHER MOODSETY1 with MOODSETY2 incestuous** {f, 19_4.6.s} **:**
where (MOODSETY2) is (MOOD MOODSETY3),
WHETHER MOODSETY1 MOOD with MOODSETY3 incestuous {f}
or MOOD is firm union of MOODSETY1 MOODSETY3 mode {23_7.1.m} **;**
where (MOODSETY2) is (EMPTY),
WHETHER false.

g) **WHETHER MOIDS ravels to MOODS** {g, 19_4.6.s} **:**
where (MOIDS) is (MOODS),
WHETHER true ;

where (MOIDS) is (MOODSETY union of MOODS1 mode MOIDSETY),
WHETHER MOODSETY MOODS1 MOIDSETY ravels to MOODS {g}**.**

{A component mode of a union may not be firmly coerced to one of the other component modes or to the union of those others (rule f) for, otherwise, ambiguities could arise. For example,

```
UNION (REF INT, INT) (LOC INT)
```

is ambiguous in that dereferencing may or may not occur before the uniting. Similarly,

```
MODE SZP = UNION (SZEREDI, PETER);
UNION (REF SZP, SZP) (LOC SZP)
```

is ambiguous. Note that, because of ravelling (rule g), the mode specified by the **declarer** of the **cast** is more closely suggested by `UNION (REF SZP, SZEREDI, PETER)`.}

19.8 Indicators and field selectors

19.8.1 Syntax

A) **INDICATOR :: identifier ; mode indication ; operator.**

B) **DEFIED :: defining ; applied.**

C) **PROPSETY :: PROPS ; EMPTY.**

D) **PROPS :: PROP ; PROPS PROP.**

E) **PROP :: DEC ; LAB ; FIELD.**

F) **QUALITY :: MODE ; MOID TALLY ; DYADIC ; label ; MODE field.**

G) **TAX :: TAG ; TAB ; TAD ; TAM.**

a) **QUALITY NEST new PROPSETY1 QUALITY TAX PROPSETY2**
defining INDICATOR with TAX
{18_3.2.c, 18_3.5.b, 19_4.2.b, 19_4.3.b, 19_4.4.c, f, 19_4.5.c, 20_5.4.1.f} **:**
where QUALITY TAX independent PROPSETY1 PROPSETY2 {23_7.1.a, b, c} **,**
TAX {25_9.4.2.A, D, F, K} **token.**

b) **QUALITY NEST applied INDICATOR with TAX**
{19_4.2.c, 19_4.6.a, b, 20_5.D, 20_5.4.2.a, b, 20_5.4.4.a} **:**
where QUALITY TAX identified in NEST {72a} **,**
TAX {25_9.4.2.A, D, F, K} **token.**

c) **MODE field PROPSETY1 MODE field TAG PROPSETY2**
defining field selector with TAG {19_4.6.f} **:**
where MODE field TAG independent PROPSETY1 PROPSETY2 {23_7.1.a, b, c} **,**
TAG {25_9.4.2.A} **token.**

d) **MODE field FIELDS applied field selector with TAG** {20_5.3.1.a} **:**
where MODE field TAG resides in FIELDS {23_7.2.b, c, -}**,**
TAG {25_9.4.2.A} **token.**

e) ***QUALITY NEST DEFIED indicator with TAX :**
QUALITY NEST DEFIED INDICATOR with TAX {a, b}**.**

f) ***MODE DEFIED field selector with TAG :**
MODE field FIELDS DEFIED field selector with TAG {c, d}**.**

{Examples:

a) `x` (in `REAL x, y`)

b) `x` (in `x + y`)

c) `next` (see 16_1.1.2)

d) `next` (in `next OF draft`) }

19.8.2 Semantics

a) When a value or a scene V is "ascribed" to a **QUALITY-defining-indicator-with-TAX**, in an environ E, then **'QUALITY TAX'** is made to access V inside the locale of E {17_2.1.2.c}.

b) The yield W of a **QUALITY-applied-indicator-with-TAX** I in an environ E composed of an environ $E1$ and a locale L is determined as follows:
If L corresponds to a **'DECSETY LABSETY'** which envelops {16_1.1.4.1.c} that **'QUALITY TAX'**,
then

> W is the value or scene, if any, accessed inside L by **'QUALITY TAX'** and, otherwise, is undefined;

otherwise, W is the yield of I in $E1$.

{Consider the following **closed-clause**, which contains another one:
`BEGIN CO range 1 CO`

```
    INT i = 421, INT a := 5, PROC p = VOID: print (a);
    BEGIN CO range 2 CO
      REAL a; a := i; p
    END
  END.
```

By the time `a := i` is encountered during the elaboration, two new environs have been created, one for each **range**. The **defining-identifier** `i` is first sought in the newer one, $E2$, is not found there, and then is sought and found in the older one, $E1$. The locale of $E1$ corresponds to **'integral letter i reference to integral letter a procedure yielding void letter p'**. The yield of the **applied-identifier** `i` is therefore the value 421 which has been ascribed {a} to **'integral letter i'** inside the locale of $E1$. The yield of `a`, in `a := i`, however, is found from the locale of $E2$.

When `p` is called {20_5.4.3.2.b}, its **unit** is elaborated in an environ $E3$ established around $E1$ but upon $E2$ {18_3.2.2.b}. This means that, for scope purposes, $E3$ is newer than $E2$, but the component environ of $E3$ is $E1$. When `a` comes to be printed, it is the yield 5 of the **reference-to-integral-identifier** a declared in the outer **range** that is obtained.

Thus, the meaning of an **indicator** applied but not defined within a routine is determined by the context in which the routine was created, rather than that in which it is called.}

20 Units

{**Units** are used to program the more primitive actions or to put into one single piece the larger constructs of Chapter 18_3.

NOTION-coercees are the results of coercion (Chapter 22_6), but **hips** are not; in the case of **ENCLOSED-clauses**, any coercions needed are performed inside them.

The syntax below implies, for example, that `text OF draft + "the␣end"` is parsed as `(text OF draft) + "the␣end"` since a **selection** is a **'SECONDARY'** whereas a **formula** is a **'TERTIARY'**.}

20.1 Syntax

A) **UNIT** {18_3.2.d} **::**
assignation {20_5.2.1.a} **coercee ;**
identity relation {20_5.2.2.a} **coercee ;**
routine text {20_5.4.1.a, b} **coercee ;**
jump {20_5.4.4.a} **;**
skip {20_5.5.2.a} **;**
TERTIARY {B}**.**

B) **TERTIARY** {A, 20_5.2.1.b, 20_5.2.2.a} **::**
ADIC formula {20_5.4.2.a, b} **coercee ;**
nihil {20_5.2.4.a} **;**
SECONDARY {C}**.**

C) **SECONDARY** {B, 20_5.3.1.a, 20_5.4.2.c} **::**
LEAP generator {20_5.2.3.a} **coercee ;**
selection {20_5.3.1.a} **coercee ;**
PRIMARY {D}**.**

D) **PRIMARY** {C, 20_5.3.2.a, 20_5.4.3.a} **::**
slice {20_5.3.2.a} **coercee ;**
call {20_5.4.3.a} **coercee ;**
cast {20_5.5.1.a} **coercee ;**

denoter {24_{8}.0.a} **coercee ;**
format text {26_{10}.3.4.1.a} **coercee ;**
applied identifier with TAG {19_{4}.8.b} **coercee ;**
ENCLOSED clause {18_{3}.1.a, 18_{3}.3.a, c, d, e, 18_{3}.4.a, 18_{3}.5.a} **.**

{The hyper-rules for **'SORT MOID FORM coercee'** are given in 22_{6}.1.1.a, b, c, d and e, the entry rules of the coercion syntax. When the coercion syntax is invoked for some **'SORT MOID FORM coercee'**, it will eventually return to a rule in this chapter for some **'MOID1 FORM'** (blind alleys apart). It is the cross-reference to that rule that is given in the metaproduction rules above. No other visible descendent has been produced in the meantime; the coercion syntax merely transforms **'MOID'** into **'MOID1'** for semantical purposes.}

a) ***SOME hip : SOME jump** {20_{5}.4.4.a} **; SOME skip** {20_{5}.5.2.a} **; SOME nihil** {20_{5}.2.4.a} **.**

{The mode of a **hip** is always that required, a posteriori, by its context, and its yield is acceptable to that mode. Since any mode is so easily accommodated, no coercion is permitted.}

20.2 Units associated with names

{Names may be assigned to {20_{5}.2.1}, compared with other names {20_{5}.2.2} and created {20_{5}.2.3}.}

20.2.1 Assignations

{In **assignations**, a value is "assigned", to a name. E.g., in `x := 3.14`, the real number yielded by the **source** 3.14 is assigned to the name yielded by the **destination** x.}

20.2.1.1 Syntax

a) **REF to MODE NEST assignation** {20_{5}.A} **:**
REF to MODE NEST destination {b}**,**
becomes {25_{9}.4.c} **token,**
MODE NEST source {c}**.**

b) **REF to MODE NEST destination** {a} **:**
soft REF to MODE NEST TERTIARY {20_{5}.B} **.**

c) **MODE1 NEST source** {a, 19_4.4.d} **:**
strong MODE2 NEST unit {18_3.2.d} **,**
where MODE1 deflexes to MODE2 {19_4.7.a, b, c, -}**.**

{Examples:

a) `x := 3.14`

b) `x`

c) `3.14` }

20.2.1.2 Semantics

a) An **assignation** A is elaborated as follows:

- let N and W be the {collateral} yields {a name and another value} of the **destination** and **source** of A;
- W is assigned to {b}N;
- the yield of A is N.

b) A value W is "assigned to" a name N, whose mode is some **'REF to MODE'**, as follows: It is required that

- N be not nil, and that
- W be not newer in scope than N;

Case A: **'MODE'** is some **'structured with FIELDS mode'**:

- For each **'TAG'** selecting a field in W,
- that field is assigned to the subname selected by **'TAG'** in N;

Case B: **'MODE'** is some **'ROWS of MODE1'**:

- let V be the {old} value referred to by N;
- it is required that the descriptors of W and V be identical;
- For each index I selecting an element in W,

- that element is assigned to the subname selected by I in N;

Case C: **'MODE'** is some **'flexible ROWS of MODE1'**:

- let V be the {old} value referred to by N;
- N is made to refer to a multiple value composed of

(i) the descriptor of W,

(ii) variants {19_4.4.2.c} of some element {possibly a ghost element} of V;

- N is endowed with subnames {17_2.1.3.4.g};
  For each index I selecting an element in W,
  - that element is assigned to the subname selected by I in N;

Other Cases {e.g., where **'MODE'** is some **'PLAIN'** or some **'UNITED'**} :

- N is made to refer {17_2.1.3.2.a} to W.

{Observe how, given
```
FLEX [1: 0] [1: 3] INT semiflex,
```
the presence of the ghost element {17_2.1.3.4.c} ensures that the meaning of
```
semiflex := LOC [1 : 1] [1 : 3] INT
```
is well defined, but that of
```
semiflex := LOC [1 : 1] [1 : 4] INT
```
is not, since the bound pairs of the second dimension are different.}

20.2.2 Identity relations

{**Identity-relations** may be used to ask whether two names of the same mode are the same.

E.g., after the **assignation** `draft := ("abc", NIL)`, the **identity-relation** `next OF draft :=: REF BOOK (NIL)` yields `true`. However, `next OF draft :=: NIL` yields `false` because it is equivalent to `next OF draft :=: REF REF BOOK (NIL)`; the yield of `next OF draft`, without any coercion, is the name referring to the second field of the structured value referred to by the value of `draft` and, hence, is not nil.}

20.2.2.1 Syntax

a) **boolean NEST identity relation** {20_5.A} **:**
where soft balances SORT1 and SORT2 {18_3.2.f} **,**
SORT1 reference to MODE NEST TERTIARY1 {20_5.B} **,**
identity relator {b}**,**
SORT2 reference to MODE NEST TERTIARY2 {5B} **.**

b) **identity relator {a} : is** {25_9.4.f} **token ; is not** {25_9.4.f} **token.**

{Examples:

a) `next OF draft:=: REF BOOK (NIL)`

b) `:=: • :≠:` }

{Observe that `a1[i] :=: a1[j]` is not produced by this syntax. The comparison, by an **identity-relation**, of transient names {17_2.1.3.6.c} is thus prevented.}

20.2.2.2 Semantics

The yield W of an **identity-relation** I is determined as follows:
• let $N1$ and $N2$ be the {collateral} yields of the **'TERTIARY'**s of I;
Case A: The **token** of the **identity-relator** of I is an **is-token**:

- W is `true` if {the name} $N1$ is the same as $N2$, and is `false` otherwise;

Case B: The **token** of the **identity-relator** of I is an **is-not-token**:

- W is `true` if $N1$ is not the same as $N2$, and is `false`, otherwise.

20.2.3 Generators

{And as imagination bodies forth
The forms of things unknown, the poet's pen
Turns them to shapes, and gives to airy nothing
A local habitation and a name.
A Midsummer-night's Dream, William Shakespeare. }

{The elaboration of a **generator**, e.g., `LOC REAL` in `xx := LOC REAL := 3.14`, or of a **sample-generator**, e.g., `[1 : n] CHAR` in `[1 : n] CHAR u, v;`, involves the creation of a name, i.e., the reservation of storage.

The use of a **local-generator** implies (with most implementations) the reservation of storage on a run-time stack, whereas **heap-generators** imply the reservation of storage in another region, termed the "heap", in which garbage-collection techniques may be used for storage retrieval. Since this is less efficient, **local-generators** are preferable; this is why only `LOC` may be omitted from **sample-generators** of **variable-declarations**.}

20.2.3.1 Syntax

{**LEAP :: local ; heap primal.**}

a) **reference to MODE NEST LEAP generator** {20_5.C} **:**
LEAP {25_9.4.d, -} **token, actual MODE NEST declarer** {19_4.6.a} **.**

b) **reference to MODINE NEST LEAP sample generator** {19_4.4.e} **:**
LEAP {25_9.4.d, -} **token, actual MODINE NEST declarer** {19_4.4.b, 19_4.6.a} **;**
where (LEAP) is (local),
actual MODINE NEST declarer {19_4.4.b, 19_4.6.a} **.**

{Examples:

a) `LOC REAL`

b) `LOC REAL • REAL`}

{There is no representation for the **primal-symbol** (see 25_9.4.a).}

20.2.3.2 Semantics

a) The yield W of a **LEAP-generator** or **LEAP-sample-generator** G, in an environ E, is determined as follows:
• W is a newly created name which is made to refer {17_2.1.3.2.a} to the yield in E of the **actual-declarer** {19_4.4.2.d, 19_4.6.2.a} of G;
• W is equal in scope to the environ $E1$ determined as follows:

Case A: **'LEAP'** is **'local'**:

- $E1$ is the "local environ" {b} accessible from E;

Case B: **'LEAP'** is **'heap'**:

- $E1$ is {the first environ created during the elaboration of the **particular-program**, which is} such that

(i) the primal environ {17_2.2.2.a} is the environ of the environ of the environ of the environ of $E1$ {sic}, and

(ii) $E1$ is, or is older than, E;

Case C: **'LEAP'** is **'primal'**:

- $E1$ is the primal environ;

• if W is a stowed name {17_2.1.3.2.b}, then W is endowed with subnames {17_2.1.3.3.e, 17_2.1.3.4.g}.

{The only examples of **primal-generators** occur in the **standard-** and **system-preludes** {26_{10}.3.1.1.h, 26_{10}.3.1.4.b, n, o, 26_{10}.4.1.a}.

When G is a **reference-to-routine-sample-generator**, the mode of W is of no relevance.}

b) The "local environ" accessible from an environ E is an environ $E1$ determined as follows:

If E is "nonlocal" {18_3.2.2.b},

then $E1$ is the local environ accessible from the environ of E;

otherwise, $E1$ is E.

{An environ is nonlocal if it has been established according to a **serial-clause** or **enquiry-clause** which contains no constituent **mode-**, **identifier-**, or **operation-declaration**, or according to a **for-part** {18_3.5.1.b} or a **specification** {18_3.4.1.j, k}.}

20.2.4 Nihils

20.2.4.1 Syntax

a) **strong reference to MODE NEST nihil** {5B} **: nil** {94f} **token.**

{Example:

a) `NIL` }

20.2.4.2 Semantics

The yield of a **nihil** is a nil name.

20.3 Units associated with stowed values

{In Flanders fields the poppies blow
Between the crosses, row on row, ...
In Flanders Fields, John McCrae. }

{The fields of structured values may be obtained by **selections** {20_5.3.1} and the elements of multiple values by **slices** {20_5.3.2}; the corresponding effects on stowed names are defined also.}

20.3.1 Selections

{A **selection** selects a field from a structured value or (if it is a "multiple selection") it selects a multiple value from a multiple value whose elements are structured values. For example, `re OF z` selects the first real field (usually termed the real part) of the yield of `z`. If `z` yields a name, then `re OF z` also yields a name, but if `g` yields a complex value, then `re OF g` yields a real value, not a name referring to one.}

20.3.1.1 Syntax

A) **REFETY :: REF to ; EMPTY.**

B) **REFLEXETY :: REF to ; REF to flexible ; EMPTY.**
{**REF :: reference ; transient reference.**}

a) **REFETY MODE1 NEST selection** {20_5.C} **:**
MODE1 field FIELDS applied field selector with TAG {19_4.8.d} **,**
of {25_9.4.f} **token,**
weak REFETY structured with FIELDS mode NEST SECONDARY {20_5.C}
;
where (MODE1) is (ROWS of MODE2),
MODE2 field FIELDS applied field selector with TAG {19_4.8.d} **,**
of {94f} **token,**
weak REFLEXETY ROWS of structured with FIELDS mode
NEST SECONDARY {20_5.C} **,**
where (REFETY) is derived from (REFLEXETY) {b, c, -}**.**

b) **WHETHER (transient reference to) is derived from (REF to flexible)**
{a, 20_5.3.2.a, 22_6.6.a} **:**
WHETHER true.

c) **WHETHER (REFETY) is derived from (REFETY)** {a, 20_5.3.2.a, 22_6.6.a} **:**
WHETHER true.

{Examples:

a) `re OF z • re OF z1` }

{The mode of `re OF z` begins with **'reference to'** because that of `z` does.
Example:

```
INT age := 7; STRUCT (BOOL gender, INT age) jill;
age OF jill := age;
```

Note that the **destination** `age OF jill` yields a name because `jill` yields one. After the **identity-declaration**

```
STRUCT (BOOL gender, INT age) jack = (TRUE, 9),
```

`age OF jack` cannot be assigned to since `jack` is not a **variable**.}

20.3.1.2 Semantics

The yield W of a **selection** S is determined as follows:
• let V be the yield of the **SECONDARY** of S;
• it is required that V {if it is a name} be not nil;
• W is the value selected in {17_2.1.3.3.a, e, 17_2.1.3.4.k} or the name generated from {17_2.1.3.4.l} V by the **field-selector** of S.

{A **selection** in a name referring to a structured value yields an existing subname {17_2.1.3.3.e} of that name. The name generated from a name referring to a multiple value, by way of a selection with a **ROWS-of-MODE-SECONDARY** (as in `re OF z1`), is a name which may or may not be newly created for the purpose.}

20.3.2 Slices

{**Slices** are obtained by subscripting, e.g., `x1[i]`, by trimming, e.g., `x1[2 : n]` or by both, e.g., `x2[j : n, j]` or `x2 [, k]`. Subscripting and trimming may be done only to **PRIMARY**s, e.g., `x1` or `(p | x1 | y1)` but not `re OF z1`. The value of a **slice** may be either one element of the yield of its **PRIMARY** or a subset of the elements; e.g., `x1[i]` is a real number from the row of real numbers `x1`, `x2[i, ]` is the `i`-th row of the matrix `x2` and `x2[, k]` is its `k`-th column.}

20.3.2.1 Syntax

A) **ROWSETY :: ROWS ; EMPTY.**

a) **REFETY MODE1 NEST slice** {20_5.D} **:**
weak REFLEXETY ROWS1 of MODE1 NEST PRIMARY {20_5.D} **,**
ROWS1 leaving EMPTY NEST indexer {b, c, -} **STYLE bracket,**
where (REFETY) is derived from (REFLEXETY) {20_5.3.1.b, c, -}**;**
where (MODE1) is (ROWS2 of MODE2),
weak REFLEXETY ROWS1 of MODE2 NEST PRIMARY {20_5.D} **,**
ROWS1 leaving ROWS2 NEST indexer {b, d, -} **STYLE bracket,**
where (REFETY) is derived from (REFLEXETY) {20_5.3.1.b, c, -}**.**
{**ROWS :: row ; ROWS row.**} item[b)] **row ROWS leaving ROWSETY1 ROWSETY2 NEST indexer** {a, b} **:**
row leaving ROWSETY1 NEST indexer {c, d, -}**,**
and also {25_9.4.f} **token,**
ROWS leaving ROWSETY2 NEST indexer {b, c, d, -}**.**

c) **row leaving EMPTY NEST indexer** {a, b} **: NEST subscript** {e}**.**

d) **row leaving row NEST indexer** {a, b} **:**
NEST trimmer {f}**;**
NEST revised lower bound {g} **option.**

e) **NEST subscript** {c} **: meek integral NEST unit** {32d} **.**

f) **NEST trimmer** {d} **:**
NEST lower bound {19_4.6.m} **option,**
up to {94f} **token,**
NEST upper bound {19_4.6.n} **option,**
NEST revised lower bound {g} **option.**

g) **NEST revised lower bound** {d, f} **:**
at {25_9.4.f} **token,**
NEST lower bound {19_4.6.m} **.**

h) ***trimscript :**
NEST subscript {e}**;**
NEST trimmer {f}**;**
NEST revised lower bound {g} **option.**

i) ***indexer : ROWS leaving ROWSETY NEST indexer** {b, c, d}**.**

j) ***boundscript :**
NEST subscript {e}**;**
NEST lower bound {19_4.6.m} **;**
NEST upper bound {19_4.6.n} **;**
NEST revised lower bound {g}**.**

{Examples:

a) `x2[i, j] • x2[, j]`

b) `1 : 2, j (in x2[1 : 2, j] • i, j (in x2[i, j])`

c) `j (in x2[1 : 2, j])`

d) `1 : 2 • @0 (in x1[@0])`

e) `j`

f) `1 : 2 @0`

g) `@0` }

{A **subscript** decreases the number of dimensions by one, but a **trimmer** leaves it unchanged. In rule a, **'ROWS1'** reflects the number of **trimscripts** in the **slice**, and **'ROWS2'** the number of these which are **trimmers** or **revised-lower-bound-options**. If the value to be sliced is a name, then the yield of the **slice** is also a name. Moreover, if the mode of the former name is **'reference to flexible ROWS1 of MODE'**, then that yield is a transient name (see 17_2.1.3.6.c).}

20.3.2.2 Semantics

a) The yield W of a **slice** S is determined as follows:
• let V and $(I_1, ..., I_n)$ be the {collateral} yields of the **PRIMARY** of S and of the **indexer** {b} of S;
• it is required that V {if it is a name} be not nil;
• let $((r_1, s_1), ..., (r_n, s_n))$ be the descriptor of V or of the value referred to by V;
For $i = 1, ..., n$,

Case A: I_i is an integer:

- it is required that $r_i \leq I_i \leq s_i$;

Case B: I_i is some triplet (l, u, l'):

- let L be r_i, if l is $absent$, and be l otherwise;
- let U be s_i, if u is $absent$, and be u otherwise;
- it is required that $r_i \leq L$ and $U \leq s_i$;
- let D be 0 if l' is $absent$, and be $L - l'$ otherwise; {D is the amount to be subtracted from L in order to get the revised lower bound;}
- I_i is replaced by (L, U, D);

• W is the value selected in {17_2.1.3.4.a, g, i} or the name generated from {17_2.1.3.4.j} V by $I_1, ..., I_n$.

b) The yield of an **indexer** I of a **slice** S is a trim {17_2.1.3.4.h} or an index {17_2.1.3.4.a} $I_1, ..., I_n$ determined as follows:
• the constituent **boundscripts** of S are elaborated collaterally; For $i = 1...n$, where n is the number of constituent **trimscripts** of S,

Case A: the i-th **trimscript** is a **subscript**:

- I_i is {the integer which is} the yield of that **subscript**;

Case B: the i-th **trimscript** is a **trimmer** T:

- I_i is the triplet (l, u, l'), where
  - l is the yield of the constituent **lower-bound**, if any, of T, and is $absent$, otherwise,
  - u is the yield of the constituent **upper-bound**, if any, of T, and is $absent$, otherwise,
  - l' is the yield of the constituent **revised-lower-bound**, if any, of T, and is 1, otherwise;

Case C: the i-th **trimscript** is a **revised-lower-bound-option** N:

- I_i is the triplet (absent, absent, l'), where
- l' is the yield of the **revised-lower-bound**, if any, of N, and is absent otherwise.

{Observe that, if $(I_1, ..., I_n)$ contains no triplets, it is an index, and selects one element; otherwise, it is a trim, and selects a subset of the elements.}

{A **slice** from a name referring to a multiple value yields an existing subname {17_2.1.3.4.j} of that name if all the constituent **trimscripts** of that **slice** are **subscripts**. Otherwise, it yields a generated name which may or may not be newly created for the purpose. Hence, the yield of `x1[1 : 2] :=: x1[1 : 2]` is not defined, although `x1[1] :=: x1[1]` must always yield `true`.}

{The various possible bounds in the yield of a **slice** are illustrated by the following examples, for each of which the descriptor of the value referred to by the yield is shown:
`[0 : 9, 2 : 11] INT i3;`
`i3[1, 3 : 10 @3]` ¢$((3,10))$¢;
`i3[1, 3 : 10]` ¢$((1,8))$¢;
`i3[1, 3 : ]` ¢$((1,9))$¢;
`i3[1, : ]` ¢$((1,10))$¢;
`i3[1, ]` ¢$((2,11))$¢;
`i3[, 2]` ¢$((0,9))$¢ }

20.4 Units associated with routines

{Routines are created from **routine-texts** {20_5.4.1} or from **jumps** {20_5.4.4}, and they may be "called" by **calls** {20_5.4.3}, **formulas** {20_5.4.2} or by deproceduring {22_6.3}.}

20.4.1 Routine texts

{A **routine-text** always has a **formal-declarer**, specifying the mode of the result, and a **routine-token**, viz., a colon. To the right of this colon stands a **unit**, which prescribes the computations to be performed when the routine is called. If there are parameters, then to the left of the **formal-declarer** stands a **declarative** containing the various **formal-parameters** required.
Examples:

```
VOID: print (x);
(REF REAL a, REAL b) BOOL: (a <b | a := b; TRUE | FALSE).}
```

20.4.1.1 Syntax

a) **procedure yielding MOID NEST1 routine text** {19_4.4.d, 20_5.A} **:**
formal MOID NEST1 declarer {19_4.6.b} **,**
routine {25_9.4.f} **token,**
strong MOID NEST1 unit {18_3.2.d} **.**

b) **procedure with PARAMETERS yielding MOID NEST1 routine text** {19_4.4.d, 20_5.A} **:**
NEST1 new DECS2 declarative defining new DECS2 {e}**brief pack,**
where DECS2 like PARAMETERS {c, d, -}**,**
formal MOID NEST1 declarer {19_4.6.b} **,**
routine {25_9.4.f} **token,**
strong MOID NEST1 new DECS2 unit {18_3.2.d} **.**

c) **WHETHER DECS DEC like PARAMETERS PARAMETER** {b, c} **:**
WHETHER DECS like PARAMETERS {c, d, -}
and DEC like PARAMETER {d, -}**.**
{**PARAMETER :: MODE parameter.**}

d) **WHETHER MODE TAG like MODE parameter** {b, c} **: WHETHER true.**

e) **NEST2 declarative defining new DECS2** {b, e, 18_3.4.j} **:**
formal MODE NEST2 declarer {19_4.6.b} **,**
NEST2 MODE parameter joined definition of DECS2 {19_4.1.b, c} **;**
where (DECS2) is (DECS3 DECS4),

formal MODE NEST2 declarer {19_4.6.b} **,**
NEST2 MODE parameter joined definition of DECS3 {19_4.1.b, c} **,**
and also {25_9.4.f} **token,**
NEST2 declarative defining new DECS4 {e}**.**

f) **NEST2 MODE parameter definition of MODE TAG2** {19_4.1.c} **:**
MODE NEST2 defining identifier with TAG2 {19_4.8.a} **.**

g) ***formal MODE parameter :**
NEST MODE parameter definition of MODE TAG {f}**.**

{Examples:

a) `REAL: random × 10`

b) `(BOOL a, b) BOOL: (a | b | FALSE)`

e) `BOOL a, b • BOOL a, BOOL b`

f) `a }`

20.4.1.2 Semantics

The yield of a **routine-text** T, in an environ E, is the routine composed of

(i) T, and

(ii) the environ necessary for {23_7.2.2.c} T in E.

20.4.2 Formulas

{**Formulas** are either dyadic or monadic: e.g., `x + i` or `ABS x`. The order of elaboration of a **formula** is determined by the priority of its **operators**; monadic **formulas** are elaborated first and then the dyadic ones from the highest to the lowest priority.}

20.4.2.1 Syntax

A) **DYADIC :: priority PRIO.**

B) **MONADIC :: priority iii iii iii i.**

C) **ADIC :: DYADIC ; MONADIC.**

D) **TALLETY :: TALLY ; EMPTY.**

a) **MOID NEST DYADIC formula** {c, 5B} **:**
MODE1 NEST DYADIC TALLETY operand {c, -}**,**
procedure with MODE1 parameter MODE2 parameter yielding
MOID NEST applied operator with TAD {19_4.8.b} **,**
where DYADIC TAD identified in NEST {23_7.2.a} **,**
MODE2 NEST DYADIC TALLY operand {c, -}**.**

b) **MOID NEST MONADIC formula** {c, 20_5.B} **:**
procedure with MODE parameter yielding
MOID NEST applied operator with TAM {19_4.8b} **,**
MODE NEST MONADIC operand {c}**.**

c) **MODE NEST ADIC operand** {a, b} **:**
firm MODE NEST ADIC formula {a, b} **coercee** {22_6.1.b} **;**
where (ADIC) is (MONADIC),
firm MODE NEST SECONDARY {5C} **.**

d) ***MOID formula : MOID NEST ADIC formula** {a, b}**.**

e) ***DUO dyadic operator with TAD :**
DUO NEST DEFIED operator with TAD {19_4.8.a, b} **.**

f) ***MONO monadic operator with TAM :**
MONO NEST DEFIED operator with TAM {19_4.8.a, b} **.**

g) ***MODE operand : MODE NEST ADIC operand** {c}**.**

{Examples:

a) `-x + 1`

b) `-x`

c) `-x • 1` }

20.4.2.2 Semantics

The yield W of a **formula** F, in an environ E, is determined as follows:

- let R be the routine yielded in E by the **operator** of F;
- let $V_1, ..., V_n$ {n is 1 or 2} be the {collateral} yields of the **operands** of F, in an environ $E1$ established {locally, see 18_3.2.2.b} around E;

- W is the yield of the calling {20_5.4.3.2.b} of R in $E1$, with $V_1, ..., V_n$;
- it is required that W be not newer in scope than E.

{Observe that `a ↑ b` is not precisely the same as a^b in the usual notation; indeed, the value of `(- 1 ↑ 2 + 4 = 5)` and that of `(4 - 1 ↑ 2 = 3)` both are `true`, since the first **minus-symbol** is a **monadic-operator**, whereas the second is a **dyadic-operator**.}

20.4.3 Calls

{**Calls** are used to command the elaboration of routines parametrized with **actual-parameters**. Examples:

```
sin (x) • (p | sin | cos) (x).}
```

20.4.3.1 Syntax

a) **MOID NEST call** {5D} **:**
meek procedure with PARAMETERS yielding MOID NEST PRIMARY {20_5.D}
,
actual NEST PARAMETERS {b, c} **brief pack.**

b) **actual NEST PARAMETERS PARAMETER** {a, b} **:**
actual NEST PARAMETERS {b, c}**,**
and also {94f} **token,**
actual NEST PARAMETER {c}**.**

c) **actual NEST MODE parameter** {a, b} **: strong MODE NEST unit** {18_3.2.d} **.**

{Examples:

a) `put (stand out, x)` (see 26_{10}.3.3.1.a)

b) `stand out, x`

c) `x`}

20.4.3.2 Semantics

a) The yield W of a **call** C, in an environ E, is determined as follows:

- let R {a routine} and $V_1, ..., V_n$ be the {collateral} yields of the **PRIMARY** of C, in E, and of the constituent **actual-parameters** of C, in an environ $E1$ established {locally, see 18_3.2.2.b} around E;
- W is the yield of the calling {b} of R in $E1$ with $V_1, ..., V_n$;
- it is required that W be not newer in scope than E.

b) The yield W of the "calling", of a routine R in an environ $E1$, possibly with {parameter} values $V_1, ..., V_n$, is determined as follows:

- let $E2$ be the environ established {18_3.2.2.b} upon $E1$, around the environ of R, according to the **declarative** of the **declarative-pack**, if any, of the **routine-text** of R, with the values $V_1, ..., V_n$, if any;
- W is the yield in $E2$ of the **unit** of the **routine-text** of R.

{Consider the following **serial-clause**:

```
PROC samelson = (INT n, PROC (INT) REAL f) REAL:
  BEGIN LONG REAL s := LONG 0;
    FOR i TO n DO s +:= LENG f (i) ↑ 2 OD;
    SHORTEN long sqrt (s)
  END;
samelson (m, (INT j) REAL: x1[j]).
```

In that context, the last **call** has the same effect as the following **cast**:

```
REAL (
  INT n = m, PROC (INT) REAL f = (INT j) REAL: x1[j];
  BEGIN LONG REAL s := LONG 0;
    FOR i TO n DO s +:= LENG f (i) ↑ 2 OD;
    SHORTEN long sqrt (s)
  END).
```

The transmission of **actual-parameters** is thus similar to the elaboration of **identity-declarations** {19_4.4.2.a}; see also establishment {18_3.2.2.b} and ascription {19_4.8.2.a}.}

20.4.4 Jumps

{A **jump** may terminate the elaboration of a **series** and cause some other labelled **series** to be elaborated in its place.
Examples:

```
y = IF x ≥ 0 THEN sqrt (x) ELSE GOTO princeton FI •
GOTO st pierre de chartreuse.
```

Alternatively, if the context expects the mode **'procedure yielding MOID'**, then a routine whose **unit** is that **jump** is yielded instead, as in
`PROC VOID m := GOTO north berwick.`}

20.4.4.1 Syntax

a) **strong MOID NEST jump** {20_5.A} **:**
go to {b} **option,**
label NEST applied identifier with TAG {19_4.8.b} **.**

b) **go to {a} :**
STYLE go to {25_9.4.f, -} **token ;**
STYLE go {25_9.4.f, -} **token, STYLE to symbol** {25_9.4.g, -}**.**

{Examples:

a) `GOTO kootwijk • GO TO warsaw • zandvoort`

b) `GOTO • GO TO`}

20.4.4.2 Semantics

A **MOID-NEST-jump** J, in an environ E, is elaborated as follows:
• let the scene yielded in E by the **label-identifier** of J be composed of a **series** $S2$ and an environ $E1$;
Case A: **'MOID'** is not any **'procedure yielding MOID1'**:

- let $S1$ be the **series** of the smallest {16_1.1.3.2.g} **serial-clause** containing $S2$;
- the elaboration of $S1$ in $E1$, or of any **series** in $E1$ elaborated in its place, is terminated {17_2.1.4.3.e};
- $S2$ in $E1$ is elaborated "in place of" $S1$ in $E1$;

Case B: **'MOID'** is some **'procedure yielding MOID1'**:

- J in E {is completed and} yields the routine composed of
- a new **MOID-NEST-routine-text** whose **unit** is akin {16_1.1.3.2.k} to J,
- $E1$.

20.5 Units associated with values of any mode

20.5.1 Casts

{**Casts** may be used to provide a strong position. For example,
`REF REAL (xx)` in `REF REAL (xx) := 1`,
`REF BOOK (NIL)` in `next OF draft :=: REF BOOK (NIL)` and
`STRING (p | c | r)` in `s +:= STRING (p | c | r)`.}

20.5.1.1 Syntax

a) **MOID NEST cast** {20_5.D} **:**
formal MOID NEST declarer {19_4.6.b} **,**
strong MOID NEST ENCLOSED clause {18_3.1.a, 18_3.3.a, c, d, e, 18_3.4.a, 18_3.5.a, -}**.**

{Example:

a) `REF BOOK (NIL)` }

{The yield of a **cast** is that of its **ENCLOSED-clause**, by way of pre-elaboration {17_2.1.4.1.c}.}

20.5.2 Skips

20.5.2.1 Syntax

a) **strong MOID NEST skip** {20_5.A} **: skip** {25_9.4.f} **token.**

20.5.2.2 Semantics

The yield of a **skip** is some {undefined} value equal in scope to the primal environ.

{The mode of the yield of a **MOID-skip** is **'MOID'**. A **void-skip** serves as a dummy statement and may be used, for example, after a **label** which marks the end of a **serial-clause**.}

21

Specification of partial parametrization proposal

By C.H. Lindsey (University of Manchester)

The following specification[1] has been released by the IFIP Working Group 2.1 Standing subcommittee on Algol 68 Support, with the authorization of the Working Group. This proposal has been scrutinized to ensure that

a. it is strictly upwards-compatible with Algol 68,

b. it is consistent with the philosophy and orthogonal framework of that language, and

c. it fills a clearly discernible gap in the expressive power of that language.

In releasing this extension, the intention is to encourage implementers experimenting with features similar to those described below to use the formulation here given, so as to avoid proliferation of dialects.

{{ Although routines are values in Algol 68, and can therefore be yielded by other routines, the practical usefulness of this facility is limited by scope restrictions. Consider:

```
PROC f = (REAL x) PROC (REAL) REAL: (REAL y) REAL: x + y;
PROC (REAL) REAL g := f (3);
x := g (4)
```

This attempts to assign to `g` the routine "add 3". It does not work because the body of the routine is still fundamentally the **routine-text** `(REAL y) REAL : x + y` which expects to find the value `x` (i.e. 3) on the stack in the form of an actual-parameter of `f`, and by this time `f` is finished with and its stack level has disappeared. The problem arises whenever a **routine-text** uses identifiers declared globally to itself and the limitation is expressed in the Report by making the scope of a routine dependent on its necessary environ (23_7.2.2.c). Here is an attempt at functional composition which fails to work for the same reason:

[1] This chapter is not a part of the Algol 68 Revised Report, and is reproduced here with kind permission of C.H. Lindsey. The original publication is ALGOL BULLETIN 39.3.1 pages 6-9.

```
PROC compose = (PROC (REAL) REAL f, g) PROC (REAL) REAL: (REAL x) REAL:
f (g (x));
PROC (REAL) REAL sinex = compose (sqrt, exp)
```

Clearly, if the restriction is to be lifted, a routine value has to have associated with it copies of these global values. Unfortunately, their number is in general indeterminable at compile time, and so the implementation of such values must be similar to that of multiple values referred to by flexible names (17_2.1.3.4) requiring, in most implementations, the use of the heap.

In this variant, all the intended global values appear to the **routine-text** as its own formal-parameters. At each call, some or all of these parameters are provided with actual values, resulting in a routine with that number of parameters fewer. Ultimately (possibly after several calls) a routine without parameters is obtained and, if the context so demands, deproceduring can now take place. Thus, all calls in the original language turn out to be parametrizations followed by immediate deproceduring, but their effect is the same. Here are some examples:

1)
```
PROC f = (REAL x, y) x + y;
  PROC (REAL) REAL g := f (3, );
x := g (4) ¢ or x := f (3, ) (4) ¢
```

2)
```
PROC compose = (PROC (REAL) REAL f, g, REAL x) REAL; f (g (x));
PROC (REAL) REAL sinex = compose (sqrt, exp, )
```

3)
```
OP ↑ = (PROC (REAL) REAL a, INT b) PROC (REAL) REAL:
  ((PROC (REAL) REAL a, INT b, REAL p) REAL:
    (REAL x := 1; TO b DO x ×:= a (p) OD; x )) (a, b, );
REAL theta; print ((cos ↑ 2) (theta) + (sin ↑ 2) (theta))
```

}}

{{A routine now includes an extra locale.}}

17_2.1.3.5 Routines

a) A "routine" is a value composed of a **routine-text** {20_5.4.1.1.a,b}, an environ {17_2.1.1.1.c} and a locale {17_2.1.1.1.b}. {The locale corresponds to a **'DECSETY'** reflecting the formal-parameters, if any, of the **routine-text**.}

b) The mode of a routine is some **'PROCEDURE'**.

c) The scope of a routine is the newest of the scopes of its environ and of the values, if any, accessed {17_2.1.2.c} inside its locale.

{{A **routine-text** yields the new style of routine.}}

20_5.4.1.2 Semantics

The yield of a **routine-text** T, in an environ E, is the routine composed of

(i) T,

(ii) the environ necessary for {23_7.2.2.c} T in E, and

(iii) a locale corresponding to **'DECS2'** if T has a **declarative-defining-new-DECS2-brief-pack**, and to **'EMPTY'** otherwise.

{{Most of the remaining changes to the Report needed to incorporate this facility are in section 20_5.4.3 (calls).}}

20_5.4.3 Calls (with partial parametrization)

A **call** is used to provide **actual-parameters** to match some or all of the **formal-parameters** of a routine. It yields a routine with correspondingly fewer **formal-parameters** or with none at all, in which case the yield is usually subject to deproceduring (22_6.3).

{Examples:

```
y := sin (x) •
  PROC REAL ncossini = (p | ncos | nsin) (i) •
  print ((set char number (, 5), x)).}
```

20_5.4.3.1 Syntax

A) **PARAMSETY :: PARAMETERS ; EMPTY.**

a) **procedure yielding MOID NEST call** {20_5.D}**:**
meek procedure with PARAMETERS1 yielding MOID NEST PRIMARY {20_5.D} **,**
actual NEST PARAMETERS1 leaving EMPTY {c,d,e} **brief pack.**

b) **procedure with PARAMETERS2 yielding MOID NEST call** {20_5.D} **:**
meek procedure with PARAMETERS1 yielding MOID NEST PRIMARY {20_5.D} **,**
actual NEST PARAMETERS1 leaving PARAMETERS2 {c,d,e,f} **brief pack.**

c) **actual NEST PARAMETER PARAMETERS leaving PARAMSETY1 PARAMSETY2** {a,b,c}**:**
actual NEST PARAMETER leaving PARAMSETY1 {d,e}**, and also** {25_9.4.f} **token,**
actual NEST PARAMETERS leaving PARAMSETY2 {c,d,e}**.**

d) **actual NEST MODE parameter leaving EMPTY** {a,b,c}**: strong MODE NEST unit** {18_3.2.d} **.**

e) **actual NEST PARAMETER leaving PARAMETER** {a,b,c}**: EMPTY.**

f) *** actual MODE parameter: actual NEST MODE parameter leaving EMPTY** {d}**.**

g) *** dummy parameter: actual NEST PARAMETER leaving PARAMETER** {e}**.**

{Examples:

a) `set char number (stand out, 5)`

b) `set char number (, 5)`

c) `, 5`

d) `5`

}

20_5.4.3.2 Semantics

a1) The yield W of a **call** C, in an environ E, is determined as follows:

- let R {a routine} and V_1, ..., V_n be the {collateral} yields of the **PRIMARY** of C, in E, and of the constituent **actual-** and **dummy-parameters** of C, in an environ $E1$ established {locally, see 18_3.2.2.b} around E, where the yield of a **dummy-parameter** is "*absent*";

- W is {the routine which is} the yield of the "parametrization" a2 of R with V_1, ..., V_n;

- except where C is the constituent **call** of a **deprocedured-to-MOID-call** 22_6.3.1.a, it is required that W be not newer in scope than E {; thus, `PROC (CHAR, STRING) BOOL cs = char in string (, LOC INT,)` is undefined but `q := char in string ("A", LOC INT, s)` is not}.

a2) The yield W of the "parametrization" of a routine $R0$ with values V_1, ..., V_n is determined as follows:

- let $T0$, $E0$ and $L0$ be, respectively, the **routine-text**, the environ and the locale of $R0$, and let $L0$ correspond {17_2.1.1.1.b} to some **'DECS0'**;

- let $L1$ be a new locale corresponding to **'DECS0'**, and let the value, if any, accessed by any **'DEC0'** inside $L0$ be accessed also by that **'DEC0'** inside $L1$;
- let **'DECS1'** be a sequence composed of all those **'DEC0'**s enveloped by **'DECS0'** which have not {yet} been made to access values inside $L1$, taken in their order within **'DECS0'**;

  For i = 1, ..., n, If V_i is not $absent$, {see a1}, then the i-th **'DEC1'** enveloped by **'DECS1'** is made to access V_i inside $L1$; otherwise, the i-th **'DEC1'** still does not access anything;
- W is the routine composed of $T0$, $E0$ and $L1$.

{A routine may be parametrized in several stages. Upon each occasion the yields of the new **actual-parameters** are made to be accessed inside its locale and the scope of the routine becomes the newest of its original scope and the scopes of those yields.}

b) The yield W of the "calling" of a routine $R0$ in an environ $E1$ {see 20_5.4.2.2 and 22_6.3.2} is determined as follows:

- let $T0$, $E0$ and $L0$ be, respectively, the **routine-text**, the environ and the locale of $R0$;
- let $E2$ be a {newly established} environ, newer in scope than $E1$, composed of $E0$ and $L0$ {$E2$ is local};
- W is the yield, in $E2$, of the unit of $T0$.

Consider the following **serial-clause**:

```
PROC samelson = (INT n, PROC (INT) REAL f) REAL:
  BEGIN LONG REAL s := LONG 0;
    FOR i TO n DO s +:= LENG f (i) ↑ 2 OD;
    SHORTEN long sqrt (s)
  END;
y := samelson (m, (INT j) REAL: x1[j])
```

In that context, the last **deprocedured-to-real-call** has the same effect as the **deprocedured-to-real-routine-text** in:

```
y := REAL: (
  INT n = m, PROC (INT) REAL f = (INT j) REAL: x1[j];
  BEGIN LONG REAL s := LONG 0;
    FOR i TO n DO s +:= LENG f (i) ↑ 2 OD;
    SHORTEN long sqrt (s)
  END).
```

The transmission of the **actual-parameters** is thus similar to the elaboration of **identity-declarations** (19_4.4.2.a); see also establishment (18_3.2.2.b) and ascription (19_4.8.2.a).

{{Minor changes are required at other places in the Report.}}

{{The third bullet of 20_5.4.2.2 (semantics of formulas) is replaced by}}

- let $R1$ be {the routine which is} the yield of the parametrization {20_5.4.3.2.a2} of R with V_1, ..., V_n;
- W is the yield of the calling {20_5.4.3.2.b} of $R1$ in $E1$;

{{20_5.4.4.2.Case B, 26_{10}.3.4.1.2.c and 26_{10}.3.4.9.2 must be modified to show that the routines there created are composed, additionally, from a vacant locale {17_2.1.1.1.b}.}}

{Revised Report } Part III

Context Dependence

{This Part deals with those rules which do not alter the underlying syntactical structure:

- the transformations of modes implicitly defined by the context, with their accompanying actions;
- the syntax needed for the equivalence of modes and for the safe application of the properties kept in the nests.}

22 Coercion

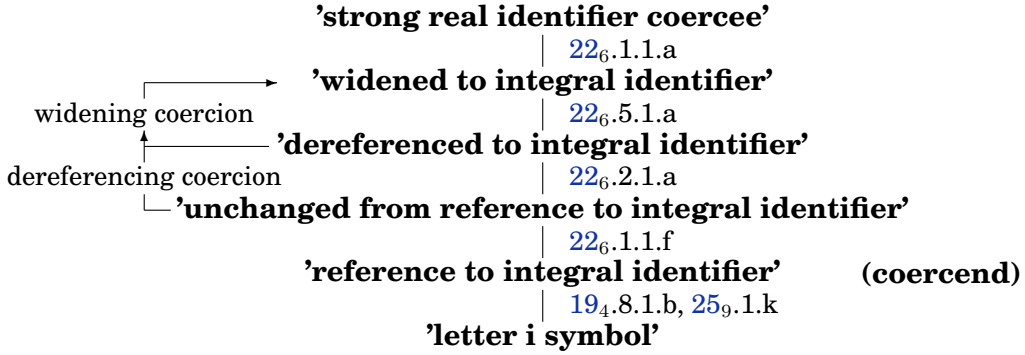
{The coercions produce a **coercend** from a **coercee** according to three criteria: the a priori mode of the **coercend** before the application of any coercion, the a posteriori mode of the **coercee** required after those coercions, and the syntactic position or "sort" of the **coercee**. Coercions may be cascaded.

There are six possible coercions, termed "deproceduring", "dereferencing", "uniting", "widening", "rowing" and "voiding". Each coercion, except "uniting", prescribes a corresponding dynamic effect on the associated values. Hence, a number of primitive actions can be programmed implicitly by coercions.}

22.1 Coercees

{A **coercee** is a construct whose production tree may begin a sequence of coercions ending in a **coercend**. The order of (completion of) the elaboration of the coercions is therefore from the **coercend** to the **coercee** (hence the choice of these paranotions). For example, `i` in `REAL (i)` is a **coercee** whose production tree involves **'widened to'** and **'dereferenced to'**, in that order, in passing from the **coercee** to the **coercend**. Note that the dereferencing must be completed before the widening takes place.

The relevant production tree (with elision of **'NEST'**, **'applied'** and **'with TAG'**, and with invisible subtrees omitted) is:



}

22.1.1 Syntax

A) **STRONG** {a, 22_6.6.a } **:: FIRM** {B}**; widened to** {22_6.5.a, b, c, d} **;**
rowed to {22_6.6.a} **; voided to** {22_6.7.a, b } **.**

B) **FIRM** {A, b} **:: MEEK** {c}**; united to** {22_6.4.a } **.**

C) **MEEK** {B, c, d, 22_6.2.a, 22_6.3.a, 22_6.4.a, 22_6.5.a, b, c, d} **::**
unchanged from {f}**; dereferenced to** {22_6.2.a } **; deprocedured to** {22_6.3.a } **.**

D) **SOFT** {e, 22_6.3.b } **:: unchanged from** {f}**; softly deprocedured to** {22_6.3.b } **.**

E) **FORM :: MORF ; COMORF.**

F) **MORF :: NEST selection ; NEST slice ; NEST routine text ; NEST ADIC formula ;**
NEST call ; NEST applied identifier with TAG.

