An Expert's Guide to the

Lout

Document Formatting System

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Version 3.36
July, 2007

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Preface

This manual is addressed to those who wish to become expert users of the Lout document formatting system. An expert user is someone who understands the principles of document formatting that Lout embodies, and is able to apply them, for example to design a document format or a special-purpose package. In contrast, a non-expert user is someone who simply uses Lout to format documents.

Chapter 1 explains these principles, and it should be read carefully and in sequence. Chapters 2 and 3 are for reference; respectively, they contain descriptions of the detailed operation of Lout's major components, and a complete description of each predefined symbol. The final chapter presents a collection of advanced examples.

This manual presents Version 3 of Basser Lout, publicly released in September 1994 [4] and developed continuously since then. This manual was rendered into PostScript by Version 3.36 of the Basser Lout interpreter, using the symbols described in the User's Guide [5].

Acknowledgment. Version 3 has benefited from hundreds of comments received since the release of Version 1 in October 1991. Not every suggestion could be followed, but many have been, and the encouragement was greatly appreciated.

Contents

Preface ii

Chapter 1. Principles 1
1.1. Objects 1
1.2. Definitions 4
1.3. Cross references 8
1.4. Galleys 9

Chapter 2. Details 14
2.1. Lexical structure (words, spaces, symbols) and macros 14
2.2. Named parameters 16
2.3. Nested definitions, body parameters, extend, import, and export 18
2.4. Filtered right and body parameters 21
2.5. Precedence and associativity of symbols 23
2.6. The style and size of objects 24
2.7. Galleys and targets 27
2.8. Sorted galleys 33
2.9. Horizontal galleys 34
2.10. Optimal galley breaking 36

Chapter 3. Predefined symbols 37
3.1. @Begin and @End 37
3.2. Concatenation symbols and paragraphs 37
3.3. @Font, @Char, and @FontDef 41
3.4. @Break 44
3.5. @Space 46
3.6. @YUnit, @ZUnit, @CurrYUnit, and @CurrZUnit 47
3.7. @SetContext and @GetContext 47
3.8. @SetColour and @SetColor 48
3.9. @SetUnderlineColour and @SetUnderlineColor 49
3.10. @SetTexture 50
3.11. @Outline 51
3.12. @Language and @CurrLang 51
3.13. @OneCol and @OneRow 52
3.14. @Wide and @High 53
3.15. @HShift and @VShift 53

3.16. @HExpand and @VExpand 54
3.17. @HContract and @VContract 54
3.18. @HLimited and @VLimited 54
3.19. @HAdjust, @VAdjust, and @PAdjust 54
3.20. @HScale and @VScale 55
3.21. @HMirror and @VMirror 55
3.22. @HCover and @VCover 56
3.23. @StartHSpan,@StartVSpan, @StartHVSpan, @HSpan, and @VSpan .. 57
3.24. @Scale 57
3.25. @Rotate 58
3.26. @Background 59
3.27. @KernShrink 59
3.28. @Common, @Rump, and @Meld 59
3.29. @Insert 61
3.30. @OneOf 61
3.31. @Next 63
3.32. @Case 63
3.33. @Moment 64
3.34. @Null 64
3.35. @Galley and @ForceGalley 65
3.36. @BeginHeaderComponent, @EndHeaderComponent, @SetHeaderComponent, and @ClearHeaderComponent 65
3.37. @NotRevealed 67
3.38. The cross reference symbols && and &&& 68
3.39. @Tagged 68
3.40. @Open and @Use 68
3.41. @LinkSource, @LinkDest, and @URLLink 69
3.42. @Database and @SysDatabase 71
3.43. @Graphic 71
3.44. @PlainGraphic 75
3.45. @IncludeGraphic and @SysIncludeGraphic 75
3.46. @IncludeGraphicRepeated and @SysIncludeGraphicRepeated 76
3.47. @PrependGraphic and @SysPrependGraphic 76
3.48. @Include and @SysInclude 77
3.49. @BackEnd and the PlainText and PDF back ends 77
3.50. @Verbatim and @RawVerbatim 78
3.51. @Underline 79
3.52. @PageLabel 79

Chapter 4. Examples 81
4.1. An equation formatting package 81
4.2. Paragraphs, displays, and lists 83
4.3. Page layout 87
4.4. Chapters and sections 92
4.5. Bibliographies 97
4.6. Merged index entries 101

Appendix A. Implementation of Textures 105

References 110

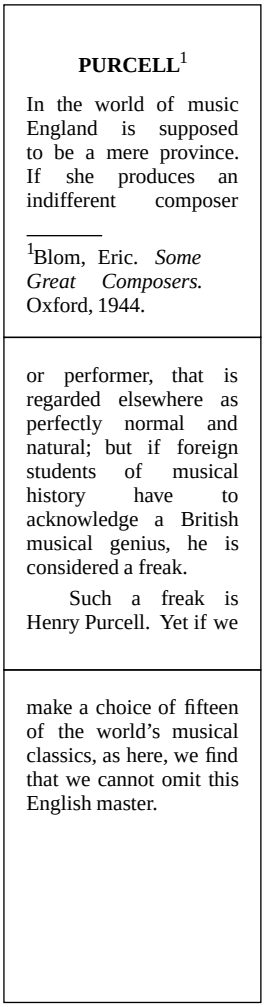
Index 111

Chapter 1. Principles

The Lout document formatting language is based on just four key ideas: objects, definitions, cross references, and galleys. This chapter concentrates on them, postponing the inevitable details.

1.1. Objects

Since our aim is to produce neatly formatted documents, we should begin by looking at a typical example of such a document:



PURCELL[1]

In the world of music England is supposed to be a mere province. If she produces an indifferent composer

[1]Blom, Eric. *Some Great Composers.* Oxford, 1944.

or performer, that is regarded elsewhere as perfectly normal and natural; but if foreign students of musical history have to acknowledge a British musical genius, he is considered a freak.

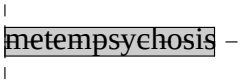
Such a freak is Henry Purcell. Yet if we

make a choice of fifteen of the world's musical classics, as here, we find that we cannot omit this English master.

It is a large rectangle made from three smaller rectangles – its pages. Each page is made of lines; each line is made of words, although it makes sense for any rectangle (even a complete document) to be part of a line, provided it is not too large.

Lout deals with something a little more complicated than rectangles: *objects.* An object is a rectangle with at least one *column mark* protruding above and below it, and at least one *row*

mark protruding to the left and right. The simplest objects contain words like metempsychosis, and have one mark of each type:



The rectangle exactly encloses the word; its column mark is at the left edge, and its row mark passes through the middle of the lower-case letters. The rectangle and marks do not appear on the printed page, but to understand what Lout is doing you have to imagine them.

To place two objects side by side, we separate them by the symbol |, which denotes the act of *horizontal concatenation.* So, if we write

```
USA | Australia
```

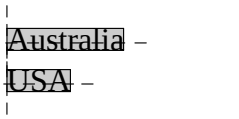
the result will be the object

Notice that this object has two column marks, but still only one row mark, because | merges the two row marks together. This merging of row marks fixes the vertical position of each object with respect to the other, but it does not determine how far apart they are. This distance, or *gap*, may be given just after the symbol, as in |0.5i for example, which specifies horizontal concatenation with a gap of half an inch. If no gap is given, it is assumed to be 0i.

Vertical concatenation, denoted by /, is the same apart from the change of direction:

```
Australia /0.1i USA
```

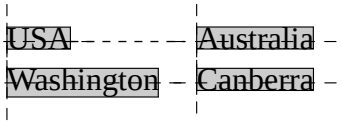
has result



The usual merging of marks occurs, and now the gap determines the vertical separation. Horizontal and vertical can be combined:

```
      USA          |0.2i Australia
/0.1i Washington   |     Canberra
```

has result



There are several things to note carefully here. White space (including tabs and newlines) adjacent to a concatenation symbol is ignored, so it may be used to lay out the expression clearly. The symbol | takes precedence over /, which means that the rows are formed first, then vertically concatenated. The symbol / will merge two or more column marks, creating multiple columns (and | will merge two or more row marks). This implies that the gap 0.2i used above is between columns, not individual items in columns; a gap in the second row would therefore be redundant, and so is omitted.

A variant of / called // left-justifies two objects instead of merging their marks.

By enclosing an object in braces, it is possible to override the set precedences. Here is another expression for the table above, in which the columns are formed first:

```
      { USA       /0.1i  Washington }
|0.2i { Australia /      Canberra }
```

Braces have no effect other than to alter the grouping.

Paragraph breaking occurs when an object is too wide to fit into the space available to it; by breaking its paragraphs into lines, its width is reduced to an acceptable amount. The available space is determined by the @Wide symbol, whose form is

length @Wide *object*

and whose result is the given object modified to have exactly the given length. For example,

```
5i @Wide {
Macbeth was very ambitious. This led him to wish to become king of
Scotland. The witches told him that this wish of his would come true. The
king of Scotland at this time was Duncan. Encouraged by his wife, Macbeth
murdered Duncan. He was thus enabled to succeed Duncan as king. (51 words)
|0.5i
Encouraged by his wife, Macbeth achieved his ambition and realized the
prediction of the witches by murdering Duncan and becoming king of Scotland
in his place. (26 words)
}
```

has for its result the following five inch wide object [8]:

Macbeth was very ambitious. This led him to wish to become king of Scotland. The witches told him that this wish of his would come true. The king of Scotland at this time was Duncan. Encouraged by his wife, Macbeth murdered Duncan. He was thus enabled to succeed Duncan as king. (51 words)

Encouraged by his wife, Macbeth achieved his ambition and realized the prediction of the witches by murdering Duncan and becoming king of Scotland in his place. (26 words)

A paragraph of text can be included anywhere, and it will be broken automatically if necessary to fit the available space. The spaces between words are converted into concatenation symbols.

These are the most significant of Lout's object-building symbols. There are others, for changing fonts, controlling paragraph breaking, printing graphical objects like boxes and circles, and so on, but they do not add anything new in principle.

1.2. Definitions

The features of Lout are very general. They do not assume that documents are composed of pages, nor that there are such things as margins and footnotes, for example. *Definitions* bridge the gap between Lout's general features and the special features – footnotes, equations, pages – that particular documents require. They hold the instructions for producing these special features, conveniently packaged ready for use.

For example, consider the challenge posed by 'TEX', which is the name of one of Lout's most illustrious rivals [6]. Lout solves it easily enough, like this:

```
T{ /0.2fo E }X
```

but to type this every time TEX is mentioned would be tedious and error-prone. So we place a definition at the beginning of the document:

```
def  @TeX  {  T{ /0.2fo E }X  }
```

Now @TeX stands for the object following it between braces, and we may write

```
consider the challenge posed by '@TeX', …
```

as the author did earlier in this paragraph.

A *symbol* is a name, like @TeX, which stands for something other than itself. The initial @ is not compulsory, but it does make the name stand out clearly. A *definition* of a symbol declares a name to be a symbol, and says what the symbol stands for. The *body* of a definition is the part following the name, between the braces. To *invoke* a symbol is to make use of it.

Another expression ripe for packaging in a definition is

```
@OneRow { | -2p @Font n ^/0.5fk 2 }
```

which produces 2^n (see Chapter 2). But this time we would like to be able to write

```
object  @Super  object
```

so that a @Super 2 would come out as a^2, and so on, for in this way the usefulness of the definition is greatly increased. Here is how it is done:

```
def @Super
  left x
  right y
{ @OneRow { | -2p @Font y ^/0.5fk x }
}
```

This definition says that @Super has two *parameters*, x and y. When @Super is invoked, all occurrences of x in the body will be replaced by the object just to the left of @Super, and all occurrences of y will be replaced by the object just to the right. So, for example, the expression

```
2  @Super  { Slope @Font n }
```

is equal to

```
@OneRow { | -2p @Font { Slope @Font n } ^/0.5fk 2 }
```

and so comes out as 2^n.

Lout permits definitions to invoke themselves, a peculiarly circular thing to do which goes by the name of *recursion*. Here is an example of a recursive definition:

```
def @Leaders { .. @Leaders }
```

The usual rule is that the value of an invocation of a symbol is a copy of the body of the symbol's definition, so the value of @Leaders must be

```
.. @Leaders
```

But now this rule applies to this new invocation of @Leaders; substituting its body gives

```
.. .. @Leaders
```

and so on forever. In order to make this useful, an invocation of a recursive symbol is replaced by its body only if sufficient space is available. So, for example,

```
4i @Wide { Chapter 7 @Leaders 62 }
```

has for its result the object

Chapter 7 62

with Lout checking before each replacement of @Leaders by .. @Leaders that the total length afterwards, including the other words, would not exceed four inches.

The remaining issue is what happens when Lout decides that it is time to stop. The obvious thing to do is to replace the last invocation by an empty object:

```
.. .. .. .. .. .. .. .. {}
```

As the example shows, this would leave a small trailing space, which is a major headache. Lout fixes this by replacing the last invocation with a different kind of empty object, called @Null, whose effect is to make an adjacent concatenation symbol disappear, preferably one preceding the @Null. Thus, when Lout replaces @Leaders by @Null in the expression

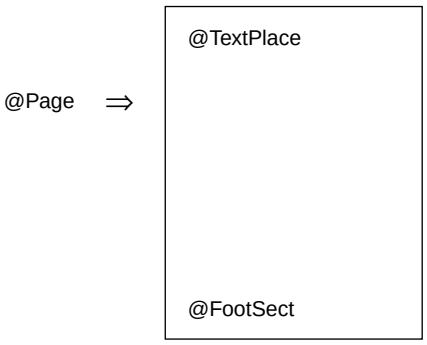
```
.. .. .. .. .. .. .. .. @Leaders
```

the trailing space, which is really a horizontal concatenation symbol, disappears as well. This is taken into account when deciding whether there is room to replace @Leaders by its body.

The remainder of this section is devoted to showing how definitions may be used to specify the *page layout* of a document. To begin with, we can define a page like this:

```
def @Page
{
   //1i  ||1i
   6i @Wide 9.5i @High
   { @TextPlace  //1rt  @FootSect }
   ||1i  //1i
}
```

Now @Page is an eight by eleven and a half inch object, with one inch margins, a place at the top for text, and a section at the bottom for footnotes (since //1rt bottom-justifies the following object). It will be convenient for us to show the effect of invoking @Page like this:

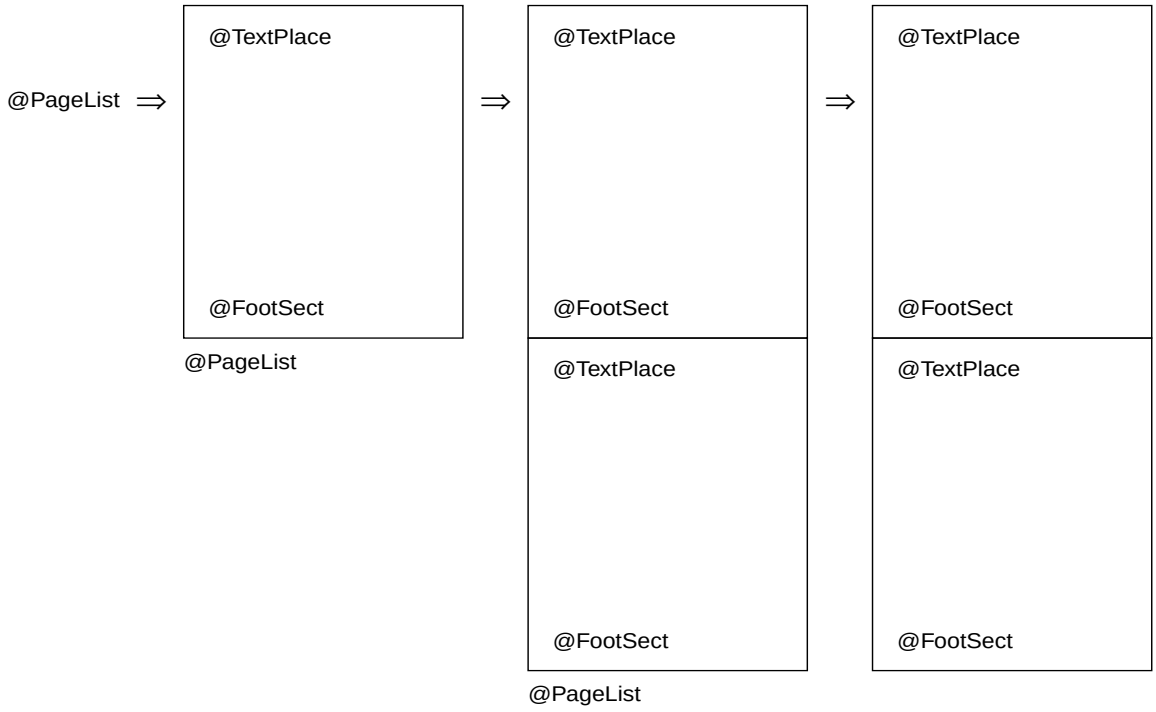


with the invoked symbol appearing to the left of the arrow, and its body to the right.

The definition of a vertical list of pages should come as no surprise:

```
def @PageList
{
   @Page  //  @PageList
}
```

This allows invocations like the following:



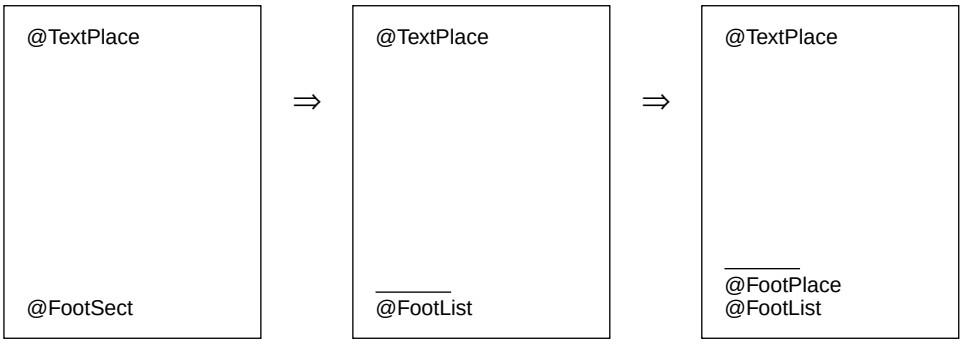
setting @PageList to @Null on the last step. Any number of pages can be generated.

A definition for @TextPlace is beyond us at present, since @TextPlace must be replaced by different parts of the text of the document on different pages. But we can define @FootSect to be a small space followed by a horizontal line followed by a list of places where footnotes go:

```
def @FootList
{
  @FootPlace  //0.3v  @FootList
}

def @FootSect
{
  //0.3v 1i @Wide @HLine
  //0.3v @FootList
}
```

assuming that @HLine will produce a horizontal line of the indicated width. With this definition we can generate pages like this:



and so on for arbitrarily many footnotes.

We will see in the next section how invocations of @PageList, @FootSect and @FootList are replaced by their bodies only when the need to insert text and footnotes obliges Lout to do so; otherwise the invocations are replaced by @Null. In this way, the right number of pages is made, the small line appears only on pages that have at least one footnote, and unnecessary concatenation symbols disappear.

This approach to page layout is the most original contribution Lout has made to document formatting. It is extraordinarily flexible. Two-column pages? Use

```
{2.8i @Wide @TextPlace}  ||0.4i  {2.8i @Wide @TextPlace}
```

instead of @TextPlace. Footnotes in smaller type? Use -2p @Font @FootPlace instead of @FootPlace. And on and on.

1.3. Cross references

A cross reference in common terminology is something like ‘see Table 6’ or ‘see page 57’ – a reference within a document to some other part of it. Readers find them very useful, but they are a major problem for authors. As the document is revised, Table 6 becomes Table 7, the thing on page 57 moves to page 63, and all the cross references must be changed.

The Scribe document formatter, developed by Brian K. Reid [7], introduced a scheme for keeping track of cross references. It allows you to give names to tables, figures, etc., and to refer to them by name. The formatter inserts the appropriate numbers in place of the names, so that as the document is revised, the cross references are kept up to date automatically. Lout has adopted and extended this scheme.

In Lout, automatic cross referencing works in the following way. First define a symbol with a parameter with the special name @Tag:

```
def @Table
  left @Tag
  right @Value
{
  ||1i  @Value
}
```

When this symbol is invoked, the value given to @Tag should be a simple word like cities, or several simple words juxtaposed like cities compare; it serves to name the invocation:

```
{ cities compare } @Table
{
   Washington  |0.5i  Canberra
}
```

We may now refer to this invocation elsewhere in the document, using the *cross reference* @Table&&{ cities compare }. Here && is the *cross reference symbol*; its left parameter is a symbol and its right parameter is the value of the @Tag parameter of some invocation of that symbol. Of course it’s simplest if you use just a one-word tag; then no braces are needed.

A cross reference is not an object; the reader should think of it as an arrow in the final printed document, beginning at the cross reference and ending at the top of the target invocation. Three special values may be given to the right parameter of &&: preceding, following, and foll_or_prec. The cross reference @Table&&preceding points to some table appearing earlier in the final printed document than itself; that is, the arrow is guaranteed to point backwards through the document. Usually it points to the nearest preceding invocation. Similarly, @Table&&following points forwards, usually to the nearest following invocation. @Table&&foll_or_prec is the same as @Table&&following if it exists, otherwise it is the same as @Table&&preceding.

This section has been concerned with what a cross reference is – an arrow from one point in a document to another – but not with how it is used. One simple way to use a cross reference is to put it where an object is expected, like this:

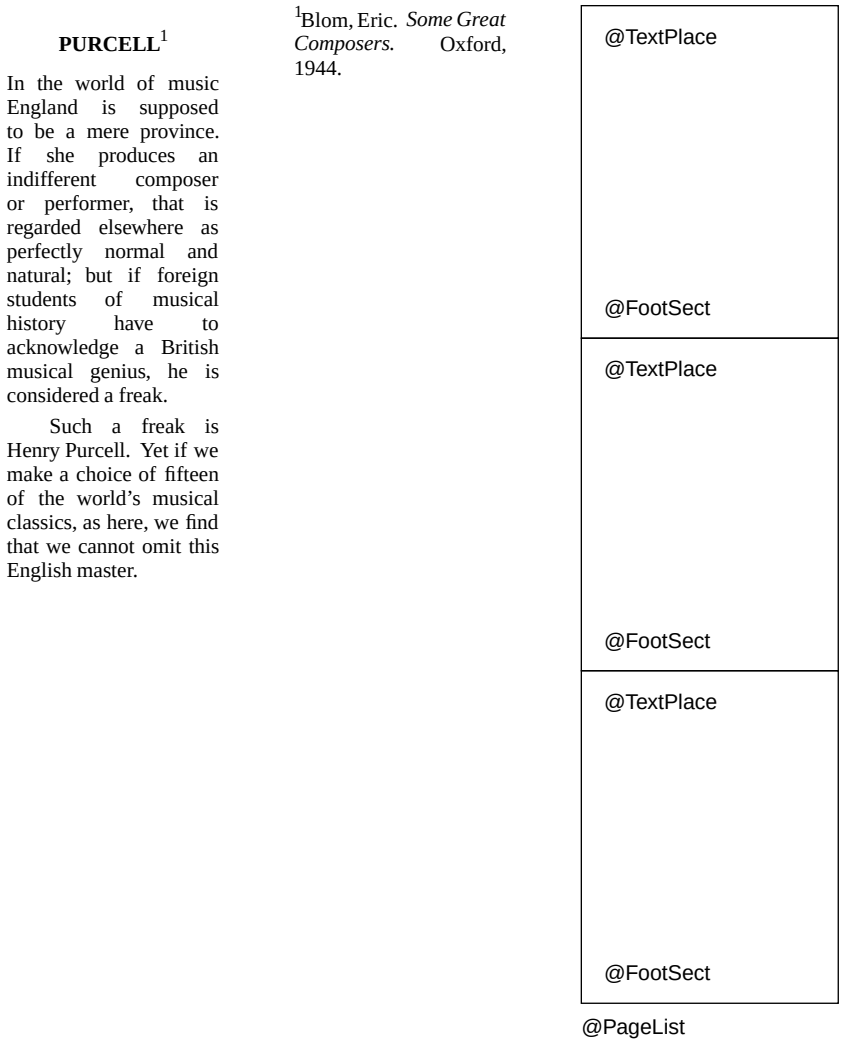
```
a | @Table&&cities | c
```

In this case the cross reference will be replaced by a copy of the invocation it points to: in the example just given, a table will appear between a and c. Other applications of cross references may be found in Chapter 4, including finding the number of the page where something appears, producing running page headers and footers, and accessing databases of Roman numerals, references, etc. Cross references are also used by galleys, as will be explained in the next section.

The implementation of cross referencing copies every symbol invocation with a @Tag parameter into the *cross-reference database*, a collection of files whose names end in .ld indexed by one file whose name is lout.li. It is generally the case that the bulk content of a symbol such as the table above is contained in its right or body parameter, and that this bulk content is not needed by cross references to the symbol. Hence, to save space in the database, Lout replaces the right parameter of each symbol it writes into it by the word ??? whenever the right parameter appears to be large. The table above would appear as ??? because of this optimization, and in general, the user must ensure that any content required by cross references is contained in parameters other than the right or body parameter. This optimization does not apply when the symbol being written into the cross-reference database is a galley.

