

The CWEAVE processor

(Version 4.12.2)

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1. Introduction. This is the CWEAVE program by Silvio Levy and Donald E. Knuth, based on WEAVE by Knuth. We are thankful to Steve Avery, Nelson Beebe, Hans-Hermann Bode (to whom the original C++ adaptation is due), Klaus Guntermann, Norman Ramsey, Tomas Rokicki, Joachim Schnitter, Joachim Schrod, Lee Wittenberg, Saroj Mahapatra, Cesar Augusto Rorato Crusius, and others who have contributed improvements.

The “banner line” defined here should be changed whenever CWEAVE is modified.

```
#define banner "This is CWEAVE (Version 4.12.2)"
```

```
⟨ Include files 5 ⟩
⟨ Preprocessor definitions ⟩
⟨ Common code for CWEAVE and CTANGLE 3 ⟩
⟨ Typedef declarations 22 ⟩
⟨ Private variables 21 ⟩
⟨ Predeclaration of procedures 4 ⟩
```

2. CWEAVE has a fairly straightforward outline. It operates in three phases: First it inputs the source file and stores cross-reference data, then it inputs the source once again and produces the T_EX output file, finally it sorts and outputs the index.

Please read the documentation for COMMON, the set of routines common to CTANGLE and CWEAVE, before proceeding further.

```
int main(int ac,      ▷ argument count <
        char **av)    ▷ argument values <
{
    argc ← ac; argv ← av; program ← cweave; ⟨ Set initial values 24 ⟩
    common_init(); ⟨ Start TEX output 89 ⟩
    if (show_banner) puts(banner);    ▷ print a “banner line” <
    ⟨ Store all the reserved words 34 ⟩
    phase_one();    ▷ read all the user’s text and store the cross-references <
    phase_two();    ▷ read all the text again and translate it to TEX form <
    phase_three();  ▷ output the cross-reference index <
    if (tracing ≡ fully ∧ ¬show_progress) new_line();
    return wrap_up();    ▷ and exit gracefully <
}
```

3. The next few sections contain stuff from the file “common.w” that must be included in both “ctangle.w” and “cweave.w”. It appears in file “common.h”, which is also included in “common.w” to propagate possible changes from this COMMON interface consistently.

First comes general stuff:

```
#define ctangle false
#define cweave true
⟨ Common code for CWEAVE and CTANGLE 3 ⟩ ≡
typedef uint8_t eight_bits;
typedef uint16_t sixteen_bits;
extern bool program;    ▷ CWEAVE or CTANGLE? <
extern int phase;    ▷ which phase are we in? <
```

See also sections 6, 7, 8, 10, 11, 13, 15, and 16.

This code is used in section 1.

4. The procedure that gets everything rolling:

```

⟨Predeclaration of procedures 4⟩ ≡
extern void common_init(void);

```

See also sections 9, 12, 14, 25, 40, 45, 65, 69, 71, 83, 86, 90, 95, 98, 115, 118, 122, 181, 189, 194, 201, 210, 214, 228, 235, 244, 248, 258, and 267.

This code is used in section 1.

5. Interface to the standard C library:

```

⟨Include files 5⟩ ≡
#include <ctype.h>    ▷ definition of isalpha, isdigit and so on ◁
#include <stdbool.h>  ▷ definition of bool, true and false ◁
#include <stddef.h>   ▷ definition of ptrdiff_t ◁
#include <stdint.h>   ▷ definition of uint8_t and uint16_t ◁
#include <stdio.h>    ▷ definition of printf and friends ◁
#include <stdlib.h>   ▷ definition of getenv and exit ◁
#include <string.h>   ▷ definition of strlen, strcmp and so on ◁

```

See also section 19.

This code is used in section 1.

6. Code related to the character set:

```

#define and_and °4    ▷ '&&'; corresponds to MIT's ∧ and ASCII EOT ◁
#define lt_lt °20     ▷ '<<'; corresponds to MIT's ⋈ and ASCII DLE ◁
#define gt_gt °21     ▷ '>>'; corresponds to MIT's ⋉ and ASCII DC1 ◁
#define plus_plus °13  ▷ '++'; corresponds to MIT's ↑ and ASCII VT aka '\v' ◁
#define minus_minus °1 ▷ '--'; corresponds to MIT's ↓ and ASCII SOH ◁
#define minus_gt °31   ▷ '->'; corresponds to MIT's → and ASCII EM ◁
#define non_eq °32     ▷ '!='; corresponds to MIT's ≠ and ASCII SUB ◁
#define lt_eq °34      ▷ '<='; corresponds to MIT's ≤ and ASCII FS ◁
#define gt_eq °35      ▷ '>='; corresponds to MIT's ≥ and ASCII GS ◁
#define eq_eq °36      ▷ '=='; corresponds to MIT's ≡ and ASCII RS ◁
#define or_or °37      ▷ '||'; corresponds to MIT's ∨ and ASCII US ◁
#define dot_dot_dot °16 ▷ '...'; corresponds to MIT's ∅ and ASCII SO ◁
#define colon_colon °6 ▷ '::'; corresponds to MIT's € and ASCII ACK ◁
#define period_ast °26 ▷ '.*'; corresponds to MIT's ⊗ and ASCII SYN ◁
#define minus_gt_ast °27 ▷ '->*'; corresponds to MIT's ⋞ and ASCII ETB ◁

#define compress(c) if (loc++ ≤ limit) return c

```

```

⟨Common code for CWEAVE and CTANGLE 3⟩ +≡

```

```

extern char section_text[];    ▷ text being sought for ◁
extern char *section_text_end; ▷ end of section_text ◁
extern char *id_first;         ▷ where the current identifier begins in the buffer ◁
extern char *id_loc;          ▷ just after the current identifier in the buffer ◁

```

7. Code related to input routines:

```
#define xisalpha(c) (isalpha((int)(c)) ^ ¬ishigh(c))
#define xisdigit(c) (isdigit((int)(c)) ^ ¬ishigh(c))
#define xisspace(c) (isspace((int)(c)) ^ ¬ishigh(c))
#define xislower(c) (islower((int)(c)) ^ ¬ishigh(c))
#define xisupper(c) (isupper((int)(c)) ^ ¬ishigh(c))
#define xisxdigit(c) (isxdigit((int)(c)) ^ ¬ishigh(c))
#define isxalpha(c) ((c) ≡ '_' ∨ (c) ≡ '$')    ▷ non-alpha characters allowed in identifier ◁
#define ishigh(c) ((eight_bits)(c) > °177)
```

◁ Common code for CWEAVE and CTANGLE 3 ▷ +≡

```
extern char buffer[];    ▷ where each line of input goes ◁
extern char *buffer_end;    ▷ end of buffer ◁
extern char *loc;    ▷ points to the next character to be read from the buffer ◁
extern char *limit;    ▷ points to the last character in the buffer ◁
```

8. Code related to file handling:

```
format line x    ▷ make line an unreserved word ◁
#define max_include_depth 10
    ▷ maximum number of source files open simultaneously, not counting the change file ◁
#define max_file_name_length 60
#define cur_file file[include_depth]    ▷ current file ◁
#define cur_file_name file_name[include_depth]    ▷ current file name ◁
#define cur_line line[include_depth]    ▷ number of current line in current file ◁
#define web_file file[0]    ▷ main source file ◁
#define web_file_name file_name[0]    ▷ main source file name ◁
```

◁ Common code for CWEAVE and CTANGLE 3 ▷ +≡

```
extern int include_depth;    ▷ current level of nesting ◁
extern FILE *file[];    ▷ stack of non-change files ◁
extern FILE *change_file;    ▷ change file ◁
extern char file_name[][max_file_name_length];    ▷ stack of non-change file names ◁
extern char change_file_name[];    ▷ name of change file ◁
extern int line[];    ▷ number of current line in the stacked files ◁
extern int change_line;    ▷ number of current line in change file ◁
extern int change_depth;    ▷ where @y originated during a change ◁
extern bool input_has_ended;    ▷ if there is no more input ◁
extern bool changing;    ▷ if the current line is from change_file ◁
extern bool web_file_open;    ▷ if the web file is being read ◁
```

9. ◁ Predeclaration of procedures 4 ▷ +≡

```
extern bool get_line(void);    ▷ inputs the next line ◁
extern void check_complete(void);    ▷ checks that all changes were picked up ◁
extern void reset_input(void);    ▷ initialize to read the web file and change file ◁
```

10. Code related to section numbers:

◁ Common code for CWEAVE and CTANGLE 3 ▷ +≡

```
extern sixteen_bits section_count;    ▷ the current section number ◁
extern bool changed_section[];    ▷ is the section changed? ◁
extern bool change_pending;    ▷ is a decision about change still unclear? ◁
extern bool print_where;    ▷ tells CTANGLE to print line and file info ◁
```

11. Code related to identifier and section name storage:

```
#define length(c) ((size_t)((c + 1)-byte_start - (c)-byte_start)    ▷ the length of a name ◁
#define print_id(c) term_write((c)-byte_start, length(c))    ▷ print identifier ◁
#define llink link    ▷ left link in binary search tree for section names ◁
#define rlink dummy.Rlink    ▷ right link in binary search tree for section names ◁
#define root name_dir-rlink    ▷ the root of the binary search tree for section names ◁
#define ilk dummy.Ilk    ▷ used by CWEAVE only ◁
```

⟨ Common code for CWEAVE and CTANGLE 3 ⟩ +≡

```
typedef struct name_info {
    char *byte_start;    ▷ beginning of the name in byte_mem ◁
    struct name_info *link;
    union {
        struct name_info *Rlink;    ▷ right link in binary search tree for section names ◁
        eight_bits ilk;    ▷ used by identifiers in CWEAVE only ◁
    } dummy;
    void *equiv_or_xref;    ▷ info corresponding to names ◁
} name_info;    ▷ contains information about an identifier or section name ◁
typedef name_info *name_pointer;    ▷ pointer into array of name_infos ◁
typedef name_pointer *hash_pointer;
extern char byte_mem[];    ▷ characters of names ◁
extern char *byte_mem_end;    ▷ end of byte_mem ◁
extern char *byte_ptr;    ▷ first unused position in byte_mem ◁
extern name_info name_dir[];    ▷ information about names ◁
extern name_pointer name_dir_end;    ▷ end of name_dir ◁
extern name_pointer name_ptr;    ▷ first unused position in name_dir ◁
extern name_pointer hash[];    ▷ heads of hash lists ◁
extern hash_pointer hash_end;    ▷ end of hash ◁
extern hash_pointer hash_ptr;    ▷ index into hash-head array ◁
```

12. ⟨ Predeclaration of procedures 4 ⟩ +≡

```
extern name_pointer id_lookup(const char *, const char *, eight_bits);
    ▷ looks up a string in the identifier table ◁
extern name_pointer section_lookup(char *, char *, bool);    ▷ finds section name ◁
extern void print_prefix_name(name_pointer);
extern void print_section_name(name_pointer);
extern void sprint_section_name(char *, name_pointer);
extern bool names_match(name_pointer, const char *, size_t, eight_bits);
    ▷ two routines defined in ctangle.w and cweave.w ◁
extern void init_node(name_pointer);
```

13. Code related to error handling:

```
#define spotless 0    ▷ history value for normal jobs ◁
#define harmless_message 1    ▷ history value when non-serious info was printed ◁
#define error_message 2    ▷ history value when an error was noted ◁
#define fatal_message 3    ▷ history value when we had to stop prematurely ◁
#define mark_harmless() if (history == spotless) history ← harmless_message
#define mark_error() history ← error_message
#define confusion(s) fatal("!␣This␣can't␣happen:␣", s)
```

⟨ Common code for CWEAVE and CTANGLE 3 ⟩ +≡

```
extern int history;    ▷ indicates how bad this run was ◁
```

14. \langle Predeclaration of procedures 4 $\rangle + \equiv$

```

extern int wrap_up(void);    ▷ indicate history and exit ◁
extern void err_print(const char *);    ▷ print error message and context ◁
extern void fatal(const char *,const char *);    ▷ issue error message and die ◁
extern void overflow(const char *);    ▷ succumb because a table has overflowed ◁
extern void print_stats(void);    ▷ defined in ctangle.w and cweave.w ◁

```

15. Code related to command line arguments:

```

#define show_banner flags['b']    ▷ should the banner line be printed? ◁
#define show_progress flags['p']    ▷ should progress reports be printed? ◁
#define show_happiness flags['h']    ▷ should lack of errors be announced? ◁
#define show_stats flags['s']    ▷ should statistics be printed at end of run? ◁
#define make_xrefs flags['x']    ▷ should cross references be output? ◁

```

 \langle Common code for CWEAVE and CTANGLE 3 $\rangle + \equiv$

```

extern int argc;    ▷ copy of ac parameter to main ◁
extern char **argv;    ▷ copy of av parameter to main ◁
extern char C_file_name[];    ▷ name of C_file ◁
extern char tex_file_name[];    ▷ name of tex_file ◁
extern char idx_file_name[];    ▷ name of idx_file ◁
extern char scn_file_name[];    ▷ name of scn_file ◁
extern bool flags[];    ▷ an option for each 7-bit code ◁

```

16. Code related to output:

```

#define update_terminal() fflush(stdout)    ▷ empty the terminal output buffer ◁
#define new_line() putchar('\n')
#define term_write(a,b) fflush(stdout),fwrite(a,sizeof(char),b,stdout)

```

 \langle Common code for CWEAVE and CTANGLE 3 $\rangle + \equiv$

```

extern FILE *C_file;    ▷ where output of CTANGLE goes ◁
extern FILE *tex_file;    ▷ where output of CWEAVE goes ◁
extern FILE *idx_file;    ▷ where index from CWEAVE goes ◁
extern FILE *scn_file;    ▷ where list of sections from CWEAVE goes ◁
extern FILE *active_file;    ▷ currently active file for CWEAVE output ◁

```

17. The following parameters are sufficient to handle T_EX (converted to CWEB), so they should be sufficient for most applications of CWEB.

```

#define buf_size 200    ▷ maximum length of input line, plus one ◁
#define longest_name 10000    ▷ file names, section names, and section texts shouldn't be longer than this ◁
#define long_buf_size (buf_size + longest_name)    ▷ for CWEAVE ◁
#define max_bytes 100000
    ▷ the number of bytes in identifiers, index entries, and section names; must be less than 224 ◁
#define max_names 5000    ▷ number of identifiers, strings, section names; must be less than 10240 ◁
#define max_sections 2000    ▷ greater than the total number of sections ◁

```

18. End of COMMON interface.

19. CWEAVE will use the INT_MAX limit in section \langle Output the code for the beginning of a new section 231 \rangle below.

```

 $\langle$ Include files 5 $\rangle + \equiv$ 
#include <limits.h>

```

20. Data structures exclusive to CWEAVE. As explained in `common.w`, the field of a `name_info` structure that contains the *rlink* of a section name is used for a completely different purpose in the case of identifiers. It is then called the *ilk* of the identifier, and it is used to distinguish between various types of identifiers, as follows:

normal and *func_template* identifiers are part of the C program that will appear in italic type (or in typewriter type if all uppercase).

custom identifiers are part of the C program that will be typeset in special ways.

roman identifiers are index entries that appear after @~ in the `CWEB` file.

wildcard identifiers are index entries that appear after @: in the `CWEB` file.

typewriter identifiers are index entries that appear after @. in the `CWEB` file.

alfop, ..., *attr* identifiers are C or C++ reserved words whose *ilk* explains how they are to be treated when C code is being formatted.

```
#define normal 0    ▷ ordinary identifiers have normal ilk ◁
#define roman 1    ▷ normal index entries have roman ilk ◁
#define wildcard 2  ▷ user-formatted index entries have wildcard ilk ◁
#define typewriter 3 ▷ 'typewriter type' entries have typewriter ilk ◁
#define abnormal(a) ((a)-ilk > typewriter) ▷ tells if a name is special ◁
#define func_template 4 ▷ identifiers that can be followed by optional template ◁
#define custom 5    ▷ identifiers with user-given control sequence ◁
#define alfop 22    ▷ alphabetic operators like and or not_eq ◁
#define else_like 26 ▷ else ◁
#define public_like 40 ▷ public, private, protected ◁
#define operator_like 41 ▷ operator ◁
#define new_like 42   ▷ new ◁
#define catch_like 43 ▷ catch ◁
#define for_like 45   ▷ for, switch, while ◁
#define do_like 46    ▷ do ◁
#define if_like 47    ▷ if, ifdef, endif, pragma, ... ◁
#define delete_like 48 ▷ delete ◁
#define raw_ubin 49   ▷ '&' or '*' when looking for const following ◁
#define const_like 50 ▷ const, volatile ◁
#define raw_int 51    ▷ int, char, ...; also structure and class names ◁
#define int_like 52   ▷ same, when not followed by left parenthesis or :: ◁
#define case_like 53  ▷ case, return, goto, break, continue ◁
#define sizeof_like 54 ▷ sizeof ◁
#define struct_like 55 ▷ struct, union, enum, class ◁
#define typedef_like 56 ▷ typedef ◁
#define define_like 57 ▷ define ◁
#define template_like 58 ▷ template ◁
#define alignas_like 59 ▷ alignas ◁
#define using_like 60 ▷ using ◁
#define default_like 61 ▷ default ◁
#define attr 62    ▷ noexcept and attributes ◁
```

21. We keep track of the current section number in *section_count*, which is the total number of sections that have started. Sections which have been altered by a change file entry have their *changed_section* flag turned on during the first phase.

⟨Private variables 21⟩ ≡

```
static bool change_exists;    ▷ has any section changed? ◁
```

See also sections 23, 30, 37, 43, 46, 48, 67, 76, 81, 85, 106, 113, 119, 184, 208, 213, 229, 238, 250, 253, 255, and 264.

This code is used in section 1.

22. The other large memory area in CWEAVE keeps the cross-reference data. All uses of the name *p* are recorded in a linked list beginning at *p-xref*, which points into the *xmem* array. The elements of *xmem* are structures consisting of an integer, *num*, and a pointer *xlink* to another element of *xmem*. If $x \leftarrow p\text{-}xref$ is a pointer into *xmem*, the value of *x-num* is either a section number where *p* is used, or *cite_flag* plus a section number where *p* is mentioned, or *def_flag* plus a section number where *p* is defined; and *x-xlink* points to the next such cross-reference for *p*, if any. This list of cross-references is in decreasing order by section number. The next unused slot in *xmem* is *xref_ptr*. The linked list ends at &*xmem*[0].

The global variable *xref_switch* is set either to *def_flag* or to zero, depending on whether the next cross-reference to an identifier is to be underlined or not in the index. This switch is set to *def_flag* when @! or @d is scanned, and it is cleared to zero when the next identifier or index entry cross-reference has been made. Similarly, the global variable *section_xref_switch* is either *def_flag* or *cite_flag* or zero, depending on whether a section name is being defined, cited or used in C text.

⟨Typedef declarations 22⟩ ≡

```
typedef struct xref_info {
    sixteen_bits num;    ▷ section number plus zero or def_flag ◁
    struct xref_info *xlink;    ▷ pointer to the previous cross-reference ◁
} xref_info;
typedef xref_info *xref_pointer;
```

See also sections 29, 112, and 207.

This code is used in section 1.

23. #define *max_refs* 30000 ▷ number of cross-references; must be less than 65536 ◁

⟨Private variables 21⟩ +≡

```
static xref_info xmem[max_refs];    ▷ contains cross-reference information ◁
static xref_pointer xmem_end ← xmem + max_refs - 1;
static xref_pointer xref_ptr;    ▷ the largest occupied position in xmem ◁
static sixteen_bits xref_switch, section_xref_switch;    ▷ either zero or def_flag ◁
```

24. A section that is used for multi-file output (with the @(< feature) has a special first cross-reference whose *num* field is *file_flag*.

```
#define file_flag (3 * cite_flag)
#define def_flag (2 * cite_flag)
#define cite_flag 10240    ▷ must be strictly larger than max_sections ◁
#define xref equiv_or_xref
```

⟨Set initial values 24⟩ ≡

```
xref_ptr ← xmem; init_node(name_dir); xref_switch ← section_xref_switch ← 0; xmem->num ← 0;
▷ sentinel value ◁
```

See also sections 31, 38, 61, 92, 107, 114, 155, 204, 209, 254, and 256.

This code is used in section 2.

25. A new cross-reference for an identifier is formed by calling *new_xref*, which discards duplicate entries and ignores non-underlined references to one-letter identifiers or C's reserved words.

If the user has sent the *no_xref* flag (the *-x* option of the command line), it is unnecessary to keep track of cross-references for identifiers. If one were careful, one could probably make more changes around section \langle Match a production at *pp*, or increase *pp* if there is no match 121 \rangle to avoid a lot of identifier looking up.

```
#define append_xref(c)
    if (xref_ptr  $\equiv$  xmem_end) overflow("cross-reference");
    else (++xref_ptr)-num  $\leftarrow$  c
#define no_xref  $\neg$ make_xrefs
#define is_tiny(p) length(p)  $\equiv$  1
#define unindexed(a) ((a) < res_wd_end  $\wedge$  (a)-ilk  $\geq$  custom)
     $\triangleright$  tells if uses of a name are to be indexed  $\triangleleft$ 
```

\langle Predeclaration of procedures 4 \rangle \equiv

```
static void new_xref(name_pointer);
static void new_section_xref(name_pointer);
static void set_file_flag(name_pointer);
```

```
26. static void new_xref(name_pointer p)
{
    xref_pointer q;  $\triangleright$  pointer to previous cross-reference  $\triangleleft$ 
    sixteen_bits m, n;  $\triangleright$  new and previous cross-reference value  $\triangleleft$ 
    if (no_xref) return;
    if ((unindexed(p)  $\vee$  is_tiny(p))  $\wedge$  xref_switch  $\equiv$  0) return;
    m  $\leftarrow$  section_count + xref_switch; xref_switch  $\leftarrow$  0; q  $\leftarrow$  (xref_pointer) p-xref;
    if (q  $\neq$  xmem) {
        n  $\leftarrow$  q-num;
        if (n  $\equiv$  m  $\vee$  n  $\equiv$  m + def_flag) return;
        else if (m  $\equiv$  n + def_flag) {
            q-num  $\leftarrow$  m; return;
        }
    }
    append_xref(m); xref_ptr-xlink  $\leftarrow$  q; update_node(p);
}
```

27. The cross-reference lists for section names are slightly different. Suppose that a section name is defined in sections m_1, \dots, m_k , cited in sections n_1, \dots, n_l , and used in sections p_1, \dots, p_j . Then its list will contain $m_1 + \text{def_flag}, \dots, m_k + \text{def_flag}, n_1 + \text{cite_flag}, \dots, n_l + \text{cite_flag}, p_1, \dots, p_j$, in this order.

Although this method of storage takes quadratic time with respect to the length of the list, under foreseeable uses of **CWEAVE** this inefficiency is insignificant.

```
static void new_section_xref(name_pointer p)
{
    xref_pointer q ← (xref_pointer) p-xref;
    xref_pointer r ← xmem;    ▷ pointers to previous cross-references ◁
    if (q > r)
        while (q-num > section_xref_switch) {
            r ← q; q ← q-xlink;
        }
    if (r-num ≡ section_count + section_xref_switch) return;    ▷ don't duplicate entries ◁
    append_xref(section_count + section_xref_switch); xref_ptr-xlink ← q; section_xref_switch ← 0;
    if (r ≡ xmem) update_node(p);
    else r-xlink ← xref_ptr;
}
```

28. The cross-reference list for a section name may also begin with *file_flag*. Here's how that flag gets put in.

```
static void set_file_flag(name_pointer p)
{
    xref_pointer q ← (xref_pointer) p-xref;
    if (q-num ≡ file_flag) return;
    append_xref(file_flag); xref_ptr-xlink ← q; update_node(p);
}
```

29. A third large area of memory is used for sixteen-bit ‘tokens’, which appear in short lists similar to the strings of characters in *byte_mem*. Token lists are used to contain the result of C code translated into **TEX** form; further details about them will be explained later. A **text_pointer** variable is an index into *tok_start*.

⟨ Typedef declarations 22 ⟩ +≡

```
typedef sixteen_bits token;
typedef token *token_pointer;
typedef token_pointer *text_pointer;
```

30. The first position of *tok_mem* that is unoccupied by replacement text is called *tok_ptr*, and the first unused location of *tok_start* is called *text_ptr*. Thus, we usually have $*\text{text_ptr} \equiv \text{tok_ptr}$.

```
#define max_toks 30000    ▷ number of symbols in C texts being parsed; must be less than 65536 ◁
#define max_texts 8000   ▷ number of phrases in C texts being parsed; must be less than 10240 ◁
```

⟨ Private variables 21 ⟩ +≡

```
static token tok_mem[max_toks];    ▷ tokens ◁
static token_pointer tok_mem_end ← tok_mem + max_toks - 1;    ▷ end of tok_mem ◁
static token_pointer tok_ptr;    ▷ first unused position in tok_mem ◁
static token_pointer max_tok_ptr;    ▷ largest value of tok_ptr ◁
static token_pointer tok_start[max_texts];    ▷ directory into tok_mem ◁
static text_pointer tok_start_end ← tok_start + max_texts - 1;    ▷ end of tok_start ◁
static text_pointer text_ptr;    ▷ first unused position in tok_start ◁
static text_pointer max_text_ptr;    ▷ largest value of text_ptr ◁
```

31. $\langle \text{Set initial values } 24 \rangle + \equiv$

```
tok_ptr ← max_tok_ptr ← tok_mem + 1;
tok_start[0] ← tok_start[1] ← tok_mem + 1;
text_ptr ← max_text_ptr ← tok_start + 1;
```

32. Here are the two procedures needed to complete *id_lookup*:

```
bool names_match(name_pointer p,      ▷ points to the proposed match ◁
    const char *first,      ▷ position of first character of string ◁
    size_t l,      ▷ length of identifier ◁
    eight_bits t)      ▷ desired ilk ◁
{
    if (length(p) ≠ l) return false;
    if (p-ilk ≠ t ∧ ¬(t ≡ normal ∧ abnormal(p))) return false;
    return ¬strcmp(first, p-byte_start, l);
}

void init_node(name_pointer p)
{
    p-xref ← (void *) xmem;
}
```

33. And here's a small helper function to simplify the code.

```
#define update_node(p) (p)-xref ← (void *) xref_ptr
```

34. We have to get C's and C++'s reserved words into the hash table, and the simplest way to do this is to insert them every time **CWEAVE** is run. Fortunately there are relatively few reserved words. (Some of these are not strictly “reserved,” but are defined in header files of the ISO Standard C Library. An ever growing list of C++ keywords can be found here: <https://en.cppreference.com/w/cpp/keyword>.)

(Store all the reserved words 34) \equiv

```

id_lookup("alignas",  $\Lambda$ , alignas_like); id_lookup("alignof",  $\Lambda$ , sizeof_like); id_lookup("and",  $\Lambda$ , alfop);
id_lookup("and_eq",  $\Lambda$ , alfop); id_lookup("asm",  $\Lambda$ , sizeof_like); id_lookup("auto",  $\Lambda$ , int_like);
id_lookup("bitand",  $\Lambda$ , alfop); id_lookup("bitor",  $\Lambda$ , alfop); id_lookup("bool",  $\Lambda$ , raw_int);
id_lookup("break",  $\Lambda$ , case_like); id_lookup("case",  $\Lambda$ , case_like); id_lookup("catch",  $\Lambda$ , catch_like);
id_lookup("char",  $\Lambda$ , raw_int); id_lookup("char8_t",  $\Lambda$ , raw_int); id_lookup("char16_t",  $\Lambda$ , raw_int);
id_lookup("char32_t",  $\Lambda$ , raw_int); id_lookup("class",  $\Lambda$ , struct_like); id_lookup("clock_t",  $\Lambda$ , raw_int);
id_lookup("compl",  $\Lambda$ , alfop); id_lookup("concept",  $\Lambda$ , int_like); id_lookup("const",  $\Lambda$ , const_like);
id_lookup("constexpr",  $\Lambda$ , const_like); id_lookup("constexpr",  $\Lambda$ , const_like);
id_lookup("constinit",  $\Lambda$ , const_like); id_lookup("const_cast",  $\Lambda$ , raw_int);
id_lookup("continue",  $\Lambda$ , case_like); id_lookup("co_await",  $\Lambda$ , case_like);
id_lookup("co_return",  $\Lambda$ , case_like); id_lookup("co_yield",  $\Lambda$ , case_like);
id_lookup("decltype",  $\Lambda$ , sizeof_like); id_lookup("default",  $\Lambda$ , default_like);
id_lookup("define",  $\Lambda$ , define_like); id_lookup("defined",  $\Lambda$ , sizeof_like);
id_lookup("delete",  $\Lambda$ , delete_like); id_lookup("div_t",  $\Lambda$ , raw_int); id_lookup("do",  $\Lambda$ , do_like);
id_lookup("double",  $\Lambda$ , raw_int); id_lookup("dynamic_cast",  $\Lambda$ , raw_int); id_lookup("elif",  $\Lambda$ , if_like);
id_lookup("else",  $\Lambda$ , else_like); id_lookup("endif",  $\Lambda$ , if_like); id_lookup("enum",  $\Lambda$ , struct_like);
id_lookup("error",  $\Lambda$ , if_like); id_lookup("explicit",  $\Lambda$ , int_like); id_lookup("export",  $\Lambda$ , int_like);
id_lookup("extern",  $\Lambda$ , int_like); id_lookup("FILE",  $\Lambda$ , raw_int); id_lookup("false",  $\Lambda$ , normal);
id_lookup("float",  $\Lambda$ , raw_int); id_lookup("for",  $\Lambda$ , for_like); id_lookup("fpos_t",  $\Lambda$ , raw_int);
id_lookup("friend",  $\Lambda$ , int_like); id_lookup("goto",  $\Lambda$ , case_like); id_lookup("if",  $\Lambda$ , if_like);
id_lookup("ifdef",  $\Lambda$ , if_like); id_lookup("ifndef",  $\Lambda$ , if_like); id_lookup("include",  $\Lambda$ , if_like);
id_lookup("inline",  $\Lambda$ , int_like); id_lookup("int",  $\Lambda$ , raw_int); id_lookup("jmp_buf",  $\Lambda$ , raw_int);
id_lookup("ldiv_t",  $\Lambda$ , raw_int); id_lookup("line",  $\Lambda$ , if_like); id_lookup("long",  $\Lambda$ , raw_int);
id_lookup("mutable",  $\Lambda$ , int_like); id_lookup("namespace",  $\Lambda$ , struct_like); id_lookup("new",  $\Lambda$ , new_like);
id_lookup("noexcept",  $\Lambda$ , attr); id_lookup("not",  $\Lambda$ , alfop); id_lookup("not_eq",  $\Lambda$ , alfop);
id_lookup("NULL",  $\Lambda$ , custom); id_lookup("nullptr",  $\Lambda$ , custom); id_lookup("offsetof",  $\Lambda$ , raw_int);
id_lookup("operator",  $\Lambda$ , operator_like); id_lookup("or",  $\Lambda$ , alfop); id_lookup("or_eq",  $\Lambda$ , alfop);
id_lookup("pragma",  $\Lambda$ , if_like); id_lookup("private",  $\Lambda$ , public_like);
id_lookup("protected",  $\Lambda$ , public_like); id_lookup("ptrdiff_t",  $\Lambda$ , raw_int);
id_lookup("public",  $\Lambda$ , public_like); id_lookup("register",  $\Lambda$ , int_like);
id_lookup("reinterpret_cast",  $\Lambda$ , raw_int); id_lookup("requires",  $\Lambda$ , int_like);
id_lookup("restrict",  $\Lambda$ , int_like); id_lookup("return",  $\Lambda$ , case_like); id_lookup("short",  $\Lambda$ , raw_int);
id_lookup("sig_atomic_t",  $\Lambda$ , raw_int); id_lookup("signed",  $\Lambda$ , raw_int);
id_lookup("size_t",  $\Lambda$ , raw_int); id_lookup("sizeof",  $\Lambda$ , sizeof_like); id_lookup("static",  $\Lambda$ , int_like);
id_lookup("static_assert",  $\Lambda$ , sizeof_like); id_lookup("static_cast",  $\Lambda$ , raw_int);
id_lookup("struct",  $\Lambda$ , struct_like); id_lookup("switch",  $\Lambda$ , for_like);
id_lookup("template",  $\Lambda$ , template_like); id_lookup("this",  $\Lambda$ , custom);
id_lookup("thread_local",  $\Lambda$ , raw_int); id_lookup("throw",  $\Lambda$ , case_like);
id_lookup("time_t",  $\Lambda$ , raw_int); id_lookup("true",  $\Lambda$ , normal); id_lookup("try",  $\Lambda$ , else_like);
id_lookup("typedef",  $\Lambda$ , typedef_like); id_lookup("typeid",  $\Lambda$ , sizeof_like);
id_lookup("typename",  $\Lambda$ , struct_like); id_lookup("undef",  $\Lambda$ , if_like); id_lookup("union",  $\Lambda$ , struct_like);
id_lookup("unsigned",  $\Lambda$ , raw_int); id_lookup("using",  $\Lambda$ , using_like);
id_lookup("va_dcl",  $\Lambda$ , decl);    > Berkeley's variable-arg-list convention <
id_lookup("va_list",  $\Lambda$ , raw_int);    > ditto <
id_lookup("virtual",  $\Lambda$ , int_like); id_lookup("void",  $\Lambda$ , raw_int); id_lookup("volatile",  $\Lambda$ , const_like);
id_lookup("wchar_t",  $\Lambda$ , raw_int); id_lookup("while",  $\Lambda$ , for_like); id_lookup("xor",  $\Lambda$ , alfop);
id_lookup("xor_eq",  $\Lambda$ , alfop); res_wd_end  $\leftarrow$  name_ptr; id_lookup("TeX",  $\Lambda$ , custom);

```

```
id_lookup("complex",  $\Lambda$ , int_like); id_lookup("imaginary",  $\Lambda$ , int_like);  
id_lookup("make_pair",  $\Lambda$ , func_template);
```

This code is used in section [2](#).