G) **COMORF :: NEST assignation ; NEST identity relation ; NEST LEAP generator ; NEST cast ; NEST denoter ; NEST format text.**

a) **strong MOID FORM coercee** {20_5.A, B, C, D, 26_{10}.3.4.1.i} **:**
where (FORM) is (MORF), STRONG {A} **MOID MORF ;**
where (FORM) is (COMORF), STRONG {A} **MOID COMORF,**
unless (STRONG MOID) is (deprocedured to void).

b) **firm MODE FORM coercee** {20_5.A, B, C, D, 20_5.4.2.c} **: FIRM** {B} **MODE FORM.**

c) **meek MOID FORM coercee** {20_5.A, B, C, D} **: MEEK** {C} **MOID FORM.**

d) **weak REFETY STOWED FORM coercee** {20_5.A, B, C, D} **:**
MEEK {C} **REFETY STOWED FORM,**
unless (MEEK) is (dereferenced to) and (REFETY) is (EMPTY).

e) **soft MODE FORM coercee** {20_5.A, B, C, D} **: SOFT** {D} **MODE FORM.**

f) **unchanged from MOID FORM** {C, D, 22_6.7.a, b } **: MOID FORM.**

g) ***SORT MOID coercee : SORT MOID FORM coercee** {a, b, c, d, e}**.**

h) ***MOID coercend : MOID FORM.**

{Examples:

a) `3.14` (in `x := 3.14`)

b) `3.14` (in `x + 3.14`)

c) `sin` (in `sin (x)`)

d) `x1` (in `x1[2] := 3.14`)

e) `x` (in `x := 3.14`) }

{For **'MOID FORM'** (rule f), see the cross-references inserted in sections 20_5.1.A, B, C, D before "**coercee**". Note, however, that a **'MOID FORM'** may be a blind alley. Blind alleys within this chapter are not indicated.}

{There are five sorts of syntactic position. They are:

- "strong" positions, i.e., **actual-parameters**, e.g., `x` in `sin (x)`, **sources**, e.g., `x` in `y := x`, the **ENCLOSED-clause** of a **cast**, e.g., `(NIL)` in `REF BOOK (NIL)`, and statements, e.g., `y := x` in `(y := x; x := 0)`;
- "firm" positions, i.e., **operands**, e.g., `x` in `x + y`;
- "meek" positions, i.e., **enquiry-clauses**, e.g., `x >0` in `(x >0 | x | 0)`, **bound-scripts**, e.g., `i` in `x1 [i]`, and the **PRIMARY** of a **call**, e.g., `sin` in `sin (x)`;
- "weak" positions, i.e., the **SECONDARY** of a **selection** and the **PRIMARY** of a **slice**, e.g., `x1` in `x1[i]`;
- "soft" positions, i.e., **destinations**, e.g., `x` in `x := y` and one of the **TERTIARY**s of an **identity-relation**, e.g., `x` in `xx :=: x`.

Strong positions also arise in balancing {18_3.2.1.e}.

In strong positions, all six coercions may occur; in firm positions, rowing, widening and voiding are forbidden; in meek and weak positions, uniting is forbidden also, and in soft positions only deproceduring is allowed. However, a **dereferenced-to-STOWED-FORM** may not be directly descended from a **weak-STOWED-FORM-coercee** (rule d) for, otherwise, `x := x1[i]` would be syntactically ambiguous (although, in this case, not semantically). Also, a **deprocedured-to-void-COMORF** may not be directly descended from a **strong-void-COMORF-coercee** (rule a) for, otherwise,

```
(PROC VOID engelfriet; PROC VOID rijpens = SKIP;
engelfriet := rijpens; SKIP)
```

would be ambiguous.}

22.2 Dereferencing

{Dereferencing serves to obtain the value referred to by a name, as in `x := y`, where `y` yields a name referring to a real number and it is this number which is assigned to the name yielded by `x`. The a priori mode of `y`, regarded as a **coercend**, is **'reference to real'** and its a posteriori mode, when `y` is regarded as a **coercee**, is **'real'**.}

22.2.1 Syntax

a) **dereferenced to** {22_6.1.C } **MODE1 FORM :**
MEEK {22_6.1.C} **REF to MODE2 FORM,**
where MODE2 deflexes to MODE1 {19_4.7.a,b,c, -}**.**

{Example:

a) `x` (in `REAL (x)`) }

22.2.2 Semantics

The yield W of a **dereferenced-to-MODE-FORM** F is determined as follows:

- let {the name} N be the yield of the **MEEK-FORM** of F;
- it is required that N be not nil;
- W is the value referred to by N.

22.3 Deproceduring

{Deproceduring is used when a routine without parameters is to be called. E.g., in `x := random`, the routine yielded by `random` is called and the real number yielded is assigned; the a posteriori mode of `random` is **'real'**. Syntactically, an initial **'procedure yielding'** is removed from the a priori mode.}

22.3.1 Syntax

a) **deprocedured to** {22_6.1.C, 22_6.7.a} **MOID FORM :**
MEEK {22_6.1.C } **procedure yielding MOID FORM.**

b) **softly deprocedured to** {22_6.1.D } **MODE FORM :**
SOFT {22_6.1.D } **procedure yielding MODE FORM.**

{Examples:

a) `random` (in `REAL (random)`)

b) `x or y` (in `x or y := 3.14`, see 16_1.1.2) }

22.3.2 Semantics

The yield W of a **deprocedured-to-MOID-FORM** or **softly-deprocedured-to-MOID-FORM** F, in an environ E, is determined as follows:

- let {the routine} R be the yield in E of the direct descendent of F;
- W is the yield of the calling {20_5.4.3.2.b} of R in E;
- it is required that W be not newer in scope than E.

22.4 Uniting

{Uniting does not change the mode of the run-time value yielded by a construct, but simply gives more freedom to it. That value must be acceptable to not just that one mode, but rather to the whole of a given set of modes. However, after uniting, that value may be subject to a primitive action only after being dynamically tested in a **conformity-clause** {18_3.4.1.q}; indeed, no primitive action can be programmed with a construct of a **'UNITED'** mode (except to assign it to a **UNITED-variable**, of course).

Example:

```
UNION (BOOL, CHAR) t, v;
t := "a"; t := TRUE; v := t.}
```

22.4.1 Syntax

a) **united to** {22_6.1.B } **UNITED FORM :**
MEEK {22_6.1.C} **MOID FORM,**
where MOID unites to UNITED {b}**.**

b) **WHETHER MOID1 unites to MOID2** {a, 18_3.4.i, 23_7.1.m} **:**
where MOID1 equivalent MOID2 {23_7.3.a } **, WHETHER false ;**
unless MOID1 equivalent MOID2 {23_7.3.a } **,**
WHETHER safe MOODS1 subset of safe MOODS2 {23_7.3.l, m, n} **,**
where (MOODS1) is (MOID1)
or (union of MOODS1 mode) is (MOID1),
where (MOODS2) is (MOID2)
or (union of MOODS2 mode) is (MOID2).

{Examples:

a) `x (in uir := x)` •
`u` (in `UNION (CHAR, INT, VOID) (u)`, in a reach containing
`UNION (INT, VOID) u := EMPTY`) }

22.5 Widening

{Widening transforms integers to real numbers, real numbers to complex numbers (in both cases, with the same size), a value of mode **'BITS'** to an unpacked vector of truth values, or a value of mode **'BYTES'** to an unpacked vector of characters.

For example, in `z := 1`, the yield of `1` is widened to the real number `1.0` and then to the complex number `(1.0, 0.0)`; syntactically, the a priori mode specified by `INT` is changed to that specified by `REAL` and then to that specified by `COMPL`.}

22.5.1 Syntax

A) **BITS :: structured with row of boolean field SITHETY letter aleph mode.**

B) **BYTES :: structured with row of character field SITHETY letter aleph mode.**

C) **SITHETY :: LENGTH LENGTHETY ; SHORTH SHORTHETY ; EMPTY.**

D) **LENGTH :: letter l letter o letter n letter g.**

E) **SHORTH :: letter s letter h letter o letter r letter t.**

F) **LENGTHETY :: LENGTH LENGTHETY ; EMPTY.**

G) **SHORTHETY :: SHORTH SHORTHETY ; EMPTY.**

a) **widened to** {b, 22_6.1.A } **SIZETY real FORM :**
MEEK {22_6.1.C } **SIZETY integral FORM.** {**SIZETY :: long LONGSETY ; short SHORTSETY ; EMPTY.**}

b) **widened to** {22_6.1.A } **structured with SIZETY real field letter r letter e SIZETY real field letter i letter m mode FORM : MEEK** {61C } **SIZETY real FORM ; widened to {a} SIZETY real FORM.**

c) **widened to** {22_6.1.A } **row of boolean FORM : MEEK** {61C } **BITS FORM.**

d) **widened to** {22_6.1.A } **row of character FORM : MEEK** {61C } **BYTES FORM.**

{Examples:

a) `1` (in `x := 1`)

b) `1.0` (in `z := 1.0`) • `1` (in `z := 1`)

c) `2r101` (in `[] BOOL (2r101)`)

d) `r` (in `[] CHAR (r)`, see 16_1.1.2)

22.5.2 Semantics

The yield W of a **widened-to-MODE-FORM** F is determined as follows:
•let V be the yield of the direct descendent of F; Case A: **'MODE'** is some **'SIZETY real'**:

- W is the real number widenable from {17_2.1.3.1.e} V;

Case B: **'MODE'** is some **'structured with SIZETY real letter r letter e SIZETY real letter i letter m mode'**:

- W is {the complex number which is} a structured value whose fields are respectively V and the real number 0 of the same size {17_2.1.3.1.b} as V;

Case C: **'MODE'** is **'row of boolean'** or **'row of character'**:

- W is the {only} field of V.

22.6 Rowing

{Rowing permits the building of a multiple value from a single element. If the latter is a name then the result of rowing may also be a name referring to that multiple value.
Example:
`[1 : 1] REAL b1 := 4.13`}

22.6.1 Syntax

a) **rowed to** {22_6.1.A } **REFETY ROWS1 of MODE FORM :**
where (ROWS1) is (row),
STRONG {22_6.1.A } **REFLEXETY MODE FORM,**
where (REFETY) is derived from (REFLEXETY) {20_5.3.1.b,c, -}**;**
where (ROWS1) is (row ROWS2),
STRONG {22_6.1.A } **REFLEXETY ROWS2 of MODE FORM,**
where (REFETY) is derived from (REFLEXETY) {20_5.3.1.b, c, -}**.**

{Examples:

a) `4.13` (in `[1 : 1] REAL b1 := 4.13`) •
`x1` (in `[1 : 1, 1 : n] REAL b2 := x1`) }

22.6.2 Semantics

a) The yield W of a **rowed-to-REFETY-ROWS1-of-MODE-FORM** F is determined as follows:
•let V be the yield of the **STRONG-FORM** of F;
Case A: **'REFETY'** is **'EMPTY'**:

- W is the multiple value "built" {b} from V for **'ROWS1'**;

Case B: **'REFETY'** is **'REF to'**:

- If V is nil,
- then W is a nil name;
- otherwise, W is the name "built" {c} from V for **'ROWS1'**.

b) The multiple value W "built" from a value V, for some **'ROWS1'**, is determined as follows:
Case A: **'ROWS1'** is **'row'**:

- W is composed of
- a descriptor $((1, 1))$,
- {one element} V;

Case B: **'ROWS1'** is some **'row ROWS2'**:

- let the descriptor of V be $((l_1, u_1), ..., (l_n, u_n))$;
- W is composed of
  - a descriptor $((1, 1), (l_1, u_1), ..., (l_n, u_n))$,
  - the elements of V:
- the element selected by an index $(i_1, ..., i_n)$ in V is that selected by $(1, i_1, ..., i_n)$ in W.

c) The name $N1$ "built" from a name N, for some **'ROWS1'**, is determined as follows:
•$N1$ is a name {not necessarily newly created}, equal in scope to N and referring to the multiple value built {b}, for **'ROWS1'**, from the value referred to by N;
Case A: **'ROWS1'** is **'row'**:

the {only} subname of $N1$ is N;

Case B: **'ROWS1'** is some **'row ROWS2'**:

the subname of $N1$ selected by $(1, i_1, ..., i_n)$ is the subname of N selected by ($(i_1, ..., i_n)$.

22.7 Voiding

{Voiding is used to discard the yield of some **unit** whose primary purpose is to cause its side-effects; the a posteriori mode is then simply **'void'**. For example, in `x := 1; y := 1;`, the **assignation** `y := 1` is voided, and in `PROC t = INT: ENTIER (random × 100); t;`, the **applied-identifier** `t` is voided after a deproceduring, which prescribes the calling of a routine.

Assignations and other **COMORF**s are voided without any deproceduring so that, in `PROC VOID p: p := finish`, the **assignation** `p := finish` does not prescribe an unexpected calling of the routine `finish`.}

22.7.1 Syntax

A) **NONPROC :: PLAIN ; STOWED ; REF to NONPROC ;**
procedure with PARAMETERS yielding MOID ; UNITED.

a) **voided to** {22_6.1.A } **void MORF :**
deprocedured to {22_6.3.a } **NONPROC MORF ;**
unchanged from {22_6.1.f} **NONPROC MORF.**

b) **voided to** {22_6.1.A } **void COMORF :**
unchanged from {22_6.1.f} **MODE COMORF.**

{Examples:

a) `random` (in `SKIP; random;`) •
`next random (last random)` (in `SKIP; next random (last random);`)

b) `PROC VOID (pp)` (in `PROC PROC VOID pp = PROC VOID: (print (1);`
`VOID: print (2)); PROC VOID (pp);`)}

22.7.2 Semantics

The elaboration of a **voided-to-void-FORM** consists of that of its direct descendent, and yields `empty`.

23 Modes and nests

{The identification of a property in a nest is the static counterpart of the dynamic determination (4.8.2.b) of a value in an environ: the search is conducted from the newest (youngest) level towards the previous (older) ones.

Modes are composed from the primitive modes, such as **'boolean'**, with the aid of **'HEAD'**s, such as **'structured with'**, and they may be recursive. Recursive modes spelled in different ways may nevertheless be equivalent. The syntax tests the equivalence of such modes by proving that it is impossible to find any discrepancy between their respective structures or component modes.

A number of unsafe uses of properties are prevented. An **identifier** or **mode-indication** is not declared more than once in each reach. The modes of the **operands** of a **formula** do not determine more than one operation. Recursions in modes do not cause the creation of dynamic objects of unlimited size and do not allow ambiguous coercions.}

23.1 Independence of properties

{The following syntax determines whether two properties (i.e., two **'PROP'**s), such as those corresponding to `REAL x` and `INT x`, may or may not be enveloped by the same **'LAYER'**.}

23.1.1 Syntax

A) **PREF :: procedure yielding ; REF to.**

B) **NONPREF :: PLAIN ; STOWED ;**
procedure with PARAMETERS yielding MOID ; UNITED ; void.

C) ***PREFSETY :: PREF PREFSETY ; EMPTY.**

{PROP :: DEC ; LAB ; FIELD.
QUALITY :: MODE ; MOID TALLY ; DYADIC ; label ; MODE field.

TAX :: TAG ; TAB ; TAD ; TAM.
TAO :: TAD ; TAM.}

a) **WHETHER PROP1 independent PROPS2 PROP2** {a, 19_4.8.a,c, 23_7.2.a} **:**
WHETHER PROP1 independent PROPS2 {a, c} **and PROP1 independent PROP2** {c}**.**

b) **WHETHER PROP independent EMPTY** {19_4.8.a,c, 23_7.2.a} **: WHETHER true.**

c) **WHETHER QUALITY1 TAX1 independent QUALITY2 TAX2** {a, 19_4.8.a,c, 23_7.2.a}
:
unless (TAX1) is (TAX2), WHETHER true ;
where (TAX1) is (TAX2) and (TAX1) is (TAO),
WHETHER QUALITY1 independent QUALITY2 {d}**.**

d) **WHETHER QUALITY1 independent QUALITY2** {c} **:**
where QUALITY1 related QUALITY2 {e, f, g, h, i, j, -}**, WHETHER false ;**
unless QUALITY1 related QUALITY2 {e, f, g, h, i, j, -}**, WHETHER true.**

e) **WHETHER MONO related DUO** {d} **: WHETHER false.**

f) **WHETHER DUO related MONO** {d} **: WHETHER false.**

g) **WHETHER PRAM related DYADIC** {d} **: WHETHER false.**

h) **WHETHER DYADIC related PRAM** {d} **: WHETHER false.**

i) **WHETHER procedure with MODE1 parameter MODE2 parameter**
yielding MOID1 related
procedure with MODE3 parameter MODE4 parameter
yielding MOID2 {d} **:**
WHETHER MODE1 firmly related MODE3 {k}
and MODE2 firmly related MODE4 {k}**.**

j) **WHETHER procedure with MODE1 parameter yielding MOID1**
related procedure with MODE2 parameter yielding MOID2 {d} **:**
WHETHER MODE1 firmly related MODE2 {k}**.**

k) **WHETHER MOID1 firmly related MOID2** {i, j} **:**
WHETHER MOODS1 is firm MOID2 {l, m} **or MOODS2 is firm MOID1** {l, m}**,**
where (MOODS1) is (MOID1) or (union of MOODS1 mode) is (MOID1),
where (MOODS2) is (MOID2) or (union of MOODS2 mode) is (MOID2).

l) **WHETHER MOODS MOOD is firm MOID** {k, l} **:**
WHETHER MOODS is firm MOID {l, m} **or MOOD is firm MOID** {m}**.**

m) **WHETHER MOID1 is firm MOID2** {k, l, n, 19_4.7.f } **:**
WHETHER MOID1 equivalent MOID2 {23_7.3.a }

or MOID1 unites to MOID2 {22_6.4.b} **or MOID1 deprefs to firm MOID2** {n}**.**

n) **WHETHER MOID1 deprefs to firm MOID2** {m} **:**
where (MOID1) is (PREF MOID3),
WHETHER MOID5 is firm MOID2 {m}**,**
where MOID3 deflexes to MOID5 {19_4.7.a, b, c} **;**
where (MOID1) is (NONPREF), WHETHER false.

{To prevent the ambiguous application of **indicators**, as in `REAL x, INT x; x := 0`, certain restrictions are imposed on **defining-indicators** contained in a given reach. These are enforced by the syntactic test for "independence" of properties enveloped by a given **'LAYER'** (rules a, b, c). A sufficient condition, not satisfied in the example above, for the independence of a pair of properties, each being some **'QUALITY TAX'**, is that the **'TAX'**s differ (rule c). For **'TAX'**s which are not some **'TAO'**, this condition is also necessary, so that even `REAL x, INT x; SKIP` is not a **serial-clause**.

For two properties **'QUALITY1 TAO'** and **'QUALITY2 TAO'** the test for independence is more complicated, as is exemplified by the **serial-clause**

```
OP + = (INT i) BOOL: TRUE,
  OP + = (INT i, j) INT: 1,
  OP + = (INT i, BOOL j) INT: 2,
  PRIO + = 6;
  0 + + 0 ¢ = 2 ¢.
```

Ambiguities would be present in

```
PRIO + = 6, + = 7; 1 + 2 * 3 ¢ 7 or 9 ? ¢,
```

in

```
OP Z = (INT i) INT: 1, MODE Z = INT;
  Z i ¢ formula or declaration? ¢; SKIP,
```

and in

```
OP ? = (UNION (REF REAL, CHAR) a) INT: 1, OP ? = (REAL a) INT: 2;
  ? LOC REAL ¢ 1 or 2 ? ¢.
```

In such cases a test is made that the two **'QUALITY'**s are independent (rules c, d). A **'MOID TALLY'** is never independent of any **'QUALITY'** (rule d). A **'MONO'** is always independent of a **'DUO'** (rules d, e, f) and both are independent of a **'DYADIC'** (i.e., of a **'priority PRIO'**) (rules d, g, h). In the case of two **'PRAM'**s which are both **'MONO'** or both **'DUO'**, ambiguities could arise if the corresponding parameter modes were "firmly related", i.e., if some (pair of) operand mode (s) could be firmly coerced to the (pair of) parameter mode (s) of either **'PRAM'** (rules i, j). In the example with the two definitions of `?`, the two **'PRAM'**s are related since the modes specified by `UNION (REF REAL, CHAR)` and by `REAL` are firmly related, the mode specified by `REF REAL` being firmly coercible to either one.

It may be shown that two modes are firmly related if one of them, or some component

'MOOD' of one of them, may be firmly coerced to the other (rules k, l), which requires a sequence of zero or more meek coercions followed by at most one uniting {22_6.4.1.a}. The possibility or otherwise of such a sequence of coercions between two modes is determined by the predicate **'is firm'** (rules m, n).

A **'PROP1'** also renders inaccessible a **'PROP2'** in an outer **'LAYER'** if that **'PROP2'** is not independent of **'PROP1'**; e.g.,

```
BEGIN INT x;
  BEGIN REAL x; ¢ here the 'PROP1' is 'reference to real letter x' ¢
    SKIP
  END
END
```

and likewise

```
BEGIN OP ? = (INT i) INT: 1, INT k := 2;
  BEGIN OP ? = (REF INT i) INT: 3;
    ? k ¢ delivers 3, but ? 4 could not occur here because its
      operator is inaccessible ¢
  END
END.}
```

23.2 Identification in nests

{This section ensures that for each **applied-indicator** there is a corresponding property in some suitable **'LAYER'** of the nest.}

23.2.1 Syntax

{**PROPSETY :: PROPS ; EMPTY.**
PROPS :: PROP ; PROPS PROP.
PROP :: DEC ; LAB ; FIELD.
QUALITY :: MODE ; MOID TALLY ; DYADIC ; label ; MODE field.
TAX :: TAG ; TAB ; TAD ; TAM.}

a) **WHETHER PROP identified in NEST new PROPSETY** {a, 19_4.8.b, 20_5.4.2.a} **:**
where PROP resides in PROPSETY {b, c, -}**, WHETHER true ;**
where PROP independent PROPSETY {23_7.1.a, b, c} **,**
WHETHER PROP identified in NEST {a, -}**.**

b) **WHETHER PROP1 resides in PROPS2 PROP2** {a, b, 19_4.8.d } **:**
WHETHER PROP1 resides in PROP2 {c, -} **or PROP1 resides in PROPS2**

{b, c, -}.

c) **WHETHER QUALITY1 TAX resides in QUALITY2 TAX** {a, b, 19_4.8.d } **:**
where (QUALITY1) is (label) or (QUALITY1) is (DYADIC)
or (QUALITY1) is (MODE field),
WHETHER (QUALITY1) is (QUALITY2) ;
where (QUALITY1) is (MOID1 TALLETY) and (QUALITY2) is (MOID2 TALLETY),
WHETHER MOID1 equivalent MOID2 {23_7.3.a } **.**

{A nest, except the primal one (which is just **'new'**), is some **'NEST LAYER'** (i.e., some **'NEST new PROPSETY'**). A **'PROP'** is identified by first looking for it in that **'LAYER'** (rule a). If the **'PROP'** is some **'label TAX'** or **'DYADIC TAX'**, then a simple match of the **'PROP'**s is a sufficient test (rule c). If the **'PROP'** is some **'MOID TALLETY TAX'**, then the mode equivalencing mechanism must be invoked (rule c). If it is not found in the **'LAYER'**, then the search continues with the **'NEST'** (without that **'LAYER'**), provided that it is independent of all **'PROP'**s in that **'LAYER'**; otherwise the search is abandoned (rule a). Note that rules b and c do double duty in that they are also used to check the validity of **applied-field-selectors** {19_4.8.1.d}.}

23.2.2 Semantics

a) If some **NEST-range** R {18_3.0.1.f} contains an **applied-indicator** I {19_4.8.1.b} of which there is a descendent **where-PROP-identified-in-NEST-LAYER**, but no descendent **where-PROP-identified-in-NEST**, then R is the "defining **range**" of that I. {Note that **'NEST'** is always the nest in force just outside the **range**.}

b) A **QUALITY-applied-indicator-with-TAX** I whose defining **NEST-range** {a} is R "identifies" the **QUALITY-NEST-LAYER-defining-indicator-with-TAX** contained in R.

{For example, in

```
(¢ 1 ¢ REAL i = 2.0; (¢ 2 ¢ INT i = 1;
(¢ 3 ¢ REAL x; print (i) ¢ 3 ¢) ¢ 2 ¢) ¢ 1 ¢)
```

there are three **ranges**. The **applied-identifier** `i` in `print (i)` is forced, by the syntax, to be an **integral-NEST-new-real-letter-i- new-integral-letter-i- new-reference-to-real-letter-x- applied- identifier- with- letter-i** {19_4.8.1.b}. Its defining **range** is the **NEST-new-real-letter-i-serial-clause-defining-new-integral-letter-i** {18_3.2.1.a} numbered `¢ 2 ¢`, it identifies the **defining- identifier** `i` contained in `INT i` (not the one in `REAL i`), and its mode is **'integral'**.}

{By a similar mechanism, a **DYADIC-formula** {20_5.4.2.1.a} may be said to "identify" that **DYADIC-defining-operator** {19_4.8.1.a} which determines its priority.}

c) The environ E "necessary for" a construct C in an environ $E1$ is determined as follows:

If $E1$ is the primal environ {17_2.2.2.a },

then E is $E1$;

otherwise, letting $E1$ be composed of a locale L corresponding to some **'PROPSETY'** and another environ $E2$,

If C contains any **QUALITY-applied-indicator-with-TAX**

- which does not identify {b} a **defining-indicator** contained in C,
- which is not a **mode-indication** directly descended from a **formal-** or **virtual-declarer**, and
- which is such that the predicate **'where QUALITY TAX resides in PROPSETY'** {23_7.2.1.b} holds,

- then E is $E1$;
- otherwise, {L is not necessary for C and} E is the environ necessary for C in $E2$.

{The environ necessary for a construct is used in the semantics of **routine-texts** {20_5.4.1.2} and in "establishing" {18_3.2.2.b}. For example, in

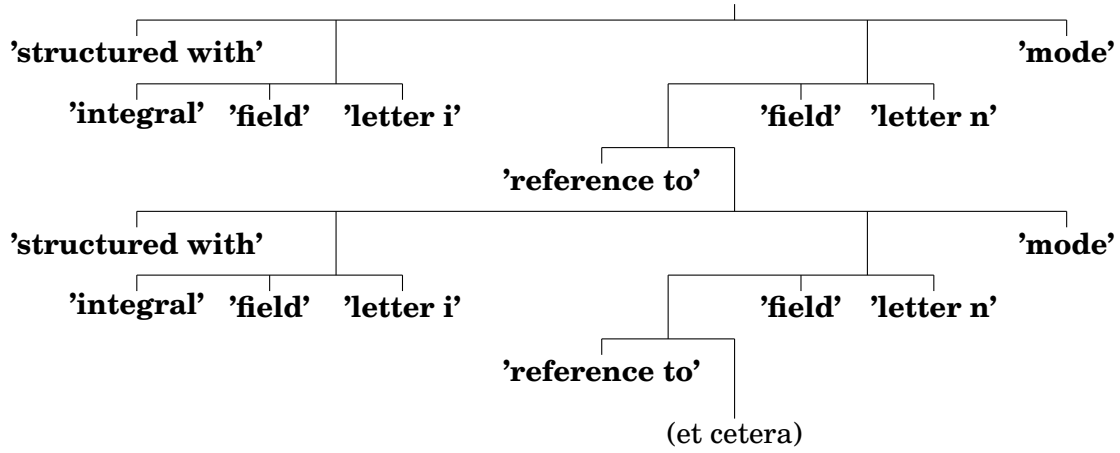
```
¢ 2 ¢ PROC VOID pp; INT n;
 (¢ 1 ¢ PROC p = VOID: print (n); pp := p)
```

if $E1$ and $E2$ are the environs established by the elaboration of the **serial-clauses** marked by the **comments** `¢ 1 ¢` and `¢ 2 ¢`, then $E2$ is the environ necessary in $E1$ for the **routine-text** `VOID: print (n)`, and so the routine yielded by `p` in $E1$ is composed of that **routine-text** together with E2 {20_5.4.1.2}. Therefore, the scope of that routine is the scope of $E2$ {17_2.1.3.5.c} and hence the assignment {20_5.2.1.2.b} invoked by `pp := p` is well defined.}

23.3 Equivalence of modes

{The equivalence or nonequivalence of **'MOID'**s is determined in this section. For a discussion of equivalent **'MOID'**s see 17_2.1.1.2.}

{One way of viewing recursive modes is to consider them as infinite trees. Such a "mode tree" is obtained by repeatedly substituting in some spelling, for each **'MU application'**, the **'MODE'** of the corresponding **'MU definition of MODE'**. Thus, the spelling **'mui definition of structured with integral field letter i reference to mui application field letter n mode'** would give rise to the following mode tree:



Two spellings are equivalent if and only if they give rise to identical mode trees. The equivalence syntax tests the equivalence of two spellings by, as it were, simultaneously developing the two trees until a difference is found (resulting in a blind alley) or until it becomes apparent that no difference can be found. The growing production tree reflects to some extent the structure of the mode trees.}

23.3.1 Syntax

A) **SAFE :: safe ; MU has MODE SAFE ; yin SAFE ; yang SAFE ;**
remember MOID1 MOID2 SAFE.

B) **HEAD :: PLAIN ; PREF** {23_7.1.A } **; structured with ;**
FLEXETY ROWS of ; procedure with ; union of ; void.

C) **TAILETY :: MOID ; FIELDS mode ; PARAMETERS yielding MOID ;**
MOODS mode ; EMPTY.

D) **PARTS :: PART ; PARTS PART.**

E) **PART :: FIELD ; PARAMETER.**

a) **WHETHER MOID1 equivalent MOID2** {22_6.4.b, 23_7.1.m, 23_7.2.c} **:**
WHETHER safe MOID1 equivalent safe MOID2 {b}**.**

b) **WHETHER SAFE1 MOID1 equivalent SAFE2 MOID2** {a, b, e, i, j, n} **:**
where (SAFE1) contains (remember MOID1 MOID2)
or (SAFE2) contains (remember MOID2 MOID1),
WHETHER true ;
unless (SAFE1) contains (remember MOID1 MOID2)
or (SAFE2) contains (remember MOID2 MOID1),
WHETHER (HEAD3) is (HEAD4)

and remember MOID1 MOID2 SAFE3 TAILETY3
equivalent SAFE4 TAILETY4 {b, d, e, k, q, -}**,**
where SAFE3 HEAD3 TAILETY3 develops from SAFE1 MOID1 {c}**and**
SAFE4 HEAD4 TAILETY4 develops from SAFE2 MOID2 {c}**.**

c) **WHETHER SAFE2 HEAD TAILETY develops from SAFE1 MOID** {b, c} **:**
where (MOID) is (HEAD TAILETY),
WHETHER (HEAD) shields SAFE1 to SAFE2 {23_7.4.a, b, c, d, -}**;**
where (MOID) is (MU definition of MODE),
unless (SAFE1) contains (MU has),
WHETHER SAFE2 HEAD TAILETY develops from MU
has MODE SAFE1 MODE {c}**;**
where (MOID) is (MU application)
and (SAFE1) is (NOTION MU has MODE SAFE3)
and (NOTION) contains (yin) and (NOTION) contains (yang),
WHETHER SAFE2 HEAD TAILETY develops from SAFE1 MODE {c}**.**

[d) **WHETHER SAFE1 FIELDS1 mode equivalent SAFE2 FIELDS2 mode** {b} **:**
WHETHER SAFE1 FIELDS1 equivalent SAFE2 FIELDS2 {f, g, h, i}**.**

e) **WHETHER SAFE1 PARAMETERS1 yielding MOID1**
equivalent SAFE2 PARAMETERS2 yielding MOID2 {b} **:**
WHETHER SAFE1 PARAMETERS1 equivalent SAFE2 PARAMETERS2 {f, g, h, j}
and SAFE1 MOID1 equivalent SAFE2 MOID2 {b}**.**

f) **WHETHER SAFE1 PARTS1 PART1 equivalent SAFE2 PARTS2 PART2** {d, e, f} **:**
WHETHER SAFE1 PARTS1 equivalent SAFE2 PARTS2 {f, g, h, i, j}
and SAFE1 PART1 equivalent SAFE2 PART2 {i, j}**.**

g) **WHETHER SAFE1 PARTS1 PART1 equivalent SAFE2 PART2** {d, e, f} **:**
WHETHER false.

h) **WHETHER SAFE1 PART1 equivalent SAFE2 PARTS2 PART2** {d, e, f} **:**
WHETHER false.

i) **WHETHER SAFE1 MODE1 field TAG1 equivalent SAFE2 MODE2 field TAG2** {d, f} **:**
WHETHER (TAG1) is (TAG2) and SAFE1 MODE1 equivalent SAFE2 MODE2 {b}**.**

j) **WHETHER SAFE1 MODE1 parameter equivalent SAFE2 MODE2 parameter** {e, f} **:**
WHETHER SAFE1 MODE1 equivalent SAFE2 MODE2 {b}**.**

k) **WHETHER SAFE1 MOODS1 mode equivalent SAFE2 MOODS2 mode** {b} **:**
WHETHER SAFE1 MOODS1 suhset of SAFE2 MOODS2 {l, m, n}
and SAFE2 MOODS2 subset of SAFE1 MOODS1 {l, m, n}
and MOODS1 number equals MOODS2 number {o, p}**.**

l) **WHETHER SAFE1 MOODS1 MOOD1 subset of SAFE2 MOODS2** {k, l, 19_4.6.s, 22_6.4.b} **:**
WHETHER SAFE1 MOODS1 subset of SAFE2 MOODS2 {l, m, n}
and SAFE1 MOOD1 subset of SAFE2 MOODS2 {m, n}**.**

m) **WHETHER SAFE1 MOOD1 subset of SAFE2 MOODS2 MOOD2** {k, l, m, 19_4.6.s, 22_6.4.b} **:**
WHETHER SAFE1 MOOD1 subset of SAFE2 MOODS2 {m, n}
or SAFE1 MOOD1 subset of SAFE2 MOOD2 {n}**.**

n) **WHETHER SAFE1 MOOD1 subset of SAFE2 MOOD2** {k, l, m, 22_6.4.b } **:**
WHETHER SAFE1 MOOD1 equivalent SAFE2 MOOD2 {b}**.**

o) **WHETHER MOODS1 MOOD1 number equals MOODS2 MOOD2 number** {k, o} **:**
WHETHER MOODS1 number equals MOODS2 number {o, p, -}**.**

p) **WHETHER MOOD1 number equals MOOD2 number** {k, o} **: WHETHER true.**

q) **WHETHER SAFE1 EMPTY equivalent SAFE2 EMPTY** {b} **: WHETHER true.**

{Rule a introduces the **'SAFE'**s which are used as associative memories during the determination of equivalence. There are two of them, one belonging to each mode. Rule b draws an immediate conclusion if the **'MOID'**s under consideration are already remembered (see below) in an appropriate **'SAFE'** in the form **'remember MOID1 MOID2'**. If this is not the case, then the two **'MOID'**s are first remembered in a **'SAFE'** (the one on the left) and then each **'MOID'** is developed (rule c) and split into its **'HEAD'** and its **'TAILETY'**, e.g., **'reference to real'** is split into **'reference to'** and **'real'**.

If the **'HEAD'**s differ, then the matter is settled (rule b); otherwise the **'TAILETY'**s are analyzed according to their structure (which must be the same if the **'HEAD'**s are identical). In each case, except where the **'HEAD'**s were **'union of'**, the equivalence is determined by examining the corresponding components, according to the following scheme:

rule	**'TAILETY'**	components
d	**'FIELDS mode'**	**'FIELDS'**
e	**'PARAMETERS yielding MOID'**	**'PARAMETERS'** and **'MOID'**
f	**'FIELDS FIELD'**	**'FIELDS'** and **'FIELD'**
f	**'PARAMETERS PARAMETER'**	**'PARAMETERS' and 'PARAMETER'**
i	**'MODE field TAG'**	**'MODE' and 'TAG'**
j	**'MODE parameter'**	**'MODE'**

In the case of unions, the **'TAILETY'**s are of the form **'MOODS1 mode'** and **'MOODS2 mode'**. Since **'MOOD'**s within equivalent unions may commute, as in the modes specified by `UNION (REAL, INT)` and `UNION (INT, REAL)`, the equivalence is determined by checking that **'MOODS1'** is a subset of **'MOODS2'** and that **'MOODS2'** is a subset of **'MOODS1'**, where the subset test, of course, invokes the equivalence test recursively (rules k, l, m, n, o, p).

A **'MOID'** is developed (rule c) into the form **'HEAD TAILETY'** by determining that

> it is already of that form: in which case markers (**'yin'** and **'yang'**) may be placed in its **'SAFE'** for the later determination of well-formedness (see 23_7.4);
>
> it is some **'MU definition of MODE'**: in which case **'MU has MODE'** is stored in its **'SAFE'** (provided that this particular **'MU'** is not there already) and the **'MODE'** is developed;
>
> it is some **'MU application'**: in which case there must be some **'MU has MODE'** in its **'SAFE'** already. That **'MODE'** is then developed after a well-formedness check (see 23_7.4) consisting of the determination that there is at least one **'yin'** and at least one **'yang'** in the **'SAFE'** which is more recent than the **'MU has MODE'**.

}

{Before a pair of **'TAILETY'**s is tested for equivalence, it is remembered in the **'SAFE'** that the original pair of **'MOID'**s is being tested. This is used to force a shortcut to **'WHETHER true'** if these **'MOID'**s should ever be tested again for equivalence lower down the production tree. Since the number of pairs of component **'MOID'**s that can be derived from any two given **'MOID'**s is finite, it follows that the testing process terminates.

It remains to be shown that the process is correct. Consider the unrestricted (possibly infinite) production tree that would be obtained if there were no shortcut in the syntax (by omitting the first alternative together with the first member of the other alternative of rule b). If two **'MOID'**s are not equivalent, then there exists in their mode trees a shortest path from the top node to some node exhibiting a difference. Obviously, the reflection of this shortest path in the unrestricted production tree cannot contain a repeated test for the equivalence of any pair of **'MOID'**s, and therefore none of the shortcuts to **'WHETHER true'** in the restricted production tree can occur on this shortest path. Consequently, the path to the difference must be present also in the (restricted) production tree produced by the syntax. If the testing process does not exhibit a difference in the restricted tree, then no difference can be found in any number of steps: i.e., the **'MOID'**s are equivalent.}

23.4 Well-formedness

{A mode is well formed if

(i) the elaboration of an **actual-declarer** specifying that mode is a finite action (i.e., any value of that mode can be stored in a finite memory)
and

(ii) it is not strongly coercible from itself (since this would lead to ambiguities in coercion).

}

23.4.1 Syntax

a) **WHETHER (NOTION) shields SAFE to SAFE** {73c } **:**
where (NOTION) is (PLAIN)
or (NOTION) is (FLEXETY ROWS of)
or (NOTION) is (union of)
or (NOTION) is (void),
WHETHER true.

b) **WHETHER (PREF) shields SAFE to yin SAFE** {73c } **: WHETHER true.**

c) **WHETHER (structured with) shields SAFE to yang SAFE** {73c } **:**
WHETHER true.

d) **WHETHER (procedure with) shields SAFE to yin yang SAFE** {73c } **:**
WHETHER true.

{As a by-product of mode equivalencing, modes are tested for well-formedness {23_7.3.1.c}. All nonrecursive modes are well formed. For recursive modes, it is necessary that each cycle in each spelling of that mode (from **'MU definition of MODE'** to **'MU application'**) passes through at least one **'HEAD'** which is yin, ensuring condition (i) and one (possibly the same) **'HEAD'** which is yang, ensuring condition (ii). Yin **'HEAD'**s are **'PREF'** and **'procedure with'**. Yang **'HEAD'**s are **'structured with'** and **'procedure with'**. The other **'HEAD'**s, including **'FLEXETY ROWS of'** and **'union of'**, are neither yin nor yang.

This means that the modes specified by `A`, `B` and `C` in

```
MODE A = STRUCT (INT n, REF A next),
B = STRUCT (PROC B next),
C = PROC (C) C
```

are all well formed. However,

```
MODE D = [1 : 10] D,
E = UNION (INT, E)
```

is not a **mode-declaration**.}

{Tao produced the one.
The one produced the two.
The two produced the three.
And the three produced the ten thousand things.
The ten thousand things carry the yin and embrace the yang, and through the blending of the material force they achieve harmony.
Tao-te Ching, 42, Lao Tzu. }

{Revised Report } Part IV

Elaboration-independent constructions

24 Denotations

{**Denotations**, e.g., `3.14` or `"abc"`, are constructs whose yields are independent of any action. In other languages, they are sometimes termed "literals" or "constants".}

24.0.1. Syntax

a) **MOID NEST denoter** {20_5.D, 26_{10}.3.4.1.i} **:**
pragment {25_9.2.a } **sequence option,**
MOID denotation {24_8.1.0.a, 24_8.1.1.a, 24_8.1.2.a, 24_8.1.3.a, 24_8.1.4.a, 24_8.1.5.a, 24_8.2.a, b, c, 18_3.3.a, -}**.**

{The meaning of a **denotation** is independent of any nest.}

24.1 Plain denotations

{**Plain-denotations** are those of arithmetic values, truth values, characters and the void value, e.g., `1`, `3.14`, `true`, "a" and `EMPTY`.}

24.1.0.1. Syntax

A) **SIZE :: long ; short.**

B) ***NUMERAL ::**
fixed point numeral ; variable point numeral ; floating point numeral.

a) **SIZE INTREAL denotation** {a, 24_8.0.a } **:**
SIZE symbol {25_9.4.d } **, INTREAL denotation** {a, 811a, 812a} **.** b) ***plain denotation :**
PLAIN denotation {a, 811a, 812a, 813a, 814a} **; void denotation** {815a } **.**

{Example:

a) `LONG 0` }

24.1.0.2. Semantics

The yield W of an **INTREAL-denotation** is the "intrinsic value" {24_8.1.1.2, 24_8.1.2.2.a, b} of its constituent **NUMERAL**;

- it is required that W be not greater than the largest value of mode **'INTREAL'** that can be distinguished {17_2.1.3.1.d}.

{An **INTREAL-denotation** yields an arithmetic value {17_2.1.3.1.a}, but arithmetic values yielded by different **INTREAL-denotations** are not necessarily different (e.g., `123.4` and `1.234`$_{10}$`+2`). }

24.1.1 Integral denotations

24.1.1.1 Syntax

a) **integral denotation** {24_8.0.a, 810a} **: fixed point numeral** {b}**.**

b) **fixed point numeral** {a, 24_8.1.2.c, d, f, i, 26_{10}.3.4.1.h} **: digit cypher** {c} **sequence.**

c) **digit cypher** {b} **: DIGIT symbol** {25_9.4.b } **.**

{Example:

a) `4096`

b) `4096`

c) `4` }

24.1.1.2 Semantics

The intrinsic value of a **fixed-point-numeral** N is the integer of which the reference-language form of N {25_9.3.b} is a decimal representation.

24.1.2 Real denotations

24.1.2.1 Syntax

a) **real denotation** {24_8.0.a, 810a} **: variable point numeral** {b}**; floating point numeral** {e}**.**

b) **variable point numeral** {a, f} **:**
integral part {c} **option, fractional part** {d}**.**

c) **integral part** {b} **: fixed point numeral** {24_8.1.1.b } **.**

d) **fractional part** {b} **: point symbol** {25_9.4.b } **, fixed point numeral** {24_8.1.1.b } **.**

e) **floating point numeral {a} : stagnant part** {f}**, exponent part** {g}**.**

f) **stagnant part** {e} **:**
fixed point numeral {24_8.1.1.b } **; variable point numeral** {b}**.**

g) **exponent part** {e} **: times ten to the power choice** {h}**, power of ten** {i}**.**

h) **times ten to the power choice** {g} **:**
times ten to the power symbol {25_9.4.b } **; letter e symbol** {25_9.4.a} **.**

i) **power of ten** {g} **: plusminus** {j} **option, fixed point numeral** {811b } **.**

j) **plusminus** {i} **: plus symbol** {25_9.4.c } **; minus symbol** {25_9.4.c } **.**

{Example:

a) `0.00123 • 1.23e-3`

b) `0.00123`

c) `0`

d) `.00123`

e) `1.23e-3`

f) `123 • 1.23`

g) `e-3`

h) $_{10}$ `• e`

i) `-3`

j) `+ • - }`

24.1.2.2 Semantics

a) The intrinsic value V of a **variable-point-numeral** N is determined as follows:

- let I be the intrinsic value of the **fixed-point-numeral** of its constituent **integral-part**, if any, and be 0 otherwise;
- let F be the intrinsic value of the **fixed-point-numeral** of its **fractional-part** P divided by 10 as many times as there are **digit-cyphers** contained in P;
- V is the sum in the sense of numerical analysis of I and F.

b) The intrinsic value V of a **floating-point-numeral** N is determined as follows:

- let S be the intrinsic value of the **NUMERAL** of its **stagnant-part**;
- let E be the intrinsic value of the constituent **fixed-point-numeral** of its **exponent-part**;

Case A: The constituent **plusminus-option** of N contains a **minus-symbol**:

- V is the product in the sense of numerical analysis of S and 1/10 raised to the power E;

Case B: The direct descendent of that **plusminus-option** contains a **plus-symbol** or is empty:

- V is the product in the sense of numerical analysis of S and 10 raised to the power E.

24.1.3 Boolean denotations

24.1.3.1 Syntax

a) **boolean denotation** {24_8.0.a } **: true** {25_9.4.b} **symbol ; false** {25_9.4.b } **symbol.**

{Example:

a) TRUE • FALSE }

24.1.3.2 Semantics

The yield of a **boolean-denotation** is `true` (`false`) if its direct descendent is a **true-symbol** (**false-symbol**).

24.1.4 Character denotations

{**Character-denotations** consist of a **string-item** between two **quote-symbols**, e.g., `"a"`. To indicate a quote, a **quote-image-symbol** (represented by `""`) is used, e.g., `""""`. Since the syntax nowhere allows **character-** or **string-denotations** to follow one another, this causes no ambiguity.}

24.1.4.1 Syntax

a) **character denotation** {24_8.0.a } **:**
quote {25_9.4.b} **symbol, string item** {b}**, quote symbol** {25_9.4.b } **.**

b) **string item** {a, 24_8.3.b } **:**
character glyph {c}**;**
quote image symbol {25_9.4.b } **;**
other string item {d}**.**

c) **character glyph** {b, $25_9.17_2$.c } **:**
LETTER symbol {25_9.4.a} **; DIGIT symbol** {25_9.4.b } **; point symbol** {25_9.4.b} **;**
open symbol {25_9.4.f } **; close symbol** {25_9.4.f} **; comma symbol** {25_9.4.b } **;**
space symbol {25_9.4.b} **; plus symbol** {25_9.4.c } **; minus symbol** {25_9.4.c} **.**

d) A production rule may be added for the notion **'other string item'** {b, for which no hyper-rule is given in this Report} each of whose alternatives is a symbol {16_1.1.3.1.f} which is different from any terminal production of **'character glyph'** {c} and which is not the **'quote symbol'**.

{Example:

a) `"a"`

b) `a • "" • ?`

c) `a • 1 • . • ( • ) • , •␣• + • - }`

24.1.4.2 Semantics

a) The yield of a **character-denotation** is the intrinsic value of the **symbol** descended from its **string-item**.

b) The intrinsic value of each distinct **symbol** descended from a **string-item** is a unique character. {Characters have no inherent meaning, except insofar as some of them are interpreted in particular ways by the transput declarations {26_{10}.3 }. The **character-glyphs**,

which include all the characters needed for transput, form a minimum set which all implementations {17_2.2.2.c} are expected to provide.}

24.1.5 Void denotation

{A **void-denotation** may be used to assign a void value to a **UNITED-variable**, e.g., `UNION ([ ]REAL, VOID) u := EMPTY`.}

24.1.5.1 Syntax

a) **void denotation** {24_8.0.a } **: empty** {25_9.4.b} **symbol.**

{Example:

a) EMPTY }

24.1.5.2 Semantics

The yield of a **void-denotation** is `empty`.

24.2 Bits denotations

24.2.1 Syntax

A) **RADIX :: radix two ; radix four ; radix eight ; radix sixteen.**

a) **structured with row of boolean field**
LENGTH LENGTHETY letter aleph mode denotation {a, 24_8.0.a } **:**
long {25_9.4.d} **symbol, structured with row of boolean field**
LENGTHETY letter aleph mode denotation {a, c}**.**

b) **structured with row of boolean field**
SHORTH SHORTHETY letter aleph mode denotation {b, 24_8.0.a } **:**
short {25_9.4.d} **symbol, structured with row of boolean field**
SHORTHETY letter aleph mode denotation {b, c}**.**

c) **structured with row of boolean field letter aleph mode denotation** {a, b, 24_8.0.a } **:**
RADIX {d, e, f, g}**, letter r symbol** {25_9.4.a } **, RADIX digit** {h, i, j, k} **sequence.**

d) **radix two** {c, 26_{10}.3.4.7.b} **: digit two** {25_9.4.b} **symbol.**

e) **radix four** {c, 26_{10}.3.4.7.b} **: digit four** {25_9.4.b} **symbol.**

f) **radix eight** {c, 26_{10}.3.4.7.b} **: digit eight** {25_9.4.b} **symbol.**

g) **radix sixteen** {c, 26_{10}.3.4.7.b} **: digit one symbol** {25_9.4.b } **, digit six symbol** {25_9.4.b} **.**

h) **radix two digit** {c, i} **: digit zero symbol** {25_9.4.b } **; digit one symbol** {25_9.4.b } **.**

i) **radix four digit** {c, j} **: radix two digit** {h}**;**
digit two symbol {25_9.4.b } **; digit three symbol** {25_9.4.b} **.**

j) **radix eight digit** {c, k} **: radix four digit** {i}**;**
digit four symbol {25_9.4.b } **; digit five symbol** {25_9.4.b} **;**
digit six symbol {25_9.4.b } **; digit seven symbol** {25_9.4.b} **.**

k) **radix sixteen digit** {c} **: radix eight digit** {j}**;**
digit eight symbol {25_9.4.b } **; digit nine symbol** {25_9.4.b} **;**
letter a symbol {25_9.4.a } **; letter b symbol** {25_9.4.a} **;**
letter c symbol {25_9.4.a } **; letter d symbol** {25_9.4.a} **;**
letter e symbol {25_9.4.a } **; letter f symbol** {25_9.4.a} **.**

l) ***bits denotation : BITS denotation** {a, b, c}**.**
{**BITS :: structured with row of boolean field SITHETY letter aleph mode.**}

m) ***radix digit : RADIX digit** {h, i, j, k}**.**

{Example:

a) `LONG 2r101`

b) `SHORT 16rfffff`

c) `8r231` }

24.2.2 Semantics

a) The yield V of a **bits-denotation** D is determined as follows:

- let W be the intrinsic boolean value {b} of its constituent **RADIX-digit-sequence**:
- let m be the length of W;
- let n be the value of `{l} bits width` {26_{10}.2.1.j}, where `{l}` stands for as many times `long` (`short`) as there are **long-symbols** (**short-symbols**) contained in D;

- it is required that m be not greater than n:
- V is a structured value {whose mode is some **'BITS'**} whose only field is a multiple value having

  (i) a descriptor ((1, n)) and

  (ii) n elements, that selected by (i) being `false` if $1 \leq i \leq n - m$, and being the $(i + m - n)^{th}$ truth value of {the sequencer} W otherwise.

b) The intrinsic boolean value of a **RADIX-digit-sequence** S is the shortest sequence of truth values which, regarded as a binary number (`true` corresponding to 1 and `false` to 0), is the same as the intrinsic integral value {c} of S.

c) The intrinsic integral value of a **radix-two-** (**radix-four-**, **radix-eight-**, **radix-sixteen-**) **-digit-sequence** S is the integer of which the reference-language form of S {25_9.3.b } is a binary, (quaternary, octal, hexadecimal) representation, where the representations `a`, `b`, `c`, `d`, `e` and `f`, considered as digits, have values 10, 11, 12, 13, 14 and 15 respectively.