1.4. Galleys

It is time to pause and ask ourselves how close we are to achieving our aim of producing neatly formatted documents. We can certainly produce the pieces of a document:

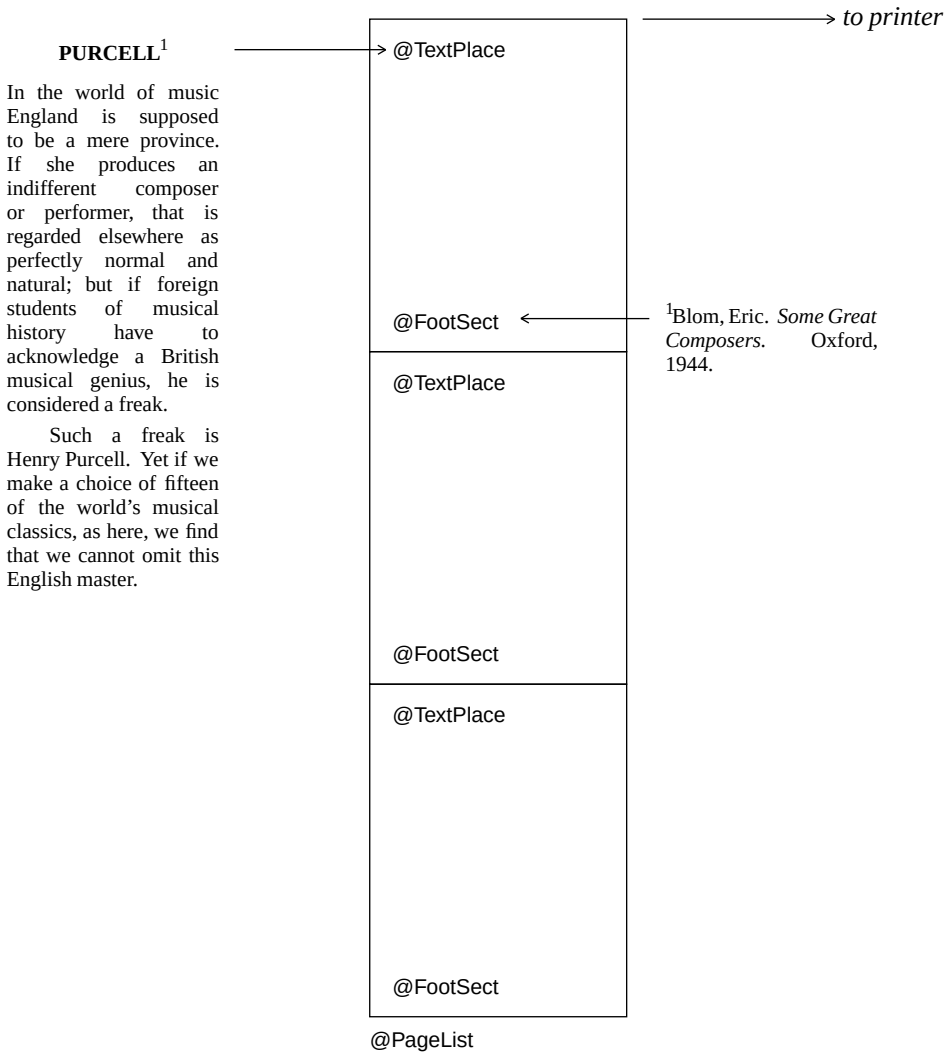


but when we try to merge them together, we encounter two obstacles.

First, when an object is entered at a certain place in the document, it appears at that place. But a footnote is naturally entered immediately after the point it refers to ('PURCELL' in this case), yet it appears somewhere else: at the bottom of a page.

Second, all our features build up larger objects out of smaller ones, but the PURCELL object, for example, must be broken down into page-sized pieces. This occurs when the available space at the 'somewhere else' is insufficient to hold the entire object, so this second obstacle arises out of the first.

Lout's last major feature, which we introduce to overcome these obstacles, is the *galley* (the name is borrowed from the galleys used in manual typesetting). A galley is an object plus a cross reference which points to where the object is to appear. The example above has three galleys:



A galley replaces the invocation pointed to by its cross reference. If space is not sufficient there to hold it all, the remainder of the galley is split off (the vertical concatenation symbol preceding it being discarded) and it replaces later invocations of the same symbol. This is exactly what is required to get text and footnotes onto pages.

To create a galley, first define a symbol with a special into clause, like this:

```
def @FootNote into { @FootPlace&&following }
  right x
{
  8p @Font x
}
```

An invocation of such a symbol will then be a galley whose object is the result of the invocation, and whose cross reference is given by the into clause. The right parameter of the cross reference must be one of preceding, following, and foll_or_prec.

A symbol, like @FootPlace, which is the *target* of a galley, must contain the special symbol @Galley exactly once in its body; often this is all that the body contains:

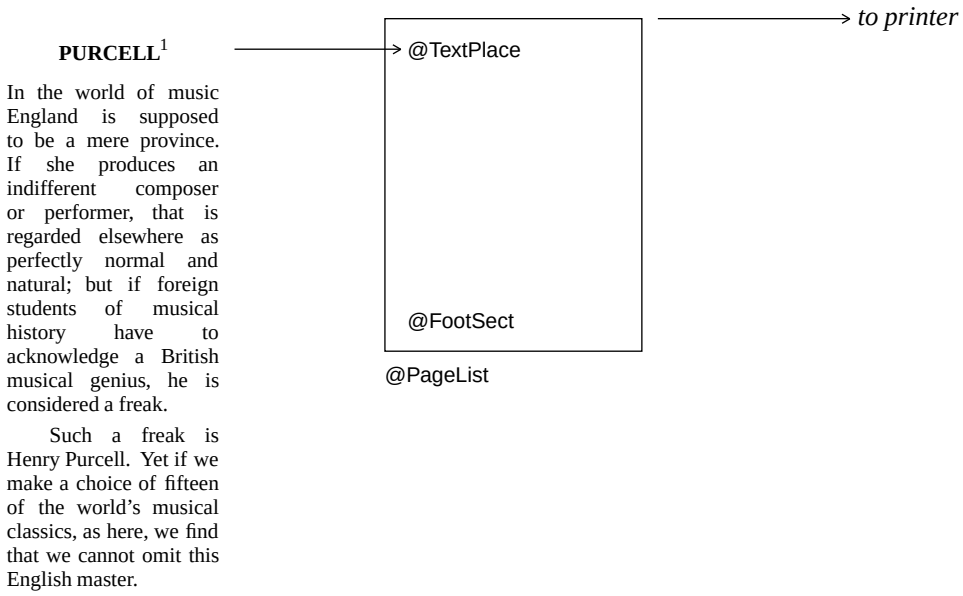
```
def @FootPlace { @Galley }
```

It is this special symbol that is replaced by the incoming galley, in fact, not the @FootPlace symbol as a whole.

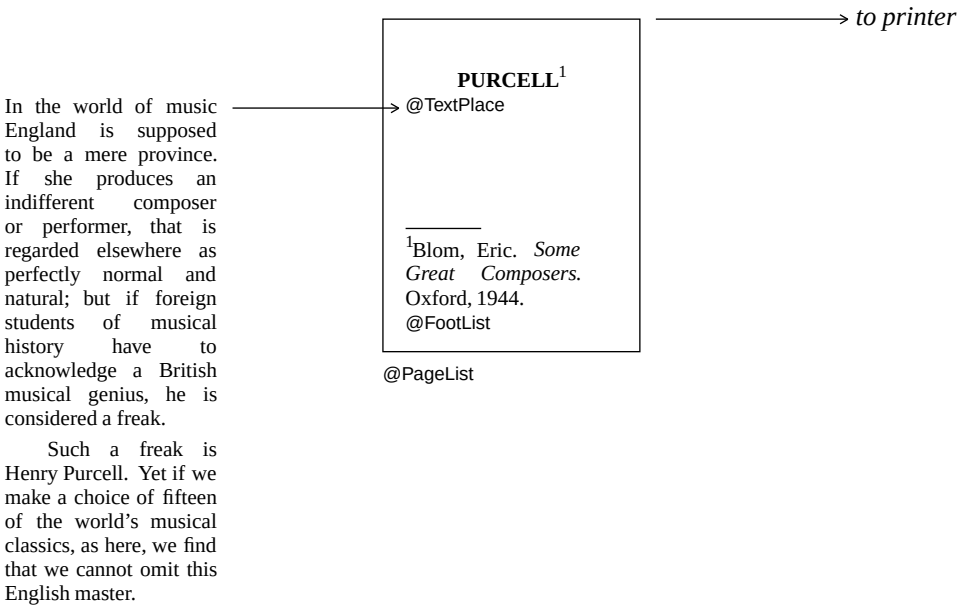
A symbol which contains @Galley, either directly within its body or indirectly within the body of a symbol it invokes, is called a *receptive* symbol, meaning receptive to galleys. @FootPlace is receptive, which makes @FootList, @FootSect and @PageList receptive since they invoke @FootPlace. If no galley replaces any @Galley within some invocation of a receptive symbol, that invocation is replaced by @Null. The advantages of this rule for page layout were explained at the end of Section 1.2.

Let us now follow through the construction of our example document. Initially there is just the one *root* galley, containing an unexpanded invocation of @PageList:

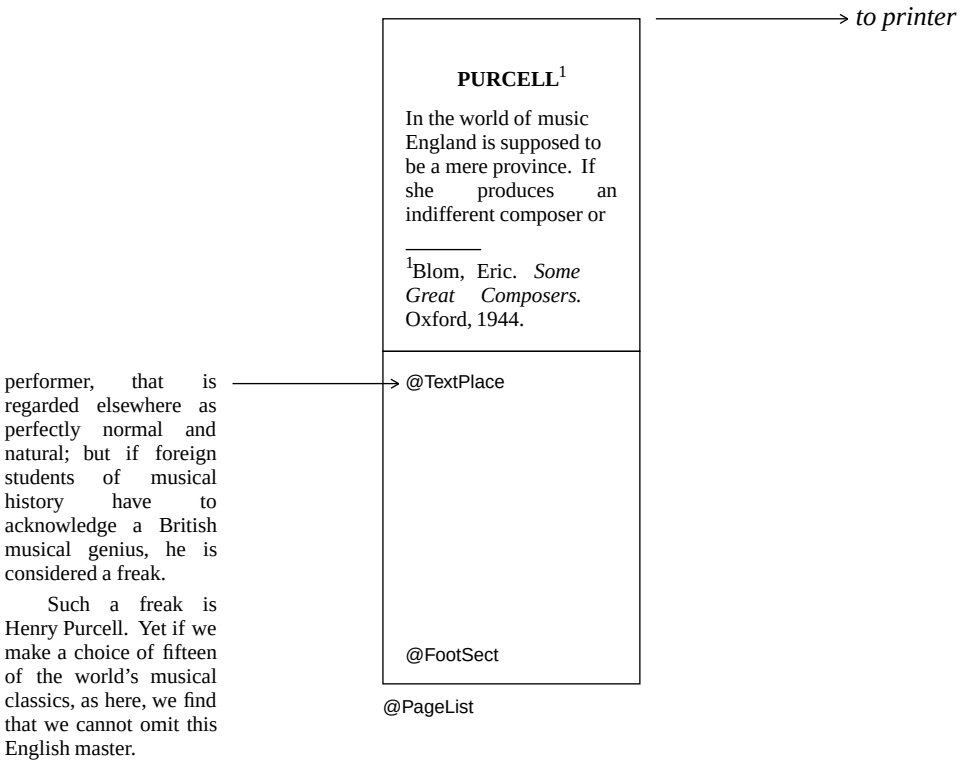
Then the PURCELL galley appears, targeted to a @TextPlace. Lout knows that there is a @TextPlace hidden inside @PageList, so it expands @PageList:



After promoting the first line into @TextPlace, the footnote galley attached to it appears and demands an invocation of @FootPlace following its attachment point ('PURCELL'). Such a @FootPlace is found at the bottom of the first page, inside @FootSect, which is accordingly expanded, and the footnote is promoted onto the page:



Now the promotion of the PURCELL galley resumes. When the first page is filled, Lout searches forwards for another @TextPlace to receive the remainder, once again expanding a @PageList:



and so on. All these expansions and replacements are done with total integrity. For example, if Lout finds after expanding @FootSect that the page is too full to accept even the first line of the footnote, @FootSect is reset to unexpanded and the search for a target for the footnote moves on. And the cross reference direction, preceding or following, is always obeyed (although lack of space sometimes prevents Lout from choosing the nearest target). Only the root galley contains receptive symbols in our running example, but any galley may contain them.

Chapter 2. Details

2.1. Lexical structure (words, spaces, symbols) and macros

The input to Lout consists of a sequence of *textual units*, which may be either *white spaces*, *identifiers*, *delimiters*, or *literal words*. Each is a sequence of *characters* chosen from:

letter	@ab-zAB-Z_
white space	*space formfeed tab newline*
quote	"
escape	\
comment	#
other	!$%&'()*+,-./0123456789:;<=>?[]^`{|}~

Notice that @ and _ are classed as letters. Basser Lout accepts the accented letters of the ISO-LATIN-1 character set (depending on how it is installed), and these are also classed as letters. The ten digits are classed as 'other' characters, and in fact the 'other' class contains all 8-bit characters (except octal 0) not assigned to previous classes.

A *white space* is a sequence of one or more white space characters. Lout treats the formfeed character exactly like the space character; it is useful for getting page breaks when printing Lout source code.

A *delimiter* is a sequence of one or more 'other' characters which is the name of a symbol. For example, { and // are delimiters. When defining a delimiter, the name must be enclosed in quotes:

```
def "^" { {} ^& {} }
```

but quotes are not used when the delimiter is invoked. A delimiter may have delimiters and any other characters adjacent, whereas identifiers may not be adjacent to letters or other identifiers. The complete list of predefined delimiters is

/	|	&	&&
//	||	^&	{
^/	^|		}
^//	^||		

A longer delimiter like <= will be recognised in preference to a shorter one like <.

An *identifier* is a sequence of one or more letters which is the name of a symbol. It is conventional but not essential to begin identifiers with @; Basser Lout will print a warning message if it finds an unquoted literal word (see below) beginning with @, since such words are usually misspelt identifiers. The ten digits are not letters and may not appear in identifiers; and although the underscore character is a letter and may be used in identifiers, it is not conventional

to do so. The complete list of predefined identifiers is

@BackEnd	@HSpan	@SetColour
@Background	@Include	@SetContext
@Begin	@IncludeGraphic	@SetHeaderComponent
@BeginHeaderComponent	@IncludeGraphicRepeated	@Space
@Break	@Insert	@StartHSpan
@Case	@KernShrink	@StartHVSpan
@ClearHeaderComponent	@Key	@StartVSpan
@Common	@Language	@SysDatabase
@Char	@LClos	@SysInclude
@CurrFace	@LEnv	@SysIncludeGraphic
@CurrFamily	@LInput	@SysIncludeGraphicRepeated
@CurrLang	@LUse	@SysPrependGraphic
@CurrYUnit	@LinkSource	@Tag
@CurrZUnit	@LinkDest	@Tagged
@Database	@Meld	@Target
@Enclose	@Merge	@Texture
@End	@Minus	@SetTexture
@EndHeaderComponent	@Moment	@Underline
@Filter	@Next	@SetUnderlineColor
@FilterErr	@NotRevealed	@SetUnderlineColour
@FilterIn	@Null	@Use
@FilterOut	@OneCol	@URLLink
@Font	@OneOf	@VAdjust
@FontDef	@OneRow	@VContract
@ForceGalley	@Open	@VCover
@Galley	@Optimize	@Verbatim
@GetContext	@Outline	@VExpand
@Graphic	@PAdjust	@VLimited
@HAdjust	@PageLabel	@VMirror
@HContract	@PlainGraphic	@VScale
@HCover	@Plus	@VShift
@HExpand	@PrependGraphic	@VSpan
@High	@RawVerbatim	@Wide
@HLimited	@Rotate	@Yield
@HMirror	@Rump	@YUnit
@HScale	@Scale	@ZUnit
@HShift	@SetColor	

plus the names of the parameters of @Moment. The symbols @LClos, @LEnv, @LInput, @LVis and @LUse appear in cross reference databases generated by Lout and are not for use elsewhere.

A sequence of characters which is neither a white space, an identifier, nor a delimiter, is by default a *literal word*, which means that it will pass through Lout unchanged. An arbitrary sequence of characters enclosed in double quotes, for example "{ }", is also a literal word. Space characters may be included, but not tabs or newlines. There are special character sequences, used

only between quotes, for obtaining otherwise inaccessible characters:

\"	produces "
\\	\
\ddd	the character whose ASCII code is the up to three digit octal number ddd

So, for example, "\"@PP\"" produces "@PP".

When the comment character # is encountered, everything from that point to the end of the line is ignored. This is useful for including reminders to oneself, like this:

```
# Lout user manual
# J. Kingston, June 1989
```

for temporarily deleting parts of the document, and so on.

Macros provide a means of defining symbols which stand for a sequence of textual units rather than an object. For example, the macro definition

```
macro  @PP  {  //1.3vx  2.0f @Wide  &0i }
```

makes Lout replace the symbol @PP by the given textual units before assembling its input into objects. A similar macro to this one is used to separate the paragraphs of the present document. The enclosing braces and any spaces adjacent to them are dropped, which can be a problem: @PP2i has result //1.3vx 2.0f @Wide &0i2i which is erroneous.

The meaning of symbols used within the body of a macro is determined by where the macro is defined, not by where it is used. Due to implementation problems, @Open symbols will not work within macros. Named and body parameters will work if the symbol that they are parameters of is also present. There is no way to get a left or right brace into the body of a macro without the matching brace.

Macros may be nested within other definitions and exported, but they may not be parameters. They may not have parameters or nested definitions of their own, and consequently a preceding export clause (Section 2.3) would be pointless; however, an import clause is permitted.

2.2. Named parameters

In addition to left and right (or body) parameters, a symbol may have any number of *named parameters*:

```
def @Chapter
   named @Tag {}
   named @Title {}
   right x
{
   ...
}
```

Their definitions appear in between those of any left and right parameters, and each is followed by a *default value* between braces. When @Chapter is invoked, its named parameters are given values in the following way:

```
@Chapter
   @Tag { intro }
   @Title { Introduction }
{
   ...
}
```

That is, a list of named parameters appears immediately following the symbol, each with its value enclosed in braces. Any right parameter follows after them. They do not have to appear in the order they were defined, and they can even be omitted altogether, in which case the default value from the definition is used instead.

If the keyword compulsory appears after named and before the parameter's name, Lout will print a warning message whenever this parameter is missing. However it will still use the default value as just described.

A named @Tag parameter does not take its default value from the definition; instead, if a default value is needed, Lout invents a simple word which differs from every other tag. This is important, for example, in the production of numbered chapters and sections (Section 4.4). The same thing occurs if there is a @Tag parameter but its value is the empty object: the value will be replaced by an invented one.

Named parameters may have parameters, as in the following definition:

```
def @Strange
   named @Format right @Val { [@Val] }
   right x
{
   @Format x
}
```

The named parameter @Format has right parameter @Val, and the default value of @Format is this parameter enclosed in brackets. When @Format is invoked it must be supplied with a right parameter, which will replace @Val. Thus,

```
@Strange 27
```

equals @Format 27 and so has result

```
[27]
```

The @Format symbol is like a definition with parameters whose body can be changed:

```
@Strange
   @Format { Slope @Font @Val. }
27
```

still equals @Format 27, but this time the result is

27.

In practice, examples of named parameters with parameters all have this flavour of format being separated from content; running headers (Section 4.3) and printing styles for bibliographies (Section 4.5) are two major ones.

2.3. Nested definitions, body parameters, extend, import, and export

A definition may contain other definitions at the beginning of its body:

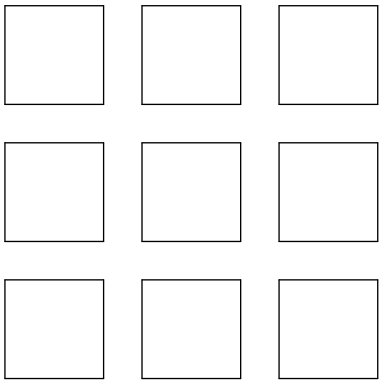
```
def @NineSquare
  right x
{
  def @Three { x |0.2i x |0.2i x }

  @Three /0.2i @Three /0.2i @Three
}
```

A parameter like x may be invoked anywhere within the body of the symbol it is a parameter of, including within nested definitions. A nested symbol like @Three may be invoked anywhere from the beginning of its own body to the end of the body of the symbol it is defined within. So, assuming an appropriate definition of @Box,

```
@NineSquare @Box
```

has result



Nested definitions may themselves contain nested definitions, to arbitrary depth.

There are three special features which permit a nested symbol or parameter to be invoked outside its normal range; that is, outside the body of the enclosing symbol. The first and simplest of these features is the *body parameter*, an alternative form of right parameter. The Eq equation formatting package [5, Chapter 7] is a classic example of the use of a body parameter. In outline, it looks like this:

```
export "+" sup over

def @Eq
   body x
{
   def "+" ...
   def sup ...
   def over ...
   ...

   Slope @Font x
}
```

First we list those nested symbols and parameters that we intend to refer to outside the body of @Eq in an export clause, preceding the definition as shown. Only exported symbols may be invoked outside the body of @Eq. The body parameter is like a right parameter except that the exported symbols are visible within it:

```
@Eq { {x sup 2 + y sup 2} over 2 }
```

calls on the nested definitions of @Eq to produce the result

$$\frac{x^2 + y^2}{2}$$

The body parameter's value must be enclosed in braces. The term 'body parameter' is a reminder that the value is interpreted as if it was within the body of the symbol.

A body parameter may not be exported, and in fact a body parameter may be invoked only within the body of the enclosing symbol, not within any nested definitions. For example, x above may not be invoked within sup. This restriction is needed to avoid the possibility of recursion, when the actual body parameter invokes an exported nested definition which invokes the body parameter, etc.

The second place where exported symbols may be used is in the right parameter of the @Open symbol, and following its alternative form, @Use (Section 3.40).

Exported nested symbols and parameters may be made visible within a subsequent definition or macro by preceding it with an import clause, like this:

```
import @Eq
def pythag { sqrt { x sup 2 + y sup 2 } }
```

Note however that pythag can only be used with some invocation of @Eq: within the body parameter of an invocation of @Eq, within the right parameter of an @Eq&&tag @Open, or following a @Use { @Eq ... }. There may be several symbols in the import clause.

In a similar way to import, a definition may be preceded by extend followed by a symbol name:

```
extend @Eq
def pythag { sqrt { x sup 2 + y sup 2 } }
```

The effect of this is just as though the definition of pythag had occurred directly after the existing definitions within @Eq, with pythag added to @Eq's export list. This is useful for extending the capabilities of a package of definitions like @Eq without modifying its source file. The essential differences to import are that all the symbols of @Eq become visible within pythag, not just the exported ones, and only one symbol may follow the extend keyword.

Actually, more than one symbol may follow extend, but this usage indicates a 'path name' of the symbol. For example,

```
extend @DocumentLayout @ReportLayout
def @Keywords ...
```

causes the definition of @Keywords to occur directly after the existing definitions of @Report-Layout, which itself lies within @DocumentLayout.

A named parameter may also be preceded by an import clause. As usual, the meaning is that the visible local definitions of the import symbol(s) are visible within the body (the default value) of the named parameter. But furthermore, those symbols will be visible within all invocations of the parameter. For example, suppose we define

```
def @Diag
   import @Algebra named linewidth { 1p }
   import @Algebra named dashlength { 2p }
   ...
```

Then, if @Algebra exports symbols +, -, and so on, we may write

```
@Diag
   linewidth { 1f - 2p }
   dashlength { 1f + 2p }
```

using the symbols from @Algebra. There may be several symbols after the import keyword. All these symbols share an important restriction: they may not have parameters. This is necessary because Lout would be unable to determine suitable values for any such parameters, if they did exist.

As an exception to the rule just given, a named parameter may import the symbol it is a parameter of:

```
export @Cell
def @Tbl
   import @Tbl named @Format { ... }
```

In this example the exported definitions of @Tbl (i.e. @Cell) will be visible within @Format. However, they may only be used in actual parameters, not in the default value of the named parameter. This is owing to implementation problems: at the time the default value of @Format is read, the exported symbols have not been read and are consequently not known.

Since @Cell is nested within @Tbl, the value of an invocation of @Cell may depend on the

value of parameters of @Tbl. If @Cell is used within an actual @Format parameter, its value depends on the value of parameters of the invocation of @Tbl of which the @Format parameter is a part.

A definition, macro, or named parameter may have several alternative names, like this:

```
macro @CD @CentredDisplay @CenteredDisplay { ... }
```

This is useful for abbreviated and alternative spellings, as shown. The names appear together, and they may subsequently be used interchangeably.

If one name of a symbol appears in an export or import list, its other names are automaticaly included as well, and should not also appear in the list.

2.4. Filtered right and body parameters

A right or body parameter may be filtered by some other computer program before being included by Lout. As an example of such a program we will use the Unix sort command:

```
sort  -o outfile  infile
```

This causes file outfile to contain a sorted copy of file infile. We incorporate this into a Lout definition as follows:

```
def @Sort
   named @Options {}
   right x
{
   def @Filter { sort @Options  -o @FilterOut  @FilterIn }

   lines @Break x
}
```

The presence within @Sort of a definition of a symbol called @Filter tells Lout that the right parameter of @Sort is to be filtered before inclusion. When @Sort is invoked, @Filter is evaluated and its value executed as a system command. In addition to the symbols ordinarily available within the body of @Filter, there are three others:

@FilterIn	the name of a file which will, at the time the system command is executed, contain the actual right or body parameter of the symbol, exactly as it appears in the input file;
@FilterOut	the name of a file of Lout text whose contents Lout will read after the system command has finished, as a replacement for what was put into file @FilterIn;
@FilterErr	the name of a file that Lout will attempt to read after the system command has finished, containing error messages produced by the command that Lout will pass on to the user as non-fatal errors. Use of this file is optional.

It is a fatal error for the system command to return a non-zero status.

Now the sort command has options -u for deleting duplicate lines, and -r for reversing the sorting order. So the result of

```
@Sort
   @Options { -r -u }
{
Austen, Jane
Dickens, Charles
Eliot, George
Hardy, Thomas
Bront{@Char edieresis}, Charlotte
}
```

is

Hardy, Thomas
Eliot, George
Dickens, Charles
Brontë, Charlotte
Austen, Jane

Unlike all the other examples in this manual, this output is simulated. This was done so that the ability to format this manual is not dependent on the existence of the Unix sort command, and it highlights the fact that filtered actual parameters are by their nature of uncertain portability.

There is no need for an actual filtered parameter to obey the lexical rules of Lout, since it is passed directly to the other program. However, Lout must be able to work out where the parameter ends, which gives rise to the following rules. As with a body parameter, a symbol @Sym with a filtered parameter must be invoked in either the form @Sym { ... } or the form @Sym @Begin ... @End @Sym, plus options as usual. In the former case, braces within the actual parameter must match; in the latter case, the actual parameter may not contain @End.

If an actual filtered parameter contains @Include, this is taken to begin a Lout @Include directive in the usual form (Section 3.48):

```
@Sort {
Austen, Jane
@Include { authors }
Hardy, Thomas
}
```

The included file becomes part of @FilterIn, but any braces, @Include, or @End within it are not noticed by Lout.

The first character of file @FilterIn will be the first non-white space character following the opening { or @Begin, or the first character of an included file if @Include comes first. The second-last character of file @FilterIn will be the last non-white space character preceding the closing } or @End @Sym, or the last character of an included file if @Include comes last. One newline character is always appended and is the last character of file @FilterIn. This effects

a compromise between the Lout convention, that spaces following { or preceding } are not significant, with the Unix convention that all text files end with a newline character.

2.5. Precedence and associativity of symbols

Every symbol in Lout has a *precedence*, which is a positive whole number. When two symbols compete for an object, the one with the higher precedence wins it. For example,

```
a | b / c
```

is equivalent to { a | b } / c rather than a | { b / c }, because | has higher precedence than / and thus wins the b.

When the two competing symbols have equal precedence, Lout applies a second rule. Each symbol is either *left-associative* or *right-associative.* The value of a op1 b op2 c is taken to be { a op1 b } op2 c if the symbols are both left-associative, and a op1 { b op2 c } if they are right-associative. In cases not covered by these two rules, use braces.