35. Lexical scanning. Let us now consider the subroutines that read the **CWEB** source file and break it into meaningful units. There are four such procedures: One simply skips to the next ‘@_’ or ‘@*’ that begins a section; another passes over the **TeX** text at the beginning of a section; the third passes over the **TeX** text in a C comment; and the last, which is the most interesting, gets the next token of a C text. They all use the pointers *limit* and *loc* into the line of input currently being studied.

36. Control codes in **CWEB**, which begin with ‘@’, are converted into a numeric code designed to simplify **CWEAVE**’s logic; for example, larger numbers are given to the control codes that denote more significant milestones, and the code of *new_section* should be the largest of all. Some of these numeric control codes take the place of **char** control codes that will not otherwise appear in the output of the scanning routines.

```
#define ignore °0      ▷ control code of no interest to CWEAVE ◁
#define verbatim °2     ▷ takes the place of ASCII STX ◁
#define begin_short_comment °3   ▷ C++ short comment ◁
#define begin_comment °'\t'    ▷ tab marks will not appear ◁
#define underline °'\n'      ▷ this code will be intercepted without confusion ◁
#define noop °177        ▷ takes the place of ASCII DEL ◁
#define xref_roman °203     ▷ control code for '@~' ◁
#define xref_wildcard °204    ▷ control code for '@:' ◁
#define xref_typewriter °205   ▷ control code for '@.' ◁
#define TeX_string °206     ▷ control code for '@t' ◁
    format TeX_string TeX
#define ord °207         ▷ control code for '@' ◁
#define join °210        ▷ control code for '@&' ◁
#define thin_space °211    ▷ control code for '@,' ◁
#define math_break °212    ▷ control code for '@|' ◁
#define line_break °213    ▷ control code for '@/' ◁
#define big_line_break °214  ▷ control code for '@#' ◁
#define no_line_break °215   ▷ control code for '@+' ◁
#define pseudo_semi °216    ▷ control code for '@;' ◁
#define macro_arg_open °220  ▷ control code for '@[' ◁
#define macro_arg_close °221 ▷ control code for '@]' ◁
#define trace °222        ▷ control code for '@0', '@1' and '@2' ◁
#define translit_code °223   ▷ control code for '@1' ◁
#define output_defs_code °224 ▷ control code for '@h' ◁
#define format_code °225    ▷ control code for '@f' and '@s' ◁
#define definition °226     ▷ control code for '@d' ◁
#define begin_C °227        ▷ control code for '@c' ◁
#define section_name °230    ▷ control code for '@<' ◁
#define new_section °231    ▷ control code for '@_’ and '@*’ ◁
```

37. Control codes are converted to **CWEAVE**’s internal representation by means of the table *ccode*.

(Private variables 21) +≡

```
static eight_bits ccode[256] ← {ignore};    ▷ meaning of a char following @ ◁
```

38. \langle Set initial values 24 $\rangle + \equiv$

```

ccode['\l'] ← ccode['\t'] ← ccode['\n'] ← ccode['\v'] ← ccode['\r'] ← ccode['\f'] ← ccode['*'] ←
  new_section; ccode['@'] ← '@';      ▷ 'quoted' at sign ◁
ccode['='] ← verbatim; ccode['d'] ← ccode['D'] ← definition;
ccode['f'] ← ccode['F'] ← ccode['s'] ← ccode['S'] ← format_code;
ccode['c'] ← ccode['C'] ← ccode['p'] ← ccode['P'] ← begin_C;
ccode['t'] ← ccode['T'] ← TEX_string; ccode['l'] ← ccode['L'] ← translit_code;
ccode['q'] ← ccode['Q'] ← noop; ccode['h'] ← ccode['H'] ← output_defs_code; ccode['&'] ← join;
ccode['<'] ← ccode['('] ← section_name; ccode['!'] ← underline; ccode['^'] ← xref_roman;
ccode[':'] ← xref_wildcard; ccode['.'] ← xref_typewriter; ccode[','] ← thin_space;
ccode['|'] ← math_break; ccode['/'] ← line_break; ccode['#'] ← big_line_break;
ccode['+'] ← no_line_break; ccode[';'] ← pseudo_semi; ccode['['] ← macro_arg_open;
ccode[''] ← macro_arg_close; ccode['\'] ← ord;  $\langle$ Special control codes for debugging 39 $\rangle$ 

```

39. Users can write @2, @1, and @0 to turn tracing *fully* on, *partly* on, and *off*, respectively. \langle Special control codes for debugging 39 $\rangle \equiv$

```
ccode['0'] ← ccode['1'] ← ccode['2'] ← trace;
```

This code is used in section 38.

40. The *skip_limbo* routine is used on the first pass to skip through portions of the input that are not in any sections, i.e., that precede the first section. After this procedure has been called, the value of *input_has_ended* will tell whether or not a section has actually been found.

There's a complication that we will postpone until later: If the @s operation appears in limbo, we want to use it to adjust the default interpretation of identifiers.

 \langle Predeclaration of procedures 4 $\rangle + \equiv$

```

static void skip_limbo(void);
static eight_bits skip_TEX(void);

```

41. static void skip_limbo(void)

```

{
  while (true) {
    if (loc > limit ∧ get_line() ≡ false) return;
    *(limit + 1) ← '@';
    while (*loc ≠ '@') loc++;      ▷ look for '@', then skip two chars ◁
    if (loc++ ≤ limit)
      switch (ccode[(eight_bits)*loc++]) {
        case new_section: return;
        case noop: skip_restricted(); break;
        case format_code:  $\langle$ Process simple format in limbo 79 $\rangle$ 
      }
  }
}

```

42. The *skip_TeX* routine is used on the first pass to skip through the TeX code at the beginning of a section. It returns the next control code or ‘|’ found in the input. A *new_section* is assumed to exist at the very end of the file.

format *skip_TeX* *TeX*

```
static eight_bits skip_TeX(void)    ▷ skip past pure TeX code ◁
{
  while (true) {
    if (loc > limit ∧ get_line() ≡ false) return new_section;
    *(limit + 1) ← ‘@’;
    while (*loc ≠ ‘@’ ∧ *loc ≠ ‘|’) loc++;
    if (*loc++ ≡ ‘|’) return (eight_bits) ‘|’;
    if (loc ≤ limit) return ccode[(eight_bits) * (loc++)];
  }
}
```


43. Inputting the next token. As stated above, **CWEAVE**'s most interesting lexical scanning routine is the *get_next* function that inputs the next token of C input. However, *get_next* is not especially complicated.

The result of *get_next* is either a **char** code for some special character, or it is a special code representing a pair of characters (e.g., '!='), or it is the numeric value computed by the *ccode* table, or it is one of the following special codes:

identifier: In this case the global variables *id_first* and *id_loc* will have been set to the beginning and ending-plus-one locations in the buffer, as required by the *id_lookup* routine.

string: The string will have been copied into the array *section_text*; *id_first* and *id_loc* are set as above (now they are pointers into *section_text*).

constant: The constant is copied into *section_text*, with slight modifications; *id_first* and *id_loc* are set.

Furthermore, some of the control codes cause *get_next* to take additional actions:

xref_roman, *xref_wildcard*, *xref_typewriter*, *TEX_string*, *verbatim*: The values of *id_first* and *id_loc* will have been set to the beginning and ending-plus-one locations in the buffer.

section_name: In this case the global variable *cur_section* will point to the *byte_start* entry for the section name that has just been scanned. The value of *cur_section_char* will be '(' if the section name was preceded by @C instead of @<.

If *get_next* sees '@!' it sets *xref_switch* to *def_flag* and goes on to the next token.

```
#define constant °200    ▷ C constant ◁
#define string °201      ▷ C string ◁
#define identifier °202   ▷ C identifier or reserved word ◁
⟨Private variables 21⟩ +=
static name_pointer cur_section;    ▷ name of section just scanned ◁
static char cur_section_char;      ▷ the character just before that name ◁
```

44. As one might expect, *get_next* consists mostly of a big switch that branches to the various special cases that can arise.

```
static eight_bits get_next(void)    ▷ produces the next input token ◁
{
    eight_bits c;    ▷ the current character ◁
    while (true) {
        ⟨Check if we're at the end of a preprocessor command 50⟩
        if (loc > limit ∧ get_line() ≡ false) return new_section;
        c ← *(loc++);
        if (xisdigit((int)c) ∨ c ≡ '.' ∨ c ≡ ',') ⟨Get a constant 53⟩
        else if (c ≡ '\\' ∨ c ≡ '"' ∨ ((c ≡ 'L' ∨ c ≡ 'u' ∨ c ≡ 'U') ∧ (*loc ≡ '\\' ∨ *loc ≡ '"'))
                  ∨ ((c ≡ 'u' ∧ *loc ≡ '8') ∧ (*(loc + 1) ≡ '\\' ∨ *(loc + 1) ≡ '"'))
                  ∨ (c ≡ '<' ∧ sharp_include_line ≡ true)) ⟨Get a string 57⟩
        else if (isalpha((int)c) ∨ isalpha(c) ∨ ishigh(c)) ⟨Get an identifier 52⟩
        else if (c ≡ '@') ⟨Get control code and possible section name 59⟩
        else if (xispace(c)) continue;    ▷ ignore spaces and tabs ◁
        if (c ≡ '#' ∧ loc ≡ buffer + 1) ⟨Raise preprocessor flag 47⟩
        mistake: ⟨Compress two-symbol operator 51⟩
        return c;
    }
}
```

45. ⟨Predeclaration of procedures 4⟩ += static eight_bits get_next(void);

46. Because preprocessor commands do not fit in with the rest of the syntax of C, we have to deal with them separately. One solution is to enclose such commands between special markers. Thus, when a `#` is seen as the first character of a line, *get_next* returns a special code *left_preproc* and raises a flag *preprocessing*.

We can use the same internal code number for *left_preproc* as we do for *ord*, since *get_next* changes *ord* into a string.

```
#define left_preproc ord    ▷ begins a preprocessor command ◁
#define right_preproc °217  ▷ ends a preprocessor command ◁
⟨Private variables 21⟩ +≡
    static bool preprocessing ← false;    ▷ are we scanning a preprocessor command? ◁
```

```
47. ⟨Raise preprocessor flag 47⟩ ≡
{
    preprocessing ← true; ⟨Check if next token is include 49⟩
    return left_preproc;
}
```

This code is used in section 44.

48. An additional complication is the freakish use of `<` and `>` to delimit a file name in lines that start with `#include`. We must treat this file name as a string.

```
⟨Private variables 21⟩ +≡
    static bool sharp_include_line ← false;    ▷ are we scanning a #include line? ◁
```

```
49. ⟨Check if next token is include 49⟩ ≡
    while (loc ≤ buffer_end - 7 ∧ xisspace(*loc)) loc++;
    if (loc ≤ buffer_end - 6 ∧ strcmp(loc, "include", 7) ≡ 0) sharp_include_line ← true;
```

This code is used in section 47.

50. When we get to the end of a preprocessor line, we lower the flag and send a code *right_preproc*, unless the last character was a `\`.

```
⟨Check if we're at the end of a preprocessor command 50⟩ ≡
    while (loc ≡ limit - 1 ∧ preprocessing ∧ *loc ≡ '\\')
        if (get_line() ≡ false) return new_section;    ▷ still in preprocessor mode ◁
    if (loc ≥ limit ∧ preprocessing) {
        preprocessing ← sharp_include_line ← false; return right_preproc;
    }
```

This code is used in section 44.

51. The following code assigns values to the combinations ++, --, ->, >=, <=, ==, <<, >>, !=, || and &&, and to the C++ combinations ..., ::, .* and ->*. The compound assignment operators (e.g., +=) are treated as separate tokens.

⟨Compress two-symbol operator 51⟩ ≡

```

switch (c) {
case '/':
    if (*loc ≡ '/*') { compress(begin_comment); }
    else if (*loc ≡ '/') compress(begin_short_comment);
    break;
case '+':
    if (*loc ≡ '++') compress(plus_plus);
    break;
case '-':
    if (*loc ≡ '--') { compress(minus_minus); }
    else if (*loc ≡ '>') {
        if (*(loc + 1) ≡ '/*') {
            loc++; compress(minus_gt_ast);
        }
        else compress(minus_gt);
    }
    break;
case '.':
    if (*loc ≡ '/*') { compress(period_ast); }
    else if (*loc ≡ '.' ∧ *(loc + 1) ≡ '.') {
        loc++; compress(dot_dot_dot);
    }
    break;
case ':':
    if (*loc ≡ '::') compress(colon_colon);
    break;
case '=':
    if (*loc ≡ '==') compress(eq_eq);
    break;
case '>':
    if (*loc ≡ '==') { compress(gt_eq); }
    else if (*loc ≡ '>') compress(gt_gt);
    break;
case '<':
    if (*loc ≡ '==') { compress(lt_eq); }
    else if (*loc ≡ '<') compress(lt_lt);
    break;
case '&':
    if (*loc ≡ '&&') compress(and_and);
    break;
case '|':
    if (*loc ≡ '||') compress(or_or);
    break;
case '!':
    if (*loc ≡ '!=') compress(non_eq);
    break;
}

```

This code is used in section 44.

```

52.  ⟨ Get an identifier 52 ⟩ ≡
{
  id_first ← --loc;
  do ++loc; while (isalpha((int)*loc) ∨ isdigit((int)*loc) ∨ isxalpha(*loc) ∨ ishigh(*loc));
  id_loc ← loc; return identifier;
}

```

This code is used in section 44.

53. Different conventions are followed by T_EX and C to express octal and hexadecimal numbers; it is reasonable to stick to each convention within its realm. Thus the C part of a CWEB file has octals introduced by 0 and hexadecimals by 0x, but CWEAVE will print with T_EX macros that the user can redefine to fit the context. In order to simplify such macros, we replace some of the characters.

On output, the `␣` that replaces ' in C++ literals will become “\␣”.

Notice that in this section and the next, *id_first* and *id_loc* are pointers into the array *section_text*, not into *buffer*.

```

#define gather_digits_while(t) while ((t) ∨ *loc ≡ '\')
  if (*loc ≡ '\') {      ▷ C++-style digit separator ◁
    *id_loc++ ← '␣'; loc++;      ▷ insert a little white space ◁
  } else *id_loc++ ← *loc++

⟨ Get a constant 53 ⟩ ≡
{
  id_first ← id_loc ← section_text + 1;
  if (*(loc - 1) ≡ '.' ∧ ¬isdigit(*loc)) goto mistake;      ▷ not a constant ◁
  if (*(loc - 1) ≡ '0') {
    if (*loc ≡ 'x' ∨ *loc ≡ 'X') ⟨ Get a hexadecimal constant 54 ⟩
    else if (*loc ≡ 'b' ∨ *loc ≡ 'B') ⟨ Get a binary constant 55 ⟩
    else if (isdigit(*loc)) ⟨ Get an octal constant 56 ⟩
  }
  *id_loc++ ← *(loc - 1);      ▷ decimal constant ◁
  gather_digits_while(isdigit(*loc) ∨ *loc ≡ '.');
get_exponent:
  if (*loc ≡ 'e' ∨ *loc ≡ 'E') *id_loc++ ← '_';
  else if (*loc ≡ 'p' ∨ *loc ≡ 'P') *id_loc++ ← '%';
  else goto digit_suffix;
  loc++;
  if (*loc ≡ '+' ∨ *loc ≡ '-') *id_loc++ ← *loc++;
  gather_digits_while(isdigit(*loc));
digit_suffix:
  while (*loc ≡ 'u' ∨ *loc ≡ 'U' ∨ *loc ≡ 'l' ∨ *loc ≡ 'L' ∨ *loc ≡ 'f' ∨ *loc ≡ 'F') {
    *id_loc++ ← '$'; *id_loc++ ← toupper((int)*loc); loc++;
  }
  return constant;
}

```

This code is used in section 44.

```

54.  ⟨ Get a hexadecimal constant 54 ⟩ ≡
{
  *id_loc++ ← '^'; loc++; gather_digits_while(isxdigit(*loc) ∨ *loc ≡ '.'); goto get_exponent;
}

```

This code is used in section 53.

55. \langle Get a binary constant 55 $\rangle \equiv$
 $\{$
 $*id_loc++ \leftarrow '\\'; loc++; gather_digits_while(*loc \equiv '0' \vee *loc \equiv '1');$ **goto** *digit_suffix*;
 $\}$

This code is used in section 53.

56. \langle Get an octal constant 56 $\rangle \equiv$
 $\{$
 $*id_loc++ \leftarrow '~'; gather_digits_while(xisdigit(*loc));$ **goto** *digit_suffix*;
 $\}$

This code is used in section 53.

57. C strings and character constants, delimited by double and single quotes, respectively, can contain newlines or instances of their own delimiters if they are protected by a backslash. We follow this convention, but do not allow the string to be longer than *longest_name*.

⟨Get a string 57⟩ ≡

```
{ char delim ← c;    ▷ what started the string ◁
  id_first ← section_text + 1; id_loc ← section_text;
  if (delim ≡ '\ ' ∧ loc − 2 ≡ '0') {
    *++id_loc ← '0'; *++id_loc ← '0';
  }
  *++id_loc ← delim;
  if (delim ≡ 'L' ∨ delim ≡ 'u' ∨ delim ≡ 'U') ⟨Get a wide character constant 58⟩
  if (delim ≡ '<') delim ← '>';    ▷ for file names in #include lines ◁
  while (true) {
    if (loc ≥ limit) {
      if (loc − 1 ≠ '\\') {
        err_print("!String didn't end"); loc ← limit; break;
      }
      if (get_line() ≡ false) {
        err_print("!Input ended in middle of string"); loc ← buffer; break;
      }
    }
    if ((c ← *loc++) ≡ delim) {
      if (++id_loc ≤ section_text_end) *id_loc ← c;
      break;
    }
    if (c ≡ '\\') {
      if (loc ≥ limit) continue;
      else {
        if (++id_loc ≤ section_text_end) {
          *id_loc ← '\\'; c ← *loc++;
        }
      }
    }
    if (++id_loc ≤ section_text_end) *id_loc ← c;
  }
  if (id_loc ≥ section_text_end) {
    printf("%s", "\n!String too long:"); term_write(section_text + 1, 25); printf("...");
    mark_error();
  }
  id_loc++; return string;
}
```

This code is used in sections 44 and 59.

58. ⟨Get a wide character constant 58⟩ ≡

```
{
  if (delim ≡ 'u' ∧ *loc ≡ '8') *++id_loc ← *loc++;
  delim ← *loc++; *++id_loc ← delim;
}
```

This code is used in section 57.

59. After an @ sign has been scanned, the next character tells us whether there is more work to do.

```

⟨Get control code and possible section name 59⟩ ≡
  switch (ccode[c ← *loc++]) {
    case translit_code: err_print("!_Use_@l_in_limbo_only"); continue;
    case underline: xref_switch ← def_flag; continue;
    case trace: tracing ← c - '0'; continue;
    case section_name: ⟨Scan the section name and make cur_section point to it 60⟩
    case verbatim: ⟨Scan a verbatim string 66⟩
    case ord: ⟨Get a string 57⟩
    case xref_roman: case xref_wildcard: case xref_typewriter: case noop: case TEX_string:
      skip_restricted(); /*_fall_through_*/
    default: return ccode[c];
  }

```

This code is used in section 44.

60. The occurrence of a section name sets *xref_switch* to zero, because the section name might (for example) follow **int**.

```

⟨Scan the section name and make cur_section point to it 60⟩ ≡
{
  char *k ← section_text;    ▷ pointer into section_text ◁
  cur_section_char ← *(loc - 1); ⟨Put section name into section_text 62⟩
  if (k - section_text > 3 ∧ strncmp(k - 2, "...", 3) ≡ 0)
    cur_section ← section_lookup(section_text + 1, k - 3, true);    ▷ true indicates a prefix ◁
  else cur_section ← section_lookup(section_text + 1, k, false);
  xref_switch ← 0; return section_name;
}

```

This code is used in section 59.

61. Section names are placed into the *section_text* array with consecutive spaces, tabs, and carriage-returns replaced by single spaces. There will be no spaces at the beginning or the end. (We set *section_text*[0] ← ' ' to facilitate this, since the *section_lookup* routine uses *section_text*[1] as the first character of the name.)

```

⟨Set initial values 24⟩ +≡
  section_text[0] ← ' ';

```

62. \langle Put section name into *section_text* 62 $\rangle \equiv$

```

while (true) {
  if (loc > limit  $\wedge$  get_line()  $\equiv$  false) {
    err_print("!_Input_ended_in_section_name"); loc  $\leftarrow$  buffer + 1; break;
  }
  c  $\leftarrow$  *loc;  $\langle$  If end of name or erroneous control code, break 63  $\rangle$ 
  loc++;
  if (k < section_text_end) k++;
  if (xisspace(c)) {
    c  $\leftarrow$  '_';
    if (*(k - 1)  $\equiv$  '_') k--;
  }
  *k  $\leftarrow$  c;
}
if (k  $\geq$  section_text_end) {
  printf("%s", "\n!_Section_name_too_long:_"); term_write(section_text + 1, 25); printf("...");
  mark_harmless();
}
if (*k  $\equiv$  '_'  $\wedge$  k > section_text) k--;

```

This code is used in section 60.

63. \langle If end of name or erroneous control code, break 63 $\rangle \equiv$

```

if (c  $\equiv$  '@') {
  c  $\leftarrow$  *(loc + 1);
  if (c  $\equiv$  '>') {
    loc += 2; break;
  }
  if (c[c]  $\equiv$  new_section) {
    err_print("!_Section_name_didn't_end"); break;
  }
  if (c  $\neq$  '@') {
    err_print("!_Control_codes_are_forbidden_in_section_name"); break;
  }
  *(++k)  $\leftarrow$  '@'; loc++;  $\triangleright$  now c  $\equiv$  *loc again  $\triangleleft$ 
}

```

This code is used in section 62.

64. This function skips over a restricted context at relatively high speed.

```
static void skip_restricted(void)
{
    id_first ← loc; *(limit + 1) ← '@';
false_alarm:
    while (*loc ≠ '@') loc++;
    id_loc ← loc;
    if (loc++ > limit) {
        err_print("!Control_text_didn't_end"); loc ← limit;
    }
    else {
        if (*loc ≡ '@' ∧ loc ≤ limit) {
            loc++; goto false_alarm;
        }
        if (*loc++ ≠ '>') err_print("!Control_codes_are_forbidden_in_control_text");
    }
}
```

65. ⟨Predeclaration of procedures 4⟩ +≡ **static void** *skip_restricted*(**void**);

66. At the present point in the program we have $*(loc - 1) \equiv verbatim$; we set *id_first* to the beginning of the string itself, and *id_loc* to its ending-plus-one location in the buffer. We also set *loc* to the position just after the ending delimiter.

⟨Scan a verbatim string 66⟩ ≡

```
id_first ← loc++; *(limit + 1) ← '@'; *(limit + 2) ← '>';
while (*loc ≠ '@' ∨ *(loc + 1) ≠ '>') loc++;
if (loc ≥ limit) err_print("!Verbatim_string_didn't_end");
id_loc ← loc; loc += 2; return verbatim;
```

This code is used in section 59.

67. Phase one processing. We now have accumulated enough subroutines to make it possible to carry out CWEAVE's first pass over the source file. If everything works right, both phase one and phase two of CWEAVE will assign the same numbers to sections, and these numbers will agree with what CTANGLE does.

The global variable *next_control* often contains the most recent output of *get_next*; in interesting cases, this will be the control code that ended a section or part of a section.

```
<Private variables 21> +=
  static eight_bits next_control;    ▷ control code waiting to be acting upon <
```

68. The overall processing strategy in phase one has the following straightforward outline.

```
static void phase_one(void)
{
  phase ← 1; reset.input(); section_count ← 0; skip_limbo(); change_exists ← false;
  while (¬input.has_ended) <Store cross-reference data for the current section 70>
    changed_section[section_count] ← change_exists;    ▷ the index changes if anything does <
  <Print error messages about unused or undefined section names 84>
}
```

69. <Predeclaration of procedures 4> += static void phase_one(void);

```
70. <Store cross-reference data for the current section 70> ≡
{
  if (++section_count ≡ max_sections) overflow("section_number");
  changed_section[section_count] ← changing;    ▷ it will become true if any line changes <
  if (*(loc - 1) ≡ '*' ^ show_progress) {
    printf("%d", (int) section_count); update_terminal();    ▷ print a progress report <
  }
  <Store cross-references in the TEX part of a section 74>
  <Store cross-references in the definition part of a section 77>
  <Store cross-references in the C part of a section 80>
  if (changed_section[section_count]) change_exists ← true;
}
```

This code is used in section 68.

71. The *C_xref* subroutine stores references to identifiers in C text material beginning with the current value of *next_control* and continuing until *next_control* is '{' or '|', or until the next "milestone" is passed (i.e., *next_control* ≥ *format_code*). If *next_control* ≥ *format_code* when *C_xref* is called, nothing will happen; but if *next_control* ≡ '|' upon entry, the procedure assumes that this is the '|' preceding C text that is to be processed.

The parameter *spec_ctrl* is used to change this behavior. In most cases *C_xref* is called with *spec_ctrl* ≡ *ignore*, which triggers the default processing described above. If *spec_ctrl* ≡ *section_name*, section names will be gobbled. This is used when C text in the T_EX part or inside comments is parsed: It allows for section names to appear in |...|, but these strings will not be entered into the cross reference lists since they are not definitions of section names.

The program uses the fact that our internal code numbers satisfy the relations *xref_roman* ≡ *identifier* + *roman* and *xref_wildcard* ≡ *identifier* + *wildcard* and *xref_typewriter* ≡ *identifier* + *typewriter*, as well as *normal* ≡ 0.

```
<Predeclaration of procedures 4> +=
  static void C_xref(eight_bits);
  static void outer_xref(void);
```

72. `static void C_xref(` ▷ makes cross-references for C identifiers ◁
 `eight_bits spec_ctrl)`
 {
 `while (next_control < format_code ∨ next_control ≡ spec_ctrl) {`
 `if (next_control ≥ identifier ∧ next_control ≤ xref_ttypewriter) {`
 `if (next_control > identifier) ◁ Replace ‘@@’ by ‘@’ 75 ◁`
 `new_xref(id_lookup(id_first, id_loc, next_control − identifier));`
 }
 `if (next_control ≡ section_name) {`
 `section_xref_switch ← cite_flag; new_section_xref(cur_section);`
 }
 `next_control ← get_next();`
 `if (next_control ≡ ‘|’ ∨ next_control ≡ begin_comment ∨ next_control ≡ begin_short_comment)`
 `return;`
 }
 }

73. The `outer_xref` subroutine is like `C_xref` except that it begins with `next_control ≠ ‘|’` and ends with `next_control ≥ format_code`. Thus, it handles C text with embedded comments.

`static void outer_xref(void)` ▷ extension of `C_xref` ◁
 {
 `int bal;` ▷ brace level in comment ◁
 `while (next_control < format_code)`
 `if (next_control ≠ begin_comment ∧ next_control ≠ begin_short_comment) C_xref(ignore);`
 `else {`
 `bool is_long_comment ← (next_control ≡ begin_comment);`
 `bal ← copy_comment(is_long_comment, 1); next_control ← ‘|’;`
 `while (bal > 0) {`
 `C_xref(section_name);` ▷ do not reference section names in comments ◁
 `if (next_control ≡ ‘|’) bal ← copy_comment(is_long_comment, bal);`
 `else bal ← 0;` ▷ an error message will occur in phase two ◁
 }
 }
 }

74. In the \TeX part of a section, cross-reference entries are made only for the identifiers in C texts enclosed in $| \dots |$, or for control texts enclosed in $@^{\sim} \dots @>$ or $@. \dots @>$ or $@: \dots @>$.

\langle Store cross-references in the \TeX part of a section 74 $\rangle \equiv$

```
while (true) {
  switch (next_control  $\leftarrow$  skip_T $\text{\TeX}$ ()) {
    case translit_code: err_print("!_Use_@l_in_limbo_only"); continue;
    case underline: xref_switch  $\leftarrow$  def_flag; continue;
    case trace: tracing  $\leftarrow$  *(loc - 1) - '0'; continue;
    case '|': C_xref(section_name); break;
    case xref_roman: case xref_wildcard: case xref_typewriter: case noop: case section_name: loc -= 2;
      next_control  $\leftarrow$  get_next();  $\triangleright$  scan to @>  $\triangleleft$ 
      if (next_control  $\geq$  xref_roman  $\wedge$  next_control  $\leq$  xref_typewriter) {
         $\langle$  Replace '@@' by '@' 75  $\rangle$ 
        new_xref(id_lookup(id_first, id_loc, next_control - identifier));
      }
      break;
  }
  if (next_control  $\geq$  format_code) break;
}
```

This code is used in section 70.

75. \langle Replace '@@' by '@' 75 $\rangle \equiv$

```
{
  char *src  $\leftarrow$  id_first, *dst  $\leftarrow$  id_first;
  while (src < id_loc) {
    if (*src  $\equiv$  '@') src++;
    *dst++  $\leftarrow$  *src++;
  }
  id_loc  $\leftarrow$  dst;
  while (dst < src) *dst++  $\leftarrow$  '_';  $\triangleright$  clean up in case of error message display  $\triangleleft$ 
}
```

This code is used in sections 72 and 74.

76. During the definition and C parts of a section, cross-references are made for all identifiers except reserved words. However, the right identifier in a format definition is not referenced, and the left identifier is referenced only if it has been explicitly underlined (preceded by @!). The \TeX code in comments is, of course, ignored, except for C portions enclosed in $| \dots |$; the text of a section name is skipped entirely, even if it contains $| \dots |$ constructions.

The variables *lhs* and *rhs* point to the respective identifiers involved in a format definition.

\langle Private variables 21 $\rangle + \equiv$

```
static name_pointer lhs, rhs;  $\triangleright$  pointers to byte_start for format identifiers  $\triangleleft$ 
static name_pointer res_wd_end;  $\triangleright$  pointer to the first nonreserved identifier  $\triangleleft$ 
```

77. When we get to the following code we have $next_control \geq format_code$.

```

⟨Store cross-references in the definition part of a section 77⟩ ≡
  while ( $next\_control \leq definition$ ) {    ▷  $format\_code$  or  $definition$  ◁
    if ( $next\_control \equiv definition$ ) {
       $xref\_switch \leftarrow def\_flag$ ;    ▷ implied @! ◁
       $next\_control \leftarrow get\_next()$ ;
    }
    else ⟨Process a format definition 78⟩
       $outer\_xref()$ ;
  }

```

This code is used in section 70.

78. Error messages for improper format definitions will be issued in phase two. Our job in phase one is to define the *ilk* of a properly formatted identifier, and to remove cross-references to identifiers that we now discover should be unindexed.

```

⟨Process a format definition 78⟩ ≡
  {
     $next\_control \leftarrow get\_next()$ ;
    if ( $next\_control \equiv identifier$ ) {
       $lhs \leftarrow id\_lookup(id\_first, id\_loc, normal)$ ;  $lhs\_ilk \leftarrow normal$ ;
      if ( $xref\_switch$ )  $new\_xref(lhs)$ ;
       $next\_control \leftarrow get\_next()$ ;
      if ( $next\_control \equiv identifier$ ) {
         $rhs \leftarrow id\_lookup(id\_first, id\_loc, normal)$ ;  $lhs\_ilk \leftarrow rhs\_ilk$ ;
        if ( $unindexed(lhs)$ ) {    ▷ retain only underlined entries ◁
          xref_pointer  $q, r \leftarrow \Lambda$ ;
          for ( $q \leftarrow$  (xref_pointer)  $lhs\_xref$ ;  $q > xmem$ ;  $q \leftarrow q\_xlink$ )
            if ( $q\_num < def\_flag$ )
              if ( $r$ )  $r\_xlink \leftarrow q\_xlink$ ;
              else  $lhs\_xref \leftarrow (void *) q\_xlink$ ;
            else  $r \leftarrow q$ ;
          }
           $next\_control \leftarrow get\_next()$ ;
        }
      }
    }
  }

```

This code is used in section 77.

79. A much simpler processing of format definitions occurs when the definition is found in limbo.

```

⟨Process simple format in limbo 79⟩ ≡
  if ( $get\_next() \neq identifier$ )  $err\_print("!\_Missing\_left\_identifier\_of\_s")$ ;
  else {
     $lhs \leftarrow id\_lookup(id\_first, id\_loc, normal)$ ;
    if ( $get\_next() \neq identifier$ )  $err\_print("!\_Missing\_right\_identifier\_of\_s")$ ;
    else {
       $rhs \leftarrow id\_lookup(id\_first, id\_loc, normal)$ ;  $lhs\_ilk \leftarrow rhs\_ilk$ ;
    }
  }

```

This code is used in section 41.

80. Finally, when the \TeX and definition parts have been treated, we have $next_control \geq begin_C$.

```

⟨Store cross-references in the C part of a section 80⟩ ≡
  if ( $next\_control \leq section\_name$ ) {    ▷  $begin\_C$  or  $section\_name$  ◁
    if ( $next\_control \equiv begin\_C$ )  $section\_xref\_switch \leftarrow 0$ ;
    else {
       $section\_xref\_switch \leftarrow def\_flag$ ;
      if ( $cur\_section\_char \equiv '(\wedge cur\_section \neq name\_dir$ )  $set\_file\_flag(cur\_section)$ ;
    }
  }
  do {
    if ( $next\_control \equiv section\_name \wedge cur\_section \neq name\_dir$ )  $new\_section\_xref(cur\_section)$ ;
     $next\_control \leftarrow get\_next()$ ;  $outer\_xref()$ ;
  } while ( $next\_control \leq section\_name$ );
}

```

This code is used in section 70.