24.3 String denotations

{**String-denotations** are a convenient way of specifying "strings", i.e., multiple values of mode **'row of character'**.

{Example:

```
STRING message := "all is well" }
```

24.3.1 Syntax

a) **row of character denotation** {24_8.0.a } **:**
quote {25_9.4.b } **symbol, string** {b} **option, quote symbol** {25_9.4.b } **.**

b) **string {a} : string item** {24_8.1.4.b } **, string item** {24_8.1.4.b} **sequence.**

c) ***string denotation : row of character denotation {a}.**

{Example:

a) `"abc"`

b) `abc` }

24.3.2 Semantics

The yield of a **string-denotation** D is a multiple value V determined as follows:

- let n be the number of **string-items** contained in D;
- the descriptor of V is $((1, n))$;
- for $i = 1, ..., n$, the element of V with index (i) is the intrinsic value {24_8.1.4.2.b} of the i^{th} constituent **symbol** of the string of D.

{`"a"` is a **character-denotation**, not a **string-denotation**. However, in all strong positions, e.g., `STRING s := "a"`, it can be rowed to a multiple value {22_6.6 }. Elsewhere, where a multiple value is required, a **cast** {20_5.5.1.1.a} may be used, e.g., `UNION (CHAR, STRING) cs := STRING ("a")`.}

25 Tokens and symbols

25.1 Tokens

{**Tokens** {25_9.1.1.f} are **symbols** {25_9.1.1.h} possibly preceded by **pragments** {25_9.2.1.a}. Therefore, **pragments** may appear between **symbols** wherever the syntax produces a succession of **tokens**. However, in a few places, the syntax specifically produces **symbols** rather than **tokens**, notably within **denotations** {8}, **format-texts** {26_{10}.3.4.1.1.a} and, of course, within **pragments**. Therefore, **pragments** may not occur in these places.}

25.1.1 Syntax

a) **CHOICE STYLE start** {18_3.4.a } **:**
where (CHOICE) is (choice using boolean),
STYLE if {25_9.4.f, -} **token ;**
where (CHOICE) is (CASE),
STYLE case {25_9.4.f, -} **token.**

b) **CHOICE STYLE in** {18_3.4.e } **:**
where (CHOICE) is (choice using boolean),
STYLE then {25_9.4.f, -} **token ;**
where (CHOICE) is (CASE),
STYLE in {25_9.4.f, -} **token.**

c) **CHOICE STYLE again** {18_3.4.l } **:**
where (CHOICE) is (choice using boolean),
STYLE else if {25_9.4.f, -} **token ;**
where (CHOICE) is (CASE),
STYLE ouse {25_9.4.f, -} **token.**

d) **CHOICE STYLE out** {18_3.4.l } **:**
where (CHOICE) is (choice using boolean),
STYLE else {25_9.4.f, -} **token ;**
where (CHOICE) is (CASE),
STYLE out {25_9.4.f, -} **token.**

e) **CHOICE STYLE finish** {18_3.4.a } **:**
where (CHOICE) is (choice using boolean),
STYLE fi {25_9.4.f, -} **token ;**
where (CHOICE) is (CASE),
STYLE esac {25_9.4.f, -} **token.**

f) **NOTION token :**
pragment {25_9.2.a } **sequence option,**
NOTION symbol {25_9.4.a, b, c, d, e, f, g, h} **.**

g) ***token : NOTION token** {f}**.**

h) ***symbol : NOTION symbol** {25_9.4.a, b, c, d, e, f, g, h} **.**

25.2 Comments and pragmats

{A source of innocent merriment.
Mikado, W.S. Gilbert. }

{A **pragment** is a **comment** or a **pragmat**. No semantics of **pragments** is given and therefore the meaning {17_2.1.4.1.a} of any **program** is quite unaffected by their presence. It is indeed the intention that **comments** should be entirely ignored by the implementation, their sole purpose being the enlightenment of the human interpreter of the **program**.

Pragmats may, on the other hand, convey to the implementation some piece of information affecting some aspect of the meaning of the **program** which is not defined by this Report, for example:

- the action to be taken upon overflow {17_2.1.4.3.h} or if the scope rule is violated (as in 20_5.2.1.2.b), e.g., `PR overflow check on PR`, `PR overflow check off PR`, `PR scope check on PR` **or** `PR scope check off PR`;
- the action to be taken upon completion of the compilation process, e.g., `PR compile only PR`, `PR dump PR` **or** `PR run PR`;
- that the language to be implemented is some sublanguage or superlanguage of Algol 68, e.g., `PR nonrec PR` (for a **routine-text** which may be presumed to be non-recursive);
- that the compilation may check for the truth, or attempt to prove the correctness, of some assertion, e.g.:

```
INT a, b; read ((a, b)) PR ASSERT a ≥ 0 ∧ b > 0 PR
INT q := 0, r := a;
WHILE r ≥ b PR ASSERT a = b × q + r ∧ 0 < r PR
```

```
DO (q +:= 1, r -:= b) OD
PR ASSERT a = b × q + r ∧ 0 ≤ r ∧ r < b PR.
```

They may also be used to convey to the implementation that the source text is to be augmented with some other text, or edited in some way, for example:

- some previously compiled portion of the **particular-program** is to be invoked, e.g., `PR WITH segment FROM album PR`;
- the source text is continued on some other document, e.g., `PR READ FROM another file PR`;
- the end of the source text has been reached, e.g., `PR FINISH PR`.

The interpretation of **pragmats** is not defined in this Report, but is left to the discretion of the implementer, who ought, at least, to provide some means whereby all further **pragmats** may be ignored, for example:

```
PR pragmats off PR.}
```

```
PR algol 68 PR
BEGIN
  PROC PR nonrec PR pr = VOID: pr;
  pr
END PR run PR PR ? PR
```

Revised report on the Algorithmic Language
Algol 68. }

25.2.1 Syntax

A) **PRAGMENT :: pragmat ; comment.**

a) **pragment** {80a, 91f, A341b, h, A348a, b, c, A349a, A34Ab} **: PRAGMENT** {b}**.**

b) **PRAGMENT {a} :**
STYLE PRAGMENT symbol {25_9.4.b, -}**,**
STYLE PRAGMENT item {c} **sequence option,**
STYLE PRAGMENT symbol {25_9.4.b, -}**.**
{**STYLE :: brief ; bold ; style TALLY.**}

c) **STYLE PRAGMENT item** {b} **: character glyph** {24_8.1.4.c } **; STYLE other PRAGMENT item** {d}**.**

d) A production rule may be added for each notion designated by **'STYLE other PRAGMENT item'** {c, for which no hyper-rule is given in this Report} each of whose alternatives is a symbol {16_1.1.3.1.f}, different from any terminal production of **'character glyph'** {24_8.1.4.1.c}, and such that no terminal production of any **'STYLE other PRAGMENT item'** is the corresponding **'STYLE PRAGMENT symbol'**. {Thus `COMMENT # COMMENT` might be a **comment**, but `#; #; #;` could not.}

{Examples:

a) `PR list PR • ¢ source program to be listed ¢`

c) `l • ?` }

25.3 Representations

a) A construct in the strict language must be represented in some "representation language" such as the "reference language", which is used in this Report. Other representation languages specially suited to the supposed preference of some human or mechanical interpreter of the language may be termed "publication" or "hardware" languages. {The reference language is intended to be used for the representation of **particular-programs** and of their descendents. It is, however, also used in Chapter 26_{10} for the definition of the standard environment.}

b) A "construct in a representation language" is obtained from the terminal production T {16_1.1.3.2.f} of the corresponding construct in the strict language {16_1.1.3.2.e} by replacing the **symbols** in T by their representations, as specified in 25_9.4 below in the case of the reference language.

{Thus, the strict-language **particular-program** whose terminal production is **'bold begin symbol' 'skip symbol' 'bold end symbol'** gives rise to the reference language **particular-program** `BEGIN SKIP END`.}

c) An implementation {17_2.2.2.c} of Algol 68 which uses representations which are sufficiently close to those of the reference language to be recognized without further elucidation, and which does not augment or restrict the available representations other than as provided for below {25_9.4.a, b, c }, is an "implementation of the reference language".

{E.g., `BEGIN`, begin, `BEGIN`, `'begin` and `'begin'` could all be representations of the **bold-begin-symbol** in an implementation of the reference language; some combination of holes in a punched card might be a representation of it in some hardware language.}

25.4 The reference language

a) The reference language provides representations for various **symbols**, including an arbitrarily large number of **TAX-symbols** {where **TAX :: TAG ; TAB ; TAD ; TAM.**} . The representations of some of them are specified below {25_9.4.1 }, and to these may be added suitable representations for **style-TALLY-letter-ABC-symbols** and **style-TALLY-monad-symbols** and any terminal productions of **'STYLE other PRAGMENT item'** {25_9.2.1.d} and of **'other string item'** {24_8.1.4.1.d}. Representations are not provided for any of these {but they enable individual implementations to make available their full character sets for use as characters, to provide additional or extended alphabets for the construction of **TAG-** and **TAB-symbols**, and to provide additional **symbols** for use as **operators**} . There is not, however, {and there must not be, } except in representations of the **standard-**, and other, **preludes** {26_{10}.1.3.Step 6 }, any representation of the **letter-aleph-symbol** or the **primal-symbol**. {For the remaining **TAX-symbols**, see 25_9.4.2 . There are, however, some **symbols** produced by the syntax, e.g., the **brief-pragmat-symbol**, for which no representation is provided at all. This does not preclude the representation of such **symbols** in other representation languages.}

b) Where more than one representation of a **symbol** is given, any of them may be chosen. Moreover, it is sufficient for an implementation of the reference language to provide only one. Also, it is not necessary to provide a representation of any particular **MONAD-symbol** or **NOMAD-symbol** so long as those that are provided are sufficient to represent at least one version {26_{10}.1.3.Step 3 } of each **operator** declared in the **standard-prelude**.

{For certain different **symbols**, one same or nearly the same representation is given; e.g., the representation ":" is given for the **routine-symbol**, the **colon-symbol** and the **up-to-symbol** and ":" for the **label-symbol**. It follows uniquely from the syntax which of these four **symbols** is represented by an occurrence, outside **comments**, **pragmats** and **string-denotations**, of any mark similar to either of those representations. It is also the case that ".." could be used, without ambiguity, for any of them, and such might indeed be necessary in implementations with limited character sets. It may be noted that, for such implementations, no ambiguity would be introduced were "(/" and "/)" to be used as representations of the **style-ii-sub-symbol** and the **style-ii-bus-symbol**, respectively.

Also, some of the given representations appear to be composite; e.g., the representation ":=" of the **becomes-symbol** appears to consist of ":", the representation of the **routine-symbol**, etc., and "=", the representation of the **equals-symbol** and of the **is-defined-as-symbol**. It follows from the syntax that ":=" can occur, outside **comments**, **pragmats** and **string-denotations**, as a representation of the **becomes-symbol** only (since "=" cannot occur as the representation of a **monadic-operator**). Similarly, the other given composite representations do not cause ambiguity.}

c) The fact that the representations of the **letter-ABC-symbols** given {25_9.4.1.a} are usually spoken of as small letters is not meant to imply that the corresponding capital letters

could not serve equally well. {On the other hand, if both a small letter and the corresponding capital letter occur, then one of them is presumably the representation of some **style-TALLY-letter-ABC-symbol** or of a **bold-letter-ABC-symbol**. See also 16_1.1.5.b for the possibility of additional **'ABC'**s in a variant of the language.}

d) A "typographical display feature" is a blank, or a change to a new line or a new page. Such features, when they appear between the **symbols** of a construct in the reference language, are of no significance and do not affect the meaning of that construct. However, a blank contained within a **string-** or **character-denotation** is one of the representations of the **space-symbol** {25_9.4.1.b } rather than a typographical display feature. Where the representation of a **symbol** in the reference language is composed of several marks {e.g., `TO`, `:=`}, those marks form one {indivisible} **symbol** and, unless the contrary is explicitly stated {25_9.4.2.2.a, c }, typographical display features may not separate them.

25.4.1 Representations of symbols

a) Letter symbols

symbol	representation
letter a symbol {24_8.1.4.c, 24_8.2.k, 25_9.4.2.B, 26_{10}.3.4.6.b}	a
letter b symbol {24_8.1.4.c, 24_8.2.k, 25_9.4.2.B, 26_{10}.3.4.4.b}	b
letter c symbol {24_8.1.4.c, 24_8.2.k, 25_9.4.2.B, 26_{10}.3.4.8.a}	c
letter d symbol {24_8.1.4.c, 24_8.2.k, 25_9.4.2.B, 26_{10}.3.4.2.f}	d
letter e symbol {24_8.1.2.h, 24_8.1.4.c, 24_8.2.k, 25_9.4.2.B, 26_{10}.3.4.3.e}	e
letter f symbol {24_8.1.4.c, 24_8.2.k, 25_9.4.2.B, 26_{10}.3.4.9.a}	f
letter g symbol {24_8.1.4.c, 25_9.4.2.B, 26_{10}.3.4.26_{10}.a}	g
letter h symbol {24_8.1.4.c, 25_9.4.2.B}	h
letter i symbol {24_8.1.4.c, 25_9.4.2.B, 26_{10}.3.4.5.b}	i
letter j symbol {24_8.1.4.c, 25_9.4.2.B}	j
letter k symbol {24_8.1.4.c, 25_9.4.2.B, 26_{10}.3.4.1.f}	k
letter l symbol {24_8.1.4.c, 25_9.4.2.B, 26_{10}.3.4.1.f}	l
letter m symbol {24_8.1.4.c, 25_9.4.2.B}	m
letter n symbol {24_8.1.4.c, 25_9.4.2.B, 26_{10}.3.4.1.h}	n
letter o symbol {24_8.1.4.c, 25_9.4.2.B}	o
letter p symbol {24_8.1.4.c, 25_9.4.2.B, 26_{10}.3.4.1.f}	p
letter q symbol {24_8.1.4.c, 25_9.4.2.B, 26_{10}.3.4.1.f}	q
letter r symbol {24_8.1.4.c, 24_8.2.c, 25_9.4.2.B, 26_{10}.3.4.7.c}	r
letter s symbol {24_8.1.4.c, 25_9.4.2.B, 26_{10}.3.4.1.l}	s
letter t symbol {24_8.1.4.c, 25_9.4.2.B}	t

letter u symbol {24_8.1.4.c, 25_9.4.2.B}	u
letter v symbol {24_8.1.4.c, 25_9.4.2.B}	v
letter w symbol {24_8.1.4.c, 25_9.4.2.B}	w
letter x symbol {24_8.1.4.c, 25_9.4.2.B, 26_{10}.3.4.1.f}	x
letter y symbol {24_8.1.4.c, 25_9.4.2.B, 26_{10}.3.4.1.f}	y
letter z symbol {24_8.1.4.c, 25_9.4.2.B, 26_{10}.3.4.2.d}	z

b) Denotation symbols

symbol	representation
digit zero symbol {811c, 814c, 82h, 25_9.4.2.C}	0
digit one symbol {43b, 811c, 814c, 82g, h, 25_9.4.2.C}	1
digit two symbol {43b, 811c, 814c, 82d, i, 25_9.4.2.C}	2
digit three symbol {43b, 811c, 814c, 82i, 25_9.4.2.C}	3
digit four symbol {43b, 811c, 814c, 82e, j, 25_9.4.2.C}	4
digit five symbol {43b, 811c, 814c, 82j, 25_9.4.2.C}	5
digit six symbol {43b, 811c, 814c, 82g, j, 25_9.4.2.C}	6
digit seven symbol {43b, 811c, 814c, 82j, 25_9.4.2.C}	7
digit eight symbol {43b, 811c, 814c, 82f, k, 25_9.4.2.C}	8
digit nine symbol {43b, 811c, 814c, 82k, 25_9.4.2.C}	9
point symbol {812d, 814c, A343d}	.
times ten to the power symbol {812h}	10
true symbol {813a}	TRUE
false symbol {813a}	FALSE
quote symbol {814a, 83a}	"
quote image symbol {814b}	""
space symbol {24_8.1.4.c}	␣
comma symbol {24_8.1.4.c}	,
empty symbol {815a}	EMPTY

c) Operator symbols

symbol	representation
or symbol {25_9.4.2.H}	∨
and symbol {25_9.4.2.H}	∧
ampersand symbol {25_9.4.2.H}	&
differs from symbol {25_9.4.2.H}	≠
is less than symbol {25_9.4.2.I}	<
is at most symbol {25_9.4.2.H}	≤
is at least symbol {25_9.4.2.H}	≥
is greater than symbol {25_9.4.2.I}	>
divided by symbol {25_9.4.2.I}	/
over symbol {25_9.4.2.H}	÷

percent symbol {25_9.4.2.H}	%
window symbol {25_9.4.2.H}	□
floor symbol {25_9.4.2.H}	⌊
ceiling symbol {25_9.4.2.H}	⌈
plus i times symbol {25_9.4.2.H}	⊥
not symbol {25_9.4.2.H}	¬
tilde symbol {25_9.4.2.H}	~
down symbol {25_9.4.2.H}	↓
up symbol {25_9.4.2.H}	↑
plus symbol {24_8.1.2.j, 24_8.1.4.c, 25_9.4.2.H, 26_{10}.3.4.2.e}	+
minus symbol {24_8.1.2.j, 24_8.1.4.c, 25_9.4.2.H, 26_{10}.3.4.2.e}	-
equals symbol {25_9.4.2.I}	=
times symbol {25_9.4.2.I}	×
asterisk symbol {25_9.4.2.I}	*
assigns to symbol {25_9.4.2.J}	=:
becomes symbol {19_4.4.f, 20_5.2.1.a, 25_9.4.2.J}	:=

d) Declaration symbols

symbol	representation
is defined as symbol {19_4.2.b, 19_4.3.b, 19_4.4.c, 19_4.5.c}	=
long symbol {24_8.1.0.a, 24_8.2.a}	LONG
short symbol {24_8.1.0.a, 24_8.2.b}	SHORT
reference to symbol {19_4.6.c}	REF
local symbol {20_5.2.3.a, b}	LOC
heap symbol {20_5.2.3.a, b}	HEAP
structure symbol {19_4.6.d}	STRUCT
flexible symbol {19_4.6.g}	FLEX
procedure symbol {19_4.19_4.b, 19_4.6.o}	PROC
union of symbol {19_4.6.s}	UNION
operator symbol {19_4.5.a}	OP
priority symbol {19_4.3.a}	PRIO
mode symbol {19_4.2.a}	MODE

e) Mode standards

symbol	representation
integral symbol {25_9.4.2.E}	INT
real symbol {25_9.4.2.E}	REAL
boolean symbol {25_9.4.2.E}	BOOL
character symbol {25_9.4.2.E}	CHAR
format symbol {25_9.4.2.E}	FORMAT

void symbol {25_9.4.2.E}	VOID
complex symbol {25_9.4.2.E}	COMPL
bits symbol {25_9.4.2.E}	BITS
bytes symbol {25_9.4.2.E}	BYTES
string symbol {25_9.4.2.E}	STRING
sema symbol {25_9.4.2.E}	SEMA
file symbol {25_9.4.2.E}	FILE
channel symbol {25_9.4.2.E}	CHANNEL

f) Syntactic symbols

symbol	representation
bold begin symbol {16_1.3.3.d}	BEGIN
bold end symbol {16_1.3.3.d}	END
brief begin symbol {16_1.3.3.d, 26_{10}.3.4.8.b, 26_{10}.3.4.A.b}	(
brief end symbol {16_1.3.3.d, 26_{10}.3.4.8.b, 26_{10}.3.4.A.b}	)
and also symbol {16_1.3.3.c, 18_3.3.b, f, 18_3.4.h, 19_4.1.a, b, 19_4.6.e,i,q,t, 20_5.3.2.b, 20_5.4.1.e, 20_5.4.3.b, 26_{10}.3.4.8.b, 26_{10}.3.4.A.c, d}	,
go on symbol {18_3.2.b}	;
completion symbol {18_3.2.b}	EXIT
label symbol {18_3.2.c}	:
parallel symbol {18_3.3.c}	PAR
open symbol {24_8.1.4.c}	(
close symbol {24_8.1.4.c}	)
bold if symbol {25_9.1.a}	IF
bold then symbol {25_9.1.b}	THEN
bold else if symbol {25_9.1.c}	ELIF
bold else symbol {25_9.1.d}	ELSE
bold fi symbol {25_9.1.e}	FI
bold case symbol {25_9.1.a}	CASE
bold in symbol {25_9.1.b}	IN
bold ouse symbol {25_9.1.c}	OUSE
bold out symbol {25_9.1.d}	OUT

bold esac symbol {25_9.1.e}	ESAC
brief if symbol {25_9.1.a}	(
brief then symbol {25_9.1.b}	|
brief else if symbol {25_9.1.c}	|:
brief else symbol {25_9.1.d}	|
brief fi symbol {25_9.1.e}	)
brief case symbol {25_9.1.a}	(
brief in symbol {25_9.1.b}	|
brief ouse symbol {25_9.1.c}	|:
brief out symbol {25_9.1.d}	|
brief esac symbol {25_9.1.e}	)
colon symbol {18_3.4.j, k}	:
brief sub symbol {16_1.3.3.e}	[
brief bus symbol {16_1.3.3.e}	]
style i sub symbol {16_1.3.3.e}	(
style i bus symbol {16_1.3.3.e}	)
up to symbol {19_4.6.j,k,l, 20_5.3.2.f}	:
at symbol {20_5.3.2.g}	@ AT
is symbol {20_5.2.2.b}	:=: IS
is not symbol {20_5.2.2.b}	:≠: :/=: ISNT
nil symbol {20_5.2.4.a}	∘ NIL
of symbol {20_5.3.1.a}	OF
routine symbol {20_5.4.1.a, b}	:
bold go to symbol {20_5.4.4.b}	GOTO
bold go symbol {20_5.4.4.b}	GO
skip symbol {20_5.5.2.a}	~ SKIP
formatter symbol {26_{10}.3.4.1.a}	$

g) Loop symbols

symbol	representation
bold for symbol {18_3.5.b}	FOR
bold from symbol {18_3.5.d}	FROM
bold by symbol {18_3.5.d}	BY
bold to symbol {18_3.5.d, 544b}	TO
bold while symbol {18_3.5.g}	WHILE
bold do symbol {18_3.5.h}	DO
bold od symbol {18_3.5.h}	OD

h) Pragment symbols

symbol	representation
brief comment symbol {25_9.2.b}	¢
bold comment symbol {25_9.2.b}	COMMENT
style i comment symbol {25_9.2.b}	CO
style ii comment symbol {25_9.2.b}	#
bold pragmat symbol {25_9.2.b}	PRAGMAT
style i pragmat symbol {25_9.2.b}	PR

25.4.2 Other TAX symbols

25.4.2.1 Metasyntax

A) **TAG** {D, F, K, 19_4.8.a, b, c, d} **::**
LETTER {B}**; TAG LETTER** {B}**; TAG DIGIT** {C}**.**

B) **LETTER {A} ::**
letter ABC {25_9.4.a } **; letter aleph** {-}**; style TALLY letter ABC** {-}**.**

C) **DIGIT {A} ::**
digit zero {25_9.4.b } **; digit one** {25_9.4.b } **; digit two** {25_9.4.b} **;**
digit three {25_9.4.b } **; digit four** {25_9.4.b} **; digit five** {25_9.4.b } **;**
digit six {25_9.4.b} **; digit seven** {25_9.4.b } **; digit eight** {25_9.4.b} **;**
digit nine {25_9.4.b } **.**

D) **TAB** {19_4.8.a,b } **::**
bold TAG {A, -}**; SIZETY STANDARD** {E}**.**

E) **STANDARD** {D} **::**
integral {25_9.4.e } **; real** {25_9.4.e } **; boolean** {25_9.4.e} **;**
character {25_9.4.e } **; format** {25_9.4.e} **; void** {25_9.4.e } **;**
complex {25_9.4.e} **; bits** {25_9.4.e } **; bytes** {25_9.4.e} **;**
string {25_9.4.e } **; sema** {25_9.4.e} **; file** {25_9.4.e } **;**
channel {25_9.4.e} **.**

F) **TAD** {19_4.8.a, b } **::**
bold TAG {A, -}**;**
DYAD {G} **BECOMESETY** {J}**;**
DYAD {G} **cum NOMAD** {I} **BECOMESETY** {J}**.**

G) **DYAD** {F} **:: MONAD** {H}**; NOMAD** {I} **.**

H) **MONAD** {G, K} **::**
or {25_9.4.c } **; and** {25_9.4.c} **; ampersand** {25_9.4.c } **;**
differs from {25_9.4.c} **; is at most** {25_9.4.c } **; is at least** {25_9.4.c} **;**
over {25_9.4.c } **; percent** {25_9.4.c} **; window** {25_9.4.c } **;**
floor {25_9.4.c} **; ceiling** {25_9.4.c } **; plus i times** {25_9.4.c} **;**
not {25_9.4.c } **; tilde** {25_9.4.c} **; down** {25_9.4.c } **;**
up {25_9.4.c} **; plus** {25_9.4.c } **; minus** {25_9.4.c} **;**
style TALLY monad {-}**.**

I) **NOMAD** {F, G, K} **::**
is less than {25_9.4.c } **; is greater than** {25_9.4.c } **; divided by** {25_9.4.c} **;**
equals {25_9.4.c } **; times** {25_9.4.c} **; asterisk** {25_9.4.c } **.**

J) **BECOMESETY** {F, K} **:: cum becomes** {25_9.4.c } **; cum assigns to** {25_9.4.c } **;**
EMPTY.

K) **TAM** {19_4.8.a, b } **::**
bold TAG {A, -}**;**
MONAD {H} **BECOMESETY** {J}**;**
MONAD {H} **cum NOMAD** {I} **BECOMESETY** {J}**.**

L) **ABC** {B} **::**
a ; b ; c ; d ; e ; f ; g ; h ; i ; j ; k ; l ; m ; n ; o ; p ; q ; r ; s ; t ; u ; v ; w ; x ; y ; z.

M) ***DOP :: DYAD** {G}**; DYAD** {G}**cum NOMAD** {I}**.**

{The metanotion "**ABC**" is provided, in addition to the metanotion "**ALPHA**", in order to facilitate the definition of variants of Algol 68 {16_1.1.5.b}.}

25.4.2.2 Representation

a) The representation of each **TAG-symbol** not given above {25_9.4.1 } is composed of marks corresponding, in order, to the **'LETTER'**s or **'DIGIT'**s contained in that **'TAG'**. These marks may be separated by typographical display features {25_9.4.d }. The mark corresponding to each **'LETTER'** (**'DIGIT'**) is the representation of that **LETTER-symbol** (**DIGIT-symbol**). {For example, the representation of a **letter-x-digit-one-symbol** is `x1`, which may be written `x 1`. **TAG-symbols** are used for **identifiers** and **field-selectors**.}

b) The representation, if any, of each **bold-TAG-symbol** is composed of marks corresponding, in order, to the **'LETTER'**s or **'DIGIT'**s contained in that **'TAG'** {but with no typographical display features in between}. The mark corresponding to each **'LETTER'** (**'DIGIT'**) is similar to the mark representing the corresponding **LETTER-symbol** (**DIGIT-symbol**), being, in this Report, the corresponding bold faced letter (digit). {Other methods of indicating the similarity which are recognizable without further elucidation are also

acceptable, e.g., **person**, person, PERSON, 'person and 'person' could all be representations of the **bold-letter-p-letter-e-letter-r-letter-s-letter-o-letter-n-symbol**.}

However, the representation of a **bold-TAG-symbol** may not be the same as any representation of any other **symbol** {; thus there may be a finite number of **bold-TAG-symbols** which have no representation; e.g., there is no representation for the **bold-letter-r-letter-e-letter-a-letter-l-symbol** because REAL is a representation of the **real-symbol**; note that the number of **bold-TAG-symbols** available is still arbitrarily large}. If, according to the convention used, a given sequence of marks could be either the representation of one **bold-TAG-symbol** or the concatenation of the representations of two or more other **symbols**, then it is always to be construed as that one **symbol** {; the inclusion of a blank can always force the other interpretation; e.g., REFREAL is one **symbol**, whereas REF REAL must always be two}. {**Bold-TAG-symbols** are used for **mode-indications** and for **operators**.}

c) The representation of each **SIZE-SIZETY-STANDARD-symbol** is composed of the representation of the corresponding **SIZE-symbol**, possibly followed by typographical display features, followed by the representation of the corresponding **SIZETY-STANDARD-symbol**. {For example, the representation of a **long-real-symbol** is LONG REAL, or perhaps 'long"real' (but not, according to section b above, LONGREAL or 'longreal', for those would be representations of the **bold-letter-l-letter-o-letter-n-letter-g-letter-r-letter-e-letter-a-letter-l-symbol**). **SIZETY-STANDARD-symbols** are used for **mode-indications**.}

d) The representation of each **DOP-cum-becomes-symbol** (**DOP-cum-assigns-to-symbol**) is composed of the mark or marks representing the corresponding **DOP-symbol** followed (without intervening typographical display features) by the marks representing the **becomes-symbol** (the **assigns-to-symbol**). {For example, the representation of a **plus-cum-becomes-symbol** is +:=. **DOP-cum-becomes-symbols** are used for **operators**.}

e) The representation of each **DYAD-cum-NOMAD-symbol** is composed of the mark representing the corresponding **DYAD-symbol** followed {without intervening typographical display features} by the mark representing the corresponding **NOMAD-symbol**. {For example, the representation of an **over-cum-times-symbol** is ÷×. **DYAD-cum-NOMAD-symbols** are used for **operators**, but note that **NOMAD1-cum-NOMAD2-symbols** may be only **dyadic-operators**.}

{Revised Report } Part V

Environment and examples

26 Standard environment

{The "standard environment" encompasses the constituent **EXTERNAL-preludes**, **system-tasks** and **particular-postludes** of a **program-text**.}

26.1 Program texts

{The programmer is concerned with **particular-programs** {26_{10}.1.1.g}. These are always included in a **program-text** {26_{10}.1.1.a} which also contains the **standard-prelude**, a **library-prelude**, which depends upon the implementation, a **system-prelude** and **system-tasks**, which correspond to the operating environment, possibly some other **particular-programs**, one or more **particular-preludes** (one for each **particular-program**) and one or more **particular-postludes**.}

26.1.1 Syntax

A) **EXTERNAL :: standard ; library ; system ; particular.**

B) **STOP :: label letter s letter t letter o letter p.**

a) **program text :**
STYLE begin {25_9.4.f, -} **token,**
new LAYER1 preludes {b},
parallel {25_9.4.f} **token, new LAYER1 tasks** {d} **PACK,**
STYLE end {25_9.4.f, -} **token.**

b) **NEST1 preludes {a} :**
NEST1 standard prelude with DECS1 {c},
NEST1 library prelude with DECSETY2 {c},
NEST1 system prelude with DECSETY3 {c},
where (NEST1) is (new EMPTY new DECS1 DECSETY2 DECSETY3) .

c) **NEST1 EXTERNAL prelude with DECSETY** {b,f} **:**
strong void NEST1 series with DECSETY1 {18_3.2.b} **,**
go on {25_9.4.f} **token where (DECSETY1) is (EMPTY), EMPTY.**

d) **NEST1 tasks** {a} **:**
NEST1 system task {e} **list,**
and also {25_9.4.f} **token,**
NEST1 user task {f} **PACK list.**

e) **NEST1 system task** {d} **: strong void NEST1 unit** {18_3.2.d} **.**

f) **NEST1 user task** {d} **:**
NEST2 particular prelude with DECS {c}**,**
NEST2 particular program {g} **PACK, go on** {25_9.4.f} **token,**
NEST2 particular prelude {i}**,**
where (NEST2) is (NEST1 new DECS STOP) .

g) **NEST2 particular program** {f} **:**
NEST2 new LABSETY3 joined label definition of LABSETY3 {h}**,**
strong void NEST2 new LABSETY3 ENCLOSED clause
{18_3.1.a, 18_3.3.a,c, 18_3.4.a, 18_3.5.a} **.**

h) **NEST joined label definition of LABSETY** {g,h} **:**
where (LABSETY) is (EMPTY),
EMPTY;
where (LABSETY) is (LAB1 LABSETY1),
NEST label definition of LAB1 {18_3.2.c} **,**
NEST joined label definition of LABSETY1 {h}**.**

i) **NEST2 particular postlude** {f} **: strong void NEST2 series with STOP** {18_3.2.b}
.

{Examples:

a) (**C** standard-prelude **C** ; **C** library-prelude **C**; **C** system-prelude **C** ;
`PAR BEGIN` **C** system-task-1 **C** , **C** system-task-2 **C** ,
(**C** particular-prelude **C** ;
`(start: commence: BEGIN SKIP END);`
C particular-postlude **C**) ,
(**C** another user-task **C**)
`END)`

b) **C** standard-prelude (26_{10}.2, 26_{10}.3) **C**; **C** library-prelude **C** ;
C system-prelude (26_{10}.4.1) **C**;

d) **C** system-task-1 (26_{10}.4.2.a) **C**, **C** system-task-2 **C**,
(**C** particular-prelude **C** ;
`(start: commence: BEGIN SKIP END);`
C particular-postlude **C**),
(**C** another user-task **C**)

f) **C** particular-prelude (26_{10}.5.1) **C** ;
`(start: commence: BEGIN SKIP END);`
C particular-postlude **C**),

g) `start: commence: BEGIN SKIP END`

h) `start: commence:`

i) `stop: lock (stand in); lock (stand out); lock (stand back)` }

26.1.2 The environment condition

a) A **program** in the strict language must be akin {16_1.1.3.2.k} to some **program-text** whose constituent **EXTERNAL-preludes** and **particular-postludes** are as specified in the remainder of this section. {It is convenient to speak of the **standard-prelude**, the **library-prelude**, the **particular-programs**, etc. of a **program** when discussing those parts of that **program** which correspond to the constituent **standard-prelude**, etc. of the corresponding **program-text**.}

b) The constituent **standard-prelude** of all **program-texts** is that **standard-prelude** whose representation is obtained {26_{10}.1.3} from the forms given in sections 26_{10}.2 and 26_{10}.3.

c) The constituent **library-prelude** of a **program-text** is not specified in this Report {but must be specified for each implementation; the syntax of **'program text'** ensures that a **declaration** contained in a **library-prelude** may not contradict any **declaration** contained in the **standard-prelude**} .

d) The constituent **system-prelude** (**system-task-list**) of all **program-texts** is that **system-prelude** (**system-task-list**) whose representation is obtained from the forms given in section 26_{10}.4, with the possible addition of other forms not specified in this Report {but to be specified to suit the operating environment of each implementation} .

e) Each constituent **particular-prelude** (**particular-postlude**) of all **program-texts** is that **particular-prelude** (**particular-postlude**) whose representation is obtained from the forms given in section 26_{10}.5, with the possible addition of other forms not specified in this Report {but to be specified for each implementation}.

26.1.3 The method of description of the standard environment

A representation of an **EXTERNAL-prelude**, **system-task** or **particular-postlude** is obtained by altering each form in the relevant sections of this chapter in the following steps:

Step 1: If a given form F begins with OP {the **operator-symbol**} followed by one of the marks P, Q, R or E, then F is replaced by a number of new forms each of which is a copy of F in which that mark {following the OP} is (all other occurrences in F of that mark are) replaced, in each respective new form, by:

Case A: The mark is P:

- $-$, $+$, $\ll$ $\times$, $\star$ $\gg$ or $/$
  ($-$, $+$, $\star$ or $/$);

Case B: The mark is Q:

- $\ll$ MINUSAB, $-:=$ $\gg$, $\ll$ PLUSAB, $+:=$ $\gg$,
  $\ll$ TIMESAB, $\times:=$, $\star:=$ $\gg$ or $\ll$ DIVAB, $/:=$ $\gg$
  ($-:=$, $+:=$, $\times:=$, $\star:=$ or $/:=$);

Case C: The mark is R:

- $\ll$ $<$, LT $\gg$, $\ll$ $\leq$, $<=$, LE $\gg$, $\ll$ $=$, EQ $\gg$,
  $\ll$ $\neq$, $/=$, NE $\gg$, $\ll$ $\geq$, $>=$, GE $\gg$ or $\ll$ $>$, GT $\gg$
  ($<$, $\leq$, $=$, $/=$, $\geq$ or $>$);

Case D: The mark is E:

- $\ll$ $=$, EQ $\gg$ or $\ll$ $\neq$, $/=$, NE $\gg$
  ($=$ or $\neq$);

Step 2: If, in some form, as possibly made in the step above, $\aleph_0$ occurs followed by an **INDICATOR** (a **field-selector**) I, then that occurrence of $\aleph_0$ is deleted and each **INDICATOR** (**field-selector**) akin {16_1.1.3.2.k} to I contained in any form is replaced by a copy of one same **INDICATOR** (**field-selector**) which does not occur elsewhere in the **program** and Step 2 is taken again[1]

Step 3: If a given form F, as possibly modified or made in the steps above, begins with OP {the **operator-symbol**} followed by a chain of **TAO-symbols** separated by **and-also-symbols**, the chain being enclosed between $\ll$ and $\gg$, then F is replaced by a number

[1] This relates to the problem of unspeakable names. In the standard environment a number of definitions occur that cannot be used by the programmer, and therefore need an unspeakable name. In earlier versions of the report these names were started by a sequence of $\aleph_0$ f's, generated by an infinite production **ALEPH**. Later, infinite productions were removed from the report and **ALEPH** would have been replaced by $\aleph$ if the authors would have had a font containing that symbol. They did not, and replaced it with a question-mark-cum-superimposed-tilde in the Revised Report. Since LaTeX supports $\aleph_0$ (but not the mark used in the Revised Report), the former mark is used here.

of different "versions" of that form each of which is a copy of F in which that chain, together with its enclosing $\ll$ and $\gg$, has been replaced by one of those **TAO-symbols** {; however, an implementation is not obliged to provide more than one such version {25_9.4.b} } ;

Step 4: If, in a given form, as possibly modified or made in the steps above, there occurs a sequence S of **symbols** enclosed between $\ll$ and $\gg$ and if, in that S, L `INT`, L `REAL`, L `COMPL`, L `BITS` or L `BYTES` occurs, then S is replaced by a chain of a sufficient number of sequences separated by **and-also-symbols**, the n^{th} of which is a copy of S in which copy each occurrence of L (L, K, S) is replaced by $(n-1)$ times `long` (`LONG`, `LENG`, `SHORTEN`), followed by an **and-also-symbol** and a further chain of a sufficient number of sequences separated by **and-also-symbols**, the m^{th} of which is a copy of S in which copy each occurrence of L (L, K, S) has been replaced by m times `short` (`SHORT`, `SHORTEN`, `LENG`); the $\ll$ and $\gg$ enclosing that S are then deleted;

Step 5: If, in a given form F, as possibly modified or made in the steps above, L `INT`, L `REAL`, L `COMPL`, L `BITS` or L `BYTES`) occurs, then F is replaced by a sequence of a sufficient number of new forms, the n^{th} of which is a copy of F in which copy each occurrence of L (L, K, S) is replaced by $(n-1)$ times `long` (`LONG`, `LENG`, `SHORTEN`), and each occurrence of `long` L (`LONG` L) by n times `long` (`LONG`), followed by a further sequence of a sufficient number of new forms, the m^{th} of which is a copy of F in which copy each occurrence of L (L, K, S) is replaced by m times `short` (`SHORT`, `SHORTEN`, `LENG`), and each occurrence of `LONG` L (`long` L) by $(m-1)$ times `SHORT` (`short`);

Step 6: Each occurrence of F (`PRIM`) in any form, as possibly modified or made in the steps above, is replaced by a representation of a **letter-aleph-symbol** (**primal-symbol**) {25_9.4.a};

Step 7: If a sequence of representations beginning with and ending with **C** occurs in any form, as possibly modified or made in the steps above, then this sequence, which is termed a "pseudo-comment", is replaced by a representation of a **declarer** or **closed-clause** suggested by the sequence;

Step 8: If, in any form, as possibly modified or made in the steps above, a **routine-text** occurs whose calling involves the manipulation of real numbers, then this **routine-text** may be replaced by any other **routine-text** whose calling has approximately the same effect {; the degree of approximation is left undefined in this Report (see also 17_2.1.3.1.e) };

Step 9: In the case of an **EXTERNAL-prelude**, a form consisting of a **skip-symbol** followed by a **go-on-symbol** {`SKIP;`} is added at the end.

{The term "sufficient number", as used in Steps 4 and 5 above, implies that no intended **particular-program** should have a different meaning or fail to be produced by the syntax solely on account of an insufficiency of that number.}

Wherever {in the transput declarations} the representation $_{10}$ (\, $\perp$) occurs within a **character-denotation** or **string-denotation**, it is to be interpreted as the representation of the **string-item** {24_8.1.4.1.b} used to indicate "times ten to the power" (an alternative form {, if any,} of "times ten to the power", "plus i times") on external media. {Clearly, these representations have been chosen because of their similarity to those of the **times-ten-to-the-power-symbol** {25_9.4.1.b} and the **plus-i-times-symbol** {25_9.4.1.c}, but, on media on which these characters are not available, other **string-items** must be chosen (and the **letter-e-symbol** and the **letter-i-symbol** are obvious candidates) .}

{The declarations in this chapter are intended to describe their effect clearly. The effect may very well be obtained by a more efficient method.}

26.2 The standard prelude

{The **declarations** of the **standard-prelude** comprise "environment enquiries", which supply information concerning a specific property of the implementation {17_2.2.2.c}, "standard modes", "standard operators and functions", "synchronization operations" and "transput declarations" (which are given in section 26_{10}.3) .}

26.2.1 Environment enquiries

a) `INT int lengths` = **C** 1 plus the number of extra lengths of integers {17_2.1.3.1.d} **C** ;

b) `INT int shorths` = **C** 1 plus the number of extra shorths of integers {17_2.1.3.1.d} **C** ;

c) *L* `INT` *L* `max int` = **C** the largest *L* integral value {17_2.2.2.b} **C** ;

d) `INT real lengths` = **C** 1 plus the number of extra lengths of real numbers {17_2.1.3.1.d} **C** ;

e) `INT real shorths` = **C** 1 plus the number of extra shorths of real numbers {17_2.1.3.1.d} **C** ;

f) *L* `REAL` *L* `max real` = **C** the largest *L* real value {17_2.2.2.b} **C** ;

g) *L* `REAL` *L* `small real` = **C** the smallest *L* real value such that both *L* `1 +` *L* `smal real > 1` and *L* `1 +` *L* `small real < 1` {17_2.2.2.b} **C** ;

h) `INT bits lengths` = **C** 1 plus the number of extra widths {j} of bits **C** ;

i) `INT bits shorths` = **C** 1 plus the number of extra shorths {j} of bits **C** ;

j) `INT` *L* `bits width` = **C** the number of elements in *L* bits; see *L* `BITS` {26_{10}.2.2.g} ; this number increases (decreases) with the "size", i.e., the number of 'long's (minus the number of 'short's) of which '*L*' is composed, until a certain size is reached, viz., "the number of extra widths" (minus "the number of extra shorths") of bits, after which it is constant **C** ;

k) `INT bytes lengths` = **C** 1 plus the number of extra widths {m} of bytes **C** ;

l) `INT bytes shorths` = **C** 1 plus the number of extra shorths {m} of bytes **C** ;

m) `INT` *L* `bytes width` = **C** the number of elements in *L* bytes; see *L* `BYTES` {26_{10}.2.2.h} ; this number increases (decreases) with the "size", i.e., the number of 'long's (minus the number of 'short's) of which '*L*' is composed, until a certain size is reached, viz., "the number of extra widths" (minus "the number of extra shorths") of bits, after which it is constant **C** ;

n) `OP ABS = (CHAR a) INT:` **C** the integral equivalent {17_2.1.3.1.g} of the character 'a' **C** ;

o) `OP REPR = (INT a) CHAR:` **C** that character 'x', if it exists, for which `ABS x = a` **C** ;

p) `INT max abs char` = **C** the largest integral equivalent {17_2.1.3.1.g} of a character **C** ;

q) `CHAR null character` = **C** some character **C** ;

r) `CHAR flip` = **C** the character used to represent 'true' during transput {26_{10}.3.3.1.a, 26_{10}.3.3.2.a} **C** ;

s) `CHAR flop` = the character used to represent 'false' during transput **C** ;

t) `CHAR error char` = **C** the character used to represent unconvertible arithmetic values {26_{10}.3.2.1.b, c, d, e, f} `during transput` **C** ;

u) `CHAR blank = "␣";`

26.2.2 Standard modes

a) `MODE VOID` = **C** an actual-declarer specifying the mode 'void' **C** ;

b) `MODE BOOL` = **C** an actual-declarer specifying the mode 'boolean' **C** ;

c) `MODE` *L* `INT` = **C** an actual-declarer specifying the mode '*L* integral' **C** ;

d) `MODE` *L* `REAL` = **C** an actual-declarer specifying the mode ' *L* real' **C** ;

e) `MODE CHAR` = **C** an actual-declarer specifying the mode 'character' **C** ;

f) `MODE` *L* `COMPL = STRUCT (`*L* `REAL re, im);`

g) `MODE` *L* `BITS = STRUCT ([1 :` *L* `bits width] BOOL` *L* `F );` {See 26_{10}.2.1.j}
{The **field-selector** is hidden from the user in order that he may not break open the structure; in particular, he may not subscript the field.}

h) `MODE` *L* `BYTES = STRUCT ([1 :` *L* `bytes width] CHAR` *L* `F);` {See 26_{10}.2.1.m}

i) `MODE STRING = FLEX [1 : 0] CHAR;`

26.2.3 Standard operators and routines

26.2.3.1 Standard priorities

a)
```
PRIO MINUSAB = 1, PLUSAB = 1, TIMESAB = 1, DIVAB = 1, OVERAB = 1,
     MODAB = 1, PLUSTO = 1,
     -:= = 1, +:= = 1, ×:= = 1, *:= = 1,
     /:= = 1, ÷:= = 1, %:= = 1, ÷×:= = 1,
```

```
÷×:= = 1, %×:= = 1, %*:= = 1, +=: = 1,

∨ = 2, OR = 2,

∧ = 3, AND = 3,

= = 4, EQ = 4, ≠ = 4, /= = 4, NE = 4,

< = 5, LT = 5, ≤ = 5, <= = 5, LE = 5,
>= = 5, ≥ = 5, GE = 5, > = 5, GT = 5,

- = 6, + = 6,

× = 7, * = 7, / = 7, % = 7, OVER = 7,
÷× = 7, ÷* = 7, %× = 7, %* = 7, MOD = 7,
□ = 7, ELEM = 7,

↑ = 8, ** = 8, ↓ = 8, UP = 8,
DOWN = 8, SHL = 8, SHR = 8,
LWB = 8, UPB = 8, ⌊ = 8, ⌈ = 8

⊥ = 9, +× = 9, +* = 9, I = 9;
```

26.2.3.2 Rows and associated operations

a) `MODE` $\aleph_0$ `ROWS =` **C** an actual-declarer specifying a mode united from {17_2.1.3.6.a} a sufficient set of modes each of which begins with 'row' **C** ;

b) `OP ≪ LWB, ⌊ ≫ = (INT n, ROWS a) INT:` **C** the lower bound in the n-th bound pair of the descriptor of the value of 'a', if that bound pair exists **C** ;

c) `OP ≪ UPB, ⌈ ≫ = (INT n, ROWS a) INT:` **C** the upper bound in the n-th bound pair of the descriptor of the value of 'a', if that bound pair exists **C** ;

d) `OP ≪ LWB, ⌊ ≫ = (ROWS a) INT: 1 ⌊ a;`

e) `OP ≪ UPB, ⌈ ≫ = (ROWS a) INT: 1 ⌈ a;`

{The term "sufficient set", as used in a above and also in 26_{10}.3.2.2.b and d, implies that no intended **particular-program** should fail to be produced (nor any unintended **particular-program** be produced) by the syntax solely on account of an insufficiency of modes in that set.}

26.2.3.3 Operations on boolean operands

a) `OP ≪ ∨, OR ≫ = (BOOL b) BOOL: (a | TRUE | b);`

b) `OP ≪ ∧, AND ≫ = (BOOL a, b) BOOL: (a | b | FALSE);`

c) `OP ≪ ¬, ~, NOT ≫ = (BOOL a) BOOL: (a | FALSE | TRUE);`

d) `OP ≪ =, EQ ≫ = (BOOL a, b) BOOL: (a ∧ b) ∨ (¬ a ∧ ¬ b);`

e) `OP ≪ ≠, /=, NE ≫ = (BOOL a, b) BOOL: ¬ (a = b);`

f) `OP ABS = (BOOL a) INT: (a | 1 | 0);`

26.2.3.4 Operations on integral operands

a) `OP ≪ <, LT ≫ = (`*L* `INT a, b) BOOL:`
C *true if the value of 'a' is smaller than* {17_2.1.3.1.e} *that of 'b' and false otherwise* **C** ;

b) `OP ≪ ≤, <=, LE ≫ = (`*L* `INT a, b) BOOL: ¬ (b < a);`

c) `OP ≪ =, EQ ≫ = (`*L* `INT a, b) BOOL: a ≤ b ∧ b ≤ a;`

d) `OP ≪ ≠, /=, NE ≫ = (`*L* `INT a, b) BOOL: ¬ (a = b);`

e) `OP ≪ ≥, >=, GE ≫ = (`*L* `INT a, b) BOOL: b ≤ a;`

f) `OP ≪ >, GT ≫ = (`*L* `INT a, b) BOOL: b < a;`

g) `OP - = (`*L* `INT a, b)` *L* `INT:`
C *the value of 'a' minus* {17_2.1.3.1.e} *that of 'b'* **C** ;

h) `OP - = (`*L* `INT a)` *L* `INT:` *L* `0 - a;`

i) `OP + = (`*L* `INT a, b)` *L* `INT: a - -b;`

j) `OP + = (`*L* `INT a)` *L* `INT: a;`

k) `OP ABS = (`*L* `INT a)` *L* `INT: (a <` *L* `0 | -a | a);`

l)
```
OP ≪ ×, * ≫ = (L INT a) L INT:
  BEGIN L INT s := L 0, i := ABS b;
    WHILE i ≥ L 1
    DO s := s + a, i := i - L 1 OD;
    (b < L 0 | -s | s)
  END;
```

m)
```
OP ≪ ÷, %, OVER ≫ = (L INT a, b) L INT:
  IF b ≠ L 0
  THEN L INT q := L 0, r := ABS a;
    WHILE (r := r - ABS b) ≥ L 0 DO q := q + L 1 OD;
    (a < L 0 ∧ b > L 0 ∨ a ≥ L 0 ∧ b < L 0 | -q | q)
  FI;
```

n)
```
OP ≪ ÷×, ÷*, %*, MOD ≫ = (L INT a, b) L INT:
  ( L INT r = a - a ÷ b × b; r < 0 | r + ABS b | r);
```
[2]

o) `OP / = (`*L* `INT a, b)` *L* `REAL: (a) /` *L* `REAL (b);`

[2] `MOD` always yields a non-negative result.