It sometimes happens that the result is the same regardless of how the expression is grouped. For example, { a | b } | c and a | { b | c } are always the same, for any combination of objects, gaps, and variants of |. In such cases the symbols are said to be *associative*, and we can confidently omit the braces.

User-defined symbols may be given a precedence and associativity:

```
def @Super
  precedence 50
  associativity right
  left x
  right y
{
  @OneRow { | -2p @Font y ^/0.5fk x }
}
```

They come just after any into clause and before any parameter definitions. The precedence may be any whole number between 10 and 100, and if omitted is assigned the value 100. The higher the number, the higher the precedence. The associativity may be left or right, and if omitted defaults to right.

In the example above, the precedence and associativity are both literal words (50 and right). It is also possible to define a macro whose value is a suitable literal word, and invoke that macro as the value of a precedence or associativity. But arbitrary expressions, including invocations of symbols other than macros, are not permitted.

Lout's symbols have the following precedences and associativities:

Precedence	Associativity	Symbols
5	associative	/ ^/ // ^//
6	associative	| ^| || ^||
7	associative	& ^&
7	associative	& in the form of one or more white space characters
10-100	left or right	user-defined symbols
100	right	@Wide, @High, @Graphic, etc.
101	-	&&
102	associative	& in the form of 0 spaces
103	-	Body parameters and right parameters of @Open

Actually the precedence of juxtaposition (two objects separated by zero spaces) is a little more complicated. If either of the two objects is enclosed in braces, the precedence is 7 as for one or more spaces. If neither object is enclosed in braces, the precedence is 102 as shown above. This complicated rule seems to accord better with what people expect and need in practice than a pure precedence rule can do.

2.6. The style and size of objects

This section explains how Lout determines the style and size of each object. Together, these attributes determine the object's final appearance in the output.

The style of an object comprises the following:

- Which font family, face and size to use (also defining the f unit);
- Whether small capitals are in effect or not, and also what fraction of the height of full capitals the small capitals are to have;
- What gap to replace a single space between two objects by (also defining the s unit);
- The interpretation to place on white space separating two objects (lout, compress, separate, troff, or tex as in Section 3.5);
- The current value of the y and z units of measurement (Section 3.6);
- The kind of paragraph breaking to employ (adjust, ragged, etc.)
- What gap to insert between the lines of paragraphs (also defining the v unit);
- The size of the outdent to use in the outdent paragraph breaking style;
- Whether the unbreakablefirst and unbreakablelast paragraph breaking options are in effect;
- Whether the row marks of words are to pass along the baseline or half the height of an 'x' above the baseline;

- Whether to permit hyphenation or not;
- What colour the object is to appear in;
- What colour underlines within the object are to appear in;
- Whether @Outline is in effect;
- The language of the object;
- Whether @VAdjust, @HAdjust and @PAdjust are in effect.

The style of an object depends on where it appears in the final document. For example, the style of a parameter depends on where it is used; the style of a galley is the style of the first target that it attempts to attach itself to. Of course, the style of any object can be changed by using the @Font, @Break, @Space, @SetColour or @SetColor, @SetUnderlineColour or @SetUnderlineColor, @Outline, and @Language symbols.

There are no standard default values for style, except that row marks of words initially pass half the height of an 'x' above the baseline, small capitals are initially off and will be 0.7 times the size of full capitals, outlining is initially off, the interpretation of white space is initially lout, and the values of the y and z units are zero. Therefore one must ensure that the root galley or each of its components is enclosed in @Font, @Break, @SetColour or @SetColor, and @Language symbols. From there the style is passed to incoming galleys and the objects within them. Enclosure in @Space is not required because the s unit is also set by @Font (Section 3.5).

The remainder of this section explains how the size of each object (its width and height on the printed page) is determined. We will treat width only, since height is determined in exactly the same way, except that the complications introduced by paragraph breaking are absent.

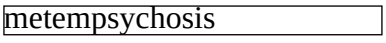
With three exceptions (see below), the width of an object is as large as it possibly could be without violating a @Wide symbol or intruding into the space occupied by neighbouring gaps or objects. As an aid to investigating this rule, we will use the definition

```
def @TightBox right x
{
  "0 0 moveto xsize 0 lineto xsize ysize lineto 0 ysize lineto closepath stroke"
  @Graphic x
}
```

which draws a box around the boundary of its right parameter (Section 3.43) with no margin. The result of

```
5c @Wide @TightBox metempsychosis
```

is



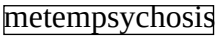
The widest that @TightBox metempsychosis could possibly be is five centimetres, and accordingly that is its width. The same applies to metempsychosis, which is five centimetres wide as well. Note carefully that there is no object in this example whose width is equal to the sum of

the widths of the letters of metempsychosis.

The first of the three exceptions to the ‘as wide as possible’ rule is the @HContract symbol, which causes the width of its right parameter to be reduced to a reasonable minimum (a formal definition will not be attempted):

```
5c @Wide @HContract @TightBox metempsychosis
```

produces



The object @HContract @TightBox metempsychosis is still five centimetres wide, but the object @TightBox metempsychosis has been reduced.

The second of the three exceptions is the horizontal concatenation symbol | (and also &). Consider this example:

```
5c @Wide @TightBox { A  |1c  B  |1c  C }
```

As usual, the right parameter of @Wide is five centimetres wide, and the result looks like this:

Lout has to apportion the size minus inter-column gaps among the three columns.

If the columns are wide enough to require paragraph breaking, Lout will assign sizes to the columns in such a way as to leave narrow columns unbroken and break wider columns to equal width, occupying the full size. Otherwise, paragraph breaking is not required, and each column will be assigned a reasonable minimum size in the manner of @HContract, except that the last column receives all the leftover width. For example,

```
5c @Wide { @TightBox A  |1c  @TightBox B  |1c  @TightBox C }
```

has result

If it is desired that the leftover width remain unused, rather than going into the last column, an empty column can be appended, or the last column can be enclosed in @HContract. Two other ways to apportion the leftover width are provided by the @HExpand and @HAdjust symbols (Sections 3.16 and 3.19).

The third and final exception to the ‘as wide as possible’ rule concerns the components of the root galley. Each is considered to be enclosed in @HContract and @VContract symbols.

Up to this point we have treated width as a single quantity, but of course it has two parts: width to left and right of the mark. The ‘as wide as possible’ rule applies to both directions:

```
@HContract { @TightBox 953^.05 /0.5c @TightBox 2^.8286 }
```

has result

953.05

2.8286

Leftover width usually goes to the right, as we have seen, but here some width was available only to the left of 2.8286 owing to the column mark alignment.

2.7. Galleys and targets

The behaviour of galleys and their targets, as described in Section 1.4, can be summarized in three laws:

First Law: The first target is the closest invocation of the target symbol, either preceding or following the invocation point of the galley as required, which has sufficient space to receive the first component;

Second Law: Each subsequent target is the closest invocation of the target symbol, following the previous target and lying within the same galley, which has sufficient space to receive the first remaining component;

Third Law: A receptive symbol that does not receive at least one component of any galley is replaced by @Null.

The terms ‘closest,’ ‘preceding,’ and ‘following’ refer to position in the final printed document. This section explains the operation of these laws in Basser Lout.

When a galley cannot be fitted into just one target, Lout must find points in the galley where it can be split in two. The object lying between two neighbouring potential split points is called a *component* of the galley. By definition, a component cannot be split.

To determine the components of a galley, expand all symbols other than recursive and receptive ones, discard all @Font, @Break, @Space, @SetColor, @SetColour, and @Language symbols, perform paragraph breaking as required, and discard all redundant braces. Then view the galley as a sequence of one or more objects separated by vertical concatenation symbols; these are the components and split points, except that concatenation symbols whose gaps are unbreakable (Section 3.2) are not eligible to be split points. For example, given the definition

```
def @Section into { @SectionPlace&&preceding }
   named @Title {}
   right @Body
{
   15p @Font { @Title //0.7f }
   //
   @Body
}
```

the galley

```
@Section
   @Title { Introduction }
{ This is a subject that really
needs no introduction. }
```

becomes

```
Introduction
//0.7f
{}
//
This is a subject that really needs
//1vx
no introduction.
```

with four components. If @Body had been preceded by |1.0c in the definition, the result would have been

```
Introduction
//0.7f
{}
//
|1.0c { This is a subject that really needs //1vx no introduction. }
```

with //1vx buried within one component and hence not a potential split point. If 0.7f had been 0.7fu, the gap would have been unbreakable and //0.7fu would not have been a potential split point.

Version 3.03 has liberalized this somewhat in the following way. When a component consists of a horizontal sequence of two or more objects $A_1, \ldots, A_n$ separated by | (not ||, not &), Lout will investigate the component to see whether it can be broken up. It looks at each A_i to see whether it is a vertical concatenation of objects $A_{i1}, \ldots, A_{im}$; if two or more of the A_i satisfy this condition, the component will not be broken up. So now suppose we have just one A_i which is a vertical concatenation. Lout will break the component into one component for each of the $A_{i1}, \ldots, A_{im}$, provided that they are separated by // symbols (not /), and provided this can be done without introducing any apparent change into the appearance of the component (this second rule will be satisfied if the other A_j are not very large). The example above satisfies all these rules and will be broken up into two components, so the //1vx becomes a potential split point after all.

The lines of a paragraph become separate components if the paragraph occupies an entire component before breaking; otherwise they are enclosed in a @OneRow symbol within one component. The same is true of incoming components of other galleys. If a @Galley symbol occupies an entire component by the rules above, then the incoming components that replace it become components of their new home:

```
An example                An example
//0.5c              ⇒      //0.5c
@Galley                   Incoming components
//0.5c                    //0.2c
@SomethingList            from some other galley
                          //0.5c
                          @SomethingList
```

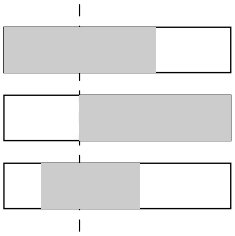
Otherwise the incoming components are grouped within a @OneRow symbol and lie within one component.

This distinction has a marked effect on the vertical concatenation symbol //1.1b, which calls for more space than is available (Section 3.2). There is no room for this symbol within any component, so it will force a split and be discarded in that case. But it can be promoted to between two components.

Components may be separated by / as well as by //, giving rise to column mark alignment between adjacent components:

When aligned components are promoted into different targets, the meaning of alignment becomes very doubtful. For example, what if the targets are in different columns of one page, or what if one lies within 90d @Rotate?

The truth is that / causes all the objects that share a mark to have equal width:



This is a consequence of the 'as wide as possible' rule (Section 2.6). Mark alignment occurs *incidentally*, whenever the fragments are placed into similar contexts.

In this connection we must also consider the special case of a @Galley symbol which shares its column mark with some other object:

```
@Galley
/0.2c
@SomethingList
```

(The @Galley may or may not occupy an entire component; that doesn't matter here.) If incoming components are separated by // rather than by /, the meaning is so doubtful that this is forbidden. In fact, a galley whose components replace such a @Galley must have a single column mark

running its full length; that is, its components must all share a single column mark. This mark will be merged with the column mark passing through each @Galley that these components replace; all the objects on the resulting merged mark will have equal width.

The root galley, where everything collects immediately prior to output, is created automatically, not by a definition. Its target is the output file, and its object is the entire input, which typically looks like this:

```
@PageList
//
@Text {
  Body text of the document ...
}
```

where @PageList expands to a sequence of pages containing @TextPlace symbols (see Section 1.2), and @Text is a galley:

```
def @TextPlace { @Galley }

def @Text into { @TextPlace&&preceding }
   right x
{
   x
}
```

The spot vacated by a galley – its invocation point – becomes a @Null object, so this root galley is effectively @PageList alone, as required. The @Text galley will find its first target preceding its invocation point, within @PageList.

Printing the root galley on the output file is somewhat problematical, because Lout has no way of knowing how large the paper is. Basser Lout simply prints one root galley component per page (except it skips components of height zero), and the user is responsible for ensuring that each component is page-sized. Gaps between root galley components, even unbreakable ones, have no effect on the result.

Basser Lout will promote a component only after any receptive symbols within it have been replaced, either by galleys or by @Null, since until then the component is not complete. A component which shares a mark with following components is held up until they are all complete, since until then their width is uncertain.

Consider a page with @TextPlace and @FootSect receptive symbols. The rule just given will prevent the page from being printed until @TextPlace is replaced by body text, quite rightly; but @FootSect will also prevent its printing, even when there are no footnotes.

Basser Lout is keen to write out pages as soon as possible, to save memory, and it cannot afford to wait forever for non-existent footnotes. A variant of the galley concept, called a *forcing galley*, is introduced to solve this problem. A forcing galley is defined like this:

```
def @Text force into { @TextPlace&&preceding }
  ...
```

and so on. When such a galley replaces a @Galley symbol, Lout replaces every receptive symbol preceding the @Galley by @Null, thus ensuring that as soon as text enters a page, for example, everything up to and including the preceding page can be printed. This does not take care of the very last page, but Basser Lout replaces all receptive symbols by @Null when it realizes that its input has all been read, thus allowing the last page to print.

A forcing galley causes the Third Law to be applied earlier than expected, and this creates two problems. First, the replacement by @Null may be premature: a galley may turn up later wanting one of the defunct targets. Such galleys (entries in tables of contents are typical examples) are copied into the cross reference database and read in during the next run just before their targets are closed, and so they find their targets in the end. Care must be taken to ensure that large galleys such as chapters and sections do not have defunct targets, since the cost of copying them to and from the database is unacceptably high.

It is actually an over-simplification to say that these replacements occur when the forcing galley replaces its @Galley. What really happens is that from this moment on Lout understands that it has the right to make these replacements, and it will do each one at the first moment when not doing it would hold things up. So there is a short period of grace when galleys, such as the entries in tables of contents just alluded to, can sneak into these receptive symbols.

The into and force into forms are actually just abbreviations for the true way that galleys are defined, which is by giving the symbol that is to be a galley a parameter or nested definition with the special name @Target:

```
def @Text
   right x
{
   def @Target { @TextPlace&&preceding }

   x
}
```

A forcing galley is obtained by using &&& instead of &&. @Target may be an arbitrary object, provided that it yields such a cross reference when evaluated. In this way, different invocations may have different targets.

The forcing galley effect can be obtained in another way, by replacing the @Galley symbol to which the galley is attached by @ForceGalley. The advantage of this form is that the galley can then be forcing at some places and not at others, using the formula

```
def @SomePlace right x
{
   x @Case {
      noforce  @Yield @Galley
      force    @Yield @ForceGalley
   }
}
```

Now a galley may have @SomePlace for its target, and if it happens to attach to

```
@SomePlace force
```

it will have the effect of a forcing galley, while if it happens to attach to

```
@SomePlace noforce
```

it will not.

Although it doesn't matter whether a galley is declared as a forcing galley or merely arrives at a @ForceGalley symbol from the point of view of the effect on nearby targets, there is one way in which Lout treats the two cases differently. If a forcing galley's first component does not fit into the available space, that component will be scaled vertically until it does. The rationale for this is that forcing galleys are meant to carry the bulk of the document and cannot afford to be held up because the user has inadvertently included an over-high component, which for all Lout knows to the contrary may not fit on any page. If this scaling is not wanted but forcing is, the galley may be declared not forcing but all its targets may be set to contain @ForceGalley.

Within a galley, a symbol whose name is @Enclose has a special meaning: when components of the galley replace a @Galley or @ForceGalley symbol, that symbol is first replaced by @Enclose @Galley or @Enclose @ForceGalley. For example,

```
def @Figure into @FigurePlace&&following
   right @Body
{
   def @Enclose
      right x
   {
      @Box x
   }

   @Body
}
```

causes each @Galley or @ForceGalley symbol that receives components of galley @Figure to be replaced by @Box @Galley or @Box @ForceGalley, assuming an appropriate definition of @Box. This is useful, for example, when producing multi-page boxed displays, figures, and tables.

An @Enclose symbol may have only one parameter, which must be a right parameter. It would not make sense to allow more parameters, since there is no suitable value to assign to them. However, the @Enclose symbol may contain inner definitions, and it may make use of any symbol that is available at that point, in the usual way. The @Enclose symbol may be a named parameter (itself with a right parameter) of the galley symbol, rather than an inner definition as shown above, if desired.

It makes sense for sorted galleys containing a @Merge symbol (Section 2.8) to also have an @Enclose symbol. The meaning is that after all merging is done, each resulting galley has an @Enclose symbol which is applied in the usual way. The value of this @Enclose symbol will be the value of an @Enclose symbol from one of the contributing galleys, but exactly which one is not defined. So it is safest if all such @Enclose symbols produce the same result.

A following galley may fail to find a first target lying in a following component of the same galley as its invocation point. This is a deficiency of Basser Lout, which occurs if the target has not been read from input at the time the galley tries to find it. A workaround is to use a preceding galley instead, defined like this:

```
def @AGalley into { @AGalleyPlace&&preceding }
   right @Body
{
   //1.1b
   @Body
}
```

and invoked like this:

```
@AGalleyPlace | @AGalley { content of galley }
//
...
@AGalleyPlace
```

The first @AGalleyPlace receives only the initial empty object, since the //1.1b forces a split; and the Second Law puts Basser Lout on the right track thereafter.

2.8. Sorted galleys

When footnotes are placed at the bottom of a page, they appear there in first come, first served order. To make galleys appear in sorted order, as is needed in bibliographies and indexes, a parameter or nested definition with the special name @Key is added to the galley definition, like this:

```
def @IndexEntry into { @IndexPlace&&following }
  left @Key
  right x
{ x }
```

@Key must be set to a simple word, or several words with nothing more complex than font changes within them, when the galley is invoked:

```
{ cities compare } @IndexEntry { cities, comparison of, 27 }
```

and this key is used to sort the galleys.

If several sorted galleys with the same key are sent to the same place, the default behaviour is to print only the first of them; the assumption is that the others are probably unwanted duplicates. This holds good for sorted reference lists, for example: we don't want two copies of a reference just because we happen to cite it twice.

The other common example of sorted galleys, index entries, requires something different from discarding duplicates: *merged* galleys. Suppose that at some point of the document we insert the index entry

```
aardvarks @IndexEntry { Aardvarks, 23 }
```

while at another point we insert

```
aardvarks @IndexEntry { Aardvarks, 359 }
```

How the page numbers are worked out is not relevant here. Clearly we would like to merge these two entries into one entry that comes out as

```
Aardvarks, 23, 359
```

The following definition will merge two objects x and y in this way:

```
def @Merge left x right y
{
   { x @Rump { x @Meld y } } @Case
   {
      "" @Yield x
      else @Yield { { x{@OneCol ,} } @Meld y }
   }

}
```

The @Rump and @Meld symbols are the subject of Section 3.28; and a detailed explanation of how this definition works is the subject of Section 4.6. Our only problem is that this symbol has to be applied to two galleys from widely separated parts of the document.

Lout makes this possible by the following special rule: if a sorted galley contains a nested definition of a symbol whose name is @Merge (@Merge must have just two parameters, left and right), and if that sorted galley is preceded in the list of sorted galleys destined for some target by another sorted galley with the same key, then rather than being discarded, the second galley is merged into the first using the @Merge symbol.

The natural thing to do when more than two galleys have the same key is to merge the first two, then merge the third with the result of that, then the fourth with the result of that, and so on. For efficiency reasons beyond our scope here, Lout does the merging in a different order: it merges n galleys by merging the first $\lfloor n/2 \rfloor$ together, then the last $\lceil n/2 \rceil$ together, then merging the result. Of course, if the @Merge symbol is associative this has the same effect. The total time it takes to merge n galleys with equal keys is $O(n^2)$ or somewhat higher (but always polynomial in n) depending on how many times the parameters occur within the body of @Merge; to do it in the natural linear order would take Lout exponential time.

For horrible reasons concerning making it possible to print reference lists sorted by point of first citation, the particular sort key ?? is treated differently. If two galleys have this key, according to the rules above either the second would be discarded or else it would be merged with the first. However, for this particular key only, the two galleys will in fact be kept distinct, just as though their sort keys had been different.

2.9. Horizontal galleys

All the galleys so far have been *vertical galleys*: galleys whose components are separated by vertical concatenation symbols. There are also horizontal galleys, whose components are separated by the horizontal concatenation operator & (or equivalently, by spaces). These work in the same way as vertical galleys, except for the change of direction. For example, the following defines the equivalent of an ordinary outdented paragraph, except that an option is provided for varying the size of the outdent:

```
def @OutdentPar
   named outdent { 2f }
   right x
{
   def @ParPlace { @Galley }

   def @LineList
   {
      outdent @Wide {} | @PAdjust @ParPlace
      //1vx @LineList
   }

   def @ParGalley force horizontally into { @ParPlace&&preceding }
      right x
   {
      x
   }

      @PAdjust @ParPlace
   //  @ParGalley { x &1rt }
   //1vx  @LineList
}
```

Notice the use of `&1rt` to cancel the effect of `@PAdjust` on the last line of the paragraph. This definition has a problem in that there will be a concluding unexpanded `@LineList` symbol which will hold up promotion of the enclosing galley; this problem may be fixed by the same method used to end a list.

In an ideal world, there would be nothing further to say about horizontal galleys. However there are a few differences which arise from various practical considerations and limitations. Perhaps some day a more perfect symmetry will be implemented.

Each vertical galley has a fixed finite width, and every component is broken to that width. This is needed basically to trigger paragraph breaking. However, there is no equivalent of paragraph breaking in the vertical direction, so horizontal galleys do not have any particular fixed height. Instead, each component has its own individual height.

When two objects are separated by /, they are assigned the same width (Section 2.7), and this holds true even if the two objects are subsequently separated by being promoted into different targets. For example, two aligned equations will have the same width, and hence their alignment

will be preserved, even if they appear in different columns or pages. However, even though & aligns the marks of its two parameters, it does not assign them a common height. This means that the height of any component of a horizontal galley promoted into one target does not affect the height consumed by the components promoted into any other target. The other horizontal concatenation operator, |, does assign a common height to its two parameters; but sequences of objects separated by this operator cannot be the components of a horizontal galley.

Lout is able to read vertical galleys one paragraph at a time; in this way it processes the document in small chunks, never holding more than a few pages in memory at any time. However, horizontal galleys are always read in completely, so they should not be extremely long.

In principle Lout should be able to hyphenate the components of horizontal galleys when they are simple words, but this is not implemented at present.

In an ideal world, every paragraph would be treated as a horizontal galley. However, to do so in practice would be too slow and would lead to excessive clumsiness in notation, so at present Lout has two competing mechanisms in this area: the built-in paragraph breaker with its limited set of options as given under the @Break operator, and horizontal galleys. As the example above shows, horizontal galleys are in principle capable of implementing many more paragraph styles than the built-in paragraph breaker could ever hope to do. The recommended practical strategy is to use the built-in paragraph breaker most of the time, and switch to horizontal galleys only for occasional tricks, such as paragraphs with drop capitals, circular outlines, etc.

2.10. Optimal galley breaking

As explained in Section 2.7, the components of a galley are promoted one by one into a target. When space runs out there, the galley searches for a new target and promotion resumes.

This process is exactly analogous to placing words onto a line until space runs out, then moving to another line. But, as we know, that simple method is inferior to the optimal paragraph breaking used by Lout (copied from the TEX system), which examines the entire paragraph and determines the most even assignment of words to lines.

Lout offers *optimal galley breaking*, the equivalent for galleys of optimal paragraph breaking. Optimal galley breaking can reduce the size of ugly blank spaces at the bottom of pages preceding large unbreakable displays, sometimes quite dramatically.

Optimal galley breaking is applied to each galley, horizontal or vertical, that possesses a parameter or nested symbol called @Optimize whose value is Yes. Like cross referencing, it takes two runs to have effect. On the first run, Lout records the sizes of the galley's components and gaps, and also the space available at each of its targets. At end of run this information is used to find an optimal break, which is written to the cross-reference database. On the second run, the optimal break is retrieved and used.

Considering that this process must cope with floating figures, new page and conditional new page symbols, breaks for new chapters, and evolving documents, it is surprisingly robust. If it does go badly wrong, removing file lout.li then running Lout twice without changing the document may solve the problem. However, cases are known where the optimization never converges. These are usually related to figures and footnotes whose anchor points fall near page boundaries.

Chapter 3. Predefined symbols

3.1. @Begin and @End

The body of a symbol @Sym may be enclosed in @Begin and @End @Sym instead of the more usual braces:

```
def @Section
   named @Title {}
   right @Body
@Begin
   @Title //2v @Body
@End @Section
```

They may also enclose the right or body parameter of a symbol invocation:

```
@Chapter
   @Title { Introduction }
@Begin
This subject needs no introduction.
@End @Chapter
```

Apart from their utility as documentation aids, these forms allow Basser Lout to pinpoint mismatched braces, which can otherwise create total havoc. For this reason, they should enclose the major parts of documents, such as chapters and sections. Note that braces cannot be replaced by @Begin and @End in general.

3.2. Concatenation symbols and paragraphs

There are ten concatenation symbols, in three families:

/	^/	//	^//	Vertical concatenation
|	^|	||	^||	Horizontal concatenation
&	^&			In-paragraph concatenation

Each symbol produces an object which combines together the two parameters. The right parameter must be separated from the symbol by at least one white space character.

The vertical concatenation symbol / places its left parameter above its right parameter with their column marks aligned. If one parameter has more column marks than the other, empty columns are inserted at the right to equalize the numbers. The variant // ignores column marks and left-justifies the objects.

The horizontal concatenation symbols | and || are horizontal analogues of / and //: they place

their two parameters side by side, with row mark alignment or top-justification respectively. The in-paragraph concatenation symbol & produces horizontal concatenation within a paragraph; its special properties are treated in detail at the end of this section.

The concatenation symbols in any one family are *mutually associative*, which means that

{ *x* |*p* *y* } |*q* *z*

is always the same as

x |*p* { *y* |*q* *z* }

for any objects *x*, *y*, and *z*, any gaps *p* and *q* (defined below), and any choice of |, ^|, ||, and ^||. In practice we always omit such braces, since they are redundant and can be misleading. The result of the complete sequence of concatenations will be called the *whole concatenation object*, and the objects which make it up will be called the *components*.

One mark is designated as the *principal mark*, usually the mark of the first component. A later mark can be chosen for this honour by attaching ^ to the preceding concatenation symbol. See Section 3.13 for examples.

A *gap*, specifying the distance between the two parameters, may follow any concatenation symbol. There may be no spaces between a concatenation symbol and its gap. A missing gap is taken to be 0ie. The gap is effectively a third parameter of the concatenation symbol, and it may be an arbitrary object provided that it evaluates to a juxtaposition of simple words. In general, the gap must be enclosed in braces, like this:

```
//{ @Style&&mystyle @Open { @TopMargin } }
```

but the braces may be omitted when the object is a juxtaposition of simple words or an invocation of a symbol without parameters, as in //0.3vx and ||@Indent.

A gap consists of a length plus a gap mode plus an optional indication of unbreakability. A *length* is represented by an decimal number (which may not be negative) followed by a unit of measurement. For example, 2.5c represents the length 2.5 centimetres. Figure 3.1 gives the full selection of units of measurement.