81. After phase one has looked at everything, we want to check that each section name was both defined and used. The variable cur_xref will point to cross-references for the current section name of interest.

```

⟨Private variables 21⟩ +≡
  static xref_pointer  $cur\_xref$ ;    ▷ temporary cross-reference pointer ◁
  static bool  $an\_output$ ;    ▷ did  $file\_flag$  precede  $cur\_xref$ ? ◁

```

82. The following recursive procedure walks through the tree of section names and prints out anomalies.

```

static void section_check(name_pointer  $p$ )    ▷ print anomalies in subtree  $p$  ◁
{
  if ( $p$ ) {
    section_check( $p\_llink$ );  $cur\_xref \leftarrow (xref\_pointer) p\_xref$ ;
    if (( $an\_output \leftarrow (cur\_xref\_num \equiv file\_flag) \equiv true$ )  $cur\_xref \leftarrow cur\_xref\_xlink$ ;
    if ( $cur\_xref\_num < def\_flag$ ) {
      printf("%s", "\n!␣Never␣defined:␣<"); print_section_name( $p$ ); putchar('>'); mark_harmless();
    }
    while ( $cur\_xref\_num \geq cite\_flag$ )  $cur\_xref \leftarrow cur\_xref\_xlink$ ;
    if ( $cur\_xref \equiv xmem \wedge \neg an\_output$ ) {
      printf("%s", "\n!␣Never␣used:␣<"); print_section_name( $p$ ); putchar('>'); mark_harmless();
    }
    section_check( $p\_rlink$ );
  }
}

```

83. ⟨Predeclaration of procedures 4⟩ +≡ static void section_check(name_pointer);

84. ⟨Print error messages about unused or undefined section names 84⟩ ≡
 $section_check(root)$;

This code is used in section 68.

85. Low-level output routines. The \TeX output is supposed to appear in lines at most *line_length* characters long, so we place it into an output buffer. During the output process, *out_line* will hold the current line number of the line about to be output.

```
#define line_length 80    ▷ lines of  $\text{\TeX}$  output have at most this many characters; should be less than 256 ◁
⟨ Private variables 21 ⟩ +=
    static char out_buf[line_length + 1];    ▷ assembled characters ◁
    static char *out_buf_end ← out_buf + line_length;    ▷ end of out_buf ◁
    static char *out_ptr;    ▷ last character in out_buf ◁
    static int out_line;    ▷ number of next line to be output ◁
```

86. The *flush_buffer* routine empties the buffer up to a given breakpoint, and moves any remaining characters to the beginning of the next line. If the *per_cent* parameter is *true*, a '%' is appended to the line that is being output; in this case the breakpoint *b* should be strictly less than *out_buf_end*. If the *per_cent* parameter is *false*, trailing blanks are suppressed. The characters emptied from the buffer form a new line of output; if the *carryover* parameter is *true*, a "%" in that line will be carried over to the next line (so that \TeX will ignore the completion of commented-out text).

```
#define c_line_write(c) fflush(active_file), fwrite(out_buf + 1, sizeof(char), c, active_file)
#define tex_printf(c) fprintf(active_file, "%s", c)
#define tex_putc(c) fputc(c, active_file)
#define tex_puts(c) fputs(c, active_file)
⟨ Predeclaration of procedures 4 ⟩ +=
    static void flush_buffer(char *, bool, bool);
    static void finish_line(void);
```

```
87. static void flush_buffer(char *b,    ▷ outputs from out_buf + 1 to b, where  $b \leq out\_ptr$  ◁
    bool per_cent, bool carryover)
{
    char *j ← b;    ▷ pointer into out_buf ◁
    if (¬per_cent)    ▷ remove trailing blanks ◁
        while (j > out_buf ∧ *j ≡ ' ') j--;
    c_line_write(j - out_buf);
    if (per_cent) tex_putc('%');
    tex_putc('\n'); out_line++;
    if (carryover)
        while (j > out_buf)
            if (*j ≡ '%' ∧ (j ≡ out_buf ∨ *j ≠ '\\')) {
                *b-- ← '%'; break;
            }
    if (b < out_ptr) memcpy(out_buf + 1, b + 1, (size_t)(out_ptr - b));
    out_ptr -= b - out_buf;
}
```

88. When we are copying T_EX source material, we retain line breaks that occur in the input, except that an empty line is not output when the T_EX source line was nonempty. For example, a line of the T_EX file that contains only an index cross-reference entry will not be copied. The *finish_line* routine is called just before *get_line* inputs a new line, and just after a line break token has been emitted during the output of translated C text.

```
static void finish_line(void)    ▷ do this at the end of a line ◁
{
    char *k;    ▷ pointer into buffer ◁
    if (out_ptr > out_buf) flush_buffer(out_ptr, false, false);
    else {
        for (k ← buffer; k ≤ limit; k++)
            if (¬(xisspace(*k))) return;
        flush_buffer(out_buf, false, false);
    }
}
```

89. In particular, the *finish_line* procedure is called near the very beginning of phase two. We initialize the output variables in a slightly tricky way so that the first line of the output file will be ‘\input cwebmac’.

⟨Start T_EX output 89⟩ ≡
 out_ptr ← out_buf + 1; out_line ← 1; active_file ← tex_file; tex_printf("\input_cwebma");
 *out_ptr ← 'c';

This code is used in section 2.

90. When we wish to append one character *c* to the output buffer, we write ‘out(*c*)’; this will cause the buffer to be emptied if it was already full. If we want to append more than one character at once, we say out_str(*s*), where *s* is a string containing the characters.

A line break will occur at a space or after a single-nonletter T_EX control sequence.

```
#define out(c)
{
    if (out_ptr ≥ out_buf_end) break_out();
    *(++out_ptr) ← c;
}
```

⟨Predeclaration of procedures 4⟩ +≡
 static void out_str(const char *);
 static void break_out(void);

91. static void out_str(▷ output characters from *s* to end of string ◁
 const char *s)
{
 while (*s) out(*s++);
}

92. The *break_out* routine is called just before the output buffer is about to overflow. To make this routine a little faster, we initialize position 0 of the output buffer to ‘\’; this character isn’t really output.

⟨Set initial values 24⟩ +≡
 out_buf[0] ← '\\’;

93. A long line is broken at a blank space or just before a backslash that isn't preceded by another backslash or a \TeX comment marker. In the latter case, a `'\'` is output at the break.

```
static void break_out(void)    ▷ finds a way to break the output line ◁
{
  char *k ← out_ptr;    ▷ pointer into out_buf ◁
  while (true) {
    if (k ≡ out_buf) ◁ Print warning message, break the line, return 94 ▷
    if (*k ≡ '\ ') {
      flush_buffer(k, false, true); return;
    }
    if (*(k--) ≡ '\\\' ∧ *k ≠ '\\\' ∧ *k ≠ '%') {    ▷ we've decreased k ◁
      flush_buffer(k, true, true); return;
    }
  }
}
```

94. We get to this section only in the unusual case that the entire output line consists of a string of backslashes followed by a string of nonblank non-backslashes. In such cases it is almost always safe to break the line by putting a `'\'` just before the last character.

```
◁ Print warning message, break the line, return 94 ▷ ≡
{
  printf("\n!_Line_had_to_be_broken_(output_l._%d):\n", out_line);
  term_write(out_buf + 1, out_ptr - out_buf - 1); new_line(); mark_harmless();
  flush_buffer(out_ptr - 1, true, true); return;
}
```

This code is used in section 93.

95. Here is a macro that outputs a section number in decimal notation. The number to be converted by `out_section` is known to be less than `def_flag`, so it cannot have more than five decimal digits. If the section is changed, we output `'*` just after the number.

```
◁ Predeclaration of procedures 4 ▷ +≡
static void out_section(sixteen_bits);
static void out_name(name_pointer, bool);
```

```
96. static void out_section(sixteen_bits n)
{
  char s[6];
  snprintf(s, 6, "%d", (int) n); out_str(s);
  if (changed_section[n]) out_str("\\*");
}
```

97. The `out_name` procedure is used to output an identifier or index entry, enclosing it in braces.

```
static void out_name(name_pointer p, bool quote_xalpha)
{
  char *k;    ▷ pointer into byte_mem ◁
  out('{');
  for (k ← p-byte_start; k < (p + 1)-byte_start; k++) {
    if (isxalpha(*k) ∧ quote_xalpha) out('\\');
    out(*k);
  }
  out('}');
}
```

98. Routines that copy T_EX material. During phase two, we use the subroutines *copy_limbo* and *copy_T_EX* (and *copy_comment*) in place of the analogous *skip_limbo* and *skip_T_EX* that were used in phase one.

The *copy_limbo* routine, for example, takes T_EX material that is not part of any section and transcribes it almost verbatim to the output file. The use of ‘@’ signs is severely restricted in such material: ‘@@’ pairs are replaced by singletons; ‘@l’ and ‘@q’ and ‘@s’ are interpreted.

⟨Predeclaration of procedures 4⟩ +≡

```
static void copy_limbo(void);
static eight_bits copy_TEX(void);
static int copy_comment(bool,int);
```

99. static void copy_limbo(void)

```
{
  while (true) {
    if (loc > limit ∧ (finish_line(), get_line() ≡ false)) return;
    *(limit + 1) ← '@';
    while (*loc ≠ '@') out(*(loc++));
    if (loc++ ≤ limit) {
      switch (ccode[(eight_bits)*loc++]) {
        case new_section: return;
        case translit_code: out_str("\\ATL"); break;
        case '@': out('@'); break;
        case noop: skip_restricted(); break;
        case format_code:
          if (get_next() ≡ identifier) get_next();
          if (loc ≥ limit) get_line();    ▷ avoid blank lines in output ◁
          break;    ▷ the operands of @s are ignored on this pass ◁
        default: err_print("!_Double_@_should_be_used_in_limbo"); out('@');
      }
    }
  }
}
```

100. The *copy_T_EX* routine processes the T_EX code at the beginning of a section; for example, the words you are now reading were copied in this way. It returns the next control code or ‘|’ found in the input. We don’t copy spaces or tab marks into the beginning of a line. This makes the test for empty lines in *finish_line* work.

```

format copy_TeX TeX
static eight_bits copy_TEX(void)
{
    char c;     ▷ current character being copied ◁
    while (true) {
        if (loc > limit ∧ (finish_line() , get_line() ≡ false)) return new_section;
        *(limit + 1) ← ‘@’;
        while ((c ← *(loc++)) ≠ ‘|’ ∧ c ≠ ‘@’) {
            out(c);
            if (out_ptr ≡ out_buf + 1 ∧ (xisspace(c))) out_ptr--;
        }
        if (c ≡ ‘|’) return ‘|’;
        if (loc ≤ limit) return ccode[(eight_bits) * (loc++)];
    }
}

```

101. The *copy_comment* function issues a warning if more braces are opened than closed, and in the case of a more serious error it supplies enough braces to keep T_EX from complaining about unbalanced braces. Instead of copying the T_EX material into the output buffer, this function copies it into the token memory (in phase two only). The abbreviation *app_tok(t)* is used to append token *t* to the current token list, and it also makes sure that it is possible to append at least one further token without overflow.

```
#define app_tok(c)
{
    if (tok_ptr + 2 > tok_mem_end) overflow("token");
    *(tok_ptr++) ← c;
}

static int copy_comment(    ▷ copies TEX code in comments ◁
    bool is_long_comment,  ▷ is this a traditional C comment? ◁
    int bal)               ▷ brace balance ◁
{
    char c;    ▷ current character being copied ◁
    while (true) {
        if (loc > limit) {
            if (is_long_comment) {
                if (get_line() ≡ false) {
                    err_print("!_Input_ended_in_mid-comment"); loc ← buffer + 1; goto done;
                }
            }
            else {
                if (bal > 1) err_print("!_Missing_}_in_comment");
                goto done;
            }
        }
        c ← *(loc++);
        if (c ≡ ' | ') return bal;
        if (is_long_comment) ◁ Check for end of comment 102 ◁
        if (phase ≡ 2) {
            if (ishigh(c)) app_tok(quoted_char);
            app_tok(c);
        }
        ◁ Copy special things when c ≡ '@', '\\ ' 103 ◁
        if (c ≡ '{') bal++;
        else if (c ≡ '}') {
            if (bal > 1) bal--;
            else {
                err_print("!_Extra_}_in_comment");
                if (phase ≡ 2) tok_ptr--;
            }
        }
    }
done: ◁ Clear bal and return 104 ◁
}
```

102. \langle Check for end of comment [102](#) $\rangle \equiv$
 if ($c \equiv '*' \wedge *loc \equiv '/'$) {
 $loc++$;
 if ($bal > 1$) *err_print*("!Missing}incomment");
 goto *done*;
 }

This code is used in section [101](#).

103. \langle Copy special things when $c \equiv '@', '\\'$ [103](#) $\rangle \equiv$
 if ($c \equiv '@'$) {
 if ($*(loc++) \neq '@'$) {
 err_print("!Illegal use of @incomment"); $loc -= 2$;
 if ($phase \equiv 2$) $*(tok_ptr - 1) \leftarrow '_'$;
 goto *done*;
 }
 }
 else {
 if ($c \equiv '\\'$ $\wedge *loc \neq '@'$) {
 if ($phase \equiv 2$) *app_tok*($*(loc++)$);
 else $loc++$;
 }
 }

This code is used in section [101](#).

104. We output enough right braces to keep T_EX happy.
 \langle Clear *bal* and **return** [104](#) $\rangle \equiv$
 if ($phase \equiv 2$)
 while ($bal-- > 0$) *app_tok*('}');
 return 0;

This code is used in section [101](#).

105. Parsing. The most intricate part of **CWEAVE** is its mechanism for converting C-like code into **TEX** code, and we might as well plunge into this aspect of the program now. A “bottom up” approach is used to parse the C-like material, since **CWEAVE** must deal with fragmentary constructions whose overall “part of speech” is not known.

At the lowest level, the input is represented as a sequence of entities that we shall call *scraps*, where each scrap of information consists of two parts, its *category* and its *translation*. The category is essentially a syntactic class, and the translation is a token list that represents **TEX** code. Rules of syntax and semantics tell us how to combine adjacent scraps into larger ones, and if we are lucky an entire C text that starts out as hundreds of small scraps will join together into one gigantic scrap whose translation is the desired **TEX** code. If we are unlucky, we will be left with several scraps that don’t combine; their translations will simply be output, one by one.

The combination rules are given as context-sensitive productions that are applied from left to right. Suppose that we are currently working on the sequence of scraps $s_1 s_2 \dots s_n$. We try first to find the longest production that applies to an initial substring $s_1 s_2 \dots$; but if no such productions exist, we try to find the longest production applicable to the next substring $s_2 s_3 \dots$; and if that fails, we try to match $s_3 s_4 \dots$, etc.

A production applies if the category codes have a given pattern. For example, one of the productions (see rule 3) is

$$exp \left\{ \begin{array}{c} binop \\ ubinop \end{array} \right\} exp \rightarrow exp$$

and it means that three consecutive scraps whose respective categories are *exp*, *binop* (or *ubinop*), and *exp* are converted to one scrap whose category is *exp*. The translations of the original scraps are simply concatenated. The case of

$$exp \text{ comma } exp \rightarrow exp \qquad E_1 C \text{ opt} 9 E_2$$

(rule 4) is only slightly more complicated: Here the resulting *exp* translation consists not only of the three original translations, but also of the tokens *opt* and 9 between the translations of the *comma* and the following *exp*. In the **TEX** file, this will specify an optional line break after the comma, with penalty 90.

At each opportunity the longest possible production is applied. For example, if the current sequence of scraps is *if_clause stmt else_like if_like*, rule 63 is applied; but if the sequence is *if_clause stmt else_like* followed by anything other than *if_like*, rule 64 takes effect; and if the sequence is *if_clause stmt* followed by anything other than *else_like*, rule 65 takes effect.

Translation rules such as ‘ $E_1 C \text{ opt} 9 E_2$ ’ above use subscripts to distinguish between translations of scraps whose categories have the same initial letter; these subscripts are assigned from left to right.

106. Here is a list of the category codes that scraps can have. (A few others, like *int_like*, have already been defined; the *cat_name* array contains a complete list.)

```
#define exp 1    ▷ denotes an expression, including perhaps a single identifier ◁
#define unop 2   ▷ denotes a unary operator ◁
#define binop 3   ▷ denotes a binary operator ◁
#define ubinop 4  ▷ denotes an operator that can be unary or binary, depending on context ◁
#define cast 5   ▷ denotes a cast ◁
#define question 6 ▷ denotes a question mark and possibly the expressions flanking it ◁
#define lbrace 7  ▷ denotes a left brace ◁
#define rbrace 8  ▷ denotes a right brace ◁
#define decl_head 9 ▷ denotes an incomplete declaration ◁
#define comma 10  ▷ denotes a comma ◁
#define lpar 11   ▷ denotes a left parenthesis ◁
#define rpar 12   ▷ denotes a right parenthesis ◁
#define prelang 13 ▷ denotes '<' before we know what it is ◁
#define prerang 14 ▷ denotes '>' before we know what it is ◁
#define lang 15   ▷ denotes '<' when it's used as angle bracket in a template ◁
#define colcol 18 ▷ denotes '::' ◁
#define base 19   ▷ denotes a colon that introduces a base specifier ◁
#define decl 20   ▷ denotes a complete declaration ◁
#define struct_head 21 ▷ denotes the beginning of a structure specifier ◁
#define stmt 23   ▷ denotes a complete statement ◁
#define function 24 ▷ denotes a complete function ◁
#define fn_decl 25 ▷ denotes a function declarator ◁
#define semi 27   ▷ denotes a semicolon ◁
#define colon 28  ▷ denotes a colon ◁
#define tag 29    ▷ denotes a statement label ◁
#define if_head 30 ▷ denotes the beginning of a compound conditional ◁
#define else_head 31 ▷ denotes a prefix for a compound statement ◁
#define if_clause 32 ▷ pending if together with a condition ◁
#define lproc 35  ▷ begins a preprocessor command ◁
#define rproc 36  ▷ ends a preprocessor command ◁
#define insert 37 ▷ a scrap that gets combined with its neighbor ◁
#define section_scrap 38 ▷ section name ◁
#define dead 39   ▷ scrap that won't combine ◁
#define ftemplate 63 ▷ make_pair ◁
#define new_exp 64 ▷ new and a following type identifier ◁
#define begin_arg 65 ▷ @[ ◁
#define end_arg 66 ▷ @] ◁
#define lbrack 67 ▷ denotes a left bracket ◁
#define rbrack 68 ▷ denotes a right bracket ◁
#define attr_head 69 ▷ denotes beginning of attribute ◁
```

(Private variables 21) +=

```
static char cat_name[256][12]; ▷ 12 ≡ strlen("struct_head") + 1 ◁
```

107. \langle Set initial values 24 $\rangle \vdash \equiv$

```

{
  int c;
  for (c ← 0; c < 256; c++) strcpy(cat_name[c], "UNKNOWN");
}
strcpy(cat_name[exp], "exp"); strcpy(cat_name[unop], "unop"); strcpy(cat_name[binop], "binop");
strcpy(cat_name[ubinop], "ubinop"); strcpy(cat_name[cast], "cast"); strcpy(cat_name[question], "?");
strcpy(cat_name[lbrace], "{"); strcpy(cat_name[rbrace], "}");
strcpy(cat_name[decl_head], "decl_head"); strcpy(cat_name[comma], ","); strcpy(cat_name[lpar], "(");
strcpy(cat_name[rpar], ")"); strcpy(cat_name[prelangle], "<"); strcpy(cat_name[prerangle], ">");
strcpy(cat_name[langle], "\\<"); strcpy(cat_name[colcol], "::"); strcpy(cat_name[base], "\\:");
strcpy(cat_name[decl], "decl"); strcpy(cat_name[struct_head], "struct_head");
strcpy(cat_name[alfop], "alfop"); strcpy(cat_name[stmt], "stmt");
strcpy(cat_name[function], "function"); strcpy(cat_name[fn_decl], "fn_decl");
strcpy(cat_name[else_like], "else_like"); strcpy(cat_name[semi], ";"); strcpy(cat_name[colon], ":");
strcpy(cat_name[tag], "tag"); strcpy(cat_name[if_head], "if_head");
strcpy(cat_name[else_head], "else_head"); strcpy(cat_name[if_clause], "if()");
strcpy(cat_name[lproc], "#{"); strcpy(cat_name[rproc], "#}"); strcpy(cat_name[insert], "insert");
strcpy(cat_name[section_scrap], "section"); strcpy(cat_name[dead], "@d");
strcpy(cat_name[public_like], "public"); strcpy(cat_name[operator_like], "operator");
strcpy(cat_name[new_like], "new"); strcpy(cat_name[catch_like], "catch");
strcpy(cat_name[for_like], "for"); strcpy(cat_name[do_like], "do"); strcpy(cat_name[if_like], "if");
strcpy(cat_name[delete_like], "delete"); strcpy(cat_name[raw_ubin], "ubinop?");
strcpy(cat_name[const_like], "const"); strcpy(cat_name[raw_int], "raw");
strcpy(cat_name[int_like], "int"); strcpy(cat_name[case_like], "case");
strcpy(cat_name[sizeof_like], "sizeof"); strcpy(cat_name[struct_like], "struct");
strcpy(cat_name[typedef_like], "typedef"); strcpy(cat_name[define_like], "define");
strcpy(cat_name[template_like], "template"); strcpy(cat_name[alignas_like], "alignas");
strcpy(cat_name[using_like], "using"); strcpy(cat_name[default_like], "default");
strcpy(cat_name[attr], "attr"); strcpy(cat_name[ftemplate], "ftemplate");
strcpy(cat_name[new_exp], "new_exp"); strcpy(cat_name[begin_arg], "@[");
strcpy(cat_name[end_arg], "@]"); strcpy(cat_name[lbrack], "["); strcpy(cat_name[rbrack], "]");
strcpy(cat_name[attr_head], "attr_head"); strcpy(cat_name[0], "zero");

```

108. This code allows CWEAVE to display its parsing steps.

```

#define print_cat(c) fputs(cat_name[c], stdout)    ▷ symbolic printout of a category ◁

```


109. The token lists for translated \TeX output contain some special control symbols as well as ordinary characters. These control symbols are interpreted by **CWEAVE** before they are written to the output file.

break_space denotes an optional line break or an en space;

force denotes a line break;

big_force denotes a line break with additional vertical space;

preproc_line denotes that the line will be printed flush left;

opt denotes an optional line break (with the continuation line indented two ems with respect to the normal starting position)—this code is followed by an integer n , and the break will occur with penalty $10n$;

backup denotes a backspace of one em;

cancel obliterates any *break_space*, *opt*, *force*, or *big_force* tokens that immediately precede or follow it and also cancels any *backup* tokens that follow it;

indent causes future lines to be indented one more em;

outdent causes future lines to be indented one less em;

dindent causes future lines to be indented two more ems.

All of these tokens are removed from the \TeX output that comes from C text between `| ... |` signs; *break_space* and *force* and *big_force* become single spaces in this mode. The translation of other C texts results in \TeX control sequences `\1`, `\2`, `\3`, `\4`, `\5`, `\6`, `\7`, `\8` corresponding respectively to *indent*, *outdent*, *opt*, *backup*, *break_space*, *force*, *big_force* and *preproc_line*. However, a sequence of consecutive ‘`\1`’, *break_space*, *force*, and/or *big_force* tokens is first replaced by a single token (the maximum of the given ones).

A *dindent* token becomes `\1\1`. It is equivalent to a pair of *indent* tokens. However, if *dindent* immediately precedes *big_force*, the two tokens are swapped, so that the indentation happens after the line break.

The token *math_rel* will be translated into `\MRL{`, and it will get a matching `}` later. Other control sequences in the \TeX output will be ‘`\{ ... }`’ surrounding identifiers, ‘`\&\{ ... }`’ surrounding reserved words, ‘`\. { ... }`’ surrounding strings, ‘`\C{ ... }`’ surrounding comments, and ‘`\Xn: ... \X`’ surrounding section names, where n is the section number.

```
#define math_rel °206
#define big_cancel °210    ▷ like cancel, also overrides spaces ◁
#define cancel °211      ▷ overrides backup, break_space, force, big_force ◁
#define indent °212      ▷ one more tab (\1) ◁
#define outdent °213     ▷ one less tab (\2) ◁
#define opt °214         ▷ optional break in mid-statement (\3) ◁
#define backup °215     ▷ stick out one unit to the left (\4) ◁
#define break_space °216 ▷ optional break between statements (\5) ◁
#define force °217      ▷ forced break between statements (\6) ◁
#define big_force °220   ▷ forced break with additional space (\7) ◁
#define preproc_line °221 ▷ begin line without indentation (\8) ◁
#define quoted_char °222 ▷ introduces a character token in the range °200–°377 ◁
#define end_translation °223 ▷ special sentinel token at end of list ◁
#define inserted °224    ▷ sentinel to mark translations of inserts ◁
#define qualifier °225   ▷ introduces an explicit namespace qualifier ◁
#define dindent °226     ▷ two more tabs (\1\1) ◁
```

110. The raw input is converted into scraps according to the following table, which gives category codes followed by the translations. The symbol ‘**’ stands for ‘\&{identifier}’, i.e., the identifier itself treated as a reserved word. The right-hand column is the so-called *mathness*, which is explained further below.

An identifier *c* of length 1 is translated as \|*c* instead of as \\{*c*}. An identifier **CAPS** in all caps is translated as \.{**CAPS**} instead of as \\{**CAPS**}. An identifier that has become a reserved word via **typedef** is translated with \& replacing \ and *raw_int* replacing *exp*.

A string of length greater than 20 is broken into pieces of size at most 20 with discretionary breaks in between.

!=	<i>binop</i> : \I	yes
<=	<i>binop</i> : \Z	yes
>=	<i>binop</i> : \G	yes
==	<i>binop</i> : \E	yes
&&	<i>binop</i> : \W	yes
	<i>binop</i> : \V	yes
++	<i>unop</i> : \PP	yes
--	<i>unop</i> : \MM	yes
->	<i>binop</i> : \MG	yes
>>	<i>binop</i> : \GG	yes
<<	<i>binop</i> : \LL	yes
::	<i>colcol</i> : \DC	maybe
.*	<i>binop</i> : \PA	yes
->*	<i>binop</i> : \MGA	yes
...	<i>raw_int</i> : \, \ldots \,	yes
"string"	<i>exp</i> : \.{string with special characters quoted}	maybe
@=string@>	<i>exp</i> : \vb{string with special characters quoted}	maybe
@'7'	<i>exp</i> : \.{@'7'}	maybe
077 or \77	<i>exp</i> : \T{\^77}	maybe
0x7f	<i>exp</i> : \T{\^7f}	maybe
0b10111	<i>exp</i> : \T{\^10111}	maybe
77	<i>exp</i> : \T{77}	maybe
77L	<i>exp</i> : \T{77\\$_L}	maybe
0.1E5	<i>exp</i> : \T{0.1_5}	maybe
0x10p3	<i>exp</i> : \T{\^10}\p{3}	maybe
1'000'000	<i>exp</i> : \T{1_000_000}	maybe
+	<i>ubinop</i> : +	yes
-	<i>ubinop</i> : -	yes
*	<i>raw_ubin</i> : *	yes
/	<i>binop</i> : /	yes
<	<i>prelangle</i> : \langle	yes
=	<i>binop</i> : \K	yes
>	<i>prerangle</i> : \rangle	yes
.	<i>binop</i> : .	yes
	<i>binop</i> : \OR	yes
~	<i>binop</i> : \XOR	yes
%	<i>binop</i> : \MOD	yes
?	<i>question</i> : \?	yes
!	<i>unop</i> : \R	yes
~	<i>unop</i> : \CM	yes
&	<i>raw_ubin</i> : \AND	yes
(<i>lpar</i> : (maybe
)	<i>rpar</i> :)	maybe
[<i>lbrack</i> : [maybe

]	<i>rbrack:</i>]	maybe
{	<i>lbrace:</i> {	yes
}	<i>lbrace:</i> }	yes
,	<i>comma:</i> ,	yes
;	<i>semi:</i> ;	maybe
:	<i>colon:</i> :	no
# (within line)	<i>ubinop:</i> \#	yes
# (at beginning)	<i>lproc:</i> <i>force preproc_line</i> \#	no
end of # line	<i>rproc:</i> <i>force</i>	no
identifier	<i>exp:</i> \#{identifier with underlines and dollar signs quoted}	maybe
<i>alignas</i>	<i>alignas_like:</i> **	maybe
<i>alignof</i>	<i>sizeof_like:</i> **	maybe
<i>and</i>	<i>alfop:</i> **	yes
<i>and_eq</i>	<i>alfop:</i> **	yes
<i>asm</i>	<i>sizeof_like:</i> **	maybe
<i>auto</i>	<i>int_like:</i> **	maybe
<i>bitand</i>	<i>alfop:</i> **	yes
<i>bitor</i>	<i>alfop:</i> **	yes
<i>bool</i>	<i>raw_int:</i> **	maybe
<i>break</i>	<i>case_like:</i> **	maybe
<i>case</i>	<i>case_like:</i> **	maybe
<i>catch</i>	<i>catch_like:</i> **	maybe
<i>char</i>	<i>raw_int:</i> **	maybe
<i>char8_t</i>	<i>raw_int:</i> **	maybe
<i>char16_t</i>	<i>raw_int:</i> **	maybe
<i>char32_t</i>	<i>raw_int:</i> **	maybe
<i>class</i>	<i>struct_like:</i> **	maybe
<i>clock_t</i>	<i>raw_int:</i> **	maybe
<i>compl</i>	<i>alfop:</i> **	yes
<i>complex</i>	<i>int_like:</i> **	yes
<i>concept</i>	<i>int_like:</i> **	maybe
<i>const</i>	<i>const_like:</i> **	maybe
<i>consteval</i>	<i>const_like:</i> **	maybe
<i>constexpr</i>	<i>const_like:</i> **	maybe
<i>constinit</i>	<i>const_like:</i> **	maybe
<i>const_cast</i>	<i>raw_int:</i> **	maybe
<i>continue</i>	<i>case_like:</i> **	maybe
<i>co_await</i>	<i>case_like:</i> **	maybe
<i>co_return</i>	<i>case_like:</i> **	maybe
<i>co_yield</i>	<i>case_like:</i> **	maybe
<i>decltype</i>	<i>sizeof_like:</i> **	maybe
<i>default</i>	<i>default_like:</i> **	maybe
<i>define</i>	<i>define_like:</i> **	maybe
<i>defined</i>	<i>sizeof_like:</i> **	maybe
<i>delete</i>	<i>delete_like:</i> **	maybe
<i>div_t</i>	<i>raw_int:</i> **	maybe
<i>do</i>	<i>do_like:</i> **	maybe
<i>double</i>	<i>raw_int:</i> **	maybe
<i>dynamic_cast</i>	<i>raw_int:</i> **	maybe
<i>elif</i>	<i>if_like:</i> **	maybe
<i>else</i>	<i>else_like:</i> **	maybe
<i>endif</i>	<i>if_like:</i> **	maybe

enum	<i>struct_like</i> : **	maybe
error	<i>if_like</i> : **	maybe
explicit	<i>int_like</i> : **	maybe
export	<i>int_like</i> : **	maybe
extern	<i>int_like</i> : **	maybe
FILE	<i>raw_int</i> : **	maybe
false	<i>normal</i> : **	maybe
float	<i>raw_int</i> : **	maybe
for	<i>for_like</i> : **	maybe
fpos_t	<i>raw_int</i> : **	maybe
friend	<i>int_like</i> : **	maybe
goto	<i>case_like</i> : **	maybe
if	<i>if_like</i> : **	maybe
ifdef	<i>if_like</i> : **	maybe
ifndef	<i>if_like</i> : **	maybe
imaginary	<i>int_like</i> : **	maybe
include	<i>if_like</i> : **	maybe
inline	<i>int_like</i> : **	maybe
int	<i>raw_int</i> : **	maybe
jmp_buf	<i>raw_int</i> : **	maybe
ldiv_t	<i>raw_int</i> : **	maybe
line	<i>if_like</i> : **	maybe
long	<i>raw_int</i> : **	maybe
make_pair	<i>ftemplate</i> : \\{make_pair}	maybe
mutable	<i>int_like</i> : **	maybe
namespace	<i>struct_like</i> : **	maybe
new	<i>new_like</i> : **	maybe
noexcept	<i>attr</i> : **	maybe
not	<i>alfop</i> : **	yes
not_eq	<i>alfop</i> : **	yes
NULL	<i>exp</i> : \NULL	yes
nullptr	<i>exp</i> : \NULL	yes
offsetof	<i>raw_int</i> : **	maybe
operator	<i>operator_like</i> : **	maybe
or	<i>alfop</i> : **	yes
or_eq	<i>alfop</i> : **	yes
pragma	<i>if_like</i> : **	maybe
private	<i>public_like</i> : **	maybe
protected	<i>public_like</i> : **	maybe
ptrdiff_t	<i>raw_int</i> : **	maybe
public	<i>public_like</i> : **	maybe
register	<i>int_like</i> : **	maybe
reinterpret_cast	<i>raw_int</i> : **	maybe
requires	<i>int_like</i> : **	maybe
restrict	<i>int_like</i> : **	maybe
return	<i>case_like</i> : **	maybe
short	<i>raw_int</i> : **	maybe
sig_atomic_t	<i>raw_int</i> : **	maybe
signed	<i>raw_int</i> : **	maybe
size_t	<i>raw_int</i> : **	maybe
sizeof	<i>sizeof_like</i> : **	maybe
static	<i>int_like</i> : **	maybe

<code>static_assert</code>	<i>sizeof_like: **</i>	maybe
<code>static_cast</code>	<i>raw_int: **</i>	maybe
<code>struct</code>	<i>struct_like: **</i>	maybe
<code>switch</code>	<i>for_like: **</i>	maybe
<code>template</code>	<i>template_like: **</i>	maybe
<code>TeX</code>	<i>exp: \TeX</i>	yes
<code>this</code>	<i>exp: \this</i>	yes
<code>thread_local</code>	<i>raw_int: **</i>	maybe
<code>throw</code>	<i>case_like: **</i>	maybe
<code>time_t</code>	<i>raw_int: **</i>	maybe
<code>try</code>	<i>else_like: **</i>	maybe
<code>typedef</code>	<i>typedef_like: **</i>	maybe
<code>typeid</code>	<i>sizeof_like: **</i>	maybe
<code>typename</code>	<i>struct_like: **</i>	maybe
<code>undef</code>	<i>if_like: **</i>	maybe
<code>union</code>	<i>struct_like: **</i>	maybe
<code>unsigned</code>	<i>raw_int: **</i>	maybe
<code>using</code>	<i>using_like: **</i>	maybe
<code>va_dcl</code>	<i>decl: **</i>	maybe
<code>va_list</code>	<i>raw_int: **</i>	maybe
<code>virtual</code>	<i>int_like: **</i>	maybe
<code>void</code>	<i>raw_int: **</i>	maybe
<code>volatile</code>	<i>const_like: **</i>	maybe
<code>wchar_t</code>	<i>raw_int: **</i>	maybe
<code>while</code>	<i>for_like: **</i>	maybe
<code>xor</code>	<i>alfop: **</i>	yes
<code>xor_eq</code>	<i>alfop: **</i>	yes
<code>@,</code>	<i>insert: \,</i>	maybe
<code>@ </code>	<i>insert: opt 0</i>	maybe
<code>@/</code>	<i>insert: force</i>	no
<code>@#</code>	<i>insert: big_force</i>	no
<code>@+</code>	<i>insert: big_cancel {} break_space {} big_cancel</i>	no
<code>@;</code>	<i>semi:</i>	maybe
<code>@[</code>	<i>begin_arg:</i>	maybe
<code>@]</code>	<i>end_arg:</i>	maybe
<code>@&</code>	<i>insert: \J</i>	maybe
<code>@h</code>	<i>insert: force \ATH force</i>	no
<code>@< section name @></code>	<i>section_scrap: \Xn: translated section name\X</i>	maybe
<code>@(section name @></code>	<i>section_scrap: \Xn:\.{section name with special characters quoted\,}\X*</i>	maybe
<code>/* comment */</code>	<i>insert: cancel \C{translated comment} force</i>	no
<code>// comment</code>	<i>insert: cancel \SHC{translated comment} force</i>	no

The construction `@t stuff @>` contributes `\hbox{ stuff }` to the following scrap.