p) `OP ≪ ↑, **, UP ≫ = (L INT a, b) L INT:`
`(b ≥ 0 | L INT p := L 1; TO b DO p := p × a OD; p);`

q) `OP LENG = (L INT a) LONG L INT:`
C *the long L integral value lengthened from* {17_2.1.3.1.e} *the value of 'a'* **C** ;

r) `OP SHORTEN = (LONG L INT a) L INT:`
C *the L integral value, if it exists, which can be lengthened to* {17_2.1.3.1.e} *the value of 'a'* **C** ;

s) `OP ODD = (L INT a) BOOL: ABS a ÷× L 2 = L 1;`

t) `OP SIGN = (L INT a) INT: (a > L 0 | 1 |: a < L 0 | -1 | 0);`

u) `OP ≪ ⊥, +×, +*, I ≫ = (L INT a, b) L COMPL : (a, b);`

26.2.3.5 Operations on real operands

a) `OP ≪ <, LT ≫ = (L REAL a, b) BOOL:`
C *true if the value of 'a' is smaller than* {17_2.1.3.1.e} *that of 'b' and false otherwise* **C** ;

b) `OP ≪ ≤, <=, LE ≫ = (L REAL a, b) BOOL: ¬ (b < a);`

c) `OP ≪ =, EQ ≫ = (L REAL a, b) BOOL: a ≤ b ∧ b ≤ a;`

d) `OP ≪ ≠, /=, NE ≫ = (L REAL a, b) BOOL: ¬ (a = b);`

e) `OP ≪ ≥, >=, GE ≫ = (L REAL a, b) BOOL: b ≤ a;`

f) `OP ≪ >, GT ≫ = (L REAL a, b) BOOL: b < a;`

g) `OP - = (L REAL a, b) L REAL:`
C *the value of 'a' minus* {17_2.1.3.1.e} *that of 'b'* **C** ;

h) `OP - = (L REAL a) L REAL: L 0 - a;`

i) `OP + = (L REAL a, b) L REAL: a - -b;`

j) `OP + = (L REAL a) L REAL: a;`

k) `OP ABS = (L REAL a) L REAL: (a < L 0 | -a | a);`

l) `OP ≪ ×, * ≫ = (L REAL a) L REAL:`
C *the value of 'a' times {*17_2*.1.3.1.e} that of 'b'* **C** ;

m) `OP / = (L REAL a, b) L REAL:`
C *the value of 'a' divided by {*17_2*.1.3.1.e} that of 'b'* **C** ;

n) `OP LENG = (L REAL a) LONG L REAL:`
C *the long L real value lengthened from {*17_2*.1.3.1.e} the value of 'a'* **C** ;

o) `OP SHORTEN = (LONG L REAL a) L REAL:`
C *if* `ABS a ≤ S LENG max real` *, then a L* `REAL` *value 'v' such that, for any L* `REAL` *value 'w',*
`ABS (LENG v - a) ≤ ABS (LENG w - a)` **C** ;

p) `OP ROUND = (L REAL a) L INT:`
C *a L integral value, if one exists, which is widenable to* {17_2.1.3.1.e} *a L* `REAL` *value differing by not more than one-half from the value of 'a'* **C** ;

q) OP SIGN = (L REAL a) INT: (a > L 0 | 1 |: a < L 0 | -1 | 0);

r)
```
OP ENTIER = (L REAL a) L REAL:
     BEGIN L INT j := L 0;
       WHILE j < a DO j := j + L 1 OD;
       WHILE j > a DO j := j - L 1 OD;
       j
     END;
```

s) OP ≪ ⊥, +×, +*, I ≫ = (L REAL a, b) L COMPL : (a, b);

26.2.3.6 Operations on arithmetic operands

a) OP P = (L REAL a, L INT b) L REAL: a P L REAL (b);

b) OP P = (L INT a, L REAL b) L REAL: L REAL (a) P b;

c) OP R = (L REAL a, L INT b) BOOL: a R L REAL (b);

d) OP R = (L INT a, L REAL b) BOOL: L REAL (a) R b;

e) OP ≪ ⊥, +×, +*, I ≫ = (L REAL a, L INT b) L COMPL: (a, b);

f) OP ≪ ⊥, +×, +*, I ≫ = (L INT a, L REAL b) L COMPL: (a, b);

g)
```
OP ≪ ↑, **, UP ≫ = (L REAL a, INT b) L REAL:
   (L REAL p := L 1; TO ABS b DO p := p × a OD; (b ≥ 0 | p | L 1 / p));
```

26.2.3.7 Operations on character operands

a) OP R = (CHAR a, b) BOOL: ABS a R ABS b; {26_{10}.2.1.n}

b) OP + = (CHAR a, b) STRING: (a, b);

26.2.3.8 Operations on complex operands

a) OP RE = (L COMPL a) L REAL: re OF a;

b) OP IM = (L COMPL a) L REAL: im OF a;

c) OP ABS = (L COMPL a) L REAL: L sqrt (RE a ↑ 2 + IM a ↑ 2);

d)
```
OP ARG = (L COMPL a) L REAL:
   IF L REAL re = RE a, im = IM a;
     re ≠ L 0 ∨ im ≠ L 0
   THEN IF ABS re > ABS im
     THEN L arctan (im / re) + L pi / L 2 *
       (im < L 0 | SIGN re - 1 | 1 - SIGN re)
     ELSE - L arctan (re / im) + L pi / L 2 × SIGN im
     FI
   FI;
```

e) OP CONJ = (*L* COMPL a) *L* COMPL: RE a ⊥ − IM a;

f) OP ≪ =, EQ ≫ = (*L* COMPL a, b) BOOL: RE a = RE b ∧ IM a = IM b;

g) OP ≪ ≠, /=, NE ≫ = (*L* COMPL a, b) BOOL: ¬ (a = b);

h) OP − = (*L* COMPL a, b) *L* COMPL: (RE a − RE b) ⊥ (IM a − IM b);

i) OP − = (*L* COMPL a) *L* COMPL: −RE a ⊥ −IM a;

j) OP + = (*L* COMPL a, b) *L* COMPL: (RE a + RE b) ⊥ (IM a + IM b);

k) OP + = (*L* COMPL a) *L* COMPL: a;

l) OP ≪ ×, * ≫ = (*L* COMPL a, b) *L* COMPL:
(RE a × RE b − IM a × IM b) ⊥ (RE a × IM b + IM a × RE b);

m) OP / = (*L* COMPL a, b) *L* COMPL:
(*L* REAL d = RE (b × CONJ b); *L* COMPL n = a* CONJ b;
(RE n / d) ⊥ (IM n / d));

n) OP LENG = (*L* COMPL a) LONG *L* COMPL: LENG RE a ⊥ LENG IM a;

o) OP SHORTEN = (LONG *L* COMPL a) *L* COMPL: SHORTEN RE a ⊥ SHORTEN IM a;

p) OP *P* = (*L* COMPL a, *L* INT b) *L* COMPL: a *P* *L* COMPL (b);

q) OP *P* = (*L* COMPL a, *L* REAL b) *L* COMPL: a *P* *L* COMPL (b);

r) OP *P* = (*L* INT a, *L* COMPL b) *L* COMPL: *L* COMPL (a) *P* b;

s) OP *P* = (*L* REAL a, *L* COMPL b) *L* COMPL: *L* COMPL (a) *P* b;

t) OP ≪ ↑, **, UP ≫ = (*L* COMPL a, INT b) *L* COMPL:
(*L* COMPL p := *L* 1; TO ABS b DO p := p × a OD; (b ≥ 0 | p | *L* 1 / p));

u) OP *E* = (*L* COMPL a, *L* INT b) BOOL: a *E* *L* COMPL (b);

v) OP *E* = (*L* COMPL a, *L* REAL b) BOOL: a *E* *L* COMPL (b);

w) OP *E* = (*L* INT a, *L* COMPL b) BOOL: b *E* a;

x) OP *E* = (*L* REAL a, *L* COMPL b) BOOL: b *E* a;

26.2.3.9 Bits and associated operations

a)
```
OP ≪ =, EQ ≫ = (L BITS a, b) BOOL:
  BEGIN BOOL c;
    FOR i TO L bits width
    WHILE c := (L F OF a) [i]= (L F OF b) [i]
    DO SKIP OD;
    c
  END;
```

b) OP ≪ ≠, /=, NE ≫ = (*L* BITS a, b) BOOL: ¬ (a = b);

c)
```
OP ≪ ∨, OR ≫ = (L BITS a, b) L BITS :
    BEGIN L BITS c;
      FOR i TO L bits width
      DO (L F OF c) [i] = (L F OF a) [i] ∨ (L F OF b) [i] OD;
      c
    END;
```

d)
```
OP ≪ ∧, &, AND ≫ = (L BITS a, b) L BITS :
    BEGIN L BITS c;
      FOR i TO L bits width
      DO (L F OF c) [i]:= (L F OF a) [i] ∧ (L F OF b) [i] OD;
      c
    END;
```

e)
```
OP ≪ ≤, <=, LE ≫ = (L BITS a, b) BOOL: (a ∨ b) = b;
```

f)
```
OP ≪ ≥, >=, GE ≫ = (L BITS a, b) BOOL: b ≤ a;
```

g)
```
OP ≪ ↑, UP, SHL ≫ = (L BITS a, INT b) L BITS :
    IF ABS b ≤ L bits width
    THEN L BITS c := a;
      TO ABS b
      DO IF b >0 THEN
        FOR i FROM 2 TO L bits width
        DO (L F OF e) [i - 1] := (L F OF c) [i] OD;
        (L F OF c) [L bits width] := FALSE
      ELSE
        FOR i FROM L bits width BY -1 TO 2
        DO (L F OF c) [i] := (L F OF c) [i - 1] OD;
        (L F OF c) [1] := FALSE
      FI OD;
      c
    FI;
```

h)
```
OP ≪ ↓, DOWN, SHR ≫ = (L BITS x, INT n) L BITS: x ↑ -n;
```

i)
```
OP ABS = (L BITS a) L INT :
    BEGIN L INT c := L 0;
      FOR i TO L bits width
      DO c := L2 × c + K ABS (L F OF a) [i] OD;
      c
    END;
```

j)
```
OP BIN = (L INT a) L BITS :
    IF a ≥ L 0
    THEN L INT b := a; L BITS c;
      FOR i FROM L bits width BY - 1 TO 1
      DO (L F OF c) [i] := ODD b; b := b % L 2 OD;
      c
    FI;
```

k)
```
OP ≪ ELEM, □ ≫ = (INT a, L BITS b) BOOL: (L F OF b) [a];
```

l) PROC L bits pack = ([] BOOL a) L BITS :
    IF INT n = ⌈ a[@1];
      n ≤ L bits width
    THEN L BITS c;
      FOR i TO L bits width
      DO (L F OF c) [i] :=
        (i ≤ L bits width − n | FALSE | a[@1][i − L bits width + n])
      OD;
      c
    FI;

m) OP ≪ ¬, ~, NOT ≫ = (L BITS a) L BITS :
    BEGIN L BITS c;
      FOR i TO L bits width DO (L F OF c) [i] := ¬ (L F OF a) [i] OD;
      c
    END;

n) OP LENG = (L BITS a) LONG L BITS : long L bits pack (a);

o) OP SHORTEN = (LONG L BITS a) L BITS: L bits pack ([] BOOL (a)
    [long L bits width − L bits width + 1 :]);

26.2.3.10 Bytes and associated operations

a) OP R = (L BYTES a, b) BOOL: STRING (a) R STRING (b);

b) OP ≪ ELEM, □ ≫ = (INT a, L BYTES b) CHAR: (L F OF b) [a];

c) PROC L bytes pack = (STRING a) L BYTES:
    IF INT n = ⌈ a [@1];
      n ≤ L bytes width
    THEN L BYTES c;
      FOR i TO L bytes width
      DO (L F OF c) [i] := (i ≤ n | a[@1][i] | null character) OD;
      c
    FI;

d) OP LENG = (L BYTES a) LONG L BYTES: long L bytes pack (a);

e) OP SHORTEN = (LONG L BYTES a) L BYTES:
    L bytes pack (STRING (a) [: L bytes width]);

26.2.3.11 Strings and associated operations

a) OP ≪ <, LT ≫ = (STRING a, b) BOOL:
    BEGIN INT m = ⌈ a[@1], n = ⌈ b[@1]; INT c := 0;
      FOR i TO (m < n | m | n)
      WHILE (c := ABS a [@1][i] − ABS b[@1][i]) = 0
      DO SKIP OD;

```
      (c = 0 | m < n ∧ n > 0 | c < 0)
    END;
```

b) `OP ≪ ≤, <=, LE ≫ = (STRING a, b) BOOL: ¬ (b < a);`

c) `OP ≪ =, EQ ≫ = (STRING a, b) BOOL: a ≤ b ∧ b ≥ a;`

d) `OP ≪ ≠, /=, NE ≫ = (STRING a, b) BOOL: ¬ (a = b);`

e) `OP ≪ ≥, >=, GE ≫ = (STRING a, b) BOOL: b ≤ a;`

f) `OP ≪ >, GT ≫ = (STRING a, b) BOOL: b < a;`

g) `OP` R `= (STRING a, CHAR b) BOOL: a` R `STRING (b);`

h) `OP` R `= (CHAR a, STRING b) BOOL: STRING (a)` R `b;`

i)
```
OP + = (STRING a, b) STRING:
  (INT m = (INT la = ⌈ a[@1]; la < 0 | 0 | la),
    n = (INT lb = ⌈ b[@1]; lb < 0 | 0 | lb);
  [1 : m + n] CHAR c;
  c[1 : m] := a[@1]; c[m + 1 : m + n] := b[@1]; c);
```
[3]

j) `OP + = (STRING a, CHAR b) STRING: a + STRING (b);`

k) `OP + = (CHAR a, STRING b) STRING: STRING (a) + b;`

l)
```
OP ≪ ×, * ≫ = (STRING a, INT b) STRING: (STRING c; TO b DO c := c + a OD;
  c);
```

m) `OP ≪ ×, * ≫ = (INT a, STRING b) STRING: b × a;`

n) `OP ≪ ×, * ≫ = (CHAR a, INT b) STRING: STRING (a) × b;`

o) `OP ≪ ×, * ≫ = (INT a, CHAR b) STRING: b × a;`

{The operations defined in a, g and h imply that if `ABS "a" < ABS "b"`, then `""< "a"; "a"< "b"; "aa"< "ab"; "aa" < "ba"; "ab" < "b"` and `"ab" < "ba"`.}

26.2.3.12 Operations combined with assignations

a)
```
OP ≪ MINUSAB, -:= ≫ = (REF L INT a, L INT b) REF L INT:
    a := a - b;
```

b)
```
OP ≪ MINUSAB, -:= ≫ = (REF L REAL a, L REAL b) REF L REAL:
    a := a - b;
```

c)
```
OP ≪ MINUSAB, -:= ≫ = (REF L COMPL a, L COMPL b) REF L COMPL:
    a := a - b;
```

d)
```
OP ≪ PLUSAB, +:= ≫ = (REF L INT a, L INT b) REF L INT:
    a := a + b;
```

[3] The assignments in this line have potential bounds errors when `⌈ a[@1] < 0` or `⌈ b[@1] < 0` and should read
`(m > 0 | c[1 : m] := a[@1]); (n > 0 | c[m + 1 : m + n] := b[@1]); c`

e) `OP ≪ PLUSAB, +:= ≫ = (REF L REAL a, L REAL b) REF L REAL:`
`a := a + b;`

f) `OP ≪ PLUSAB, +:= ≫ = (REF L COMPL a, L COMPL b) REF L COMPL:`
`a := a + b;`

g) `OP ≪ TIMESAB, ×:=, *:= ≫ = (REF L INT a, L INT b) REF L INT :`
`a := a × b;`

h) `OP ≪ TIMESAB, ×:=, *:= ≫ = (REF L REAL a, L REAL b) REF L REAL:`
`a := a × b;`

i) `OP ≪ TIMESAB, ×:=, *:= ≫ = (REF L COMPL a, L COMPL b) REF L COMPL:`
`a := a × b;`

j) `OP ≪ OVERAB, ÷:=, %:= ≫ = (REF L INT a, L INT b) REF L INT:`
`a := a ÷ b;`

k) `OP ≪ MODAB, ÷×:=, ÷*:=, %*:= ≫ = (REF L INT a, L INT b) REF L INT:`
`a := a ÷× b;`

l) `OP ≪ DIVAB, /:= ≫ = (REF L REAL a, L REAL b) REF L REAL:`
`a := a / b;`

m) `OP ≪ DIVAB, /:= ≫ = (REF L COMPL a, L COMPL b) REF L COMPL:`
`a := a / b;`

n) `OP Q = (REF L REAL a, L INT b) REF L REAL:`
`a Q L REAL (b);`

o) `OP Q = (REF L COMPL a, L INT b) REF L COMPL:`
`a Q L COMPL (b);`

p) `OP Q = (REF L COMPL a, L REAL b) REF L COMPL:`
`a Q L COMPL (b);`

q) `OP ≪ PLUSAB, +:= ≫ = (REF STRING a, STRING b) REF STRING:`
`a := a + b;`

r) `OP ≪ PLUSTO, +=: ≫ = (STRING a, REF STRING b) REF STRING:`
`b := a + b;`

s) `OP ≪ PLUSAB, +:= ≫ = (REF STRING a, CHAR b) REF STRING:`
`a +:= STRING (b);`

t) `OP ≪ PLUSTO, +=: ≫ = (CHAR a, REF STRING b) REF STRING:`
`STRING (a) +=: b;`

u) `OP ≪ TIMESAB, ×:=, *:= ≫ = (REF STRING a, INT b) REF STRING:`
`a := a × b;`

26.2.3.13 Standard mathematical constants and functions

a) `L REAL L pi` = **C** a L real value close to π; see Math. of Comp. V. 16, 1962, pp. 80-99 **C** ;

b) `PROC L sqrt = (L REAL x) L REAL:` **C** if `x` $\geq$ `L 0`, a L real value close to the square root of 'x' **C** ;

c) PROC L exp = (L REAL x) L REAL: **C** a L real value, if one exists, close to the exponential function of 'x' **C** ;

d) PROC L ln = (L REAL x) L REAL: **C** a L real value, if one exists, close to the natural logarithm of x **C** ;

e) PROC L cos = (L REAL x) L REAL: **C** a L real value close to the cosine of 'x' **C** ;

f) PROC L arccos = (L REAL x) L REAL: **C** if ABS x ≤ L 1, a L real value close to the inverse cosine of 'x', L 0 ≤ L arccos (x) ≤ L pi **C** ;

g) PROC L sin = (L REAL x) L REAL: **C** a L real value close to the sine of 'x' **C** ;

h) PROC L arcsin = (L REAL x) L REAL: **C** if ABS x ≤ L 1, a L real value close to the inverse sine of 'x', ABS L arcsin (x) ≤ L pi / L 2 **C** ;

i) PROC L tan = (L REAL x) L REAL: **C** a L real value, if one exists, close to the tangent of 'x' **C** ;

j) PROC L arctan = (L REAL x) L REAL: **C** a L real value close to the inverse tangent of 'x', ABS L arctan (x) ≤ L pi / L 2 **C** ;

k) PROC L next random = (REF L INT a) L REAL:
(a :=
C the next pseudo-random L integral value after 'a' from a uniformly distributed sequence on the interval [L 0, maxint] **C** ;
C the real value corresponding to 'a' according to some mapping of integral values [L 0, L max int] into real values [L 0, L 1) {i.e., such that 0 ≤ x < 1} such that the sequence of real values so produced preserves the properties of pseudo-randomness and uniform distribution of the sequence of integral values **C**) ;

26.2.4 Synchronization operations

The elaboration of a **parallel-clause** P {18_3.3.1.c} in an environ E is termed a "parallel action". The elaboration of a constituent **unit** of P in E is termed a "process" of that parallel action.

Any elaboration A {in some environ} of either of the **ENCLOSED-clauses** delineated by the **pragmats** {25_9.2.1.b} PR start of incompatible part PR and PR finish of incompatible part PR in the forms 26_{10}.2.4.d and 26_{10}.2.4.e is incompatible with {17_2.1.4.2.e} any elaboration B of either of those **ENCLOSED-clauses** if A and B are descendent actions {17_2.1.4.2.b} of different processes of some same parallel action.

a) MODE SEMA = STRUCT (REF INT F);

b) OP LEVEL = (INT a) SEMA: (SEMA s; F OF s := HEAP INT := a; s);

c) OP LEVEL = (SEMA a) INT: F OF a;

d) OP DOWN = (SEMA edsger) VOID:
BEGIN REF INT dijkstra = F OF edsger;
WHILE
PR start of incompatible part PR
IF dijkstra $\geq$ 1 THEN dijkstra −:= 1; FALSE
ELSE

C let P be the process such that the elaboration of this pseudo-comment {26_{10}.1.3.Step 7} is a descendent action of P, but not of any other process descended from P; the process P is halted {17_2.1.4.3.f} **C** ;

TRUE
FI
PR finish of incompatible part PR
DO SKIP OD
END;

e) OP UP = (SEMA edsger) VOID:
PR start of incompatible part PR
IF REF INT dijkstra = F OF edsger; (dijkstra +:= 1) $\geq$ 1
THEN

C all processes are resumed {17_2.1.4.3.g} which are halted because the integer referred to by the name yielded by 'dijkstra' was smaller than one **C**

FI
PR finish of incompatible part PR;

26.3 Transput declarations

{"So it does!" said Pooh, "It goes in!"
"So it does!" said Piglet, "And it comes out!"
"Doesn't it?" said Eeyore,
"It goes in and out like anything,"
Winnie-the-Pooh, A.A. Milne. }

{Three ways of "transput" (i.e., input and output) are provided by the **standard-prelude**, viz., formatless transput {26_{10}.3.3}, formatted transput {26_{10}.3.5} and binary transput {26_{10}.3.6}.}

26.3.1 Books, channels and files

{"Books", "channels" and "files" model the transput devices of the physical machine used in the implementation.}

26.3.1.1 Books and backfiles

{aa) All information within the system is to be found in a number of "books". A book {a} is a structured value including a field `text` of the mode specified by `FLEXTEXT` {b} which refers to information in the form of characters. The `text` has a variable number of pages, each of which may have a variable number of lines, each of which may have a variable number of characters. Positions within the `text` are indicated by a page number, a line number and a character number. The book includes a field `lpos` which indicates the "logical end" of the book, i.e., the position up to which it has been filled with information, a string `idf`, which identifies the book and which may possibly include other information, e.g., ownership, and fields `putting` and `users` which permit the book to be opened {26_{10}.3.1.4.d} on more than one file simultaneously only if putting is not possible on any of them.

bb) The books in the system are accessed via a chain of backfiles. The chain of books available for opening {26_{10}.3.1.4.dd} is referenced by `chainbfile`. A given book may be referenced by more than one backfile on this chain, thus allowing simultaneous access to a single book by more than one process {26_{10}.2.4}. However such access can only be for reading a book, since only one process may access a book such that it may be written to {aa}. The chain of books which have been locked {26_{10}.3.1.4.o} is referenced by `lockedbfile`.

cc) Simultaneous access by more than one process to the chain of backfiles is prevented by use of the semaphore `bfileprotect`, which provides mutual exclusion between such processes.

dd) Books may be created (e.g., by input) or destroyed (e.g., after output) by tasks (e.g., the operating system) in the **system-task-list** {26_{10}.4.2}, such books being then added to or removed from the chain of backfiles.}

a)
```
MODE ℵ0 BOOK =
  STRUCT (FLEXTEXT text,
    POS lpos ¢ logical end of book ¢,
    STRING idf ¢ identification ¢,
    BOOL putting ¢ TRUE if the book may be written to ¢,
    INT users ¢ the number of times the book is opened ¢);
```

b)
```
MODE ℵ0 TEXT = REF [][][] CHAR,
MODE ℵ0 FLEXTEXT = REF FLEX [] FLEX [] FLEX [] CHAR;
```

c)
```
MODE ℵ0 POS = STRUCT (INT p, l, c);
```

d)
```
PRIO ℵ0 BEYOND=5,
OP BEYOND = (POS a, b) BOOL:
  IF p OF a < p OF b THEN FALSE
  ELIF p OF a > p OF b THEN TRUE
  ELIF l OF a < l OF b THEN FALSE
  ELIF l OF a > l OF b THEN TRUE
  ELSE c OF a > c OF b
  FI;
```

e) `MODE ℵ0 BFILE = STRUCT (REF BOOK book, REF BFILE next);`

f) `REF BFILE ℵ0 chainbfile := NIL;`

g) `REF BFILE ℵ0 lockedbfile := NIL;`

h) `SEMA ℵ0 bfileprotect = (SEMA s; F OF s := PRIM INT := 1; s);`

26.3.1.2 Channnels

{aa) A "channel" corresponds to one or more physical devices (e.g., a card reader, a card punch or a line printer, or even to a set up in nuclear physics the results of which are collected by the computer), or to a filestore maintained by the operating system. A channel is a structured value whose fields are routines returning truth values which determine the available methods of access to a book linked via that channel, Since the methods of access to a book may well depend on the book as well as on the channel (e.g., a certain book may have been trapped so that it may be read, but not written to), most of these properties depend on both the channel and the book. These properties may be examined by use of the environment enquiries provided for files {26_{10}.3.1.3.ff}. Two environment enquiries are provided for channels. These are:

- `estab possible`, which returns `true` if another file may be "established" {26_{10}.3.1.4.cc} on the channel;
- `standconv`, which may be used to obtain the default "conversion key" {bb} for the channel,

bb) A "conversion key" is a value of the mode specified by `CONV` which is used to convert characters to and from the values as stored in "internal" form and as stored in "external" form in a book. It is a structured value comprising a row of structures, each of which contains a value in internal form and its corresponding external value. The implementation may provide additional conversion keys in its **library-prelude**.

cc) Three standard channels are provided, with properties as defined below (e,f,g); the implementation may provide additional channels in its **library-prelude**. The channel number field is provided in order that different channels with otherwise identical possibilities may be distinguished.}

a)
```
MODE CHANNEL =
    STRUCT (PROC (REF BOOK) BOOL ℵ0 reset, ℵ0 set, ℵ0 get,
       ℵ0 put, ℵ0 bin, ℵ0 compress, ℵ0 reidf,
      PROC BOOL ℵ0 estab, PROC POS ℵ0 max pos,
      PROC (REF BOOK) CONV ℵ0 standconv, INT ℵ0 channel number);
```

b)
```
MODE ℵ0 CONV = STRUCT ([1: INT (SKIP)]
    STRUCT (CHAR internal, external) F);
```

c) `PROC estab possible = (CHANNEL chan) BOOL: estab OF chan;`

d) `PROC standconv = (CHANNEL chan) PROC (REF BOOK) CONV: standconv OF chan;`

e) `CHANNEL stand in channel` = **C** a channel value whose field selected by 'get' is a routine which always returns true, and whose other fields are some suitable values **C** ;

f) `CHANNEL stand out channel` = **C** a channel value whose field selected by 'put' is a routine which always returns true, and whose other fields are some suitable values **C** ;

g) `CHANNEL stand back channel` = **C** a channel value whose fields selected by 'set', 'reset', 'get', 'put' and 'bin' are routines which always return true, and whose other fields are some suitable values **C** ;

26.3.1.3 Files

{aa) A "file" is the means of communication between a **particular-program** and a book which has been opened on that file via some channel. It is a structured value which includes a reference to the book to which it has been linked {26_{10}.3.1.4.bb} and a separate reference to the `text` of the book. The file also contains information necessary for the transput routines to work with the book, including its current position `cpos` in the `text`, its current "state" {bb}, its current "format" {26_{10}.3.4} and the channel on which it has been opened.

bb) The "state" of a file is determined by five fields:

- `read mood`, which is `true` if the file is being used for input;
- `write mood`, which is `true` if the file is being used for output;
- `char mood`, which is `true` if the file is being used for character transput;
- `bin mood`, which is `true` if the file is being used for binary transput:
- `opened`, which is `true` if the file has been linked to a book.

cc) A file includes some "event routines", which are called when certain conditions arise during transput. After opening a file, the event routines provided by default return `false` when called, but the programmer may provide other event routines. Since the fields of a file are not directly accessible to the user, the event routines may be changed by use of the "on routines" (l,m,n,o,p,q,r) . The event routines are always given a reference to the file as a parameter. If the elaboration of an event routine is terminated, then the transput routine which called it can take no further action: otherwise, if it returns `true`, then it is assumed that the condition has been mended in some way, and, if possible, transput continues, but if it returns `false`, then the system continues with its default action. The on routines are:

- `on logical file end`. The corresponding event routine is called when, during input from a book or as a result of calling `set`, the logical end of the book is reached (see 26_{10}.3.1.6.dd) .

Example: The programmer wishes to count the number of integers on his input tape. The file `intape` was opened in a surrounding **range**. If he writes:

```
BEGIN INT n := 0;
  on logical file end (intape, (REF FILE file) BOOL: GOTO f);
  DO get (intape, LOC INT); n +:= 1 OD;
  f: print (n)
END,
```

then the assignment to the field of `intape` violates the scope restriction, since the scope of the routine `(REF FILE file) BOOL: GOTO f` is smaller than the scope of `intape`, so he has to write:

```
BEGIN INT n := 0; FILE auxin := intape;
  on logical file end (auxin, (REF FILE file) BOOL: GOTO f);
  DO get (auxin, LOC INT); n +:= 1 OD;
  f: print (n)
END.
```

- `on physical file end`. The corresponding event routine is called when the current page number of the file exceeds the number of pages in the book and further transput is attempted (see 26_{10}.3.1.6.dd),

- `on page end`. The corresponding event routine is called when the current line number exceeds the number of lines in the current page and further transput is attempted (see 26_{10}.3.1.6.dd) .

- `on line end`. The corresponding event routine is called when the current character number of the file exceeds the number of characters in the current line and further transput is attempted (see 26_{10}.3.1.6.dd),

  Example: The programmer wishes automatically to give a heading at the start of each page on his file `f`:

  ```
  on page end (f, (REF FILE file) BOOL:
    (put (file, (newpage, "page number ", whole (i +:= 1, 0),
      newline)); TRUE)
    ¢ it is assumed that i has been declared elsewhere ¢)
  ```

- `on char error`. The corresponding event routine is called when a character conversion was unsuccessful or when, during input, a character is read which was not "expected" {26_{10}.3.4.1.ll}. The event routine is called with a reference to a character suggested as a replacement. The event routine provided by the programmer may assign some character other than the suggested one. If the event routine returns `true`, then that suggested character as possibly modified is used,

  Example: The programmer wishes to read sums of money punched as `"$123.45"`, `" $23.45"`, `"  $3.45"`, etc.:

```
on char error (stand in, (REF FILE f, REF CHAR sugg) BOOL:
  IF sugg = "0"
  THEN CHAR c; backspace (f); get (f, c);
    (c = "$" | get (f, sugg); TRUE | FALSE)
  ELSE FALSE
  FI);
INT cents; readf (($3z"."dd$, cents))
```

- `on value error`. The corresponding event routine is called when:

  (i) during formatted transput an attempt is made to transput a value under the control of a "picture" with which it is incompatible, or when the number of "frames" is insufficient. If the routine returns `true`, then the current value and picture are skipped and transput continues; if the routine returns `false`, then first, on output, the value is output by put, and next `undefined` is called;

  (ii) during input it is impossible to convert a string to a value of some given mode (this would occur if, for example, an attempt were made to read an integer larger than `max int` (26_{10}.2.1.c)) .

- `on format end`. The corresponding event routine is called when, during formatted transput, the format is exhausted while some value still remains to be transput. If the routine returns `true`, then `undefined` is called if a new format has not been provided for the file by the routine; otherwise, the current format is repeated.

dd) The `conv` field of a file is its current conversion key (26_{10}.3.1.2.bb) . After opening a file, a default conversion key is provided. Some other conversion key may be provided by the programmer by means of a call of `make conv` {j}. Note that such a key must have been provided in the **library-prelude**.

ee) The routine `make term` is used to associate a string with a file. This string is used when inputting a variable number of characters, any of its characters serving as a terminator.

ff) The available methods of access to a book which has been opened on a file may be discovered by calls of the following routines (note that the yield of such a call may be a function of both the book and the channel, and of other environmental factors not defined by this Report):

- `get possible`, which returns `true` if the file may be used for input;
- `put possible`, which returns `true` if the file may be used for output;
- `bin possible`, which returns `true` if the file may be used for binary transput;
- `compressible`, which returns `true` if lines and pages will be compressed {26_{10}.3.1.6.aa} during output, in which case the book is said to be "compressible";

- `reset possible`, which returns `true` if the file may be reset, i.e., its current position set to (1, 1, 1);
- `set possible`, which returns `true` if the file may be set, i.e., the current position changed to some specified value; the book is then said to be a "random access" book and, otherwise, a "sequential access" book:
- `reidf possible`, which returns `true` if the `idf` field of the book may be changed:
- `chan`, which returns the channel on which the file has been opened {this may be used, for example, by a routine assigned by `on physical file end`, in order to open another file on the same channel}.

gg) On sequential access books, `undefined` (26_{10}.3.1.4.a) is called if binary and character transput is alternated, i.e., after opening or resetting (26_{10}.3.1.6.j), either is possible but, once one has taken place, the other may not until after another reset.

hh) On sequential access books, output immediately causes the logical end of the book to be moved to the current position (unless both are in the same line); thus input may not follow output without first resetting (26_{10}.3.1.6.j) .

Example:

```
BEGIN FILE f1, t2; [1: 10000] INT x; INT n := 0;
  open (f1, "", channel 2);
  f2 := f1;
    ¢ now f1 and f2 can be used interchangeably ¢
  make conv (f1, flexocode); make conv (f2, telexcode);
    ¢ now f1 and f2 use different codes; flexocode and telexcode are
    defined in the library-prelude for this implementation ¢
  reset (f1);
    ¢ consequently, f2 is reset too ¢
  on logical file end (f1, (REF FILE f) BOOL: GOTO done);
  FOR i DO get (f1, x [i]); n := i OD;
    ¢ too bad if there are more than 10000 integers in the input ¢
done:
  reset (f1); FOR i TO n DO put (f2, x [i]) OD;
  close (f2) ¢ f1 is now closed too ¢
END }
```

a)

```
MODE FILE =
     STRUCT (REF BOOK ℵ0 book,
       UNION (FLEXTEXT, TEXT) ℵ0 text,
       CHANNEL ℵ0 chan,
       REF FORMAT ℵ0 format,
       REF INT ℵ0 forp,
       REF BOOL ℵ0 read mood, ℵ0 write mood, ℵ0 char mood, ℵ0 bin mood,
```

```
      ℵ0 opened,
    REF POS ℵ0 cpos ¢ current position ¢,
    STRING ℵ0 term ¢ string terminator ¢,
    CONV ℵ0 conv ¢ character conversion key ¢,
    PROC (REF FILE) BOOL ℵ0 logical file mended,
      ℵ0 physical file mended, ℵ0 page mended,
      ℵ0 line mended, ℵ0 format mended,
      ℵ0 value error mended,
    PROC (REF FILE, REF CHAR) BOOL ℵ0 char error mended);
```

b) `PROC get possible = (REF FILE f) BOOL:`
`(opened OF f | (get OF chan OF f) (book OF f) | undefined; SKIP);`

c) `PROC put possible = (REF FILE f) BOOL:`
`(opened OF f | (put OF chan OF f) (book OF f) | undefined; SKIP);`

d) `PROC bin possible = (REF FILE f) BOOL:`
`(opened OF f | (bin OF chan OF f) (book OF f) | undefined; SKIP);`

e) `PROC compressible = (REF FILE f) BOOL:`
`(opened OF f | (compress OF chan OF f) (book OF f) | undefined; SKIP);`

f) `PROC reset possible = (REF FILE f) BOOL:`
`(opened OF f | (reset OF chan OF f) (book OF f) | undefined; SKIP);`

g) `PROC set possible = (REF FILE f) BOOL:`
`(opened OF f | (set OF chan OF f) (book OF f) | undefined; SKIP);`

h) `PROC reidf possible = (REF FILE f) BOOL:`
`(opened OF f | (reidf OF chan OF f) (book OF f) | undefined; SKIP);`

i) `PROC chan = (REF FILE f) CHANNEL:`
`(opened OF f | chan OF f | undefined; SKIP);`

j) `PROC make conv = (REF FILE f, PROC (REF BOOK) CONV c) VOID:`
`(opened OF f | conv OF f := c (book OF f) | undefined);`

k) `PROC make term = (REF FILE f, STRING t) VOID: term OF f := t;`

l) `PROC on logical file end = (REF FILE f, PROC (REF FILE) BOOL p) VOID:`
`logical file mended OF f := p;`

m) `PROC on physical file end = (REF FILE f, PROC (REF FILE) BOOL p) VOID:`
`physical file mended OF f:= p;`

n) `PROC on page end = (REF FILE f, PROC (REF FILE) BOOL p) VOID:`
`page mended OF f := p;`

o) `PROC on line end = (REF FILE f, PROC (REF FILE) BOOL p) VOID:`
`line mended OF f := p;`

p) `PROC on format end = (REF FILE f, PROC (REF FILE) BOOL p) VOID:`
`format mended OF f := p;`

q) `PROC on value error = (REF FILE f, PROC (REF FILE) BOOL p) VOID:`
`value error mended OF f := p;`

```
r) PROC on char error = (REF FILE f, PROC (REF FILE,
      REF CHAR) BOOL p) VOID:
    char error mended OF f := p;

s) PROC reidf = (REF FILE f, STRING idf) VOID:
    IF opened OF f ∧ reidf possible (f) ∧ idf ok (idf)
    THEN idf OF book OF f := idf
    FI;
```

26.3.1.4 Opening and closing files

{aa) When, during transput, something happens which is left undefined, for example by explicitly calling `undefined` (a), this does not imply that the elaboration is catastrophically and immediately interrupted (2.1.4.3.h), but only that some sensible action is taken which is not or cannot be described by this Report alone and is generally implementation-dependent.

bb) A book is "linked" with a file by means of `establish` (b), `create` (c) or `open` (d) . The linkage may be terminated by means of `close` (n), `lock` (o) or `scratch` (p) .

cc) When a file is "established" on a channel, then a book is generated {20_5.2.3} with a `text` of the given size, the given identification string, with `putting` set to `true`, and the logical end of the book at (1, 1, 1) . An implementation may require (g) that the characters forming the identification string should be taken from a limited set and that the string should be limited in length, it may also prevent two books from having the same string. If the establishing is completed successfully, then the value 0 is returned; otherwise, some nonzero integer is returned (the value of this integer might indicate why the file was not established successfully). When a file is "created" on a channel, then a file is established with a book whose `text` has the default size for the channel and whose identification string is undefined.

dd) When a file is "opened", then the chain of backfiles is searched for the first book which is such that `match` (h) returns `true`. (The precise method of matching is not defined by this Report and will, in general, be implementation dependent. For example, the string supplied as parameter to open may include a password of some form.) If the end of the chain of backfiles is reached or if a book has been selected, but `putting` of the book yields `true`, or if putting to the book via the channel is possible and the book is already open, then the further elaboration is undefined. If the file is already open, an `UP gremlins` provides an opportunity for an appropriate system action on the book previously linked (in case no other copy of the file remains to preserve that linkage) .

ee) The routine `associate` may be used to associate a file with a value of the mode specified by either `REF [] CHAR`, `REF [][] CHAR` or `REF [][][] CHAR`, thus enabling such variables to be used as the book of a file,

ff) When a file is "closed", its book is attached to the chain of backfiles referenced by `chainbfile`. Some **system-task** is then activated by means of an `UP gremlins`. (This may reorganize the chain of backfiles, removing this book, or adding further copies of it. It may also cause the book to be output on some external device.)

gg) When a file is "locked", its book is attached to the chain of backfiles referenced by `lockedbfile`. Some **system-task** is then activated by means of an `UP gremlins`. A book which has been locked cannot be re-opened until some subsequent **system-task** has re-attached the book to the chain of backfiles available for opening.

hh) When a file is "scratched", some **system-task** is activated by means of an `UP gremlins`. (This may cause the book linked to the file to be disposed of in some manner.) }

a) `PROC ℵ0 undefined = INT:`
C some sensible system action yielding an integer to indicate what has been done; it is presumed that the system action may depend on a knowledge of any values accessible {17_2.1.2.c} inside the locale of any environ which is older than that in which this pseudo-comment is being elaborated notwithstanding that no Algol 68 construct written here could access those values **C** ;

b)
```
PROC establish =
  (REF FILE file, STRING idf, CHANNEL chan, INT p, l, c) INT:
  BEGIN
    DOWN bfileprotect;
    PRIM BOOK book :=
      (PRIM FLEX [1 : p] FLEX [1 : l] FLEX [1 : c] CHAR,
        (1, 1, 1), idf, TRUE, 1);
    IF file available (chan) ∧ (put OF chan) (book)
    ∧ estab OF chan ∧ ¬ (POS (p, l, c) BEYOND max pos OF chan)
    ∧ ¬ (POS (1, 1, 1) BEYOND POS (p, l, c)) ∧ idfok (idf)
    THEN
      (opened OF file | UP gremlins | UP bfileprotect);
      file :=
        (book, text OF book, chan, SKIP, SKIP,
        ¢ state: ¢ HEAP BOOL := FALSE, HEAP BOOL := TRUE,
        HEAP BOOL := FALSE, HEAP BOOL := FALSE, HEAP BOOL := TRUE,
        HEAP POS := (1, 1, 1), "", (standconv OF chan) (book),
        ¢ event routines: ¢ false, false, false, false, false, false,
        (REF FILE f, REF CHAR a) BOOL: FALSE);
      (¬ bin possible (file) | set char mood (file));
      0
    ELSE UP bfileprotect; undefined
    FI
  END;
```

c)
```
PROC create = (REF FILE file, CHANNEL chan) INT:
  BEGIN POS max pos = max pos OF chan;
    establish (file, SKIP, chan,
      p OF max pos, l OF max pos, c OF max pos)
  END;
```

d)
```
PROC open = (REF FILE file, STRING idf, CHANNEL chan) INT:
    BEGIN
      DOWN bfileprotect;
      IF file available (chan)
      THEN REF REF BFILE bf := chainbfile; BOOL found := FALSE;
        WHILE (REF BFILE (bf) :≠: NIL) ∧ ¬ found
        DO
          IF match (idf, chan, book OF bf)
          THEN found := TRUE
          ELSE bf := next OF bf
          FI
        OD;
        IF ¬ found
        THEN UP bfileprotect; undefined
        ELSE REF BOOK book := book OF bf;
          IF putting OF book ∨ (put OF chan) (book) ∧ users OF book > 0
          THEN
            UP bfileprotect; undefined ¢ in this case opening is
              inhibited by other users - the system may either
              wait, or yield nonzero (indicating unsuccessful
              opening) immediately ¢
          ELSE
            users OF book +:= 1;
            ((put OF chan) (book) | putting OF book := TRUE);
            REF REF BFILE (bf) := next OF bf; ¢ remove bfile from chain ¢
            (opened OF file | UP gremlins | UP bfileprotect);
            file :=
              (book, text OF book, chan, SKIP, SKIP,
              ¢ state: ¢ HEAP BOOL := FALSE, HEAP BOOL := FALSE,
              HEAP BOOL := FALSE, HEAP BOOL := FALSE,
              HEAP BOOL := TRUE,
              HEAP POS := (1, 1, 1), "", (standconv OF chan) (book),
              ¢ event routines: ¢ false, false, false, false, false,
              false, (REF FILE f, REF CHAR a) BOOL: FALSE);
            (¬ bin possible (file) | set char mood (file));
            (¬ get possible (file) | set write mood (file));
            (¬ put possible (file) | set read mood (file));
            0
          FI
        FI
      ELSE UP bfileprotect; undefined
      FI
    END;
```

e)
```
PROC associate =
    (REF FILE file, REF [][][] CHAR sss) VOID:
    IF ll ANW - this fails when UPB sss < 1 or UPB sss[1] < 1 gg
      INT p = LWB sss; INT l = LWB sss [p]; INT c = LWB sss[p][l];
      p = 1 ∧ l = 1 ∧ c = 1
    THEN
```

```
      PROC t = (REF BOOK a) BOOL: TRUE;
      PROC f = (REF BOOK a) BOOL: FALSE;
      CHANNEL chan = (t, t, t, t, f, f, f, BOOL: FALSE,
        POS: (max int, max int, max int), SKIP, SKIP);
      (opened OF file | DOWN bfileprotect; UP gremlins);
      file :=
        (HEAP BOOK := (SKIP, (UPB sss + 1, 1, 1),
          SKIP, TRUE, 1), sss, chan,
        SKIP, SKIP,
        ¢ state: ¢ HEAP BOOL := FALSE, HEAP BOOL := FALSE,
        HEAP BOOL := TRUE, HEAP BOOL := FALSE, HEAP BOOL := TRUE,
        HEAP POS := (1, 1, 1), "", SKIP,
        ¢ event routines: ¢ false, false, false, false, false, false,
        (REF FILE f, REF CHAR a) BOOL: FALSE)
    ELSE undefined
    FI;
```

f) `PROC ℵ0 file available = (CHANNEL chan) BOOL:`
`  ¢ true if another file, at this instant of time, may be opened on 'chan' and false otherwise ¢;`

g) `PROC ℵ0 idf ok = (STRING idf) BOOL:`
`  ¢ true if 'idf' is acceptable to the implementation as the identification of a new book and false otherwise ¢;`

h) `PROC ℵ0 match = (STRING idf, CHANNEL chan, REF BOOK book name) BOOL:`
`  ¢ true if the book referred to by 'book name' may be identified by 'idf', and if the book may legitimately be accessed through 'chan', and false otherwise ¢;`

i) `PROC ℵ0 false = (REF FILE file) BOOL: FALSE`
`  ¢ this is included for brevity in 'establish', 'open' and 'associate' ¢;`

j)
```
PROC ℵ0 set write mood = (REF FILE f) VOID:
  IF ¬ put possible (f) OR
    ¬ set possible (f) ∧ bin mood OF f ∧ read mood OF f
  THEN undefined
  ELSE REF BOOL (read mood OF f) := FALSE;
  REF BOOL (write mood OF f) := TRUE
  FI;
```

k)
```
PROC ℵ0 set read mood = (REF FILE f) VOID:
  IF ¬ get possible (f) OR
    ¬ set possible (f) ∧ bin mood OF f write mood OF f
  THEN undefined
  ELSE REF BOOL (read mood OF f) := TRUE;
    REF BOOL (write mood OF f) := FALSE
  FI;
```

l)
```
PROC ℵ0 set char mood = (REF FILE f) VOID:
  IF ¬ set possible (f) ∧ bin mood OF f
  THEN undefined
```

```
      ELSE REF BOOL (char mood OF f) := TRUE;
      REF BOOL (bin mood OF f) := FALSE
      FI;
```

m) `PROC ℵ0 set bin mood = (REF FILE f) VOID:`
```
      IF ¬ bin possible (f) ∨ ¬ set possible (f) ∧ char mood OF f
      THEN undefined
      ELSE REF BOOL (char mood OF f) := FALSE;
      REF BOOL (bin mood OF f) := TRUE
      FI;
```

n) `PROC close = (REF FILE file) VOID:`
```
      IF opened OF file
      THEN
        DOWN bfileprotect;
          REF BOOL (opened OF file) := FALSE;
          REF BOOK book = book OF file;
          putting OF book := FALSE; users OF book -:= 1;
          (text OF file | (FLEXTEXT): chainbfile :=
            PRIM BFILE := (book, chainbfile));
        UP gremlins
      FI;
```

o) `PROC lock (REF FILE file) VOID:`
```
      IF opened OF file
      THEN DOWN bfileprotect;
          REF BOOL (opened OF file) := FALSE;
          REF BOOK book = book OF file;
          putting OF book := FALSE; users OF book -:= 1;
          (text OF file | (FLEXTEXT): lockedbfile :=
            PRIM BFILE = (book, lockedbfile));
        UP gremlins
      FI;
```

p) `PROC scratch = (REF FILE file) VOID:`
```
      IF opened OF file
      THEN
        DOWN bfileprotect;
          REF BOOL (opened OF file) := FALSE;
          putting OF book OF file := FALSE;
          users OF book OF file -:= 1;
        UP gremlins
      FI;
```

26.3.1.5 Position enquiries

{aa) The "current position" of a book opened on a given file is the value referred to by the `cpos` field of that file. It is advanced by each transput operation in accordance with the number of characters written or read.