After the length comes an optional *gap mode*, which is a single letter following the length, indicating how the length is to be measured. As shown in Figure 3.2, with edge-to-edge gap mode the length *l* is measured from the trailing edge of the first object to the leading edge of the second. Edge-to-edge is the default mode: the e may be omitted. Hyphenation gap mode is similar, except as explained at the end of this section.

Mark-to-mark, overstrike, and kerning measure the length from the last mark of the first object to the first mark of the second. In the case of mark-to-mark, if the length is too small to prevent the objects almost overlapping, it is widened until they no longer do. (The extra *l/10* is not applied when plain text output is in effect.) Kerning also widens, with the aim of preventing the mark of either object from overlapping the other object; this mode is used for subscripts and superscripts.

Tabulation ignores the first object and places the leading edge of the second object at a distance *l* from the left edge of the whole concatenation object. It is the main user of the b and r units of measurement; for example, |1rt will right-justify the following component, and |0.5rt

c	Centimetres.
i	Inches.
p	Points (72p = 1i).
m	Ems (12m = 1i).
f	One f equals the size of the current font, as specified by the @Font symbol (Section 3.3). This unit is appropriate for lengths that should change with the font size.
s	One s equals the preferred gap between two words in the current font, as specified in the definition of the font, or by the @Space symbol (Section 3.4).
v	One v equals the current gap between lines introduced during paragraph breaking, as specified by the @Break symbol (Section 3.4). This unit is appropriate for lengths, such as the spaces between paragraphs, which should change with the inter-line gap.
w	One w equals the width of the following component, or its height if the symbol is vertical concatenation.
b	One b equals the width of the whole concatenation object, or its height if the symbol is vertical concatenation.
r	One r equals one b minus one w. This unit is used for centring, and for left and right justification.
d	Degrees. This unit may only be used with the @Rotate symbol.
y	One y equals the current value set by the @YUnit symbol (Section 3.6). This unit is not used internally by Lout; it is included for the convenience of application packages.
z	One z equals the current value set by the @ZUnit symbol (Section 3.6). This unit is not used internally by Lout; it is included for the convenience of application packages.

Figure 3.1. The thirteen units of measurement provided by Lout.

will centre it.

The value |0rt separating the first and second items in a sequence of horizontally concatenated objects is somewhat special in that it denotes left justification of the object to its left in the available space. This is identical with |0ie when the object to the left also has the principal mark; but when it does not, |0rt will cause the object to the left to appear further to the left than it would otherwise have done, if space to do so is available.

A gap is optionally concluded with an indication of unbreakability, which is a letter u appended to the gap. A paragraph will never be broken at an unbreakable gap, nor will a galley be broken across two targets at such a gap. Basser Lout's implementation is slightly defective in that it ignores any unbreakable indication in the gap separating the first component promoted into any target from the second.

When two objects are separated only by zero or more white space characters (spaces, tabs, newlines, and formfeeds), Lout inserts &*k*s between the two objects, where *k* is the number of spaces. Precisely, *k* is determined by discarding all space characters and tabs that precede newlines (these are invisible so are better ignored), then counting 1 for each newline, formfeed or space, and 8 for each tab character. The gap will be unbreakable if *k* is zero.

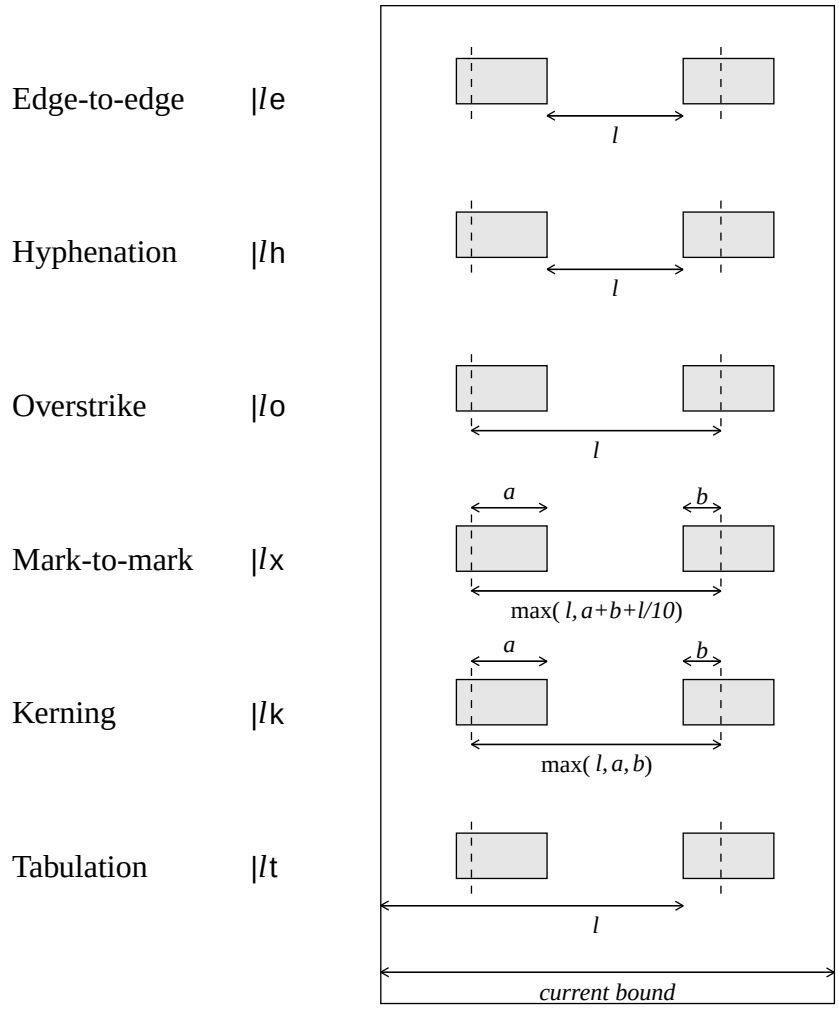


Figure 3.2. The six gap modes provided by Lout.

A sequence of two or more objects separated by & symbols is a *paragraph.* Lout breaks paragraphs into lines automatically as required, by converting some of the & symbols into //1vx. Unbreakable gaps are not eligible for this conversion. 'Optimal' line breaks are chosen, using a method adapted from TEX [6].

If an & symbol whose gap has hyphenation mode is chosen for replacement by //1vx, a hyphen will be appended to the preceding object, unless that object is a word which already ends with a hyphen or slash. For example,

```
Long words may be hyph &0ih enat &0ih ed.
```

could have the following result, depending where the line breaks fall:

Long words may be hyphenat-
ed.

Basser Lout inserts hyphenation gaps automatically as required, again following the method of TEX, which approximates the hyphenations in Webster's dictionary. However it does not insert hyphenation gaps in words on either side of a concatenation symbol which already has

hyphenation mode. To prevent the hyphenation of a single word, enclose it in quotes. Further control over paragraph breaking and hyphenation is provided by the @Break and @Space symbols (Sections 3.4 and 3.5).

3.3. @Font, @Char, and @FontDef

A *font* is a collection of characters which may be printed. Many fonts come in *families*, which are groups of fonts that have been designed to go together. For example, the Times family includes the following fonts:

Times Base
Times Slope
Times Bold
Times BoldSlope

Thus, each font has two names: its *family name* (Times, Helvetica, etc.) and its *face name* (Base, Slope, etc.). Times Base is more commonly called Times Roman, and Times Slope is more commonly called Times Italic. Lout avoids these names in favour of generic names which can be applied to many font families.

Ligatures, such as fl for fl and fi for fi, are considered by Basser Lout to be an integral part of the font: if the font definition (see below) mentions them, they will be used. Similarly, kerning (fine adjustment of the space between adjacent characters to improve the appearance) is done whenever indicated in the font definition. Enclosing one of the letters in @OneCol is one sure way to disable a ligature or kern. You can also turn off ligatures using

```
nolig @Font { ... }
```

and turn them on with

```
lig @Font { ... }
```

Since they are on initially this second option is rarely needed.

More generally, the @Font symbol returns its right parameter in a font and size specified by its left:

```
{ Times Base 12p } @Font object
```

The family and face names must have appeared together in a @FontDef (see below); the size is arbitrary and may be given in any one of the c, i, p, m, f, s, and v units of measurement (Section 3.2), although 10p and 12p are the most common sizes for text. There may be empty objects and @Null objects in the left parameter of @Font; these are ignored.

When a @Font symbol is nested inside the right parameter of another @Font symbol, the inner one determines the font of its own right parameter. However, it may be abbreviated so as to inherit part of the outer symbol:

```
{ Times Base 12p } @Font
{ hello, Slope @Font hello, 15p @Font hello }
```

has result

hello, *hello,* hello

The first inner @Font inherits the outer family and size, changing only the face; the second inherits the outer family and face. When a family name is given, it must be followed immediately by a face name. A size change may appear first or last.

Sizes of the form *+length* and *–length* may also be used, meaning that the font size is to be *length* larger or smaller than the inherited value. For example, –2p is often used for superscripts and subscripts. These forms are highly recommended, since they don't need to be changed if a decision is made to alter the font size of the document as a whole.

The @Font symbol also switches to and from small capitals:

```
smallcaps @Font ...
nosmallcaps @Font ...
```

These may be nested, and they cooperate with other font changes. The precise effect depends on the font (see below). There is a default value (nosmallcaps), so it is not necessary to mention this attribute when giving an initial font.

By default, the size of the small capitals is 0.7 times the size of full-size capitals. You can change this ratio, for example to 0.8, using

```
{ setsmallcaps 0.8 } @Font ...
```

This does not itself cause a change to small capitals, but wherever they are used in the right parameter of @Font they will have size 0.8 times the size that ordinary capitals would have had at that point. Note that the number following setsmallcaps is a ratio, not a length, so there is no unit of measurement.

The @Font symbol also controls a feature added in Version 3.25 which determines where the row mark is placed in a word. Usually, as described elsewhere in this document, the row mark passes through the word at a height of half the height of the letter 'x' above the baseline of the word. However this can be changed so that it passes through the baseline, or not, like this:

```
baselinemark @Font ...
xheight2mark @Font ...
```

The default value is xheight2mark; this was how Lout did it before this option was added, because it makes equation formatting easy. The other value, baselinemark, is useful when words in different font sizes appear side by side on a line.

Finally, a feature added in Version 3.33 requests that the height and depth of every character be increased to the 'bounding box' size of the font – that is, to the height of the font's highest character and the depth of the font's deepest character. Ensuring in this way that every character has the same height and depth can make documents more uniform in layout. To get this feature, use

```
strut @Font ...
```

either alone or combined with other options to @Font. It is called strut because it is like inserting

an invisible vertical strut into every non-empty word. By default struts are off; but anyway if you need to turn them off for some reason, use nostrut @Font. Struts are always turned off in equations, for example, because they are not appropriate for equation formatting.

There are two predefined symbols, @CurrFamily and @CurrFace, which respectively return the family and face names of the current font. For example, right now @CurrFamily is Times and @CurrFace is Base.

To inform Lout that certain fonts exist, it is necessary to create a database of @FontDef symbols. A typical entry in such a database looks like this:

```
{ @FontDef
   @Tag { Times-Base }
   @Family { Times }
   @Face { Base }
   @Name { Times-Roman }
   @Metrics { Ti-Rm }
   @Mapping { LtLatin1.LCM }
}
```

This entry informs Lout of the existence of a font whose family name is the value of @Family and whose face name is the value of @Face. The @Tag value must be exactly equal to @Family followed by a hyphen followed by @Face. There are a few fonts which are the only members of their families; even though these fonts do not need a face name, they must be given one, probably Base, by their @FontDef.

The other fields are implementation-dependent, but in Basser Lout Version 3 they are @Name, a PostScript font name; @Metrics, an Adobe font metrics (formerly AFM) file whose FontName entry must agree with the PostScript font name just mentioned; and @Mapping, the name of a Lout Character Mapping (LCM) file. The files are searched for in standard places. Consult the PostScript Reference Manual [1] for general information about fonts and encoding vectors; briefly, an 8-bit character code *c* in Lout's input is mapped to the character in the Adobe font metrics file whose name appears on the line labelled *c* in the LCM file. The LCM file also defines various character-to-character mappings, such as upper-case to lower-case, which are used for such purposes as the production of small capitals.

The options shown above are all compulsory, but there are two other options which are optional. The @Recode option, if given, must have value Yes (the default, so rarely seen) or No. If @Recode { No } is given, Lout assumes that the given encoding vector is already associated with this font in the PostScript interpreter, and optimizes its output accordingly.

The other optional option, @ExtraMetrics, has value equal to the name of a second font metrics file which, if given, is added to the main one defined by @Metrics. This extra metrics file contains C (define character) and CC (define composite character) entries in the same format as in AFM files; Lout will build composite characters declared in this extra file from the given pieces, which it does not do for composite characters in the main AFM file. There are example extra metrics files in the current Lout distribution which show the precise format of these files.

It is not possible to have two @FontDef database entries with the same family and face names, because then they must have the same @Tag, which is not allowed. However, a PostScript font name and file may appear in two or more font definitions, allowing one PostScript font

to have two or more equally valid Lout names. The LCM files may be equal or different as desired.

The @Char symbol allows a character to be specified by its name (its PostScript name in Basser Lout) rather than by its code:

```
@Char nine
```

is equivalent to 9 in most fonts. This is useful as a documentation aid and to be sure of getting the right character even if the encoding vector of the font is changed. However @Char will fail if the character named is not in the encoding vector of the current font.

3.4. @Break

The @Break symbol influences the appearance of paragraphs (Section 3.2), offering a fixed set of styles:

adjust @Break *object*	Break the paragraphs of *object* into lines, and apply @PAdjust (Section 3.19) to every line except the last in each paragraph;
outdent @Break *object*	Like adjust, except that 2.0f @Wide {} &0i is inserted at the beginning of every line except the first, creating an outdented paragraph (the outdent width may be changed – see below);
ragged @Break *object*	Break the paragraphs of *object* into lines, but do not adjust the lines ('ragged right');
cragged @Break *object*	Like ragged, except that each line will be centred with respect to the others;
rragged @Break *object*	Like ragged, except that each line will be right-justified with respect to the others ('ragged left');
oragged @Break *object*	The obvious combination of ragged and outdent;
lines @Break *object*	Break the paragraphs of *object* into lines at the same points that they are broken into lines in the input, and also at concatenation symbols of the form &*k*b for any *k* greater than 1. Do not adjust the lines. Any spaces at the start of a line other than the first line will appear in the output;
clines @Break *object*	Break the paragraphs of *object* into lines as for lines @Break, then centre each line with respect to the others;
rlines @Break *object*	Break the paragraphs of *object* into lines as for lines @Break, then right-justify each line with respect to the others.

olines @Break *object* — Break the paragraphs of *object* into lines as for lines @Break, then as for outdenting.

If the paragraph was an entire component of a galley, so will each of its lines be; otherwise the lines are enclosed in a @OneRow symbol after breaking.

The length of the gap used to separate the lines produced by paragraph breaking is always 1v, except when lines, clines, or rlines encounter a completely blank line, for which see below. However, the v unit itself and the gap mode may be changed:

gap @Break *object* — Within *object*, take the value of the v unit to be the length of *gap*;

+*gap* @Break *object* — Within *object*, take the value of the v unit to be larger by the length of *gap* than it would otherwise have been;

–*gap* @Break *object* — Within *object*, take the value of the v unit to be smaller by the length of *gap* than it would otherwise have been.

In each case, the mode of *gap* is adopted within *object*.

When lines, clines, or rlines encounter one or more completely blank lines, a single vertical concatenation operator is inserted to implement these, ensuring that the entire set of lines will disappear if they happen to fall on a page or column break. The gap width of the concatenation operator is 1v for the first newline as usual, plus 1v multiplied by the *blank line scale factor*, an arbitrary decimal number with no units, for the remaining newlines. This scale factor is settable by

{ blanklinescale *num* } @Break *object*

The default value is 1.0, which gives blank lines their full height. However it often looks better if they are reduced somewhat. A value as small as 0.6 looks good; it gives width 1.6v to the concatenation symbol inserted at a single blank line. The usual gap mode is of course appended.

The @Break symbol also controls hyphenation:

hyphen @Break *object* — Permit hyphenation within the paragraphs of *object*;

nohyphen @Break *object* — Prohibit hyphenation within the paragraphs of *object*; all hyphenation gaps without exception revert to edge-to-edge mode.

The @Break also has options which control widow and orphan lines:

unbreakablefirst @Break *object* — Prevent column and page breaks (i.e. prevent a galley from splitting) between the first and second lines of the paragraphs of *object*;

unbreakablelast @Break *object* — Prevent column and page breaks between the last and second last lines of the paragraphs of *object*.

These options work by adding the u (unbreakable) suffix to the appropriate gaps during

paragraph breaking, so their precise effect is as described for this suffix. These options may be countermanded by breakablefirst @Break and breakablelast @Break.

The width of the outdenting used in the outdent style may be changed like this:

{ setoutdent *width* } @Break *object*	Within *object*, whenever outdenting is required, use *width* for the amount of outdenting. Note that this does not itself cause a switch to outdenting style. The width may be preceded by + or – to indicate a change to the existing outdent value.

Margin kerning, in which small (usually punctuation) characters protrude into the margin, may be obtained by marginkerning @Break and turned off by nomarginkerning @Break.

Several options may be given to the @Break symbol simultaneously, in any order. For example,

```
{ adjust 1.2fx hyphen } @Break ...
```

is a typical initial value. There may be empty objects and @Null objects in the left parameter of @Break; these are ignored.

3.5. @Space

The @Space symbol changes the value of the s unit of measurement (Section 3.2) within its right parameter to the value given by the left parameter:

```
1c @Space { a b c d }
```

has result

a b c d

As for the @Break symbol, the left parameter of @Space may be given relative to the enclosing s unit, and it may include a gap mode. Note that the @Font symbol also sets the s unit.

The left parameter of the @Space symbol may also hold any one of the five special values lout, compress, separate, troff, and tex, which control the way in which Lout treats white space separating two objects. The names troff and tex indicate that the behaviour of these options is inspired by these other document formatting systems.

The default setting, lout, produces as many spaces in the output as there are in the input. The compress setting causes all sequences of two or more white space characters to be treated the same as one white space character. The separate setting is like compress but also causes zero white spaces between two objects (but not within one word) to be treated the same as one white space character.

The troff setting is the same as lout except that wherever a sentence ends at the end of a line, one extra space is added. Formally, when two objects are separated by white space characters which include at least one newline character, and the first object is a word ending in any one of a certain set of sequences of characters, the extra space is added. The set of sequences of characters depends on the current language and is defined in the langdef for that language (see

Section 3.12).

The tex option is the most complicated. First, the compress option is applied. Then, at every sentence ending, whether or not at the end of a line, one extra space is added. A sentence ending is defined as for troff except that, in addition to the preceding word having to end in one of a certain set of sequences of characters, the character preceding that sequence must exist and must be a lower-case letter. A character is a lower-case letter if, in the Lout Character Mapping file (Section 3.3) associated with the current font, an upper-case equivalent of the character is defined.

3.6. @YUnit, @ZUnit, @CurrYUnit, and @CurrZUnit

The @YUnit symbol changes the value of the y unit of measurement (Section 3.2) within its right parameter to the value given by the left parameter:

```
1c @YUnit { ... }
```

ensures that the value of 1y within the right parameter will be 1c. The @ZUnit symbol is similar, setting the value of the z unit in its right parameter. Both units have default value zero. The left parameter may not include a gap mode, nor may it use the w, b, r, or of course d units, but it may begin with + or - to indicate that value is to be added to or subtracted from the current value. Any negative result of using - will be silently replaced by zero.

The @CurrYUnit and @CurrZUnit symbols report the value of the y and z units, in points, truncated to the nearest integer. For example,

```
1i @YUnit { The current value of the y unit is @CurrYUnit }
```

produces

The current value of the y unit is 72p

since there are 72 points in one inch (at least, Lout thinks there are).

These units are not used internally by Lout. They are supplied as part of the style information for the convenience of application packages. For example, the Eq equation formatting package uses them to fine-tune the appearance of equations.

3.7. @SetContext and @GetContext

As earlier sections showed, the style information contains many attributes: the current font, break style, colour and texture, and so on. It is also possible[1] to add arbitrary additional information to the style, using the @SetContext symbol, and retrieve it using @GetContext. For example,

```
{dirn @Yield up} @SetContext {
The current direction is {@GetContext dirn}.
}
```

[1]From Version 3.34 of Basser Lout.

produces

The current direction is up.

The object to the left of @SetContext must be a @Yield symbol whose left parameter, the *key*, evaluates to a simple word, and whose right parameter, the *value*, may be an arbitrary object. Since @Yield has high precedence it will usually be necessary to enclose non-trivial values in braces. The effect is to associate the value with the key in a symbol table throughout the right parameter of the @SetContext symbol, as part of the style information. The value may be retrieved anywhere in this region by invoking @GetContext with the key as its right parameter.

The value is evaluated using the style and environment where it occurs, not where it is used. In any case in most applications the value will be a simple word, independent of any style and environment, used to select a branch in a case expression, like this:

```
{@GetContext dirn} @Case {
  up @Yield ...
  down @Yield ...
}
```

@GetContext reports an error if there is no value associated with its key in the current style.

3.8. @SetColour and @SetColor

The @SetColour and @SetColor symbols, which have identical effect, return their right parameter in the colour specified by their left parameter. The form of the left parameter is implementation-dependent; in Basser Lout it must be an object whose value is a sequence of words comprising a PostScript command for setting colour. For example,

```
{ 1.0 0.0 0.0 setrgbcolor } @SetColour { hello, world }
```

produces the red result

hello, world

Of course, a colour output device is needed to see the effect; on a monochrome device the result will be some shade of grey.

The @SetColour command accepts the special value nochange for the left parameter. This value causes the right parameter to have the colour it would have had without the @SetColour command. An empty left parameter also has this effect.

There is no default colour, so the user must ensure that the root galley or each of its components is enclosed in a @SetColour symbol whose left parameter is not nochange.

In addition to setting the colour used in the following object, the @SetColour command also sets the underline colour in that object, like @SetUnderlineColour from Section 3.9. While a case could be made for keeping these two attributes of style independent, most people want to underline in the same colour as the text most of the time, and this behaviour gives this without any need to use @SetUnderlineColour explicitly.

Lout makes no attempt to understand colour, it simply prints the PostScript or PDF

commands when appropriate. This has the advantage of permitting access to any of PostScript's colour models (some require initialization which can be supplied using @PrependGraphic), but the disadvantage of offering no way to make relative changes ('as before only redder,' and so on).

For those who wish to obtain colour without working very hard, the setrgbcolor command used above is available in every version of PostScript, requires no initialization, and is simple to use. The three numbers, which range from 0.0 to 1.0, determine the intensity of red, green, and blue respectively. Some useful values for the left parameter are

1.0 0.0 0.0 setrgbcolor	*red*
0.0 1.0 0.0 setrgbcolor	*green*
0.0 0.0 1.0 setrgbcolor	*blue*
1.0 1.0 1.0 setrgbcolor	*white*
0.5 0.5 0.5 setrgbcolor	*grey*
0.0 0.0 0.0 setrgbcolor	*black*

Colouring an object white is useful for producing an empty space whose size is that of some object.

Since the introduction of textures to Lout in Version 3.27, direct use of PostScript colour setting operations such as setrgbcolor is deprecated. Instead, Lout offers its own versions of the standard PostScript colour setting operations:

If you want this	*You should rather write this*
num setgray	num LoutSetGray
num num num setrgbcolor	num num num LoutSetRGBColor
num num num sethsbcolor	num num num LoutSetHSBColor
num num num setcmykcolor	num num num LoutSetCMYKColor

The Lout versions are equivalent to the PostScript ones but without the unwanted effect of causing the current texture to be forgotten.

3.9. @SetUnderlineColour and @SetUnderlineColor

The @SetUnderlineColour and @SetUnderlineColor symbols, which have identical effect, ensure that any underlining in the right parameter is done in the colour specified by their left parameter. The left parameter is a colour as for @SetColour in Section 3.8.

To actually get underlining, you have to use the @Underline symbol (Section 3.51).

Note that the @SetColour symbol from Section 3.8 includes the effect of @SetUnderlineColour, so in the usual case where underlining is to be in the same colour as the text being underlined, there is no need to use @SetUnderlineColour.

3.10. @SetTexture

The @SetTexture symbol returns its right parameter in the texture specified by its left parameter. A texture is a pattern used when filling areas to get a texture rather than solid color.

In the PostScript world, textures are called patterns, and the relevant PostScript commands use this terminology. The author has preferred the term 'texture' because it is more precise: a pattern could be a pattern for anything.

The @SetTexture command accepts the special value nochange for the left parameter. This value causes the right parameter to have the texture it would have had without the @SetTexture command. An empty left parameter also has this effect.

Another special value is LoutTextureSolid, which means no texture at all, just solid colour. It would be useful to change back to solid colour within an enclosing textured region. It is also the initial texture; thus there is no need to ensure that the root galley or each of its components is enclosed in a @SetTexture symbol.

The form of the left parameter is implementation-dependent; in Basser Lout it must be an object whose value is a sequence of words comprising PostScript for setting a texture, up to and including the PostScript setpattern command (or equivalent) which installs the texture into the graphics state. Lout makes no attempt to understand textures, it simply prints the PostScript commands when appropriate. Consult [1] for information about PostScript patterns. You'll need to do that in order to make sense of the rest of this section.

Since building even a simple texture takes a lot of PostScript and is quite error-prone, Lout defines two symbols in the PostScript prologue called LoutMakeTexture and LoutSetTexture that you can use to make and set a texture, like this:

```
{  "1 1 1 0 dg 0 pt 0 pt"
   "2 [0 0 2 pt 3 pt] 2 pt 3 pt { ... }"
   "LoutMakeTexture LoutSetTexture"
} @SetTexture ...
```

We'll explain both symbols in detail in a moment, but just briefly, LoutMakeTexture makes a texture, leaving a pattern dictionary as returned by makepattern on the execution stack, and LoutSetTexture installs this texture into the current graphics state, like setpattern but without any mention of colour.

LoutMakeTexture is just a convenience definition that constructs a pattern matrix and dictionary, populating them with the stack elements to its left, then calls makepattern. You don't have to use it if you don't want to. The above example of LoutMakeTexture sets the pattern matrix and dictionary as follows.

The first number is a scale factor, and the second and third are horizontal and vertical scale factors. The fourth (0 dg) is an angle of rotation. The fifth and sixth are horizontal and vertical shifts. These six numbers determine the pattern transformation matrix passed to makepattern.