111. Here is a table of all the productions. Each production that combines two or more consecutive scraps implicitly inserts a **\$** where necessary, that is, between scraps whose abutting boundaries have different *mathness*. In this way we never get double **\$\$**.

A translation is provided when the resulting scrap is not merely a juxtaposition of the scraps it comes from. An asterisk* next to a scrap means that its first identifier gets an underlined entry in the index, via the function *make_underlined*. Two asterisks** means that both *make_underlined* and *make_reserved* are called; that is, the identifier's ilk becomes *raw_int*. A dagger † before the production number refers to the notes at the end of this section, which deal with various exceptional cases.

We use *in*, *out*, *back*, *bsp*, and *din* as shorthands for *indent*, *outdent*, *backup*, *break_space*, and *dindent*, respectively.

LHS	→ RHS	Translation	Example
0 $\left\{ \begin{array}{c} \text{any} \\ \text{any any} \\ \text{any any any} \end{array} \right\} \text{insert}$	$\rightarrow \left\{ \begin{array}{c} \text{any} \\ \text{any any} \\ \text{any any any} \end{array} \right\}$		stmt; ▷ comment ◁
1 $\text{exp} \left\{ \begin{array}{c} \text{lbrace} \\ \text{int_like} \\ \text{decl} \end{array} \right\}$	$\rightarrow \text{fn_decl} \left\{ \begin{array}{c} \text{lbrace} \\ \text{int_like} \\ \text{decl} \end{array} \right\}$	$F = \text{din } E^*$	<i>main</i> () { <i>main</i> (<i>ac</i> , <i>av</i>) int <i>ac</i> ;
2 exp unop	$\rightarrow \text{exp}$		<i>x</i> ++
3 $\text{exp} \left\{ \begin{array}{c} \text{binop} \\ \text{ubinop} \end{array} \right\} \text{exp}$	$\rightarrow \text{exp}$		<i>x</i> / <i>y</i> <i>x</i> + <i>y</i>
4 exp comma exp	$\rightarrow \text{exp}$	$E_1 C \text{ opt } 9 E_2$	<i>f</i> (<i>x</i> , <i>y</i>)
5 $\text{exp} \left\{ \begin{array}{c} \text{lpar rpar} \\ \text{cast} \end{array} \right\} \text{colon}$	$\rightarrow \text{exp} \left\{ \begin{array}{c} \text{lpar rpar} \\ \text{cast} \end{array} \right\} \text{base}$		C () : C (int <i>i</i>) :
6 exp semi	$\rightarrow \text{stmt}$		<i>x</i> = 0;
7 exp colon	$\rightarrow \text{tag}$	$E^* C$	<i>found</i> :
8 exp rbrace	$\rightarrow \text{stmt rbrace}$		end of enum list
9 $\text{exp} \left\{ \begin{array}{c} \text{lpar rpar} \\ \text{cast} \end{array} \right\} \left\{ \begin{array}{c} \text{const_like} \\ \text{case_like} \end{array} \right\}$	$\rightarrow \text{exp} \left\{ \begin{array}{c} \text{lpar rpar} \\ \text{cast} \end{array} \right\}$	$\left\{ \begin{array}{l} R = R \sqcup C \\ C_1 = C_1 \sqcup C_2 \end{array} \right\}$	<i>f</i> () const <i>f</i> (int) throw
10 $\text{exp} \left\{ \begin{array}{c} \text{exp} \\ \text{cast} \end{array} \right\}$	$\rightarrow \text{exp}$		<i>time</i> ()
11 $\text{lpar} \left\{ \begin{array}{c} \text{exp} \\ \text{ubinop} \end{array} \right\} \text{rpar}$	$\rightarrow \text{exp}$		(<i>x</i>) (*)
12 lpar rpar	$\rightarrow \text{exp}$	$L \setminus, R$	functions, declarations
13 $\text{lpar} \left\{ \begin{array}{c} \text{decl_head} \\ \text{int_like} \\ \text{cast} \end{array} \right\} \text{rpar}$	$\rightarrow \text{cast}$		(char *)
14 $\text{lpar} \left\{ \begin{array}{c} \text{decl_head} \\ \text{int_like} \\ \text{exp} \end{array} \right\} \text{comma}$	$\rightarrow \text{lpar}$	$L \left\{ \begin{array}{c} D \\ I \\ E \end{array} \right\} C \text{ opt } 9$	(int ,
15 $\text{lpar} \left\{ \begin{array}{c} \text{stmt} \\ \text{decl} \end{array} \right\}$	$\rightarrow \text{lpar}$	$\left\{ \begin{array}{c} LS \sqcup \\ LD \sqcup \end{array} \right\}$	(<i>k</i> = 5; int <i>k</i> = 5;
16 $\text{unop} \left\{ \begin{array}{c} \text{exp} \\ \text{int_like} \end{array} \right\}$	$\rightarrow \text{exp}$		¬ <i>x</i> ~ C
17 ubinop cast rpar	$\rightarrow \text{cast rpar}$	$C = \{U\} C$	* CPtr)
18 $\text{ubinop} \left\{ \begin{array}{c} \text{exp} \\ \text{int_like} \end{array} \right\}$	$\rightarrow \left\{ \begin{array}{c} \text{exp} \\ \text{int_like} \end{array} \right\}$	$\{U\} \left\{ \begin{array}{c} E \\ I \end{array} \right\}$	* <i>x</i> * CPtr
19 ubinop binop	$\rightarrow \text{binop}$	$\text{math_rel } U \{B\}$	*=
20 binop binop	$\rightarrow \text{binop}$	$\text{math_rel } \{B_1\} \{B_2\}$	≫=

21	$\text{cast } \left\{ \begin{smallmatrix} lpar \\ exp \end{smallmatrix} \right\}$	$\rightarrow \left\{ \begin{smallmatrix} lpar \\ exp \end{smallmatrix} \right\}$	$\left\{ \begin{smallmatrix} CL \\ C \setminus, E \end{smallmatrix} \right\}$	$(\text{double})(x + 2)$ $(\text{double}) x$
22	cast semi	$\rightarrow \text{exp semi}$		$(\text{int});$
23	sizeof_like cast	$\rightarrow \text{exp}$		$\text{sizeof}(\text{double})$
24	sizeof_like exp	$\rightarrow \text{exp}$	$S \sqcup E$	$\text{sizeof } x$
25	$\text{int_like } \left\{ \begin{smallmatrix} int_like \\ struct_like \end{smallmatrix} \right\}$	$\rightarrow \left\{ \begin{smallmatrix} int_like \\ struct_like \end{smallmatrix} \right\}$	$I \sqcup \left\{ \begin{smallmatrix} I \\ S \end{smallmatrix} \right\}$	extern char
26	$\text{int_like exp } \left\{ \begin{smallmatrix} raw_int \\ struct_like \end{smallmatrix} \right\}$	$\rightarrow \text{int_like } \left\{ \begin{smallmatrix} raw_int \\ struct_like \end{smallmatrix} \right\}$		extern "Ada" int
27	$\text{int_like } \left\{ \begin{smallmatrix} exp \\ ubinop \\ colon \end{smallmatrix} \right\}$	$\rightarrow \text{decl_head } \left\{ \begin{smallmatrix} exp \\ ubinop \\ colon \end{smallmatrix} \right\}$	$D = I \sqcup$	int x int $*x$ unsigned :
28	$\text{int_like } \left\{ \begin{smallmatrix} semi \\ binop \end{smallmatrix} \right\}$	$\rightarrow \text{decl_head } \left\{ \begin{smallmatrix} semi \\ binop \end{smallmatrix} \right\}$		int $x;$ int $f(\text{int} = 4)$
29	public_like colon	$\rightarrow \text{tag}$		private:
30	public_like	$\rightarrow \text{int_like}$		private
31	$\text{colcol } \left\{ \begin{smallmatrix} exp \\ int_like \end{smallmatrix} \right\}$	$\rightarrow \left\{ \begin{smallmatrix} exp \\ int_like \end{smallmatrix} \right\}$	$\text{qualifier } C \left\{ \begin{smallmatrix} E \\ I \end{smallmatrix} \right\}$	C :: x
32	colcol colcol	$\rightarrow \text{colcol}$		C :: B ::
33	decl_head comma	$\rightarrow \text{decl_head}$	$DC \text{ opt9}$	int $x,$
34	decl_head ubinop	$\rightarrow \text{decl_head}$	$D \{U\}$	int $*$
†35	decl_head exp	$\rightarrow \text{decl_head}$	DE^*	int x
36	$\text{decl_head } \left\{ \begin{smallmatrix} binop \\ colon \end{smallmatrix} \right\} \text{exp } \left\{ \begin{smallmatrix} comma \\ semi \\ rpar \end{smallmatrix} \right\}$	$\rightarrow \text{decl_head } \left\{ \begin{smallmatrix} comma \\ semi \\ rpar \end{smallmatrix} \right\}$	$D = D \left\{ \begin{smallmatrix} B \\ C \end{smallmatrix} \right\} E$	int $f(\text{int } x = 2)$ int $b : 1$
37	decl_head cast	$\rightarrow \text{decl_head}$		int $f(\text{int})$
38	$\text{decl_head } \left\{ \begin{smallmatrix} int_like \\ lbrace \\ decl \end{smallmatrix} \right\}$	$\rightarrow \text{fn_decl } \left\{ \begin{smallmatrix} int_like \\ lbrace \\ decl \end{smallmatrix} \right\}$	$F = \text{din } D$	long $\text{time}() \{$
39	decl_head semi	$\rightarrow \text{decl}$		int $n;$
40	decl decl	$\rightarrow \text{decl}$	$D_1 \text{ force } D_2$	int $n; \text{double } x;$
41	$\text{decl } \left\{ \begin{smallmatrix} stmt \\ function \end{smallmatrix} \right\}$	$\rightarrow \left\{ \begin{smallmatrix} stmt \\ function \end{smallmatrix} \right\}$	$D \text{ big_force } \left\{ \begin{smallmatrix} S \\ F \end{smallmatrix} \right\}$	extern $n; \text{main}() \{ \}$
42	$\text{base } \left\{ \begin{smallmatrix} int_like \\ exp \end{smallmatrix} \right\} \text{comma}$	$\rightarrow \text{base}$	$B \sqcup \left\{ \begin{smallmatrix} I \\ E \end{smallmatrix} \right\} C \text{ opt9}$: public A , : $i(5),$
43	$\text{base } \left\{ \begin{smallmatrix} int_like \\ exp \end{smallmatrix} \right\} \text{lbrace}$	$\rightarrow \text{lbrace}$	$B \sqcup \left\{ \begin{smallmatrix} I \\ E \end{smallmatrix} \right\} \sqcup L$	D : public A {
44	$\text{struct_like lbrace}$	$\rightarrow \text{struct_head}$	$S \sqcup L$	struct {
45	$\text{struct_like } \left\{ \begin{smallmatrix} exp \\ int_like \end{smallmatrix} \right\} \text{semi}$	$\rightarrow \text{decl_head semi}$	$S \sqcup \left\{ \begin{smallmatrix} E^{**} \\ I^{**} \end{smallmatrix} \right\}$	struct forward;
46	$\text{struct_like } \left\{ \begin{smallmatrix} exp \\ int_like \end{smallmatrix} \right\} \text{lbrace}$	$\rightarrow \text{struct_head}$	$S \sqcup \left\{ \begin{smallmatrix} E^{**} \\ I^{**} \end{smallmatrix} \right\} \sqcup L$	struct name_info {
47	$\text{struct_like } \left\{ \begin{smallmatrix} exp \\ int_like \end{smallmatrix} \right\} \text{colon}$	$\rightarrow \text{struct_like } \left\{ \begin{smallmatrix} exp \\ int_like \end{smallmatrix} \right\} \text{base}$		class C :
†48	$\text{struct_like } \left\{ \begin{smallmatrix} exp \\ int_like \end{smallmatrix} \right\}$	$\rightarrow \text{int_like}$	$S \sqcup \left\{ \begin{smallmatrix} E \\ I \end{smallmatrix} \right\}$	struct name_info $z;$

49	$struct_head \left\{ \begin{array}{c} decl \\ stmt \\ function \end{array} \right\} rbrace$	$\rightarrow int_like$	$S \text{ in } force \left\{ \begin{array}{c} D \\ S \\ F \end{array} \right\} out \text{ force } R$	struct { declaration }
50	$struct_head rbrace$	$\rightarrow int_like$	$S \setminus, R$	class C { }
51	$fn_decl decl$	$\rightarrow fn_decl$	$F \text{ force } D$	$f(z)$ double z ;
52	$fn_decl stmt$	$\rightarrow function$	$F \text{ out out force } S$	$main()$...
53	$function \left\{ \begin{array}{c} stmt \\ decl \\ function \end{array} \right\}$	$\rightarrow \left\{ \begin{array}{c} stmt \\ decl \\ function \end{array} \right\}$	$F \text{ big-force } \left\{ \begin{array}{c} S \\ D \\ F \end{array} \right\}$	outer block
54	$lbrace rbrace$	$\rightarrow stmt$	$L \setminus, R$	empty statement
†55	$lbrace \left\{ \begin{array}{c} stmt \\ decl \\ function \end{array} \right\} rbrace$	$\rightarrow stmt$	$force L \text{ in } force S \text{ force back } R \text{ out force}$	compound statement
56	$lbrace exp [comma] rbrace$	$\rightarrow exp$		initializer
57	$if_like exp$	$\rightarrow if_clause$	$I \sqcup E$	if (z)
58	$else_like colon$	$\rightarrow else_like \text{ base}$		try :
59	$else_like lbrace$	$\rightarrow else_head lbrace$		else {
60	$else_like stmt$	$\rightarrow stmt$	$force E \text{ in bsp } S \text{ out force}$	else $x = 0$;
61	$else_head \left\{ \begin{array}{c} stmt \\ exp \end{array} \right\}$	$\rightarrow stmt$	$force E \text{ bsp noop cancel } S \text{ force}$	else { $x = 0$; }
62	$if_clause lbrace$	$\rightarrow if_head lbrace$		if (x) {
63	$if_clause stmt else_like if_like$	$\rightarrow if_like$	$force I \text{ in bsp } S \text{ out force } E \sqcup I$	if (x) y ; else if
64	$if_clause stmt else_like$	$\rightarrow else_like$	$force I \text{ in bsp } S \text{ out force } E$	if (x) y ; else
65	$if_clause stmt$	$\rightarrow else_like \text{ stmt}$		if (x) y ;
66	$if_head \left\{ \begin{array}{c} stmt \\ exp \end{array} \right\} else_like if_like$	$\rightarrow if_like$	$force I \text{ bsp noop cancel } S \text{ force } E \sqcup I$	if (x) { y ; } else if
67	$if_head \left\{ \begin{array}{c} stmt \\ exp \end{array} \right\} else_like$	$\rightarrow else_like$	$force I \text{ bsp noop cancel } S \text{ force } E$	if (x) { y ; } else
68	$if_head \left\{ \begin{array}{c} stmt \\ exp \end{array} \right\}$	$\rightarrow else_head \left\{ \begin{array}{c} stmt \\ exp \end{array} \right\}$		if (x) { y }
†69	$do_like stmt else_like semi$	$\rightarrow stmt$	$D \text{ bsp noop cancel } S \text{ cancel noop bsp } ES$	do $f(x)$; while ($g(x)$);
70	$case_like semi$	$\rightarrow stmt$		return ;
71	$case_like colon$	$\rightarrow tag$		default :
72	$case_like exp$	$\rightarrow exp$	$C \sqcup E$	return 0
73	$catch_like \left\{ \begin{array}{c} cast \\ exp \end{array} \right\}$	$\rightarrow fn_decl$	$C \text{ din } \left\{ \begin{array}{c} C \\ E \end{array} \right\}$	catch (...)
74	$tag tag$	$\rightarrow tag$	$T_1 \text{ bsp } T_2$	case 0: case 1:
75	$tag \left\{ \begin{array}{c} stmt \\ decl \\ function \end{array} \right\}$	$\rightarrow \left\{ \begin{array}{c} stmt \\ decl \\ function \end{array} \right\}$	$force \text{ back } T \text{ bsp } S$	case 0: $z = 0$;
†76	$stmt \left\{ \begin{array}{c} stmt \\ decl \\ function \end{array} \right\}$	$\rightarrow \left\{ \begin{array}{c} stmt \\ decl \\ function \end{array} \right\}$	$S \left\{ \begin{array}{c} force S \\ big_force D \\ big_force F \end{array} \right\}$	$x = 1$; $y = 2$;
77	$semi$	$\rightarrow stmt$	$\sqcup S$	empty statement
†78	$lproc \left\{ \begin{array}{c} if_like \\ else_like \\ define_like \end{array} \right\}$	$\rightarrow lproc$		#include
				#else
				#define
79	$lproc rproc$	$\rightarrow insert$		#endif

80	$lproc \left\{ \begin{smallmatrix} exp \\ function \end{smallmatrix} \right\} rproc$	$\rightarrow insert$	$I_{\sqcup} \left\{ \begin{smallmatrix} E[\sqcup \setminus 5E] \\ F \end{smallmatrix} \right\}$	#define <i>a</i> 1 #define <i>a</i> { <i>b</i> ; }
81	<i>section_scrap semi</i>	$\rightarrow stmt$	<i>MS force</i>	$\langle section\ name \rangle;$
82	<i>section_scrap</i>	$\rightarrow exp$		$\langle section\ name \rangle$
83	<i>insert function</i>	$\rightarrow function$		#include before <i>main</i>
84	<i>prelangle</i>	$\rightarrow binop$	$<$	$<$ not in template
85	<i>prerangle</i>	$\rightarrow binop$	$>$	$>$ not in template
86	<i>langle prerangle</i>	$\rightarrow cast$	$L \setminus , P$	$\langle \rangle$
87	$langle \left\{ \begin{smallmatrix} decl_head \\ int_like \\ exp \end{smallmatrix} \right\} prerangle$	$\rightarrow cast$		$\langle class\ C \rangle$
88	$langle \left\{ \begin{smallmatrix} decl_head \\ int_like \\ exp \end{smallmatrix} \right\} comma$	$\rightarrow langle$	$L \left\{ \begin{smallmatrix} D \\ I \\ E \end{smallmatrix} \right\} C\ opt9$	$\langle class\ C,$
89	<i>template_like exp prelangle</i>	$\rightarrow template_like\ exp\ langle$		template <i>a</i> $\langle 100 \rangle$
90	<i>template_like</i> $\left\{ \begin{smallmatrix} exp \\ raw_int \end{smallmatrix} \right\}$	$\rightarrow \left\{ \begin{smallmatrix} exp \\ raw_int \end{smallmatrix} \right\}$	$T_{\sqcup} \left\{ \begin{smallmatrix} E \\ R \end{smallmatrix} \right\}$	C::template <i>a</i> $()$
91	<i>template_like</i>	$\rightarrow raw_int$		template $\langle class\ T \rangle$
92	<i>new_like lpar exp rpar</i>	$\rightarrow new_like$		new (<i>nothrow</i>)
93	<i>new_like cast</i>	$\rightarrow exp$	$N_{\sqcup} C$	new (<i>int</i> *)
†94	<i>new_like</i>	$\rightarrow new_exp$		new <i>C</i> $()$
95	<i>new_exp</i> $\left\{ \begin{smallmatrix} int_like \\ const_like \end{smallmatrix} \right\}$	$\rightarrow new_exp$	$N_{\sqcup} \left\{ \begin{smallmatrix} I \\ C \end{smallmatrix} \right\}$	new const int
96	<i>new_exp struct_like</i> $\left\{ \begin{smallmatrix} exp \\ int_like \end{smallmatrix} \right\}$	$\rightarrow new_exp$	$N_{\sqcup} S_{\sqcup} \left\{ \begin{smallmatrix} E \\ I \end{smallmatrix} \right\}$	new struct S
97	<i>new_exp raw_ubin</i>	$\rightarrow new_exp$	$N \{ R \}$	new int * $[2]$
98	<i>new_exp</i> $\left\{ \begin{smallmatrix} lpar \\ exp \end{smallmatrix} \right\}$	$\rightarrow exp \left\{ \begin{smallmatrix} lpar \\ exp \end{smallmatrix} \right\}$	$E = N \left\{ \begin{smallmatrix} \\ \sqcup \end{smallmatrix} \right\}$	operator $[]$ (<i>int</i>) new int (2)
†99	<i>new_exp</i>	$\rightarrow exp$		new int ;
100	<i>ftemplate prelangle</i>	$\rightarrow ftemplate\ langle$		<i>make_pair</i> $\langle int, int \rangle$
101	<i>ftemplate</i>	$\rightarrow exp$		<i>make_pair</i> $(1, 2)$
102	<i>for_like exp</i>	$\rightarrow else_like$	$F_{\sqcup} E$	while (1)
103	<i>raw_ubin const_like</i>	$\rightarrow raw_ubin$	$RC \setminus \sqcup$	*const <i>x</i>
104	<i>raw_ubin</i>	$\rightarrow ubinop$		* <i>x</i>
105	<i>const_like</i>	$\rightarrow int_like$		const <i>x</i>
106	<i>raw_int prelangle</i>	$\rightarrow raw_int\ langle$		C \langle
107	<i>raw_int colcol</i>	$\rightarrow colcol$		C::
108	<i>raw_int cast</i>	$\rightarrow raw_int$		C $\langle class\ T \rangle$
109	<i>raw_int lpar</i>	$\rightarrow exp\ lpar$		complex (<i>x</i> , <i>y</i>)
†110	<i>raw_int</i>	$\rightarrow int_like$		complex <i>z</i>
†111	<i>operator_like</i> $\left\{ \begin{smallmatrix} binop \\ unop \\ ubinop \end{smallmatrix} \right\}$	$\rightarrow exp$	$O \{ \left\{ \begin{smallmatrix} B \\ U \\ U \end{smallmatrix} \right\} \}$	operator +
112	<i>operator_like</i> $\left\{ \begin{smallmatrix} new_like \\ delete_like \end{smallmatrix} \right\}$	$\rightarrow exp$	$O_{\sqcup} \left\{ \begin{smallmatrix} N \\ S \end{smallmatrix} \right\}$	operator delete
113	<i>operator_like comma</i>	$\rightarrow exp$		operator ,
†114	<i>operator_like</i>	$\rightarrow new_exp$		operator char*
115	<i>typedef_like</i> $\left\{ \begin{smallmatrix} int_like \\ cast \end{smallmatrix} \right\} \left\{ \begin{smallmatrix} comma \\ semi \end{smallmatrix} \right\} \rightarrow typedef_like\ exp \left\{ \begin{smallmatrix} comma \\ semi \end{smallmatrix} \right\}$			typedef int I,

116	<i>typedef_like int_like</i>	\rightarrow <i>typedef_like</i>	$T_{\sqcup}I$	typedef char
†117	<i>typedef_like exp</i>	\rightarrow <i>typedef_like</i>	$T_{\sqcup}E^{**}$	typedef I @[@] (*P)
118	<i>typedef_like comma</i>	\rightarrow <i>typedef_like</i>	TC	typedef int x,
119	<i>typedef_like semi</i>	\rightarrow <i>decl</i>		typedef int x, y;
120	<i>typedef_like ubinop</i> $\left\{ \begin{smallmatrix} \text{cast} \\ \text{ubinop} \end{smallmatrix} \right\}$	\rightarrow <i>typedef_like</i> $\left\{ \begin{smallmatrix} \text{cast} \\ \text{ubinop} \end{smallmatrix} \right\}$	$\left\{ \begin{smallmatrix} C = \{U\}C \\ U_2 = \{U_1\}U_2 \end{smallmatrix} \right\}$	typedef ** (CPtr)
121	<i>delete_like lbrack rbrack</i>	\rightarrow <i>delete_like</i>	$DL \setminus, R$	delete[]
122	<i>delete_like exp</i>	\rightarrow <i>exp</i>	$D_{\sqcup}E$	delete p
†123	<i>question exp</i> $\left\{ \begin{smallmatrix} \text{colon} \\ \text{base} \end{smallmatrix} \right\}$	\rightarrow <i>binop</i>		? x : ? f() :
124	<i>begin_arg end_arg</i>	\rightarrow <i>exp</i>		@[char*@]
125	<i>any_other end_arg</i>	\rightarrow <i>end_arg</i>		char*@]
126	<i>alignas_like decl_head</i>	\rightarrow <i>attr</i>		alignas(struct s *)
127	<i>alignas_like exp</i>	\rightarrow <i>attr</i>		alignas(8)
128	<i>lbrack lbrack</i>	\rightarrow <i>attr_head</i>		attribute begins
129	<i>lbrack</i>	\rightarrow <i>lpar</i>		[elsewhere
130	<i>rbrack</i>	\rightarrow <i>rpar</i>] elsewhere
131	<i>attr_head rbrack rbrack</i>	\rightarrow <i>attr</i>		[[...]]
132	<i>attr_head exp</i>	\rightarrow <i>attr_head</i>		[[<i>deprecated</i>
133	<i>attr_head using_like exp colon</i>	\rightarrow <i>attr_head</i>		[[using NS:
134	<i>attr</i> $\left\{ \begin{smallmatrix} \text{lbrace} \\ \text{stmt} \end{smallmatrix} \right\}$	\rightarrow $\left\{ \begin{smallmatrix} \text{lbrace} \\ \text{stmt} \end{smallmatrix} \right\}$	$A_{\sqcup} \left\{ \begin{smallmatrix} S \\ L \end{smallmatrix} \right\}$	[[<i>likely</i>]] {
135	<i>attr tag</i>	\rightarrow <i>tag</i>	$A_{\sqcup}T$	[[<i>likely</i>]] case 0:
136	<i>attr semi</i>	\rightarrow <i>stmt</i>		[[<i>fallthrough</i>]];
137	<i>attr attr</i>	\rightarrow <i>attr</i>	$A_1 \sqcup A_2$	alignas(x) [[...]]
138	<i>attr decl_head</i>	\rightarrow <i>decl_head</i>		[[<i>nodiscard</i>]] f()
139	<i>decl_head attr</i>	\rightarrow <i>decl_head</i>		(int x [[<i>deprecated</i>]])
140	<i>using_like</i>	\rightarrow <i>int_like</i>		using not in attributes
141	<i>struct_like attr</i>	\rightarrow <i>struct_like</i>	$S_{\sqcup}A$	struct [[<i>deprecated</i>]]
142	<i>exp attr</i>	\rightarrow <i>exp</i>	$E_{\sqcup}A$	enum {x [[...]]}
143	<i>attr typedef_like</i>	\rightarrow <i>typedef_like</i>	$A_{\sqcup}T$	[[<i>deprecated</i>]] typedef
144	<i>raw_int lbrack</i>	\rightarrow <i>exp</i>		int [3]
145	<i>attr_head comma</i>	\rightarrow <i>attr_head</i>		[[x,y
146	<i>if_head attr</i>	\rightarrow <i>if_head</i>	$I_{\sqcup}A$	if (x) [[<i>unlikely</i>]] {
147	<i>lbrack lbrack rbrack rbrack</i>	\rightarrow <i>exp</i>		[[]]
148	<i>attr function</i>	\rightarrow <i>function</i>	$A_{\sqcup}F$	attribute and function
149	<i>default_like colon</i>	\rightarrow <i>case_like colon</i>		default:
150	<i>default_like</i>	\rightarrow <i>exp</i>		f() = default;
151	<i>struct_like struct_like</i>	\rightarrow <i>struct_like</i>	$S_1 \sqcup S_2$	enum class
152	<i>exp colcol int_like</i>	\rightarrow <i>int_like</i>		std:: atomic
†153	<i>langle struct_like</i> $\left\{ \begin{smallmatrix} \text{exp} \\ \text{int_like} \end{smallmatrix} \right\}$ <i>comma</i>	\rightarrow <i>langle</i>	$LS_{\sqcup} \left\{ \begin{smallmatrix} E^{**} \\ I^{**} \end{smallmatrix} \right\} C \text{ opt9}$	<typename t,
†154	<i>langle struct_like</i> $\left\{ \begin{smallmatrix} \text{exp} \\ \text{int_like} \end{smallmatrix} \right\}$ <i>prerangle</i>	\rightarrow <i>cast</i>	$LS_{\sqcup} \left\{ \begin{smallmatrix} E^{**} \\ I^{**} \end{smallmatrix} \right\} P$	<typename t>
155	<i>template_like cast struct_like</i>	\rightarrow <i>struct_like</i>	$T_{\sqcup}CS$	template <...> class
156	<i>tag rbrace</i>	\rightarrow <i>decl rbrace</i>		public: }
157	<i>fn_decl attr</i>	\rightarrow <i>fn_decl</i>	$F_{\sqcup}A$	void f() noexcept
158	<i>alignas_like cast</i>	\rightarrow <i>attr</i>		alignas(int)

†Notes

- Rules 35, 117: The *exp* must not be immediately followed by *lpar*, *lbrack*, *exp*, or *cast*.
- Rule 48: The *exp* or *int_like* must not be immediately followed by *base*.
- Rule 55: The second *force* becomes *bsp* if **CWEAVE** has been invoked with the **-F** option.
- Rule 69: The **do . . . while** loop is wrapped in *force* if **CWEAVE** is invoked with the **-f** option.
- Rule 76: The *force* in the *stmt* line becomes *bsp* if **CWEAVE** has been invoked with the **-f** option.
- Rule 78: The *define_like* case calls *make_underlined* on the following scrap.
- Rule 94: The *new_like* must not be immediately followed by *lpar*.
- Rule 99: The *new_exp* must not be immediately followed by *raw_int*, *struct_like*, or *colcol*.
- Rule 110: The *raw_int* must not be immediately followed by *langle*.
- Rule 111: The operator after *operator_like* must not be immediately followed by a *binop*.
- Rule 114: The *operator_like* must not be immediately followed by *raw_ubin*.
- Rule 123: The mathness of the *colon* or *base* changes to ‘yes’.
- Rules 153, 154: *make_reserved* is called only if **CWEAVE** has been invoked with the **+t** option.

112. Implementing the productions. More specifically, a scrap is a structure consisting of a category *cat* and a **text_pointer** *trans*, which points to the translation in *tok_start*. When C text is to be processed with the grammar above, we form an array *scrap_info* containing the initial scraps. Our production rules have the nice property that the right-hand side is never longer than the left-hand side. Therefore it is convenient to use sequential allocation for the current sequence of scraps. Five pointers are used to manage the parsing:

pp is a pointer into *scrap_info*. We will try to match the category codes *pp-cat*, $(pp + 1)\text{-cat}$, ... to the left-hand sides of productions.

scrap_base, *lo_ptr*, *hi_ptr*, and *scrap_ptr* are such that the current sequence of scraps appears in positions *scrap_base* through *lo_ptr* and *hi_ptr* through *scrap_ptr*, inclusive, in the *cat* and *trans* arrays. Scraps located between *scrap_base* and *lo_ptr* have been examined, while those in positions $\geq hi_ptr$ have not yet been looked at by the parsing process.