If c is the current character number and lb is the length of the current line, then at all times $1 \leq c \leq lb + 1$. $c = 1$ implies that the next transput operation will be to the first character of the line and $c = lb + 1$ implies that the line has overflowed and that the next transput operation will call an event routine. If $lb = 0$, then the line is empty and is therefore always in the overflowed state. Corresponding restrictions apply to the current line and page numbers. Note that, if the page has overflowed, the current line is empty and, if the book has overflowed, the current page and line are both empty (e).

bb) The user may determine the current position by means of the routines `char number`, `line number` and `page number` (a, b, c) .

cc) If the current position has overflowed the line, page or book, then it is said to be outside the "physical file" (f, g, h) .

dd) If, on reading, the current position is at the logical end, then it is said to be outside the "logical file" (i).}

{Each routine in this section calls `undefined` if the file is not open on entry.}

a)
```
PROC char number = (REF FILE f) INT:
    (opened OF f | c OF cpos OF f | undefined);
```

b)
```
PROC line number = (REF FILE f) INT:
    (opened OF f | l OF cpos OF f | undefined);
```

c)
```
PROC page number = (REF FILE f) INT:
    (opened OF f | p OF cpos OF f | undefined);
```

d)
```
PROC ℵ0 current pos = (REF FILE f) POS:
    (opened OF f | cpos OF f | undefined; SKIP);
```

e)
```
PROC ℵ0 book bounds = (REF FILE f) POS:
    BEGIN POS cpos = current pos (f);
        INT p = p OF cpos, l = l OF cpos;
        CASE text OF f IN
          (TEXT t1):
            (INT pb = UPB t1;
            INT lb = (p ≤ 0 ∨ p > pb | 0 | UPB t1 [p]);
            INT cb = (l ≤ 0 ∨ l > lb | 0 | UPB t1[p][l]);
            (pb, lb, cb)),
          (FLEXTEXT t2):
            (INT pb = UPB t2;
            INT lb = (p ≤ 0 ∨ p > pb | 0 | UPB t2[p]);
            INT cb = (l ≤ 0 ∨ l > lb | 0 | UPB t2[p][l]);
            (pb, lb, cb))
        ESAC
    END;
```

f)
```
PROC ℵ0 line ended = (REF FILE f) BOOL:
    (INT c = c OF current pos (f); c > c OF book bounds (f));
```

g) `PROC ℵ0 page ended = (REF FILE f) BOOL:`
`(INT l = l OF current pos (f); l > l OF book bounds (f));`

h) `PROC ℵ0 physical file ended = (REF FILE f) BOOL:`
`(INT p = p OF current pos (f); p > p OF book bounds (f));`

i) `PROC ℵ0 logical file ended = (REF FILE f) BOOL:`
`(lpos OF book OF f BEYOND current pos (f));`

26.3.1.6 Layout routines

{aa) A book input from an external medium by some **system-task** may contain lines and pages not all of the same length. Contrariwise, the lines and pages of a book which has been established (26_{10}.3.1.4.cc) are all initially of the size specified by the user. However if, during output to a compressible book (26_{10}.3.1.3.ff), `newline` (`newpage`) is called with the current position in the same line (page) as the logical end of the book, then that line (the page containing that line) is shortened to the character number (line number) of the logical end. Thus `print (("abcde", newline))` could cause the current line to be reduced to 5 characters in length. Note that it is perfectly meaningful for a line to contain no characters and for a page to contain no lines.

Although the effect of a channel whose books are both compressible and of random access (26_{10}.3.1.3.ff) is well defined, it is not anticipated that such a combination is likely to occur in actual implementations.

bb) The routines `space` (a), `newline` (c) and `newpage` (d) serve to advance the current position to the next character, line or page, respectively. They do not, however, (except as provided in cc below) alter the contents of the positions skipped over. Thus `print (("a", backspace, space))` has a different effect from `print (("a", backspace, blank))`.

The current position may be altered also by calls of `backspace` (b), `set char number` (k) and, on appropriate channels, of `set` (i) and `reset` (j).

cc) The contents of a newly established book are undefined and both its current position and its logical end are at (1, 1, 1) . As output proceeds, it is filled with characters and the logical end is moved forward accordingly. If, during character output with the current position at the logical end of the book, `space` is called, then a space character is written (similar action being taken in the case of `newline` and `newpage` if the book is not compressible) .

A call of `set` which attempts to leave the current position beyond the logical end results in a call of `undefined` (a sensible system action might then be to advance the logical end to the current position, or even to the physical end of the book) . There is thus no defined way in which the current position can be made to be beyond the logical end, nor in which any character within the logical file can remain in its initial undefined state.

dd) A reading or writing operation, or a call of `space`, `newline`, `newpage`, `set` or `set char number`, may bring the current position outside the physical or logical file (26_{10}.3.1.5.cc, dd), but this does not have any immediate consequence. However, before any further transput is attempted, or a further call of `space`, `newline` or `newpage` (but not of `set` or `set char number`) is made, the current position must be brought to a "good" position. The file is "good" if, on writing (reading), the current position is not outside the physical (logical) file (26_{10}.3.1.5.cc, dd). The page (line) is "good" if the line number (character number) has not overflowed. The event routine (26_{10}.3.1.3.cc) corresponding to `on logical file end`, `on physical file end`, `on page end` or `on line end` is therefore called as appropriate. Except in the case of formatted transput (which uses `check pos`, 26_{10}.3.3.2.c), the default action, if the event routine returns `false`, is to call, respectively, `undefined`, `undefined`, `newpage` or `newline`. After this (or if `true` is returned), if the position is still not good, an event routine (not necessarily the same one) is called again.

ee) The state of the file (26_{10}.3.1.3.bb) controls some effects of the layout routines. If the read/write mood is reading, the effect of `space`, `newline` and `newpage`, upon attempting to pass the logical end, is to call the event routine corresponding to `on logical file end` with default action `undefined`; if it is writing, the effect is to output spaces (or, in bin mood, to write some undefined character) or to compress the current line or page (see cc) . If the read/write mood is not determined on entry to a layout routine, `undefined` is called. On exit, the read/write mood present on entry is restored.)

a)
```
PROC space = (REF FILE f) VOID:
    IF ¬ opened OF f THEN undefined
    ELSE
      BOOL reading = (read mood OF f | TRUE |:
        write mood OF f | FALSE | undefined; SKIP);
      (¬ get good line (f, reading) | undefined);
      REF POS cpos = cpos OF f;
      IF reading THEN c OF cpos +:= 1
      ELSE IF logical file ended (f) THEN
          IF bin mood OF f THEN
            (text OF f | (FLEXTEXT t2):
              t2[p OF cpos][l OF cpos][c OF cpos] := SKIP);
            c OF pos +:= 1;
            lpos OF book OF f := cpos
          ELSE put char (f, " ")
          FI
        ELSE c OF cpos +:= 1
        FI
      FI
    FI;
```

b)
```
PROC backspace = (REF FILE f) VOID:
    IF ¬ opened OF f THEN undefined
    ELSE REF INT c = c OF cpos OF f;
      (c>1 | c-:= 1 | undefined)
    FI;
```

c)
```
PROC newline = (REF FILE f) VOID:
    IF ¬ opened OF f THEN undefined
    ELSE BOOL reading = (read mood OF f | TRUE |:
        write mood OF f | FALSE | undefined; SKIP);
    (get good page (f, reading) | undefined);
    REF POS cpos = cpos OF f, lpos = lpos OF book OF f;
    IF p OF cpos = p OF lpos ∧ l OF cpos = l OF lpos
    THEN c OF cpos := c OF lpos;
      IF reading THEN newline (f)
      ELSE
        IF compressible (f)
        THEN REF INT pl = p OF lpos, ll = l OF lpos;
          FLEXTEXT text = (text OF f | (FLEXTEXT t2): t2);
          text [pl][ll] := text [pl][ll][ : c OF lpos - 1]
        ELSE WHILE ¬ line ended (f) DO space (f) OD
        FI;
        cpos := lpos := (p OF cpos, l OF cpos + 1, 1)
      FI
    ELSE cpos := (p OF cpos, l OF cpos + 1, 1)
    FI
    FI;
```

d)
```
PROC newpage = (REF FILE f) VOID:
    IF ¬ opened OF f THEN undefined
    ELSE
      BOOL reading = (read mood OF f) | TRUE |:
        write mood OF f | FALSE | undefined; SKIP);
      (get good file (f, reading) | undefined);
      REF POS cpos = cpos OF f, lpos = lpos OF book OF f;
      IF p OF cpos = p OF lpos
      THEN cpos := lpos;
        IF reading THEN newpage (f)
        ELSE
          IF compressible (f) ∧ l OF lpos ≤ l OF book bounds (f)
          THEN REF INT pl = p OF lpos, ll = l OF lpos;
            FLEXTEXT text = (text OF f | (FLEXTEXT t2): t2);
            text[pl][ll] := text [pl][ll]t: c OF lpos - 1];
            text[pl] := text [pl][ : (c OF lpos > 1 | ll | ll - 1)]
          ELSE WHILE ¬ page ended (f) DO newline (f) OD
          FI;
          cpos := lpos := (p OF cpos + 1, 1, 1)
        FI
      ELSE cpos := (p OF cpos + 1, 1, 1)
      FI
    FI;
```

{Each of the following 3 routines either returns `true`, in which case the line, page or file is good (dd), or it returns `false`, in which case the current position may be outside the logical file or the page number may have overflowed, or it loops until the matter is resolved, or it

is terminated by a **jump**. On exit, the read/write mood is as determined by its `reading` parameter.}

e)
```
PROC ℵ0 get good line = (REF FILE f, BOOL reading) BOOL:
  BEGIN BOOL not ended;
    WHILE not ended := get good page (f, reading);
      line ended (f) ∧ not ended
    DO (¬ (line mended OF f) (f) |
      set mood (f, reading); newline (f)) OD;
    not ended
  END;
```

f)
```
PROC ℵ0 get good page = (REF FILE f, BOOL reading) BOOL:
  BEGIN BOOL not ended;
    WHILE not ended := get good file (f, reading);
      page ended (f) ∧ not ended
    DO (¬ (page mended OF f) (f) |
      set mood (f, reading); newpage (f)) OD;
    not ended
  END;
```

g)
```
PROC ℵ0 get good file = (REF FILE f, BOOL reading) BOOL:
  BEGIN BOOL not ended := TRUE;
    WHILE set mood (f, reading);
      not ended ∧
        (reading | logical file ended | physical file ended) (f)
    DO not ended := (reading | logical file mended OF f
      | physical file mended OF f) (f)
    OD;
    not ended
  END;
```

h)
```
PROC ℵ0 set mood = (REF FILE f, BOOL reading) VOID:
  (reading | set read mood (f) | set write mood (f));
```

i)
```
PROC set = (REF FILE f, INT p, l, c) VOID:
  IF ¬ opened OF f ∨ ¬ get possible (f) THEN undefined
  ELSE BOOL reading = (read mood OF f | TRUE
    |: write mood OF f | FALSE undefined; SKIP);
    REF POS cpos = cpos OF f, lpos = lpos OF book OF f;
    POS ccpos = cpos;
    IF (cpos := (p, l, c)) BEYOND lpos
    THEN cpos := lpos;
      (¬ (logical file mended OF f) (f) | undefined);
      set mood (f, reading)
    ELIF POS bounds = book bounds (f);
      p < 1 ∨ p > p OF bounds + 1
      ∨ l < 1 ∨ l > l OF bounds + 1
      ∨ c < 1 ∨ c > c OF bounds + 1
    THEN cpos := ccpos; undefined
    FI
  FI;
```

```
j) PROC reset = (REF FILE f) VOID:
     IF ¬ opened OF f ∨ ¬ reset possible (f) THEN undefined
     ELSE
       REF BOOL (read mood OF f) := ¬ put possible (f);
       REF BOOL (write mood OF f) := ¬ get possible (f);
       REF BOOL (char mood OF f) := ¬ bin possible (f);
       REF BOOL (bin mood OF f) := FALSE;
       REF POS (cpos OF f) := (1, 1, 1)[4]
     FI;

k) PROC set char number = (REF FILE f, INT c) VOID:
     IF ¬ opened OF f THEN undefined
     ELSE REF REF POS cpos = cpos OF f;
       WHILE c OF cpos ≠ c
       DO
         IF c < 1 ∨ c > c OF book bounds (f) + 1
         THEN undefined
         ELIF c > c OF cpos
         THEN space (f)
         ELSE backspace (f)
         FI
       OD
     FI;
```

26.3.2 Transput values

26.3.2.1 Conversion routines

{The routines `whole`, `fixed` and `float` are intended to be used with the formatless output routines `put`, `print` and `write` when it is required to have a little extra control over the layout produced. Each of these routines has a `width` parameter whose absolute value specifies the length of the string to be produced by conversion of the arithmetic value V provided. Each of `fixed` and `float` has an `after` parameter to specify the number of digits required after the decimal point, and an `exp` parameter in `float` specifies the width allowed for the exponent. If V cannot be expressed as a string within the given width, even when the value of `after`, if provided, has been reduced, then a string filled with `errorchar` (26_{10}.2.1.t) is returned instead. Leading zeroes are replaced by spaces and a sign is normally included. The user can, however, specify that a sign is to be included only for negative values by specifying a negative width. If the width specified is zero, then the shortest possible string into which V can be converted, consistently with the other parameters, is returned. The following examples illustrate some of the possibilities:

```
print (whole (i, -4))
```

[4] These lines should be followed by `; DOWN bfileprotect; UP gremlins`

which might print "␣␣␣0", "␣␣99", "␣-99", "9999" or, if i were greater than 9999, "****", where "*" is the yield of errorchar;

```
print (whole (i, 4))
```

which would print "␣+99" rather than "␣␣99";

```
print (whole (i, 0))
```

which might print "0", "99", "-99", "9999" or "99999";

```
print (fixed (x, -6, 3))
```

which might print "␣2.718", "27.183" or "271.83" (in which one place after the decimal point has been sacrificed in order to fit the number in);

```
print (fixed (x, 0, 3))
```

which might print "2.718", "27.183" or "271.823";

```
print (float (x, 9, 3, 2))
```

which might print "$-2.718_{10}+0$", "$+2.718_{10}-1$", or "$+2.72_{10}+11$" (in which one place after the decimal point has been sacrificed in order to make room for the unexpectedly large exponent) .}

a)
```
MODE ℵ0 NUMBER= UNION (≪ L REAL ≫, ≪ L INT ≫ );
```

b)
```
PROC whole = (NUMBER v, INT width) STRING:
  CASE v IN
    ≪ (L INT x):
      (INT length := ABS width - (x < L 0 ∨ width > 0 | 1 | 0),
      L INT n := ABS x;
      IF width = 0 THEN
        L INT m := n; length := 0;
        WHILE m ÷:= 10; length +:= 1; m ≠ L 0
        DO SKIP OD
      FI;
      STRING s := subwhole (n, length);
      IF length = 0 ∨ char in string (errorchar, LOC INT, s)
      THEN ABS width*errorchar[5]
      ELSE (x < L 0 | "-" |: width > 0 | "+" | "") PLUSTO s;
        (width ≠ 0 | (ABS width - UPB s) × " " PLUSTO s);
        s
      FI) ≫,
    ≪ (L REAL x): fixed (x, width, 0) ≫
  ESAC;
```

[5] This line should read `ELSE undefined;`

c)
```
PROC fixed (NUMBER v, INT width, after) STRING:
    CASE v IN
      ≪ (L REAL x):
        IF INT length := ABS width - (x < L 0 ∨ width > 0 | 1 | 0);
          after ≥ 0 ∧ (length > after ∨ width = 0)
        THEN L REAL y = ABS x;
          IF width = 0
          THEN length := (after = 0 | 1 | 0);
            WHILE y + L .5 × L .1 ↑ after ≥ L10.0 ↑ length
            DO length +:= 1 OD;
            length +:= (after = 0 | 0 | after + 1)
          FI;
          STRING s := sub fixed (y, length, after);
          IF ¬ char in string (errorchar, LOC INT, s)
          THEN (length > UPB s ∧ y < L 1.0 | "0" PLUSTO s);[6]
            (x < L 0 | "-" |: width > 0 | "+" | "") PLUSTO s;
            (width ≠ 0 | (ABS width - UPB s) × " " PLUSTO s);
            s
          ELIF after > 0
          THEN fixed (v, width, after - 1)
          ELSE ABS width × errorchar
          FI
        ELSE undefined; ABS width × errorchar[7]
        FI ≫,
      ≪ (L INT x): fixed (L REAL (x), width, after) ≫
      ESAC;
```

d)
```
PROC float = (NUMBER v, INT width, after, exp) STRING:
    CASE v IN
      ≪ (L REAL x):
        IF INT before = ABS width - ABS exp -
          (after ≠ 0| after + 1| 0) -2;
          SIGN before + SIGN after > 0
        THEN STRING s, L REAL y := ABS x, INT p := 0;
          L standardize (y, before, after, p);
          s := fixed (SIGN x × y, SIGN width × (ABS width - ABS exp - 1),
            after)
            + "10" + whole (p, exp);[8]
          IF exp = 0 ∨ char in string (errorchar, LOC INT, s)
          THEN float (x, width, (after ≠ 0 | after - 1 | 0),
            (exp > 0 | exp + 1 | exp - 1))
          ELSE s
          FI
```

[6] This line should read `THEN (length > UPB s ∧ y + L 0.5 + L .1 ↑ after < L 1.0 | "0" PLUSTO s);`

[7] This line should read `ELIF undefined; width = 0 THEN errorchar ELSE ABS width × errorchar`

[8] This line is debated

```
        ELSE undefined; ABS width × errorchar[9]
        FI ≫,
      ≪ (L INT x): float (L REAL (x), width, after, exp) ≫
    ESAC;
```

e)
```
PROC ℵ0 subwhole = (NUMBER v, INT width) STRING:
    ¢ returns a string of maximum length 'width' containing a
        decimal representation of the positive integer 'v' ¢
    CASE v IN
      ≪ (L INT x):
        BEGIN STRING s, L INT n := x;
          WHILE dig char (S (n ÷× L 10)) PLUSTO s;
            n ÷:= L 10; n ≠ L 0
          DO SKIP OD;
          (UPB s > width | width × errorchar | s)
        END ≫
    ESAC;
```

f)
```
PROC ℵ0 subfixed = (NUMBER v, INT width, after) STRING:
    ¢ returns a string of maximum length 'width' containing a
        rounded decimal representation of the positive real number
        'v'; if 'after' is greater than zero, this string contains a
        decimal point followed by 'after' digits ¢
    CASE v IN
      ≪ (L REAL x):
        BEGIN STRING s, INT before := 0;
          L REAL y := x + L .5 × L .1 ↑ after;
          PROC choose dig = (REF L REAL y) CHAR:
            dig char ((INT c := S ENTIER (y *:= L 10.0);
            (c > 9 | c := 9);
            y −:= K c; c));
          WHILE y > L 10.0 ↑ before DO before +:= 1 OD;
          y /:= L 10.0 ↑ before;
          TO before DO s PLUSAB choose dig (y) OD;
          (after > 0 | s PLUSAB ".");
          TO after DO s PLUSAB choose dig (y) OD;
          (UPB s > width | width × errorchar | s)
        END ≫
    ESAC;
```

g)
```
PROC ℵ0 L standardize = (REF L REAL y,
    INT before, after, REF INT p) VOID:
    ¢ adjusts the value of 'y' so that it may be transput according
        to the format $n (before) d.n (after) d$ ; 'p' is set so that
        y × 10 ↑ p is equal to the original value of 'y' ¢
    BEGIN
      L REAL g = L 10.0 ↑ before; L REAL h = g × L .1;
      WHILE y > g DO y *:= L .1; p +:= 1 OD;
```

[9] This line should read `ELIF undefined; width = 0 THEN errorchar ELSE ABS width × errorchar`

```
    (y ≠ L 0.0| WHILE y < h DO y *:= L 10.0; p -:= 1 OD);
    (y + L .5 × L .1 ↑ after ≥ g | y := h; p +:= 1)
  END;
```

h) `PROC ℵ0 dig char = (INT x) CHAR: "0123456789abcdef"[x + 1];`

i)
```
PROC ℵ0 string to L int = (STRING s, INT radix, REF L INT i) BOOL:
  ¢ returns true if the absolute value of the result is ≤ L max int ¢
  BEGIN
    L INT lr = K radix; BOOL safe := TRUE;
    L INT n := L 0, L INT m = L max int ÷ lr;
    L INT m1 = L max int - m × lr;
    FOR i FROM 2 TO UPB s
    WHILE L INT dig = K char dig (s[i]);
        safe := n < m ∨ n = m ∧ dig ≤ m1
    DO n := n × lr + dig OD;
    IF safe THEN i := (s[1] = "+" | n | -n); TRUE ELSE FALSE FI
  END;
```

j)
```
PROC ℵ0 string to L real = (STRING s, REF L REAL r) BOOL:
  ¢ returns true if the absolute value of the result is ≤ max real ¢
  BEGIN
    INT e := UPB s + 1;
    char in string ("10", e, s);
    INT p := e; char in string (".", p, s);
    INT j := 1, length = 0, L REAL x := L 0.0;
  ¢ skip leading zeroes: ¢
    FOR i FROM 2 TO e -1
    WHILE s[i] = "0" ∨ s[i] = "." ∨ s[i] = " "
    DO j := i OD;
    FOR i FROM j + 1 TO e - 1 WHILE length < L real width
    DO IF s [i] ≠ "."
      THEN x := x × L 10.0 + K char dig (s[j := i]); length +:= 1
      FI ¢ all significant digits converted ¢
    OD;
  ¢ set preliminary exponent: ¢
    INT exp := (p > j | p - j - 1 | p - j), expart := 0;
  ¢ convert exponent part: ¢
    BOOL safe := IF e < UPB s
      THEN string to int (s[e + 1: ], 10, expart)
      ELSE TRUE
      FI;
  ¢ prepare a representation of L max real to compare with the
      L REAL value to be delivered: ¢
    L REAL max stag := L max real, INT max exp := 0;
    L standardize (max stag, length, 0, max exp); exp +:= expart;
    IF ¬ safe ∨ (exp > max exp ∨ exp = max exp ∧ x > max stag)
    THEN FALSE
    ELSE r := (s[1] = "+" | x | -x) × L 10.0 ↑ exp; TRUE
    FI
  END;
```

k) PROC $\aleph_0$ char dig = (CHAR x) INT:
(x = " " | 0 | INT i;
char in string (x, i, "0123456789abcdef"); i - 1);

l) PROC char in string = (CHAR c, REF INT i, STRING s) BOOL:
(BOOL found := FALSE;
FOR k FROM LWB s TO UPB s WHILE ¬ found
DO (c = s[k] | i := k; found := TRUE) OD;
found);

m) INT L int width =
¢ the smallest integral value such that 'L max int' may be
converted without error using the pattern n (L int width) d ¢
(INT c := 1;
WHILE L 10 ↑ (c-1) < L .1 × L maxint DO c +:= 1 OD;
c);

n) INT L real width =
¢ the smallest integral value such that different strings are
produced by conversion of '1.0' and of '1.0 + L small real'
using the pattern d.n (L real width - 1) d ¢
1 - S ENTIER (L ln (L small real) / L ln (L 10));

o) INT L exp width =
¢ the smallest integral value such that 'L max real' may be
converted without error using the pattern
d.n (L real width - 1) d e n (L exp width) d ¢
1 + S ENTIER (L ln (L ln (L max real) /L ln (L 10)) /L ln (L 10));

26.3.2.2 Transput modes

a) MODE $\aleph_0$ SIMPLOUT = UNION (≪ L INT ≫, ≪ L REAL ≫, ≪ L COMPL ≫,
BOOL, ≪ L BITS ≫, CHAR, []CHAR);

b) MODE $\aleph_0$ OUTTYPE =
C an actual-declarer specifying a mode united from {17_2.1.3.6.a} a sufficient set of modes none of which is **'void'** or contains **'flexible'**, **'reference to'**, **'procedure'** or **'union of' C** ;

c) MODE $\aleph_0$ SIMPLIN = UNION (≪ REF L INT ≫, ≪ REF L REAL ≫,
≪ REF L COMPL ≫, REF BOOL, ≪ REF L BITS ≫,
REF CHAR, REF [] CHAR, REF STRING);

d) MODE $\aleph_0$ INTYPE =
C an actual-declarer specifying a mode united from {17_2.1.3.6.a} **'reference to flexible row of character'** together with a sufficient set of modes each of which is **'reference to'** followed by a mode which does not contain **'flexible'**, **'reference to'**, **'procedure'** or **'union of' C** ;

{See the remarks after 26_{10}.2.3.1 concerning the term "sufficient set".}

26.3.2.3 Straightening

a) `OP` $\aleph_0$ `STRAIGHTOUT = (OUTTYPE x) [] SIMPLOUT:`
C the result of "straightening" 'x' **C** ;

b) `OP` $\aleph_0$ `STRAIGHTIN = (INTYPE x) [] SIMPLIN:`
C the result of straightening 'x' **C** ;

c) The result of "straightening" a given value V is a multiple value W {of one dimension} obtained as follows:

- it is required that V (if it is a name) be not nil;
- a counter i is set to 0:
- V is "traversed" {d} using i
- W is composed of, a descriptor ((1, i)) and the elements obtained by traversing V:
- if V is not (is) a name, then the mode of the result is the mode specified by `[] SIMPLOUT` (`[] SIMPLIN`) .

d) A value V is "traversed", using a counter i, as follows:
If V is (refers to) a value from whose mode that specified by `SIMPLOUT` is united,
then

- i is increased by one:
- the element of W selected by (i) is V:

otherwise,

Case A: V is (refers to) a multiple value (of one dimension) having a descriptor $((l, u))$:

- for $j = l, ..., u$, the element (the subname) of V selected by (j) is traversed using i;

Case B: V is (refers to) a multiple value {of n dimensions, $n \geq 2$} whose descriptor is $((l_1, u_1), ..., (l_n, u_n))$ where $n \geq 2$:

- for $j = l_1, ...u_1$, the multiple value selected {17_2.1.3.4.i} by (the name generated {17_2.1.3.4.j} by) the trim $(j, (l_2, u_2, 0), ..., (l_n, u_n, 0))$ is traversed using i;

Case C: V is (refers to) a structured value $V1$:

- the fields (the subnames of V referring to the fields) of $V1$, taken in order, are traversed using i.

26.3.3 Formatless transput

{In formatless transput, the elements of a "data list" are transput, one after the other, via a specified file. Each element of the data list is either a layout routine of the mode specified by `PROC (REF FILE) VOID` (26_{10}.3.1.6) or a value of the mode specified by `OUTTYPE` (on output) or `INTYPE` (on input) . On encountering a layout routine in the data list, that routine is called with the specified file as parameter. Other values in the data list are first straightened (26_{10}.3.2.3) and the resulting values are then transput via the given file one after the other.

Transput normally takes place at the current position but, if there is no room on the current line (on output) or if a readable value is not present there (on input), then first, the event routine corresponding to `on line end` (or, where appropriate, to `on page end`, `on physical file end` or `on logical file end`) is called, and next, if this returns `false`, the next "good" character position of the book is found, viz., the first character position of the next nonempty line.}

26.3.3.1 Formatless output

{For formatless output, `put` (a) and `print` (or `write`) (26_{10}.5.1.d) may be used. Each straightened value V from the data list is output as follows:

aa) If the mode of V is specified by L `INT`, then first, if there is not enough room for L `int width + 2` characters on the remainder of the current line, a good position is found on a subsequent line (see 26_{10}.3.3): next, when not at the beginning of a line, a space is given and then V is output as if under the control of the **picture** `n (`L `int width - 1) z + d`.

bb) If the mode of V is specified by L `REAL`, then first, if there is not enough room for L `real width +` L `exp width + 5` characters on the current line, then a good position is found on a subsequent line: next, when not at the beginning of a line, a space is given and then V is output as if under control of the **picture**
`+d.n (`L `real width - 1) den (`L `exp width - 1) z+d`.

cc) If the mode of V is specified by L `COMPL`, then first, if there is not enough room for `2 ×` (L `real width +` L `exp width) + 11` characters on the current line, then a good position is found on a subsequent line: next, when not at the beginning of a line, a space is given and then V is output as if under control of the **picture**
`+d.n (`L `real width - 1) den (`L `exp width - 1) z+d" "i`
`+d.n (`L `real width - 1) den (`L `exp width - 1) z+d .`

dd) If the mode of V is specified by `BOOL`, then first, if the current line is full, a good position is found on a subsequent line: next, if V is `true` (`false`), the character yielded by `flip` (`flop`) is output (with no intervening space) .

ee) If the mode of V is specified by L BITS, then the elements of the only field of V are output (as in dd) one after the other (with no intervening spaces, and with new lines being taken as required),

ff) If the mode of V is specified by CHAR, then first, if the current line is full, a good position is found on a subsequent line: next V is output (with no intervening space) .

gg) If the mode of V is specified by [] CHAR, then the elements of V are output (as in ff) one after the other (with no intervening spaces, and with new lines being taken as required) .}

```
a) PROC put = (REF FILE f, [] UNION (OUTTYPE,
     PROC (REF FILE) VOID) x) VOID:
   IF opened OF f THEN
     FOR i TO UPB x
     DO CASE set write mood (f); set char mood (f); x[i] IN
       (PROC (REF FILE) VOID pf): pf (f),
       (OUTTYPE ot):
       BEGIN [] SIMPLOUT y = STRAIGHTOUT ot;
           ≪ PROC L real conv = (L REAL r) STRING:
             float (r, L real width + L exp width + 4,
               L real width - 1, L exp width + 1) ≫ ;
           FOR j TO UPB y
           DO CASE y[j] IN
             (UNION (NUMBER, ≪ L COMPL ≫ ) nc):
               BEGIN STRING s :=
                 CASE nc IN
                   ≪ (L INT k): whole (k, L int width + 1) ≫,
                   ≪ (L REAL r): L real conv (r) ≫,
                   ≪ (L COMPL z): L real conv (RE z) + " I"
                     + L real conv (IM z) ≫
                 ESAC;
                 REF REF POS cpos = cpos OF f, INT n = UPB s;
                 WHILE nextpos (f);
                     (n > c OF book bounds (f) | undefined);
                     c OF cpos + (c OF cpos = 1 | n | n + 1) >
                       c OF book bounds (f) + 1
                 DO (¬ (line mended OF f) (f) | put (f, newline));
                   set write mood (f)
                 OD;
                 (c OF cpos ≠ 1 | " " PLUSTO s);
                 FOR k TO UPB s DO put char (f, s[k]) OD
               END ¢ numeric ¢,
             (BOOL b): (next pos (f); put char (f, (b | flip | flop))),
             ≪ (L BITS lb):
               FOR k TO L bits width
               DO put (f, (L F OF lb) [k]) OD ≫,
             (CHAR k): (nextpos (f); put char (f, k)),
             ([] CHAR ss):
               FOR k FROM LWB ss TO UPB ss
```

```
            DO next pos (f); put char (f, ss[k]) OD
          ESAC
        OD
    END
    ESAC
  OD
ELSE undefined
FI;
```

b)
```
PROC ℵ0 put char = (REF FILE f, CHAR char) VOID:
  IF opened OF f ∧ ¬ line ended (f)
  THEN REF POS cpos = cpos OF f, lpos = lpos OF book OF f;
    set char mood (f); set write mood (f);
    REF INT p = p OF cpos, l = l OF cpos, c = c OF cpos;
    CHAR k; BOOL found := FALSE;
    CASE text OF f IN
    (TEXT): (k := char; found := TRUE),
    (FLEXTEXT):
      FOR i TO UPB F OF conv OF f WHILE ¬ found
      DO STRUCT (CHAR internal, external) key = (F OF conv OF f) [i];
        (internal OF key = char | k := external OF key; found := TRUE)
      OD
    ESAC;
    IF found THEN
      CASE text OF f IN
        (TEXT t1): t1 [p][l][c] := k,
        (FLEXTEXT t2): t2[p][l][c] := k
      ESAC;
      c +:= 1;
      IF cpos BEYOND lpos THEN lpos := cpos
      ELIF ¬ set possible (f) ∧
        POS (p OF lpos, l OF lpos, 1) BEYOND cpos
      THEN lpos := cpos;
        (compressible (f) |
          C the size of the line and page containing the logical
            end of the book and of all subsequent lines and
            pages may be increased {e.g., to the sizes with
            which the book was originally established
            {26₁₀.3.1.4.cc} or to the sizes implied by maxpos OF
            chan OF f} C)
      FI
    ELSE k := " ";
      IF ¬ (char error mended OF f) (f, k)
      THEN undefined; k := " "
      FI;
      check pos (f); put char (f, k)
    FI
  ELSE undefined
  FI ¢ write mood is still set ¢ ;
```

c)
```
PROC ℵ0 next pos = (REF FILE f) VOID:
```

```
(¬ get good line (f, read mood OF f) | undefined)
¢ the line is now good {26₁₀.3.1.6.dd} and the read/write mood is
  as on entry ¢ ;
```

26.3.3.2 Formatless input

{For formatless input, `get` (a) and `read` (26_{10}.5.1.e) may be used. Values from the book are assigned to each straightened name N from the data list as follows:

aa) If the mode of N is specified by `REF` L `INT`, then first, the book is searched for the first character that is not a space (finding good positions on subsequent lines as necessary); next, the largest string is read from the book that could be "indited" (26_{10}.3.4.1.1.kk) under the control of some **picture** of the form `+n(k1)"␣"n(k2)d d` or `n(k2) d d` (where `k1` and `k2` yield arbitrary nonnegative integers): this string is converted to an integer and assigned to N; if the conversion is unsuccessful, the event routine corresponding to `on value error` is called.

bb) If the mode of N is specified by `REF` L `REAL`, then first, the book is searched for the first character that is not a space (finding good positions on subsequent lines as necessary); next, the largest string is read from the book that could be indited under the control of some **picture** of the form

`+n(k1)"␣" n(k2)d` or `n(k2)d` followed by `.n(k3)d d` or by `ds.`, possibly followed again by

`e n(k4)"␣"+n(k5)"␣" n(k6)d d` or by

`e n(k5)"␣" n(k6)d d`;

this string is converted to a real number and assigned to N; if the conversion is unsuccessful, the event routine corresponding to `on value error` is called.

cc) If the mode of N is specified by `REF` L `COMPL`, then first, a real number is input (as in bb) and assigned to the first subname of N; next, the book is searched for the first character that is not a space; next, a character is input and, if it is not `"I"` or `"i"`, then the event routine corresponding to `on char error` (26_{10}.3.1.3.cc) is called, the suggestion being `"I"`; finally, a real number is input and assigned to the second subname of N.

dd) If the mode of N is specified by `REF BOOL`, then first, the book is searched for the first character that is not a space (finding good positions on subsequent lines as necessary); next, a character is read: if this character is the same as that yielded by `flip` (`flop`), then `true` (`false`) is assigned to N; otherwise, the event routine corresponding to `on char error` is called, the suggestion being `flop`.

ee) If the mode of N is specified by `REF` L `BITS`, then input takes place (as in dd) to the subnames of N one after the other (with new lines being taken as required) .

ff) If the mode of N is specified by `REF CHAR`, then first, if the current line is exhausted, a good position is found on a subsequent line; next, a character is read and assigned to N.

gg) If the mode of N is specified by `REF [] CHAR`, then input takes place (as in ff) to the subnames of N one after the other (with new lines being taken as required) .

hh) If the mode of N is specified by `REF STRING`, then characters are read until either

(i) a character is encountered which is contained in the string associated with the file by a call of the routine `make term`, or

(ii) the current line is exhausted, whereupon the event routine corresponding to `on line end` (or, where appropriate, to `on page end`, `on physical file end` or `on logical file end`) is called; if the event routine moves the current position to a good position (see 26_{10}.3.3), then input of characters is resumed.

The string consisting of the characters read is assigned to N (note that, if the current line has already been exhausted, or if the current position is at the start of an empty line or outside the logical file, then an empty string is assigned to N) .}

a)
```
PROC get = (REF FILE f, [] UNION (INTYPE,
    PROC (REF FILE) VOID) x) VOID:
  IF opened OF f THEN
  FOR i TO UPB x
  DO CASE set read mood (f); set char mood (f); x[i] IN
    (PROC (REF FILE) VOID pf): pf (f),
    (INTYPE it) :
    BEGIN
      [] SIMPLIN y = STRAIGHTIN it; CHAR k; BOOL k empty;
      OP ? = (STRING s) BOOL: C true if the next character, if any,
                              in the current line is contained in 's'
                              (the character is assigned to 'k')
                              and false otherwise C
        IF k empty ∧ (line ended (f) ∨ logical file ended (f))
        THEN FALSE
        ELSE (k empty | get char (f, k));
          k empty := char in string (k, LOC INT, s)
        FI;
      OP ? = (CHAR c) BOOL: ? STRING (c);
      PRIO ! = 8;
      OP ! = (STRING s, CHAR c) CHAR:
            C expects a character contained in 's'; if the character
            read is not in 's', the event routine corresponding to
            'on char error' is called with the suggestion 'c' C
        IF (k empty | check pos (f); get char (f, k));
          k empty := TRUE;
          char in string (k, LOC INT, s)
        THEN k
```

```
    ELSE CHAR sugg := c;
      IF (char error mended OF f) (f, sugg) THEN
        (char in string (sugg, LOC INT, s) | sugg | undefined; c)
      ELSE undefined; c
      FI;
      set read mood (f)[10]
    FI;
  OP ! = (CHAR s, c) CHAR: STRING (s) ! c;
  PROC skip initial spaces = VOID:
    WHILE (k empty | next pos (f)); ? " " DO SKIP OD;
  PROC skip spaces = VOID:
    WHILE ? " " DO SKIP OD;
  PROC read dig = STRING:
    (STRING t := "0123456789" ! "0";
    WHILE ? "0123456789" DO t PLUSAB k OD; t);
  PROC read sign = char:
    (CHAR t = (skipspaces; ? "+-" | k | "+");
    skip spaces; t);
  PROC read num = STRING:
    (CHAR t = read sign; t + read dig);
  PROC read real = STRING:
    (STRING t := read sign;
    (¬ ? "." | t PLUSAB read dig | k empty := FALSE);
    (ℵ0 "." | t PLUSAB "." + read dig);
    (ℵ0 "10\e" | t PLUSAB "10" + read num); t);

  FOR j TO UPB y
  DO BOOL incomp := FALSE; k empty := TRUE;
    CASE y[j] IN
    ≪ (REF L INT ii) :
      (skip initial spaces;
        incomp := ¬ string to L int (read num, 10, ii)) ≫,
    ≪ (REF L REAL rr) :
      (skip initial spaces;
        incomp := ¬ string to L real (read real, rr)) ≫,
    ≪ (REF L COMPL zz) :
      (skip initial spaces;
        incomp := ¬ string to L real (read real, re OF zz);
        skip spaces; "iI" ! "I;";
        incomp := incomp ∨
          string to L real (read real, im OF zz)) ≫
    (REF BOOL bb) :
      (skip initial spaces;
```

[10] This line and the four preceeding ones should read

```
CHAR cc = IF (char error mended OF f) (f, sugg) THEN
(char in string (sugg, LOC INT, s) | sugg | undefined; c)
ELSE undefined; c
FI;
set read mood (f); cc
```

```
            bb := (flip + flop) ! flop = flip),
          ≪ (REF L BITS lb) :
            FOR i TO L bits width
            DO get (f, (L F OF lb) [i]) OD ≫,
          (REF CHAR cc): (next pos (f); get char (f, cc)),
          (REF []CHAR ss) :
            FOR i FROM LWB ss TO UPB ss
            DO next pos (f); get char (f, ss [i]) OD,
          (REF STRING ss):
            BEGIN STRING t;
              WHILE check pos (f);
                IF line ended (f) ∨ logical file ended (f)
                THEN FALSE
                ELSE get char (f, k);
                  k empty := ¬ char in string (k, LOC INT, term OF f)
                FI
              DO t PLUSAB k OD;
              ss := t
            END
          ESAC;
          (¬ k empty | backspace (f));
          IF incomp
          THEN (¬ (value error mended OF f) (f) | undefined);
            set read mood (f)
          FI
        OD
      END
      ESAC
    OD
    ELSE undefined
    FI;
```

b)

```
PROC ℵ0 get char = (REF FILE f, REF CHAR char) VOID:
    IF opened OF f ∧ ¬ line ended (f) ∧ ¬ logical file ended (f)
    THEN REF POS cpos = cpos OF f;
      set char mood (f); set read mood (f);
      INT p = p OF cpos, l = l OF cpos, c = c OF cpos;
      c OF cpos +:= 1;
      char := CASE text OF f IN
        (TEXT t1): t1[p][l][c],
        (FLEXTEXT t2) :
          (CHAR k := t2[p][l][c];
          BOOL found := FALSE;
          FOR i TO UPB F OF conv OF f WHILE ¬ found
          DO STRUCT (CHAR internal, external) key =
            (F OF conv OF f) [i];
            (external OF key = k | k := internal OF key; found := TRUE)
          OD;
          IF found THEN k
          ELSE k:= " ";
```

```
                IF (char error mended OF f) (f, k)
                THEN k
                ELSE undefined; " "
                FI; set read mood (f);
            FI)
          ESAC
      ELSE undefined
      FI ¢ read mood is still set ¢ ;

c) PROC ℵ0 check pos = (REF FILE f) VOID:
      BEGIN BOOL reading = read mood OF f;
        BOOL not ended := TRUE;
        WHILE not ended := not ended ∧ get good page (f, reading);
            line ended (f) ∧ not ended
        DO not ended := (line mended OF f) (f) OD
      END;
```

{The routine `check pos` is used in formatted transput before each call of `put char` or `get char`. If the position is not good (26_{10}.3.1.6.dd), it calls the appropriate event routine, and may call further event routines if `true` is returned. If the event routine corresponding to `on page end` returns `false`, `newpage` is called but, if any other event routine returns `false`, no default action is taken and no more event routines are called. On exit, the read/write mood is as on entry, but the current position may not be good, in which case `undefined` will be called in the following `put char` or `get char`. However, `check pos` is also called when getting strings (hh), in which case the string is then terminated if the current position is not good.}

26.3.4 Format texts

{In formatted transput, each straightened value from a data list (cf. 26_{10}.3.3) is matched against a constituent **picture** of a **format-text** provided by the user. A **picture** specifies how a value is to be converted to or from a sequence of characters and prescribes the layout of those characters in the book. Features which may be specified include the number of digits, the position of the decimal point and of the sign, if any, suppression of zeroes and the insertion of arbitrary strings. For example, using the **picture** `-d.3d " " 3d " " e z+d`, the value 1234.567 would be transput as the string "␣`1.234 567`$_{10}$`+3`".

A "format" is a structured value (i.e., an internal object) of mode **'FORMAT'**, which mirrors the hierarchical structure of a **format-text** (which is an external object) . In this section are given the syntax of **format-texts** and the semantics for obtaining their corresponding formats. The actual formatted transput is performed by the routines given in section 26_{10}.3.5 but, for convenience, a description of their operation is given here, in association with the corresponding syntax.}

26.3.4.1 Collections and pictures

26.3.4.1.1. Syntax

{The following **mode-declarations** (taken from rr10.3.5.a) are reflected in the metaproduction rules A to K below.

A) `MODE FORMAT = STRUCT (FLEX [1 : 0] PIECE` *F* `);`

B) `MODE PIECE = STRUCT (INT cp, count, bp, FLEX [1: 0] COLLECTION c);`

C) `MODE COLLECTION =UNION (PICTURE, COLLITEM);`

D) `MODE COLLITEM = STRUCT (INSERTION i1, PROC INT rep, INT p, INSERTION i2);`

E) `MODE INSERTION = FLEX [1 : 0] STRUCT (PROC INT rep, UNION (STRING, CHAR) sa);`

F) `MODE PICTURE = STRUCT (UNION (PATTERN, CPATTERN, FPATTERN, GPATTERN, VOID) p, INSERTION i);`

G) `MODE PATTERN = STRUCT (INT type, FLEX [1 : 0] FRAME frames);`

H) `MODE FRAME = STRUCT (INSERTION i, PROC INT rep, BOOL supp, CHAR marker);`

I) `MODE CPATTERN = STRUCT (INSERTION i, INT type, FLEX [1 : 0] INSERTION c);`

J) `MODE FPATTERN = STRUCT (INSERTION i, PROC FORMAT pf);`

K) `MODE GPATTERN = STRUCT (INSERTION i, FLEX [1 : 0] PROC INT spec);` }

A) **FORMAT :: structured with row of PIECE field letter aleph mode.**

B) **PIECE ::**
structured with integral field letter c letter p
integral field letter c letter o letter u letter n letter t
integral field letter b letter p
row of COLLECTION field letter c mode.

C) **COLLECTION :: union of PICTURE COLLITEM mode.**

D) **COLLITEM ::**
structured with
INSERTION field letter i digit one
procedure yielding integral field letter r letter e letter p
integral field letter p
INSERTION field letter i digit two mode.

E) **INSERTION ::**
row of structured with
procedure yielding integral field letter r letter e letter p
union of row of character character mode field letter s letter a mode.

F) **PICTURE ::**
structured with
union of PATTERN CPATTERN FPATTERN GPATTERN void mode field letter p
INSERTION field letter i mode.

G) **PATTERN ::**
structured with
integral field letter t letter y letter p letter e
row of FRAME field letter f letter r letter a letter m letter e letter s mode.

H) **FRAME ::**
structured with
INSERTION field letter i
procedure yielding integral field letter r letter e letter p
boolean field letter s letter u letter p letter p
character field letter m letter a letter r letter k letter e letter r mode.

I) **CPATTERN ::**
structured with
INSERTION field letter i
integral field letter t letter y letter p letter e
row of INSERTION field letter c mode.

J) **FPATTERN ::**
structured with
INSERTION field letter i
procedure yielding FIVMAT field letter p letter f mode.

K) **GPATTERN ::**
structured with
INSERTION field letter i
row of procedure yielding integral field letter s letter p letter e letter c mode.

L) **FIVMAT ::**
mui definition of structured with
row of structured with integral field letter c letter p
integral field letter c letter o letter u letter n letter t
integral field letter b letter p
row of union of
structured with
union of PATTERN CPATTERN
structured with INSERTION field letter i
procedure yielding mui application field
letter p letter f

mode
GPATTERN void
mode field letter p
INSERTION field letter i
mode
COLLITEM
mode field letter c
mode field letter aleph
mode.
{**'FIVMAT'** is equivalent (17_2.1.1.2.a) to **'FORMAT'**.}

M) **MARK :: sign ; point ; exponent ; complex ; boolean.**

N) **COMARK :: zero ; digit ; character.**

O) **UNSUPPRESSETY :: unsuppressible ; EMPTY.**

P) **TYPE :: integral ; real ; boolean ; complex ; string ; bits ; integral choice ; boolean choice ; format ; general.**

a) **FORMAT NEST format text** {20_5.D} **:**
formatter {25_9.4.f} **token, NEST collection** {b} **list, formatter** {25_9.4.f} **token.**

b) **NEST collection** {a,b} **:**
pragment {25_9.2.a} **sequence option, NEST picture** {c}**;**
pragment {25_9.2.a} **sequence option, NEST insertion** {d}**,**
NEST replicator {g}**, NEST collection** {b} **list brief pack,**
pragment {25_9.2.a} **sequence option, NEST insertion** {d}**.**

c) **NEST picture** {b} **:**
NEST TYPE pattern {26_{10}.3.4.2.a, 26_{10}.3.4.3.a, 26_{10}.3.4.4.a, 26_{10}.3.4.5.a, 26_{10}.3.4.6.a, 26_{10}.3.4.7.a, 26_{10}.3.4.8.a,b, 26_{10}.3.4.9.a, 26_{10}.3.4.10.a}
option, NEST insertion {d}**.**

d) **NEST insertion** {b,c,j,k, 26_{10}.3.4.7.b, 26_{10}.3.4.3.a,b, 26_{10}.3.4.9.a, 26_{10}.3.4.10.a} **:**
NEST literal {i} **option, NEST alignment** {e} **sequence option.**

e) **NEST alignment** {d} **:**
NEST replicator {g}**, alignment code** {f}**, NEST literal** {i} **option.**

f) **alignment code** {e} **:**
letter k {25_9.4.a} **symbol ; letter x** {25_9.4.a} **symbol ; letter y** {25_9.4.a} **symbol ;**
letter l {25_9.4.a} **symbol ; letter p** {25_9.4.a} **symbol ; letter q** {25_9.4.a} **symbol.**

g) **NEST replicator** {b,e,i,k} **: NEST unsuppressible replicator** {h} **option.**

h) **NEST unsuppressible replicator** {g,i} **:**
fixed point numeral {24_8.1.1.b} **; letter n** {25_9.4.a} **symbol,**

meek integral NEST ENCLOSED clause {18_3.1.a, 18_3.4.a, -}**,**
pragment {25_9.2.a} **sequence option.**

i) **NEST UNSUPPRESSETY literal** {d,e,i, 26_{10}.3.4.8.c} **:**
NEST UNSUPPRESSETY replicator {g,h}**,**
strong row of character NEST denoter {24_8.0.a} **coercee** {22_6.1.a} **,**
NEST unsuppressible literal {i} **option.**

j) **NEST UNSUPPRESSETY MARK frame**
{26_{10}.3.4.2.c, 26_{10}.3.4.3.b,c, 26_{10}.3.4.4.a, 26_{10}.3.4.5.a} **:**
NEST insertion {d}**, UNSUPPRESSETY suppression** {l} **,**
MARK marker {26_{10}.3.4.2.e, 26_{10}.3.4.3.d,e, 26_{10}.3.4.4.b, 26_{10}.3.4.5.b} **.**

k) **NEST UNSUPPRESSETY COMARK frame** {26_{10}.3.4.2.b,c, 26_{10}.3.4.6.a} **:**
NEST insertion {d} **, NEST replicator** {g}**,**
UNSUPPRESSETY suppression {l} **,**
COMARK marker {26_{10}.3.4.2.d,f, 26_{10}.3.4.6.b} **.**

l) **UNSUPPRESSETY suppression** {j,k, 26_{10}.3.4.7.b} **:**
where (UNSUPPRESSETY) is (unsuppressible), EMPTY ;
where (UNSUPPRESSETY) is (EMPTY), letter s {25_9.4.a} **symbol option.**

m) ***frame :**
NEST UNSUPPRESSETY MARK frame {j} **;**
NEST UNSUPPRESSETY COMARK frame {k}**;**
NEST RADIX frame {26_{10}.3.4.7.b} **.**

n) ***marker :**
MARK marker {26_{10}.3.4.2.e, 26_{10}.3.4.3.d,e, 26_{10}.3.4.4.b, 26_{10}.3.4.5.b} **;**
COMARK marker {26_{10}.3.4.2.d,f, 26_{10}.3.4.6.b} **; radix marker** {26_{10}.3.4.7.c} **.**

o) ***pattern : NEST TYPE pattern**
{26_{10}.3.4.2.a, 26_{10}.3.4.3.a, 26_{10}.3.4.4.a, 26_{10}.3.4.5.a, 26_{10}.3.4.6.a,
26_{10}.3.4.7.a, 26_{10}.3.4.8.a,h, 26_{10}.3.4.9.a, 26_{10}.3.4.10.a} **.**

{Examples:

a)
```
$p"table of"x 10a,l n(lim-1)("x="12z+d 2x,
  +.12de+2d3q"+j*"3" "si+.10de+2d l)p$
```

b)
```
p"table of"x10a • l n(lim-1)("x="12z+d 2x,
  +.12de+2d3q"+j*"3" "si+.10de+2d l)p
```

c)
```
120k c("mon", "tues", "wednes", "thurs",
  "fri", "satur", "sun") "day"
```

d)
```
p"table of"x
```

e) `p"table of"`

h) `10 • n(lim-1)`

i) `"+j*"3" "`

j) `si`

k) `"x="12z`

l) `s }`

{The positions where pragments {25_9.2.1.a} may occur in **format-texts** are restricted. In general (as elsewhere in the language), a pragment may not occur between two **DIGIT-** or **LETTER-symbols**.}

{aa) For formatted output, `putf` {26_{10}.3.5.1.a} and `printf` (or `writef`) {26_{10}.5.1.f} may be used and, for formatted input, `getf` {26_{10}.3.5.2.a} and `readf` {26_{10}.5.1.g}. Each element in the data list (cf. 26_{10}.3.3) is either a format to be associated with the file or a value to be transput (thus a format may be included in the data list immediately before the values to be transput using that format) .

bb) During a call of `putf` or `getf` transput proceeds as follows:
For each element of the data list, considered in turn,

> If it is a format,
>
> then it is made to be the current format of the file by `associate format` (26_{10}.3.5.k):
>
> otherwise, the element is straightened (26_{10}.3.2.3.c) and each element of the resulting multiple value is output {hh} or input {ii} using the next "picture" {cc, gg} from the current format.

cc) A "picture" is the yield of a **picture**. It is composed of a "pattern"of some specific **'TYPE'** (according to the syntax of the **TYPE-pattern** of that **picture**), followed by an "insertion" {ee}. Patterns, apart from **'choice'**, **'format'** and **'general'** patterns, are composed of "frames", possibly "suppressed", each of which has an insertion, a "replicator" {dd}, and a "marker" to indicate whether it is a `"d"`, `"z"`, `"i"` etc. frame. The frames of each pattern may be grouped into "sign moulds", "integral moulds", etc., according to the syntax of the corresponding pattern.

dd) A "replicator" is a routine, returning an integer, constructed from a **replicator** {26_{10}.3.4.1.2.c}, For example, the **replicator** `10` gives rise to a routine composed from `INT: 10;` moreover, `n (lim - 1)` is a "dynamic" **replicator** and gives rise to `INT: (lim - 1)`. Note that the scope of a replicator restricts the scope of any format containing it, and thus it may be necessary to take a local copy of a file before associating a format with it (see, e.g.. 11.D)

. A replicator which returns a negative value is treated as if it had returned zero ("k" alignments apart) .