The remaining elements go into the pattern dictionary. PaintType is set to the first of them, or the seventh item overall (2 in our example, denoting an uncoloured pattern, which will usually be the best choice; the pattern will be painted in the current colour), BBox is set to the eighth item, here [0 0 2 pt 3 pt], XStep is set to the ninth item, here 2 pt, YStep is set to the tenth item, here 3 pt, and PaintProc is set to the eleventh and last item, which should be an executable array

as shown. All non-zero lengths must be in absolute units, that is, followed by in, cm, pt, or em, otherwise the results will be unpredictable.

LoutSetTexture installs the given texture into the graphics state, preserving the current colour. You must use LoutSetTexture and you must not use setcolorspace, setcolor, and setpattern, because Lout considers colour and texture to be independent of each other, and these PostScript commands don't.

Another advantage of LoutMakeTexture and LoutSetTexture is that they behave sensibly on Level 1 PostScript interpreters, which do not have patterns. Rather than failing altogether, these commands will make sure everything appears in solid colour. Be aware, though, that interpreters exist (e.g gv ca. 1997) which appear to be Level 2 but actually leave textured areas blank.

For information on how these symbols are implemented, consult Appendix A.

3.11. @Outline

The @Outline symbol causes all the words in the right parameter (which may be an arbitrary object) to be printed in outline, rather than filled as is usual. For example,

```
@Outline @Box 24p @Font HELP
```

produces

Outlining is part of the style information, in the same way as colour, font, underlining, and so forth. Outlining can be applied to any font likely to be used in practice. At the time of writing, there is no way to control the thickness of the outline, and @Outline has no effect in PDF output. The size of outlined words is taken by Lout to be the same as if they had not been outlined, even though they are in reality slightly larger.

3.12. @Language and @CurrLang

The @Language symbol informs Lout that its right parameter is written in the language of its left parameter:

```
Danish  @Language  { ... }
```

Basser Lout Version 3 uses this information in two ways: to hyphenate words appropriately to that language, and to change the value of the @CurrLang symbol (see below). Other uses, such as right-to-left formatting of certain languages, may be added in the future.

The left parameter must either be empty (which means to leave the current language unchanged) or else it must have been given in a langdef language definition at the beginning of the input:

```
langdef  Danish  Dansk  { implementation-dependent }
```

After langdef comes a sequence of one or more simple words, which are alternative names for

the language being defined. Following them comes an implementation-dependent part between braces. In Basser Lout Version 3 this part contains the name of the Lout hyphenation information file (minus its .lh suffix) to be used when hyphenating words in this language, followed by a sequence of words which define the ends of sentences. For example:

```
langdef English { english . : ? ! .) ?) !) }
```

defines a language called English with hyphenation patterns file english.lh and seven ways to end a sentence. The use of these sentence endings is described in Section 3.5. If there is no hyphenation file available, this is indicated by writing - for the file name; if there are no sentence ends, they are simply omitted.

The @CurrLang symbol, which has no parameters, evaluates to the first name given in the langdef of the language in force at the point where it is invoked:

```
Dansk @Language { This is @CurrLang. }
```

has result

This is Danish.

It is typically used with the @Case symbol like this:

```
@CurrLang @Case {
   Danish @Yield tirsdag
   English @Yield Tuesday
   French @Yield Mardi
}
```

This example evaluates to the name of the third day of the week in the current language.

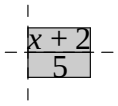
The current language is part of the style of an object, like its font. As explained in Section 2.6, style is inherited through the point of appearance, which for language can be unexpected. For example, an index entry which originates in a French chapter but appears in an English index will have English for its language, so must be explicitly set to French using @Language.

3.13. @OneCol and @OneRow

The @OneRow symbol returns its right parameter modified so that only the principal row mark protrudes. This is normally the first row mark, but another one may be chosen by preceding it with ^/ or ^//. For example,

```
@OneRow { |0.5rt Slope @Font x + 2 ^//1p @HLine //1p |0.5rt 5 }
```

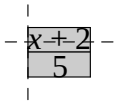
has result



with one row mark protruding from the bar as shown. Compare this with

```
@OneRow { |0.5rt Slope @Font x + 2 //1p @HLine //1p |0.5rt 5 }
```

where the mark protrudes from the numerator:



@OneCol has the same effect on columns as @OneRow does on rows, with the symbols ^| and ^|| (or ^&) determining which mark is chosen.

3.14. @Wide and @High

The @Wide symbol returns its right parameter modified to have the width given by its left parameter, which must be a length (Section 3.2) whose unit of measurement is c, i, p, m, f, s, or v. If the right parameter is not as wide as required, white space is added at the right; if it is too wide, its paragraphs are broken (Section 3.4) so that it fits. A @OneCol operation is included in the effect of @Wide, since it does not make sense for an object of fixed width to have two column marks.

The @High symbol similarly ensures that its result is of a given height, by adding white space at the bottom. In this case it is an error for the right parameter to be too large. A @OneRow operation is included.

3.15. @HShift and @VShift

The @HShift symbol returns its right parameter with principal mark shifted as prescribed by its left parameter:

+length @HShift *object*	Principal mark shifted to the right by *length*;
-length @HShift *object*	Principal mark shifted to the left by *length*;
length @HShift *object*	Principal mark shifted so as to lie *length* to the right of the left edge of *object*;

In each chase @HShift includes a @OneCol effect.

The units of measurement of *length* may be c, i, p, m, f, s, v, or w. In the latter case, 1w is taken to be the width of the right parameter, so that, for example, 0.5w @HShift will centre the principal column mark within the right parameter.

The @VShift symbol is similar except that it applies vertically to the principal row mark: *+length* shifts it down, *-length* shifts it up, and *length* shifts it to *length* below the top edge of the object. With @VShift, 1w is taken to be the height of the right parameter.

3.16. @HExpand and @VExpand

The @HExpand symbol causes its right parameter to be as wide as it possibly could be without violating a @Wide symbol or intruding into the space occupied by neighbouring gaps or objects. The @VExpand symbol is similar, but it affects height. For example, in the object

```
8i @Wide 11i @High {
   //1i  ||1i @HExpand @VExpand x ||1i
   //1i
}
```

object x could have any size up to six inches wide by nine inches high, so the @HExpand and @VExpand symbols cause it to have exactly this size. This is important, for example, if x contains |1rt or /1rt; without the expansion these might not move as far across or down as expected.

As Section 2.6 explains in detail, most objects are already as large as they possibly could be. Consequently these symbols are needed only rarely. @HExpand includes a @OneCol effect, and @VExpand includes a @OneRow effect.

3.17. @HContract and @VContract

The @HContract symbol reduces the size of its right parameter to a reasonable minimum (after paragraph breaking). For example,

```
5i @Wide @HContract { A |1rt B }
```

has result

AB

in which the B is much closer to the A than it would otherwise have been. @VContract is similar, but in a vertical direction. See Section 2.6 for a more extensive discussion.

3.18. @HLimited and @VLimited

The @HLimited symbol limits the width available to recursive and receptive symbols within its right parameter to whatever is available without increasing the existing size of the @HLimited object. So this symbol acts like @Wide with respect to limiting the space occupied by recursive and receptive symbols, except that instead of enforcing a fixed constant limit, it enforces whatever size is already in place.

The @VLimited symbol is exactly the same, except that it applies vertically rather than horizontally.

3.19. @HAdjust, @VAdjust, and @PAdjust

These symbols spread their right parameter apart until it occupies all the space available to it; @HAdjust adjusts | sequences, @VAdjust adjusts / sequences, and @PAdjust adjusts & sequences. For example,

```
4i @Wide @PAdjust { 1 2 3 4 5 6 7 8 }
```

has result

1 2 3 4 5 6 7 8

More precisely, the widening is effected by enlarging the size of each component except the last by an equal fraction of the space that would otherwise be left over – just the opposite of the usual procedure, which assigns all the leftover space to the last component (Section 2.6).

@PAdjust is used by the adjust and outdent options of the @Break symbol (Section 3.4). It has a slight peculiarity: it will not enlarge components when the immediately following gap has width 0. This is to prevent space from appearing (for example) between a word and an immediately following comma. The other two symbols will enlarge such components.

3.20. @HScale and @VScale

@HScale causes its right parameter to expand to fill the space available, by geometricallly scaling it:

```
4i @Wide @HScale { 1 2 3 4 5 6 7 8 }
```

has result

and

```
0.5i @Wide @HScale { 1 2 3 4 5 6 7 8 }
```

has result

@HScale first applies @HContract to its parameter, then horizontally scales it to the actual size. The principal mark of the right parameter has no effect on the result; the parameter is scaled to the actual size and positioned to fill the space available. (Taking account of alignment of the principal mark only causes trouble in practice.)

@VScale is similar, but in a vertical direction. @HScale and @VScale each have both a @OneCol and a @OneRow effect.

3.21. @HMirror and @VMirror

@HMirror and @VMirror cause their right parameter to be reflected, either horizontally or vertically. For example,

```
@HMirror AMBULANCE
```

has result

and

@VMirror AMBULANCE

has result

∀ꟽBꟼΓ∀ИCE

The parameters of these symbols may be arbitrary Lout objects as usual. Both symbols have both a @OneCol and a @OneRow effect.

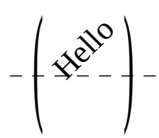
In each case the reflection is about the mark of the object (that is, the reflected objects have the same marks as the originals), so that, for example, when used within a line of text the results are ƎƆИAꟻUƁMA and ∀ꟽBꟼΓ∀ИCE respectively.

3.22. @HCover and @VCover

The @VCover symbol vertically scales its right parameter so that it covers every object that shares its row mark. For example,

@VCover (45d @Rotate Hello @VCover)

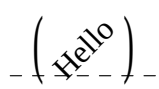
produces



The row mark has been added to show clearly where it lies. This should be compared with

@VScale (45d @Rotate Hello @VScale)

which produces



Scaling abandons mark alignment and so is able to exactly cover the rest of the row, whereas covering preserves mark alignment and so is obliged in general to more than cover the rest of the row.

If the parameter of @VCover has zero vertical size, this is taken to mean that covering is not required after all and the @VCover is silently ignored. If however the parameter has non-zero size above the mark but zero size below, or vice versa, this is taken to be an error since scaling cannot make the parameter cover the rest of the row.

@HCover is similar, horizontally covering all objects that share its column mark. Neither symbol works well near galley targets, because the scale factor to apply is determined before any galley flushing takes place.

3.23. @StartHSpan,@StartVSpan, @StartHVSpan, @HSpan, and @VSpan

These symbols work together to produce spanning columns and rows in a more flexible way than is possible in practice with // and ||. An object

```
@StartHSpan object
```

causes object to be printed, but occupying all the horizontal space to the right on the row mark on which it lies up to and including the rightmost @HSpan symbol on that mark not preceded by @StartHVSpan, @StartHSpan, @StartVSpan, or @VSpan. The column mark of this spanning object is not constrained to align with any of the column marks of the columns it spans.

If there is no @HSpan symbol anywhere to the right of @StartHSpan, then the object spans only its own column. This means that it occupies that column as usual but its mark is not constrained to align with those of the other objects in the column.

Similarly, the @StartVSpan symbol causes its object to occupy all the vertical space below it on the column mark on which it lies, down to and including the bottommost @VSpan symbol on that mark not preceded by a @StartHVSpan, @StartHSpan, @StartVSpan, or @HSpan; and if there is no @VSpan symbol anywhere below it on that mark, then the object spans only its own row, occupying its row but with its mark not constrained to align with the row mark.

The @StartHVSpan symbol combines the effects of @StartHSpan and @StartVSpan, allowing an object to span both columns and rows simultaneously. For example, in

```
@StartHVSpan x  | | @HSpan
/
@VSpan   | |
```

the object x will occupy a rectangular area spanning three columns, two rows, and the gaps between them.

The objects lying in the region spanned should all be empty, or the @HSpan and @VSpan symbols can be used to document the spanning that is occurring. At present there may be no galley targets or recursive symbols within the right parameter of @StartHSpan, @StartVSpan, or @StartHVSpan. However, the right parameter may otherwise be an arbitrary object, including paragraphs of text that require breaking.

If the right parameter of @StartHSpan, @StartVSpan, or @StartHVSpan occupies more horizontal or vertical space than all of the spanned columns or rows combined require, the extra space goes into the last spanned column or row. Overlapping spanning rows and columns are permitted. Gaps spanned by span objects are unbreakable (their u indicator is set automatically and cannot be revoked).

3.24. @Scale

This symbol geometrically scales its right parameter by the scale factor given in its left parameter:

```
1.0 @Scale Hello  2.0 @Scale Hello  0.5 @Scale Hello
```

has result

Hello Hello Hello

The left parameter can be two scale factors, in which case the first applies horizontally, and the second vertically:

```
{0.5 2.0} @Scale Hello
```

has result

Hello

The left parameter may be empty, in which case Lout will scale the object by a common factor horizontally and vertically so as to occupy all available horizontal space:

```
{} @Scale { Hello world }
```

has result

Hello world

The right parameter may be any object. @Scale has both a @OneCol and a @OneRow effect, and the marks of the result coincide with the principal marks of the right parameter.

3.25. @Rotate

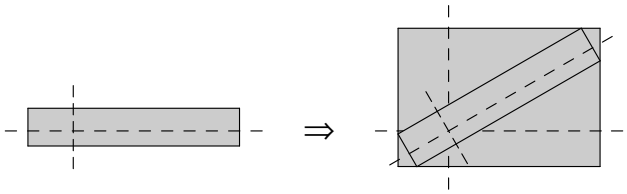
The @Rotate symbol will rotate its right parameter counterclockwise an amount given in degrees (positive or negative) by its left parameter. For example,

```
30d  @Rotate  { hello, world }
```

has result

hello, world

Before rotating the object, @OneCol and @OneRow are applied to it. The result is a rectangle whose marks pass through the point where the original marks crossed:



As this example shows, rotation by an angle other than a multiple of ninety degrees introduces quite a lot of white space. So, for example, the result of

```
-30d @Rotate 30d @Rotate object
```

is a much larger object than *object*, despite the fact that one rotation cancels the other.

Rotation of objects containing receptive and recursive symbols is permitted, but for angles other than multiples of ninety degrees it is best to make the size of the rotated object clear with @Wide and @High symbols:

```
30d @Rotate 5i @Wide 4i @High
{   //1i @TextPlace
    //1i
}
```

This is because for angles other than multiples of ninety degrees the space available for @TextPlace to occupy is indeterminate, and the result is poor.

3.26. @Background

The @Background symbol will print its left parameter in the background of its right parameter. That is, the result has the size of the right parameter, but the left parameter will be printed first in the same space, with its marks aligned with the marks of the right parameter.

3.27. @KernShrink

This symbol returns its right parameter unchanged in appearance but occupying a slightly smaller bounding box. The reduction is by the amount of kerning that would be applied if the right parameter was immediately *followed* by the left parameter. For example,

```
. @KernShrink P
```

has result

where a box of size 0 has been drawn around the result to make its extent clear. Compare this with ‘P’ alone:

in which the bounding box exactly encloses the object, or at least is supposed to. The bounding box is smaller on the right by the amount of kerning that would be applied between ‘P’ and ‘.’.

The only known use for this symbol is to produce tucked-in subscripts in the Eq equation formatting package.

3.28. @Common, @Rump, and @Meld

The @Common and @Rump symbols compare two paragraph objects:

```
{ Aardvark, 29 } @Common { Aardvark, 359 }
```

If either parameter is not a paragraph object, it is converted into a single-object paragraph first. The result of @Common is the common prefix of the two paragraphs; that is, those initial objects which are equal in the two paragraphs. In the example above, the result is Aardvark,. The result of @Rump is that part of the second object which is not included in @Common; the result of

```
{ Aardvark, 29 } @Rump { Aardvark, 359 }
```

is 359.

If the two objects have nothing in common, the result of @Common will be an empty object and the result of @Rump will be the second object. If the two objects are identical, the result of @Common will be the first object, and the result of @Rump will be an empty object.

The only known use for @Rump and @Common is to implement merged index entries (Section 2.8).

The @Meld symbol returns the minimum meld of two paragraphs, that is, the shortest paragraph that contains the two original paragraphs as subsequences. For example,

```
{ Aardvark , 1 , 2 } @Meld { Aardvark , 2 , 3 }
```

produces

```
Aardvark , 1 , 2 , 3
```

The result is related to the well-known longest common substring, in that the meld contains everything not in the lcs plus one copy of everything in the lcs. Where there are several minimum melds, @Meld returns the one in which the components of the first parameter are as far left as possible.

Determining the values of all these symbols requires testing whether one component of the first paragraph is equal to one component of the second. Since Version 3.25, the objects involved may be arbitrary and Lout will perform the necessary detailed checking for equality; previously, only simple words were guaranteed to be tested correctly. Two words are equal if they contain the same sequence of characters, regardless of whether they are enclosed in quotes, and regardless of the current font or any other style information. Otherwise, objects are equal if they are of the same type and have the same parameters, including gaps in concatenation objects. The sole exception is @LinkSource, whose left parameter is ignored during equality testing, since otherwise there would be problems in the appearance of melded clickable index entries.

Style changing operations (@Font, @SetColour etc.) are not considered in equality testing, since these have been processed and deleted by the time that the tests are done. Also, Lout tries hard to get rid of redundant braces around concatenation objects, which is why

```
{ a { b c } } @Meld { { a b } c }
```

produces

```
a b c
```

The two parameters are equal by the time they are compared by @Meld.

One problematic area in the use of these operators is the definition of equality when objects

are immediately adjacent. Lout contains an optimization which merges immediately adjacent words whenever they have the same style. For example,

```
{Hello}{world}
```

would be treated internally as one word, whereas

```
{Hello}{yellow @Colour world}
```

would be treated as two adjacent words. Thus, although @Font, @SetColour, and the other style operators are ignored in equality testing, they may affect the structure of the objects they lie within.

At present, @Common and @Rump treat all unmerged components of their paragraph as separate, even if one is immediately adjacent to another. @Common and @Rump would thus see one component in the first example and two in the second. @Meld treats each group of immediately adjacent components as a single component, so it would see one component in both examples; but it would still not report them as equal, since one is a single word and the other is a pair of adjacent words. These confusing and inconsistent properties might be revised in the future. See Section 4.6 for an example of the practical use of these operators, in which very small unbreakable gaps are used to ensure that apparently adjacent components are separate, and @OneCol is used to prevent the word merging optimization from taking effect when it would otherwise cause trouble.

3.29. @Insert

The @Insert symbol inserts its left parameter at the beginning of the first paragraph of its right parameter:

```
X @Insert { A B // C // D }
```

is equivalent to

```
{ XA B // C // D }
```

Notice that a zero-width space separates X from the first paragraph, so if some wider space is required it must be placed at the end of X. The @Insert operation is applied to the value of the right parameter after evaluation.

The only known use for this symbol is to attach something like **Figure 6** to the front of a multi-paragraph caption.

3.30. @OneOf

The @OneOf symbol returns one of the sequence of objects which is its right parameter as its result:

```
@OneOf {
   @ResultA
   @ResultB
```

```
    @ResultC
}
```

The choice is made to ensure that whatever galley target is required at the moment is found. For example, if we are evaluating @OneOf as part of an attempt to attach a galley whose target is @SomeTarget, then the result above will be @ResultA if it contains @SomeTarget, or else @ResultB if it contains @SomeTarget, or else @ResultC (whether or not it contains the target, or if there is no target).

Use of @OneOf in conjunction with recursive symbols can lead to problems. Consider this example:

```
def @Recursive {

  def @ChoiceA { @APlace // @Recursive }

  def @ChoiceB { @BPlace // @Recursive }

  @OneOf {
    @ChoiceA
    @ChoiceB
  }
}
```

Lout believes that expanding @Recursive is the right thing to do when searching for either of the galley targets @APlace and @BPlace. When searching for @BPlace this leads Lout to expand @Recursive, then @ChoiceA, then the @Recursive symbol within @ChoiceA, and so on infinitely. This problem can be avoided by attaching a @NotRevealed symbol to each of the inner @Recursive symbols: these are then not available for expansion until a decision has been made to expand the symbol they lie within. In this particular example it would be simpler to write

```
def @Recursive {

  @OneOf {
    @APlace
    @BPlace
  }
  // @Recursive
}
```

but this factoring is not possible when the recursive calls have parameters that are required to differ in the two cases.

3.31. @Next

The @Next symbol returns its parameter plus one. It is rather clever at working this out: it hunts through the parameter from right to left, looking for a number to increment:

```
@Next (3.99)
```

has result (3.100). If @Next cannot find a digit inside its parameter, it is an error. Roman numerals are handled by storing them in a database, as explained in Section 4.2; @Next will not increment a Roman numeral.

3.32. @Case

The @Case symbol selects its result from a list of alternatives, depending on a tag:

```
@Day @Case {
   { 1 21 31 } @Yield st
   { 2 22 } @Yield nd
   { 3 23 } @Yield rd
   else @Yield th
}
```

In this example the result will be st if @Day is 1, 21, or 31, and nd if @Day is 2 or 22, etc. The effect is similar to accessing a database, though in a more compact form. The right parameter is a sequence of @Yield symbols, each with a left parameter whose value is a sequence of one or more juxtapositions of simple words, and a right parameter which may be any object.

We first describe the behaviour when the value of the left parameter of @Case is a juxtaposition of one or more simple words. Then the result of the @Case is the right parameter of the first @Yield whose left parameter contains either the value of the left parameter of the @Case, or the special value else. If there is no such @Yield it is an error.

When the left parameter of @Case is not a juxtaposition of simple words, the result is the right parameter of the first @Yield whose left parameter is else, or an error otherwise. This permits examples like

```
@RunningTitle @Case {
   dft @Yield @Title
   else @Yield @RunningTitle
}
```

where a running title is returned unless it has the value dft (which presumably means that no running title was supplied), in which case an ordinary title is returned instead.

When a receptive symbol is placed within a @Case, it should be included in each alternative, since otherwise Basser Lout may become confused when trying to predict whether the symbol will be a part of the result or not. Alternatively, if it can be guaranteed that the receptive symbol will never be searched for when the cases that it does not lie within are selected, that is all right too.

3.33. @Moment

The predefined symbol @Moment has the following definition:

```
def @Moment
  named @Tag {}
  named @Second {}
  named @Minute {}
  named @Hour {}
  named @Day {}
  named @Month {}
  named @Year {}
  named @Century {}
  named @WeekDay {}
  named @YearDay {}
  named @DaylightSaving {}
{}
```

It may be used like any other symbol. Lout provides an invocation of @Moment with tag now, whose other parameters are numbers encoding the current date and time:

@Second	the current second, usually between 00 and 59
@Minute	the current minute, between 00 and 59
@Hour	the current hour, between 00 and 23
@Day	the current day of the month, between 1 and 31
@Month	the current month, between 1 (January) and 12 (December)
@Year	the current year of the century, between 00 and 99
@Century	the current century, e.g. 19 or 20
@WeekDay	the current day of the week, between 1 (Sunday) and 7 (Saturday)
@YearDay	the current day of the year, between 0 and 365
@DaylightSaving	an implementation-dependent number that may encode the daylight saving currently in effect

Unix manual entries state that @Second can be as high as 61, to allow for leap seconds. Judicious use of databases can convert these numbers into useful dates. For example,

```
@Moment&&now @Open { @Day {@Months&&@Month}, @Century{@Year} }
```

produces something like 19 February, 2008 given a suitable database of months.

3.34. @Null

This symbol provides a convenient way to remove unwanted concatenation symbols. If there is a concatenation symbol preceding @Null, the @Null and the concatenation symbol are both deleted. Otherwise, if there is a following concatenation symbol, it and the @Null are both deleted. Otherwise, @Null becomes an empty object.

These rules apply to a fully parenthesized version of the expression. For example, in

```
... //1vx @Null |0.5i ...
```

it is the horizontal concatenation symbol following @Null that disappears, because in the fully parenthesized version

```
... //1vx { @Null |0.5i ... }
```

there is no concatenation symbol preceding the @Null.

3.35. @Galley and @ForceGalley

These symbols both act as a placeholder for a galley. That is, they may be replaced by components of a galley. In the case of @ForceGalley the galley will then have a forcing galley effect at this point although it need not be declared using force into. See Section 2.7 for a detailed discussion of galleys, forcing galleys, and targets.

3.36. @BeginHeaderComponent, @EndHeaderComponent, @SetHeaderComponent, and @ClearHeaderComponent

Informally, header components are running headers that appear at the top of the displayed segments of galleys. They are used, for example, by the @Tbl table formatting package to place running headers at the top of each page of a multi-page table, after the first page.

Formally, a header component of a galley is an ordinary component of a galley (Section 2.7) together with an indication that the component is a header component. When printed, a header component looks exactly like it would have done as an ordinary component; the difference is in whether the component is printed at all, and if so where.

Every non-header component of every galley has associated with it a sequence of zero or more header components. Whenever a galley attaches to a target, and the target does not itself occupy an entire component of the enclosing galley, copies of the header components associated with the first ordinary component to be promoted into that target are promoted into it first.

The condition ‘and the target does not itself occupy an entire component of the enclosing galley’ ensures that, for example, when part of a section has header components, these are not printed where the section is promoted into its chapter, but rather where the chapter is promoted onto pages. If the target occupies the whole component, then the incoming galley will not split at all, so headers would be of no interest there.

The one remaining question is ‘How is the sequence of header components of each ordinary component determined?’ By default, the header components of one component are the same as those of the previous component. We can show this graphically as follows:

$$C_i : H_1, H_2, \ldots, H_n$$
$$/$$
$$C_{i+1} : H_1, H_2, \ldots, H_n$$

which may be read: ‘If ordinary component C_i has header component sequence $H_1, H_2, \ldots, H_n$, then its successor component C_{i+1} has header component sequence $H_1, H_2, \ldots, H_n$ also.’ Using this notation, we may now define the four symbols that affect header component sequences:

$C_i : H_1, H_2, \ldots, H_n$
/
gap @BeginHeaderComponent H_{n+1}
/
$C_{i+1} : H_1, H_2, \ldots, H_n, H_{n+1}$

That is, @BeginHeaderComponent occupying an entire component appends a header component to the sequence of the following ordinary components. When printed, this header component is separated by *gap* from the following component; if *gap* is empty it denotes 0ie as usual with concatenation gaps. The appearance of the header component will be exactly as it would have been had it occurred alone at that point, rather than after @BeginHeaderComponent.

Next comes @EndHeaderComponent:

$C_i : H_1, H_2, \ldots, H_n, H_{n+1}$
/
@EndHeaderComponent
/
$C_{i+1} : H_1, H_2, \ldots, H_n$

That is, @EndHeaderComponent (which has no parameters) occupying an entire component deletes the last header component. If the sequence is empty, a warning message is printed and it remains empty. @BeginHeaderComponent and @EndHeaderComponent are naturally used in matching (possibly nested) pairs, to introduce and subsequently retract a header component.