Initially *scrap_ptr* is set to the position of the final scrap to be parsed, and it doesn't change its value. The parsing process makes sure that $lo_ptr \geq pp + 3$, since productions have as many as four terms, by moving scraps from *hi_ptr* to *lo_ptr*. If there are fewer than $pp + 3$ scraps left, the positions up to $pp + 3$ are filled with blanks that will not match in any productions. Parsing stops when $pp \equiv lo_ptr + 1$ and $hi_ptr \equiv scrap_ptr + 1$.

Since the *scrap* structure will later be used for other purposes, we declare its second element as a union.

```
#define trans trans_plus.Trans    ▷ translation texts of scraps ◁
```

```
< Typedef declarations 22 > +≡
```

```
typedef struct {
    eight_bits cat;
    eight_bits mathness;
    union {
        text_pointer Trans;
        < Rest of trans_plus union 252 >
    } trans_plus;
} scrap;
typedef scrap *scrap_pointer;
```

```
113. #define max_scraps 5000    ▷ number of tokens in C texts being parsed ◁
```

```
< Private variables 21 > +≡
```

```
static scrap scrap_info[max_scraps];    ▷ memory array for scraps ◁
static scrap_pointer scrap_info_end ← scrap_info + max_scraps - 1;    ▷ end of scrap_info ◁
static scrap_pointer scrap_base;    ▷ beginning of the current scrap sequence ◁
static scrap_pointer scrap_ptr;    ▷ ending of the current scrap sequence ◁
static scrap_pointer max_scr_ptr;    ▷ largest value assumed by scrap_ptr ◁
static scrap_pointer pp;    ▷ current position for reducing productions ◁
static scrap_pointer lo_ptr;    ▷ last scrap that has been examined ◁
static scrap_pointer hi_ptr;    ▷ first scrap that has not been examined ◁
```

```
114. < Set initial values 24 > +≡
```

```
scrap_base ← scrap_info + 1; max_scr_ptr ← scrap_ptr ← scrap_info;
```

115. Token lists in *tok_mem* are composed of the following kinds of items for T_EX output.

- Character codes and special codes like *force* and *math_rel* represent themselves;
- *id_flag* + *p* represents `\{identifier p}`;
- *res_flag* + *p* represents `\&{identifier p}`;
- *section_flag* + *p* represents section name *p*;
- *tok_flag* + *p* represents token list number *p*;
- *inner_tok_flag* + *p* represents token list number *p*, to be translated without line-break controls.

```
#define id_flag 10240    ▷ signifies an identifier ◁
#define res_flag (2 * id_flag)    ▷ signifies a reserved word ◁
#define section_flag (3 * id_flag)    ▷ signifies a section name ◁
#define tok_flag (4 * id_flag)    ▷ signifies a token list ◁
#define inner_tok_flag (5 * id_flag)    ▷ signifies a token list in '| ... |' ◁
⟨Predeclaration of procedures 4⟩ +=
#ifdef DEBUG
    static void print_text(text_pointer p);
#endif
```

116. This function prints a token list for debugging; it is not used in *main* at this time.

```
#ifdef DEBUG
    static void print_text(text_pointer p)
    {
        token_pointer j;    ▷ index into tok_mem ◁
        sixteen_bits r;    ▷ remainder of token after the flag has been stripped off ◁
        if (p ≥ text_ptr) printf("BAD");
        else
            for (j ← *p; j < *(p + 1); j++) {
                r ← *j % id_flag;
                switch (*j) {
                    case id_flag: printf("\\\\{"); print_id((name_dir + r)); putchar('}'); break;
                    case res_flag: printf("\\&{"); print_id((name_dir + r)); putchar('}'); break;
                    case section_flag: putchar('<'); print_section_name((name_dir + r)); putchar('>'); break;
                    case tok_flag: printf("[[%d]]", (int) r); break;
                    case inner_tok_flag: printf("| [[%d]] |", (int) r); break;
                    default: ⟨Print token r in symbolic form 117⟩
                }
            }
        update_terminal();
    }
#endif    ▷ DEBUG ◁
```

117. \langle Print token r in symbolic form 117 $\rangle \equiv$

```

switch ( $r$ ) {
  case math_rel: printf("\\mathrel{"); break;
  case big_cancel: printf("[ccancel]"); break;
  case cancel: printf("[cancel]"); break;
  case indent: printf("[indent]"); break;
  case outdent: printf("[outdent]"); break;
  case dindent: printf("[dindent]"); break;
  case backup: printf("[backup]"); break;
  case opt: printf("[opt]"); break;
  case break_space: printf("[break]"); break;
  case force: printf("[force]"); break;
  case big_force: printf("[fforce]"); break;
  case preproc_line: printf("[preproc]"); break;
  case quoted_char:  $j++$ ; printf("[%o]", (unsigned int)* $j$ ); break;
  case end_translation: printf("[quit]"); break;
  case inserted: printf("[inserted]"); break;
  default: putchar((int) $r$ );
}

```

This code is used in section 116.

118. The production rules listed above are embedded directly into **CWEAVE**, since it is easier to do this than to write an interpretive system that would handle production systems in general. Several macros are defined here so that the program for each production is fairly short.

All of our productions conform to the general notion that some k consecutive scraps starting at some position j are to be replaced by a single scrap of some category c whose translation is composed from the translations of the disappearing scraps. After this production has been applied, the production pointer pp should change by an amount d . Such a production can be represented by the quadruple (j, k, c, d) . For example, the production ‘ $exp\ comma\ exp \rightarrow exp$ ’ would be represented by ‘ $(pp, 3, exp, -2)$ ’; in this case the pointer pp should decrease by 2 after the production has been applied, because some productions with exp in their second or third positions might now match, but no productions have exp in the fourth position of their left-hand sides. Note that the value of d is determined by the whole collection of productions, not by an individual one. The determination of d has been done by hand in each case, based on the full set of productions but not on the grammar of C or on the rules for constructing the initial scraps.

We also attach a serial number to each production, so that additional information is available when debugging. For example, the program below contains the statement ‘ $reduce(pp, 3, exp, -2, 4)$ ’ when it implements the production just mentioned.

Before calling *reduce*, the program should have appended the tokens of the new translation to the *tok_mem* array. We commonly want to append copies of several existing translations, and macros are defined to simplify these common cases. For example, *big_app2(pp)* will append the translations of two consecutive scraps, *pp-trans* and $(pp + 1)\text{-trans}$, to the current token list. If the entire new translation is formed in this way, we write ‘*squash(j, k, c, d, n)*’ instead of ‘*reduce(j, k, c, d, n)*’. For example, ‘*squash(pp, 3, exp, -2, 3)*’ is an abbreviation for ‘*big_app3(pp); reduce(pp, 3, exp, -2, 3)*’.

A couple more words of explanation: Both *big_app* and *app* append a token (while *big_app1* to *big_app4* append the specified number of scrap translations) to the current token list. The difference between *big_app* and *app* is simply that *big_app* checks whether there can be a conflict between math and non-math tokens, and intercalates a ‘\$’ token if necessary. When in doubt what to use, use *big_app*.

```
#define app(a) *(tok_ptr++) ← (token)(a)
#define big_app2(a) big_app1(a); big_app1(a + 1)
#define big_app3(a) big_app2(a); big_app1(a + 2)
#define big_app4(a) big_app3(a); big_app1(a + 3)
#define big_app1_insert(p, c) big_app1(p); big_app(c); big_app1(p + 1)
#define big_app1_insert_str(p, s) big_app1(p); app_str(s); big_app1(p + 1)
#define big_app2_insert(p, c) big_app2(p); big_app(c); big_app2(p + 2)
⟨Predeclaration of procedures 4⟩ +=
static void app_str(const char *);
static void big_app(token);
static void big_app1(scrap_pointer);
```

119. The *mathness* is an attribute of scraps that says whether they are to be printed in a math mode context or not. It is separate from the “part of speech” (the *cat*) because to make each *cat* have a fixed *mathness* (as in the original **WEAVE**) would multiply the number of necessary production rules.

The low two bits (i.e., $\text{mathness} \% 4$) control the left boundary. (We need two bits because we allow cases *yes_math*, *no_math* and *maybe_math*, which can go either way.) The next two bits (i.e., $\text{mathness}/4$) control the right boundary. If we combine two scraps and the right boundary of the first has a different *mathness* from the left boundary of the second, we insert a \$ in between. Similarly, if at printing time some irreducible scrap has a *yes_math* boundary the scrap gets preceded or followed by a \$. The left boundary is *maybe_math* if and only if the right boundary is.

```
#define no_math 2    ▷ should be in horizontal mode ◁
#define yes_math 1   ▷ should be in math mode ◁
#define maybe_math 0 ▷ works in either horizontal or math mode ◁
⟨ Private variables 21 ⟩ +≡
    static int cur_mathness, init_mathness;
```


120. The code below is an exact translation of the production rules into C, using such macros, and the reader should have no difficulty understanding the format by comparing the code with the symbolic productions as they were listed earlier.

```
#define begin_math()
    if (cur_mathness  $\equiv$  maybe_math) init_mathness  $\leftarrow$  yes_math;
    else if (cur_mathness  $\equiv$  no_math) app_str("${}")
#define end_math()
    if (cur_mathness  $\equiv$  maybe_math) init_mathness  $\leftarrow$  no_math;
    else if (cur_mathness  $\equiv$  yes_math) app_str("{}$")

static void app_str(const char *s)
{
    while (*s) app_tok(*s++);
}

static void big_app(token a)
{
    if (a  $\equiv$  '␣'  $\vee$  (a  $\geq$  big_cancel  $\wedge$  a  $\leq$  big_force)  $\vee$  a  $\equiv$  dindent)    ▷ non-math token ◁
    {
        end_math(); cur_mathness  $\leftarrow$  no_math;
    }
    else {
        begin_math(); cur_mathness  $\leftarrow$  yes_math;
    }
    app(a);
}

static void big_app1(scrap_pointer a)
{
    switch (a-mathness % 4) {    ▷ left boundary ◁
    case (no_math): end_math(); cur_mathness  $\leftarrow$  a-mathness/4;    ▷ right boundary ◁
        break;
    case (yes_math): begin_math(); cur_mathness  $\leftarrow$  a-mathness/4;    ▷ right boundary ◁
        break;
    case (maybe_math):    ▷ no changes ◁
        break;
    }
    app(tok_flag + (int)((a)-trans - tok_start));
}
```

121. Let us consider the big switch for productions now, before looking at its context. We want to design the program so that this switch works, so we might as well not keep ourselves in suspense about exactly what code needs to be provided with a proper environment.

```
#define cat1 (pp + 1)-cat
#define cat2 (pp + 2)-cat
#define cat3 (pp + 3)-cat
#define lhs_not_simple (pp-cat ≠ public_like ∧ pp-cat ≠ semi ∧ pp-cat ≠ prelangue ∧ pp-cat ≠ prerangle
                        ∧ pp-cat ≠ template_like ∧ pp-cat ≠ new_like ∧ pp-cat ≠ new_exp ∧ pp-cat ≠ ftemplate
                        ∧ pp-cat ≠ raw_ubin ∧ pp-cat ≠ const_like ∧ pp-cat ≠ raw_int ∧ pp-cat ≠ operator_like)
    ▷ not a production with left side length 1 ◁
```

⟨ Match a production at *pp*, or increase *pp* if there is no match 121 ⟩ ≡

```
if (cat1 ≡ end_arg ∧ lhs_not_simple)
    if (pp-cat ≡ begin_arg) squash(pp, 2, exp, -2, 124);
    else squash(pp, 2, end_arg, -1, 125);
else if (pp-cat ≡ rbrack) reduce(pp, 0, rpar, -3, 130);
else if (pp-cat ≡ using_like) reduce(pp, 0, int_like, -3, 140);
else if (cat1 ≡ insert) squash(pp, 2, pp-cat, -2, 0);
else if (cat2 ≡ insert) squash(pp + 1, 2, (pp + 1)-cat, -1, 0);
else if (cat3 ≡ insert) squash(pp + 2, 2, (pp + 2)-cat, 0, 0);
else
    switch (pp-cat) {
    case exp: ⟨ Cases for exp 128 ⟩ break;
    case lpar: ⟨ Cases for lpar 129 ⟩ break;
    case unop: ⟨ Cases for unop 130 ⟩ break;
    case ubinop: ⟨ Cases for ubinop 131 ⟩ break;
    case binop: ⟨ Cases for binop 132 ⟩ break;
    case cast: ⟨ Cases for cast 133 ⟩ break;
    case sizeof_like: ⟨ Cases for sizeof_like 134 ⟩ break;
    case int_like: ⟨ Cases for int_like 135 ⟩ break;
    case public_like: ⟨ Cases for public_like 136 ⟩ break;
    case colcol: ⟨ Cases for colcol 137 ⟩ break;
    case decl_head: ⟨ Cases for decl_head 138 ⟩ break;
    case decl: ⟨ Cases for decl 139 ⟩ break;
    case base: ⟨ Cases for base 140 ⟩ break;
    case struct_like: ⟨ Cases for struct_like 141 ⟩ break;
    case struct_head: ⟨ Cases for struct_head 142 ⟩ break;
    case fn_decl: ⟨ Cases for fn_decl 143 ⟩ break;
    case function: ⟨ Cases for function 144 ⟩ break;
    case lbrace: ⟨ Cases for lbrace 145 ⟩ break;
    case if_like: ⟨ Cases for if_like 146 ⟩ break;
    case else_like: ⟨ Cases for else_like 147 ⟩ break;
    case else_head: ⟨ Cases for else_head 148 ⟩ break;
    case if_clause: ⟨ Cases for if_clause 149 ⟩ break;
    case if_head: ⟨ Cases for if_head 150 ⟩ break;
    case do_like: ⟨ Cases for do_like 151 ⟩ break;
    case case_like: ⟨ Cases for case_like 152 ⟩ break;
    case catch_like: ⟨ Cases for catch_like 153 ⟩ break;
    case tag: ⟨ Cases for tag 154 ⟩ break;
    case stmt: ⟨ Cases for stmt 156 ⟩ break;
    case semi: ⟨ Cases for semi 157 ⟩ break;
    case lproc: ⟨ Cases for lproc 158 ⟩ break;
    case section_scrap: ⟨ Cases for section_scrap 159 ⟩ break;
```

```

case insert: < Cases for insert 160 > break;
case preangle: < Cases for preangle 161 > break;
case prerangle: < Cases for prerangle 162 > break;
case langle: < Cases for langle 163 > break;
case template_like: < Cases for template_like 164 > break;
case new_like: < Cases for new_like 165 > break;
case new_exp: < Cases for new_exp 166 > break;
case ftemplate: < Cases for ftemplate 167 > break;
case for_like: < Cases for for_like 168 > break;
case raw_ubin: < Cases for raw_ubin 169 > break;
case const_like: < Cases for const_like 170 > break;
case raw_int: < Cases for raw_int 171 > break;
case operator_like: < Cases for operator_like 172 > break;
case typedef_like: < Cases for typedef_like 173 > break;
case delete_like: < Cases for delete_like 174 > break;
case question: < Cases for question 175 > break;
case alignas_like: < Cases for alignas_like 176 > break;
case lbrack: < Cases for lbrack 177 > break;
case attr_head: < Cases for attr_head 178 > break;
case attr: < Cases for attr 179 > break;
case default_like: < Cases for default_like 180 > break;
}

```

pp++; ▷ if no match was found, we move to the right ◁

This code is cited in section 25.

This code is used in section 186.

122. In C, new specifier names can be defined via **typedef**, and we want to make the parser recognize future occurrences of the identifier thus defined as specifiers. This is done by the procedure *make_reserved*, which changes the *ilk* of the relevant identifier.

We first need a procedure to recursively seek the first identifier in a token list, because the identifier might be enclosed in parentheses, as when one defines a function returning a pointer.

If the first identifier found is a keyword like ‘**case**’, we return the special value *case_found*; this prevents underlining of identifiers in case labels.

If the first identifier is the keyword ‘**operator**’, we give up; users who want to index definitions of overloaded C++ operators should say, for example, ‘@!@^\&{operator} \$+{=}\$@>’ (or, more properly alphabetized, ‘@!@:operator+=}{\&{operator} \$+{=}\$@>’).

```

#define no_ident_found (token_pointer)0    ▷ distinct from any identifier token ◁
#define case_found (token_pointer)1    ▷ likewise ◁
#define operator_found (token_pointer)2    ▷ likewise ◁

```

< Predeclaration of procedures 4 > +=

```

static token_pointer find_first_ident(text_pointer);
static void make_reserved(scrap_pointer);
static void make_underlined(scrap_pointer);
static void underline_xref(name_pointer);

```

```

123. static token_pointer find_first_ident(text_pointer p)
{
    token_pointer q;    ▷ token to be returned ◁
    token_pointer j;    ▷ token being looked at ◁
    sixteen_bits r;    ▷ remainder of token after the flag has been stripped off ◁
    if (p ≥ text_ptr) confusion("find_first_ident");
    for (j ← *p; j < *(p + 1); j++) {
        r ← *j % id_flag;
        switch (*j / id_flag) {
            case 2:    ▷ res_flag ◁
                if (name_dir[r].ilk ≡ case_like) return case_found;
                if (name_dir[r].ilk ≡ operator_like) return operator_found;
                if (name_dir[r].ilk ≠ raw_int) break;
                /*_else_fall_through_*/
            case 1: return j;
            case 4: case 5:    ▷ tok_flag or inner_tok_flag ◁
                if ((q ← find_first_ident(tok_start + r)) ≠ no_ident_found) return q;
                /*_else_fall_through_*/
            default: ;    ▷ char, section_flag, fall thru: move on to next token ◁
                if (*j ≡ inserted) return no_ident_found;    ▷ ignore inserts ◁
                else if (*j ≡ qualifier) j++;    ▷ bypass namespace qualifier ◁
        }
    }
    return no_ident_found;
}

```

124. The scraps currently being parsed must be inspected for any occurrence of the identifier that we're making reserved; hence the **for** loop below.

```

static void make_reserved(    ▷ make the first identifier in p-trans like int ◁
    scrap_pointer p)
{
    sixteen_bits tok_value;    ▷ the name of this identifier, plus its flag ◁
    token_pointer tok_loc;    ▷ pointer to tok_value ◁
    if ((tok_loc ← find_first_ident(p-trans)) ≤ operator_found) return;    ▷ this should not happen ◁
    tok_value ← *tok_loc;
    for (; p ≤ scrap_ptr; p ≡ lo_ptr ? p ← hi_ptr : p++)
        if (p-cat ≡ exp)
            if (**(p-trans) ≡ tok_value) {
                p-cat ← raw_int; **(p-trans) ← tok_value % id_flag + res_flag;
            }
    (name_dir + (sixteen_bits)(tok_value % id_flag))-ilk ← raw_int;
    *tok_loc ← tok_value % id_flag + res_flag;
}

```

125. In the following situations we want to mark the occurrence of an identifier as a definition: when *make_reserved* is just about to be used; after a specifier, as in **char** ***argv*; before a colon, as in *found*::; and in the declaration of a function, as in *main()*{...}. This is accomplished by the invocation of *make_underlined* at appropriate times. Notice that, in the declaration of a function, we find out that the identifier is being defined only after it has been swallowed up by an *exp*.

```
static void make_underlined(    ▷ underline the entry for the first identifier in p-trans ◁
    scrap_pointer p)
{
    token_pointer tok_loc;    ▷ where the first identifier appears ◁
    if ((tok_loc ← find_first_ident(p-trans)) ≤ operator_found) return;
    ▷ this happens, for example, in case found: ◁
    xref_switch ← def_flag; underline_xref(*tok_loc % id_flag + name_dir);
}
```

126. We cannot use *new_xref* to underline a cross-reference at this point because this would just make a new cross-reference at the end of the list. We actually have to search through the list for the existing cross-reference.

```
static void underline_xref(name_pointer p)
{
    xref_pointer q ← (xref_pointer) p-xref;    ▷ pointer to cross-reference being examined ◁
    xref_pointer r;    ▷ temporary pointer for permuting cross-references ◁
    sixteen_bits m;    ▷ cross-reference value to be installed ◁
    sixteen_bits n;    ▷ cross-reference value being examined ◁
    if (no_xref) return;
    m ← section_count + xref_switch;
    while (q ≠ xmem) {
        n ← q-num;
        if (n ≡ m) return;
        else if (m ≡ n + def_flag) {
            q-num ← m; return;
        }
        else if (n ≥ def_flag ∧ n < m) break;
        q ← q-xlink;
    }
    ◁ Insert new cross-reference at q, not at beginning of list 127 ◁
}
```

127. We get to this section only when the identifier is one letter long, so it didn't get a non-underlined entry during phase one. But it may have got some explicitly underlined entries in later sections, so in order to preserve the numerical order of the entries in the index, we have to insert the new cross-reference not at the beginning of the list (namely, at *p-xref*), but rather right before *q*.

```
◁ Insert new cross-reference at q, not at beginning of list 127 ◁ ≡
append_xref(0);    ▷ this number doesn't matter ◁
xref_ptr-xlink ← (xref_pointer) p-xref; r ← xref_ptr; update_node(p);
while (r-xlink ≠ q) {
    r-num ← r-xlink-num; r ← r-xlink;
}
r-num ← m;    ▷ everything from q on is left undisturbed ◁
```

This code is used in section 126.

128. Now comes the code that tries to match each production starting with a particular type of scrap. Whenever a match is discovered, the *squash* or *reduce* function will cause the appropriate action to be performed.

```

⟨ Cases for exp 128 ⟩ ≡
  if (cat1 ≡ lbrace ∨ cat1 ≡ int_like ∨ cat1 ≡ decl) {
    make_underlined(pp); big_app(dindent); big_app1(pp); reduce(pp, 1, fn_decl, 0, 1);
  }
  else if (cat1 ≡ unop) squash(pp, 2, exp, -2, 2);
  else if ((cat1 ≡ binop ∨ cat1 ≡ ubinop) ∧ cat2 ≡ exp) squash(pp, 3, exp, -2, 3);
  else if (cat1 ≡ comma ∧ cat2 ≡ exp) {
    big_app2(pp); app(opt); app('9'); big_app1(pp + 2); reduce(pp, 3, exp, -2, 4);
  }
  else if (cat1 ≡ lpar ∧ cat2 ≡ rpar ∧ cat3 ≡ colon) reduce(pp + 3, 0, base, 0, 5);
  else if (cat1 ≡ cast ∧ cat2 ≡ colon) reduce(pp + 2, 0, base, 0, 5);
  else if (cat1 ≡ semi) squash(pp, 2, stmt, -1, 6);
  else if (cat1 ≡ colon) {
    make_underlined(pp); squash(pp, 2, tag, -1, 7);
  }
  else if (cat1 ≡ rbrace) reduce(pp, 0, stmt, -1, 8);
  else if (cat1 ≡ lpar ∧ cat2 ≡ rpar ∧ (cat3 ≡ const_like ∨ cat3 ≡ case_like)) {
    big_app1_insert(pp + 2, '␣'); reduce(pp + 2, 2, rpar, 0, 9);
  }
  else if (cat1 ≡ cast ∧ (cat2 ≡ const_like ∨ cat2 ≡ case_like)) {
    big_app1_insert(pp + 1, '␣'); reduce(pp + 1, 2, cast, 0, 9);
  }
  else if (cat1 ≡ exp ∨ cat1 ≡ cast) squash(pp, 2, exp, -2, 10);
  else if (cat1 ≡ attr) {
    big_app1_insert(pp, '␣'); reduce(pp, 2, exp, -2, 142);
  }
  else if (cat1 ≡ colcol ∧ cat2 ≡ int_like) squash(pp, 3, int_like, -2, 152);

```

This code is used in section 121.

```

129.    ⟨ Cases for lpar 129 ⟩ ≡
  if ((cat1 ≡ exp ∨ cat1 ≡ ubinop) ∧ cat2 ≡ rpar) squash(pp, 3, exp, -2, 11);
  else if (cat1 ≡ rpar) {
    big_app1_insert_str(pp, "\\,"); reduce(pp, 2, exp, -2, 12);
  }
  else if ((cat1 ≡ decl_head ∨ cat1 ≡ int_like ∨ cat1 ≡ cast) ∧ cat2 ≡ rpar) squash(pp, 3, cast, -2, 13);
  else if ((cat1 ≡ decl_head ∨ cat1 ≡ int_like ∨ cat1 ≡ exp) ∧ cat2 ≡ comma) {
    big_app3(pp); app(opt); app('9'); reduce(pp, 3, lpar, -1, 14);
  }
  else if (cat1 ≡ stmt ∨ cat1 ≡ decl) {
    big_app2(pp); big_app('␣'); reduce(pp, 2, lpar, -1, 15);
  }

```

This code is used in section 121.

```

130.    ⟨ Cases for unop 130 ⟩ ≡
  if (cat1 ≡ exp ∨ cat1 ≡ int_like) squash(pp, 2, exp, -2, 16);

```

This code is used in section 121.

131. $\langle \text{Cases for } \textit{ubinop} \text{ 131} \rangle \equiv$
if ($\textit{cat1} \equiv \textit{cast} \wedge \textit{cat2} \equiv \textit{rpar}$) {
 $\textit{big_app}(' \{ ')$; $\textit{big_app1_insert}(pp, ' \}')$; $\textit{reduce}(pp, 2, \textit{cast}, -2, 17)$;
 }
else if ($\textit{cat1} \equiv \textit{exp} \vee \textit{cat1} \equiv \textit{int_like}$) {
 $\textit{big_app}(' \{ ')$; $\textit{big_app1_insert}(pp, ' \}')$; $\textit{reduce}(pp, 2, \textit{cat1}, -2, 18)$;
 }
else if ($\textit{cat1} \equiv \textit{binop}$) {
 $\textit{big_app}(\textit{math_rel})$; $\textit{big_app1_insert}(pp, ' \{ ')$; $\textit{big_app}(' \}')$; $\textit{big_app}(' \}')$; $\textit{reduce}(pp, 2, \textit{binop}, -1, 19)$;
 }

This code is used in section 121.

132. $\langle \text{Cases for } \textit{binop} \text{ 132} \rangle \equiv$
if ($\textit{cat1} \equiv \textit{binop}$) {
 $\textit{big_app}(\textit{math_rel})$; $\textit{big_app}(' \{ ')$; $\textit{big_app1}(pp)$; $\textit{big_app}(' \}')$; $\textit{big_app}(' \{ ')$; $\textit{big_app1}(pp + 1)$;
 $\textit{big_app}(' \}')$; $\textit{big_app}(' \}')$; $\textit{reduce}(pp, 2, \textit{binop}, -1, 20)$;
 }

This code is used in section 121.

133. $\langle \text{Cases for } \textit{cast} \text{ 133} \rangle \equiv$
if ($\textit{cat1} \equiv \textit{lpar}$) $\textit{squash}(pp, 2, \textit{lpar}, -1, 21)$;
else if ($\textit{cat1} \equiv \textit{exp}$) {
 $\textit{big_app1_insert_str}(pp, "\\ , ")$; $\textit{reduce}(pp, 2, \textit{exp}, -2, 21)$;
 }
else if ($\textit{cat1} \equiv \textit{semi}$) $\textit{reduce}(pp, 0, \textit{exp}, -2, 22)$;

This code is used in section 121.

134. $\langle \text{Cases for } \textit{sizeof_like} \text{ 134} \rangle \equiv$
if ($\textit{cat1} \equiv \textit{cast}$) $\textit{squash}(pp, 2, \textit{exp}, -2, 23)$;
else if ($\textit{cat1} \equiv \textit{exp}$) {
 $\textit{big_app1_insert}(pp, ' \sqcup ')$; $\textit{reduce}(pp, 2, \textit{exp}, -2, 24)$;
 }

This code is used in section 121.

135. $\langle \text{Cases for } \textit{int_like} \text{ 135} \rangle \equiv$
if ($\textit{cat1} \equiv \textit{int_like} \vee \textit{cat1} \equiv \textit{struct_like}$) {
 $\textit{big_app1_insert}(pp, ' \sqcup ')$; $\textit{reduce}(pp, 2, \textit{cat1}, -2, 25)$;
 }
else if ($\textit{cat1} \equiv \textit{exp} \wedge (\textit{cat2} \equiv \textit{raw_int} \vee \textit{cat2} \equiv \textit{struct_like})$) $\textit{squash}(pp, 2, \textit{int_like}, -2, 26)$;
else if ($\textit{cat1} \equiv \textit{exp} \vee \textit{cat1} \equiv \textit{ubinop} \vee \textit{cat1} \equiv \textit{colon}$) {
 $\textit{big_app1}(pp)$; $\textit{big_app}(' \sqcup ')$; $\textit{reduce}(pp, 1, \textit{decl_head}, -1, 27)$;
 }
else if ($\textit{cat1} \equiv \textit{semi} \vee \textit{cat1} \equiv \textit{binop}$) $\textit{reduce}(pp, 0, \textit{decl_head}, 0, 28)$;

This code is used in section 121.

136. $\langle \text{Cases for } \textit{public_like} \text{ 136} \rangle \equiv$
if ($\textit{cat1} \equiv \textit{colon}$) $\textit{squash}(pp, 2, \textit{tag}, -1, 29)$;
else $\textit{reduce}(pp, 0, \textit{int_like}, -2, 30)$;

This code is used in section 121.

137. $\langle \text{Cases for } \text{colcol } 137 \rangle \equiv$
 if ($\text{cat1} \equiv \text{exp} \vee \text{cat1} \equiv \text{int_like}$) {
 $\text{app}(\text{qualifier})$; $\text{squash}(\text{pp}, 2, \text{cat1}, -2, 31)$;
 }
 else if ($\text{cat1} \equiv \text{colcol}$) $\text{squash}(\text{pp}, 2, \text{colcol}, -1, 32)$;

This code is used in section 121.

138. $\langle \text{Cases for } \text{decl_head } 138 \rangle \equiv$
 if ($\text{cat1} \equiv \text{comma}$) {
 $\text{big_app2}(\text{pp})$; $\text{app}(\text{opt})$; $\text{app}('9')$; $\text{reduce}(\text{pp}, 2, \text{decl_head}, -1, 33)$;
 }
 else if ($\text{cat1} \equiv \text{ubinop}$) {
 $\text{big_app1_insert}(\text{pp}, '\{')$; $\text{big_app}('}')$; $\text{reduce}(\text{pp}, 2, \text{decl_head}, -1, 34)$;
 }
 else if ($\text{cat1} \equiv \text{exp} \wedge \text{cat2} \neq \text{lpar} \wedge \text{cat2} \neq \text{lbrack} \wedge \text{cat2} \neq \text{exp} \wedge \text{cat2} \neq \text{cast}$) {
 $\text{make_underlined}(\text{pp} + 1)$; $\text{squash}(\text{pp}, 2, \text{decl_head}, -1, 35)$;
 }
 else if ($(\text{cat1} \equiv \text{binop} \vee \text{cat1} \equiv \text{colon}) \wedge \text{cat2} \equiv \text{exp} \wedge (\text{cat3} \equiv \text{comma} \vee \text{cat3} \equiv \text{semi} \vee \text{cat3} \equiv \text{rpar})$)
 $\text{squash}(\text{pp}, 3, \text{decl_head}, -1, 36)$;
 else if ($\text{cat1} \equiv \text{cast}$) $\text{squash}(\text{pp}, 2, \text{decl_head}, -1, 37)$;
 else if ($\text{cat1} \equiv \text{int_like} \vee \text{cat1} \equiv \text{lbrace} \vee \text{cat1} \equiv \text{decl}$) {
 $\text{big_app}(\text{dindent})$; $\text{squash}(\text{pp}, 1, \text{fn_decl}, 0, 38)$;
 }
 else if ($\text{cat1} \equiv \text{semi}$) $\text{squash}(\text{pp}, 2, \text{decl}, -1, 39)$;
 else if ($\text{cat1} \equiv \text{attr}$) {
 $\text{big_app1_insert}(\text{pp}, '\sqcup')$; $\text{reduce}(\text{pp}, 2, \text{decl_head}, -1, 139)$;
 }

This code is used in section 121.

139. $\langle \text{Cases for } \text{decl } 139 \rangle \equiv$
 if ($\text{cat1} \equiv \text{decl}$) {
 $\text{big_app1_insert}(\text{pp}, \text{force})$; $\text{reduce}(\text{pp}, 2, \text{decl}, -1, 40)$;
 }
 else if ($\text{cat1} \equiv \text{stmt} \vee \text{cat1} \equiv \text{function}$) {
 $\text{big_app1_insert}(\text{pp}, \text{big_force})$; $\text{reduce}(\text{pp}, 2, \text{cat1}, -1, 41)$;
 }

This code is used in section 121.

140. $\langle \text{Cases for } \text{base } 140 \rangle \equiv$
 if ($\text{cat1} \equiv \text{int_like} \vee \text{cat1} \equiv \text{exp}$) {
 if ($\text{cat2} \equiv \text{comma}$) {
 $\text{big_app1_insert}(\text{pp}, '\sqcup')$; $\text{big_app1}(\text{pp} + 2)$; $\text{app}(\text{opt})$; $\text{app}('9')$; $\text{reduce}(\text{pp}, 3, \text{base}, 0, 42)$;
 }
 else if ($\text{cat2} \equiv \text{lbrace}$) {
 $\text{big_app1_insert}(\text{pp}, '\sqcup')$; $\text{big_app}('')$; $\text{big_app1}(\text{pp} + 2)$; $\text{reduce}(\text{pp}, 3, \text{lbrace}, -2, 43)$;
 }
 }

This code is used in section 121.