When a **picture** is "staticized", all of its replicators and other routines (including those contained in its insertions) are called collaterally. A staticized pattern may be said to "control" a string, and there is then a correspondence between the frames of that pattern, taken in order, and the characters of the string. Each frame controls n consecutive characters of the string, where n is 0 for an "r" frame and, otherwise, is the integer returned by the replicator of the frame (which is always 1 for a "+", "−", ".", "e", "i" or "b" frame) . Each controlled character must be one of a limited set appropriate to that frame.

ee) An "insertion", which is the yield of an **insertion** {26_{10}.3.4.1.2.d}, is a sequence of replicated "alignments" and strings: an insertion containing no alignments is termed a "literal". An insertion is "performed" by performing its alignments {ff} and on output (input) writing ("expecting" {ll}) each character of its replicated strings (a string is replicated by repeating it the number of times returned by its replicator) .

ff) An "alignment" is the character yielded by an **alignment-code** {26_{10}.3.4.1.2.d}. An alignment which has been replicated n times is performed as follows:

- "k" causes `set char number` to be called, with n as its second parameter:
- "x" causes `space` to be called n times:
- "y" causes `backspace` to be called n times:
- "l" causes `newline` to be called n times:
- "p" causes `newpage` to be called n times;
- "q" on output (input) causes the character `blank` to be written (expected) n times.

gg) A format may consist of a sequence of **pictures**, each of which is selected in turn by `get next picture` {26_{10}.3.5.b}. In addition, a set of pictures may be grouped together to form a replicated "collection" (which may contain further such collections) . When the last picture in a collection has been selected, its first picture is selected again, and so on until the whole collection has been repeated n times, where n is the integer returned by its replicator. A collection may be provided with two insertions, the first to be performed before the collection, the second afterwards.

A format may also invoke other formats by means of **'format'** patterns {26_{10}.3.4.9.1}.

When a format has been exhausted, the event routine corresponding to `on format end` is called; if this returns `false`, the format is repeated; otherwise, if the event routine has failed to provide a new format, `undefined` is called.

hh) A value V is output, using a picture P, as follows:

If the pattern Q of P is a **'choice'** or **'general'** pattern,

then V is output using P (See 26_{10}.3.4.3.1.aa,dd, 26_{10}.3.4.10.1.aa);

otherwise, V is output as follows:

- P is staticized;

  If the mode of V is "output compatible" with Q (see the separate section dealing with each type of pattern),

  then

  - V is converted into a string controlled {dd} by Q (See the appropriate section);

  If the mode is not output compatible, or if the conversion is unsuccessful,

  then

  - the event routine corresponding to `on value error` is called;
  - if this returns `false`, V is output using `put` and `undefined` is called;

  otherwise, the string is "edited" (jj) using Q:
- the insertion of P is performed.

ii) A value is input to a name N, using a picture P, as follows:

If the pattern Q of P is a **'choice'** or **'general'** pattern,

then a value is input to N using P (see 26_{10}.3.4.8.1.bb,ee, 26_{10}.3.4.10.1.bb);

otherwise,

- P is staticized;
- a string controlled by Q is "indited" {kk};

  If the mode of N is "input compatible" with Q (see the appropriate section),

  then

  - the string is converted to an appropriate value suitable for N using Q (see the appropriate section):
  - if the conversion is successful, the value is assigned to N;

  If the mode is not input-compatible, or if the conversion is unsuccessful,

  then

  - the event routine corresponding to `on value error` is called;
  - if this returns `false`, `undefined` is called;
- the insertion of P is performed.

jj) A string is "edited", using a pattern P, as follows:
In each part of the string controlled by a sign mould,

- if the first character of the string (which indicates the sign) is "+" and the sign mould contains a "−" frame, then that character is replaced by "␣"
- the first character (i.e., the sign) is shifted to the right across all leading zeroes in this part of the string and these zeroes are replaced by spaces (for example, using the sign mould 4z+, the string "+0003" becomes "+␣␣␣3"

In each part of the string controlled by an integral mould,

- zeroes controlled by "z" frames are replaced by spaces as follows:
  - between the start of the string and the first nonzero digit;
  - between each "d", "e" or "i" frame and the next nonzero digit; (for example, using the pattern zdzd2d the string "180168" becomes "18␣168";)

For each frame F of P,

- the insertion of F is performed.
- if F is not suppressed, the characters controlled by F are written; (for example, the string "+0003.5", when edited using the pattern 4z+ s. "," d, causes the string "␣␣␣+3,5" to be written and the string "180168", using the pattern zd"−"zd"−19"2d, gives rise to "18−␣1−1968") .

kk) A string is "indited", using a pattern P, as follows:
For each frame F of P,

- the insertion of F is performed.

  For each element of the string controlled by F, a character is obtained as follows:

  If F is contained in a sign mould,

  then

  - if a sign has been found, a digit is expected, with "0" as suggestion;
  - otherwise, either a "+" or a "−" is expected, with "0" as suggestion, and, in addition, if the sign mould contains a frame, then a space preceding the first digit will be accepted as the sign (and replaced by "+");

  otherwise, if F is contained in an integral mould,

then

If F is suppressed,

then "0" is supplied,

otherwise:

Case A: F is a "d" frame:

- a digit is expected, with "0" as suggestion;

Case B: if F is "z" frame:

- a digit or space is expected, with "0" as suggestion, but a space is only acceptable as follows:
  - between the start of the string and the first nonzero digit;
  - between each "d", "e" or "i" frame and the next nonzero digit;
- such spaces are replaced by zeroes.

otherwise, if F is an "a" frame,

then

if F is not suppressed, a character is read and supplied;

otherwise " " is supplied;

otherwise, if F is not suppressed,

then

if F is a "." ("e", "i", "b") frame, a "." ("$_{10}$" or "
" or "e", "I" or "i", flip or flop) is expected, with "." ("$_{10}$", "I", flop) as suggestion;

otherwise,

if F is a suppressed "." ("e", "i") frame, the character "." ("$_{10}$", "I") is supplied.

ll) A member of a set of characters S is "expected", with the character C as suggestion, as follows:

- a character is read;

  If that character is one of the expected characters (i.e., a member of S),

  then that character is supplied;

  otherwise, the event routine corresponding to on char error is called, with C as suggestion; if this returns true and C, as possibly replaced, is one of the expected characters, then that character is supplied; otherwise, undefined is called. }

26.3.4.1.2. Semantics

{A format is brought into being by means of a **format-text**. A format is best regarded as a tree, with a collection at each node and a picture at each tip. In order to avoid violation of the scope restrictions, each node of this tree is, in this Report, packed into a value of mode **'PIECE'**. A format is composed of a row of such pieces and the pieces contain pointers to each other in the form of indices selecting from that row. An implementer will doubtless store the tree in a more efficient manner. This is possible because the **field-selector** of a format is hidden from the user in order that he may not break it open.

Although a **format-text** may contain **ENCLOSED-clauses** (in **replicators** and **format-patterns**) or **units** (in **general-patterns**,) these are not elaborated at this stage but are, rather, turned into routines for subsequent calling as and when they are encountered during formatted transput. Indeed, the elaboration of a **format-text** does not result in any actions of any significance to the user.}

a) The yield of a **format-text** F, in an environ E, is a structured value whose only field is a multiple value W, whose mode is **'row of PIECE'**, composed of a descriptor ((1, n)) and n elements determined as follows:

- a counter i is set to 1;
- F is "transformed" {b} in E into W, using i.

b) A **format-text** or a **collection-list-pack** C is "transformed" in an environ E into a multiple value W whose mode is **'row of PIECE'**, using a counter i, as follows:
•the element of W selected by (i) is a structured value, whose mode is **'PIECE'** and whose fields, taken in order, are

- {cp} undefined;
- {$count$} undefined;
- {bp} undefined;
- {c} a multiple value V whose mode is "**row of COLLECTION**", having a descriptor ((1,m)), where m is the number of constituent collections of C, and elements determined as follows:
  For $j = 1, ...m$, letting C_j be the j-th constituent collection of C,

Case A: The direct descendents of C_j include a **picture** P.

- the constituent **pattern** P if any and the **insertion** I of P are elaborated collaterally;
- the j-th element of V is a structured value, whose mode is **'PICTURE'** and whose fields, taken in order are

- {p}; the yield of T, if any, {e, 26_{10}.3.4.8.2, 26_{10}.3.4.9.2, 26_{10}.3.4.10.2} and, otherwise, `empty`.
- {i} the yield of I {d};

Case B: The direct descendents of C_j, include a first **insertion** $I1$, a **replicator** REP, a **collection-list-pack** P and a second **insertion** $I2$:

- i is increased by 1;
- $I1$, REP and $I2$ are elaborated collaterally;
- the j-th element of V is a structured value whose mode is **'COLLITEM'** and whose fields, taken in order, are
  - {$i1$} the yield of $I1$ {d};
  - {rep} the yield of REP {c};
  - {p} i;
  - {$i2$} the yield of $I2$;
- P is transformed in E into W, using i.

c) The yield, in an environ E, of a **NEST-UNSUPPRESSETY-replicator** R {26_{10}.3.4.1.1.g, h} is a routine whose mode is **'procedure yielding integral'**, composed of a **procedure-yielding-integral-NEST-routine-text** whose **unit** is U, together with the environ necessary {23_7.2.2.c} for U in E, where U is determined as follows:

Case A: R contains a **meek-integral-ENCLOSED-clause** C:

- U is a new **unit** akin {16_1.1.3.2.k} to C;

Case B: R contains a **fixed-point-numeral** D, but no **ENCLOSED-clause**:

- U is a new **unit** akin to D;

Case C: R is invisible:

- U is a new **unit** akin to a **fixed-point-numeral** which has an intrinsic value {24_8.1.1.2} of 1.

d) The yield of an **insertion** I {26_{10}.3.4.1.1.d} is a multiple value W whose mode is **'INSERTION'**, determined as follows:

- let $u_1, ..., U_n$ be the constituent **UNSUPPRESSETY-replicators** of I, and let $A_i, i = 1, ...n$, be the **denoter-coercee** or **alignment-code** {immediately} following U_i:
- let $R_1, ..., R_n$ and $D_1, ..., D_n$ be the {collateral} yields of $u_1, ..., U_n$ and $A_1, ..., A_n$, where the yield of an **alignment-code** is the {character which is the} intrinsic value {24_8.1.4.2.b} of its **LETTER-symbol**;

- the descriptor of W is $((1, n))$;
- the element of W selected by (i), $i = 1, ..., n$, is a structured value {of the mode specified by
  `STRUCT (PROC INT rep, UNION (STRING, CHAR) sa)`} whose fields, taken in order, are
  - {rep} R_i;
  - {sa} D_i.

e) The yield of an **integral-**, **real-**, **boolean-**, **complex-**, **string-** or **bits-pattern** P {26_{10}.3.4.2.1.a, 26_{10}.3.4.3.1.a, 26_{10}.3.4.4.1.a, 26_{10}.3.4.5.1.a, 26_{10}.3.4.6.1.a, 26_{10}.3.4.7.1.a} is a structured value W whose mode is **'PATTERN'**, determined as follows:

- let $V_1, ..., V_n$ be the {collateral} yields of the constituent frames of P {f};
- the fields of W, taken in order, are
- {$type$} $1(2, 3, 4, 5)$ if P is an **integral-** (**real-**, **boolean-**, **complex-**, **string-**) **-pattern** and $6(8, 12, 20)$ if P is a **bits-pattern** whose constituent **RADIX** is a **radix-two** (**-four**, **-eight**, **-sixteen**);
- {$frames$} a multiple value, whose mode is **'row of FRAME'**, having a descriptor $((1, n))$ and n elements, that selected by (i) being V_i.

f) The yield of a **frame** F {26_{10}.3.4.1.1.m} is a structured value W whose mode is **'FRAME'**, determined as follows:

- the **insertion** and the **replicator**, it any, of F are elaborated collaterally:
- the fields of W, taken in order, are
  - {i} the yield of its **insertion**;
  - {rep} the yield of its **replicator** {c}, if any, and, otherwise, the yield of an invisible **replicator**:
  - {$supp$} `true` if its first **UNSUPPRESSETY-suppression** contains a **letter-s-symbol** and, otherwise, `false`:
  - {$marker$} (the character which is the intrinsic value {24_8.1.4.2.b} of a **symbol** S determined as follows:

Case A: F is a constituent **unsuppressible-zero-frame** of a **sign-mould** {such as `3z+`} whose constituent **sign-marker** contains a **plus-symbol**:
- S is a **letter-u-symbol**.

Case B: F is a constituent **unsuppressible-zero-frame** of a **sign-mould** {such as `3z-`} whose constituent **sign-marker** contains a **minus-symbol**:

- S is a **letter-v-symbol**.

Other cases: •S is the constituent **symbol** of the **marker** of F.

{Thus the **zero-marker** `z` may be passed on as the character `"u"`, `"v"` or `"z"` according to whether it forms part of a **sign-mould** (with descendent **plus-symbol** or **minus-symbol**) or of an **integral-mould**.}

26.3.4.2 Integral patterns

26.3.4.2.1. Syntax

a) **NEST integral pattern** {26_{10}.3.4.1.c,26_{10}.3.4.3.c} **:**
NEST sign mould {c} **option, NEST integral mould** {b}**.**

b) **NEST integral mould** {a, 26_{10}.3.4.3.b, c, 26_{10}.3.4.7.a} **:**
NEST digit frame {26_{10}.3.4.1.k} **sequence.**

c) **NEST sign mould** {a, 26_{10}.3.4.3.a} **:**
NEST unsuppressible zero frame {26_{10}.3.4.1.k} **sequence option,**
NEST unsuppressible sign frame {26_{10}.3.4.1.j} **.**

d) **zero marker** {f, 26_{10}.3.4.1.k} **: letter z** {25_9.4.a} **symbol.**

e) **sign marker** {26_{10}.3.4.1.j} **: plus** {25_9.4.c} **symbol ; minus** {25_9.4.c} **symbol.**

f) **digit marker** {26_{10}.3.4.1.k} **: letter d** {25_9.4.a} **symbol ; zero marker** {d}**.**

{Examples:

a) `"x=" 12z+d`

b) `d`

c) `"x=" 12z+` }

{For the semantics of **integral-patterns** see 26_{10}.3.4.1.2.e .}

{aa) The modes which are output (input) compatible with an **'integral'** pattern are those specified by L `INT` (by `REF` L `INT`) .

bb) A value V is converted to a string S using an **'integral'** pattern P as follows:

- if P contains a sign mould, the first character of S is the sign of V; otherwise, if V < 0, the conversion is unsuccessful;
- the remainder of S contains a decimal representation of V determined as follows:
  - the elements of S controlled by `"d"` and `"z"` frames are the appropriate digits (thus the pattern specifies the number of digits to be used);
  - if V cannot be represented by such a string, the conversion is unsuccessful;

(For example, the value 99 could be converted to a string using the pattern `zzd`, but 9999 and -99 could not.)

cc) A string S is converted to an integer suitable for a name N, using an **'integral'** pattern, as follows:

- the integer I for which S contains a decimal representation {24_8.1.1.2} is considered;
- if I is greater than the largest value to which N can refer, the conversion is unsuccessful; otherwise, I is the required integer (e.g., if the mode of N is specified by `REF SHORT INT`, and the value of `short max int` is 65535, then no string containing a decimal representation of a value greater than 65535 may be converted) .}

26.3.4.3 Real patterns

26.3.4.3.1. Syntax

a) **NEST real pattern** {26_{10}.3.4.1.c, 26_{10}.3.4.5.a} **:**
NEST sign mould {26_{10}.3.4.2.c} **option,**
NEST variable point mould {b}
or alternatively NEST floating point mould {c}**.**

b) **NEST variable point mould** {a,c} **:**
NEST integral mould {26_{10}.3.4.2.b} **;**
NEST point frame {26_{10}.3.4.1.j} **, NEST integral mould** {26_{10}.3.4.2.b} **option;**
NEST point frame {26_{10}.3.4.1.j} **, NEST integral mould** {26_{10}.3.4.2.b} **.**

c) **NEST floating point mould** {a} **:**
NEST variable point mould {b}
or alternatively NEST integral mould {26_{10}.3.4.2.b} **,**
NEST exponent frame {26_{10}.3.4.1.j} **, NEST integral pattern** {26_{10}.3.4.2.a} **.**

d) **point marker** {26_{10}.3.4.1.j} **: point** {25_9.4.b} **symbol.**

e) **exponent marker** {26_{10}.3.4.1.j} **: letter e** {25_9.4.a} **symbol.**

{Examples:

a) `+zd.11d • +.12de+2d`

b) `zd.11d • +.12d`

c) `.12de+2d`}

{For the semantics of **real-patterns** see 26_{10}.3.4.1.2.e .}

{aa) The modes which are output (input) compatible with a **'real'** pattern are those specified by L `REAL` and L `INT` (by `REF` L `REAL`) .

bb) A value V is converted to a string S using a **'real'** pattern P as follows:

- if P contains a sign mould, the first character of S is the sign of V; otherwise, if V < 0, the conversion is unsuccessful;
- the remainder of S contains a decimal representation of V determined as follows:
  - if necessary, V is widened to a real number;
  - the element of S controlled by the `"."` (`"e"`) frame, if any, of P is `"."` (`"`$_{10}$`"`);

    If P contains an `"e"` frame,

    then
    - let W be the sequence of frames preceding, and IP be the **'integral'** pattern following, that `"e"` frame;
    - an exponent E is calculated by standardizing V to the largest value convertible using W (see below);
    - the part of S controlled by IP is obtained by converting E using IP (see 26_{10}.3.4.2.bb)

    otherwise,
    - let W be the whole of P;
  - the elements of S controlled by the `"d"` and `"z"` frames of W are the appropriate digits to be used, and the number of digits to be placed after the decimal point, if any);
  - if V cannot be represented by such a string, the conversion is unsuccessful.

cc) A string S is converted to a real number suitable for a name N, using a **'real'** pattern P, as follows:

- the real number R for which S contains a decimal representation is considered;
- if R is greater than the largest value to which N can refer, the conversion is unsuccessful; otherwise, R is the required real number.}

26.3.4.4 Boolean patterns

26.3.4.4.1. Syntax

a) **NEST boolean pattern** {26_{10}.3.4.1.c} **:**
NEST unsuppressible boolean frame {26_{10}.3.4.1.j} **.**

b) **boolean marker** {26_{10}.3.4.1.j, 26_{10}.3.4.8.b} **: letter b** {25_{9}.4.a} **symbol.**

{Example:

a) `14x b` }

{For the semantics of **boolean-patterns** see 26_{10}.3.4.1.2.e .}

{aa) The mode which is output (input) compatible with a **'boolean'** pattern is that specified by `BOOL` (`REF BOOL`). bb) A value V is converted to a string using a **'boolean'** pattern as follows:

- if V is `true` (`false`), then the string is that yielded by `flip` (`flop`) .

cc) A string S is converted to a boolean value, using a **'boolean'** pattern, as follows:

- if S is the same as the string yielded by `flip` (`flop`), then the required value is `true` (`false`) .}

26.3.4.5 Complex patterns

26.3.4.5.1. Syntax

a) **NEST complex pattern** {26_{10}.3.4.1.c} **:**
NEST real pattern {26_{10}.3.4.3.a} **,**
NEST complex frame {26_{10}.3.4.1.j} **,**
NEST real pattern {26_{10}.3.4.3.a} **.**

b) **complex marker** {26_{10}.3.4.1.j} **: letter i** {25_9.4.a} **symbol.**

{Example:

a) `+.12de+2d 3q"+j*"3" "si+.10de+2d`}

{For the Semantics of **complex-patterns** see 26_{10}.3.4.1.2.e .}

{aa) The modes which are output (input) compatible with a **'complex'** pattern are those specified by L `COMPL`, L `REAL` and L `INT` (by `REF` L `COMPL`) .

bb) A value V is converted to a string S using a **'complex'** pattern P as follows:

- if necessary, V is widened to a complex number;
- the element of S controlled by the `"i"` frame of P is `"I"`;
- the part of S controlled by the first (second) **'real'** pattern of P is that obtained by converting the first (second) field of V to a string using the first (second) **'real'** pattern of P {26_{10}.3.4.3.1.bb}
- if either conversion is unsuccessful, the conversion of V is unsuccessful.

cc) A string is converted to a complex value C suitable for a name N, using a **'complex'** pattern P, as follows:

- the part of the string controlled by the first (second) **'real'** pattern of P is converted to a suitable real number {26_{10}.3.4.3.1.cc}, which then forms the first (second) field of C.
- if either conversion is unsuccessful, the conversion to C is unsuccessful.}

26.3.4.6 String patterns

26.3.4.6.1. Syntax

a) **NEST string pattern** {26_{10}.3.4.1.c} **:**
NEST character frame {26_{10}.3.4.1.k} **sequence.**

b) **character marker** {26_{10}.3.4.1.k} **:**
letter a {25_{9}.4.a} **symbol.**

{Example:

a) `p "table of"x 10a` }

{For the semantics of **string-patterns** see 26_{10}.3.4.1.2.e .} {

aa) The modes which are output (input) compatible with a **'string'** pattern are those specified by `CHAR` and `[] CHAR` (by `REF CHAR`, `REF [] CHAR` and `REF STRING`) .

bb) A value V is converted to a string using a **'string'** pattern P as follows:

- if necessary, V is rowed to a string:
- if the length of the string V is equal to the length of the string controlled by P, then V is supplied: otherwise, the conversion is unsuccessful,

cc) A string S is converted to a character or a string suitable for a name N, using a **'string'** pattern, as follows:

Case A: The mode of N is specified by `REF CHAR`:

- if S does not consist of one character, the conversion is unsuccessful: otherwise, that character is supplied:

Case B: The mode of N is specified by `REF [] CHAR`:

- if the length of S is not equal to the number of characters referred to by N, the conversion is unsuccessful: otherwise, S is supplied,

Case C: The mode of N is specified by `REF STRING`:

- S is supplied.}

26.3.4.7 Bits patterns

26.3.4.7.1. Syntax

a) **NEST bits pattern** {26_{10}.3.4.1.c} **:**
NEST RADIX frame {b}**, NEST integral mould** {26_{10}.3.4.2.b} **.**

b) **NEST RADIX frame {a} :**
NEST insertion {A341d} **, RADIX** {24_8.2.d,e,f,g} **,**
unsuppressible suppression {26_{10}.3.4.1.l} **, radix marker** {c}**.**

c) **radix marker** {b} **: letter r** {25_9.4.a} **symbol.**

{Examples:

a) `2r6d26sd`

b) `2r` }

{For the semantics of **bits-patterns**, see 26_{10}.3.4.1.2.e .}

{aa) The modes which are output (input) compatible with a **'bits'**-pattern are those specified by *L* `BITS` (`REF` *L* `BITS`) .

bb) A value *V* is converted to a string using a **'bits'** pattern *P* as follows:

- the integer *I* corresponding to *V* is determined, using the **operator** `ABS` {26_{10}.2.3.8.i};

  If the `"r"` frame of *P* was yielded by a **radix-two-** (**-four-**, **-eight-**, **-sixteen-**) **-frame**,

  then

  I is converted to a string, controlled by the integral mould of *P*, containing a binary (quaternary, octal, hexadecimal) representation of *I* (cf. 26_{10}.3.4.2.1.bb);

- if *I* cannot be represented by such a string, the conversion is unsuccessful.

cc) A string *S* is converted to a bits value suitable for a name *N*, using a **'bits'** pattern *P*, as follows:

- if the `"r"` frame of *P* was yielded by a **radix-two-** (**-four-**, **-eight-**, **-sixteen-**) **-frame**, then the integer *I* for which *S* contains a binary (quaternary, octal, hexadecimal) representation is determined;

- the bits value *B* corresponding to *I* is determined, using the operator `BIN` (26_{10}.2.3.8.j) :

- if the width of *B* is greater than that of the value to which *N* refers, the conversion is unsuccessful.}

26.3.4.8 Choice patterns

26.3.4.8.1. Syntax

a) **NEST integral choice pattern** {26_{10}.3.4.1.c} **:**
NEST insertion {26_{10}.3.4.1.d} **,**
letter c {25_9.4.a} **symbol, NEST praglit** {c} **list brief pack,**
pragment {25_9.2.a} **sequence option.**

b) **NEST boolean choice pattern** {26_{10}.3.4.1.c} **:**
NEST insertion {26_{10}.3.4.1.d} **, boolean marker** {26_{10}.3.4.4.b} **,**
brief begin {25_9.4.f} **token, NEST praglit** {c}**, and also** {25_9.4.f} **token,**
NEST praglit {c}**, brief end** {25_9.4.f} **token,**
pragment {25_9.2.a} **sequence option.**

c) **NEST praglit** {a,b} **: pragment** {25_9.2.a} **sequence option, NEST literal** {26_{10}.3.4.1.i} **.**

{Examples:

a) `120kc ("mon", "tues", "wednes", "thurs", "fri", "satur", "sun")`

b) `b ("","error")`

c) `"mon" }`

{aa) A value V is output using a **picture** P whose pattern Q was yielded by an **integral-choice-pattern** C, as follows:

- the **insertion** of Q is staticized {26_{10}.3.4.1.1.dd} and performed {26_{10}.3.4.1.1.ee};

  If the mode of V is specified by `INT`, if $V > 0$ and if the number of constituent **literal**s in the **praglit-list-pack** of C is at least V,

  then

  - the literal yielded by the V-th **literal** is staticized and performed;

  otherwise,

  - the event routine corresponding to `on value error` is called;
  - if this returns `false`, V is output using `put` and `undefined` is called;
- the **insertion** of P is staticized and performed.

bb) A value is input to a name N using a picture P whose pattern Q was yielded by an **integral-choice-pattern** C as follows:

- the **insertion** of Q is staticized and performed,
- each of the literals yielded by the constituent **literal**s of the **praglit-list-pack** of C is staticized and "searched for" {cc} in turn:

  If the mode of N is specified by `REF INT` and the i-th literal is the first one present.

  then i is assigned to N:

  otherwise,

  - the event routine corresponding to `on value error` is called;
  - if this returns `false`, `undefined` is called;
- the **insertion** of P is staticized and performed.

cc) A literal is "searched for" by reading characters and matching them against successive characters of the literal. If the end of the current line or the logical end of the file is reached, or if a character fails to match, the search is unsuccessful and the current position is returned to where it started from.

dd) A value V is output using a picture P whose pattern Q was yielded by a **boolean-choice-pattern** C as follows:

- the insertion of Q is staticized and performed:

  If the mode of V is specified by `BOOL`,

  then

- if V is `true` (`false`), the literal yielded by the first (second) constituent **literal** of C is staticized and performed:

  otherwise,

  - the event routine corresponding to `on value error` is called;
  - if this returns `false`, V is output using `put` and `undefined` is called;
- the insertion of P is staticized and performed.

ee) A value is input to a name N using a picture P whose pattern Q was yielded by a **boolean-choice-pattern** C as follows:

- the insertion of Q is staticized and performed;
- each of the literals yielded by the constituent **literals** of C is staticized and searched for in turn:

If the mode of N is specified by `REF BOOL`, and the first second) insertion is present,

then `true` (`false`) is assigned to N:

otherwise,

- the event routine corresponding to `on value error` is called;
- if this returns `false`, `undefined` is called;

- the insertion of P is staticized and performed.}

26.3.4.8.2. Semantics

The yield of a **choice-pattern** P is a structured value W whose mode is **'CPATTERN'**, determined as follows:

- let n be the number of constituent **NEST-literals** of the **praglit-list-pack** of P;
- let $S_i, i = 1, ..., n$, be a **NEST-insertion** akin {16_1.1.3.2.k} to the i-th of those constituent **NEST-literals**:
- the **insertion** I of P and all of $S_1, S_2, ..., S_n$ are elaborated collaterally:
- the fields of W, taken in order, are
  - {i} the yield of I:
  - {$type$} $1(2)$ if P is a **boolean- (integral-) -choice-pattern**;
  - {c} a multiple value whose mode is **'row of INSERTION'**, having a descriptor $((1, n))$ and n elements, that selected by $(i), i = 1, ...n$, being the yield of S_i.

26.3.4.9 Format patterns

26.3.4.9.1. Syntax

a) **NEST format pattern** {26_{10}.3.4.1.c} **:**
NEST insertion {26_{10}.3.4.1.d} **, letter f** {25_{9}.4.a} **symbol,**
meek FORMAT NEST ENCLOSED clause {18_{3}.1.a, 18_{3}.4.a} **,**
pragment {25_{9}.2.a} **sequence option.**

{Example:

a) `f (uir | (INT): $5d$, (REAL): $d.3d$)` }

{A **format-pattern** may be used to provide formats dynamically for use in transput. When a **'format'** pattern is encountered during a call of `get next picture`, it is staticized and its insertion is performed. The first picture of the format returned by the routine of the pattern is supplied as the next picture, and subsequent pictures are taken from that format until it has been exhausted.}

26.3.4.9.2. Semantics

The yield, in an environ E, of a **NEST-format-pattern** P is a structured value whose mode is **'FPATTERN'** and whose fields, taken in order, are

- {i} the yield of its **insertion**;
- {pf} a routine whose mode is **'procedure yielding FORMAT'**, composed of a **procedure-yielding-FORMAT-NEST-routine-text** whose **unit** U is a new **unit** akin {16_{1}.1.3.2.k} to the **meek-FORMAT-ENCLOSED-clause** of P, together with the environ necessary for U in E.

26.3.4.10 General patterns

26.3.4.10.1. Syntax

a) **NEST general pattern** {26_{10}.3.4.1.c} **:**
NEST insertion {26_{10}.3.4.1.d} **,**
letter g {25_{9}.4.a} **symbol, NEST width specification** {b} **option.**

b) **NEST width specification {a} :**
brief begin {25_{9}.4.f} **token ;**

meek integral NEST unit {18_3.2.d} **,**
NEST after specification {c} **option, brief end** {25_9.4.f} **token,**
pragment {25_9.2.a} **sequence option.**

c) **NEST after specification** {b} **:**
and also {25_9.4.f} **token, meek integral NEST unit** {18_3.2.d} **,**
NEST exponent specification {d} **option.**

d) **NEST exponent specification** {c} **:**
and also {25_9.4.f} **token, meek integral NEST unit** {18_3.2.d} **.**

{Examples:

a) `g • g(-18, 12, -3)`

b) `-18, 12, -3`

c) `, 12, -3`

d) `, -3 }`

{aa) A value V is output using a picture P whose pattern Q was yielded by a **general-pattern** G as follows:

- P is staticized;
- the insertion of Q is performed;

  If Q is not parametrized (i.e., Q contains no **width-specification**) .

  then V is output using `put`;

  otherwise, if the mode of V is specified by L `INT` or L `REAL`,

  then

  - if Q contains one (two, three) parameter (s), V is converted to a string using `whole` (`fixed`, `float`);
  - the string is written using `put`;

  otherwise,

  - the event routine corresponding to `on value error` is called;
  - if this returns `false`, V is output using `put`, and `undefined` is called;
- the insertion of P is performed.

bb) A value is input to a name N using a **picture** P whose pattern is a **'general'** pattern as follows:

- P is staticized;
- (any parameters are ignored and) the value is input to N using `get`.}

26.3.4.10.2. Semantics

The yield, in an environ E, of a **NEST-general-pattern** P is a structured value whose mode is **'GPATTERN'** and whose fields, taken in order, are

- {i} the yield of the **insertion** of P:
- {*spec*} a multiple value W whose mode is **'row of procedure yielding integral'**, having a descriptor $((1, n))$, where n is the number of constituent **meek-integral-units** of the **width-specification-option** of P, and n elements determined as follows: For $i = 1, ...n$,
  - the i-th element of W is a routine, whose mode is **'procedure yielding integral'**, composed of a **procedure-yielding-integral-NEST-routine-text** whose **unit** U is a new **unit** akin {16_1.1.3.2.k} to the i-th of those **meek-integral-units**, together with the environ necessary for U in E.

26.3.5 Formatted transput

a)
```
MODE FORMAT = STRUCT (FLEX [1: 0] PIECE F);
MODE ℵ0 PIECE = STRUCT (INT cp ¢ pointer to current collection ¢,
  count ¢ number of times piece is to be repeated¢,
  bp ¢ back pointer ¢,
  FLEX [1 : 0] COLLECTION c);
MODE ℵ0 COLLECTION = UNION (PICTURE, COLLITEM) :
MODE ℵ0 COLLITEM = STRUCT (INSERTION i1,
  PROC INT rep; ¢ replicator ¢,
  INT p ¢ pointer to another piece ¢, INSERTION i2);
MODE ℵ0 INSERTION = FLEX [1: 0] STRUCT (PROC INT rep ¢ replicator ¢,
  UNION (STRING, CHAR) sa);
MODE ℵ0 PICTURE = STRUCT (
  UNION (PATTERN, CPATTERN, FPATTERN, GPATTERN, VOID) p,
  INSERTION i);
MODE ℵ0 PATTERN = STRUCT (INT type ¢ of pattern ¢,
  FLEX [1: 0] FRAME frames),
MODE ℵ0 FRAME = STRUCT (INSERTION i,
  PROC INT rep ¢ replicator ¢,
  BOOL supp ¢ true if suppressed ¢,
```

```
    CHAR marker);
  MODE ℵ0 CPATTERN = STRUCT (INSERTION i,
    INT type ¢ boolean or integral ¢,
    FLEX [1 : 0] INSERTION c);
  MODE ℵ0 FPATTERN = STRUCT (INSERTION i, PROC FORMAT pf);
  MODE ℵ0 GPATTERN = STRUCT (INSERTION i, FLEX [1 : 0] PROC INT spec);
```

b)
```
  PROC ℵ0 get next picture = (REF FILE f, BOOL read,
      REF PICTURE picture) VOID:
    BEGIN
    BOOL picture found := FALSE, format ended := FALSE;
    WHILE ¬ picture found
    DO IF forp OF f = 0 THEN
        IF format ended
        THEN undefined
        ELIF ¬ (format mended OF f) (f)
        THEN REF INT (forp OF f) := 1;
          cp OF (F OF format OF f) [1] := 1;
          count OF (F OF format OF f) [1] := 1
        ELSE format ended := TRUE
        FI
      ELSE REF INT forp = forp OF f;
        REF FLEX [] PIECE aleph = F OF format OF f;
        CASE (c OF aleph [forp]) [cp OF aleph [forp]] IN
          (COLLITEM cl) :
            ([1 : UPB (i1 OF cl)] SINSERT si;
            bp OF alph[p OF cl] := forp; forp := SKIP;
            (staticize insertion (i1 OF cl, si),
              count OF aleph [p OF cl] := rep OF cl);
            (aleph :≠: F OF format OF f | undefined);
            (read | get insertion (f, si) | put insertion (f, si));
            cp OF aleph[p OF cl] := 0;
            forp := p OF cl),
          (PICTURE pict): (picture found := TRUE; picture := pict)
        ESAC;
        WHILE
          (forp ≠ 0 | cp OF aleph[forp] = UPB c OF aleph[forp]) | FALSE)
        DO IF (count OF aleph[forp] −:= 1) ≤ 0
        THEN
          IF (forp := bp OF aleph [forp]) ≠ 0
          THEN
            INSERTION extra =
              CASE (c OF aleph [forp]) [cp OF aleph [forp]] IN
              (COLLITEM cl) :
                (bp OF aleph [p OF cl] := 0; i2 OF cl),
              (PICTURE pict) :
                CASE p OF pict IN
                  (FPATTERN fpatt):
                    (INT k := forp;
                    WHILE bp OF aleph [k] ≠ forp DO k +:= 1 OD;
```

```
                    aleph := aleph [ : k - 1];
                    i OF pict)
                ESAC
              ESAC;
            INT m = UPB i OF picture, n = UPB extra;
            [1 : m + n] STRUCT (PROC INT rep, UNION (STRING, CHAR) sa) c;
            c[1 : m] := i OF picture; c[m + 1 : m + n] := extra;
            i OF picture := c
              FI
          ELSE cp OF aleph [forp] := 0
          FI OD;
          (forp ≠ 0 | cp OF aleph [forp] +:= 1)
      FI OD
    END;
```

c)
```
MODE ℵ0 SINSERT = STRUCT (INT rep, UNION (STRING, CHAR) sa);
```

d)
```
PROC ℵ0 staticize insertion = (INSERTION ins, REF [] SINSERT sins) VOID:
    ¢ calls collaterally all the replicators in 'frames' ¢
    IF UPB ins = 1
    THEN
      rep OF sins[1] := rep OF ins[1];
      sa OF sins[1] := sa OF ins[1]
    ELIF UPB ins > 1
    THEN (staticize insertion (ins[1], sins[1]),
        staticize insertion (ins[2 : ], sins[2 : ])
    FI;
```

e)
```
MODE ℵ0 SFRAME = STRUCT (FLEX [1 : 0] SINSERT si,
    INT rep, BOOL supp, CHAR marker);
```

f)
```
PROC ℵ0 staticize frames =
    ([] FRAME frames, REF [] SFRAME sframes) VOID:
    ¢ calls collaterally all the replicators in 'frames' ¢
    IF UPB frames = 1
    THEN
      [1 : UPB (i OF frames [1])] SINSERT si;
      (staticize insertion (i OF frames[1], si),
        rep OF sframes [1] := rep OF frames [1]);
      si OF sframes [1] := si;
      supp OF sframes [1] := supp OF frames [1];
      marker OF sframes [1] := marker OF frames[1]
    ELIF UPB frames > 1
    THEN (staticize frames (frames[1], sframes[1]) .
        staticize frames (frames[2 : ], sframes[2 : ]))
    FI;
```

g)
```
PROC ℵ0 put insertion = (REF FILE f, [] SINSERT si) VOID:
    BEGIN set write mood (f);
      FOR k TO UPB si
```

```
    DO
      CASE sa OF si[k] IN
        (CHAR a): alignment (f, rep OF si[k], a, FALSE),
        (STRING s) :
          TO rep OF si[k]
          DO
            FOR i TO UPB s
            DO checkpos (f); putchar (f, s[i]) OD
          OD
      ESAC
    OD
  END;
```

h) `PROC ℵ0 get insertion (REF FILE f, [] SINSERT si) VOID:`

```
  BEGIN set read mood (f);
    FOR k TO UPB si
    DO
      CASE sa OF si[k] IN
        (CHAR a): alignment (f, rep OF si [k], a, TRUE),
        (STRING s) :
          (CHAR c;
          TO rep OF si[k]
          DO
            FOR i TO UPB s
            DO checkpos (f); get char (f, c);
              (c ≠ s[i]
              | (¬ (char error mended OF f) (f, c := s[i])
              | undefined);
              set read mood (f))
            OD
          OD)
      ESAC
    OD
  END;
```

i) `PROC ℵ0 alignment = (REF FILE f, INT r, CHAR a, BOOL read) VOID:`

```
  IF a = "x" THEN TO r DO space (f) OD
  ELIF a = "y" THEN TO r DO backspace (f) OD
  ELIF a = "l" THEN TO r DO newline (f) OD
  ELIF a = "p" THEN TO r DO newpage (f) OD
  ELIF a = "k" THEN set char number (f, r)
  ELIF a = "q"
  THEN TO r
    DO
      IF read
      THEN CHAR c; check pos (f); get char (f, c);
        (c ≠ blank
        | (¬ (char error mended OF f) (f, c := blank)
        | undefined); set read mood (f))
      ELSE check pos (f); put char (f, blank)
```

```
        FI
      OD
    FI;
```

j)
```
PROC ℵ0 do fpattern = (REF FILE f, FPATTERN fpattern, BOOL read) VOID:
    BEGIN FORMAT pf;
      [1 : UPB (i OF fpattern)] SINSERT si;
      (staticize insertion (i OF fpattern, si),
        pf := pf OF fpattern);
      (read | get insertion (f, si) | put insertion (f, si));
      REF INT forp = forp OF f;
      REF FLEX [] PIECE aleph = F OF format OF f;
      INT m = UPB aleph, n = UPB (F OF pf);
      [1 : m + n] PIECE c; c[1 : m] := aleph;
      c[m + 1 : m + n] := F OF pf;
      aleph := c; bp OF aleph[m + 1] := forp;
      forp := m + 1; cp OF aleph[forp] := 0;
      count OF aleph[forp] := 1;
      FOR i FROM m + 1 TO m + n
      DO
        FOR j TO UPB c OF aleph[i]
        DO
          CASE (c OF aleph[i]) [j] IN
            (c OF aleph[i]) [j] :=
              COLLITEM (i1 OF cl, rep OF cl, p OF cl + m, i2 OF cl)
          ESAC
        OD
      OD
  END;
```

k)
```
PROC ℵ0 associate format = (REF FILE f, FORMAT format) VOID:
    BEGIN
      format OF f :=
        C a newly created name which is made to refer to the yield
        of an actual-format-declarer and whose scope is equal to
        the scope of the value yielded by 'format' C
          := format;
      forp OF f := HEAP INT := 1;
      cp OF (F OF format OF f) [1] := 1;
      count OF (F OF format OF f) [1] := 1;
      bp OF OF (F OF format OF f) [1] := 1
    END;
```

26.3.5.1 Formatted output

a)
```
PROC putf = (REF FILE f, [] UNION (OUTTYPE, FORMAT) x) VOID:
    IF opened OF f THEN
    FOR k TO UPB x
    DO CASE set write mood (f); set char mood (f); x[k] IN
```

```
(FORMAT format): associate format (f, format),
(OUTTYPE ot) :
BEGIN INT j := 0;
  PICTURE picture, [] SIMPLOUT y = STRAIGHTOUT ot;
  WHILE (j +:= 1) ≤ UPB y
  DO BOOL incomp := FALSE;
    get next picture (f, FALSE, picture);
    set write mood (f);
    [1 : UPB (i OF picture)] SINSERT sinsert;
    CASE p OF picture IN
    (PATTERN pattern) :
    BEGIN INT rep, sfp := 1;
      [1 : UPB (frames OF pattern)] SFRAME sframes;
      (staticize frames (frames OF pattern, sframes),
        staticize insertion (i OF picture, sinsert));
      STRING s;

      OP ℵ0 = (STRING s) BOOL:
        ¢ true if the next marker is one of the elements of
          's' and false otherwise ¢
        IF sfp > UPB sframes
        THEN FALSE
        ELSE SFRAME sf = sframes[sfp];
          rep := rep OF sf:
          IF char in string (marker OF sf, LOC INT, s)
          THEN sfp +:= 1; TRUE
          ELSE FALSE
          FI
        FI;
      OP ℵ0 = (CHAR c) BOOL: ℵ0 STRING (c);
      PROC int pattern (REF BOOL sign mould) INT:
        (INT l := 0;
        WHILE ℵ0 "zuv" DO (rep ≥ 0 | l +:= rep) OD;
        sign mould := ℵ0 "+-";
        WHILE ℵ0 "zd" DO (rep ≥ 0 | l +:= rep) OD; l);

      ≪ PROC edit L int (L INT i) VOID:
            (BOOL sign mould; INT l := int pattern (sign mould);
            STRING t = subwhole (ABS i, l);
            IF char in string (errorchar, LOC INT, t) ∨ l = 0
                ∨ ¬ sign mould ∧ i < L 0
            THEN incomp := TRUE
            ELSE t PLUSTO s;
              (l - UPB t) × "0" PLUSTO s;
              (sign mould | (i < L 0 | "-" | "+") PLUSTO s)
            FI) ≫ ;
      ≪ PROC edit L real (L REAL r) VOID:
            (INT b := 0, a := 0, e := 0, exp := 0,
              L REAL y := ABS r,
```

```
        BOOL sign1, STRING point := "";
        b := int pattern (sign1);
        (ℵ0 "." | a := int pattern (LOC BOOL); point := ".");
        IF ℵ0 "e"
        THEN L standardize (y, b, a, exp);
          edit int (exp);
          "10" PLUSTO s
        FI;
        STRING t = subfixed (y, b + a + (a ≠ 0 | 1 | 0), a);
        IF char in string (errorchar, LOC INT, t) ∨ a + b = 0
            ∨ ¬ sign1 ∧ r < L 0 ∧ exp < 0
        THEN incomp := TRUE
        ELSE t[ : b] + point + t[b + 2 : ] PLUSTO s;
          (b + a + (a ≠ 0 | 1 | 0) - UPB t) × "0" PLUSTO s;
          (sign1 | (r < L 0 | "-" | "+") PLUSTO s)
        FI) ≫ ;

  ≪ PROC edit L compl = (L COMPL z) VOID:
        (WHILE ¬ ℵ0 "i" DO sfp +:= 1 OD; edit L real (IM z);
        "I" PLUSTO s; sfp := 1; edit L real (RE z)) ≫ ;

  ≪ PROC edit L bits (L BITS lb, INT radix) VOID:
        (L INT n := ABS lb; ℵ0 "r";
        INT l := intpattern (LOC BOOL);
        WHILE dig char (S (n ÷× K radix)) PLUSTO s;
            n %:= K radix; n ≠ L 0
        DO SKIP OD;
        IF UPB s ≤ l
        THEN (l - UPB s) × "0" PLUSTO s
        ELSE incomp := TRUE
        FI) ≫ ;

  PROC charcount = INT: (INT l := 0;
    WHILE ℵ0 "a" DO (rep ≥ 0 | l +:= rep) OD; l);

  CASE type OF pattern IN
¢ integral ¢
    (y[j] |
    ≪ (L INT i): edit L int (i) ≫
    | incomp := TRUE),
¢ real ¢
    (y[j] |
    ≪ (L REAL r): edit L real (r) ≫
    ≪ (L INT i): edit L real (i) ≫
    | incomp := TRUE),
¢ boolean ¢
    (y[j] |
    (BOOL b): s := (b | flip | flop)
    | incomp := TRUE),
```

```
¢ complex ¢
    (y[j] |
    ≪ (L COMPLEX z): edit L complex (z) ≫
    ≪ (L REAL r): edit L complex (r) ≫
    ≪ (L INT i): edit L complex (i) ≫
    | incomp := TRUE),
¢ string ¢
    (y[j] |
    (CHAR c): (charcount = 1 | s := c | incomp := TRUE),
    ([] CHAR t) :
      (charcount = UPB t - LWB t + 1
      | s := t[@1]
      | incomp := TRUE)
        | incomp := TRUE)
  OUT
¢ bits ¢
    (y[j] |
    ≪ (L BITS lb): edit L bits (lb, type OF pattern - 4) ≫
    | incomp := TRUE)
  ESAC;
  IF ¬ incomp
  THEN edit string (f, s, sframes)
  FI
END,
(CPATTERN choice) :
BEGIN
  [1 : UPB (i OF choice)] SINSERT si;
  staticize insertion (i OF choice, si) :
  put insertion (f, si);
  INT l =
    CASE type OF choice IN
  ¢ boolean ¢
      (y [j] |
      (BOOL b): (b | 1 | 2)
      | incomp := TRUE; SKIP),
  ¢ integral ¢
      (y [j] |
      (INT i): i
      | incomp := TRUE; SKIP)
    ESAC;
    IF ¬ incomp
    THEN
      IF l > UPB (c OF choice) ∨ l ≤ 0
      THEN incomp := TRUE
      ELSE
        [1 : UPB ((c OF choice) [l])) SINSERT ci:
        staticize insertion ((c OF choice) [l], ci);
        put insertion (f, ci)
      FI
```

```
            FI;
            staticize insertion (i OF picture, sinsert)
          END,
          (FPATTERN fpattern:
          BEGIN
            do fpattern (f, fpattern, FALSE);
            FOR TO UPB sinsert DO sinsert[i] := (0, "") OD;
          END,
          (GPATTERN gpattern) :
          BEGIN
            [1 : UPB (i OF gpattern)] SINSERT si;
            [] PROC INT spec = spec OF gpattern; INT n = UPB spec;
            [1 : n] INT s;
            (staticize insertion (i OF gpattern, si),
              staticize insertion (i OF picture, sinsert),
              s := (n | spec[1], (spec[1], spec[2]),
                (spec[1], spec[2], spec[3]) | ()));
            put insertion (f, si);
            IF n = 0 THEN put (f, y[j])
            ELSE
              NUMBER yj =
                (y[j] | ≪ (L INT i): i ≫, ≪ (L REAL r): r ≫
                | incomp := TRUE; SKIP);
              IF ¬ incomp
              THEN CASE n IN
                put (f, whole (yj, s[1])),
                put (f, fixed (yj, s[1], s[2])),
                put (f, float (yj, s[1], s[2], s[3]))
                ESAC
              FI
            FI
          END,
          (VOID) :
            (j -:= 1; staticize insertion (i OF picture, sinsert))
          ESAC;
          IF incomp
          THEN set write mood (f);
            (¬ (value error mended OF f) (f) | put (f, y [j]) :
              undefined)
          FI;
          put insertion (f, sinsert)
        OD
      END
    ESAC OD
    ELSE undefined
    FI;
```

b) `PROC` $\aleph_0$ `edit string (REF FILE f, STRING s, [] SFRAME sf) VOID:`

```
    BEGIN BOOL supp, zs := TRUE, signput := FALSE, again,
      INT j := 0, sign;
```

```
  PROC copy = (CHAR c) VOID:
    (¬ supp | check pos (f); put char (f, c));
  FOR k TO UPB sf
  DO SFRAME sfk = sf[k]; supp := supp OF sfk:
    put insertion (f, si OF sfk);
    TO rep OF sfk
    DO again := TRUE;
      WHILE again
      DO j +:= 1; again := FALSE;
        CHAR sj = s[j], marker = marker OF sfk;
        IF marker = "d"
        THEN copy (sj); zs := TRUE
        ELIF marker = "z" THEN
          (sj = "0" | copy ((zs | " " | sj))
          |: sj = "+" | again := TRUE
          | zs := FALSE; copy (sj))
        ELIF marker = "u" ∨ marker = "v" THEN
          (sj = "+" | sign := 1; again := TRUE
          |: sj = "-" | sign := 2; again := TRUE
          |: sj = "0" | copy ((zs | " " | sj))
          | (¬ signput |
            copy ((sign | (marker = "u" | "+" | " "), "-"));
            signput := TRUE);
            copy (sj); zs := FALSE)
        ELIF marker = "+" then
          (sj = "+" ∨ sj = "-" | copy (sj)
          | (¬ signput | copy ((sign | "+", "-")));
            j -:= 1)
        ELIF marker = "-" THEN
          (sj = "+" | copy (" ")
          |: sj = "-" | copy (sj)
          | (¬ signput | copy ((sign | " ", "-")));
            j -:= 1)
        ELIF marker = "." THEN
          copy (".")
        ELIF marker = "e" ∨ marker = "i"
          ∨ marker = "a" ∨ marker = "b"
        THEN copy (sj); zs := TRUE; signput := FALSE
        ELIF marker = "r"
        THEN j -:= 1
        FI
      OD
    OD
  OD
END;
```