Next comes @SetHeaderComponent:

$C_i : H_1, H_2, \ldots, H_n$
/
gap @SetHeaderComponent H_{n+1}
/
$C_{i+1} : H_{n+1}$

@SetHeaderComponent clears any current header components and replaces them by one of its own. Finally we have @ClearHeaderComponent:

$C_i : H_1, H_2, \ldots, H_n$
/
@ClearHeaderComponent
/
$C_{i+1} :$

This symbol clears any header components, leaving the sequence empty. These last two symbols combine less cleanly than the first two (either will wreck any enclosing @BeginHeaderComponent – @EndHeaderComponent pair), but they are useful in situations where the range of one header is terminated by the start of the range of the next.

All four symbols yield the value @Null where they appear. If they do not occupy entire components of their galley, they are silently ignored.

Owing to limitations in the way header components are implemented, the following object types are not allowed inside them, and Basser Lout will complain and quit if it finds any of them: galleys, receptive or recursive symbols, cross references, @PageLabel, @HExpand, @VExpand, @HCover, @VCover, and @Scale when it has an empty left parameter. In addition, if more than three copies of the same running header are printed on the same page, their horizontal positions will become confused, probably resulting in the apparent disappearance of all but the last three copies. (The magic number 3 can be increased by recompiling the Lout source with the `MAX_HCOPIES` constant increased.)

3.37. @NotRevealed

The @NotRevealed symbol exerts fine control over the process of expanding receptive symbols. It may appear only within the body of a definition, immediately following the name of a receptive symbol. For example:

```
def A { @Galley }

def B { @Galley }

def ABList
{
   A
   // B @NotRevealed
   // ABList
}
```

The meaning is that the symbol immediately preceding @NotRevealed, B in this example, is not revealed to galleys which encounter ABList while searching for targets; to such galleys it appears that ABList contains A only, not B, hence only galleys targeted to A will expand ABList. However, after ABList is expanded by such a galley, B will be available as a target in the usual way.

Apart from this meaning, @NotRevealed has no effect at all, and the body of the definition may be understood by deleting @NotRevealed and any preceding space. Thus, the symbol preceding @NotRevealed may have named and right parameters in the usual way; these would follow after the @NotRevealed symbol.

This symbol was introduced to overcome a problem with floating figures treated as displays. It turned out to be essential to specify the layout of a column (in part) as

```
@BodyTextPlace
// @FigurePlace
// @BodyTextPlace
// @FigurePlace
// @BodyTextPlace
...
```

so that figures could alternate with body text down the column. However, some means was needed to ensure that in the absence of any figures there could only be one @BodyTextPlace in the

column, since otherwise various problems arose, for example the @NP symbol merely causing a skip from one @BodyTextPlace to the next in the same column, rather than to the first in the next column. Also, without this feature the optimal page breaker's attempts to end a column early would be frustrated by Lout then discovering that plenty of space existed at a following @BodyTextPlace in the same column. The solution is based on ABList above; each occurrence of @BodyTextPlace after a @FigurePlace is not revealed in the enclosing definition, and so cannot be found by body text galleys unless a figure has previously attached to the preceding @FigurePlace.

3.38. The cross reference symbols && and &&&

The cross reference symbol && takes the name of a symbol (not an object) for its left parameter, and an object whose value must be a simple word, or several simple words, for its right parameter. The result is a cross reference, which may be thought of as an arrow pointing from the cross reference symbol to the beginning of an invocation of the named symbol.

The invocation pointed to, known as the *target* of the cross reference, is generally one whose @Tag parameter has value equal to the right parameter of the cross reference symbol. Three special tags, preceding, following, and foll_or_prec, point respectively to the first invocation preceding the cross reference in the final printed document, to the first invocation following it, and to the first following it if such exists else to the first preceding it.

A cross reference may be used in four ways: where an object is expected, in which case its value is a copy of the target; with the @Open and @Use symbols; with the @Tagged symbol; and in the into clause or @Target symbol of a galley definition, in which case the value of the tag must be preceding, following, or foll_or_prec.

Within an into clause or @Target symbol, the alternative form &&& is acceptable and indicates a forcing galley (Section 2.7).

Except within an into clause or @Target symbol, the symbol referred to must have a @Tag parameter. This is so even if the right parameter of the cross reference is preceding, following, or foll_or_prec.

3.39. @Tagged

The @Tagged symbol takes a cross reference for its left parameter and an object, whose value must be a juxtaposition of simple words, or several words, or an empty object, for its right parameter. It has the effect of attaching its right parameter as an additional tag to the invocation denoted by its left parameter, unless the right parameter is empty, in which case @Tagged does nothing. The result of @Tagged is always @Null, which makes it effectively invisible.

3.40. @Open and @Use

The @Open symbol takes a cross reference or symbol invocation for its left parameter, and an arbitrary object, which must be enclosed in braces, for its right parameter. The right parameter may refer to the exported parameters and nested definitions of the invocation denoted by the left parameter, and its value is the @Open symbol's result. The target of the cross reference may lie

in an external database (Section 3.42). Any symbol available outside the @Open which happens to have the same name as one of the symbols made available by the @Open will be unavailable within the @Open.

The @Use symbol is an @Open symbol in a different form. It may only appear among or after the definitions in Lout's input, and it is equivalent to enclosing the remainder of the input in an @Open symbol. For example,

```
definitions
@Use { x }
@Use { y }
rest of input
```

is equivalent to

```
definitions
x @Open
{     y @Open
      { rest of input
      }
}
```

The @Use symbol allows a set of standard packages to be opened without the inconvenience of enclosing the entire document in @Open symbols. Such enclosure could cause Basser Lout to run out of memory.

3.41. @LinkSource, @LinkDest, and @URLLink

The two symbols @LinkSource and @LinkDest work together to create *cross links* in a document, that is, points where a user viewing the document on screen can click and be transported to another point in the document. We call the point where the user clicks the *source* of the link, and the point where the user arrives the *destination* of the link.

To create a source point, place

tag @LinkSource *object*

at some point in the document, where the value of *tag* is a legal cross reference tag, and *object* is an arbitrary Lout object. The result of this is just *object*, but if the user of a screen viewer clicks on any point within the rectangular bounding box of that object, a link will be entered.

At present, *object* above is treated as though it were enclosed in @OneCol. This means that a long link source or destination point will not break over two lines as part of an enclosing paragraph.

To create a destination point, place

tag @LinkDest *object*

at some point in the document. Again, *tag* must evaluate to a legal cross reference tag, and *object* may be any Lout object. All @LinkSource symbols whose tag is equal to this one are linked to

this destination point.

For every source point there must be exactly one destination point with the same tag, otherwise it will not be clear where the link is supposed to take the user. Lout will print a warning if this condition is violated anywhere; it will refuse to insert a destination point with the same name as a previous one, but it is not able to refrain from inserting a source point with no corresponding destination point, and such points must cause errors of some kind when viewed (exactly what error will depend on the viewer).

The @URLLink symbol is similar to @LinkSource in being the source point of a link, but instead of a tag you supply a URL to some other document altogether:

```
"http://snark.ptc.spbu.ru/~uwe/lout/lout.html" @URLLink { Lout Home Page }
```

The URL will need to be enclosed in quotes, because of the / characters which are otherwise taken to be concatenation operations. As for @LinkSource, the result is just the object to the right, like this:

Lout Home Page

but if the user clicks on this object on the screen they enter a link that takes them to the given URL location, assuming that the software which they are using to display the document is clever enough to do this.

For the purposes of @Common, @Rump, and @Meld, two @LinkSource objects are considered to be equal if their right parameters are equal; the left parameters are not considered. This behaviour is needed, for example, to make index entries look reasonable when melded. If two @LinkSource objects with equal right parameters but different left parameters are melded into one, one of the two will be the result, but which one is undefined. Notice that melding cannot produce an undefined link, since the worst it can do is delete a @LinkSource.

Practically speaking, the right parameters of @LinkSource and @URLLink need to be non-null, non-empty objects, since otherwise there is nothing visible for the user to click on. (This condition is not checked or enforced by Lout.) However, the right parameter of @LinkDest could reasonably be empty or null. Usually, when @Null lies inside a non-concatenation object, for example

```
@OneCol @Null
```

the effect of the @Null is lost – the result in this example is equivalent to an empty object. However, when the right parameter of @LinkDest is @Null:

```
@LinkDest @Null
```

or when it is some object treated like @Null by Lout (e.g. a @Tagged symbol), then the @LinkDest itself has the effect on surrounding concatentation operators that @Null has, allowing it to be made effectively invisible in the printed document, though still really there.

3.42. @Database and @SysDatabase

The @Database symbol is used to declare the existence of a file of symbol invocations that Lout may refer to when evaluating cross references. In Basser Lout, for example,

```
@Database @Months @WeekDays { standard }
```

means that there is a file called standard.ld containing invocations of the previously defined symbols @Months and @WeekDays. A @Database symbol may appear anywhere a definition or a @Use symbol may appear. Different definitions packages may refer to a common database, provided the definitions they give for its symbols are compatible. An entry is interpreted as though it appears at the point where the cross reference that retrieves it does, which allows symbols like @I for Slope @Font to be used in databases. The database file may not contain @Database or @Include symbols, and each invocation within it must be enclosed in braces.

Basser Lout constructs an *index file*, which in this example is called standard.li, the first time it ever encounters the database, as an aid to searching it. If the database file is changed, its index file must be deleted by the user so that Basser Lout knows to reconstruct it. There is also an installation option which allows this deletion to be done automatically on suitable systems (including Unix).

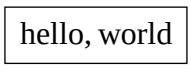
Basser Lout searches for databases in the current directory first, then in a sequence of standard places. To search the standard places only, use @SysDatabase.

3.43. @Graphic

Lout does not provide the vast repertoire of graphical objects (lines, circles, boxes, etc.) required by diagrams. Instead, it provides an escape route to some other language that does have these features, via its @Graphic symbol:

```
{ 0 0 moveto
  0 ysize lineto
  xsize ysize lineto
  xsize 0 lineto
  closepath
  stroke
}
@Graphic
{ //0.2c
  ||0.2c hello, world ||0.2c
  //0.2c
}
```

The result of the above invocation of the symbol @Graphic is

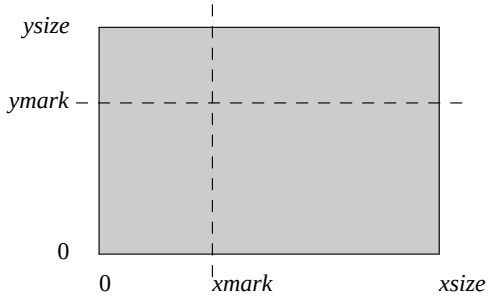


The right parameter always appears as part of the result, and indeed the result is always an object whose size is identical to the size of the right parameter with @OneCol and @OneRow applied to it. From now on we refer to this part of the result as the *base.*

The left parameter is implementation-dependent: that is, its meaning is not defined by Lout, and different implementations could require different values for it. The following description applies to Basser Lout, which uses the PostScript page description language [1]. Similar but more restricted possibilities exist with the PDF back end (see a separate document distributed with Lout); to include both, use the @BackEnd symbol like this:

```
{ @BackEnd @Case {
    PostScript @Yield
    {
      ...
    }
    PDF @Yield
    {
      ...
    }
  }
  @Graphic
  {
    ...
  }
}
```

Returning to PostScript, the left parameter refers to a coordinate system whose origin is the bottom left-hand corner of the base. It may use the symbols xsize and ysize to denote the horizontal and vertical size of the base; similarly, xmark and ymark denote the positions of the base's column and row marks:



In addition to these four symbols and 0, lengths may be denoted in centimetres, inches, points, ems, f's, v's and s's using the notation

l cm	instead of Lout's	*l*c
l in	instead of Lout's	*l*i
l pt	instead of Lout's	*l*p
l em	instead of Lout's	*l*m
l ft	instead of Lout's	*l*f
l vs	instead of Lout's	*l*v
l sp	instead of Lout's	*l*s

Note that there must be a space between the number and its unit, unlike Lout proper.

A point within the base (and, with care, a point outside it) may be denoted by a pair of lengths. For example,

```
xmark  ymark
```

is the point where the marks cross, and

```
0  2 cm
```

is a point on the left edge, two centimetres above the bottom left-hand corner. These two numbers are called the *x coordinate* and the *y coordinate* of the point.

The first step in specifying a graphic object is to define a *path*. A path can be thought of as the track of a pen moving over the page. The pen may be up (not drawing) or down (drawing a line or curve) as it moves. The entire path is a sequence of the following items:

x y moveto	Lift the pen and move it to the indicated point.
x y lineto	Put the pen down and draw a straight line to the indicated point.
x y r angle1 angle2 arc	Put the pen down and draw a circular arc whose centre has coordinates *x* and *y* and whose radius is *r*. The arc begins at the angle *angle1* measuring counterclockwise from the point directly to the right of the centre, and proceeds counterclockwise to *angle2*. If the arc is not the first thing on the path, a straight line will be drawn connecting the current point to the start of the arc.
x y r angle1 angle2 arcn	As for arc, but the arc goes clockwise from *angle1* to *angle2*.
closepath	Draw a straight line back to the point most recently moved to.

The first item should always be a moveto, arc, or arcn. It should be clear from this that the path given earlier:

```
0 0 moveto
0 ysize lineto
xsize ysize lineto
xsize 0 lineto
closepath
```

traces around the boundary of the base with the pen down.

Once a path is set up, we are ready to *paint* it onto the page. There are two choices: we can

either *stroke* it, which means to display it as described; or we can *fill* it, which means to paint everything inside it grey or black. For stroking the two main options are

length setlinewidth	The pen will draw lines of the given width.
[*length*] 0 setdash	The pen will draw dashed lines when it is down, with the dashes each of the given length.

These options are followed by the word stroke. So, for example,

```
{ 0 0 moveto xsize 0 lineto
  2 pt setlinewidth [ 5 pt ] 0 setdash stroke
}
@Graphic { 3i @Wide }
```

has result

When filling in the region enclosed by a path, the main option is setgray, which determines the shade of grey to use, on a scale from 0 (black) to 1 (white). So, for example,

```
{ 0 0 moveto xsize 0 lineto 0 ysize lineto closepath
  0.8 setgray fill
}
@Graphic
{ 2c @Wide  2c @High }
```

has result

There are many other options. The value of the left parameter of @Graphic may be any fragment of the PostScript page description language [1]. Here are two other examples:

```
xsize 2 div
```

denoting a length equal to half the horizontal size of the base, and

```
gsave fill grestore stroke
```

which both fills and strokes the path. Since Basser Lout does not check that the left parameter is valid PostScript, it is possible to cause mysterious errors in the printing device, resulting in no output, if an incorrect value is given. It is a good idea to encapsulate graphics objects in carefully tested definitions, like those of the Diag figure drawing package [5, Chapter 9], to be sure of avoiding these errors.

PostScript experts may find the following information helpful when designing advanced graphics features. The left parameter of @Graphic may have two parts, separated by //:

{ *first part* // *second part* } @Graphic *object*

If there is no //, the second part is taken to be empty. The PostScript output has the form

gsave
x y translate
Code which defines xsize, ysize, xmark, ymark, ft, vs, *and* sp
gsave
first part
grestore
Code which renders the right parameter in translated coordinates
second part
grestore

where *x*,*y* is the position of the lower left corner of the base. Having two parts permits bracketing operations, like save and restore or begin and end, to enclose an object. See the source file of the Diag package for examples.

3.44. @PlainGraphic

The @PlainGraphic symbol is avery rudimentary analogue for plain text output of the @Graphic symbol for PostScript output. Its result is its right parameter printed on a background created by repeated printings of its left parameter, which must be a simple word. For example,

"." @PlainGraphic 5s @Wide

would produce five dots. @PlainGraphic is used in the tbl table-drawing package to produce plain-text rules.

3.45. @IncludeGraphic and @SysIncludeGraphic

These symbols instruct Lout to incorporate a separately created illustration:

@IncludeGraphic "myportrait.eps"

The parameter is implementation-dependent; in Basser Lout it is an object whose value is a simple word denoting the name of a file. This file should ideally be a PostScript EPS Version 3.0 file [1], since then Lout will keep careful track of what resources are required for printing that file. However, any PostScript file containing the %%BoundingBox: comment and not requiring unusual resources is likely to work.

The result of @IncludeGraphic is an ordinary Lout object with marks through its centre. It may be rotated, scaled, and generally treated like any other object. Basser Lout determines its size by consulting the bounding box information in the file. If this cannot be found, a warning message is printed and the result object has zero size.

@IncludeGraphic searches the same directories that @Include does (Section 3.48). @SysIncludeGraphic is the same as @IncludeGraphic, except that it searches only the directories searched by @SysInclude.

If the file name ends in any of .gz, -gz, .z, -z, _z, or .Z, the file will first be uncompressed using the gunzip command into a temporary file called lout.eps in the current directory. This file is removed immediately after it is copied into the output file.

3.46. @IncludeGraphicRepeated and @SysIncludeGraphicRepeated

These symbols, which are allowed only at the start of a document, tell Lout that the EPS file named is likely to be included repeatedly:

```
@IncludeGraphicRepeated { myportrait.eps }
```

To actually see the graphic you use @IncludeGraphic as usual. The purpose of @IncludeGraphicRepeated is not to display the graphic but rather to instruct Lout to include its EPS file in the output file just once, at the start, rather than over and over again for every time it appears in an @IncludeGraphic, as would otherwise occur.

Any number of @IncludeGraphicRepeated and @SysIncludeGraphicRepeated directives may appear at the start of the document. The files involved may be compressed as for @IncludeGraphic. The file names given within @IncludeGraphicRepeated must be identical to the name used within the corresponding @IncludeGraphic symbols, or else the @IncludeGraphicRepeated will be ineffective. If @SysIncludeGraphicRepeated is used (as opposed to @IncludeGraphicRepeated) then all corresponding includes must use @SysIncludeGraphic rather than @IncludeGraphic.

Use of @IncludeGraphicRepeated does not change the appearance of the output at all, but, if the EPS file would otherwise be included many times over, the result will be a much shorter PostScript file which will usually print significantly faster as well. However, Lout uses Level 2 PostScript features to implement @IncludeGraphicRepeated, which may not be available in some old printers, and the contents of the EPS file have to be stored in the printer for the entire duration of the print job, so there is a risk that memory will run out if @IncludeGraphicRepeated is used.

The implementation of @IncludeGraphicRepeated uses code given by the authors of PostScript which employs PostScript forms to save the EPS files [2]. Lout's version of this code is somewhat modified, partly for simplicity and partly to correct a possible bug caused by their use of a single filter to read all the EPS files, rather than a separate filter for each one.

3.47. @PrependGraphic and @SysPrependGraphic

These symbols, which may appear anywhere that a definition or @Use symbol may appear, tell Lout to include the contents of a file in the preamble of its output. For Basser Lout this means that the file must contain PostScript (and ideally it would begin and end with the %%BeginResource and %%EndResource comments of DSC 3.0). For example,

```
@SysPrependGraphic { diagf.lpg }
```

appears at the start of the Diag package; the file diagf.lpg contains a number of PostScript definitions used by Diag for drawing diagrams. It saves a lot of space to include them just once at the start like this, rather than with every diagram. @PrependGraphic and @SysPrependGraphic search for the file in the same places as @Include and @SysInclude respectively.

If the same file name appears in two @PrependGraphic or @SysPrependGraphic symbols, the second occurrence is silently ignored. This allows several packages to share PostScript resources: each includes the appropriate prepend file, but in the end only one copy ot it is printed to Lout's output.

3.48. @Include and @SysInclude

These symbols instruct Lout to temporarily switch to reading another file, whose name appears in braces following the symbol. For example,

```
@Include { "/usr/lout/langdefs" }
```

will cause the contents of file /usr/lout/langdefs to be read at the point it occurs. After that file is read, the current file is resumed. The included file may contain arbitrary Lout text, including other @Include commands. The file is searched for first in the current directory, then in a sequence of standard places which are not necessarily the same places that databases are searched for. @SysInclude searches the standard places only.

From Version 3.27, a special behaviour has been instituted when an attempt is made to @Include or @SysInclude the same file twice. If a second or subsequent attempt occurs after the end of definitions, @Use clauses, and @Database clauses (i.e. if it occurs within the content of the document), it will go ahead, thus allowing the repeated inclusion of files containing objects – not necessarily recommended, but certainly one way of repeating information. But if a second or subsequent attempt occurs within the region of definitions, @Use clauses, and @Database clauses, then that attempt will be silently ignored.

This behaviour is useful for situations where two packages depend on a third, caled, say, C. We can then place

```
@SysInclude { C }
```

at the start of both packages. If neither package is included, then C won't be either. But if one or both is included, then C will be included just once at the start of the first. Any pattern of acyclic dependencies between packages can be expressed with this mechanism, just by including every package that a given package depends on at the start of the file containing that package. Cyclic dependencies are beyond Lout's one-pass comprehension anyway.

3.49. @BackEnd and the PlainText and PDF back ends

The @BackEnd symbol, which takes no parameters, has for its result a string naming the back end currently in use. Three back ends are available, PostScript, PDF and PlainText. The symbol is generally used like this:

```
@BackEnd @Case {
```

```
    PlainText @Yield { ... }
    PostScript @Yield { ... }
    PDF @Yield { ... }
}
```

to obtain different objects depending on the back end. No else is required since these are the only possible values.

When a @Case symbol has @BackEnd for its left parameter and the left parameter of each @Yield symbol within it consists of a sequence of one or more literal words (including else), Lout will optimize by evaluating the @Case symbol at the time it is read. This optimization ensures that there is only a small once-only performance penalty for multiple back ends, and it permits these @Case symbols (but no other symbols) to appear within the object following @Include and @PrependGraphic symbols.

The PlainText back end differs from the PostScript one in two main respects. First, there is effectively just one font: although all the font commands work exactly as usual, they don't actually change anything. Each character in this font is taken to be one tenth of one inch wide and 20 points high. Second, the output is an ordinary text file, not a PostScript file.

Clearly, with ordinary text output the possibility of advanced graphics features such as rotation and scaling is curtailed. Nevertheless, all symbols have well-defined (possibly null) effects in the PlainText back end, so there is no additional danger of crashing the system or obtaining grossly unreasonable output by a change to PlainText.

The PlainText back end is obtained by the -p option to Basser Lout. The character size can be changed by adding two lengths to the -p option, like this:

```
lout -p0.1i12p ...
```

which invokes the PlainText back end with each character being 0.1 inches wide and 12 points high. However, experience suggests that the best approach is to define all horizontal lengths as multiples of the s unit (the width of a space, hence the width of all characters) and to define all vertical lengths as multiples of the f unit (the font size, equal to the height of every character), and not to change the character size in the command line.

There is a -P option which is identical with the -p option except that it inserts a form-feed character between each two components of the output, but not before the first or after the last.

The PDF back end is obtained by typing lout -Z. It is similar to PostScript but much more limited in functionality. Consult a separate document distributed with Lout for further information.

3.50. @Verbatim and @RawVerbatim

These symbols instruct Lout to read the following text (enclosed in braces) verbatim, that is, turning off all special character meanings. For example,

```
@Verbatim { "hello" }
```

produces

"hello"

@Verbatim ignores all characters after the opening brace up to but not including the first non-white-space character. @RawVerbatim differs from @Verbatim only in that it ignores all characters after the opening brace up to but not including the first non-white-space character, or up to and including the first newline character, whichever comes first. This variant is useful in cases such as

```
@RawVerbatim {
    var x: Real
begin
}
```

where the first line of the verbatim text begins with white space which would be ignored by @Verbatim. Both symbols ignore all white spaces at the end of the verbatim text, preceding the closing brace.

3.51. @Underline

The @Underline symbol underlines its right parameter, but only if that parameter is a word or a paragraph:

```
We @Underline { really do } mean this.
```

produces

We <u>really do</u> mean this.

It is not possible to underline an arbitrary object using this symbol; the @Underline symbol will be ignored if this is attempted.

It is very easy to *define* a symbol which will underline an arbitrary object, using the @Graphic symbol. This raises the question of why @Underline is needed at all. The answer is that @Underline has two properties that distinguish it from symbols based on @Graphic.

First, when @Underline both contains a paragraph and is used within a paragraph, as in the example above, the inner and outer paragraphs are merged into one, permitting the underlined text to break over several lines. This is how the @Font symbol works too, but symbols based on @Graphic do not permit this merging.

Second, Adobe font files specify the correct position and thickness of underlining for each font, and the @Underline symbol follows these specifications. The font used is the font of the first object underlined, if it is a simple word, or else the font of the enclosing paragraph.

The colour of the underline is usually the same as the colour of the text being underlined, but this can be changed using the @SetUnderlineColour symbol (Section 3.9).

3.52. @PageLabel

The @PageLabel symbol associates a page label in the PostScript output file with the page within which (or just before which) the symbol occurs, so that PostScript viewers are able to

index the page by this label. (The label is printed in the %%Page comment preceding the page in the PostScript output file.) For example,

```
@PageLabel iv
```

associates the label iv with the page. The label may be an arbitrary object; if its value is not a simple word, it will be replaced by ?.

@PageLabel is unrelated to Lout's cross referencing mechanism; it is for communicating a label to the PostScript output file, not to other parts of Lout. The result of @PageLabel is a null object.

Chapter 4. Examples

This chapter presents some examples taken from the various packages available with Basser Lout. The reader who masters these examples will be well prepared to read the packages themselves. The examples have not been simplified in any way, since an important part of their purpose is to show Lout in actual practice.

Although all these examples have been taken from real code, they do not necessarily represent the current state of the Lout packages.

4.1. An equation formatting package

In this section we describe the design and implementation of the Eq equation formatting package. Equation formatting makes a natural first example, partly because its requirements have strongly influenced the design of Lout, and partly because no cross references or galleys are required.

To the author's knowledge, Eq is the first equation formatter to be implemented as a collection of high-level definitions. This approach has significant advantages: the basics of language and layout are trivial, so the implementor can concentrate on fine-tuning; and the definitions, being readily available, can be improved, extended, or even replaced.

As described in the User's Guide [5], an equation is entered in a format based on the one introduced by the eqn language of Kernighan and Cherry [3]:

```
@Eq { { x sup 2  +  y sup 2 }  over  2 }
```

The result is

$$\frac{x^2 + y^2}{2}$$

In outline, the definition of the @Eq symbol is

```
export  sup  over "+"  "2"  "<="
def @Eq
  body @Body
{
  def sup precedence 60 left x right y { ... }
  def over precedence 54 left x right y { ... }
  def "2" { Base @Font "2" }
  def "+" { {Symbol Base} @Font "+" }
  def "<=" { {Symbol Base} @Font "\243" }
  ...
```

```
    Slope @Font 1.2f @Break 0c @Space @Body
}
```

A body parameter is used to restrict the visibility of the equation formatting symbols (there are hundreds of them). The equation as a whole is set in Slope (i.e. Italic) font, and symbols such as "2" and "+" are defined when other fonts are needed. Precedences are used to resolve ambiguities such as a sup b over c. Eq takes all spacing decisions on itself, so to prevent white space typed by the user from interfering, the equation is enclosed in 0c @Space. We will discuss the 1.2f @Break later.