141. $\langle \text{Cases for } \textit{struct_like} \text{ 141} \rangle \equiv$

```

if ( $\textit{cat1} \equiv \textit{lbrace}$ ) {
   $\textit{big\_app1\_insert}(pp, ' \sqcup ');$   $\textit{reduce}(pp, 2, \textit{struct\_head}, 0, 44);$ 
}
else if ( $\textit{cat1} \equiv \textit{exp} \vee \textit{cat1} \equiv \textit{int\_like}$ ) {
  if ( $\textit{cat2} \equiv \textit{lbrace} \vee \textit{cat2} \equiv \textit{semi}$ ) {
     $\textit{make\_underlined}(pp + 1);$   $\textit{make\_reserved}(pp + 1);$   $\textit{big\_app1\_insert}(pp, ' \sqcup ');$ 
    if ( $\textit{cat2} \equiv \textit{semi}$ )  $\textit{reduce}(pp, 2, \textit{decl\_head}, 0, 45);$ 
    else {
       $\textit{big\_app}(' \sqcup ');$   $\textit{big\_app1}(pp + 2);$   $\textit{reduce}(pp, 3, \textit{struct\_head}, 0, 46);$ 
    }
  }
  else if ( $\textit{cat2} \equiv \textit{colon}$ )  $\textit{reduce}(pp + 2, 0, \textit{base}, 2, 47);$ 
  else if ( $\textit{cat2} \neq \textit{base}$ ) {
     $\textit{big\_app1\_insert}(pp, ' \sqcup ');$   $\textit{reduce}(pp, 2, \textit{int\_like}, -2, 48);$ 
  }
}
else if ( $\textit{cat1} \equiv \textit{attr}$ ) {
   $\textit{big\_app1\_insert}(pp, ' \sqcup ');$   $\textit{reduce}(pp, 2, \textit{struct\_like}, -3, 141);$ 
}
else if ( $\textit{cat1} \equiv \textit{struct\_like}$ ) {
   $\textit{big\_app1\_insert}(pp, ' \sqcup ');$   $\textit{reduce}(pp, 2, \textit{struct\_like}, -3, 151);$ 
}

```

This code is used in section 121.

142. $\langle \text{Cases for } \textit{struct_head} \text{ 142} \rangle \equiv$

```

if ( $((\textit{cat1} \equiv \textit{decl} \vee \textit{cat1} \equiv \textit{stmt} \vee \textit{cat1} \equiv \textit{function}) \wedge \textit{cat2} \equiv \textit{rbrace})$ ) {
   $\textit{big\_app1}(pp);$   $\textit{big\_app}(\textit{indent});$   $\textit{big\_app}(\textit{force});$   $\textit{big\_app1}(pp + 1);$   $\textit{big\_app}(\textit{outdent});$   $\textit{big\_app}(\textit{force});$ 
   $\textit{big\_app1}(pp + 2);$   $\textit{reduce}(pp, 3, \textit{int\_like}, -2, 49);$ 
}
else if ( $\textit{cat1} \equiv \textit{rbrace}$ ) {
   $\textit{big\_app1\_insert\_str}(pp, "\\,");$   $\textit{reduce}(pp, 2, \textit{int\_like}, -2, 50);$ 
}

```

This code is used in section 121.

143. $\langle \text{Cases for } \textit{fn_decl} \text{ 143} \rangle \equiv$

```

if ( $\textit{cat1} \equiv \textit{decl}$ ) {
   $\textit{big\_app1\_insert}(pp, \textit{force});$   $\textit{reduce}(pp, 2, \textit{fn\_decl}, 0, 51);$ 
}
else if ( $\textit{cat1} \equiv \textit{stmt}$ ) {
   $\textit{big\_app1}(pp);$   $\textit{app}(\textit{outdent});$   $\textit{app}(\textit{outdent});$   $\textit{big\_app}(\textit{force});$   $\textit{big\_app1}(pp + 1);$ 
   $\textit{reduce}(pp, 2, \textit{function}, -1, 52);$ 
}
else if ( $\textit{cat1} \equiv \textit{attr}$ ) {
   $\textit{big\_app1\_insert}(pp, ' \sqcup ');$   $\textit{reduce}(pp, 2, \textit{fn\_decl}, 0, 157);$ 
}

```

This code is used in section 121.

144. $\langle \text{Cases for function 144} \rangle \equiv$
if ($cat1 \equiv stmt \vee cat1 \equiv decl \vee cat1 \equiv function$) {
 $big_app1_insert(pp, big_force); reduce(pp, 2, cat1, -1, 53);$
}

This code is used in section 121.

145. $\langle \text{Cases for lbrace 145} \rangle \equiv$
if ($cat1 \equiv rbrace$) {
 $big_app1_insert_str(pp, "\\,"); reduce(pp, 2, stmt, -1, 54);$
}
else if ($(cat1 \equiv stmt \vee cat1 \equiv decl \vee cat1 \equiv function) \wedge cat2 \equiv rbrace$) {
 $big_app(force); big_app1(pp); big_app(indent); big_app(force_first ? force : break_space);$
 $big_app1(pp + 1); big_app(force); big_app(backup); big_app1(pp + 2); big_app(outdent);$
 $big_app(force); reduce(pp, 3, stmt, -1, 55);$
}
else if ($cat1 \equiv exp$) {
 if ($cat2 \equiv rbrace$) $squash(pp, 3, exp, -2, 56);$
 else if ($cat2 \equiv comma \wedge cat3 \equiv rbrace$) $squash(pp, 4, exp, -2, 56);$
}

This code is used in section 121.

146. $\langle \text{Cases for if-like 146} \rangle \equiv$
if ($cat1 \equiv exp$) {
 $big_app1_insert(pp, ' \sqcup '); reduce(pp, 2, if_clause, 0, 57);$
}

This code is used in section 121.

147. $\langle \text{Cases for else-like 147} \rangle \equiv$
if ($cat1 \equiv colon$) $reduce(pp + 1, 0, base, 1, 58);$
else if ($cat1 \equiv lbrace$) $reduce(pp, 0, else_head, 0, 59);$
else if ($cat1 \equiv stmt$) {
 $big_app(force); big_app1(pp); big_app(indent); big_app(break_space); big_app1(pp + 1);$
 $big_app(outdent); big_app(force); reduce(pp, 2, stmt, -1, 60);$
}

This code is used in section 121.

148. $\langle \text{Cases for else_head 148} \rangle \equiv$
if ($cat1 \equiv stmt \vee cat1 \equiv exp$) {
 $big_app(force); big_app1(pp); big_app(break_space); app(noop); big_app(cancel); big_app1(pp + 1);$
 $big_app(force); reduce(pp, 2, stmt, -1, 61);$
}

This code is used in section 121.

149. $\langle \text{Cases for } if_clause \text{ 149} \rangle \equiv$
if ($cat1 \equiv lbrace$) $reduce(pp, 0, if_head, 0, 62);$
else if ($cat1 \equiv stmt$) {
 if ($cat2 \equiv else_like$) {
 $big_app(force); big_app1(pp); big_app(indent); big_app(break_space); big_app1(pp + 1);$
 $big_app(outdent); big_app(force); big_app1(pp + 2);$
 if ($cat3 \equiv if_like$) {
 $big_app(' \sqcup '); big_app1(pp + 3); reduce(pp, 4, if_like, 0, 63);$
 }
 else $reduce(pp, 3, else_like, 0, 64);$
 }
else $reduce(pp, 0, else_like, 0, 65);$
 }
else if ($cat1 \equiv attr$) {
 $big_app1_insert(pp, ' \sqcup '); reduce(pp, 2, if_head, 0, 146);$
 }

This code is used in section 121.

150. $\langle \text{Cases for } if_head \text{ 150} \rangle \equiv$
if ($cat1 \equiv stmt \vee cat1 \equiv exp$) {
 if ($cat2 \equiv else_like$) {
 $big_app(force); big_app1(pp); big_app(break_space); app(noop); big_app(cancel);$
 $big_app1_insert(pp + 1, force);$
 if ($cat3 \equiv if_like$) {
 $big_app(' \sqcup '); big_app1(pp + 3); reduce(pp, 4, if_like, 0, 66);$
 }
 else $reduce(pp, 3, else_like, 0, 67);$
 }
else $reduce(pp, 0, else_head, 0, 68);$
 }

This code is used in section 121.

151. $\langle \text{Cases for } do_like \text{ 151} \rangle \equiv$
if ($cat1 \equiv stmt \wedge cat2 \equiv else_like \wedge cat3 \equiv semi$) {
 if ($\neg force_lines$) $big_app(force);$
 $big_app1(pp); big_app(break_space); app(noop); big_app(cancel); big_app1(pp + 1); big_app(cancel);$
 $app(noop); big_app(break_space); big_app2(pp + 2);$
 if ($\neg force_lines$) $big_app(force);$
 $reduce(pp, 4, stmt, -1, 69);$
 }

This code is used in section 121.

152. $\langle \text{Cases for } case_like \text{ 152} \rangle \equiv$
if ($cat1 \equiv semi$) $squash(pp, 2, stmt, -1, 70);$
else if ($cat1 \equiv colon$) $squash(pp, 2, tag, -1, 71);$
else if ($cat1 \equiv exp$) {
 $big_app1_insert(pp, ' \sqcup '); reduce(pp, 2, exp, -2, 72);$
 }

This code is used in section 121.

153. $\langle \text{Cases for } \textit{catch_like} \text{ 153} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{cast} \vee \textit{cat1} \equiv \textit{exp}$) {
 $\textit{big_app1_insert}(pp, \textit{dindent}); \textit{reduce}(pp, 2, \textit{fn_decl}, 0, 73);$
 }

This code is used in section 121.

154. $\langle \text{Cases for } \textit{tag} \text{ 154} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{tag}$) {
 $\textit{big_app1_insert}(pp, \textit{break_space}); \textit{reduce}(pp, 2, \textit{tag}, -1, 74);$
 }
 else if ($\textit{cat1} \equiv \textit{stmt} \vee \textit{cat1} \equiv \textit{decl} \vee \textit{cat1} \equiv \textit{function}$) {
 $\textit{big_app}(\textit{force}); \textit{big_app}(\textit{backup}); \textit{big_app1_insert}(pp, \textit{break_space}); \textit{reduce}(pp, 2, \textit{cat1}, -1, 75);$
 }
 else if ($\textit{cat1} \equiv \textit{rbrace}$) $\textit{reduce}(pp, 0, \textit{decl}, -1, 156);$

This code is used in section 121.

155. The user can decide at run-time whether short statements should be grouped together on the same line. Another form of compaction places the first line of a ‘compound statement’, a.k.a. ‘block’, next to the opening curly brace.

```
#define force_lines  flags['f']    ▷ should each statement be on its own line? <
#define force_first  flags['F']    ▷ should compound statement start on new line? <
⟨Set initial values 24⟩ +=
  force_lines ← force_first ← true;
```

156. $\langle \text{Cases for } \textit{stmt} \text{ 156} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{stmt} \vee \textit{cat1} \equiv \textit{decl} \vee \textit{cat1} \equiv \textit{function}$) {
 $\textit{big_app1_insert}(pp, (\textit{cat1} \equiv \textit{decl} \vee \textit{cat1} \equiv \textit{function}) ? \textit{big_force} : \textit{force_lines} ? \textit{force} : \textit{break_space});$
 $\textit{reduce}(pp, 2, \textit{cat1}, -1, 76);$
 }

This code is used in section 121.

157. $\langle \text{Cases for } \textit{semi} \text{ 157} \rangle \equiv$
 $\textit{big_app}(' \sqcup '); \textit{squash}(pp, 1, \textit{stmt}, -1, 77);$

This code is used in section 121.

158. $\langle \text{Cases for } \textit{lproc} \text{ 158} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{define_like}$) $\textit{make_underlined}(pp + 2);$
 if ($\textit{cat1} \equiv \textit{if_like} \vee \textit{cat1} \equiv \textit{else_like} \vee \textit{cat1} \equiv \textit{define_like}$) $\textit{squash}(pp, 2, \textit{lproc}, 0, 78);$
 else if ($\textit{cat1} \equiv \textit{rproc}$) {
 $\textit{app}(\textit{inserted}); \textit{squash}(pp, 2, \textit{insert}, -1, 79);$
 }
 else if ($\textit{cat1} \equiv \textit{exp} \vee \textit{cat1} \equiv \textit{function}$) {
 if ($\textit{cat2} \equiv \textit{rproc}$) {
 $\textit{app}(\textit{inserted}); \textit{big_app1_insert}(pp, ' \sqcup '); \textit{big_app1}(pp + 2); \textit{reduce}(pp, 3, \textit{insert}, -1, 80);$
 }
 else if ($\textit{cat1} \equiv \textit{exp} \wedge \textit{cat2} \equiv \textit{exp} \wedge \textit{cat3} \equiv \textit{rproc}$) {
 $\textit{app}(\textit{inserted}); \textit{big_app1_insert}(pp, ' \sqcup '); \textit{app_str}("\backslash 5"); \textit{big_app2}(pp + 2);$
 $\textit{reduce}(pp, 4, \textit{insert}, -1, 80);$
 }
 }

This code is used in section 121.

159. $\langle \text{Cases for } \textit{section_scrap} \text{ 159} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{semi}$) {
 $\textit{big_app2}(\textit{pp})$; $\textit{big_app}(\textit{force})$; $\textit{reduce}(\textit{pp}, 2, \textit{stmt}, -2, 81)$;
 }
 else $\textit{reduce}(\textit{pp}, 0, \textit{exp}, -2, 82)$;

This code is used in section 121.

160. $\langle \text{Cases for } \textit{insert} \text{ 160} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{function}$) $\textit{squash}(\textit{pp}, 2, \textit{function}, 0, 83)$;

This code is used in section 121.

161. $\langle \text{Cases for } \textit{prelangle} \text{ 161} \rangle \equiv$
 $\textit{init_mathness} \leftarrow \textit{cur_mathness} \leftarrow \textit{yes_math}$; $\textit{app}(\text{'<'})$; $\textit{reduce}(\textit{pp}, 1, \textit{binop}, -2, 84)$;

This code is used in section 121.

162. $\langle \text{Cases for } \textit{prerangle} \text{ 162} \rangle \equiv$
 $\textit{init_mathness} \leftarrow \textit{cur_mathness} \leftarrow \textit{yes_math}$; $\textit{app}(\text{'>'})$; $\textit{reduce}(\textit{pp}, 1, \textit{binop}, -2, 85)$;

This code is used in section 121.

163. `#define reserve_typenames flags['t']`
 ▷ should we treat **typename** in a template like **typedef**? ◁

$\langle \text{Cases for } \textit{langl} \text{ 163} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{prerangle}$) {
 $\textit{big_app1_insert_str}(\textit{pp}, "\\\", ")$; $\textit{reduce}(\textit{pp}, 2, \textit{cast}, -1, 86)$;
 }
 else if ($\textit{cat1} \equiv \textit{decl_head} \vee \textit{cat1} \equiv \textit{int_like} \vee \textit{cat1} \equiv \textit{exp}$) {
 if ($\textit{cat2} \equiv \textit{prerangle}$) $\textit{squash}(\textit{pp}, 3, \textit{cast}, -1, 87)$;
 else if ($\textit{cat2} \equiv \textit{comma}$) {
 $\textit{big_app3}(\textit{pp})$; $\textit{app}(\textit{opt})$; $\textit{app}(\text{'9'})$; $\textit{reduce}(\textit{pp}, 3, \textit{langl}, 0, 88)$;
 }
 }
 else if ($(\textit{cat1} \equiv \textit{struct_like}) \wedge (\textit{cat2} \equiv \textit{exp} \vee \textit{cat2} \equiv \textit{int_like}) \wedge (\textit{cat3} \equiv \textit{comma} \vee \textit{cat3} \equiv \textit{prerangle})$) {
 $\textit{make_underlined}(\textit{pp} + 2)$;
 if ($\textit{reserve_typenames}$) $\textit{make_reserved}(\textit{pp} + 2)$;
 $\textit{big_app2_insert}(\textit{pp}, \text{'_'})$;
 if ($\textit{cat3} \equiv \textit{comma}$) {
 $\textit{app}(\textit{opt})$; $\textit{app}(\text{'9'})$; $\textit{reduce}(\textit{pp}, 4, \textit{langl}, 0, 153)$;
 }
 else $\textit{reduce}(\textit{pp}, 4, \textit{cast}, -1, 154)$;
 }

This code is used in section 121.

164. $\langle \text{Cases for } \textit{template_like} \text{ 164} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{exp} \wedge \textit{cat2} \equiv \textit{prelangle}$) $\textit{reduce}(\textit{pp} + 2, 0, \textit{langl}, 2, 89)$;
 else if ($\textit{cat1} \equiv \textit{exp} \vee \textit{cat1} \equiv \textit{raw_int}$) {
 $\textit{big_app1_insert}(\textit{pp}, \text{'_'})$; $\textit{reduce}(\textit{pp}, 2, \textit{cat1}, -2, 90)$;
 }
 else if ($\textit{cat1} \equiv \textit{cast} \wedge \textit{cat2} \equiv \textit{struct_like}$) {
 $\textit{big_app1_insert}(\textit{pp}, \text{'_'})$; $\textit{reduce}(\textit{pp}, 2, \textit{struct_like}, 0, 155)$;
 }
 else $\textit{reduce}(\textit{pp}, 0, \textit{raw_int}, 0, 91)$;

This code is used in section 121.

165. $\langle \text{Cases for } \textit{new_like} \text{ 165} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{lpar} \wedge \textit{cat2} \equiv \textit{exp} \wedge \textit{cat3} \equiv \textit{rpar}$) $\textit{squash}(pp, 4, \textit{new_like}, 0, 92)$;
 else if ($\textit{cat1} \equiv \textit{cast}$) {
 $\textit{big_app1_insert}(pp, ' \sqcup '$); $\textit{reduce}(pp, 2, \textit{exp}, -2, 93)$;
 }
 else if ($\textit{cat1} \neq \textit{lpar}$) $\textit{reduce}(pp, 0, \textit{new_exp}, 0, 94)$;

This code is used in section 121.

166. $\langle \text{Cases for } \textit{new_exp} \text{ 166} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{int_like} \vee \textit{cat1} \equiv \textit{const_like}$) {
 $\textit{big_app1_insert}(pp, ' \sqcup '$); $\textit{reduce}(pp, 2, \textit{new_exp}, 0, 95)$;
 }
 else if ($\textit{cat1} \equiv \textit{struct_like} \wedge (\textit{cat2} \equiv \textit{exp} \vee \textit{cat2} \equiv \textit{int_like})$) {
 $\textit{big_app1_insert}(pp, ' \sqcup '$); $\textit{big_app}(' \sqcup '$); $\textit{big_app1}(pp + 2)$; $\textit{reduce}(pp, 3, \textit{new_exp}, 0, 96)$;
 }
 else if ($\textit{cat1} \equiv \textit{raw_ubin}$) {
 $\textit{big_app1_insert}(pp, ' \{ '$); $\textit{big_app}(' \} '$); $\textit{reduce}(pp, 2, \textit{new_exp}, 0, 97)$;
 }
 else if ($\textit{cat1} \equiv \textit{lpar}$) $\textit{reduce}(pp, 0, \textit{exp}, -2, 98)$;
 else if ($\textit{cat1} \equiv \textit{exp}$) {
 $\textit{big_app1}(pp)$; $\textit{big_app}(' \sqcup '$); $\textit{reduce}(pp, 1, \textit{exp}, -2, 98)$;
 }
 else if ($\textit{cat1} \neq \textit{raw_int} \wedge \textit{cat1} \neq \textit{struct_like} \wedge \textit{cat1} \neq \textit{colcol}$) $\textit{reduce}(pp, 0, \textit{exp}, -2, 99)$;

This code is used in section 121.

167. $\langle \text{Cases for } \textit{ftemplate} \text{ 167} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{prelangle}$) $\textit{reduce}(pp + 1, 0, \textit{langle}, 1, 100)$;
 else $\textit{reduce}(pp, 0, \textit{exp}, -2, 101)$;

This code is used in section 121.

168. $\langle \text{Cases for } \textit{for_like} \text{ 168} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{exp}$) {
 $\textit{big_app1_insert}(pp, ' \sqcup '$); $\textit{reduce}(pp, 2, \textit{else_like}, -2, 102)$;
 }
 }

This code is used in section 121.

169. $\langle \text{Cases for } \textit{raw_ubin} \text{ 169} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{const_like}$) {
 $\textit{big_app2}(pp)$; $\textit{app_str}("\backslash \sqcup")$; $\textit{reduce}(pp, 2, \textit{raw_ubin}, 0, 103)$;
 }
 else $\textit{reduce}(pp, 0, \textit{ubinop}, -2, 104)$;

This code is used in section 121.

170. $\langle \text{Cases for } \textit{const_like} \text{ 170} \rangle \equiv$
 $\textit{reduce}(pp, 0, \textit{int_like}, -2, 105)$;

This code is used in section 121.

171. $\langle \text{Cases for } \textit{raw_int} \text{ 171} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{prelangle}$) $\textit{reduce}(pp + 1, 0, \textit{langle}, 1, 106)$;
 else if ($\textit{cat1} \equiv \textit{colcol}$) $\textit{squash}(pp, 2, \textit{colcol}, -1, 107)$;
 else if ($\textit{cat1} \equiv \textit{cast}$) $\textit{squash}(pp, 2, \textit{raw_int}, 0, 108)$;
 else if ($\textit{cat1} \equiv \textit{lpar}$) $\textit{reduce}(pp, 0, \textit{exp}, -2, 109)$;
 else if ($\textit{cat1} \equiv \textit{lbrack}$) $\textit{reduce}(pp, 0, \textit{exp}, -2, 144)$;
 else if ($\textit{cat1} \neq \textit{langle}$) $\textit{reduce}(pp, 0, \textit{int_like}, -3, 110)$;

This code is used in section 121.

172. $\langle \text{Cases for } \textit{operator_like} \text{ 172} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{binop} \vee \textit{cat1} \equiv \textit{unop} \vee \textit{cat1} \equiv \textit{ubinop}$) {
 if ($\textit{cat2} \equiv \textit{binop}$) **break**;
 $\textit{big_app1_insert}(pp, '\{')$; $\textit{big_app1_insert}(pp, '\}')$; $\textit{reduce}(pp, 2, \textit{exp}, -2, 111)$;
 }
 else if ($\textit{cat1} \equiv \textit{new_like} \vee \textit{cat1} \equiv \textit{delete_like}$) {
 $\textit{big_app1_insert}(pp, '\sqcup')$; $\textit{reduce}(pp, 2, \textit{exp}, -2, 112)$;
 }
 else if ($\textit{cat1} \equiv \textit{comma}$) $\textit{squash}(pp, 2, \textit{exp}, -2, 113)$;
 else if ($\textit{cat1} \neq \textit{raw_ubin}$) $\textit{reduce}(pp, 0, \textit{new_exp}, 0, 114)$;

This code is used in section 121.

173. $\langle \text{Cases for } \textit{typedef_like} \text{ 173} \rangle \equiv$
 if ($(\textit{cat1} \equiv \textit{int_like} \vee \textit{cat1} \equiv \textit{cast}) \wedge (\textit{cat2} \equiv \textit{comma} \vee \textit{cat2} \equiv \textit{semi})$) $\textit{reduce}(pp + 1, 0, \textit{exp}, -1, 115)$;
 else if ($\textit{cat1} \equiv \textit{int_like}$) {
 $\textit{big_app1_insert}(pp, '\sqcup')$; $\textit{reduce}(pp, 2, \textit{typedef_like}, 0, 116)$;
 }
 else if ($\textit{cat1} \equiv \textit{exp} \wedge \textit{cat2} \neq \textit{lpar} \wedge \textit{cat2} \neq \textit{lbrack} \wedge \textit{cat2} \neq \textit{exp} \wedge \textit{cat2} \neq \textit{cast}$) {
 $\textit{make_underlined}(pp + 1)$; $\textit{make_reserved}(pp + 1)$; $\textit{big_app1_insert}(pp, '\sqcup')$;
 $\textit{reduce}(pp, 2, \textit{typedef_like}, 0, 117)$;
 }
 else if ($\textit{cat1} \equiv \textit{comma}$) $\textit{squash}(pp, 2, \textit{typedef_like}, 0, 118)$;
 else if ($\textit{cat1} \equiv \textit{semi}$) $\textit{squash}(pp, 2, \textit{decl}, -1, 119)$;
 else if ($\textit{cat1} \equiv \textit{ubinop} \wedge (\textit{cat2} \equiv \textit{ubinop} \vee \textit{cat2} \equiv \textit{cast})$) {
 $\textit{big_app}('\{')$; $\textit{big_app1_insert}(pp + 1, '\}')$; $\textit{reduce}(pp + 1, 2, \textit{cat2}, 0, 120)$;
 }

This code is used in section 121.

174. $\langle \text{Cases for } \textit{delete_like} \text{ 174} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{lbrack} \wedge \textit{cat2} \equiv \textit{rbrack}$) {
 $\textit{big_app1}(pp)$; $\textit{big_app1_insert_str}(pp + 1, "\\\",")$; $\textit{reduce}(pp, 3, \textit{delete_like}, 0, 121)$;
 }
 else if ($\textit{cat1} \equiv \textit{exp}$) {
 $\textit{big_app1_insert}(pp, '\sqcup')$; $\textit{reduce}(pp, 2, \textit{exp}, -2, 122)$;
 }

This code is used in section 121.

175. $\langle \text{Cases for } \textit{question} \text{ 175} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{exp} \wedge (\textit{cat2} \equiv \textit{colon} \vee \textit{cat2} \equiv \textit{base})$) {
 $(pp + 2)\text{-mathness} \leftarrow 5 * \textit{yes_math}$; ▷ this colon should be in math mode ◁
 $\textit{squash}(pp, 3, \textit{binop}, -2, 123)$;
 }

This code is used in section 121.

176. $\langle \text{Cases for } \textit{alignas_like} \text{ 176} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{decl_head}$) $\textit{squash}(pp, 2, \textit{attr}, -1, 126);$
 else if ($\textit{cat1} \equiv \textit{exp}$) $\textit{squash}(pp, 2, \textit{attr}, -1, 127);$
 else if ($\textit{cat1} \equiv \textit{cast}$) $\textit{squash}(pp, 2, \textit{attr}, -1, 158);$

This code is used in section 121.

177. $\langle \text{Cases for } \textit{lbrack} \text{ 177} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{lbrack}$)
 if ($\textit{cat2} \equiv \textit{rbrack} \wedge \textit{cat3} \equiv \textit{rbrack}$) $\textit{squash}(pp, 4, \textit{exp}, -2, 147);$
 else $\textit{squash}(pp, 2, \textit{attr_head}, -1, 128);$
 else $\textit{reduce}(pp, 0, \textit{lpar}, -1, 129);$

This code is used in section 121.

178. $\langle \text{Cases for } \textit{attr_head} \text{ 178} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{rbrack} \wedge \textit{cat2} \equiv \textit{rbrack}$) $\textit{squash}(pp, 3, \textit{attr}, -1, 131);$
 else if ($\textit{cat1} \equiv \textit{exp}$) $\textit{squash}(pp, 2, \textit{attr_head}, 0, 132);$
 else if ($\textit{cat1} \equiv \textit{using_like} \wedge \textit{cat2} \equiv \textit{exp} \wedge \textit{cat3} \equiv \textit{colon}$) {
 $\textit{big_app2_insert}(pp, ' \sqcup ');$ $\textit{big_app}(' \sqcup ');$ $\textit{reduce}(pp, 4, \textit{attr_head}, 0, 133);$
 }
 else if ($\textit{cat1} \equiv \textit{comma}$) $\textit{squash}(pp, 2, \textit{attr_head}, 0, 145);$

This code is used in section 121.

179. $\langle \text{Cases for } \textit{attr} \text{ 179} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{lbrace} \vee \textit{cat1} \equiv \textit{stmt}$) {
 $\textit{big_app1_insert}(pp, ' \sqcup ');$ $\textit{reduce}(pp, 2, \textit{cat1}, -2, 134);$
 }
 else if ($\textit{cat1} \equiv \textit{tag}$) {
 $\textit{big_app1_insert}(pp, ' \sqcup ');$ $\textit{reduce}(pp, 2, \textit{tag}, -1, 135);$
 }
 else if ($\textit{cat1} \equiv \textit{semi}$) $\textit{squash}(pp, 2, \textit{stmt}, -2, 136);$
 else if ($\textit{cat1} \equiv \textit{attr}$) {
 $\textit{big_app1_insert}(pp, ' \sqcup ');$ $\textit{reduce}(pp, 2, \textit{attr}, -1, 137);$
 }
 else if ($\textit{cat1} \equiv \textit{decl_head}$) {
 $\textit{big_app1_insert}(pp, ' \sqcup ');$ $\textit{reduce}(pp, 2, \textit{decl_head}, -1, 138);$
 }
 else if ($\textit{cat1} \equiv \textit{typedef_like}$) {
 $\textit{big_app1_insert}(pp, ' \sqcup ');$ $\textit{reduce}(pp, 2, \textit{typedef_like}, 0, 143);$
 }
 else if ($\textit{cat1} \equiv \textit{function}$) {
 $\textit{big_app1_insert}(pp, ' \sqcup ');$ $\textit{reduce}(pp, 2, \textit{function}, -1, 148);$
 }

This code is used in section 121.

180. $\langle \text{Cases for } \textit{default_like} \text{ 180} \rangle \equiv$
 if ($\textit{cat1} \equiv \textit{colon}$) $\textit{reduce}(pp, 0, \textit{case_like}, -3, 149);$
 else $\textit{reduce}(pp, 0, \textit{exp}, -2, 150);$

This code is used in section 121.

181. The ‘*freeze_text*’ macro is used to give official status to a token list. Before saying *freeze_text*, items are appended to the current token list, and we know that the eventual number of this token list will be the current value of *text_ptr*. But no list of that number really exists as yet, because no ending point for the current list has been stored in the *tok_start* array. After saying *freeze_text*, the old current token list becomes legitimate, and its number is the current value of *text_ptr* – 1 since *text_ptr* has been increased. The new current token list is empty and ready to be appended to. Note that *freeze_text* does not check to see that *text_ptr* hasn’t gotten too large, since it is assumed that this test was done beforehand.

```
#define freeze_text() *(&text_ptr) ← tok_ptr
```

⟨Predeclaration of procedures 4⟩ +≡

```
static void reduce(scrap_pointer, short, eight_bits, short, short);
static void squash(scrap_pointer, short, eight_bits, short, short);
```

182. Now here’s the *reduce* procedure used in our code for productions, which takes advantage of the simplifications that occur when $k \equiv 0$ or $k \equiv 1$.

```
static void reduce(scrap_pointer j, short k, eight_bits c, short d, short n)
{
    scrap_pointer i;    ▷ pointer into scrap memory ◁
    j→cat ← c;
    if (k > 0) {
        j→trans ← text_ptr; j→mathness ← 4 * cur_mathness + init_mathness; freeze_text();
    }
    if (k > 1) {
        for (i ← j + k; i ≤ lo_ptr; i++) *(i - k + 1) ← *i;
        lo_ptr ← lo_ptr - k + 1;
    }
    pp ← (pp + d < scrap_base ? scrap_base : pp + d); ⟨Print a snapshot of the scrap list if debugging 185⟩
    pp--;    ▷ we next say pp++ ◁
}
```

183. And here’s the *squash* procedure, which combines *big_app_k* and *reduce* for matching numbers k .

```
static void squash(scrap_pointer j, short k, eight_bits c, short d, short n)
{
    switch (k) {
        case 1: big_app1(j); break;
        case 2: big_app2(j); break;
        case 3: big_app3(j); break;
        case 4: big_app4(j); break;
        default: confusion("squash");
    }
    reduce(j, k, c, d, n);
}
```

184. If CWEAVE is being run in debugging mode, the production numbers and current stack categories will be printed out when *tracing* is set to *fully*; a sequence of two or more irreducible scraps will be printed out when *tracing* is set to *partly*.

```
#define off 0
```

```
#define partly 1
```

```
#define fully 2
```

⟨Private variables 21⟩ +≡

```
static int tracing ← off;    ▷ can be used to show parsing details ◁
```

185. \langle Print a snapshot of the scrap list if debugging [185](#) $\rangle \equiv$

```

if (tracing  $\equiv$  fully) {
  printf("\n%d:", n);
  for (i  $\leftarrow$  scrap_base; i  $\leq$  lo_ptr; i++) {
    putchar(i  $\equiv$  pp ? '*' : '□');
    if (i  $\rightarrow$  mathness % 4  $\equiv$  yes_math) putchar('+');
    else if (i  $\rightarrow$  mathness % 4  $\equiv$  no_math) putchar('−');
    print_cat(i  $\rightarrow$  cat);
    if (i  $\rightarrow$  mathness / 4  $\equiv$  yes_math) putchar('+');
    else if (i  $\rightarrow$  mathness / 4  $\equiv$  no_math) putchar('−');
  }
  if (hi_ptr  $\leq$  scrap_ptr) printf(". . .");    ▷ indicate that more is coming ◁
}

```

This code is used in section [182](#).

186. And here now is the code that applies productions as long as possible. Before applying the production mechanism, we must make sure it has good input (at least four scraps, the length of the lhs of the longest rules), and that there is enough room in the memory arrays to hold the appended tokens and texts. Here we use a very conservative test; it's more important to make sure the program will still work if we change the production rules (within reason) than to squeeze the last bit of space from the memory arrays.

```

#define safe_tok_incr 20
#define safe_text_incr 10
#define safe_scrap_incr 10

 $\langle$  Reduce the scraps using the productions until no more rules apply 186  $\rangle \equiv$ 
while (true) {
   $\langle$  Make sure the entries pp through pp + 3 of cat are defined 187  $\rangle$ 
  if (tok_ptr + safe_tok_incr > tok_mem_end) {
    if (tok_ptr > max_tok_ptr) max_tok_ptr  $\leftarrow$  tok_ptr;
    overflow("token");
  }
  if (text_ptr + safe_text_incr > tok_start_end) {
    if (text_ptr > max_text_ptr) max_text_ptr  $\leftarrow$  text_ptr;
    overflow("text");
  }
  if (pp > lo_ptr) break;
  init_mathness  $\leftarrow$  cur_mathness  $\leftarrow$  maybe_math;
   $\langle$  Match a production at pp, or increase pp if there is no match 121  $\rangle$ 
}

```

This code is used in section [188](#).