26.3.5.2 Formatted input

a)
```
PROC getf = (REF FILE f, [] UNION (INTYPE, FORMAT) x) VOID:
  IF opened OF f THEN
    FOR k TO UPB x
    DO CASE set read mood (f); set char mood (f); x[k] IN
      (FORMAT format): associate format (f, format),
      (INTYPE it) :
      BEGIN INT j := 0;
        PICTURE picture, [] SIMPLIN y = STRAIGHTIN it;
        WHILE (j +:=- 1) ≤ UPB y
        DO BOOL incomp := FALSE;
          get next picture (f, TRUE, picture); set read mood (f);
          [1 : UPB (i OF picture)] SINSERT sinsert;
          CASE p OF picture IN
          (PATTERN pattern) :
          BEGIN
            [1 : UPB (frames OF pattern)] SFRAME sframes;
            (staticize frames (frames OF pattern, sframes),
              staticize insertion (i OF picture, sinsert));
            STRING s;
            INT radix =
              (type OF pattern ≥ 6 | type OF pattern - 4 | 10);
            indit string (f, s, sframes, radix);
            CASE type OF pattern IN
          ¢ integral ¢
              (y[j] |
              ≪ (REF L INT ii) :
              incomp := ¬ string to L int (s, 10, ii) ≫
              | incomp := TRUE),
          ¢ real ¢
              (y[j] |
              ≪ (REF L REAL rr) :
                incomp := ¬ string to L real (s, rr) ≫
              | incomp := TRUE),
          ¢ boolean ¢
              (y[j] |
              (REF BOOL bb): bb := s = flip
              | incomp := TRUE),
          ¢ complex ¢
              (y[j] |
              ≪ (REF L COMPL zz) :
                (INT i, BOOL bi, b2; char in string ("I", i, s);
                b1 := string to L real (s [ : i - 1], re OF zz);
                b2 := string to L real (s [i + 1 : ], im OF zz);
                incomp := ¬ (b1 ∧ b2)) ≫
              | incomp := TRUE),
          ¢ string ¢
              (y[j] |
              (REF CHAR cc) :
                (UPB s = 1 | cc := s[1] | incomp := TRUE),
```

```
    (REF [] CHAR ss) :
      (UPB ss - LWB ss + 1 = UPB s | ss[@1] := s
      | incomp := TRUE),
    (REF STRING ss): ss := s
    | incomp := TRUE)
  OUT
¢ bits ¢
    (y[j] |
    ≪ (REF L BITS lb) :
      IF L INT i; string to L int (s, radix, i)
      THEN lb := BIN i
      ELSE incomp := TRUE
      FI ≫
    | incomp := TRUE)
  ESAC
END,
(CPATTERN choice) :
BEGIN
  [1 : UPB (i OF choice) SINSERT si;
  staticize insertion (i OF choice, si);
  get insertion (f, si);
  INT c = c OF cpos OF f, CHAR kk;
  INT k := 0, BOOL found := FALSE;
  WHILE k < UPB (c OF choice) ∧ ¬ found
  DO k +:= 1;
    [1 : UPB ((c OF choice) [k])] SINSERT si;
    BOOL bool := TRUE;
    staticize insertion ((c OF choice, [k], si);
    STRING s;
    FOR i TO UPB si
    DO s PLUSAB
      (sa OF si[i] | (STRING ss): ss) × rep OF si[i]
    OD;
    FOR jj TO UPB s
    WHILE bool := bool ∧ ¬ line ended (f)
      ∧ ¬ logical file ended (f)
    DO get char (f, kk); bool := kk = s[jj] OD;
    (¬ (found := bool) | set char number (f, c))
  OD;
  IF ¬ found THEN incomp := TRUE
  ELSE
    CASE type OF choice IN
  ¢ boolean ¢
      (y [j] |
      (REF BOOL b): b := k = 1
      | incomp := TRUE),
  ¢ integral ¢
      (y [j] |
      (REF INT i): i := k
```

```
                | incomp := TRUE)
              ESAC
            FI;
            staticize insertion (i OF picture, sinsert)
          END,
          (FPATTERN fpattern):
          BEGIN do fpattern (f, fpattern, TRUE);
            FOR i TO UPB sinsert DO sinsert [i] := (0, "") OD;
            j -:= 1
          END,
          (GPATTERN gpattern) :
            ([1 : UPB (i OF gpattern)] SINSERT si;
            (staticize insertion (i OF gpattern, si),
              staticize insertion (i OF picture, sinsert));
            get insertion (f, si);
            get (f, y[j])),
          (VOID) :
            (j -:= 1; staticize insertion (i OF picture, sinsert))
          ESAC;
          IF incomp
          THEN set read mood (f);
            (¬ (value error mended OF f) (f) | undefined)
          FI;
          get insertion (f, sinsert)
        OD
      END
    ESAC OD
  ELSE undefined
  FI;
```

b)
```
PROC ℵ0 indit string = (REF FILE f, REF STRING s, [] SFRAME sf,
    INT radix) VOID:
  BEGIN
    BOOL supp, zs := TRUE, sign found := FALSE, space found := FALSE,
      nosign := FALSE, INT sp := 1, rep;
    PRIO ! = 8;

    OP ! = (STRING s, CHAR c) CHAR :
        ¢ expects a character contained in 's'; if the character
        read is not in 's', the event routine corresponding to 'on
        char error' is called with the suggestion 'c' ¢
      IF CHAR k; checkpos (f); get char (f, k);
        char in string (k, LOC INT, s)
      THEN k
      ELSE CHAR sugg := c;
        IF (char error mended OF f) (f, sugg) THEN
          (char in string (sugg, LOC INT, s) | sugg | undefined; c)
        ELSE undefined; c
        FI;
```

```
    set read mood (f);[11]
FI;
OP ! = (CHAR s, c) CHAR: STRING (s) ! c;
[] CHAR good digits = "0123456789abcdef"[ : radix];
s := "+";
FOR k TO UPB sf
DO SFRAME sfk = sf[k]; supp := supp OF fsk;
  get insertion (f, si OF sfk);
  TO rep OF sfk
  DO CHAR marker = marker OF sfk;
    IF marker = "d" THEN
      s PLUSAB (supp | "0" | good digits ! "0"); zs := TRUE
    ELIF marker = "z" THEN
      s PLUSAB (supp | "0"
        | CHAR c = ((zs | " " | "") + good digits) ! "0";
          (c ≠ " " | zs := FALSE); c)
    ELIF marker = "u" ∨ marker = "+" THEN
        IF sign found
        THEN zs := FALSE; a PLUSAB ("0123456789" ! "0")
        ELSE CHAR c = ("+-" + (marker = "u" | " " | "")) ! "+";
          (c = "+" ∨ c = "-" | sign found := TRUE; s[sp] := c)
        FI
    ELIF marker = "v" ∨ marker = "-" THEN
        IF sign found
        THEN zs := FALSE; z PLUSAB ("0123456789" ! "0")
        ELIF CHAR c; space found
        THEN c := "+- 0123456789" ! "+";
          (c = "+" ∨ c = "-" | sign found := TRUE; s[sp] := c
          |: c ≠ " " | zs := FALSE; sign found := TRUE; s PLUSAB c)
        ELSE c := "+- " ! "+";
          (c = "+" ∨ c = "-" | sign found := TRUE; s[sp] := c
          | space found := TRUE)
        FI
    ELIF marker ="." THEN
        s PLUSAB (supp | "." | "."! ".")
    ELIF marker = "e" THEN
        s PLUSAB (supp | "10" | "10\e" ! "10"; "10");
        sign found := FALSE;
        zs := TRUE; s PLUSAB "+"; sp := UPB s
    ELIF marker = "i" THEN
        s PLUSAB (supp | "I" | "iI"! "I"; "I");
        sign found := FALSE; zs := TRUE; s PLUSAB "+"; sp := UPB s
```

[11] This line and the four preceeding ones should read

```
CHAR cc = IF (char error mended OF f) (f, sugg) THEN
  (char in string (sugg, LOC INT, s) | sugg | undefined; c)
ELSE undefined; c
FI;
set read mood (f); cc
```

```
        ELIF marker = "b" THEN
            s PLUSAB (flip + flop) ! flop; no sign := TRUE
        ELIF marker = "a" THEN
            s PLUSAB (supp | " "
              | CHAR c; check pos (f); get char (f, c);
            c);
            no sign := TRUE
        ELIF marker = "r"
        THEN SKIP
        FI
      OD
    OD;
    IF no sign THEN s := s[2 : ] FI
  END;
```

26.3.6 Binary transput

{In binary transput, the values obtained by straightening the elements of a data list (cf. 26_{10}.3.3) are transput, via the specified file, one after the other. The manner in which such a value is stored in the book is defined only to the extent that a value of mode M (being some mode from which that specified by `SIMPLOUT` is united) output at a given position may subsequently be re-input from that same position to a name of mode **'reference to** M**'**. Note that, during input to the name referring to a multiple value, the number of elements read will be the existing number of elements referred to by that name.

The current position is advanced after each value by a suitable amount and, at the end of each line or page, the appropriate event routine is called, and next, if this returns `false`, the next good character position of the book is found (cf. 26_{10}.3.3) .

For binary output, `put bin` (26_{10}.3.6.1.a) and `write bin` (26_{10}.5.1.h) may be used and, for binary input, `get bin` (26_{10}.3.6.2.a) and `read bin` (26_{10}.5.1.i).}

a) `PROC ℵ0 to bin = (REF FILE f, SIMPLOUT x) [] CHAR:`
C a value of mode 'row of character' whose lower bound is one and whose upper bound depends on the value of 'book OF f' and on the mode and the value of 'x'; furthermore, `x = from bin (f, x, to bin (f, x))` **C** ;

b) `PROC ℵ0 from bin = (REF FILE f, SIMPLOUT y. [] CHAR c) SIMPLOUT:`
C a value, if one exists, of the mode of the value yielded by 'y', such that `c = to bin (f, from bin (f, y, c))` **C** ;

26.3.6.1 Binary output

```
a) PROC put bin = (REF FILE f, [] OUTTYPE ot) VOID:
     IF opened OF f THEN
       set bin mood (f);
       set write mood (f);
       FOR k TO UPB ot DO
         [] SIMPLOUT y = STRAIGHTOUT ot [k];
         FOR j TO UPB y DO
           [] CHAR bin = to bin (f, y[j]);
           FOR i TO UPB bin DO
               next pos (f);
               set bin mood (f);
               REF POS cpos = cpos OF f, lpos = lpos OF book OF f;
               CASE text OF f IN
                 (FLEXTEXT t2):
                   t2 [p OF cpos][l OF cpos][c OF cpos] := bin [i]
               ESAC;
               c OF cpos+:= 1;
               IF cpos BEYOND lpos THEN
                 lpos := cpos
               ELIF ¬ set possible (f) ∧
                 POS (p OF lpos, l OF lpos, 1) BEYOND cpos THEN
                 lpos := cpos; (compressible (f) |
```

C the size of the line and page containing the logical end of the book and of all subsequent lines and pages may be increased **C**)

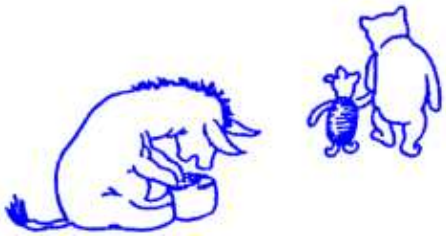
```
               FI
           OD
         OD
       OD
     ELSE undefined
     FI;
```

26.3.6.2 Binary input

```
a) PROC get bin = (REF FILE f, [] INTYPE it) VOID:
     IF opened OF f THEN
       set bin mood (f); set read mood (f);
       FOR k TO UPB it
       DO [] SIMPLIN y = STRAIGHTIN it [k];
         FOR j TO UPB y
         DO
           SIMPLOUT yj = CASE y[j] IN
             ≪ (REF L INT i): i ≫,
             ≪ (REF L REAL r): r ≫,
```

```
        ≪ (REF L COMPL z): z ≫,
        (REF BOOL b): b,
        ≪ (REF L BITS lb): lb ≫,
        (REF CHAR c): c,
        (REF [] CHAR s): s,
        (REF STRING ss): ss ESAC;
      [1 : UPB (to bin (f, yj))] CHAR bin;
      FOR i TO UPB bin
      DO next pos (f); set bin mood (f);
        REF POS cpos = cpos OF f;
        bin[i] :=
          CASE text OF f IN
            (FLEXTEXT t2) :
              t2[p OF cpos][l OF cpos][c OF cpos]
          ESAC;
        c OF cpos +:= 1
      OD;
      CASE y[j] IN
        ≪ (REF L INT ii):
          (from bin (f, ii, bin) | (L INT i): ii := i) ≫,
        ≪ (REF L REAL rr) :
          (from bin (f, rr, bin) | (L REAL r): rr := r) ≫,
        ≪ (REF L COMPL zz) :
          (from bin (f, zz, bin) | (L COMPL z): zz := z) ≫,
        (REF BOOL bb): (from bin (f, bb, bin) | (BOOL b): bb := b),
        ≪ (REF L BITS lb) :
          (from bin (f, lb, bin) | (L BITS b): lb := b) ≫,
        (REF CHAR cc): (from bin (f, cc, bin) | (CHAR c): cc := c),
        (REF []CHAR ss) :
          (from bin (f, ss, bin) | ([] CHAR s): ss := s),
        (REF STRING ssss) :
          (from bin (f, ssss, bin) | ([] CHAR s): ssss := s)
      ESAC
    OD
  OD
ELSE undefined
FI;
```

{



{But Eeyore wasn't listening. He was taking
the balloon out, and putting it back again,
as happy as could be. ...
Winnie-the-Pooh, A.A. Milne. }

}

26.4 The system prelude and task list

26.4.0.1 The system prelude

The representation of the **system-prelude** is obtained from the following form, to which may be added further forms not defined in this Report. {The syntax of **program-texts** ensures that a **declaration** contained in the **system-prelude** may not contradict any **declaration** contained in the **standard-prelude**. It is intended that the further forms should contain declarations that are needed for the correct operation of any **system-tasks** that may be added (by the implementer, as provided in 26_{10}.1.2.d) .}

a) `SEMA` $\aleph_0$ `gremlins = (SEMA s;` F `OF s := PRIM INT := 0; s);`

26.4.0.2 The system task list

The representation of the {first} constituent **system-task** or the **system-task-list** is obtained from the following form. The other **system-tasks**, if any, are not defined by this Report {but may be defined by the implementer in order to account for the particular features of his operating environment, especially in so far as they interact with the running of **particular-programs** (see, e.g., 26_{10}.3.1.1.dd) } .

a) `DO DOWN gremlins; undefined; UP bfileprotect OD`

{The intention is that this call of `undefined`, which is released by an `UP gremlins` whenever a book is closed, may reorganize the chain of backfiles and the chain of locked backfiles, such as by removing the book if it is not to be available for further opening, or by inserting it into the chain of backfiles several times over if it is to be permitted for several **particular-programs** to read it simultaneously. Note that, when an `UP gremlins` is given, `bfileprotect` is always down and remains so until such reorganization has taken place.}

{From ghoulies and ghosties and long-
leggety beasties and things that go bump
in the night,
Good Lord, deliver us!
Ancient Cornish litany }

26.5 The particular preludes and postludes

26.5.1 The particular preludes

The representation of the **particular-prelude** of each **user-task** is obtained from the following forms, to which may be added such other forms as may be needed for the proper functioning of the facilities defined in the constituent **library-prelude** of the **program-text** {, e.g., **declarations** and calls of `open` for additional standard files}. However, for each **QUALITY-new-new-PROPS1-LAYER2-defining-indicator-with-TAX** contained in such an additional form, the predicate **'where QUALITY TAX independent PROPS1'** (7.1.1.a, c) must hold {i.e., no **declaration** contained in the **standard-prelude** may be contradicted} .

a) `L INT L last random := ROUND (L maxint / L 2);`

b) `PROC L random = L REAL: L next random (L last random);`

c)
```
FILE stand in, stand out, stand back;
open (stand in, "", stand in channel);
open (stand out, "", stand out channel);
open (stand back, "", stand back channel);
```

d)
```
PROC print = ([] UNION (OUTTYPE, PROC (REF FILE) VOID) x) VOID:
  put (stand out, x),
PROC write = ([] UNION (OUTTYPE, PROC (REF FILE) VOID) x) VOID:
  put (stand out, x);
```

e)
```
PROC read = ([] UNION (INTYPE, PROC (REF FILE) VOID) x) VOID:
  get (stand in, x);
```

f)
```
PROC printf = ([] UNION (OUTTYPE, FORMAT) x) VOID:
  putf (stand out, x),
PROC writef = ([] UNION (OUTTYPE, FORMAT) x) VOID:
  putf (stand out, x);
```

g)
```
PROC readf = ([] UNION (INTYPE, FORMAT) x) VOID:
  getf (stand in, x);
```

h)
```
PROC write bin = ([] OUTTYPE x) VOID:
  put bin (stand back, x);
```

i)
```
PROC read bin = ([] INTYPE x) VOID:
  get bin (stand back, x);
```

26.5.2 The particular postludes

The representation of the **particular-postlude** of each **user-task** is obtained from the following form, to which may be added such other forms as may be needed for the proper functioning of the facilities defined in the constituent **library-prelude** of the **program-text** {, e.g., **calls** of `lock` for additional standard files}.

a) `stop: lock (stand in); lock (stand out); lock (stand back)`

27 Examples

27.1 Complex square root

```
PROC compsqrt = (COMPL z) COMPL :
  ¢ the square root whose real part is nonnegative
    of the complex number 'z' ¢
  BEGIN REAL x = RE z, y = IM z;
    REAL rp = sqrt ((ABS x + sqrt (x ↑ 2 + y ↑ 2)) / 2);
    REAL ip = (rp = 0 | 0 | y / (2 × rp));
    IF x ≥ 0 THEN rp ⊥ ip ELSE ABS ip ⊥ (y ≥ 0 | rp | -rp) FI
  END
```

Calls {20_5.4.3} using `compsqrt`:

```
compsqrt (w)
compsqrt (-3.14)
compsqrt (-1)
```

27.2 Innerproduct 1

```
PROC innerproduct1 = INT n, PROC INT) REAL x, y) REAL :
    ¢ the innerproduct of two vectors, each with 'n' components, x (i),
    y (i), i = 1, ..., n, where 'x' and 'y' are arbitrary mappings
    from integer to real numbers ¢
  BEGIN LONG REAL s := LONG 0;
    FOR i TO n DO s +:= LENG × (i) × LENG y (i) OD;
    SHORTEN s
  END
```

Real-calls using `innerproduct 1`:

```
innerproduct1 (m, (INT j) REAL: x1[j], (INT j) REAL: y1[j])
innerproduct1 (n, nsin, ncos)
```

27.3 Innerproduct 2

```
PROC innerproduct 2 = (REF [ ] REAL a, b) REAL:
  IF UPB a - LWB a = UPB b - LWB b
  THEN ¢ the innerproduct of two vectors 'a' and 'b' with equal numbers
    of elements ¢
    LONG REAL s := LONG 0;
    REF [ ] REAL a1 = a[@1], b1 = b[@1];
    ¢ note that the bounds of 'a[@1]' are [1 : UPB a - LWB a + 1] ¢
    FOR i TO UPB a1 DO s +:= LENG a1[i] × LENG b1[i] OD;
    SHORTEN s
  FI
```

Real-calls using `innerproduct 2`:

```
innerproduct2 (x1, y1)
innerproduct2 (y2[2, ], y2[, 3])
```

27.4 Largest element

```
PROC absmax = (REF [, ] REAL a, ¢ result ¢ REF REAL y,
  ¢ subscripts ¢ REF INT i, k) VOID:
    ¢ the absolute value of the element of greatest absolute value of
    the matrix 'a' is assigned to 'y', and the subscripts of this
    element to 'i' and 'k'¢
  BEGIN y := -1;
    FOR p FROM 1 LWB a TO 1 UPB a
    DO
      FOR q FROM 2 LWB a TO 2 UPB a
      DO
        IF ABS a[p, q] > y THEN y := ABS a[i := p, k := q] FI
      OD
    OD
  END
```

Calls using `absmax`:

```
absmax (x2, x, i, j)
absmax (x2, x, LOC INT, LOC INT)
```

27.5 Euler summation

```
PROC euler = (PROC (INT) REAL f, REAL eps, INT tim) REAL:
    ¢ the sum for 'i' from 1 to infinity of 'f (i) ', computed by means
    of a suitably refined Euler transformation. The summation is
    terminated when the absolute values of the terms of the
    transformed series are found to be less than 'eps' 'tim' times in
    succession. This transformation is particularly efficient in the
    case of a slowly convergent or divergent alternating series ¢
  BEGIN INT n := 1, t; REAL mn, ds := eps; [1 : 16] REAL m;
    REAL sum := (m[1] := f (1)) / 2;
    FOR i FROM 2 WHILE (t := ABS ds < eps | t + 1 | 1)) ≤ tim
    DO mn := f (i);
      FOR k TO n DO mn := ((ds := mn)) + m[k]) / 2; m[k] := ds OD;
      sum +:= (ds := (ABS mn < ABS m[n] ∧ n < 16 | n +:= 1; m[n] := mn;
        mn / 2 | mn))
    OD;
    sum
  END
```

A call using euler:

```
euler ((INT i) REAL: (ODD i | -1 / i | 1 / i), 1.e-5, 2)
```

27.6 The norm of a vector

```
PROC norm = (REF [ ] REAL a) REAL :
    ¢ the euclidean norm of the vector 'a' ¢
  (LONG REAL s := LONG 0;
  FOR k FROM LWB a TO UPB a DO s +:= LENG a[k] ↑ 2 OD;
  SHORTEN long sqrt (s))
```

For a use of norm in a call, see 27_{11}.7.

27.7 Determinant of a matrix

```
PROC det = (REF [, ] REAL x, REF [ ] INT p) REAL :
  IF REF [, ] REAL a = x[@1, @1];
      1 UPB a = 2 UPB a ∧ 1 UPB a = UPB p - LWB p + 1
  THEN INT n = 1 UPB a;
```

```
    ¢ the determinant of the square matrix 'a' of order 'n' by the
    method of Crout with row interchanges: 'a' is replaced by its
    triangular decomposition, l × u, with all u[k, k] = 1.
    The vector 'p' gives as output the pivotal row indices; the k-th
    pivot is chosen in the k-th column of T such that
    ABS l[i, k] / row norm is maximal ¢
  [1 : n] REAL v; REAL d := 1, s, pivot;
  FOR i TO n DO v[i] := norm (a[i, ]) OD;
  FOR k TO n
  DO INT k1 = k - 1; REF INT pk = p[@1][k]; REAL r := -1;
    REF [, ] REAL al = a[, 1 : k1], au = a[1 : k1,];
    REF [ ] REAL ak = a[k, ], ka = a[, k],
      alk = al[k, ], kau = au[, k];
    FOR i FROM k TO n
    DO REF REAL aik = ka[i];
      IF (s := ABS (aik -:= innerproduct2 (al[i, ], kau)) / v[i]) > r
      THEN r := s; pk := i
      FI
    OD;
    v[pk] := v[k]; pivot := ka[pk]; REF [ ] REAL apk = a[pk, ];
    FOR j TO n
    DO REF REAL akj = ak[j], apkj = apk[j];
      r := akj;
      akj := IF j ≤ k THEN apkj
        ELSE (apkj - innerproduct2 (alk, au[, j])) / pivot FI;
      IF pk /= k THEN apkj := -r FI
    OD;
    d ×:= pivot
  OD;
  d
FI
```

A call using `det`:

```
det (y2,i1)
```

27.8 Greatest common divisor

```
PROC gcd = (INT a, b) INT:
    ¢ the greatest common divisor of two integers ¢
  (b = 0 | ABS a | gcd (b, a MOD b))
```

A call using `gcd`:

```
gcd (n, 124)
```

27.9 Continued fraction

```
OP / = ([ ] REAL a, [ ] REAL b) REAL:
    ¢ the value of a / b is that of the continued fraction
    a1 / (b1 + a2 / (b2 + ... an / bn) ...) ¢
  IF LWB a = 1 ∧ LWB b = 1 ∧ UPB a = UPB b
  THEN (UPB a = 0 | 0 | a[1] / (b[1] + a[2 : ] / b[2 : ]))
  FI
```

A formula using /:

```
x1 / y1
```

{The use of recursion may often be elegant rather than efficient as in the recursive procedure 27_{11}.8 and the recursive operation 27_{11}.9 . See, however, 27_{11}.10 and 27_{11}.13 for examples in which recursion is of the essence.}

27.10 Formula manipulation

```
BEGIN
  MODE FORM = UNION (REF CONST, REF VAR, REF TRIPLE, REF CALL);
  MODE CONST = STRUCT (REAL value);
  MODE VAR = STRUCT (STRING name, REAL value);
  MODE TRIPLE = STRUCT (FORM left operand, INT operator,
    FORM right operand);
  MODE FUNCTION = STRUCT (REF VAR bound var, FORM body);
  MODE CALL = STRUCT (REF FUNCTION function name, FORM parameter);
  INT plus = 1, minus = 2, times = 3, by = 4, to = 5;
  HEAP CONST zero, one; value OF zero := 0; value OF one := 1;
  OP = = (FORM a, REF CONST b) BOOL: (a | (REF CONST ec): ec :=: b | FALSE);
  OP + = (FORM a, b) FORM:
    a = zero | b |: b = zero | a | HEAP TRIPLE := (a, plus, b));
  OP − = (FORM a, b) FORM: (b = zero | a | HEAP TRIPLE := (a, minus, b));
  OP × = (FORM a, b) FORM: (a = zero ∨ b = zero | zero |: a = one | b
      |: b = one | a | HEAP TRIPLE := (a, times, b));
  OP / = (FORM a, b) FORM: (a = zero ∧ ¬ (b = zero) | zero |:
    b = one | a | HEAP TRIPLE := (a, by, b));
  OP ↑ = (FORM a, REF CONST b) FORM:
    (a = one ∨ (b :=: zero) | one |:
```

```
      b :=: one | a | HEAP TRIPLE := (a, to, b));
  PROC derivative of = (FORM e, ¢ with respect to ¢ REF VAR x) FORM:
    CASE e IN
      (REF CONST): zero,
      (REF VAR ev): (ev :=: x | one | zero),
      (REF TRIPLE et) :
        CASE FORM u = left operand OF et, v = right operand OF et;
            FORM udash = derivative of (u, ¢ with respect to ¢ x),
            vdash = derivative of (v, ¢ with respect to ¢ x);
            operator OF et
        IN
            udash + vdash,
            udash - vdash,
            u × vdash + udash × v,
            (udash - et × vdash) / v,
            (v | (REF CONST ec): v × u ↑ (HEAP CONST c;
              value OF c := value OF ec - 1; c) × udash)
        ESAC,
      (REF CALL ef) :
        BEGIN REF FUNCTION f = function name OF ef;
          FORM g = parameter OF ef; REF VAR y = bound var OF f;
          HEAP FUNCTION fdash := (y, derivative of (body OF f, y));
          HEAP CALL := (fdash, g)) × derivative of (g, x)
        END
    ESAC;
  PROC value of = (FORM e) REAL:
    CASE e IN
      (REF CONST ec): value OF ec,
      (REF VAR ev): value OF ev,
      (REF TRIPLE et) :
        CASE REAL u = value of (left operand OF et),
            v = value of (right operand OF et);
            operator OF et
        IN u + v, u - v, u × v, u / v, exp (v × ln (u))
        ESAC,
      (REF CALL ef) :
        BEGIN REF FUNCTION f = function name OF ef;
          value OF bound var OF f := value of (parameter OF ef);
          value of (body OF f)
        END
    ESAC;
  HEAP FORM f, g;
  HEAP VAR a := ("a", SKIP), b := ("b", SKIP), x := ("x", SKIP);
¢ start here ¢
```

```
  read ((value OF a, value OF b, value OF x));
  f := a + x / (b + x);
  g := (f + one) / (f - one);
  print ((value OF a, value OF b, value OF x,
    value of (derivative of (g, ¢ with respect to ¢ x))))
END ¢ example of formula manipulation ¢
```

27.11 Information retrieval

```
BEGIN
  MODE RA = REF AUTH, RB = REF BOOK;
  MODE AUTH = STRUCT (STRING name, RA next, RB book),
  BOOK = STRUCT (STRING title, RB next);
  RA auth, first auth := NIL, last auth;
  RB book; STRING name, title; INT i; FILE input, output;
  open (input, "", remote in); open (output, "", remote out);
  putf (output, ($p
    "to enter a new author, type ""author"", a space,"x
    "and his name."l
    "to enter a new book, type ""book"", a space,"x
    "the name of the author, a new line, and the title."l
    "for a listing of the books by an author, type ""list"","x
    "a space, and his name."l
    "to find the author of a book, type ""find"", a new line,"x
    "and the title."l
    "to end, type ""end"""al$, "."));

  PROC update = VOID:
    IF RA (first auth) :=: NIL
    THEN auth := first auth := last auth := HEAP AUTH := (name, NIL, NIL)
    ELSE auth := first auth;
        WHILE RA (auth) :≠: NIL
        DO
            (name = name OF auth | GO TO known | auth := next OF auth)
        OD;
        lastauth := next OF lastauth := auth :=
          HEAP AUTH := (name, NIL, NIL);
  known: SKIP
    FI;

  DO
  try again:
    getf (input, ($c ("author", "book", "list", "find", "end", ""),
      x30al, 80al$, i));

    CASE i IN

      ¢ author¢
```

```
getf (input, name); update),

¢ book ¢
BEGIN getf (input, (name, title)); update;
  IF RB (book OF auth) :=: NIL
  THEN book OF auth := HEAP BOOK := (title, NIL)
  ELSE book := book OF auth;
    WHILE RB (next OF book) :≠: NIL
    DO
      (title = title OF book
      | GO TO try again | book := next OF book)
    OD;
    (title /= title OF book
    | next OF book := HEAP BOOK := (title, NIL))
  FI
END,

¢ list ¢
BEGIN getf (input, name); update;
  putf (output, ($p"author: "30all$, name));
  IF RB (book := book OF auth) :=: NIL
  THEN put (output, ("no publications", newline))
  ELSE on page end (output,
    (REF FILE f) BOOL:
      (putf (f, ($p"author: "30a41k"continued"ll$, name));
      TRUE));
    WHILE RB (book) :≠: NIL
    DO putf (output, ($l80a$, title OF book)); book := next OF book
    OD;
    on page end (output, (REF FILE f) BOOL: FALSE)
  FI
END,

¢ find ¢
BEGIN getf (input, (LOC STRING, title)); auth := first auth;
  WHILE RA (auth) :≠: NIL
  DO book := book OF auth;
    WHILE RB (book) :≠: NIL
    DO
      IF title = title OF book
      THEN putf (output, ($l"author: "30a$, name OF auth));
        GO TO try again
      ELSE book := next OF book
      FI
    OD;
    auth := next OF auth
  OD;
  put (output, (newline, "unknown", newline))
END,
```

```
      ¢ end ¢
      (put (output, (new page, "signed off", close)); close (input);
      GOTO stop),

      ¢ error ¢
      (put (output, (newline, "mistake, try again")); newline (input))
    ESAC
  OD
END
```

27.12 Cooperating sequential processes

```
BEGIN INT nmb magazine slots, nmb producers, nmb consumers;
  read ((nmb magazine slots, nmb producers, nmb consumers));
  [1 : nmb producers] FILE in file; [1 : nmb consumers] FILE out file;
  FOR i TO nmb producers DO open (in file[i], "", inchannel[i]) OD;
    ¢ 'inchannel' and 'outchannel' are defined in a surrounding range ¢
    FOR i TO nmb consumers
    DO open (out file[i], "", outchannel[i]) OD;
    MODE PAGE = [1 : 60, 1 : 132] CHAR ;
    [1 : nmb magazine slots] REF PAGE magazine;
    INT ¢ pointers of a cyclic magazine ¢ index:= 1, exdex := 1;
    SEMA full slots = LEVEL 0, free slots = LEVEL nmb magazine slots,
    in buffer busy = LEVEL 1, out buffer busy = LEVEL 1;
    PROC par call = (PROC (INT) VOID p, INT n) VOID:
      ¢ call 'n' incarnations of 'p' in parallel ¢
      (n > 0 | PAR (p (n), par call (p, n - 1)));
    PROC producer = (INT i) VOID:
      DO HEAP PAGE page;
        get (in file[i], page);
        DOWN free slots; DOWN in buffer busy;
        magazine[index] := page;
        index MODAB nmb magazine slots PLUSAB 1;
        UP full slots; UP in buffer busy
      OD;
    PROC consumer = (INT i) VOID:
      DO PAGE page;
        DOWN full slots; DOWN out buffer busy;
        page := magazine[exdex];
        exdex MODAB nmb magazine slots PLUSAB 1;
        UP free slots; UP out buffer busy;
        put (out file[i], page)
      OD;
```

```
    PAR (par call (producer, nmb producers),
      par call (consumer, nmb consumers))
END
```

27.13 Towers of Hanoi

```
FOR k TO 8
DO FILE f := stand out;
  PROC p = (INT me, de, ma) VOID:
    IF ma > 0 THEN
      p (me, 6 - me - de, ma - 1);
      putf (f, (me, de, ma));
      ¢ move from peg 'me' to peg 'de' piece 'ma' ¢
      p (6-me-de, de, ma -1)
    FI ;
  putf (f, ($l"k = "dl,n ((2 ↑ k + 15) ÷ 16) (2(2(4(3(d)x)x)x)l)$, k));
  p (1, 2, k)
OD
```

28 Glossaries

28.1 Technical terms

Given below are the locations of the defining occurrences of a number of words which, in this Report, have a specific technical meaning. A word appearing in different grammatical forms is given once, usually as the infinitive. Terms which are used only within pragmatic remarks are enclosed within braces.

{Denn eben, wo Begriffe fehlen,
Da stellt ein Wort zur rechten Zeit sich ein.
Faust, J.W. von Goethe. }

28.2 Paranotions

Given below are short paranotions representing the notions defined in this Report, with references to their hyper-rules.

after-specification	26_{10}.3.4.10.1.c
alignment	26_{10}.3.4.1.1.e
alignment-code	26_{10}.3.4.1.1.f
alternate-CHOICE-clause	18_{3}.4.1.d
assignation	20_{5}.2.1.1.a
bits-denotation	24_{8}.2.1.l
bits-pattern	26_{10}.3.4.7.1.a
boolean-choice-pattern	26_{10}.3.4.8.1.b
boolean-marker	26_{10}.3.4.4.1.b
boolean-pattern	26_{10}.3.4.4.1.a
boundscript	20_{5}.3.2.1.j
call	20_{5}.4.3.1.a
case-clause	18_{3}.4.1.p
case-part-of-CHOICE	18_{3}.4.1.i
cast	20_{5}.5.1.1.a
character-glyph	24_{8}.1.4.1.c
character-marker	26_{10}.3.4.6.1.b
choice-clause	18_{3}.4.1.n
chooser-CHOICE-clause	18_{3}.4.1.b
closed-clause	18_{3}.1.1.a
coercee	22_{6}.1.1.g
coercend	22_{6}.1.1.h
collateral-clause	18_{3}.3.1.a, d, e
collection	26_{10}.3.4.1.1.b
complex-marker	26_{10}.3.4.5.1.b
complex-pattern	26_{10}.3.4.5.1.a
conditional-clause	18_{3}.4.1.o
conformity-clause	18_{3}.4.1.q
constant	18_{3}.0.1.d

28.3 Predicates

Given below are abbreviated forms of the predicates defined in this Report.

'and'	16_1.3.1.c, e
'balances'	18_3.2.1.f, g
'begins with'	16_1.3.1.h, i, j
'coincides with'	16_1.3.1.k, l
'contains'	16_1.3.1.m, n
'counts'	19_4.3.1.c, d
'deflexes to'	19_4.7.1.a, b, c, d, e
'deprefs to firm'	23_7.1.1.n
'develops from'	23_7.3.1.c
'equivalent'	23_7.3.1.a, b, d, e, f, g, h, i, j, k, q
'false'	16_1.3.1.b
'firmly related'	23_7.1.1.k
'identified in'	23_7.2.1.a
'incestuous'	19_4.7.1.f
'independent'	23_7.1.1.a, b, c, d
'is'	16_1.3.1.g
'is derived from'	20_5.3.1.1.b, c
'is firm'	23_7.1.1.l, m
'like'	20_5.4.1.1.c, d
'may follow'	18_3.4.1.m
'number equals'	23_7.3.1.o, p
'or'	16_1.3.1.d, f
'ravels to'	19_4.7.1.g
'related'	23_7.1.1.e, f, g, h, i, j
'resides in'	23_7.2.1.b, c
'shields'	23_7.4.1.a, b, c, d
'subset of'	23_7.3.1.l, m, n
'true'	16_1.3.1.a
'unites to'	22_6.4.1.b

28.4 Index to the standard prelude

$\aleph_0$ staticize insertion	26_{10}.3.5.d
$\aleph_0$ string to L int	26_{10}.3.2.1.i
$\aleph_0$ string to L real	26_{10}.3.2.1.j
$\aleph_0$ subfixed	26_{10}.3.2.1.f
$\aleph_0$ subwhole	26_{10}.3.2.1.e
$\aleph_0$ to bin	26_{10}.3.6.a
$\aleph_0$ undefined	26_{10}.3.1.4.a
$\aleph_0$ L standardize	26_{10}.3.2.1.g

28.5 Alphabetic listing of metaproduction rules

ABC {25_9.4.2.L} **:: a ; b ; c ; d ; e ; f ; g ; h ; i ; j ; k ; l ; m ; n ; o ; p ; q ; r ; s ; t ; u ; v ; w ; x ; y ; z.**
ADIC {20_5.4.2.C} **:: DYADIC ; MONADIC.**
ALPHA {16_1.3.B} **:: a ; b ; c ; d ; e ; f ; g ; h ; i ; j ; k ; l ; m ; n ; o ; p ; q ; r ; s ; t ; u ; v ; w ; x ; y ; z.**
BECOMESETY {25_9.4.2.J} **:: cum becomes ; cum assigns to ; EMPTY.**
BITS {22_6.5.A} **:: structured with row of boolean field SITHETY letter aleph mode.**
BYTES {22_6.5.B} **:: structured with row of character field SITHETY letter aleph mode.**
CASE {18_3.4.B} **:: choice using integral ; choice using UNITED.**
CHOICE {18_3.4.A} **:: choice using boolean ; CASE.**
COLLECTION {26_{10}.3.4.1.C} **:: union of PICTURE COLLITEM mode.**
COLLITEM {26_{10}.3.4.1.D} **:: structured with INSERTION field letter i digit one**
procedure yielding integral field letter r letter e letter p
integral field letter p
INSERTION field letter i digit two mode.
COMARK {26_{10}.3.4.1.N} **:: zero ; digit ; character.**
COMMON {19_4.1.A} **:: mode ; priority ; MODINE identity ; reference to MODINE variable ;**
MODINE operation ; PARAMETER ; MODE FIELDS.
COMORF {22_6.1.G} **:: NEST assignation ; NEST identity relation ;**
NEST LEAP generator ; NEST cast ; NEST denoter ; NEST format text.
CPATTERN {26_{10}.3.4.1.I} **:: structured with INSERTION field letter i**
integral field letter t letter y letter p letter e
row of INSERTION field letter c mode.
DEC {16_1.2.3.E} **:: MODE TAG ; priority PRIO TAD ; MOID TALLY TAB ; DUO TAD ; MONO TAM.**
DECS {16_1.2.3.D} **:: DEC ; DECS DEC.**
DECSETY {16_1.2.3.C} **:: DECS ; EMPTY.**
DEFIED {19_4.8.B} **:: defining ; applied.**

DIGIT {25_{9}.4.2.C} **:: digit zero ; digit one ; digit two ; digit three ;**
digit four ; digit five ; digit six ; digit seven ; digit eight ; digit nine.
DOP {25_{9}4.2.M*} **:: DYAD ; DYAD cum NOMAD.**
DUO {16_{1}.2.3.H} **:: procedure with PARAMETER1 PARAMETER2 yielding MOID.**
DYAD {25_{9}.4.2.G} **:: MONAD ; NOMAD.**
DYADIC {20_{5}.4.2.A} **:: priority PRIO.**
EMPTY {16_{1}.2.G} **:: .**
ENCLOSED {16_{1}.2.2.A} **:: closed ; collateral ; parallel ; CHOICE ; loop.**
EXTERNAL {26_{10}.1.A} **:: standard ; library ; system ; particular.**
FIELD {16_{1}.2.J} **:: MODE field TAG.**
FIELDS {16_{1}.2.I} **:: FIELD ; FIELDS FIELD.**
FIRM {22_{6}.1.B} **:: MEEK ; united to.**
FIVMAT {26_{10}.3.4.1.L} **:: mui definition of structured with row of**
structured with integral field letter c letter p
integral field letter c letter o letter u letter n letter t
integral field letter b letter p row of union of structured
with union of PATTERN CPATTERN
structured with INSERTION field letter i
procedure yielding mui application field
letter p letter f mode GPATTERN void mode field letter p
INSERTION field letter i mode COLLITEM mode field
letter c mode field letter aleph mode. FLEXETY {16_{1}.2.K} **:: flexible ; EMPTY.**
FORM {22_{6}.1.E} **:: MORF ; COMORF.**
FORMAT {26_{10}.3.4.1.A} **:: structured with row of PIECE field letter aleph mode.**
FPATTERN {26_{10}.3.4.1.J} **:: structured with INSERTION field letter i**
procedure yielding FIVMAT field letter p letter f mode.
FRAME {26_{10}.3.4.1.H} **:: structured with INSERTION field letter i**
procedure yielding integral field letter r letter e letter p
boolean field letter s letter u
letter p letter p
character field letter m letter a letter r letter k
letter e letter r mode.
FROBYT {18_{3}.5.A} **:: from ; by ; to.**
GPATTERN {26_{10}.3.4.1.K} **::**
structured with INSERTION field letter i
row of procedure yielding integral field
letter s letter p letter e letter c mode. HEAD {23_{7}.3.B} **:: PLAIN ; PREF ; structured with ; FLEXETY ROWS of ; procedure with ; union of ; void.**
INDICATOR {19_{4}.8.A} **:: identifier ; mode indication ; operator.**
INSERTION {26_{10}.3.4.1.E} **:: row of structured with procedure yielding integral field**
letter r letter e letter p
union of row of character character mode field letter s letter a mode.
INTREAL {16_{1}.2.C} **:: SIZETY integral ; SIZETY real.**

LAB {16_1.2.3.K} **:: label TAG.**
LABS {16_1.2.3.J} **:: LAB ; LABS LAB.**
LABSETY {16_1.2.3.I} **:: LABS ; EMPTY.**
LAYER {16_1.2.3.B} **:: new DECSETY LABSETY.**
LEAP {19_4.4.B} **:: local ; heap ; primal.**
LENGTH {22_6.5.D} **:: letter l letter o letter n letter g.**
LENGTHETY {22_6.5.F} **:: LENGTH LENGTHETY ; EMPTY.**
LETTER {25_9.4.2.B} **:: letter ABC ; letter aleph ; style TALLY letter ABC.**
LONGSETY {16_1.2.E} **:: long LONGSETY ; EMPTY.**
MARK {26_{10}.3.4.1.M} **:: sign ; point ; exponent ; complex ; boolean.**
MEEK {22_6.1.C} **:: unchanged from ; dereferenced to ; deprocedured to.**
MODE {16_1.2.A} **:: PLAIN ; STOWED ; REF to MODE ; PROCEDURE ; UNITED ;**
MU definition of MODE ; MU application. MODINE {19_4.4.A} **:: MODE ; routine.**
MOID {16_1.2.R} **:: MODE ; void.**
MOIDS {19_4.6.C} **:: MOID ; MOIDS MOID.**
MOIDSETY {19_4.7.C} **:: MOIDS ; EMPTY.**
MONAD {25_9.4.2.H} **:: or ; and ; ampersand ; differs from ; is at most ; is at least ;**
over ; percent ; window ; floor ; ceiling ; plus i times ; not ; tilde ;
down ; up ; plus ; minus ; style TALLY monad. MONADIC {20_5.4.2.B} **:: priority iii iii iii i.**
MONO {16_1.2.3.G} **:: procedure with PARAMETER yielding MOID.**
MOOD {16_1.2.U} **:: PLAIN ; STOWED ; reference to MODE ; PROCEDURE ; void.**
MOODS {16_1.2.T} **:: MOOD ; MOODS MOOD.**
MOODSETY {19_4.7.B} **:: MOODS ; EMPTY.**
MORF {22_6.1.F} **:: NEST selection ; NEST slice ; NEST routine text ; NEST ADIC formula ; NEST call ; NEST applied identifier with TAG.**
MU {16_1.2.V} **:: muTALLY.**
NEST {16_1.2.3.A} **:: LAYER ; NEST LAYER.**
NOMAD {25_9.4.2.I} **:: is less than ; is greater than ; divided by ; equals ; times ; asterisk.**
NONPREF {23_7.1.B} **:: PLAIN ; STOWED ;**
procedure with PARAMETERS yielding MOID ; UNITED ; void.
NONPROC {22_6.7.A} **:: PLAIN ; STOWED ;**
REF to NONPROC ; procedure with PARAMETERS yielding MOID ; UNITED.
NONSTOWED {19_4.7.A} **:: PLAIN ; REF to MODE ; PROCEDURE ; UNITED ; void.**
NOTETY {16_1.3.C} **:: NOTION ; EMPTY.**
NOTION {16_1.3.A} **:: ALPHA ; NOTION ALPHA.**
NUMERAL {24_8.1.0.B*} **:: fixed point numeral ; variable point numeral ; floating point numeral.**
PACK {18_3.1.B} **:: STYLE pack.**
PARAMETER {16_1.2.Q} **:: MODE parameter.**
PARAMETERS {16_1.2.P} **:: PARAMETER ; PARAMETERS PARAMETER.**
PARAMETY {16_1.2.O} **:: with PARAMETERS ; EMPTY.**
PART {23_7.3.E} **:: FIELD ; PARAMETER.**

PARTS {23_{7}.3.D} **:: PART ; PARTS PART.**
PATTERN {26_{10}.3.4.1.G} **:: structured with**
integral field letter t letter y letter p letter e
row of FRAME field
letter f letter r letter a letter m letter e letter s mode. PICTURE {26_{10}.3.4.1.F} **:: structured with**
union of PATTERN CPATTERN FPATTERN GPATTERN void mode field letter p
INSERTION field letter i mode. PIECE {26_{10}.3.4.1.B} **:: structured with**
integral field letter c letter p
integral field letter c letter o letter u letter n letter t
integral field letter b letter p
row of COLLECTION field letter c mode.
PLAIN {16_{1}.2.B} **:: INTREAL ; boolean ; character.**
PRAGMENT {25_{9}.2.A} **:: pragmat ; comment.**
PRAM {19_{4}.5.A} **:: DUO ; MONO.**
PREF {23_{7}.1.A} **:: procedure yielding ; REF to.**
PREFSETY {23_{7}.1.C*} **:: PREF PREFSETY ; EMPTY.**
PRIMARY {20_{5}.D} **:: slice coercee ; call coercee ; cast coercee ; denoter coercee ;**
format text coercee ; applied identifier with TAG coercee ; ENCLOSED clause.
PRIO {16_{1}.2.3.F} **:: i ; ii ; iii ; iii i ; iii ii ; iii iii ; iii iii i ; iii iii ii ; iii iii iii.**
PROCEDURE {16_{1}.2.N} **:: procedure PARAMETY yielding MOID.**
PROP {19_{4}.8.E} **:: DEC ; LAB ; FIELD.**
PROPS {19_{4}.8.D} **:: PROP ; PROPS PROP.**
PROPSETY {19_{4}.8.C} **:: PROPS ; EMPTY.**
QUALITY {19_{4}.8.F} **:: MODE ; MOID TALLY ; DYADIC ; label ; MODE field.**
RADIX {24_{8}.2.A} **:: radix two ; radix four ; radix eight ; radix sixteen.**
REF {16_{1}.2.M} **:: reference ; transient reference.**
REFETY {20_{5}.3.1.A} **:: REF to ; EMPTY.**
REFLEXETY {20_{5}.3.1.B} **:: REF to ; REF to flexible ; EMPTY.**
ROWS {16_{1}.2.L} **:: row ; ROWS row.**
ROWSETY {20_{5}.3.2.A} **:: ROWS ; EMPTY.**
SAFE {23_{7}.3.A} **:: safe ; MU has MODE SAFE ; yin SAFE ; yang SAFE ; remember MOID1 MOID2 SAFE.**
SECONDARY {20_{5}.C} **:: LEAP generator coercee ; selection coercee ; PRIMARY.**
SHORTH {22_{6}.5.E} **:: letter s letter h letter o letter r letter t.**
SHORTHETY {22_{6}.5.G} **:: SHORTH SHORTHETY ; EMPTY.**
SHORTSETY {16_{1}.2.F} **:: short SHORTSETY ; EMPTY.**
SITHETY {22_{6}.5.C} **:: LENGTH LENGTHETY ; SHORTH SHORTHETY ; EMPTY.**
SIZE {24_{8}.1.0.A} **:: long ; short.**
SIZETY {16_{1}.2.D} **:: long LONGSETY ; short SHORTSETY ; EMPTY.**
SOFT {22_{6}.1.D} **:: unchanged from ; softly deprocedured to.**
SOID {18_{3}.1.A} **:: SORT MOID.**
SOME {16_{1}.2.2.B} **:: SORT MOID NEST.**

SORT {16_1.2.2.C} **:: strong ; firm ; meek ; weak ; soft.**
STANDARD {25_9.4.2.E} **:: integral ; real ; boolean ; character ; format ; void ; complex ;**
bits ; bytes ; string ; sema ; file ; channel.
STOP {26_{10}.1.B} **:: label letter s letter t letter o letter p.**
STOWED {16_1.2.H} **:: structured with FIELDS mode ; FLEXETY ROWS of MODE.**
STRONG {22_6.1.A} **:: FIRM ; widened to ; rowed to ; voided to.**
STYLE {16_1.3.3.A} **:: brief ; bold ; style TALLY.**
TAB {25_9.4.2.D} **:: bold TAG ; SIZETY STANDARD.**
TAD {25_9.4.2.F} **:: bold TAG ; DYAD BECOMESETY ; DYAD cum NOMAD BECOMESETY.**
TAG {25_9.4.2.A} **:: LETTER ; TAG LETTER ; TAG DIGIT.**
TAILETY {23_7.3.C} **:: MOID ; FIELDS mode ; PARAMETERS yielding MOID ; MOODS mode ; EMPTY.**
TALLETY {20_5.4.2.D} **:: TALLY ; EMPTY.**
TALLY {16_1.2.W} **:: i ; TALLY i.**
TAM {25_9.4.2.K} **:: bold TAG ; MONAD BECOMESETY ; MONAD cum NOMAD BECOMESETY.**
TAO {19_4.5.B} **:: TAD ; TAM.**
TAX {19_4.8.G} **:: TAG ; TAB ; TAD ; TAM.**
TERTIARY {20_5.B} **:: ADIC formula coercee ; nihil ; SECONDARY.**
THING {16_1.3.D} **:: NOTION ; (NOTETY1) NOTETY2 ; THING (NOTETY1) NOTETY2.**
TYPE {26_{10}.3.4.1.P} **:: integral ; real ; boolean ; complex ; string ; bits ;**
integral choice ; boolean choice ; format ; general.
UNIT {20_5.A} **:: assignation coercee ; identity relation coercee ; routine text coercee ;**
jump ; skip ; TERTIARY.
UNITED {16_1.2.S} **:: union of MOODS mode.**
UNSUPPRESSETY {26_{10}.3.4.1.O} **:: unsuppressible ; EMPTY.**
VICTAL {19_4.6.A} **:: VIRACT ; formal.**
VIRACT {19_4.6.B} **:: virtual ; actual.**
WHETHER {16_1.3.E} **:: where ; unless.**

V

Appendices

A Bibliography

A.1 Free or open source publications

This publication contains material from various free or open source publications:

1. Revised Report on Algol 68[1] by A. van Wijngaarden *et al.*.
   Springer Verlag [1976].
   Part IV complies with IFIP's provision: *Reproduction of the Report, for any purpose, but only of the whole text, is explicitly permitted without formality*.
2. GNU Compiler Collection documentation (GNU GPL).
3. GNU Debugger documentation (GNU GPL).
4. GNU C Library documentation (GNU GPL).
5. GNU Scientific Library documentation (GNU GPL).
6. GNU MPFR documentation (GNU GPL).
7. GNU Plotting Utilities documentation (GNU GPL).
8. GNU Quadmath documentation (GNU GPL).
9. PostgreSQL documentation (BSD LICENSE).
10. Wikipedia (GNU FDL).
11. *Programming Algol 68 Made Easy* by Sian Mountbatten (GNU GPL) [2002].
    Chapters 2-7 in Part I are based on parts of this publication that have been rewritten, improved, extended and adapted to `a68g`.
12. Biografisch Woordenboek van Nederlandse Wiskundigen (PUBLIC DOMAIN).