Thus have we disposed of the language design part of the equation formatting problem; it remains now to define the twenty or so symbols with parameters, and get the layout right.

Every equation has an *axis*: an imaginary horizontal line through the centre of variables, through the bar of built-up fractions, and so on. We can satisfy this requirement by ensuring that the result of each symbol has a single row mark, on the axis. For example, the superscripting symbol is defined as follows:

```
def sup
    precedence 60
    associativity left
    left x
    named gap { @SupGap }
    right y
{
    @HContract @VContract {
        |  @Smaller y
        ^/gap  x
    }
}
```

The @VContract and ^/ symbols together ensure that the axis of the result is the axis of the left parameter. A gap parameter has been provided for varying the height of the superscript, with default value @SupGap defined elsewhere as 0.40fk. It is important that such gaps be expressed in units that vary with the font size, so that they remain correct when the size changes. Collecting the default values into symbols like @SupGap ensures consistency and assists when tuning the values. Here is another characteristic definition:

```
def over
    precedence 54
    associativity left
    left x
    named gap { 0.2f }
    right y
{
    @HContract @VContract {
        |0.5rt  @OneCol x
        ^//gap  @HLine
        //gap  |0.5rt @OneCol y
```

```
    }
}
```

Both parameters are centred, since we do not know which will be the wider; we use @OneCol to make sure that the entire parameter is centred, not just its first column, and @HContract ensures that the fraction will never expand to fill all the available space, as Lout objects have a natural tendency to do (Section 2.6). @HLine is a horizontal line of the width of the column:

```
def @HLine
    named line { "0.05 ft setlinewidth" }
{
    { "0 0 moveto xsize 0 lineto" line "stroke" } @Graphic {}
}
```

Here we are relying on the expanding tendency just mentioned.

The remaining symbols are quite similar to these ones. We conclude with a few fine points of mathematical typesetting mentioned by a leading authority, D. E. Knuth [6].

Some symbols, such as ≤ and ≠, should have a thick space on each side; others, such as + and –, have a medium space; others have a thin space on the right only. This would be easy to do except that these spaces are not wanted in superscripts and subscripts:

$$r^{n+1} - 1$$

In effect, the definition of such symbols changes depending on the context; but Lout does not permit such a change. Luckily, the so-called 'style' information set by the @Font, @Break, and @Space symbols can change in this way. Accordingly, Eq uses the y unit, which is part of style, for these spaces:

```
def @MedGap { 0.20y }

def "+" { &@MedGap plus &@MedGap }

def @HSqueeze right x { 0.2f @YUnit x }
```

In the equation as a whole, the y unit is initially set to 1f, and so @MedGap ordinarily supplies 20% of this amount. But superscripts and subscripts are enclosed in the @HSqueeze symbol, which, by changing the y unit, ensures that any @MedGap within them is much smaller than usual.

4.2. Paragraphs, displays, and lists

The remaining sections of this chapter are all based on Version 2 of the DocumentLayout package. Version 3, which is similar but more elaborate, is described from the user's perspective in the User's Guide [5]. In 26 pages of Lout, the DocumentLaytout package defines many features required in the formatting of simple documents, technical reports, and books, including displays, lists, page layout, cross references, tables of contents, footnotes, figures, tables, references, chapters, sections, and sorted indexes.

The symbols used for separating paragraphs and producing displays and lists may lack the excitement of more exotic features, but they can teach some important lessons about robust design. The following macro for separating paragraphs produces a 0.3 cm vertical space and a 1 cm indent on the following line, and is clearly on the right track:

```
macro @PP { //0.3c &1c }
```

Nevertheless it has several major problems.

The & symbol is subject to widening during line adjustment, so it should be replaced by 1c @Wide {}. But then white space following the symbol will affect the result, so an extra &0i must be added. If the document is printed double spaced, this paragraph gap will fail to widen: it should be expressed in terms of the v unit, with mark-to-mark spacing mode. Similarly, the paragraph indent should probably be made proportional to the font size.

'Magic numbers' like 0.3c should not be buried in definitions where they cannot be changed easily, or kept consistent with similar definitions during tuning. They are much better placed as symbols, possibly parameters of the enclosing package:

```
def @DocumentLayout
   named @ParaGap { 1.3vx }
   named @ParaIndent { 2f }
   ...
@Begin

   macro @PP { //@ParaGap @ParaIndent @Wide &0i }
   macro @LP { //@ParaGap }
   ...
@End @DocumentLayout
```

and we have arrived at the definition of @PP as it appears in the DocumentLayout package.

A display is a table in which the first column is blank:

preceding text
//@DispGap |@DispIndent *display*
//@DispGap
following text

Edge-to-edge is the appropriate spacing mode before and after displays, since the display could be a table or figure whose mark does not correspond to a baseline. Thus, 1v is a reasonable value for @DispGap.

The ordinary user cannot be expected to type the Lout source shown above; a more appropriate syntax is

preceding text
@IndentedDisplay { *display* }
following text

This presents a problem: if @IndentedDisplay is made a definition with a right parameter, its

result will be an object separated from the surrounding text only by white space, hence part of the paragraph; while if it is a macro, the final //@DispGap cannot be included in it. The solution adopted in the DocumentLayout package uses a galley and a macro:

```
def @DispPlace { @Galley }
def @Disp into { @DispPlace&&preceding }
   right x
{
   @OneRow x
}

macro @IndentedDisplay
{
   //@DispGap |@DispIndent @DispPlace |
   //@DispGap // @Disp
}
```

@DispPlace and @Disp are not exported, so there is no danger of a name clash with some other symbol. The ordinary user's syntax expands to

preceding text
//@DispGap |@DispIndent @DispPlace |
//@DispGap // @Disp { *display* }
following text

and the @Disp galley appears at the preceding @DispPlace, being itself replaced by @Null. The // symbol protects the preceding //@DispGap from being deleted by this @Null when there is no following text.

An automatically numbered list could have an arbitrarily large number of items, so, by analogy with sequences of pages, we see immmediately that recursion must be involved:

```
def @List right num
{
   @DispIndent @Wide num. | @ItemPlace
   //@DispGap @List @Next num
}
```

Notice how the @Next symbol works in conjunction with the recursion to produce an ascending sequence of numbers; the result of @List 1 will be

1. @ItemPlace
2. @ItemPlace
3. @ItemPlace

...

We can follow this with items which are galleys targeted to @ItemPlace&&preceding, and @List will expand just enough to accommodate them.

The usual problem with recursive-receptive symbols now arises: there is always one unex-

panded @List, and until it can be removed the galley containing it will appear to be incomplete and will be prevented at that point from flushing into its parent (see page 30). We adopt the usual solution: a forcing galley into a later target will replace the last @List by @Null. This brings us to the definitions as they appear in DocumentLayout:

```
def @ItemPlace { @Galley }
def @ListItem into { @ItemPlace&&preceding }
   right x
{ x }

def @EndListPlace { @Galley }
def @EndList force into { @EndListPlace&&preceding }
{}

def @RawIndentedList
  named style right tag {}
  named indent { @DispIndent }
  named gap { @DispGap }
  named start { 1 }
{
   def @IList right num
   {
      indent @Wide {style num} | @ItemPlace
      //gap @IList @Next num
   }

   @IList start  //  @EndListPlace
}
```

Now given the input

```
@RawIndentedList
@ListItem { first item }
@ListItem { second item }
...
@ListItem { last item }
@EndList
```

@RawIndentedList will expand to receive the items, and will be closed off by @EndList.

The indent, gap, and start parameters are straightforward (note that the burden of typing 1 has been lifted from the ordinary user), but the style parameter has a parameter of its own (see page 17). It is used like this:

```
def @RawNumberedList { @RawIndentedList style { tag. } }
def @RawParenNumberedList { @RawIndentedList style { (tag) } }
```

In @RawNumberedList, style is given the value tag., where tag is its own right parameter, so the value of {style num} within @IList is num.; while in @RawParenNumberedList, {style num}

is (num). In this way we achieve an unlimited variety of numbering formats without having to rewrite @RawIndentedList over and over.

These list symbols are objects without surrounding space, so macros similar to those used for displays are needed:

```
macro @NumberedList { //@DispGap @RawNumberedList //@DispGap }
macro @ParenNumberedList { //@DispGap @RawParenNumberedList //@DispGap }
```

and so on.

Lists numbered by Roman numerals present a problem, because @Next will not increment Roman numerals. Instead, they must be stored in a database:

```
def @Roman
   left @Tag
   right @Val
{ @Val }

@SysDatabase @Roman { standard }
```

@SysDatabase is preferred over @Database here because this database should be kept in a standard place and shared by everyone. The database itself, a file called standard.ld in Basser Lout, contains invocations of @Roman, each enclosed in braces:

```
{ 1 @Roman i }
{ 2 @Roman ii }
...
{ 100 @Roman c }
```

Then @Roman&&12 for example has value xii, and

```
def @RawRomanList { @RawIndentedList style { {@Roman&&tag}. } }
```

produces a list numbered by Roman numerals. The counting still proceeds in Arabic, but each Arabic numeral is converted to Roman by the cross reference. Since arbitrary objects may be stored in databases, arbitrary finite sequences of objects may be 'counted' in this way.

4.3. Page layout

The page layout definitions given in Section 1.2, although correct, are very basic. In this section we present the definitions used by the DocumentLayout package for laying out the pages of books, including running page headers and footers, different formats for odd and even pages, and so on. The present document is produced with these definitions.

We begin with a few definitions which permit the user to create cross references of the 'see page 27' variety which will be kept up to date automatically. The user marks the target page by placing @PageMark intro, for example, at the point of interest, and refers to the marked page as @PageOf intro elsewhere:

```
export @Tag
def @PageMarker right @Tag { @Null }

def @PageMark right x
{
   @PageMarker&&preceding @Tagged x
}

def @PageOf right x
{
   @PageMarker&&x @Open { @Tag }
}
```

We will see below that an invocation of @PageMarker appears before each page, with @Tag parameter equal to the page number. Suppose that @PageMark intro, which expands to

```
@PageMarker&&preceding @Tagged intro
```

happens to fall on page 27 of the final printed document (of course, its value is @Null which makes it invisible). Then the effect of @Tagged is to attach intro as an extra tag to the first invocation of @PageMarker preceding that final point, and this must be @PageMarker 27. Therefore the expression

```
@PageMarker&&intro @Open { @Tag }
```

will open the invocation @PageMarker 27 and yield the value of its @Tag parameter, 27. Thus, @PageOf intro appearing anywhere in the document yields 27.

Next we have some little definitions for various parts of the page. @FullPlace will be the target of full-width body text:

```
def @FullPlace { @Galley }
```

@ColPlace will be the target of body text within one column:

```
def @ColPlace { @Galley }
```

@TopList will be the target of figures and tables:

```
export @Tag
def @TopList right @Tag
{
   @Galley
   //@TopGap @TopList @Next @Tag
}
```

We have taken a shortcut here, avoiding an unnecessary @TopPlace symbol. @FootList and @FootSect define a sequence of full-width targets at the foot of the page for footnotes, preceded by a short horizontal line:

```
export @Tag
```

```
def @FootList right @Tag
{
   @Galley
   //@FootGap  @FootList @Next @Tag
}

def @FootSect
{
   @FootLen @Wide @HLine
   //@FootGap  @FootList 1  ||@FootLen
}
```

Similarly, @ColFootList and @ColFootSect provide a sequence of targets for footnotes within one column:

```
export @Tag
def @ColFootList right @Tag
{
   @Galley
   //@FootGap  @ColFootList @Next @Tag
}

def @ColFootSect
{
   @ColFootLen @Wide @HLine
   //@FootGap  @ColFootList 1  ||@ColFootLen
}
```

The next definition provides a horizontal sequence of one or more columns:

```
def @ColList right col
{
   def @Column
   {  @VExpand { @ColPlace //1rt @OneRow { //@MidGap @ColFootSect } }  }

   col @Case {
      Single @Yield @Column
      Double @Yield { @DoubleColWidth @Wide @Column  ||@ColGap  @ColList col }
      Multi  @Yield { @MultiColWidth @Wide @Column  ||@ColGap  @ColList col }
   }
}
```

Each column consists of a @ColPlace at the top and a @FootSect at the foot. The @VExpand symbol ensures that whenever a column comes into existence, it will expand vertically so that the bottom-justification //1rt has as much space as possible to work within. The col parameter determines whether the result has a single column, double columns, or multiple columns.

The @Page symbol places its parameter in a page of fixed width, height, and margins:

```
def @Page right x
{
   @PageWidth @Wide @PageHeight @High {
      //@PageMargin  ||@PageMargin
      @HExpand @VExpand x
      ||@PageMargin  //@PageMargin
   }
}
```

@HExpand and @VExpand ensure that the right parameter occupies all the available space; this is important when the right parameter is unusually small. The @High symbol gives the page a single row mark, ensuring that it will be printed on a single sheet of paper (page 30).

Next we have @OnePage, defining a typical page of a book or other document:

```
def @OnePage
   named @Columns {}
   named @PageTop {}
   named @PageFoot {}
{
   @Page {
      @PageTop
      //@MidGap  @TopList
      //@MidGap  @FullPlace
      //@MidGap  @ColList @Columns
      // //1rt   @OneRow { //@MidGap @FootSect //@MidGap @PageFoot }
   }
}
```

The page top and page foot, and the number of columns, are parameters that will be given later when @OnePage is invoked. The body of the page is a straightforward combination of previous definitions. The // symbol protects the following //1rt from deletion in the unlikely event that all the preceding symbols are replaced by @Null. The following object is enclosed in @OneRow to ensure that all of it is bottom-justified, not just its first component.

Before presenting the definition of a sequence of pages, we must detour to describe how running page headers and footers (like those in the present document) are produced. These are based on the @Runner symbol:

```
export @TopOdd @TopEven @FootOdd @FootEven
def @Runner
   named @TopOdd right @PageNum { @Null }
   named @TopEven right @PageNum { @Null }
   named @FootOdd right @PageNum { @Null }
   named @FootEven right @PageNum { @Null }
   named @Tag {}
{ @Null }
```

The four parameters control the format of running headers and footers on odd and even pages

respectively. Invocations of @Runner, for example

```
@Runner
   @TopEven { @B @PageNum |1rt @I { Chapter 4 } }
   @TopOdd  { @I { Examples }  |1rt @B @PageNum }
```

will be embedded in the body text of the document, and, as we will see in a moment, are accessed by @Runner&&following cross references on the pages. Notice how the @PageNum parameter of each parameter allows the format of the running header to be specified while leaving the page number to be substituted later.

We may now define @OddPageList, whose result is a sequence of pages beginning with an odd-numbered page:

```
def @OddPageList
   named @Columns {}
   right @PageNum
{
   def @EvenPageList ...

      @PageMarker @PageNum
   //  @Runner&&following @Open {
         @OnePage
            @Columns { @Columns }
            @PageTop { @TopOdd @PageNum }
            @PageFoot { @FootOdd @PageNum }
      }
   //  @EvenPageList
         @Columns { @Columns }
         @Next @PageNum
}
```

Ignoring @EvenPageList for the moment, notice first that the invocation of @OnePage is enclosed in @Runner&&following @Open. Since @Runner&&following refers to the first invocation of @Runner appearing after itself in the final printed document, the symbols @TopOdd and @FootOdd will take their value from the first invocation of @Runner following the top of the page, even though @FootOdd appears at the foot of the page. Their @PageNum parameters are replaced by @PageNum, the actual page number parameter of @OddPageList.

After producing the odd-numbered page, @OddPageList invokes @EvenPageList:

```
def @EvenPageList
   named @Columns {}
   right @PageNum
{
      @PageMarker @PageNum
   //  @Runner&&following @Open {
         @OnePage
            @Columns { @Columns }
```

```
            @PageTop { @TopEven @PageNum }
            @PageFoot { @FootEven @PageNum }
        }
    // @OddPageList
        @Columns { @Columns }
        @Next @PageNum
}
```

This produces an even-numbered page, then passes the ball back to @OddPageList – a delightful example of what computer scientists call mutual recursion. The two page types differ only in their running headers and footers, but other changes could easily be made.

It was foreshadowed earlier that an invocation of @PageMarker would precede each page, and this has been done. Although this @PageMarker is a component of the root galley, it will not cause a page to be printed, because Basser Lout skips components of height zero.

4.4. Chapters and sections

The definitions of chapters and sections from the DocumentSetup package of Version 2 (in Version 3, the BookSetup extension of DocumentSetup) form the subject of this section. They allow a chapter to be entered like this:

```
@Chapter
  @Title { ... }
  @Tag { ... }
@Begin
  ...
@End @Chapter
```

Within the chapter a sequence of sections may be included by writing

```
@BeginSections
@Section { ... }
...
@Section { ... }
@EndSections
```

These are numbered automatically, and an entry is made for each in a table of contents.

The user of the DocumentSetup package can find the number of the chapter or section with a given tag by writing @NumberOf tag at any point in the document. This feature is based on the following definitions:

```
export @Tag
def @NumberMarker right @Tag { @Null }

def @NumberOf right x
{  @NumberMarker&&x @Open { @Tag }  }
```

Each chapter and section will contain one invocation of @NumberMarker; a full explanation will be given later.

A sequence of places for receiving chapters is easily defined:

```
export @Tag
def @ChapterList right @Tag
{
   @Galley
   //@ChapterGap  @ChapterList @Next @Tag
}
```

@ChapterGap will usually be 1.1b, ensuring that each chapter begins on a new page. The @Chapter galley itself is defined as follows:

```
export @FootNote @BeginSections @EndSections @Section
def @Chapter force into { @ChapterList&&preceding }
   named @Tag {}
   named @Title {}
   named @RunningTitle { dft }
   body @Body
{
   def @FootNote right x { @ColFootNote x }

   def @BeginSections ...
   def @EndSections ...
   def @Section ...

   def @ChapterTitle
   {
      @ChapterNumbers @Case {
         {Yes yes}  @Yield  { Chapter {@NumberOf @Tag}.  |2s  @Title }
         else  @Yield  @Title
      }
   }

   def @ChapterNum
   {
      @ChapterNumbers @Case {
         {Yes yes}  @Yield  { Chapter {@NumberOf @Tag} }
         else  @Yield @Null
      }
   }

      ragged @Break @BookTitleFormat @ChapterTitle
   //  @NumberMarker {
         @ChapterList&&@Tag @Open { @Tag }
      }
```

```
    //  @ChapterList&&preceding  @Tagged @Tag
    //  @NumberMarker&&preceding @Tagged @Tag
    //  @PageMarker&&preceding   @Tagged @Tag
    //  { @ChapterTitle } @MajorContentsEntry {@PageOf @Tag}
    //  @Runner
          @FootEven { |0.5rt 0.8f @Font @B @PageNum }
          @FootOdd  { |0.5rt 0.8f @Font @B @PageNum }
    //  @Body
    //@SectionGap @ChapRefSection
    //  @Runner
          @TopEven { @B @PageNum |1rt @I @ChapterNum }
          @TopOdd  { @I {@RunningTitle @OrElse @Title} |1rt @B @PageNum }
}
```

We will see the symbols for sections shortly. Notice how their use has been restricted to within the right parameter of @Chapter, by nesting them and using a body parameter.

The meaning of @FootNote within @Chapter has been set to @ColFootNote, which produces a footnote targeted to @ColFootList (see Section 4.3). In other words, footnotes within chapters go at the foot of the column, not at the foot of the page. (Of course, in single-column books this distinction is insignificant.) @ChapterTitle and @ChapterNum are trivial definitions which vary depending on whether the user has requested numbered chapters or not.

Each invocation of @Chapter has its own unique @Tag, either supplied by the user or else inserted automatically by Lout. We now trace the cross referencing of chapter numbers on a hypothetical third chapter whose tag is euclid.

@ChapterList&&preceding @Tagged euclid attaches euclid as an extra tag to the first invocation of @ChapterList preceding itself in the final printed document. But this @ChapterList must be the target of the chapter, and so

```
@ChapterList&&euclid @Open { @Tag }
```

is 3, the number of the chapter (@Tag refers to the parameter of @ChapterList, not the parameter of @Chapter). Consequently the invocation of @NumberMarker within the chapter is equal to @NumberMarker 3.

@NumberMarker&&preceding @Tagged euclid attaches euclid to @NumberMarker 3 as an extra tag, and so @NumberOf euclid, which expands to

```
@NumberMarker&&euclid @Open { @Tag }
```

must be equal to 3, as required. This scheme could be simplified by placing the invocation of @NumberMarker within @ChapterList rather than within @Chapter, but it turns out that that scheme does not generalize well to sections and subsections.

There is a trap for the unwary in the use of preceding and following. Suppose that the invocation of @NumberMarker within @Chapter is replaced by the seemingly equivalent

```
@NumberMarker { @ChapterList&&preceding @Open { @Tag } }
```

Now suppose that @NumberOf euclid appears somewhere within Chapter 7. It will expand to

```
@NumberMarker&&euclid @Open { @Tag }
```

which would now be equal to

```
@ChapterList&&preceding @Open { @Tag }
```

whose value, evaluated as it is within Chapter 7, is 7, not 3. Use of preceding or following within the parameter of a symbol, rather than within the body, is likely to be erroneous.

Much of the remainder of the definition of @Chapter is fairly self-explanatory: there is a heading, a tag sent to mark the page on which the chapter begins, a @ContentsEntry galley sent to the table of contents, galleys for the figures and tables of the chapter to collect in, @Body where the body of the chapter goes, and @ChapRefSection to hold a concluding list of references. This leaves only the two invocations of @Runner to explain.

The first @Runner is just below the heading. It will be the target of the @Runner&&following cross reference at the beginning of the first page of the chapter (see Section 4.3), which consequently will have null running headers and the given footers.

The second @Runner appears at the very end of the chapter, hence on its last page. Since no invocations of @Runner lie between it and the first @Runner, it will be the target of @Runner&&following on every page from the second page of the chapter to the last, inclusive, and will supply the format of their headers and footers.

The interested reader might care to predict the outcome in unusual cases, such as when the heading occupies two pages, or when a chapter occupies only one, or (assuming a change to the gap between chapters) when a chapter starts halfway down a page. Such predictions can be made with great confidence.

The expression @RunningTitle @OrElse @Title appearing in the second @Runner returns the value of the @RunningTitle parameter of @Chapter if this is not equal to the default value dft, or @Title otherwise:

```
def @OrElse
   left x
   right y
{
   x @Case {
      dft  @Yield  y
      else  @Yield  x
   }
}
```

This produces the effect of

```
named  @RunningTitle  {  @Title  }
```

which unfortunately is not permissible as it stands, because @Title is not visible within the default value of @RunningTitle.

Finally, the definitions for sections omitted earlier are as follows:

```
def @EndSectionsPlace { @Galley }
```

```
def @EndSections force into { @EndSectionsPlace&&preceding } {}
macro @BeginSections { //@SectionGap @SectionList 1 // @EndSectionsPlace // }

def @Section force into { @SectionList&&preceding }
   named @Tag {}
   named @Title {}
   named @RunningTitle { dft }
   body @Body
{
   def @SectionTitle
   {
      @SectionNumbers @Case {
         {Yes yes} @Yield { {@NumberOf @Tag}.  |2s  @Title }
         else      @Yield @Title
      }
   }

      @Heading @Protect @SectionTitle
   //  @NumberMarker {
         {@ChapterList&&@Tag @Open { @Tag }}.{
          @SectionList&&@Tag @Open { @Tag }}
      }
   //  @ChapterList&&preceding  @Tagged @Tag
   //  @SectionList&&preceding  @Tagged @Tag
   //  @NumberMarker&&preceding @Tagged @Tag
   //  @PageMarker&&preceding   @Tagged @Tag
   //  { &3f @SectionTitle } @ContentsEntry {@PageOf @Tag}
   //0io @Body
}
```

The @BeginSections macro invokes @SectionList, preceded by the appropriate gap and followed by an @EndSectsPlace for closing the list of sections when the @EndSections symbol is found. @Section itself is just a copy of @Chapter with slight changes to the format. The parameter of @NumberMarker is a simple generalization of the one within @Chapter. Notice that we have taken care that the value of this parameter be a juxtaposition of simple words: although

```
{@ChapterList&&@Tag @Open { @Tag }}. &
{@SectionList&&@Tag @Open { @Tag }}
```

is formally equivalent, & was not permitted within a @Tag parameter until recently.

The DocumentSetup package also contains definitions for subsections in the same style. They raise the question of whether Lout is capable of producing subsections should the user place @BeginSections, @Section, and @EndSections within a *section*, and whether such nesting could proceed to arbitrary depth. Arbitrary nesting of sections within sections is available now, although the numbering would of course be wrong. The author has worked out definitions which provide correct numbering to arbitrary depth, with an arbitrary format for each level. These were not incorporated into DocumentSetup because the author considers sub-subsections to be poor

style, and he prefers separate names for the symbols at each level.

4.5. Bibliographies

The first step in the production of a bibliography is to create a database of references based on the definition

```
export @Type @Author @Title @Institution @Number @Publisher
    @Year @Proceedings @Journal @Volume @Pages @Comment

def @Reference
  named @Tag          { TAG? }
  named @Type         { TYPE? }
  named @Author       { AUTHOR? }
  named @Title        { TITLE? }
  named @Institution  { INSTITUTION? }
  named @Number       { NUMBER? }
  named @Publisher    { PUBLISHER? }
  named @Year         { YEAR? }
  named @Proceedings  { PROCEEDINGS? }
  named @Journal      { JOURNAL? }
  named @Volume       { VOLUME? }
  named @Pages        { PAGES? }
  named @Comment      { @Null }
{ @Null }
```

For example, the database might contain

```
{ @Reference
    @Tag { strunk1979style }
    @Type { Book }
    @Author { Strunk, William and White, E. B. }
    @Title { The Elements of Style }
    @Publisher { MacMillan, third edition }
    @Year { 1979 }
}

{ @Reference
    @Tag { kingston92 }
    @Type { TechReport }
    @Author { Kingston, Jeffrey H. }
    @Title { Document Formatting with Lout (Second Edition) }
    @Number { 449 }
    @Institution { Basser Department of Computer
Science F09, University of Sydney 2006, Australia }
    @Year { 1992 }
}
```

Since named parameters are optional, we have one for every conceivable type of attribute, and simply leave out those that do not apply in any particular reference. We can print a reference by using the @Open symbol to get at its attributes:

```
@Reference&&strunk1979style @Open
{ @Author, {Slope @Font @Title}. @Publisher, @Year. }
```

The right parameter of @Open may use the exported parameters of the left, and so the result is

William Strunk and E. B. White, *The Elements of Style.* Macmillan, 1979.

Incidentally, we are not limited to just one database of references; several @Database symbols can nominate the same symbol, and invocations of that symbol can appear in the document itself as well if we wish.