187. If we get to the end of the scrap list, category codes equal to zero are stored, since zero does not match anything in a production.

\langle Make sure the entries *pp* through *pp* + 3 of *cat* are defined [187](#) $\rangle \equiv$

```

if (lo_ptr < pp + 3) {
  while (hi_ptr  $\leq$  scrap_ptr  $\wedge$  lo_ptr  $\neq$  pp + 3)  $\ast(++lo\_ptr) \leftarrow \ast(hi\_ptr++)$ ;
  for (j  $\leftarrow$  lo_ptr + 1; j  $\leq$  pp + 3; j++) j  $\rightarrow$  cat  $\leftarrow$  0;
}

```

This code is used in section [186](#).

188. The *translate* function assumes that scraps have been stored in positions *scrap_base* through *scrap_ptr* of *cat* and *trans*. It applies productions as much as possible. The result is a token list containing the translation of the given sequence of scraps.

After calling *translate*, we will have $\text{text_ptr} + 3 \leq \text{max_texts}$ and $\text{tok_ptr} + 6 \leq \text{max_toks}$, so it will be possible to create up to three token lists with up to six tokens without checking for overflow. Before calling *translate*, we should have $\text{text_ptr} < \text{max_texts}$ and $\text{scrap_ptr} < \text{max_scraps}$, since *translate* might add a new text and a new scrap before it checks for overflow.

```
static text_pointer translate(void)    ▷ converts a sequence of scraps ◁
{
    scrap_pointer j;    ▷ runs through final scraps ◁
    pp ← scrap_base; lo_ptr ← pp - 1; hi_ptr ← pp; ◁ If tracing, print an indication of where we are 192 ◁
    ◁ Reduce the scraps using the productions until no more rules apply 186 ◁
    ◁ Combine the irreducible scraps that remain 190 ◁
}
```

189. ◁ Predeclaration of procedures 4 ◁ +≡ **static text_pointer** *translate*(**void**);

190. If the initial sequence of scraps does not reduce to a single scrap, we concatenate the translations of all remaining scraps, separated by blank spaces, with dollar signs surrounding the translations of scraps where appropriate.

```
◁ Combine the irreducible scraps that remain 190 ◁ ≡
◁ If semi-tracing, show the irreducible scraps 191 ◁
for (j ← scrap_base; j ≤ lo_ptr; j++) {
    if (j ≠ scrap_base) app(' ');
    if (j~mathness % 4 ≡ yes_math) app('$');
    app(tok_flag + (int)(j-trans - tok_start));
    if (j~mathness / 4 ≡ yes_math) app('$');
    if (tok_ptr + 6 > tok_mem_end) overflow("token");
}
freeze_text(); return text_ptr - 1;
```

This code is used in section 188.

```
191. ◁ If semi-tracing, show the irreducible scraps 191 ◁ ≡
if (lo_ptr > scrap_base ∧ tracing ≡ partly) {
    printf("\nIrreducible scraps sequence in section %d:", (int) section_count); mark_harmless();
    for (j ← scrap_base; j ≤ lo_ptr; j++) {
        putchar(' '); print_cat(j-cat);
    }
}
```

This code is used in section 190.

```
192. ◁ If tracing, print an indication of where we are 192 ◁ ≡
if (tracing ≡ fully) {
    printf("\nTracing after 1. %d:\n", cur_line); mark_harmless();
    if (loc > buffer + 50) {
        printf("..."); term_write(loc - 51, 51);
    }
    else term_write(buffer, loc - buffer);
}
```

This code is used in section 188.

193. Initializing the scraps. If we are going to use the powerful production mechanism just developed, we must get the scraps set up in the first place, given a C text. A table of the initial scraps corresponding to C tokens appeared above in the section on parsing; our goal now is to implement that table. We shall do this by implementing a subroutine called *C_parse* that is analogous to the *C_xref* routine used during phase one.

Like *C_xref*, the *C_parse* procedure starts with the current value of *next_control* and it uses the operation *next_control* \leftarrow *get_next*() repeatedly to read C text until encountering the next ‘|’ or ‘/*’, or until *next_control* \geq *format_code*. The scraps corresponding to what it reads are appended into the *cat* and *trans* arrays, and *scrap_ptr* is advanced.

```
static void C_parse(      ▷ creates scraps from C tokens ◁
    eight_bits spec_ctrl)
{
    while (next_control < format_code  $\vee$  next_control  $\equiv$  spec_ctrl) {
        ◁ Append the scrap appropriate to next_control 196 ◁
        next_control  $\leftarrow$  get_next();
        if (next_control  $\equiv$  '|'  $\vee$  next_control  $\equiv$  begin_comment  $\vee$  next_control  $\equiv$  begin_short_comment)
            return;
    }
}
```

194. ◁ Predeclaration of procedures 4 ◁ \equiv **static void** *C_parse*(**eight_bits**);

195. The following macro is used to append a scrap whose tokens have just been appended:

```
#define app_scrap(c,b)
{
    ( ++scrap_ptr )  $\rightarrow$  cat  $\leftarrow$  (c); scrap_ptr  $\rightarrow$  trans  $\leftarrow$  text_ptr; scrap_ptr  $\rightarrow$  mathness  $\leftarrow$  5 * (b);
    ▷ no no, yes yes, or maybe maybe ◁
    freeze_text();
}
```

196. \langle Append the scrap appropriate to *next_control* 196 $\rangle \equiv$
 \langle Make sure that there is room for the new scraps, tokens, and texts 197 \rangle
switch (*next_control*) {
 case *section_name*: *app*(*section_flag* + (**int**)(*cur_section* - *name_dir*));
 app_scrap(*section_scrap*, *maybe_math*); *app_scrap*(*exp*, *yes_math*); **break**;
 case *string*: **case** *constant*: **case** *verbatim*: \langle Append a string or constant 199 \rangle **break**;
 case *identifier*: *app_cur_id*(**true**); **break**;
 case *TEX_string*: \langle Append a T_EX string, without forming a scrap 200 \rangle **break**;
 case \prime : **case** $\prime.$: *app*(*next_control*); *app_scrap*(*binop*, *yes_math*); **break**;
 case $\prime<$: *app_str*("\\langle"); *app_scrap*(*prelangle*, *yes_math*); **break**;
 case $\prime>$: *app_str*("\\rangle"); *app_scrap*(*prerangle*, *yes_math*); **break**;
 case $\prime=$: *app_str*("\\K"); *app_scrap*(*binop*, *yes_math*); **break**;
 case $\prime|$: *app_str*("\\OR"); *app_scrap*(*binop*, *yes_math*); **break**;
 case $\prime\sim$: *app_str*("\\XOR"); *app_scrap*(*binop*, *yes_math*); **break**;
 case $\prime\%$: *app_str*("\\MOD"); *app_scrap*(*binop*, *yes_math*); **break**;
 case $\prime!$: *app_str*("\\R"); *app_scrap*(*unop*, *yes_math*); **break**;
 case $\prime\sim$: *app_str*("\\CM"); *app_scrap*(*unop*, *yes_math*); **break**;
 case $\prime+$: **case** $\prime-$: *app*(*next_control*); *app_scrap*(*ubinop*, *yes_math*); **break**;
 case $\prime*$: *app*(*next_control*); *app_scrap*(*raw_ubin*, *yes_math*); **break**;
 case $\prime\&$: *app_str*("\\AND"); *app_scrap*(*raw_ubin*, *yes_math*); **break**;
 case $\prime?$: *app_str*("\\?"); *app_scrap*(*question*, *yes_math*); **break**;
 case $\prime\#$: *app_str*("\\#"); *app_scrap*(*ubinop*, *yes_math*); **break**;
 case *ignore*: **case** *xref_roman*: **case** *xref_wildcard*: **case** *xref_typewriter*: **case** *noop*: **break**;
 case $\prime($: *app*(*next_control*); *app_scrap*(*lpar*, *maybe_math*); **break**;
 case $\prime)$: *app*(*next_control*); *app_scrap*(*rpar*, *maybe_math*); **break**;
 case $\prime[$: *app*(*next_control*); *app_scrap*(*lbrack*, *maybe_math*); **break**;
 case $\prime]$: *app*(*next_control*); *app_scrap*(*rbrack*, *maybe_math*); **break**;
 case $\prime\{$: *app_str*("\\{"); *app_scrap*(*lbrace*, *yes_math*); **break**;
 case $\prime\}$: *app_str*("\\}"); *app_scrap*(*rbrace*, *yes_math*); **break**;
 case $\prime,$: *app*($\prime,$); *app_scrap*(*comma*, *yes_math*); **break**;
 case $\prime;$: *app*($\prime;$); *app_scrap*(*semi*, *maybe_math*); **break**;
 case $\prime:$: *app*($\prime:$); *app_scrap*(*colon*, *no_math*); **break**;
 \langle Cases involving nonstandard characters 198 \rangle
 case *thin_space*: *app_str*("\\,"); *app_scrap*(*insert*, *maybe_math*); **break**;
 case *math_break*: *app*(*opt*); *app*($\prime 0$); *app_scrap*(*insert*, *maybe_math*); **break**;
 case *line_break*: *app*(*force*); *app_scrap*(*insert*, *no_math*); **break**;
 case *left_preproc*: *app*(*force*); *app*(*preproc_line*); *app_str*("\\#"); *app_scrap*(*lproc*, *no_math*); **break**;
 case *right_preproc*: *app*(*force*); *app_scrap*(*rproc*, *no_math*); **break**;
 case *big_line_break*: *app*(*big_force*); *app_scrap*(*insert*, *no_math*); **break**;
 case *no_line_break*: *app*(*big_cancel*); *app*(*noop*); *app*(*break_space*); *app*(*noop*); *app*(*big_cancel*);
 app_scrap(*insert*, *no_math*); **break**;
 case *pseudo_semi*: *app_scrap*(*semi*, *maybe_math*); **break**;
 case *macro_arg_open*: *app_scrap*(*begin_arg*, *maybe_math*); **break**;
 case *macro_arg_close*: *app_scrap*(*end_arg*, *maybe_math*); **break**;
 case *join*: *app_str*("\\J"); *app_scrap*(*insert*, *no_math*); **break**;
 case *output_defs_code*: *app*(*force*); *app_str*("\\ATH"); *app*(*force*); *app_scrap*(*insert*, *no_math*); **break**;
 default: *app*(*inserted*); *app*(*next_control*); *app_scrap*(*insert*, *maybe_math*); **break**;
}

This code is used in section 193.

197. \langle Make sure that there is room for the new scraps, tokens, and texts 197 $\rangle \equiv$

```

if (scrap_ptr + safe_scrap_incr > scrap_info_end  $\vee$  tok_ptr + safe_tok_incr > tok_mem_end
       $\vee$  text_ptr + safe_text_incr > tok_start_end) {
  if (scrap_ptr > max_scr_ptr) max_scr_ptr  $\leftarrow$  scrap_ptr;
  if (tok_ptr > max_tok_ptr) max_tok_ptr  $\leftarrow$  tok_ptr;
  if (text_ptr > max_text_ptr) max_text_ptr  $\leftarrow$  text_ptr;
  overflow("scrap/token/text");
}
```

This code is used in sections 196 and 205.

198. Some nonstandard characters may have entered CWEAVE by means of standard ones. They are converted to T_EX control sequences so that it is possible to keep CWEAVE from outputting unusual **char** codes.

\langle Cases involving nonstandard characters 198 $\rangle \equiv$

```

case non_eq: app_str("\\I"); app_scrap(binop, yes_math); break;
case lt_eq: app_str("\\Z"); app_scrap(binop, yes_math); break;
case gt_eq: app_str("\\G"); app_scrap(binop, yes_math); break;
case eq_eq: app_str("\\E"); app_scrap(binop, yes_math); break;
case and_and: app_str("\\W"); app_scrap(binop, yes_math); break;
case or_or: app_str("\\V"); app_scrap(binop, yes_math); break;
case plus_plus: app_str("\\PP"); app_scrap(unop, yes_math); break;
case minus_minus: app_str("\\MM"); app_scrap(unop, yes_math); break;
case minus_gt: app_str("\\MG"); app_scrap(binop, yes_math); break;
case gt_gt: app_str("\\GG"); app_scrap(binop, yes_math); break;
case lt_lt: app_str("\\LL"); app_scrap(binop, yes_math); break;
case dot_dot_dot: app_str("\\,\\ldots\\,"); app_scrap(raw_int, yes_math); break;
case colon_colon: app_str("\\DC"); app_scrap(colcol, maybe_math); break;
case period_ast: app_str("\\PA"); app_scrap(binop, yes_math); break;
case minus_gt_ast: app_str("\\MGA"); app_scrap(binop, yes_math); break;
```

This code is used in section 196.

199. The following code must use *app_tok* instead of *app* in order to protect against overflow. Note that $tok_ptr + 1 \leq max_toks$ after *app_tok* has been used, so another *app* is legitimate before testing again.

Many of the special characters in a string must be prefixed by ‘\’ so that T_EX will print them properly.

⟨Append a string or constant 199⟩ ≡

```
{ int count ← -1;    ▷ characters remaining before string break ◁
  switch (next_control) {
    case constant: app_str("\\T{"); break;
    case string: count ← 20; app_str("\\.{""); break;
    default: app_str("\\vb{");
  }
  while (id_first < id_loc) {
    if (count ≡ 0) {    ▷ insert a discretionary break in a long string ◁
      app_str("}\}\}\}\.{""); count ← 20;
    }
    switch (*id_first) {
    case '␣': case '\\': case '#': case '$': case '^': case '{': case '}': case '~': case '&':
      case '_': app('\\'); break;
    case '%':
      if (next_control ≡ constant) {
        app_str("}\}\p{");    ▷ special macro for 'hex exponent' ◁
        id_first++;    ▷ skip '%' ◁
      }
      else app('\\');
      break;
    case '@':
      if (*(id_first + 1) ≡ '@') id_first++;
      else err_print("!␣Double␣@␣should␣be␣used␣in␣strings");
      break;
    default:    ▷ high-bit character handling ◁
      if ((eight_bits)(*id_first) > °177) app_tok(quoted_char);
    }
    app_tok(*id_first++); count--;
  }
  app('}'); app_scrap(exp, maybe_math);
}
```

This code is used in section 196.

200. We do not make the \TeX string into a scrap, because there is no telling what the user will be putting into it; instead we leave it open, to be picked up by the next scrap. If it comes at the end of a section, it will be made into a scrap when *finish_C* is called.

There's a known bug here, in cases where an adjacent scrap is *prelangle* or *prerangle*. Then the \TeX string can disappear when the \langle or \rangle becomes \langle or \rangle . For example, if the user writes \l x\@ty\>\<42\l , the \TeX string $\text{\hbox{y}}$ eventually becomes part of an *insert* scrap, which is combined with a *prelangle* scrap and eventually lost. The best way to work around this bug is probably to enclose the \@t\ldots\@ in \@[\ldots\@] so that the \TeX string is treated as an expression.

```

⟨ Append a  $\text{\TeX}$  string, without forming a scrap 200 ⟩ ≡
  app_str("\\hbox{");
  while (id_first < id_loc) {
    if ((eight.bits)(*id_first) > °177) app_tok(quoted_char);
    else if (*id_first ≡ '@') id_first++;
    app_tok(*id_first++);
  }
  app('}');

```

This code is used in section 196.

201. The function *app_cur_id* appends the current identifier to the token list; it also builds a new scrap if *scrapping* ≡ *true*.

```

⟨ Predeclaration of procedures 4 ⟩ +≡
  static void app_cur_id(bool);
  static text_pointer C_translate(void);
  static void outer_parse(void);

```

```

202. static void app_cur_id(bool scrapping)    ▷ are we making this into a scrap? ◁
{
  name_pointer p ← id_lookup(id_first, id_loc, normal);
  if (p-ilk ≤ custom) {    ▷ not a reserved word ◁
    app(id_flag + (int)(p - name_dir));
    if (scrapping)
      app_scrap(p-ilk ≡ func_template ? ftemplate : exp, p-ilk ≡ custom ? yes_math : maybe_math);
  }
  else {
    app(res_flag + (int)(p - name_dir));
    if (scrapping) {
      if (p-ilk ≡ alfop) app_scrap(ubinop, yes_math);
      else app_scrap(p-ilk, maybe_math);
    }
  }
}

```


203. When the ‘|’ that introduces C text is sensed, a call on *C_translate* will return a pointer to the T_EX translation of that text. If scraps exist in *scrap_info*, they are unaffected by this translation process.

```
static text_pointer C_translate(void)
{
  text_pointer p;    ▷ points to the translation ◁
  scrap_pointer save_base ← scrap_base;    ▷ holds original value of scrap_base ◁
  scrap_base ← scrap_ptr + 1; C_parse(section_name);    ▷ get the scraps together ◁
  if (next_control ≠ ' | ') err_print("!Missing '|' after C text");
  app_tok(cancel); app_scrap(insert, maybe_math);    ▷ place a cancel token as a final "comment" ◁
  p ← translate();    ▷ make the translation ◁
  if (scrap_ptr > max_scr_ptr) max_scr_ptr ← scrap_ptr;
  scrap_ptr ← scrap_base - 1; scrap_base ← save_base;    ▷ scrap the scraps ◁
  return p;
}
```

204. The *outer_parse* routine is to *C_parse* as *outer_xref* is to *C_xref*: It constructs a sequence of scraps for C text until *next_control* \geq *format_code*. Thus, it takes care of embedded comments.

The token list created from within ‘| ... |’ brackets is output as an argument to \PB. Although **cwebmac** ignores \PB, other macro packages might use it to localize the special meaning of the macros that mark up program text.

```
#define make_pb flags['e']
⟨Set initial values 24⟩ +≡
  make_pb ← true;
```

```

205. static void outer_parse(void)    ▷ makes scraps from C tokens and comments ◁
{
  int bal;    ▷ brace level in comment ◁
  text_pointer p,q;    ▷ partial comments ◁
  while (next_control < format_code)
    if (next_control ≠ begin_comment ∧ next_control ≠ begin_short_comment) C_parse(ignore);
    else {
      bool is_long_comment ← (next_control ≡ begin_comment);
      ⟨ Make sure that there is room for the new scraps, tokens, and texts 197 ⟩
      app(cancel); app(inserted);
      if (is_long_comment) app_str("\\C{");
      else app_str("\\SHC{");
      bal ← copy_comment(is_long_comment, 1); next_control ← ignore;
      while (bal > 0) {
        p ← text_ptr; freeze_text(); q ← C_translate();
        ▷ at this point we have tok_ptr + 6 ≤ max_toks ◁
        app(tok_flag + (int)(p - tok_start));
        if (make_pb) app_str("\\PB{");
        app(inner_tok_flag + (int)(q - tok_start));
        if (make_pb) app_tok('}');
        if (next_control ≡ ' | ') {
          bal ← copy_comment(is_long_comment, bal); next_control ← ignore;
        }
        else bal ← 0;    ▷ an error has been reported ◁
      }
      app(force); app_scrap(insert, no_math);    ▷ the full comment becomes a scrap ◁
    }
}

```

206. Output of tokens. So far our programs have only built up multi-layered token lists in **CWEAVE**’s internal memory; we have to figure out how to get them into the desired final form. The job of converting token lists to characters in the **T_EX** output file is not difficult, although it is an implicitly recursive process. Four main considerations had to be kept in mind when this part of **CWEAVE** was designed. (a) There are two modes of output: *outer* mode, which translates tokens like *force* into line-breaking control sequences, and *inner* mode, which ignores them except that blank spaces take the place of line breaks. (b) The *cancel* instruction applies to adjacent token or tokens that are output, and this cuts across levels of recursion since ‘*cancel*’ occurs at the beginning or end of a token list on one level. (c) The **T_EX** output file will be semi-readable if line breaks are inserted after the result of tokens like *break_space* and *force*. (d) The final line break should be suppressed, and there should be no *force* token output immediately after ‘**\Y\B**’.

207. The output process uses a stack to keep track of what is going on at different “levels” as the token lists are being written out. Entries on this stack have three parts:

end_field is the *tok_mem* location where the token list of a particular level will end;
tok_field is the *tok_mem* location from which the next token on a particular level will be read;
mode_field is the current mode, either *inner* or *outer*.

The current values of these quantities are referred to quite frequently, so they are stored in an extra slot at the very end of the *stack* array. We call the current values *cur_end*, *cur_tok*, and *cur_mode*.

The global variable *stack_ptr* tells how many levels of output are currently in progress. The end of output occurs when an *end_translation* token is found, so the stack is never empty except when we first begin the output process.

⟨Typedef declarations 22⟩ +≡

```
typedef enum {
    inner,      ▷ value of mode for C texts within TEX texts ◁
    outer      ▷ value of mode for C texts in sections ◁
} mode;
typedef struct {
    token_pointer end_field;    ▷ ending location of token list ◁
    token_pointer tok_field;    ▷ present location within token list ◁
    mode mode_field;          ▷ interpretation of control tokens ◁
} output_state;
typedef output_state *stack_pointer;
```

208. #define *stack_size* 2000 ▷ number of simultaneous output levels ◁
#define *cur_state* *stack*[*stack_size*] ▷ *cur_end*, *cur_tok*, *cur_mode* ◁
#define *cur_end* *cur_state.end_field* ▷ current ending location in *tok_mem* ◁
#define *cur_tok* *cur_state.tok_field* ▷ location of next output token in *tok_mem* ◁
#define *cur_mode* *cur_state.mode_field* ▷ current mode of interpretation ◁
#define *init_stack*() *stack_ptr* ← *stack*; *cur_mode* ← *outer* ▷ initialize the stack ◁

⟨Private variables 21⟩ +≡

```
static output_state stack[stack_size + 1];    ▷ info for non-current levels ◁
static stack_pointer stack_end ← stack + stack_size - 1;    ▷ end of stack ◁
static stack_pointer stack_ptr;    ▷ first unused location in the output state stack ◁
static stack_pointer max_stack_ptr;    ▷ largest value assumed by stack_ptr ◁
```

209. ⟨Set initial values 24⟩ +≡

```
max_stack_ptr ← stack;
```

210. ⟨Predeclaration of procedures 4⟩ +≡

```
static void push_level(text_pointer);
```

211. To insert token-list p into the output, the *push_level* subroutine is called; it saves the old level of output and gets a new one going. The value of *cur_mode* is not changed.

```
static void push_level(    ▷ suspends the current level ◁
    text_pointer p)
{
    if (stack_ptr == stack_end) overflow("stack");
    if (stack_ptr > stack)    ▷ save current state ◁
        *stack_ptr ← cur_state;
    stack_ptr++;
    if (stack_ptr > max_stack_ptr) max_stack_ptr ← stack_ptr;
    cur_tok ← *p; cur_end ← *(p + 1);
}
```

212. Conversely, the *pop_level* routine restores the conditions that were in force when the current level was begun. This subroutine will never be called when $stack_ptr \equiv 1$. It is so simple, we declare it as a macro:

```
#define pop_level() cur_state ← *(--stack_ptr)
```

213. The *get_output* function returns the next byte of output that is not a reference to a token list. It returns the values *identifier* or *res_word* or *section_code* if the next token is to be an identifier (typeset in italics), a reserved word (typeset in boldface), or a section name (typeset by a complex routine that might generate additional levels of output). In these cases *cur_name* points to the identifier or section name in question.

⟨Private variables 21⟩ +≡

```
static name_pointer cur_name;
```

214. #define *res_word* °201 ▷ returned by *get_output* for reserved words ◁

#define *section_code* °200 ▷ returned by *get_output* for section names ◁

⟨Predeclaration of procedures 4⟩ +≡

```
static eight_bits get_output(void);
static void output_C(void);
static void make_output(void);
```

215. static eight_bits *get_output*(void) ▷ returns the next token of output ◁

```
{
    sixteen_bits a;    ▷ current item read from tok_mem ◁

restart:
    while (cur_tok == cur_end) pop_level();
    a ← *(cur_tok++);
    if (a ≥ °400) {
        cur_name ← a % id_flag + name_dir;
        switch (a/id_flag) {
            case 2: return res_word;    ▷ a == res_flag + cur_name ◁
            case 3: return section_code;    ▷ a == section_flag + cur_name ◁
            case 4: push_level(a % id_flag + tok_start); goto restart;    ▷ a == tok_flag + cur_name ◁
            case 5: push_level(a % id_flag + tok_start); cur_mode ← inner; goto restart;
                    ▷ a == inner_tok_flag + cur_name ◁
            default: return identifier;    ▷ a == id_flag + cur_name ◁
        }
    }
}
return (eight_bits) a;
}
```

216. The real work associated with token output is done by *make_output*. This procedure appends an *end_translation* token to the current token list, and then it repeatedly calls *get_output* and feeds characters to the output buffer until reaching the *end_translation* sentinel. It is possible for *make_output* to be called recursively, since a section name may include embedded C text; however, the depth of recursion never exceeds one level, since section names cannot be inside of section names.

A procedure called *output_C* does the scanning, translation, and output of C text within ‘| ...|’ brackets, and this procedure uses *make_output* to output the current token list. Thus, the recursive call of *make_output* actually occurs when *make_output* calls *output_C* while outputting the name of a section.

```
static void output_C(void)    ▷ outputs the current token list ◁
{
    token_pointer save_tok_ptr ← tok_ptr;
    text_pointer  save_text_ptr ← text_ptr;
    sixteen_bits save_next_control ← next_control;    ▷ values to be restored ◁
    text_pointer p;    ▷ translation of the C text ◁
    next_control ← ignore; p ← C_translate(); app(inner_tok_flag + (int)(p - tok_start));
    if (make_pb) out_str("\\PB{");
    make_output();    ▷ output the list ◁
    if (make_pb) out('}');
    if (text_ptr > max_text_ptr) max_text_ptr ← text_ptr;
    if (tok_ptr > max_tok_ptr) max_tok_ptr ← tok_ptr;
    text_ptr ← save_text_ptr; tok_ptr ← save_tok_ptr;    ▷ forget the tokens ◁
    next_control ← save_next_control;    ▷ restore next_control to original state ◁
}
```

217. Here is **CWEAVE**'s major output handler.

```
static void make_output(void)    ▷ outputs the equivalents of tokens ◁
{
    eight_bits a ← 0;    ▷ current output byte ◁
    eight_bits b;    ▷ next output byte ◁
    int c;    ▷ count of indent and outdent tokens ◁
    char scratch[longest_name + 1];    ▷ scratch area for section names ◁
    char *k,*k.limit;    ▷ indices into scratch ◁
    char *j;    ▷ index into buffer ◁
    char *p;    ▷ index into byte_mem ◁
    char delim;    ▷ first and last character of string being copied ◁
    char *save_loc,*save.limit;    ▷ loc and limit to be restored ◁
    name_pointer cur_section_name;    ▷ name of section being output ◁
    bool save_mode;    ▷ value of cur_mode before a sequence of breaks ◁
    bool dindent_pending ← false;    ▷ should a dindent be output? ◁

    app(end_translation);    ▷ append a sentinel ◁
    freeze_text(); push_level(text_ptr - 1);
    while (true) {
        a ← get_output();
    reswitch:
        switch (a) {
            case end_translation: return;
            case identifier: case res_word: ◁ Output an identifier 218 ◁
                break;
            case section_code: ◁ Output a section name 222 ◁
                break;
            case math_rel: out_str("\\MRL{"); /*_fall_through_*/
            case noop: case inserted: break;
            case cancel: case big_cancel: c ← 0; b ← a;
            while (true) {
                a ← get_output();
                if (a ≡ inserted) continue;
                if ((a < indent ∧ ¬(b ≡ big_cancel ∧ a ≡ ' ')) ∨ (a > big_force ∧ a ≠ dindent)) break;
                switch (a) {
                    case dindent: c++; /*_fall_through_*/
                    case indent: c++; break;
                    case outdent: c--; break;
                    case opt: a ← get_output();
                }
            }
            ◁ Output saved indent or outdent tokens 221 ◁
            goto reswitch;
            case dindent: a ← get_output();
            if (a ≠ big_force) {
                out_str("\\1\\1"); goto reswitch;
            }
            else dindent_pending ← true;
            /*_fall_through_*/
            case indent: case outdent: case opt: case backup: case break_space: case force: case big_force:
            case preproc_line:
                ◁ Output a control, look ahead in case of line breaks, possibly goto reswitch 219 ◁
                break;
```

```

    case quoted_char: out(*(cur_tok++)); /*_fall_through_*/
    case qualifier: break;
    default: out(a);    ▷ otherwise a is an ordinary character ◁
  }
}
}

```

218. An identifier of length one does not have to be enclosed in braces, and it looks slightly better if set in a math-italic font instead of a (slightly narrower) text-italic font. Thus we output ‘\|a’ but ‘\{aa}’.

⟨ Output an identifier 218 ⟩ =

```

  out('\|');
  if (a ≡ identifier) {
    if (cur_name-ilk ≡ custom ∧ ¬doing_format) {
      custom_out:
        for (p ← cur_name-byte_start; p < (cur_name + 1)-byte_start; p++)
          out(*p ≡ '_' ? 'x' : *p ≡ '$' ? 'X' : *p);
        break;
    }
    else if (is_tiny(cur_name)) out('|');
    else {
      delim ← '.';
      for (p ← cur_name-byte_start; p < (cur_name + 1)-byte_start; p++)
        if (xislower(*p)) { ▷ not entirely uppercase ◁
          delim ← '\|'; break;
        }
      out(delim);
    }
  }
  else if (cur_name-ilk ≡ alfop) {
    out('X'); goto custom_out;
  }
  else out('&'); ▷ a ≡ res_word ◁
  if (is_tiny(cur_name)) {
    if (isalpha((cur_name-byte_start)[0])) out('\|');
    out((cur_name-byte_start)[0]);
  }
  else out_name(cur_name, true);

```

This code is used in section 217.

219. The current mode does not affect the behavior of CWEAVE's output routine except when we are outputting control tokens.

⟨Output a control, look ahead in case of line breaks, possibly **goto reswitch 219**⟩ ≡

```

if ( $a < break\_space \vee a \equiv preproc\_line$ ) {
  if ( $cur\_mode \equiv outer$ ) {
     $out('\\')$ ;  $out(a - cancel + '0')$ ;
    if ( $a \equiv opt$ ) {
       $b \leftarrow get\_output()$ ;  $\triangleright opt$  is followed by a digit  $\triangleleft$ 
      if ( $b \neq '0' \vee force\_lines \equiv false$ )  $out(b)$ ;
      else  $out\_str("{-1}")$ ;  $\triangleright force\_lines$  encourages more @| breaks  $\triangleleft$ 
    }
  }
  else if ( $a \equiv opt$ )  $b \leftarrow get\_output()$ ;  $\triangleright$  ignore digit following  $opt$   $\triangleleft$ 
}
else ⟨Look ahead for strongest line break, goto reswitch 220⟩

```

This code is used in section 217.

220. If several of the tokens *break_space*, *force*, *big_force* occur in a row, possibly mixed with blank spaces (which are ignored), the largest one is used. A line break also occurs in the output file, except at the very end of the translation. The very first line break is suppressed (i.e., a line break that follows ‘\Y\B’).

⟨Look ahead for strongest line break, **goto reswitch 220**⟩ ≡

```

{
   $b \leftarrow a$ ;  $save\_mode \leftarrow cur\_mode$ ;
  if ( $dindent\_pending$ ) {
     $c \leftarrow 2$ ;  $dindent\_pending \leftarrow false$ ;
  }
  else  $c \leftarrow 0$ ;
  while ( $true$ ) {
     $a \leftarrow get\_output()$ ;
    if ( $a \equiv inserted$ ) continue;
    if ( $a \equiv cancel \vee a \equiv big\_cancel$ ) {
      ⟨Output saved indent or outdent tokens 221⟩
      goto reswitch;  $\triangleright cancel$  overrides everything  $\triangleleft$ 
    }
    if ( $((a \neq '\_') \wedge a < indent) \vee a \equiv backup \vee a > big\_force$ ) {
      if ( $save\_mode \equiv outer$ ) {
        if ( $out\_ptr > out\_buf + 3 \wedge strcmp(out\_ptr - 3, "\\Y\\B", 4) \equiv 0$ ) goto reswitch;
        ⟨Output saved indent or outdent tokens 221⟩
         $out('\\')$ ;  $out(b - cancel + '0')$ ;
        if ( $a \neq end\_translation$ )  $finish\_line()$ ;
      }
      else if ( $a \neq end\_translation \wedge cur\_mode \equiv inner$ )  $out('\_')$ ;
      goto reswitch;
    }
    if ( $a \equiv indent$ )  $c++$ ;
    else if ( $a \equiv outdent$ )  $c--$ ;
    else if ( $a \equiv opt$ )  $a \leftarrow get\_output()$ ;
    else if ( $a > b$ )  $b \leftarrow a$ ;  $\triangleright$  if  $a \equiv '\_'$  we have  $a < b$   $\triangleleft$ 
  }
}

```

This code is used in section 219.

221. \langle Output saved *indent* or *outdent* tokens 221 $\rangle \equiv$

```
for ( ; c > 0; c-- ) out_str("\\1");
for ( ; c < 0; c++ ) out_str("\\2");
```

This code is used in sections 217 and 220.