[1] Note that chapter 21, *Specification of partial parametrization proposal* is not a part of the Revised Report, and is distributed with this publication with kind permission of the author of this proposal, C.H. Lindsey.

A.2 Informal texts on Algol 68

For other informal texts on Algol 68, see for instance:

1. D. F. Brailsford, A. N. Walker. Introductory Algol 68 programming.
   Ellis Horwood Ltd, Chichester [1979].

2. C. H. Lindsey and S. G. van der Meulen, Informal Introduction to Algol 68.
   North-Holland [1977].

3. A. D. McGettrick. Algol 68: a first and second course.
   Cambridge University Press [1978].

4. C. H. A. Koster, H. Meijer. Systematisch programmeren in Algol 68.
   Deel 1 [1978], 2 [1981]. Kluwer, Deventer.

A.3 Algol 68 Genie extensions

Algol 68 Genie implements extensions that are documented in the following material:

1. C. H. Lindsey. Specification of partial parametrization proposal.
   ALGOL BULLETIN 39.3.1 pages 6-9.

   This specification is not a part of the Algol 68 Revised Report, and is reproduced in this publication as section 21 with kind permission of C.H. Lindsey.

2. S. G. van der Meulen, M. Veldhorst. TORRIX - A programming language for operations on vectors and matrices over arbitrary fields and of variable size.
   Rijksuniversiteit Utrecht [1977].

3. H. J. Boom, W. J. Hansen. Report on the Standard Hardware Representation for ALGOL 68. Mathematisch Centrum, Amsterdam [1976].

A.4 Algol 68 Genie parsing algorithm

Original material on practical parsing of Algol 68 can be found in below thesis:

1. B. J. Mailloux, On the implementation of Algol 68.
   Thesis, Universiteit van Amsterdam (Mathematisch Centrum) [1968].

A.5 History of Algol 68

Example material on the history of Algol 68:

1. C. H. A. Koster, The Making of Algol 68 [1996].
2. C. H. Lindsey, A History of Algol 68.
   ACM SIGPLAN Notices **28**(3) 97 [1993].

A.6 Online information on Algol 68

Online information on Algol 68:

1. The Algol 68 Genie web pages.
   https://algol68genie.nl
2. The Algol 68 project on SourceForge.
   https://sourceforge.net/projects/algol68
3. An overview of the development of Algol, and implementations, can be found at Paul McJones's pages.
   http://www.softwarepreservation.org/projects/ALGOL/algol68impl/
   https://mcjones.org/dustydecks/archives/category/algol/
   http://www.softwarepreservation.org/projects/ALGOL/
4. The repository of CWI (*Centrum Wiskunde & Informatica*, formerly *Mathematisch Centrum*) holds various Algol 68 related publications among which the MC Revised Algol 68 Test Set:
   https://ir.cwi.nl
5. Ample Algol 68 code is available from the Rosetta Code project or the CodeCodex wiki.
   https://rosettacode.org
   http://codecodex.com
6. HOPL - History of programming languages. Online encyclopaedia of programming languages has an entry for Algol 68.
   http://HOPL.info
7. Brian Wichmann maintains the ALGOL BULLETIN online archive.
   https://archive.computerhistory.org/resources/text/algol/algol_bulletin/
8. The Wikipedia Project has an entry for Algol 68.
   https://en.wikipedia.org/wiki/ALGOL_68

9. Current wiki of IFIP WG 2.1.
   https://ifipwg21wiki.cs.kuleuven.be/IFIP21/WebHome

10. K. Henney - Procedural Programming: It's Back? It Never Went Away.
    https://www.youtube.com/watch?v=otAcmD6XEEE

A.7 Alternatives for Algol 68 Genie

Next to Algol 68 Genie, other implementations are available:

1. An Algol 68 front-end for `gcc` by José Marchesi. This front-end utilises the hand-coded Algol 68 Genie parser.
   gcc.gnu.org/wiki/Algol68FrontEnd
   https://www.algol68-lang.org

2. Algol 68 to C translator *a68toc*, a ported compiler originally distributed by Sian Mountbatten, and now maintained by Neil Matthew. The front-end essentially is the `ALGOL68RS` portable compiler originally written by the Defence Research Agency when it was known as the RSRE (Royal Signals and Radar Establishment) but formats are unavailable. `ALGOL68RS` did not implement the parallel clause.
   https://github.com/coolbikerdad

3. `ALGOL68C` Release 1.3039 for `IBM` (emulated) mainframes running `MVT` or `MVS` by Chris Cheney. This version of `ALGOL68C` is considerably enhanced and has many bugs fixed compared to the version that has been available for many years. It approximately corresponds to that in use at Cambridge University's academic computing service on its `IBM 3084` in 1995. Many of those enhancements were to reduce the number of incompatibilities between `ALGOL68C` and the language defined by the Revised Report, and to support the Report on the Standard Hardware Representation for ALGOL 68 (Hansen and Boom, 1976).
   https://bitbucket.org/algol68c/
   https://algol68genie.nl/en.tag.algol68c.html

A.8 Legacy Algol 68 implementations

This publication refers to legacy implementations of Algol 68:

1. L. Ammeraal, An interpreter for simple Algol 68 programs. Stichting Mathematisch Centrum Amsterdam [1973].

2. CONTROL DATA ALGOL 68. Zoethout et al., CDC Netherlands 1974. Full implementation (apparently it only lacked the format pattern), used mainly in teaching in Germany and the Netherlands on CDC mainframes.

3. `ALGOL68C` Bourne et al., Cambridge 1980. Subset implementation for IBM mainframes, DECsystems 10 and 20, VAX/Unix, CYBER 205 and other systems. Compiler front-end that generated code for a ZCODE back end.

4. `ALGOL68R` Currie et al., RSRE (Royal Signals and Radar Establishment, Malvern) 1970. Single pass compiler, used extensively in military and scientific circles in the UK on ICL machines.

5. `ALGOL68S` Hibbard et al., UK and Carnegie Mellon 1976. Subset, ported to small machines as the PDP-11, (apparently) mostly used in teaching.

6. `ALGOL68RS` For ICL 2900, VAX/VMS and other systems.

7. `FLACC` Full Language Algol 68 Checkout Compiler. Mailloux et al., Edmonton, Canada 1978. An interpreter for the full language, available on IBM mainframes and used in teaching, both in North America and in Europe.

B Reporting bugs

{Les erreurs passent, il n'y a que le vrai qui reste.
Denis Diderot. }

Algol 68 Genie is regression tested using a test suite containing circa 2,000 Algol 68 programs. This suite is composed of programs from various sources such as Dick Grune's *The Mathematisch Centrum Algol 68 Test Set*, test sets from Bernard Houssais and Paul Branquart, the personal applications and test programs of `a68g`'s author, contributions from `a68g` users and code from
`https://rosettacode.org` and `http://www.codecodex.com`.

As you will be aware, no matter how large a test suite, you may uncover a bug that the current suite did not detect. Therefore your bug reports play an essential role in making Algol 68 Genie reliable and keeping this publication up-to-date. When you encounter a problem, then please report it as outlined in below section B.2.

B.1 Have you found a bug?

If you are not sure whether you have found a bug, here are some guidelines:

- Check using section 10.10 that your issue is not a known one.
- If you specified option `--optimise`, use the default `--no-optimise` to check whether you get a runtime error from the interpreter proper. The plugin compiler omits many runtime checks, making a faulty Algol 68 program behave erratically.
- If `a68g` gets a fatal signal, and for instance produces a core dump, for any input, that is most likely a bug. For example:

  ```
  $ a68g hello.a68
  Segmentation fault
  ```

  But please check section 10.10 for some known conditions that can crash `a68g`.

- If `a68g` produces an error message for valid input, that is a bug. An example would be a syntax error issued for valid Algol 68 source code.
- If `a68g` does not produce an error message for invalid input, that is a bug. However, you should note that your idea of invalid input might be someone else's idea of an extension or support for traditional practice.
- If `a68g` just terminates without producing expected output, this may indicate a bug. In any case, please check that the bug is not an error in the Algol 68 source program.
- If you are an experienced user of Algol 68, your suggestions for improvement of Algol 68 Genie are welcome in any case.

B.2 How and where to report bugs

If you want to report a bug please send an e-mail to algol68g@algol68genie.nl. Please include in your bug report:

- At least the version number of `a68g` that produced the bug, but preferably the output of the command:

```
$ a68g --version
```

- A description of the bug.
- If possible, submit the Algol 68 source code that produced the bug.
- The hardware and operating system.

Your feedback is much appreciated.

C

GNU General Public License

Version 3, 29 June 2007

Preamble

The GNU General Public License is a free, copyleft license for software and other kinds of works.

The licenses for most software and other practical works are designed to take away your freedom to share and change the works. By contrast, the GNU General Public License is intended to guarantee your freedom to share and change all versions of a program–to make sure it remains free software for all its users. We, the Free Software Foundation, use the GNU General Public License for most of our software; it applies also to any other work released this way by its authors. You can apply it to your programs, too.

When we speak of free software, we are referring to freedom, not price. Our General Public Licenses are designed to make sure that you have the freedom to distribute copies of free software (and charge for them if you wish), that you receive source code or can get it if you want it, that you can change the software or use pieces of it in new free programs, and that you know you can do these things.

To protect your rights, we need to prevent others from denying you these rights or asking you to surrender the rights. Therefore, you have certain responsibilities if you distribute copies of the software, or if you modify it: responsibilities to respect the freedom of others.

For example, if you distribute copies of such a program, whether gratis or for a fee, you must pass on to the recipients the same freedoms that you received. You must make sure that they, too, receive or can get the source code. And you must show them these terms so they know their rights.

Developers that use the GNU GPL protect your rights with two steps: (1) assert copyright on the software, and (2) offer you this License giving you legal permission to copy, distribute

and/or modify it.

For the developers' and authors' protection, the GPL clearly explains that there is no warranty for this free software. For both users' and authors' sake, the GPL requires that modified versions be marked as changed, so that their problems will not be attributed erroneously to authors of previous versions.

Some devices are designed to deny users access to install or run modified versions of the software inside them, although the manufacturer can do so. This is fundamentally incompatible with the aim of protecting users' freedom to change the software. The systematic pattern of such abuse occurs in the area of products for individuals to use, which is precisely where it is most unacceptable. Therefore, we have designed this version of the GPL to prohibit the practice for those products. If such problems arise substantially in other domains, we stand ready to extend this provision to those domains in future versions of the GPL, as needed to protect the freedom of users.

Finally, every program is threatened constantly by software patents. States should not allow patents to restrict development and use of software on general-purpose computers, but in those that do, we wish to avoid the special danger that patents applied to a free program could make it effectively proprietary. To prevent this, the GPL assures that patents cannot be used to render the program non-free.

The precise terms and conditions for copying, distribution and modification follow.

TERMS AND CONDITIONS

0. Definitions.

   "This License" refers to version 3 of the GNU General Public License.

   "Copyright" also means copyright-like laws that apply to other kinds of works, such as semiconductor masks.

   "The Program" refers to any copyrightable work licensed under this License. Each licensee is addressed as "you". "Licensees" and "recipients" may be individuals or organizations.

   To "modify" a work means to copy from or adapt all or part of the work in a fashion requiring copyright permission, other than the making of an exact copy. The resulting work is called a "modified version" of the earlier work or a work "based on" the earlier work.

   A "covered work" means either the unmodified Program or a work based on the Program.

   To "propagate" a work means to do anything with it that, without permission, would make you directly or secondarily liable for infringement under applicable copyright law, except executing it on a computer or modifying a private copy. Propagation includes copying, distribution (with or without modification), making available to the public, and in some countries other activities as well.

To "convey" a work means any kind of propagation that enables other parties to make or receive copies. Mere interaction with a user through a computer network, with no transfer of a copy, is not conveying.

An interactive user interface displays "Appropriate Legal Notices" to the extent that it includes a convenient and prominently visible feature that (1) displays an appropriate copyright notice, and (2) tells the user that there is no warranty for the work (except to the extent that warranties are provided), that licensees may convey the work under this License, and how to view a copy of this License. If the interface presents a list of user commands or options, such as a menu, a prominent item in the list meets this criterion.

1. Source Code.

   The "source code" for a work means the preferred form of the work for making modifications to it. "Object code" means any non-source form of a work.

   A "Standard Interface" means an interface that either is an official standard defined by a recognized standards body, or, in the case of interfaces specified for a particular programming language, one that is widely used among developers working in that language.

   The "System Libraries" of an executable work include anything, other than the work as a whole, that (a) is included in the normal form of packaging a Major Component, but which is not part of that Major Component, and (b) serves only to enable use of the work with that Major Component, or to implement a Standard Interface for which an implementation is available to the public in source code form. A "Major Component", in this context, means a major essential component (kernel, window system, and so on) of the specific operating system (if any) on which the executable work runs, or a compiler used to produce the work, or an object code interpreter used to run it.

   The "Corresponding Source" for a work in object code form means all the source code needed to generate, install, and (for an executable work) run the object code and to modify the work, including scripts to control those activities. However, it does not include the work's System Libraries, or general-purpose tools or generally available free programs which are used unmodified in performing those activities but which are not part of the work. For example, Corresponding Source includes interface definition files associated with source files for the work, and the source code for shared libraries and dynamically linked subprograms that the work is specifically designed to require, such as by intimate data communication or control flow between those subprograms and other parts of the work.

   The Corresponding Source need not include anything that users can regenerate automatically from other parts of the Corresponding Source.

   The Corresponding Source for a work in source code form is that same work.

2. Basic Permissions.

All rights granted under this License are granted for the term of copyright on the Program, and are irrevocable provided the stated conditions are met. This License explicitly affirms your unlimited permission to run the unmodified Program. The output from running a covered work is covered by this License only if the output, given its content, constitutes a covered work. This License acknowledges your rights of fair use or other equivalent, as provided by copyright law.

You may make, run and propagate covered works that you do not convey, without conditions so long as your license otherwise remains in force. You may convey covered works to others for the sole purpose of having them make modifications exclusively for you, or provide you with facilities for running those works, provided that you comply with the terms of this License in conveying all material for which you do not control copyright. Those thus making or running the covered works for you must do so exclusively on your behalf, under your direction and control, on terms that prohibit them from making any copies of your copyrighted material outside their relationship with you.

Conveying under any other circumstances is permitted solely under the conditions stated below. Sublicensing is not allowed; section 10 makes it unnecessary.

3. Protecting Users' Legal Rights From Anti-Circumvention Law.

   No covered work shall be deemed part of an effective technological measure under any applicable law fulfilling obligations under article 11 of the WIPO copyright treaty adopted on 20 December 1996, or similar laws prohibiting or restricting circumvention of such measures.

   When you convey a covered work, you waive any legal power to forbid circumvention of technological measures to the extent such circumvention is effected by exercising rights under this License with respect to the covered work, and you disclaim any intention to limit operation or modification of the work as a means of enforcing, against the work's users, your or third parties' legal rights to forbid circumvention of technological measures.

4. Conveying Verbatim Copies.

   You may convey verbatim copies of the Program's source code as you receive it, in any medium, provided that you conspicuously and appropriately publish on each copy an appropriate copyright notice; keep intact all notices stating that this License and any non-permissive terms added in accord with section 7 apply to the code; keep intact all notices of the absence of any warranty; and give all recipients a copy of this License along with the Program.

   You may charge any price or no price for each copy that you convey, and you may offer support or warranty protection for a fee.

5. Conveying Modified Source Versions.

You may convey a work based on the Program, or the modifications to produce it from the Program, in the form of source code under the terms of section 4, provided that you also meet all of these conditions:

(a) The work must carry prominent notices stating that you modified it, and giving a relevant date.

(b) The work must carry prominent notices stating that it is released under this License and any conditions added under section 7. This requirement modifies the requirement in section 4 to "keep intact all notices".

(c) You must license the entire work, as a whole, under this License to anyone who comes into possession of a copy. This License will therefore apply, along with any applicable section 7 additional terms, to the whole of the work, and all its parts, regardless of how they are packaged. This License gives no permission to license the work in any other way, but it does not invalidate such permission if you have separately received it.

(d) If the work has interactive user interfaces, each must display Appropriate Legal Notices; however, if the Program has interactive interfaces that do not display Appropriate Legal Notices, your work need not make them do so.

A compilation of a covered work with other separate and independent works, which are not by their nature extensions of the covered work, and which are not combined with it such as to form a larger program, in or on a volume of a storage or distribution medium, is called an "aggregate" if the compilation and its resulting copyright are not used to limit the access or legal rights of the compilation's users beyond what the individual works permit. Inclusion of a covered work in an aggregate does not cause this License to apply to the other parts of the aggregate.

6. Conveying Non-Source Forms.

You may convey a covered work in object code form under the terms of sections 4 and 5, provided that you also convey the machine-readable Corresponding Source under the terms of this License, in one of these ways:

(a) Convey the object code in, or embodied in, a physical product (including a physical distribution medium), accompanied by the Corresponding Source fixed on a durable physical medium customarily used for software interchange.

(b) Convey the object code in, or embodied in, a physical product (including a physical distribution medium), accompanied by a written offer, valid for at least three years and valid for as long as you offer spare parts or customer support for that product model, to give anyone who possesses the object code either (1) a copy of the Corresponding Source for all the software in the product that is covered by this License, on a durable physical medium customarily used for software interchange, for a price no more than your reasonable cost of physically performing this conveying of source, or (2) access to copy the Corresponding Source from a network server at no charge.

(c) Convey individual copies of the object code with a copy of the written offer to provide the Corresponding Source. This alternative is allowed only occasionally and noncommercially, and only if you received the object code with such an offer, in accord with subsection 6b.

(d) Convey the object code by offering access from a designated place (gratis or for a charge), and offer equivalent access to the Corresponding Source in the same way through the same place at no further charge. You need not require recipients to copy the Corresponding Source along with the object code. If the place to copy the object code is a network server, the Corresponding Source may be on a different server (operated by you or a third party) that supports equivalent copying facilities, provided you maintain clear directions next to the object code saying where to find the Corresponding Source. Regardless of what server hosts the Corresponding Source, you remain obligated to ensure that it is available for as long as needed to satisfy these requirements.

(e) Convey the object code using peer-to-peer transmission, provided you inform other peers where the object code and Corresponding Source of the work are being offered to the general public at no charge under subsection 6d.

A separable portion of the object code, whose source code is excluded from the Corresponding Source as a System Library, need not be included in conveying the object code work.

A "User Product" is either (1) a "consumer product", which means any tangible personal property which is normally used for personal, family, or household purposes, or (2) anything designed or sold for incorporation into a dwelling. In determining whether a product is a consumer product, doubtful cases shall be resolved in favor of coverage. For a particular product received by a particular user, "normally used" refers to a typical or common use of that class of product, regardless of the status of the particular user or of the way in which the particular user actually uses, or expects or is expected to use, the product. A product is a consumer product regardless of whether the product has substantial commercial, industrial or non-consumer uses, unless such uses represent the only significant mode of use of the product.

"Installation Information" for a User Product means any methods, procedures, authorization keys, or other information required to install and execute modified versions of a covered work in that User Product from a modified version of its Corresponding Source. The information must suffice to ensure that the continued functioning of the modified object code is in no case prevented or interfered with solely because modification has been made.

If you convey an object code work under this section in, or with, or specifically for use in, a User Product, and the conveying occurs as part of a transaction in which the right of possession and use of the User Product is transferred to the recipient in perpetuity or for a fixed term (regardless of how the transaction is characterized), the Corresponding Source conveyed under this section must be accompanied by the Installation Information. But this requirement does not apply if neither you nor any

third party retains the ability to install modified object code on the User Product (for example, the work has been installed in ROM).

The requirement to provide Installation Information does not include a requirement to continue to provide support service, warranty, or updates for a work that has been modified or installed by the recipient, or for the User Product in which it has been modified or installed. Access to a network may be denied when the modification itself materially and adversely affects the operation of the network or violates the rules and protocols for communication across the network.

Corresponding Source conveyed, and Installation Information provided, in accord with this section must be in a format that is publicly documented (and with an implementation available to the public in source code form), and must require no special password or key for unpacking, reading or copying.

7. Additional Terms.

"Additional permissions" are terms that supplement the terms of this License by making exceptions from one or more of its conditions. Additional permissions that are applicable to the entire Program shall be treated as though they were included in this License, to the extent that they are valid under applicable law. If additional permissions apply only to part of the Program, that part may be used separately under those permissions, but the entire Program remains governed by this License without regard to the additional permissions.

When you convey a copy of a covered work, you may at your option remove any additional permissions from that copy, or from any part of it. (Additional permissions may be written to require their own removal in certain cases when you modify the work.) You may place additional permissions on material, added by you to a covered work, for which you have or can give appropriate copyright permission.

Notwithstanding any other provision of this License, for material you add to a covered work, you may (if authorized by the copyright holders of that material) supplement the terms of this License with terms:

(a) Disclaiming warranty or limiting liability differently from the terms of sections 15 and 16 of this License; or

(b) Requiring preservation of specified reasonable legal notices or author attributions in that material or in the Appropriate Legal Notices displayed by works containing it; or

(c) Prohibiting misrepresentation of the origin of that material, or requiring that modified versions of such material be marked in reasonable ways as different from the original version; or

(d) Limiting the use for publicity purposes of names of licensors or authors of the material; or

(e) Declining to grant rights under trademark law for use of some trade names, trademarks, or service marks; or

(f) Requiring indemnification of licensors and authors of that material by anyone who conveys the material (or modified versions of it) with contractual assumptions of liability to the recipient, for any liability that these contractual assumptions directly impose on those licensors and authors.

All other non-permissive additional terms are considered "further restrictions" within the meaning of section 10. If the Program as you received it, or any part of it, contains a notice stating that it is governed by this License along with a term that is a further restriction, you may remove that term. If a license document contains a further restriction but permits relicensing or conveying under this License, you may add to a covered work material governed by the terms of that license document, provided that the further restriction does not survive such relicensing or conveying.

If you add terms to a covered work in accord with this section, you must place, in the relevant source files, a statement of the additional terms that apply to those files, or a notice indicating where to find the applicable terms.

Additional terms, permissive or non-permissive, may be stated in the form of a separately written license, or stated as exceptions; the above requirements apply either way.

8. Termination.

You may not propagate or modify a covered work except as expressly provided under this License. Any attempt otherwise to propagate or modify it is void, and will automatically terminate your rights under this License (including any patent licenses granted under the third paragraph of section 11).

However, if you cease all violation of this License, then your license from a particular copyright holder is reinstated (a) provisionally, unless and until the copyright holder explicitly and finally terminates your license, and (b) permanently, if the copyright holder fails to notify you of the violation by some reasonable means prior to 60 days after the cessation.

Moreover, your license from a particular copyright holder is reinstated permanently if the copyright holder notifies you of the violation by some reasonable means, this is the first time you have received notice of violation of this License (for any work) from that copyright holder, and you cure the violation prior to 30 days after your receipt of the notice.

Termination of your rights under this section does not terminate the licenses of parties who have received copies or rights from you under this License. If your rights have been terminated and not permanently reinstated, you do not qualify to receive new licenses for the same material under section 10.

9. Acceptance Not Required for Having Copies.

You are not required to accept this License in order to receive or run a copy of the Program. Ancillary propagation of a covered work occurring solely as a consequence

of using peer-to-peer transmission to receive a copy likewise does not require acceptance. However, nothing other than this License grants you permission to propagate or modify any covered work. These actions infringe copyright if you do not accept this License. Therefore, by modifying or propagating a covered work, you indicate your acceptance of this License to do so.

10. Automatic Licensing of Downstream Recipients.

    Each time you convey a covered work, the recipient automatically receives a license from the original licensors, to run, modify and propagate that work, subject to this License. You are not responsible for enforcing compliance by third parties with this License.

    An "entity transaction" is a transaction transferring control of an organization, or substantially all assets of one, or subdividing an organization, or merging organizations. If propagation of a covered work results from an entity transaction, each party to that transaction who receives a copy of the work also receives whatever licenses to the work the party's predecessor in interest had or could give under the previous paragraph, plus a right to possession of the Corresponding Source of the work from the predecessor in interest, if the predecessor has it or can get it with reasonable efforts.

    You may not impose any further restrictions on the exercise of the rights granted or affirmed under this License. For example, you may not impose a license fee, royalty, or other charge for exercise of rights granted under this License, and you may not initiate litigation (including a cross-claim or counterclaim in a lawsuit) alleging that any patent claim is infringed by making, using, selling, offering for sale, or importing the Program or any portion of it.

11. Patents.

    A "contributor" is a copyright holder who authorizes use under this License of the Program or a work on which the Program is based. The work thus licensed is called the contributor's "contributor version".

    A contributor's "essential patent claims" are all patent claims owned or controlled by the contributor, whether already acquired or hereafter acquired, that would be infringed by some manner, permitted by this License, of making, using, or selling its contributor version, but do not include claims that would be infringed only as a consequence of further modification of the contributor version. For purposes of this definition, "control" includes the right to grant patent sublicenses in a manner consistent with the requirements of this License.

    Each contributor grants you a non-exclusive, worldwide, royalty-free patent license under the contributor's essential patent claims, to make, use, sell, offer for sale, import and otherwise run, modify and propagate the contents of its contributor version.

    In the following three paragraphs, a "patent license" is any express agreement or commitment, however denominated, not to enforce a patent (such as an express

permission to practice a patent or covenant not to sue for patent infringement). To "grant" such a patent license to a party means to make such an agreement or commitment not to enforce a patent against the party.

If you convey a covered work, knowingly relying on a patent license, and the Corresponding Source of the work is not available for anyone to copy, free of charge and under the terms of this License, through a publicly available network server or other readily accessible means, then you must either (1) cause the Corresponding Source to be so available, or (2) arrange to deprive yourself of the benefit of the patent license for this particular work, or (3) arrange, in a manner consistent with the requirements of this License, to extend the patent license to downstream recipients. "Knowingly relying" means you have actual knowledge that, but for the patent license, your conveying the covered work in a country, or your recipient's use of the covered work in a country, would infringe one or more identifiable patents in that country that you have reason to believe are valid.

If, pursuant to or in connection with a single transaction or arrangement, you convey, or propagate by procuring conveyance of, a covered work, and grant a patent license to some of the parties receiving the covered work authorizing them to use, propagate, modify or convey a specific copy of the covered work, then the patent license you grant is automatically extended to all recipients of the covered work and works based on it.

A patent license is "discriminatory" if it does not include within the scope of its coverage, prohibits the exercise of, or is conditioned on the non-exercise of one or more of the rights that are specifically granted under this License. You may not convey a covered work if you are a party to an arrangement with a third party that is in the business of distributing software, under which you make payment to the third party based on the extent of your activity of conveying the work, and under which the third party grants, to any of the parties who would receive the covered work from you, a discriminatory patent license (a) in connection with copies of the covered work conveyed by you (or copies made from those copies), or (b) primarily for and in connection with specific products or compilations that contain the covered work, unless you entered into that arrangement, or that patent license was granted, prior to 28 March 2007.

Nothing in this License shall be construed as excluding or limiting any implied license or other defenses to infringement that may otherwise be available to you under applicable patent law.

12. No Surrender of Others' Freedom.

If conditions are imposed on you (whether by court order, agreement or otherwise) that contradict the conditions of this License, they do not excuse you from the conditions of this License. If you cannot convey a covered work so as to satisfy simultaneously your obligations under this License and any other pertinent obligations, then as a consequence you may not convey it at all. For example, if you agree to terms that obligate you to collect a royalty for further conveying from those to whom you convey

the Program, the only way you could satisfy both those terms and this License would be to refrain entirely from conveying the Program.

13. Use with the GNU Affero General Public License.

    Notwithstanding any other provision of this License, you have permission to link or combine any covered work with a work licensed under version 3 of the GNU Affero General Public License into a single combined work, and to convey the resulting work. The terms of this License will continue to apply to the part which is the covered work, but the special requirements of the GNU Affero General Public License, section 13, concerning interaction through a network will apply to the combination as such.

14. Revised Versions of this License.

    The Free Software Foundation may publish revised and/or new versions of the GNU General Public License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns.

    Each version is given a distinguishing version number. If the Program specifies that a certain numbered version of the GNU General Public License "or any later version" applies to it, you have the option of following the terms and conditions either of that numbered version or of any later version published by the Free Software Foundation. If the Program does not specify a version number of the GNU General Public License, you may choose any version ever published by the Free Software Foundation.

    If the Program specifies that a proxy can decide which future versions of the GNU General Public License can be used, that proxy's public statement of acceptance of a version permanently authorizes you to choose that version for the Program.

    Later license versions may give you additional or different permissions. However, no additional obligations are imposed on any author or copyright holder as a result of your choosing to follow a later version.

15. Disclaimer of Warranty.

    THERE IS NO WARRANTY FOR THE PROGRAM, TO THE EXTENT PERMITTED BY APPLICABLE LAW. EXCEPT WHEN OTHERWISE STATED IN WRITING THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES PROVIDE THE PROGRAM "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK AS TO THE QUALITY AND PERFORMANCE OF THE PROGRAM IS WITH YOU. SHOULD THE PROGRAM PROVE DEFECTIVE, YOU ASSUME THE COST OF ALL NECESSARY SERVICING, REPAIR OR CORRECTION.

16. Limitation of Liability.

    IN NO EVENT UNLESS REQUIRED BY APPLICABLE LAW OR AGREED TO IN WRITING WILL ANY COPYRIGHT HOLDER, OR ANY OTHER PARTY WHO

MODIFIES AND/OR CONVEYS THE PROGRAM AS PERMITTED ABOVE, BE LIABLE TO YOU FOR DAMAGES, INCLUDING ANY GENERAL, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE THE PROGRAM (INCLUDING BUT NOT LIMITED TO LOSS OF DATA OR DATA BEING RENDERED INACCURATE OR LOSSES SUSTAINED BY YOU OR THIRD PARTIES OR A FAILURE OF THE PROGRAM TO OPERATE WITH ANY OTHER PROGRAMS), EVEN IF SUCH HOLDER OR OTHER PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

17. Interpretation of Sections 15 and 16.

    If the disclaimer of warranty and limitation of liability provided above cannot be given local legal effect according to their terms, reviewing courts shall apply local law that most closely approximates an absolute waiver of all civil liability in connection with the Program, unless a warranty or assumption of liability accompanies a copy of the Program in return for a fee.

END OF TERMS AND CONDITIONS

How to Apply These Terms to Your New Programs

If you develop a new program, and you want it to be of the greatest possible use to the public, the best way to achieve this is to make it free software which everyone can redistribute and change under these terms.

To do so, attach the following notices to the program. It is safest to attach them to the start of each source file to most effectively state the exclusion of warranty; and each file should have at least the "copyright" line and a pointer to where the full notice is found.

```
<one line to give the program's name and a brief idea of what it does.>

Copyright (C) <textyear>  <name of author>

This program is free software: you can redistribute it and/or modify
it under the terms of the GNU General Public License as published by
the Free Software Foundation, either version 3 of the License, or
(at your option) any later version.

This program is distributed in the hope that it will be useful,
but WITHOUT ANY WARRANTY; without even the implied warranty of
MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
See the
GNU General Public License for more details.

You should have received a copy of the GNU General Public License
along with this program.
If not, see <www.gnu.org/licenses/>.
```

Also add information on how to contact you by electronic and paper mail.

If the program does terminal interaction, make it output a short notice like this when it starts in an interactive mode:

```
<program>  Copyright (C) <year>  <name of author>

This program comes with ABSOLUTELY NO WARRANTY; for details type ‘show w’.
This is free software, and you are welcome to redistribute it
under certain conditions; type ‘show c’ for details.
```

The hypothetical commands `show w` and `show c` should show the appropriate parts of the General Public License. Of course, your program's commands might be different; for a GUI interface, you would use an "about box".

You should also get your employer (if you work as a programmer) or school, if any, to sign a "copyright disclaimer" for the program, if necessary. For more information on this, and how to apply and follow the GNU GPL, see https://www.gnu.org/licenses/.

The GNU General Public License does not permit incorporating your program into proprietary programs. If your program is a subroutine library, you may consider it more useful to permit linking proprietary applications with the library. If this is what you want to do, use the GNU Lesser General Public License instead of this License. But first, please read https://www.gnu.org/philosophy/why-not-lgpl.html.

D

GNU Free Documentation License

Version 1.2, November 2002

51 Franklin St, Fifth Floor, Boston, MA 02110-1301 USA

PREAMBLE

The purpose of this License is to make a manual, textbook, or other functional and useful document "free" in the sense of freedom: to assure everyone the effective freedom to copy and redistribute it, with or without modifying it, either commercially or noncommercially. Secondarily, this License preserves for the author and publisher a way to get credit for their work, while not being considered responsible for modifications made by others.

This License is a kind of "copyleft", which means that derivative works of the document must themselves be free in the same sense. It complements the GNU General Public License, which is a copyleft license designed for free software.

We have designed this License in order to use it for manuals for free software, because free software needs free documentation: a free program should come with manuals providing the same freedoms that the software does. But this License is not limited to software manuals; it can be used for any textual work, regardless of subject matter or whether it is published as a printed book. We recommend this License principally for works whose purpose is instruction or reference.

1. APPLICABILITY AND DEFINITIONS

This License applies to any manual or other work, in any medium, that contains a notice placed by the copyright holder saying it can be distributed under the terms of this License. Such a notice grants a world-wide, royalty-free license, unlimited in duration, to use that work under the conditions stated herein. The "**Document**", below, refers to any such manual or work. Any member of the public is a licensee, and is addressed as "**you**". You accept

the license if you copy, modify or distribute the work in a way requiring permission under copyright law.

A "**Modified Version**" of the Document means any work containing the Document or a portion of it, either copied verbatim, or with modifications and/or translated into another language.

A "**Secondary Section**" is a named appendix or a front-matter section of the Document that deals exclusively with the relationship of the publishers or authors of the Document to the Document's overall subject (or to related matters) and contains nothing that could fall directly within that overall subject. (Thus, if the Document is in part a textbook of mathematics, a Secondary Section may not explain any mathematics.) The relationship could be a matter of historical connection with the subject or with related matters, or of legal, commercial, philosophical, ethical or political position regarding them.

The "**Invariant Sections**" are certain Secondary Sections whose titles are designated, as being those of Invariant Sections, in the notice that says that the Document is released under this License. If a section does not fit the above definition of Secondary then it is not allowed to be designated as Invariant. The Document may contain zero Invariant Sections. If the Document does not identify any Invariant Sections then there are none.

The "**Cover Texts**" are certain short passages of text that are listed, as Front-Cover Texts or Back-Cover Texts, in the notice that says that the Document is released under this License. A Front-Cover Text may be at most 5 words, and a Back-Cover Text may be at most 25 words.

A "**Transparent**" copy of the Document means a machine-readable copy, represented in a format whose specification is available to the general public, that is suitable for revising the document straightforwardly with generic text editors or (for images composed of pixels) generic paint programs or (for drawings) some widely available drawing editor, and that is suitable for input to text formatters or for automatic translation to a variety of formats suitable for input to text formatters. A copy made in an otherwise Transparent file format whose markup, or absence of markup, has been arranged to thwart or discourage subsequent modification by readers is not Transparent. An image format is not Transparent if used for any substantial amount of text. A copy that is not "Transparent" is called "**Opaque**".

Examples of suitable formats for Transparent copies include plain ASCII without markup, Texinfo input format, LaTeX input format, SGML or XML using a publicly available DTD, and standard-conforming simple HTML, PostScript or PDF designed for human modification. Examples of transparent image formats include PNG, XCF and JPG. Opaque formats include proprietary formats that can be read and edited only by proprietary word processors, SGML or XML for which the DTD and/or processing tools are not generally available, and the machine-generated HTML, PostScript or PDF produced by some word processors for output purposes only.

The "**Title Page**" means, for a printed book, the title page itself, plus such following pages as are needed to hold, legibly, the material this License requires to appear in the title page. For works in formats which do not have any title page as such, "Title Page" means the text near the most prominent appearance of the work's title, preceding the beginning of the body of the text.

A section "**Entitled XYZ**" means a named subunit of the Document whose title either is precisely XYZ or contains XYZ in parentheses following text that translates XYZ in another language. (Here XYZ stands for a specific section name mentioned below, such as "**Acknowledgements**", "**Dedications**", "**Endorsements**", or "**History**".) To "**Preserve the Title**" of such a section when you modify the Document means that it remains a section "Entitled XYZ" according to this definition.

The Document may include Warranty Disclaimers next to the notice which states that this License applies to the Document. These Warranty Disclaimers are considered to be included by reference in this License, but only as regards disclaiming warranties: any other implication that these Warranty Disclaimers may have is void and has no effect on the meaning of this License.

2. VERBATIM COPYING

You may copy and distribute the Document in any medium, either commercially or noncommercially, provided that this License, the copyright notices, and the license notice saying this License applies to the Document are reproduced in all copies, and that you add no other conditions whatsoever to those of this License. You may not use technical measures to obstruct or control the reading or further copying of the copies you make or distribute. However, you may accept compensation in exchange for copies. If you distribute a large enough number of copies you must also follow the conditions in section 3.

You may also lend copies, under the same conditions stated above, and you may publicly display copies.

3. COPYING IN QUANTITY

If you publish printed copies (or copies in media that commonly have printed covers) of the Document, numbering more than 100, and the Document's license notice requires Cover Texts, you must enclose the copies in covers that carry, clearly and legibly, all these Cover Texts: Front-Cover Texts on the front cover, and Back-Cover Texts on the back cover. Both covers must also clearly and legibly identify you as the publisher of these copies. The front cover must present the full title with all words of the title equally prominent and visible. You may add other material on the covers in addition. Copying with changes limited to the covers, as long as they preserve the title of the Document and satisfy these conditions, can be treated as verbatim copying in other respects.

If the required texts for either cover are too voluminous to fit legibly, you should put the first ones listed (as many as fit reasonably) on the actual cover, and continue the rest onto

adjacent pages.

If you publish or distribute Opaque copies of the Document numbering more than 100, you must either include a machine-readable Transparent copy along with each Opaque copy, or state in or with each Opaque copy a computer-network location from which the general network-using public has access to download using public-standard network protocols a complete Transparent copy of the Document, free of added material. If you use the latter option, you must take reasonably prudent steps, when you begin distribution of Opaque copies in quantity, to ensure that this Transparent copy will remain thus accessible at the stated location until at least one year after the last time you distribute an Opaque copy (directly or through your agents or retailers) of that edition to the public.

It is requested, but not required, that you contact the authors of the Document well before redistributing any large number of copies, to give them a chance to provide you with an updated version of the Document.

4. MODIFICATIONS

You may copy and distribute a Modified Version of the Document under the conditions of sections 2 and 3 above, provided that you release the Modified Version under precisely this License, with the Modified Version filling the role of the Document, thus licensing distribution and modification of the Modified Version to whoever possesses a copy of it. In addition, you must do these things in the Modified Version:

A. Use in the Title Page (and on the covers, if any) a title distinct from that of the Document, and from those of previous versions (which should, if there were any, be listed in the History section of the Document). You may use the same title as a previous version if the original publisher of that version gives permission.

B. List on the Title Page, as authors, one or more persons or entities responsible for authorship of the modifications in the Modified Version, together with at least five of the principal authors of the Document (all of its principal authors, if it has fewer than five), unless they release you from this requirement.

C. State on the Title page the name of the publisher of the Modified Version, as the publisher.

D. Preserve all the copyright notices of the Document.

E. Add an appropriate copyright notice for your modifications adjacent to the other copyright notices.

F. Include, immediately after the copyright notices, a license notice giving the public permission to use the Modified Version under the terms of this License, in the form shown in the Addendum below.

G. Preserve in that license notice the full lists of Invariant Sections and required Cover Texts given in the Document's license notice.

H. Include an unaltered copy of this License.

I. Preserve the section Entitled “History”, Preserve its Title, and add to it an item stating at least the title, year, new authors, and publisher of the Modified Version as given on the Title Page. If there is no section Entitled “History” in the Document, create one stating the title, year, authors, and publisher of the Document as given on its Title Page, then add an item describing the Modified Version as stated in the previous sentence.

J. Preserve the network location, if any, given in the Document for public access to a Transparent copy of the Document, and likewise the network locations given in the Document for previous versions it was based on. These may be placed in the “History” section. You may omit a network location for a work that was published at least four years before the Document itself, or if the original publisher of the version it refers to gives permission.

K. For any section Entitled “Acknowledgements” or “Dedications”, Preserve the Title of the section, and preserve in the section all the substance and tone of each of the contributor acknowledgements and/or dedications given therein.

L. Preserve all the Invariant Sections of the Document, unaltered in their text and in their titles. Section numbers or the equivalent are not considered part of the section titles.

M. Delete any section Entitled “Endorsements”. Such a section may not be included in the Modified Version.

N. Do not retitle any existing section to be Entitled “Endorsements” or to conflict in title with any Invariant Section.

O. Preserve any Warranty Disclaimers.

If the Modified Version includes new front-matter sections or appendices that qualify as Secondary Sections and contain no material copied from the Document, you may at your option designate some or all of these sections as invariant. To do this, add their titles to the list of Invariant Sections in the Modified Version’s license notice. These titles must be distinct from any other section titles.

You may add a section Entitled “Endorsements”, provided it contains nothing but endorsements of your Modified Version by various parties–for example, statements of peer review or that the text has been approved by an organization as the authoritative definition of a standard.

You may add a passage of up to five words as a Front-Cover Text, and a passage of up to 25 words as a Back-Cover Text, to the end of the list of Cover Texts in the Modified Version. Only one passage of Front-Cover Text and one of Back-Cover Text may be added by (or through arrangements made by) any one entity. If the Document already includes a cover

text for the same cover, previously added by you or by arrangement made by the same entity you are acting on behalf of, you may not add another; but you may replace the old one, on explicit permission from the previous publisher that added the old one.

The author(s) and publisher(s) of the Document do not by this License give permission to use their names for publicity for or to assert or imply endorsement of any Modified Version.

5. COMBINING DOCUMENTS

You may combine the Document with other documents released under this License, under the terms defined in section 4 above for modified versions, provided that you include in the combination all of the Invariant Sections of all of the original documents, unmodified, and list them all as Invariant Sections of your combined work in its license notice, and that you preserve all their Warranty Disclaimers.

The combined work need only contain one copy of this License, and multiple identical Invariant Sections may be replaced with a single copy. If there are multiple Invariant Sections with the same name but different contents, make the title of each such section unique by adding at the end of it, in parentheses, the name of the original author or publisher of that section if known, or else a unique number. Make the same adjustment to the section titles in the list of Invariant Sections in the license notice of the combined work.

In the combination, you must combine any sections Entitled “History” in the various original documents, forming one section Entitled “History”; likewise combine any sections Entitled “Acknowledgements”, and any sections Entitled “Dedications”. You must delete all sections Entitled “Endorsements”.

6. COLLECTIONS OF DOCUMENTS

You may make a collection consisting of the Document and other documents released under this License, and replace the individual copies of this License in the various documents with a single copy that is included in the collection, provided that you follow the rules of this License for verbatim copying of each of the documents in all other respects.

You may extract a single document from such a collection, and distribute it individually under this License, provided you insert a copy of this License into the extracted document, and follow this License in all other respects regarding verbatim copying of that document.

7. AGGREGATION WITH INDEPENDENT WORKS

A compilation of the Document or its derivatives with other separate and independent documents or works, in or on a volume of a storage or distribution medium, is called an “aggregate” if the copyright resulting from the compilation is not used to limit the legal rights of the compilation’s users beyond what the individual works permit. When the Document is included in an aggregate, this License does not apply to the other works in the aggregate which are not themselves derivative works of the Document.

If the Cover Text requirement of section 3 is applicable to these copies of the Document, then if the Document is less than one half of the entire aggregate, the Document's Cover Texts may be placed on covers that bracket the Document within the aggregate, or the electronic equivalent of covers if the Document is in electronic form. Otherwise they must appear on printed covers that bracket the whole aggregate.

8. TRANSLATION

Translation is considered a kind of modification, so you may distribute translations of the Document under the terms of section 4. Replacing Invariant Sections with translations requires special permission from their copyright holders, but you may include translations of some or all Invariant Sections in addition to the original versions of these Invariant Sections. You may include a translation of this License, and all the license notices in the Document, and any Warranty Disclaimers, provided that you also include the original English version of this License and the original versions of those notices and disclaimers. In case of a disagreement between the translation and the original version of this License or a notice or disclaimer, the original version will prevail.

If a section in the Document is Entitled "Acknowledgements", "Dedications", or "History", the requirement (section 4) to Preserve its Title (section 1) will typically require changing the actual title.

9. TERMINATION

You may not copy, modify, sublicense, or distribute the Document except as expressly provided for under this License. Any other attempt to copy, modify, sublicense or distribute the Document is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

10. FUTURE REVISIONS OF THIS LICENSE

The Free Software Foundation may publish new, revised versions of the GNU Free Documentation License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns.
See https://www.gnu.org/copyleft/.

Each version of the License is given a distinguishing version number. If the Document specifies that a particular numbered version of this License "or any later version" applies to it, you have the option of following the terms and conditions either of that specified version or of any later version that has been published (not as a draft) by the Free Software Foundation. If the Document does not specify a version number of this License, you may choose any version ever published (not as a draft) by the Free Software Foundation.

ADDENDUM: HOW TO USE THIS LICENSE FOR YOUR DOCUMENTS

To use this License in a document you have written, include a copy of the License in the document and put the following copyright and license notices just after the title page:

> Copyright © YEAR YOUR NAME. Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the license is included in the section entitled "GNU Free Documentation License".

If you have Invariant Sections, Front-Cover Texts and Back-Cover Texts, replace the "with ... Texts." line with this:

> with the Invariant Sections being LIST THEIR TITLES, with the Front-Cover Texts being LIST, and with the Back-Cover Texts being LIST.

If you have Invariant Sections without Cover Texts, or some other combination of the three, merge those two alternatives to suit the situation.

If your document contains nontrivial examples of program code, we recommend releasing these examples in parallel under your choice of free software license, such as the GNU General Public License, to permit their use in free software.

VI

Keyword index

Keyword index