The second step is to create a database of print styles for the various types of reference (Book, TechReport, etc.), based on the following definition:

```
export @Style
def @RefStyle
  left @Tag
  named @Style right reftag {}
{}
```

Notice that the named parameter @Style has a right parameter reftag. The style database has one entry for each type of reference:

```
{ Book @RefStyle @Style
 { @Reference&&reftag @Open
   { @Author, {Slope @Font @Title}. @Publisher, @Year. @Comment }
 }
}

{ TechReport @RefStyle @Style
 { @Reference&&reftag @Open
   { @Author, {Slope @Font @Title}. Tech. Rep. @Number (@Year),
@Institution. @Comment }
 }
}
```

and so on. The following prints the reference whose tag is strunk1979style in the Book style:

```
@RefStyle&&Book @Open { @Style strunk1979style }
```

It has result

William Strunk and E. B. White. *The Elements of Style.* Macmillan. Third Edition, 1979.

Notice how the @Style parameter of @RefStyle is given the parameter strunk1979style, which it uses to open the appropriate reference.

We can consult the @Type attribute of a reference to find out its style, which brings us to the following definition for printing out a reference in the style appropriate to it:

```
def @RefPrint
  right reftag
{  @RefStyle&&{ @Reference&&reftag @Open { @Type } }
  @Open { @Style reftag }
}
```

For example, to evaluate @RefPrint strunk1979style, Lout first evaluates

```
@Reference&&strunk1979style  @Open  { @Type }
```

whose result is Book, and then evaluates

```
@RefStyle&&Book @Open { @Style strunk1979style }
```

as before. Complicated as this is, with its two databases and clever passing about of tags, the advantages of separating references from printing styles are considerable: printing styles may be changed easily, and non-expert users need never see them.

Finally, we come to the problem of printing out a numbered list of references, and referring to them by number in the body of the document. The first step is to create a numbered list of places that galleys containing references may attach to:

```
def @ReferenceSection
   named @Tag {}
   named @Title { References }
   named @RunningTitle { dft }
   named style right tag { tag. }
   named headstyle right @Title { @Heading @Title }
   named indent { @DispIndent }
   named gap { @DispGap }
   named start { 1 }
{
   def @RefList right num
   {
      @NumberMarker num  &  indent @Wide {style num}  |  @RefPlace
      //gap @RefList @Next num
   }

      @Protect headstyle @Title
   //  @PageMarker&&preceding @Tagged @Tag
   //  @Title @MajorContentsEntry {@PageOf @Tag}
   //  @Runner
         @FootEven { |0.5rt 0.8f @Font @B @PageNum }
         @FootOdd  { |0.5rt 0.8f @Font @B @PageNum }
   //@DispGap  @RefList start
   //  @Runner
```

```
        @TopEven { @B @PageNum }
        @TopOdd  { @I {@RunningTitle @OrElse @Title} |1rt @B @PageNum }
}
```

We place the expression @ReferenceSection at the point where we want the list of references to appear; its value is something like

1. @RefPlace
2. @RefPlace
3. @RefPlace

...

where @RefPlace is @Galley as usual. We can scatter multiple lists of references through the document if we wish (at the end of each chapter, for example), simply by placing @ReferenceSection at each point.

Our task is completed by the following definition:

```
def @Ref right x
{
   def sendref into { @RefPlace&&following }
      right @Key
   {
      @NumberMarker&&preceding @Tagged x  &
      @PageMarker&&preceding @Tagged x  &
      @RefPrint x
   }

   @NumberMarker&&x @Open { @Tag } sendref x
}
```

Given this definition, the invocation @Ref strunk1979style has result

```
@NumberMarker&&strunk1979style @Open { @Tag }
```

plus the galley sendref strunk1979style. We first follow what happens to the galley.

According to its into clause, the galley will replace a @RefPlace in the nearest following @ReferenceSection. If every such galley is a sorted galley whose key is the reference's tag, as this one is, they will appear sorted by tag. The galley's object is

```
@NumberMarker&&preceding @Tagged strunk1979style  &
@PageMarker&&preceding @Tagged strunk1979style  &
@RefPrint strunk1979style
```

The result of the @Tagged symbol is always @Null, so this prints the strunk1979style reference in the appropriate style at the @RefPlace, as desired.

Now @NumberMarker&&preceding is the nearest preceding invocation of @NumberMarker in the final document. This must be the invocation of @NumberMarker just before the @RefPlace that received the galley, and so this invocation of @NumberMarker is given

strunk1979style as an additional tag by the @Tagged symbol. Its original tag was the number of the reference place, which means that

```
@NumberMarker&&strunk1979style @Open { @Tag }
```

has for its result the number of the reference place that received the strunk1979style galley, and this is the desired result of @Ref strunk1979style.

It might seem that if we refer to the strunk1979style reference twice, two copies will be sent to the reference list and it will appear twice. However, when more than one sorted galley with the same key is sent to the same place, only one of them is printed (Section 1.4); so provided that sorted galleys are used there is no problem.

4.6. Merged index entries

Getting index entries to merge correctly has been quite a struggle. It is easy to specify what is wanted, but Lout lacks the lists and objects (in the object-oriented sense) that would make the implementation straightforward. The whole problem was reanalysed for Version 3.26, reimplemented, tested more carefully than is usually necessary in Lout, and proved correct as follows.

We ignore page number ranges in this proof. It is not hard to show that they will be handled correctly too, provided they do not overlap with other entries with the same key. The effect of such overlaps is undefined, leaving us nothing to prove. We also assume that every entry with a given key has the same label, including any format (that is, the same initial part before the page number). If labels differ the result is undefined and there is nothing to prove.

We will prove that raw entries always have the form

```
label &0.03fu {}
```

and that non-raw entries always have the form

```
label &0.03fu {}{@OneCol ,} pn1{@OneCol ,} pn2
```

where the pattern may repeat for any number of page numbers pn1, pn2, etc. In addition, the page numbers will be distinct, monotone increasing, and consist of exactly the numbers in the original unmerged entries.

These expressions are not the simplest that would give the correct appearance. Without &0.03fu {} the code would not work correctly, as will be explained below. Without @OneCol the commas would be subject to an optimization which can merge them into the previous word. It's too difficult to explain when this optimization will and will not be applied; suffice to say that it will sometimes not happen when melding, and this will cause @Meld to get its equality testing wrong, so it must be prevented from happening at all.

Our proof is by induction on the number of entries merged together. First, we need to establish the base cases. If the index entry is raw, the following expression is used to define its value:

```
label &0.03fu {}
```

If the index entry is non-raw, the following expression is used to define its value:

```
label &0.03fu {}{@OneCol ,} pn
```

where pn is the page number or page number range of the entry. In each case we clearly have an entry that satisfies all the requirements of the theorem.

Now consider what happens when we come to merge two entries. The code used to carry out this merge is

```
def @Merge left x right y
{
   { x @Rump { x @Meld y } } @Case
   {
      ""   @Yield  x
      else @Yield  { { x{@OneCol ,} } @Meld y }
   }

}
```

where x is the first entry and y is the second.

We call the expression

```
x @Rump { x @Meld y }
```

the *discriminant*, since it determines which case to apply. We will track this in detail below, but approximately, its function is to determine whether y contains something that is different from anything in x. If so, then x @Meld y differs from x and the discriminant is non-empty; if not, x @Meld y is equal to x and the discriminant is empty.

The first entry, x, may be raw or non-raw, and the second, y, may also be raw or non-raw, together giving four cases, which we take in turn.

If both entries are raw, then by assumption they have the same labels and so are identical. Thus, x @Meld y equals x, the discriminant is empty, and the result is x, which is correct.

If x is raw and y is non-raw, then the discriminant is non-empty and the result is the meld of two objects, the first having the form

```
label &0.03fu {}{@OneCol ,}
```

being x with a comma appended, and the second being some non-raw entry such as

```
label &0.03fu {}{@OneCol ,} pn1{@OneCol ,} pn2
```

where the pattern may repeat. We are assuming by induction that y has this form. Clearly, this meld gives a value equal to y, which is the correct result.

If x is non-raw and y is raw, the @Meld in the discriminant melds two values typified by

```
label &0.03fu {}{@OneCol ,} pn1{@OneCol ,} pn2
```

and

```
label &0.03fu {}
```

The result of this is x with an empty object added at the end. This empty object is the second element of y, which is not equal to any element of x: the second element of x is not {} but rather {}{@OneCol ,}, because @Meld treats immediately adjacent objects as single elements. The result of @Rump is then this extra empty object, so the discriminant is the empty object and we return x, correctly. It is this case that requires us to use 0.03fu; without it we would be melding

```
label{@OneCol ,} pn1{@OneCol ,} pn2
```

with

```
label
```

producing

```
label{@OneCol ,} pn1{@OneCol ,} pn2 label
```

leading to a non-empty discriminant and the wrong answer.

This leaves just the case where both x and y are non-raw. We will divide this last case into three sub-cases, but first we need some general observations.

Index entries are sorted for merging in the order in which their anchor points appear in the final printed document. This means that over the course of these entries the page numbers are non-decreasing. It is therefore clear that, although the order of merging is undefined (actually a balanced tree order is used), whenever two entries are presented for merging, all the page numbers in the first entry are no larger than all the page numbers in the second entry. We are also assuming inductively that the page numbers in each entry are distinct and monotone increasing. Thus, there can be at most one page number common to any two entries being merged, and if there is one in common it is the last page number of the first entry and the first of the second.

Our first sub-case is when the two entries have no page number in common. Since y is non-raw, it has a page number not equal to any page number in x. Therefore the discriminant is non-empty and the result is the meld of x{@OneCol ,} with y, which for example could be the meld of

```
label &0.03fu {}{@OneCol ,} pn1{@OneCol ,} pn2{@OneCol ,}
```

with

```
label &0.03fu {}{@OneCol ,} pn3{@OneCol ,} pn4
```

This will give the right answer, since @Meld treats adjacent objects as single elements, and always incorporates elements from the first parameter first when it has a choice.

Our second sub-case is when the two entries have a page number in common and y has two or more page numbers. The common page number must be the last of x and the first of y, so again y has something (its last page number) distinct from x, the discriminant is non-empty, and we end up for example melding

```
label &0.03fu {}{@OneCol ,} pn1{@OneCol ,} pn2{@OneCol ,}
```

with

```
label &0.03fu {}{@OneCol ,} pn2{@OneCol ,} pn3
```

Again it's clear that the meld will produce the right answer; in fact, this second sub-case could be unified with the first sub-case.

Our third sub-case is when the two entries have a page number in common and y has only one page number. In this case, typified by x with value

```
label &0.03fu {}{@OneCol ,} pn1{@OneCol ,} pn2
```

and y with value

```
label &0.03fu {}{@OneCol ,} pn2
```

it is clear that y offers nothing new, the discriminant is empty, and the result, quite correctly, is x. This completes the proof.

Appendix A. Implementation of Textures

The following notes detail how PostScript patterns have been used to produce textures. See the PostScript Language Reference Manual, second edition (PLRM), especially Section 4.9.

PostScript patterns are implemented as color spaces, whereas from a logical point of view they are really separate entities in the graphics state, independent of color (except that a colored texture overrides any current color while it is in effect). To ensure that Lout's @SetTexture and @SetColour symbols have this desired independence of each other, the following operators are defined in the Lout prologue:

Lout-defined operator			*What it replaces*
num	LoutSetGray	-	setgray
num num num	LoutSetRGBColor	-	setrgbcolor
num num num	LoutSetHSBColor	-	sethsbcolor
num num num num	LoutSetCMYKColor	-	setcmykcolor
p	LoutSetTexture	-	setpattern

These have similar signatures to the corresponding PostScript operators shown, and the idea is to use the Lout-defined versions where you would normally use the PostScript ones. The first four set the color without disturbing any current texture; the last sets the texture without disturbing any current color. Here p may be the PostScript null object, meaning no texture i.e. normal filling, or else it must be an instantiated pattern dictionary, as returned by makepattern.

There are three key data types used by this code:

- A colorspace, denoted cs, is a PostScript colorspace array and may have one of the following values:

[/DeviceGray]	The greyscale colorspace
[/DeviceRGB]	The RGB colorspace
[/DeviceCMYK]	The CMYK colorspace
[/Pattern]	A colored pattern
[/Pattern /name]	An uncolored pattern; /name may be /DeviceGray, /DeviceRGB, or /DeviceCMYK

- A color, denoted c, is an array containing a PostScript non-pattern color and thus may have one of the following values:

[grey]	A /DeviceGray color
[red green blue]	A /DeviceRGB color
[c m y k]	A /DeviceCMYK color

  We enclose colors in an array to make it easy for us to deal with their varying length. The array has to be unpacked with aload before calling setcolor.

- A pattern, denoted p. For us, a pattern is either the PostScript null object, meaning to fill with solid color, or else it is a dictionary as returned by makepattern. When such a dictionary is installed in the current graphics state, this code guarantees that it will contain two extra entries:

/UnderlyingColorSpace	A cs as defined above
/UnderlyingColor	A c as defined above

  We need these extra entries to make color independent of texture: without them we would lose the current color when we set a texture. Because of these variables we can't share pattern dictionaries among graphics states. We must copy them.

This representation obeys the following invariant:

- All components of the PostScript graphics state related to pattern and color have defined values (e.g. there is never a situation where we set color space but not color).
- If the PostScript graphics state contains a /Pattern colorspace, the pattern dictionary stored in the state has /UnderlyingColorSpace and /UnderlyingColor entries of types cs and c.
- If the graphics state contains an uncolored /Pattern colorspace, then the /UnderlyingColorSpace and /UnderlyingColor entries of the pattern dictionary stored in the state agree with the underlying color space and color stored in the graphics state.

And it has the following abstraction function:

- If the graphics state colorspace is /Pattern, then the abstract current texture is the pattern dictionary stored in the graphics state color. If the graphics state colorspace is not /Pattern, then the abstract current texture is null.
- If the graphics state colorspace is /Pattern, then the abstract colorspace and color are the values of /UnderlyingColorSpace and /UnderlyingColor in the pattern dictionary stored in the graphics state color. If the graphics state colorspace is not /Pattern, then the abstract current colorspace and color are as returned by currentcolorspace and [currentcolor].

The following functions are private helpers for the public functions:

```
% Current pattern (may be null): - LoutCurrentP p
/LoutCurrentP
{                                 %% -
  currentcolorspace               %% [ /name etc ]
  0 get /Pattern eq               %% bool
  {                               %% -   (have pattern)
    [ currentcolor ]              %% [ comp0 ... compn p ]
    dup length 1 sub get          %% p
  }
  {                               %% -   (no pattern)
    null                          %% null
  } ifelse                        %% p
} def
```

```
% Current color and color space: - LoutCurrentCCS c cs
/LoutCurrentCCS
{
  LoutCurrentP dup null eq     %% p bool
  {                            %% null
    pop [ currentcolor ]       %% c
    currentcolorspace          %% c cs
  }
  {                            %% p
    dup                        %% p p
    /UnderlyingColor get exch  %% c p
    /UnderlyingColorSpace get  %% c cs
  } ifelse                     %% c cs
} def

% Make c, cs, and p current: c cs p LoutSetCCSP -
/LoutSetCCSP
{                              %% c cs p
  dup null eq                  %% c cs p bool
  {                            %% c cs p    (null pattern)
    pop setcolorspace          %% c
    aload pop setcolor         %% -
  }
  {                            %% c cs p    (non-null pattern)
    % copy pattern dictionary
    12 dict copy               %% c cs p

    % record cs and c in p
    dup /UnderlyingColorSpace  %% c cs p p /UCS
    3 index put                %% c cs p
    dup /UnderlyingColor       %% c cs p p /UC
    4 index put                %% c cs p

    % do setcolorspace and setcolor
    dup /PaintType get 1 eq    %% c cs p bool
    {                          %% c cs p   (colored pattern)
      [/Pattern] setcolorspace %% c cs p
      setcolor                 %% c cs
      pop pop                  %% -
    }
    {                          %% c cs p   (uncolored pattern)
      [ /Pattern               %% c cs p [ /Pattern
      4 -1 roll                %% c p [ /Pattern cs
      ] setcolorspace          %% c p
      exch aload length 1 add  %% p comp1 ... compm m+1
      -1 roll                  %% comp1 ... compm p
      setcolor                 %% -
    } ifelse                   %% -
  } ifelse                     %% -
} def
```

With the helper functions it's now easy to derive the colour and texture setting commands that we are offering to our end users. When setting the color we pass it, plus the current pattern, to LoutSetCCSP; when setting the pattern we pass it, plus the current color, to LoutSetCCSP. Note

that there is no /DeviceHSB: hsb is a variant of rgb.

```
% num LoutSetGray -
/LoutSetGray
{
  [ 2 1 roll ]                  %% c
  [ /DeviceGray ]               %% c cs
  LoutCurrentP                  %% c cs p
  LoutSetCCSP                   %% -
} def

% r g b LoutSetRGBColor -
/LoutSetRGBColor
{                               %% r g b
  [ 4 1 roll ]                  %% c
  [ /DeviceRGB ]                %% c cs
  LoutCurrentP                  %% c cs p
  LoutSetCCSP                   %% -
} def

% h s b LoutSetHSBColor -
/LoutSetHSBColor
{                               %% h s b
  gsave sethsbcolor             %% -
  currentrgbcolor grestore      %% r g b
  LoutSetRGBColor               %% -
} def

% c m y k LoutSetRGBColor -
/LoutSetCMYKColor
{
  [ 5 1 roll ]                  %% c
  [ /DeviceCMYK ]               %% c cs
  LoutCurrentP                  %% c cs p
  LoutSetCCSP                   %% -
} def

% p LoutSetTexture -
/LoutSetTexture
{
  LoutCurrentCCS                %% p c cs
  3 -1 roll                     %% c cs p
  LoutSetCCSP                   %% -
} def
```

All we need now is some sample textures. Textures are just pattern dictionaries as returned by makepattern. Here is a PostScript function that appears in the Lout prologue. Its function is to simplify the production of textures. It first takes six parameters to specify a transformation of the texture used to build the matrix taken by makepattern, then five parameters that go into the pattern dictionary.

```
% <scale> <scalex> <scaley> <rotate> <hshift> <vshift>
% <pt> <bb> <xs> <ys> <pc> LoutMakeTexture p
/LoutMakeTexture
{                               %% s sx sy r h v pt bb xs ys pp
  12 dict begin                 %% s sx sy r h v pt bb xs ys pp
  /PaintProc exch def           %% s sx sy r h v pt bb xs ys
  /YStep exch def               %% s sx sy r h v pt bb xs
  /XStep exch def               %% s sx sy r h v pt bb
  /BBox exch def                %% s sx sy r h v pt
  /PaintType exch def           %% s sx sy r h v
  /PatternType 1 def            %% s sx sy r h v
  /TilingType 1 def             %% s sx sy r h v
  currentdict end               %% s sx sy r h v p
  7 1 roll                      %% p s sx sy r h v
  matrix translate              %% p s sx sy r mat1
  5 1 roll                      %% p mat1 s sx sy r
  matrix rotate                 %% p mat1 s sx sy mat2
  4 1 roll                      %% p mat1 mat2 s sx sy
  matrix scale                  %% p mat1 mat2 s mat3
  exch dup matrix scale         %% p mat1 mat2 mat3 mat4
  matrix concatmatrix           %% p mat1 mat2 mat34
  matrix concatmatrix           %% p mat1 mat234
  matrix concatmatrix           %% p mat1234
  /makepattern where
  {                             %% p mat123 dict
    pop makepattern             %% p
  }
  {                             %% p mat123
    pop pop null                %% null
  } ifelse                      %% p (may be null)
} def
```

For examples of textures using LoutMakeTexture, consult the standard include file coltex. There is only one built-in texture, LoutTextureSolid:

```
/LoutTextureSolid
{
  null
  LoutSetTexture
} def
```

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Index

adjust @Break, 44
Adjustment of object, 54
Adobe Systems, Inc., 43
Alignment *see* mark alignment
Associativity, 23

b unit, 38
  use in //1.1b, 29
@BackEnd symbol, 77
@Background symbol, 59
@Begin symbol, 37
@BeginHeaderComponent symbol, 66
Bibliographies, 97
Body of a definition, 4
body parameter, 18
Braces, 3

c unit, 38
@Case symbol, 63
Centring, 38
@Chapter example, 93
Chapters and sections, 92
@Char symbol, 44
Cherry, L., 81
@ClearHeaderComponent symbol, 66
clines @Break, 44
@ColList example, 89
Column mark, 1
Comment, 16
Comment character, 14
@Common symbol, 59
Components of a galley, 27
  promotion of, 30
Concatenation symbols, 37
Contraction of object, 54
cragged @Break, 44
Cross reference, 8
@CurrLang symbol, 52

d unit, 38
@Database symbol, 71
Date, printing of current, 64
Default value of parameter, 17
Definitions, 4
Delimiter, 14
Diag diagram-drawing package, 74
Diagrams, 71
DocumentLayout package, 83
  chapters and sections, 92
  displays, 84
  lists, 85
  page layout, 87
  paragraphs, 84

e gap mode, 38
Edge-to-edge gap mode, 38
@Enclose, 32
@End symbol, 37
@EndHeaderComponent symbol, 66
Eq equation formatting package, 81
@Eq example, 81
Escape character, 14
@EvenPageList example, 91
Expansion of object, 54
export clause, 19

f unit, 38
Face of a font, 41
Family of a font, 41
following, 9
following, 9
Fonts, 41
@Font symbol, 41
@FootSect example, 88
@ForceGalley symbol, 65
Forcing galley, 30
Formfeed, 14

Galleys, 10
  in detail, 27
@Galley symbol, 65
Gap, 38

Gap mode, 38
@Graphic symbol, 71

h gap mode, 38
@HAdjust symbol, 54
@HContract symbol, 54
@HCover symbol, 56
Header component of galley, 65
Height of an object, 25
@HExpand symbol, 54
@High symbol, 53
@HLimited symbol, 54
@Hline example, 83
@HMirror symbol, 55
Horizontal concatenation, 37
@HScale symbol, 55
@HShift symbol, 53
@HSpan symbol, 57
hyphen @Break, 45
Hyphenation gap mode, 40
Hyphenation gap mode, 38

Identifier, 14
import clause, 19
In-paragraph concatenation, 38
@Include symbol, 77
@IncludeGraphic symbol, 75
@IncludeGraphicRepeated symbol, 76
@IndentedDisplay example, 84
@IndentedList example, 86
Index file (for databases), 71
@Insert symbol, 61
into clause, 11
Invocation of a symbol, 4

k gap mode, 38
Kernighan, B., 81
Kerning, 41
Kerning gap mode, 38
@KernShrink symbol, 59
@Key parameter, 33
Knuth, D., 83

langdef language definition, 51
@Language symbol, 51
@LClos symbol, 15
LCM file, 43
Length, 38
@LEnv symbol, 15
Letter character, 14
Ligatures, 41
lines @Break, 44
@LinkDest symbol, 69
@LinkSource symbol, 69
@LInput symbol, 15
Literal word, 15
@LUse symbol, 15
@LVis symbol, 15

m unit, 38
Macro, 16
Mark alignment, 1
  in detail, 29
Mark-to-mark gap mode, 38
@Meld symbol, 59
@Merge symbol, 34
Mirroring an object, 55
@Moment symbol, 64

named parameter, 16
Nested definitions, 18
@Next symbol, 63
nohyphen @Break, 45
@NotRevealed symbol, 67
@Null symbol, 64
Numbered list, 85
@NumberOf example, 92

o gap mode, 38
Object, 1
@OddPageList example, 91
olines @Break, 45
@OneCol symbol, 53
@OneOf symbol, 61
@OnePage example, 90
@OneRow symbol, 52
@Open symbol, 68
Optimal galley breaking, 36
@Optimize symbol, 36
oragged @Break, 44
@OrElse example, 95

Other character, 14
outdent @Break, 44
@Outline symbol, 51
over example, 82
Overstrike gap mode, 38

p unit, 38
@PAdjust symbol, 54
@Page example, 89
Page layout
  principles of, 5
  in practice, 87
@PageLabel symbol, 79
@PageOf example, 87
Paragraph breaking, 3
  in detail, 40
Parameter, 4
  body parameter, 18
  named parameter, 16
@PlainGraphic symbol, 75
PostScript, ii
  used by @Graphic, 71
  used by @IncludeGraphic, 75
  used by @IncludeGraphicRepeated, 76
  used by @PrependGraphic, 76
@PP example, 84
Precedence, 23
preceding, 9
@PrependGraphic symbol, 76
Principal mark, 38
  effect on @OneCol and @OneRow, 52
Promotion of components, 30

Quote character, 14
Quoted word, 15

r unit, 38
ragged @Break, 44
@RawVerbatim symbol, 78
Receptive symbol, 12
Recursion, 5
@Ref example, 100
@Reference example, 97
@ReferenceSection example, 99
Reflecting an object, 55
Reid, Brian K., 8
Right justification, 38
rlines @Break, 44
Roman numerals, 87
Root galley, 12
  in detail, 30
  printing of, 30
  size of components of, 26
@Rotate symbol, 58
Rotation of object, 58
Row mark, 2
rragged @Break, 44
@Rump symbol, 59
@Runner example, 90

s unit, 38
  and @Space symbol, 46
@Scale symbol, 57
Scaling of object, 55
Scribe, 8
@Section example, 95
@SetHeaderComponent symbol, 66
@SetColor symbol, 48
@SetColour symbol, 48
@SetTexture symbol, 50
@SetUnderlineColor symbol, 49
@SetUnderlineColour symbol, 49
Size of an object, 25
small capitals, 42
Sorted galleys, 33
Space, 14
  when significant, 39
@Space symbol, 46
@StartHSpan symbol, 57
@StartHVSpan symbol, 57
@StartVSpan symbol, 57
Style of an object, 24
sup example, 82
Symbol, 4
@SysDatabase symbol, 71
@SysInclude symbol, 77
@SysIncludeGraphic symbol, 75
@SysIncludeGraphicRepeated symbol, 76
@SysPrependGraphic symbol, 76

t gap mode, 38
Tables, 2

Tabulation gap mode, 38
@Tag parameter, default value of, 17
@Tagged symbol, 68
Target of cross reference, 9
Target of a galley, 11
@Target symbol, 31
  in detail, 27
TEX
  hyphenation, 40
  optimal paragraph breaking, 40
Textual unit, 14

@Underline symbol, 79
Underscore character, 14
@Use symbol, 69

v unit, 38
  effect on paragraph breaking, 45
@VAdjust symbol, 54
@VContract symbol, 54
@VCover symbol, 56
@Verbatim symbol, 78
Vertical concatenation, 37
@VExpand symbol, 54
@VLimited symbol, 54
@VMirror symbol, 55
@VScale symbol, 55
@VShift symbol, 53
@VSpan symbol, 57

w unit, 38
White space, 14
  when significant, 39
@Wide symbol, 53
Width of an object, 25
Word, 15

x gap mode, 38

@Yield symbol, 63
@YUnit symbol, 47

@ZUnit symbol, 47