222. The remaining part of *make_output* is somewhat more complicated. When we output a section name, we may need to enter the parsing and translation routines, since the name may contain C code embedded in `| ... |` constructions. This C code is placed at the end of the active input buffer and the translation process uses the end of the active *tok_mem* area.

\langle Output a section name 222 $\rangle \equiv$

```
out_str("\\X"); cur_xref  $\leftarrow$  (xref_pointer) cur_name $\rightarrow$ xref;
if ((an_output  $\leftarrow$  (cur_xref-num  $\equiv$  file_flag))  $\equiv$  true) cur_xref  $\leftarrow$  cur_xref $\rightarrow$ xlink;
if (cur_xref-num  $\geq$  def_flag) {
    out_section(cur_xref-num - def_flag);
    if (phase  $\equiv$  3) {
        cur_xref  $\leftarrow$  cur_xref $\rightarrow$ xlink;
        while (cur_xref-num  $\geq$  def_flag) {
            out_str(", "); out_section(cur_xref-num - def_flag); cur_xref  $\leftarrow$  cur_xref $\rightarrow$ xlink;
        }
    }
}
else out('0');    ▷ output the section number, or zero if it was undefined ◁
out(':');
if (an_output) out_str("\\{");
 $\langle$  Output the text of the section name 223  $\rangle$ 
if (an_output) cur_mode  $\equiv$  inner ? out_str("}") : out_str("\\,}");
out_str("\\X");
```

This code is used in section 217.

223. \langle Output the text of the section name 223 $\rangle \equiv$

```
sprint_section_name(scratch, cur_name); k  $\leftarrow$  scratch; k_limit  $\leftarrow$  scratch + strlen(scratch);
cur_section_name  $\leftarrow$  cur_name;
while (k < k_limit) {
    b  $\leftarrow$  *(k++);
    if (b  $\equiv$  '@')  $\langle$  Skip next character, give error if not '@' 224  $\rangle$ 
    if (an_output)
        switch (b) {
            case '_': case '\\': case '#': case '%': case '$': case '^': case '{': case '}': case '~':
                case '&': case '_': out('\\\\'); /*_falls_through_*/
            default: out(b);
        }
    else if (b  $\neq$  '|') out(b);
    else {
         $\langle$  Copy the C text into the buffer array 225  $\rangle$ 
        save_loc  $\leftarrow$  loc; save_limit  $\leftarrow$  limit; loc  $\leftarrow$  limit + 2; limit  $\leftarrow$  j + 1; *limit  $\leftarrow$  '|'; output_C();
        loc  $\leftarrow$  save_loc; limit  $\leftarrow$  save_limit;
    }
}
```

This code is used in section 222.

224. \langle Skip next character, give error if not '@' 224 $\rangle \equiv$

```
if (*k++  $\neq$  '@') {
    printf("%s", "\n!_Illegal_control_code_in_section_name:<");
    print_section_name(cur_section_name); printf(">_"); mark_error();
}
```

This code is used in section 223.

225. The C text enclosed in `| ... |` should not contain `'|'` characters, except within strings. We put a `'|'` at the front of the buffer, so that an error message that displays the whole buffer will look a little bit sensible. The variable *delim* is zero outside of strings, otherwise it equals the delimiter that began the string being copied.

\langle Copy the C text into the *buffer* array 225 $\rangle \equiv$

```
j  $\leftarrow$  limit + 1; *j  $\leftarrow$  '|'; delim  $\leftarrow$  0;
while (true) {
    if (k  $\geq$  k_limit) {
        printf("%s", "\n!_C_text_in_section_name_didn't_end:<");
        print_section_name(cur_section_name); printf(">_"); mark_error(); break;
    }
    b  $\leftarrow$  *(k++);
    if (b  $\equiv$  '@'  $\vee$  (b  $\equiv$  '\\ '  $\wedge$  delim  $\neq$  0))  $\langle$  Copy a quoted character into the buffer 226  $\rangle$ 
    else {
        if (b  $\equiv$  '\\ '  $\vee$  b  $\equiv$  '"') {
            if (delim  $\equiv$  0) delim  $\leftarrow$  b;
            else if (delim  $\equiv$  b) delim  $\leftarrow$  0;
        }
        if (b  $\neq$  '| '  $\vee$  delim  $\neq$  0) {
            if (j > buffer + long_buf_size - 3) overflow("buffer");
            *(++j)  $\leftarrow$  b;
        }
        else break;
    }
}
```

This code is used in section 223.

226. \langle Copy a quoted character into the buffer 226 $\rangle \equiv$

```
{
    if (j > buffer + long_buf_size - 4) overflow("buffer");
    *(++j)  $\leftarrow$  b; *(++j)  $\leftarrow$  *(k++);
}
```

This code is used in section 225.

227. Phase two processing. We have assembled enough pieces of the puzzle in order to be ready to specify the processing in **CWEAVE**'s main pass over the source file. Phase two is analogous to phase one, except that more work is involved because we must actually output the **T_EX** material instead of merely looking at the **CWEB** specifications.

```
static void phase_two(void)
{
    phase ← 2; reset_input();
    if (show_progress) printf("%s", "\nWriting the output file...");
    section_count ← 0; format_visible ← true; copy_limbo(); finish_line();
    flush_buffer(out_buf, false, false);    ▷ insert a blank line, it looks nice ◁
    while (¬input_has_ended) ◁ Translate the current section 230 ◁
}
```

228. ◁ Predeclaration of procedures 4 ◁ +≡ **static void phase_two(void);**

229. The output file will contain the control sequence **\Y** between non-null sections of a section, e.g., between the **T_EX** and definition parts if both are nonempty. This puts a little white space between the parts when they are printed. However, we don't want **\Y** to occur between two definitions within a single section. The variables *out_line* or *out_ptr* will change if a section is non-null, so the following macros '*save_position*' and '*emit_space_if_needed*' are able to handle the situation:

```
#define save_position() save_line ← out_line; save_place ← out_ptr
#define emit_space_if_needed()
    if (save_line ≠ out_line ∨ save_place ≠ out_ptr) out_str("\Y");
    space_checked ← true;

◁ Private variables 21 ◁ +≡
static int save_line;    ▷ former value of out_line ◁
static char *save_place; ▷ former value of out_ptr ◁
static int sec_depth;    ▷ the integer, if any, following @* ◁
static bool space_checked; ▷ have we done emit_space_if_needed? ◁
static bool format_visible; ▷ should the next format declaration be output? ◁
static bool doing_format ← false; ▷ are we outputting a format declaration? ◁
static bool group_found ← false; ▷ has a starred section occurred? ◁
```

230. ◁ Translate the current section 230 ◁ ≡

```
{
    section_count++; ◁ Output the code for the beginning of a new section 231 ◁
    save_position(); ◁ Translate the TEX part of the current section 232 ◁
    ◁ Translate the definition part of the current section 233 ◁
    ◁ Translate the C part of the current section 239 ◁
    ◁ Show cross-references to this section 242 ◁
    ◁ Output the code for the end of a section 246 ◁
}
```

This code is used in section 227.

231. Sections beginning with the **CWEB** control sequence ‘@_’ start in the output with the **T_EX** control sequence ‘\M’, followed by the section number. Similarly, ‘@*’ sections lead to the control sequence ‘\N’. In this case there’s an additional parameter, representing one plus the specified depth, immediately after the \N. If the section has changed, we put * just after the section number.

⟨Output the code for the beginning of a new section 231⟩ ≡

```

if (*(loc - 1) != '*') out_str("\\M");
else {
  while (*loc == '_') loc++;
  if (*loc == '*') {    ▷ “top” level <
    sec_depth ← -1; loc++;
  }
  else {
    for (sec_depth ← 0; xisdigit(*loc); loc++)
      if (sec_depth < INT_MAX/10) sec_depth ← sec_depth * 10 + (*loc) - '0';
  }
  while (*loc == '_') loc++;    ▷ remove spaces before group title <
  group_found ← true; out_str("\\N");
  { char s[32]; snprintf(s, 32, "%d", sec_depth + 1); out_str(s); }
  if (show_progress) {
    printf("%*d", (int) section_count); update_terminal();    ▷ print a progress report <
  }
}
out('{'); out_section(section_count); out('}');

```

This code is cited in section 19.

This code is used in section 230.

232. In the **T_EX** part of a section, we simply copy the source text, except that index entries are not copied and C text within | ... | is translated.

⟨Translate the **T_EX** part of the current section 232⟩ ≡

```

do switch (next_control ← copy_TEX()) {
case '|': init_stack(); output_C(); break;
case '@': out('@'); break;
case TEX_string: case verbatim: case noop: case xref_roman: case xref_wildcard: case xref_typewriter:
  case section_name: loc -= 2; next_control ← get_next();    ▷ skip to @> <
  if (next_control == TEX_string) err_print("!_TEX_string_should_be_in_C_text_only");
  if (next_control == verbatim) err_print("!_Verbatim_string_should_be_in_C_text_only");
  break;
case thin_space: case math_break: case ord: case line_break: case big_line_break: case no_line_break:
  case join: case pseudo_semi: case macro_arg_open: case macro_arg_close: case output_defs_code:
    err_print("!_You_can't_do_that_in_TEX_text"); break;
} while (next_control < format_code);

```

This code is used in section 230.

233. When we get to the following code we have $next_control \geq format_code$, and the token memory is in its initial empty state.

```

⟨ Translate the definition part of the current section 233 ⟩ ≡
  space_checked ← false;
  while (next_control ≤ definition) {    ▷ format_code or definition <
    init_stack();
    if (next_control ≡ definition) ⟨ Start a macro definition 236 ⟩
    else ⟨ Start a format definition 237 ⟩
      outer_parse(); finish_C(format_visible); format_visible ← true; doing_format ← false;
  }

```

This code is used in section 230.

234. The *finish_C* procedure outputs the translation of the current scraps, preceded by the control sequence ‘\B’ and followed by the control sequence ‘\par’. It also restores the token and scrap memories to their initial empty state.

A *force* token is appended to the current scraps before translation takes place, so that the translation will normally end with \6 or \7 (the T_EX macros for *force* and *big-force*). This \6 or \7 is replaced by the concluding \par or by \Y\par.

```

static void finish_C(    ▷ finishes a definition or a C part <
  bool visible)    ▷ true if we should produce TEX output <
{
  text_pointer p;    ▷ translation of the scraps <
  if (visible) {
    out_str("\B"); app_tok(force); app_scrap(insert, no_math); p ← translate();
    app(tok_flag + (int)(p - tok_start)); make_output();    ▷ output the list <
    if (out_ptr > out_buf + 1)
      if (*(out_ptr - 1) ≡ '\\') {
        if (*out_ptr ≡ '6') out_ptr -= 2;
        else if (*out_ptr ≡ '7') *out_ptr ← 'Y';
      }
    out_str("\par"); finish_line();
  }
  if (text_ptr > max_text_ptr) max_text_ptr ← text_ptr;
  if (tok_ptr > max_tok_ptr) max_tok_ptr ← tok_ptr;
  if (scrap_ptr > max_scr_ptr) max_scr_ptr ← scrap_ptr;
  tok_ptr ← tok_mem + 1; text_ptr ← tok_start + 1; scrap_ptr ← scrap_info;
  ▷ forget the tokens and the scraps <
}

```

235. ⟨ Predeclaration of procedures 4 ⟩ +≡ **static void finish_C(bool);**

236. Keeping in line with the conventions of the C preprocessor (and otherwise contrary to the rules of CWEB) we distinguish here between the case that ‘(’ immediately follows an identifier and the case that the two are separated by a space. In the latter case, and if the identifier is not followed by ‘(’ at all, the replacement text starts immediately after the identifier. In the former case, it starts after we scan the matching ‘)’.

```

⟨Start a macro definition 236⟩ ≡
{
  if (save_line ≠ out_line ∨ save_place ≠ out_ptr ∨ space_checked) app(backup);
  if (¬space_checked) {
    emit_space_if_needed(); save_position();
  }
  app_str("\\D"); ▷ this will produce ‘#define ’ ◁
  if ((next_control ← get_next()) ≠ identifier) err_print("!Improper_macro_definition");
  else {
    app('$'); app_cur_id(false);
    if (*loc ≡ '(') {
      reswitch:
        switch (next_control ← get_next()) {
          case '(': case ',': app(next_control); goto reswitch;
          case identifier: app_cur_id(false); goto reswitch;
          case ')': app(next_control); next_control ← get_next(); break;
          case dot_dot_dot: app_str("\\,\\ldots\\,"); app_scrap(raw_int, no_math);
            if ((next_control ← get_next()) ≡ ')') {
              app(next_control); next_control ← get_next(); break;
            }
            /*otherwise fall through*/
          default: err_print("!Improper_macro_definition"); break;
        }
      }
    else next_control ← get_next();
    app_str("$"); app(break_space); app_scrap(dead, no_math);
    ▷ scrap won't take part in the parsing ◁
  }
}

```

This code is used in section 233.

237. \langle Start a format definition 237 $\rangle \equiv$

```
{
  doing_format  $\leftarrow$  true;
  if  $(*(loc - 1) \equiv 's' \vee *(loc - 1) \equiv 'S')$  format_visible  $\leftarrow$  false;
  if  $(\neg space\_checked)$  {
    emit_space_if_needed(); save_position();
  }
  app_str("\\F");  $\triangleright$  this will produce 'format'  $\triangleleft$ 
  next_control  $\leftarrow$  get_next();
  if  $(next\_control \equiv identifier)$  {
    app(id_flag + (int)(id_lookup(id_first, id_loc, normal) - name_dir)); app(break_space);
     $\triangleright$  this is syntactically separate from what follows  $\triangleleft$ 
    next_control  $\leftarrow$  get_next();
    if  $(next\_control \equiv identifier)$  {
      app(id_flag + (int)(id_lookup(id_first, id_loc, normal) - name_dir)); app_scrap(exp, maybe_math);
      app_scrap(semi, maybe_math); next_control  $\leftarrow$  get_next();
    }
  }
  if  $(scrap\_ptr \neq scrap\_info + 2)$  err_print("!Improper_format_definition");
}
```

This code is used in section 233.

238. Finally, when the \TeX and definition parts have been treated, we have $next_control \geq begin_C$. We will make the global variable *this_section* point to the current section name, if it has a name.

\langle Private variables 21 $\rangle + \equiv$

static name_pointer *this_section*; \triangleright the current section name, or zero \triangleleft

239. \langle Translate the C part of the current section 239 $\rangle \equiv$

```
this_section  $\leftarrow$  name_dir;
if  $(next\_control \leq section\_name)$  {
  emit_space_if_needed(); init_stack();
  if  $(next\_control \equiv begin\_C)$  next_control  $\leftarrow$  get_next();
  else {
    this_section  $\leftarrow$  cur_section;  $\langle$  Check that '=' or '==' follows this section name, and emit the scraps to
    start the section definition 240  $\rangle$ 
  }
  while  $(next\_control \leq section\_name)$  {
    outer_parse();  $\langle$  Emit the scrap for a section name if present 241  $\rangle$ 
  }
  finish_C(true);
}
```

This code is used in section 230.

240. The title of the section and an \equiv or $+\equiv$ are made into a scrap that should not take part in the parsing.

⟨ Check that '=' or '==' follows this section name, and emit the scraps to start the section definition 240 ⟩ \equiv

```

do next_control ← get_next(); while (next_control  $\equiv$  '+');    ▷ allow optional '+'  $\triangleleft$ 
if (next_control  $\neq$  '='  $\wedge$  next_control  $\neq$  eq_eq)
  err_print("!_You_need_an_=_sign_after_the_section_name");
else next_control ← get_next();
if (out_ptr > out_buf + 1  $\wedge$  *out_ptr  $\equiv$  'Y'  $\wedge$  *(out_ptr - 1)  $\equiv$  '\\') app(backup);
  ▷ the section name will be flush left  $\triangleleft$ 
app(section_flag + (int)(this_section - name_dir)); cur_xref ← (xref_pointer) this_section→xref;
if (cur_xref→num  $\equiv$  file_flag) cur_xref ← cur_xref→xlink;
app_str("${}");
if (cur_xref→num  $\neq$  section_count + def_flag) {
  app_str("\\mathrel+");    ▷ section name is multiply defined  $\triangleleft$ 
  this_section ← name_dir;    ▷ so we won't give cross-reference info here  $\triangleleft$ 
}
app_str("\\E");    ▷ output an equivalence sign  $\triangleleft$ 
app_str("{}$"); app(force); app_scrap(dead, no_math);    ▷ this forces a line break unless '@+' follows  $\triangleleft$ 

```

This code is used in section 239.

241. ⟨ Emit the scrap for a section name if present 241 ⟩ \equiv

```

if (next_control < section_name) {
  err_print("!_You_can't_do_that_in_C_text"); next_control ← get_next();
}
else if (next_control  $\equiv$  section_name) {
  app(section_flag + (int)(cur_section - name_dir)); app_scrap(section_scrap, maybe_math);
  next_control ← get_next();
}

```

This code is used in section 239.

242. Cross references relating to a named section are given after the section ends.

⟨ Show cross-references to this section 242 ⟩ \equiv

```

if (this_section > name_dir) {
  cur_xref ← (xref_pointer) this_section→xref;
  if ((an_output ← (cur_xref→num  $\equiv$  file_flag))  $\equiv$  true) cur_xref ← cur_xref→xlink;
  if (cur_xref→num > def_flag) cur_xref ← cur_xref→xlink;    ▷ bypass current section number  $\triangleleft$ 
  footnote(def_flag); footnote(cite_flag); footnote(0);
}

```

This code is used in section 230.

243. The *footnote* procedure gives cross-reference information about multiply defined section names (if the *flag* parameter is *def_flag*), or about references to a section name (if *flag* \equiv *cite_flag*), or to its uses (if *flag* \equiv 0). It assumes that *cur_xref* points to the first cross-reference entry of interest, and it leaves *cur_xref* pointing to the first element not printed. Typical outputs: ‘\A101.’; ‘\Us 370\ET1009.’; ‘\As 8, 27*\ETs64.’.

Note that the output of **CWEAVE** is not English-specific; users may supply new definitions for the macros \A, \As, etc.

```
static void footnote(    ▷ outputs section cross-references ◁
    sixteen_bits flag)
{
    xref_pointer q  $\leftarrow$  cur_xref;    ▷ cross-reference pointer variable ◁
    if (q-num  $\leq$  flag) return;
    finish_line(); out('\ '); out(flag  $\equiv$  0 ? 'U' : flag  $\equiv$  cite_flag ? 'Q' : 'A');
    ◁ Output all the section numbers on the reference list cur_xref 245 ◁
    out('. ');
}
```

244. ◁ Predeclaration of procedures 4 $\rangle + \equiv$ static void footnote(sixteen_bits);

245. The following code distinguishes three cases, according as the number of cross-references is one, two, or more than two. Variable *q* points to the first cross-reference, and the last link is a zero.

```
◁ Output all the section numbers on the reference list cur_xref 245  $\rangle \equiv$ 
if (q-xlink-num > flag) out('s');    ▷ plural ◁
while (true) {
    out_section(cur_xref-num - flag); cur_xref  $\leftarrow$  cur_xref-xlink;
    ▷ point to the next cross-reference to output ◁
    if (cur_xref-num  $\leq$  flag) break;
    if (cur_xref-xlink-num > flag) out_str(", ");    ▷ not the last ◁
    else {
        out_str("\ \ET");    ▷ the last ◁
        if (cur_xref  $\neq$  q-xlink) out('s');    ▷ the last of more than two ◁
    }
}
```

This code is used in section 243.

246. ◁ Output the code for the end of a section 246 $\rangle \equiv$
 out_str("\ \fi"); finish_line(); flush_buffer(out_buf, false, false); ▷ insert a blank line, it looks nice ◁

This code is used in section 230.

247. Phase three processing. We are nearly finished! **CWEAVE**'s only remaining task is to write out the index, after sorting the identifiers and index entries.

If the user has set the *no_xref* flag (the *-x* option on the command line), just finish off the page, omitting the index, section name list, and table of contents.

```
static void phase_three(void)
{
    phase ← 3; finish_line();    ▷ the bulk of tex.file has been written ◁
    if (no_xref) out_str("\\end");
    else {
        if (show_progress) printf("%s", "\nWriting the index...");
        if (change_exists) {
            ◁ Tell about changed sections 249 ◁
            finish_line(); flush_buffer(out_buf, false, false);    ▷ insert a blank line, it looks nice ◁
        }
        out_str("\\inx"); finish_line();
        if ((idx_file ← fopen(idx_file_name, "wb")) ≡ Λ)
            fatal("!_Cannot_open_index_file_", idx_file_name);
        active_file ← idx_file;    ▷ change active file to the index file ◁
        ◁ Do the first pass of sorting 251 ◁
        ◁ Sort and output the index 259 ◁
        finish_line(); fclose(active_file);    ▷ finished with idx_file ◁
        active_file ← tex_file;    ▷ switch back to tex.file for a tic ◁
        out_str("\\fin"); finish_line();
        if ((scn_file ← fopen(scn_file_name, "wb")) ≡ Λ)
            fatal("!_Cannot_open_section_file_", scn_file_name);
        active_file ← scn_file;    ▷ change active file to section listing file ◁
        ◁ Output all the section names 268 ◁
        finish_line(); fclose(active_file);    ▷ finished with scn_file ◁
        active_file ← tex_file;    ▷ switch back to tex.file for the last time ◁
        if (group_found) out_str("\\con"); else out_str("\\end");
    }
    finish_line(); fclose(active_file);
    if (show_happiness) {
        if (show_progress) new_line();
        printf("%s", "Done.");
    }
    check_complete();    ▷ was all of the change file used? ◁
}
```

248. ◁ Predeclaration of procedures 4 ◁ +≡ **static void phase_three(void);**

249. Just before the index comes a list of all the changed sections, including the index section itself.

```

⟨ Tell about changed sections 249 ⟩ ≡    ▷ remember that the index is already marked as changed ◁
    sixteen_bits k_section ← 0;    ▷ runs through the sections ◁
    while (¬changed_section[++k_section]) ;
    out_str("\ch□"); out_section(k_section);
    while (k_section < section_count) {
        while (¬changed_section[++k_section]) ;
        out_str(",□"); out_section(k_section);
    }
    out('.'.');

```

This code is used in section 247.

250. A left-to-right radix sorting method is used, since this makes it easy to adjust the collating sequence and since the running time will be at worst proportional to the total length of all entries in the index. We put the identifiers into different lists based on their first characters. (Uppercase letters are put into the same list as the corresponding lowercase letters, since we want to have ‘*t* < *TeX* < *to*’.) The list for character *c* begins at location *bucket*[*c*] and continues through the *blink* array.

```

⟨ Private variables 21 ⟩ +≡
    static name_pointer bucket[256] ← {Λ};
    static name_pointer next_name;    ▷ successor of cur_name when sorting ◁
    static name_pointer blink[max_names];    ▷ links in the buckets ◁

```

251. To begin the sorting, we go through all the hash lists and put each entry having a nonempty cross-reference list into the proper bucket.

```

⟨ Do the first pass of sorting 251 ⟩ ≡
    for (hash_ptr ← hash; hash_ptr ≤ hash_end; hash_ptr++) {
        next_name ← *hash_ptr;
        while (next_name) {
            cur_name ← next_name; next_name ← cur_name-link;
            if (cur_name-xref ≠ (void *)xmem) {
                int c ← (cur_name-byte_start)[0];
                if (xisupper(c)) c ← tolower(c);
                blink[cur_name - name_dir] ← bucket[c]; bucket[c] ← cur_name;
            }
        }
    }
}

```

This code is used in section 247.

252. During the sorting phase we shall use the *cat* and *trans* arrays from CWEAVE’s parsing algorithm and rename them *depth* and *head*. They now represent a stack of identifier lists for all the index entries that have not yet been output. The variable *sort_ptr* tells how many such lists are present; the lists are output in reverse order (first *sort_ptr*, then *sort_ptr* − 1, etc.). The *j*th list starts at *head*[*j*], and if the first *k* characters of all entries on this list are known to be equal we have *depth*[*j*] ≡ *k*.

```

⟨ Rest of trans_plus union 252 ⟩ ≡
    name_pointer Head;

```

This code is used in section 112.

253. `#define depth cat` ▷ reclaims memory that is no longer needed for parsing ◁
`#define head trans_plus.Head` ▷ ditto ◁
`format sort_pointer int`
`#define sort_pointer scrap_pointer` ▷ ditto ◁
`#define sort_ptr scrap_ptr` ▷ ditto ◁

⟨Private variables 21⟩ +≡

`static eight_bits cur_depth;` ▷ depth of current buckets ◁
`static char *cur_byte;` ▷ index into *byte_mem* ◁
`static sixteen_bits cur_val;` ▷ current cross-reference number ◁
`static sort_pointer max_sort_ptr;` ▷ largest value of *sort_ptr* ◁

254. ⟨Set initial values 24⟩ +≡

`max_sort_ptr ← scrap_info;`

255. The desired alphabetic order is specified by the *collate* array; namely, *collate*[0] < *collate*[1] < ... < *collate*[100].

⟨Private variables 21⟩ +≡

`static eight_bits collate[101 + 128];` ▷ collation order ◁

256. We use the order null < \sqcup < other characters < $_$ < A = a < \dots < Z = z < 0 < \dots < 9. Warning: The collation mapping needs to be changed if ASCII code is not being used.

We initialize *collate* by copying a few characters at a time, because some C compilers choke on long strings.

(Set initial values 24) $\vdash \equiv$

```
collate[0]  $\leftarrow$  0; memcpy((char *) collate + 1, "\1\2\3\4\5\6\7\10\11\12\13\14\15\16\17", 16);
```

▷ 16 characters + 1 = 17 ◁

```
memcpy((char *) collate + 17, "\20\21\22\23\24\25\26\27\30\31\32\33\34\35\36\37", 16);
```

▷ 16 characters + 17 = 33 ◁

```
memcpy((char *) collate + 33, "! \42#$%&'()*+,-./:;<=>?@[\\]^_`{|}~", 32);
```

▷ 32 characters + 33 = 65 ◁

```
memcpy((char *) collate + 65, "abcdefghijklmnopqrstuvwxyz0123456789", 36);
```

▷ (26 + 10) characters + 65 = 101 ◁

```
memcpy((char *) collate + 101,
```

```
"\200\201\202\203\204\205\206\207\210\211\212\213\214\215\216\217", 16);
```

▷ 16 characters + 101 = 117 ◁

```
memcpy((char *) collate + 117,
```

```
"\220\221\222\223\224\225\226\227\230\231\232\233\234\235\236\237", 16);
```

▷ 16 characters + 117 = 133 ◁

```
memcpy((char *) collate + 133,
```

```
"\240\241\242\243\244\245\246\247\250\251\252\253\254\255\256\257", 16);
```

▷ 16 characters + 133 = 149 ◁

```
memcpy((char *) collate + 149,
```

```
"\260\261\262\263\264\265\266\267\270\271\272\273\274\275\276\277", 16);
```

▷ 16 characters + 149 = 165 ◁

```
memcpy((char *) collate + 165,
```

```
"\300\301\302\303\304\305\306\307\310\311\312\313\314\315\316\317", 16);
```

▷ 16 characters + 165 = 181 ◁

```
memcpy((char *) collate + 181,
```

```
"\320\321\322\323\324\325\326\327\330\331\332\333\334\335\336\337", 16);
```

▷ 16 characters + 181 = 197 ◁

```
memcpy((char *) collate + 197,
```

```
"\340\341\342\343\344\345\346\347\350\351\352\353\354\355\356\357", 16);
```

▷ 16 characters + 197 = 213 ◁

```
memcpy((char *) collate + 213,
```

```
"\360\361\362\363\364\365\366\367\370\371\372\373\374\375\376\377", 16);
```

▷ 16 characters + 213 = 229 ◁

257. Procedure *unbucket* goes through the buckets and adds nonempty lists to the stack, using the collating sequence specified in the *collate* array. The parameter to *unbucket* tells the current depth in the buckets. Any two sequences that agree in their first 255 character positions are regarded as identical.

```
#define infinity 255    ▷ ∞ (approximately) ◁

static void unbucket(    ▷ empties buckets having depth d ◁
    eight_bits d)
{
    int c;    ▷ index into bucket; cannot be a simple char because of sign comparison below ◁
    for (c ← 100 + 128; c ≥ 0; c--)
        if (bucket[collate[c]]) {
            if (sort_ptr ≥ scrap_info_end) overflow("sorting");
            sort_ptr++;
            if (sort_ptr > max_sort_ptr) max_sort_ptr ← sort_ptr;
            if (c ≡ 0) sort_ptr→depth ← infinity;
            else sort_ptr→depth ← d;
            sort_ptr→head ← bucket[collate[c]]; bucket[collate[c]] ← Λ;
        }
}
```

258. 〈Predeclaration of procedures 4〉 +≡ **static void** *unbucket*(**eight_bits**);

259. 〈Sort and output the index 259〉 ≡
sort_ptr ← *scrap_info*; *unbucket*(1);
while (*sort_ptr* > *scrap_info*) {
 cur_depth ← *sort_ptr*→depth;
 if (*blink*[*sort_ptr*→head − *name_dir*] ≡ 0 ∨ *cur_depth* ≡ infinity)
 〈Output index entries for the list at *sort_ptr* 261〉
 else 〈Split the list at *sort_ptr* into further lists 260〉
}

This code is used in section 247.

260. 〈Split the list at *sort_ptr* into further lists 260〉 ≡
{
 int *c*;
 next_name ← *sort_ptr*→head;
 do {
 cur_name ← *next_name*; *next_name* ← *blink*[*cur_name* − *name_dir*];
 cur_byte ← *cur_name*→byte_start + *cur_depth*;
 if (*cur_byte* ≡ (*cur_name* + 1)→byte_start) *c* ← 0; ▷ hit end of the name ◁
 else if (*xisupper*(*c* ← **cur_byte*)) *c* ← *tolower*(*c*);
 blink[*cur_name* − *name_dir*] ← *bucket*[*c*]; *bucket*[*c*] ← *cur_name*;
 } **while** (*next_name*);
 --*sort_ptr*; *unbucket*(*cur_depth* + 1);
}

This code is used in section 259.

261. \langle Output index entries for the list at *sort_ptr* 261 $\rangle \equiv$

```

{
  cur_name ← sort_ptr-head;
  do {
    out_str("\\I");  $\langle$  Output the name at cur_name 262  $\rangle$ 
     $\langle$  Output the cross-references at cur_name 263  $\rangle$ 
    cur_name ← blink[cur_name - name_dir];
  } while (cur_name);
  --sort_ptr;
}

```

This code is used in section 259.

262. \langle Output the name at *cur_name* 262 $\rangle \equiv$

```

switch (cur_name-ilk) { char *p;    ▷ index into byte_mem ◁
case normal: case func_template:
  if (is_tiny(cur_name)) out_str("\\|");
  else { bool all_caps ← true;
    for (p ← cur_name-byte_start; p < (cur_name + 1)-byte_start; p++)
      if (xislower(*p)) {    ▷ not entirely uppercase ◁
        all_caps ← false; break;
      }
    out_str(all_caps ? "\\." : "\\\\");
  }
  break;
case wildcard: out_str("\\9"); goto not_an_identifier;
case typewriter: out_str("\\."); goto not_an_identifier;
case roman: not_an_identifier: out_name(cur_name, false); goto name_done;
case custom: out_str("$\\");
  for (p ← cur_name-byte_start; p < (cur_name + 1)-byte_start; p++)
    out(*p ≡ '_' ? 'x' : *p ≡ '$' ? 'X' : *p);
  out('$'); goto name_done;
default: out_str("\\&");
}
out_name(cur_name, true);
name_done:

```

This code is used in section 261.

263. Section numbers that are to be underlined are enclosed in ‘ $\underline{\hspace{1cm}}$ ’.

\langle Output the cross-references at *cur_name* 263 $\rangle \equiv$

\langle Invert the cross-reference list at *cur_name*, making *cur_xref* the head 265 \rangle

```

do {
  out_str(",_"); cur_val ← cur_xref-num;
  if (cur_val < def_flag) out_section(cur_val);
  else {
    out_str("\\["); out_section(cur_val - def_flag); out(']');
  }
  cur_xref ← cur_xref-xlink;
} while (cur_xref ≠ xmem);
out(' '); finish_line();

```

This code is used in section 261.

264. List inversion is best thought of as popping elements off one stack and pushing them onto another. In this case *cur_xref* will be the head of the stack that we push things onto.

⟨Private variables 21⟩ +≡

static xref_pointer *next_xref*, *this_xref*; ▷ pointer variables for rearranging a list ◁

265. ⟨Invert the cross-reference list at *cur_name*, making *cur_xref* the head 265⟩ ≡

```
this_xref ← (xref_pointer) cur_name-xref; cur_xref ← xmem;
do {
    next_xref ← this_xref-xlink; this_xref-xlink ← cur_xref; cur_xref ← this_xref; this_xref ← next_xref;
} while (this_xref ≠ xmem);
```

This code is used in section 263.

266. The following recursive procedure walks through the tree of section names and prints them.

```
static void section_print(    ▷ print all section names in subtree p ◁
    name_pointer p)
{
    if (p) {
        section_print(p-llink); out_str("\\I"); tok_ptr ← tok_mem + 1; text_ptr ← tok_start + 1;
        scrap_ptr ← scrap_info; init_stack(); app(section_flag + (int)(p - name_dir)); make_output();
        footnote(cite_flag); footnote(0);    ▷ cur_xref was set by make_output ◁
        finish_line();
        section_print(p-rlink);
    }
}
```

267. ⟨Predeclaration of procedures 4⟩ +≡ **static void** *section_print*(**name_pointer**);

268. ⟨Output all the section names 268⟩ ≡

```
section_print(root);
```

This code is used in section 247.

269. Because on some systems the difference between two pointers is a **ptrdiff_t** rather than an **int**, we use %td to print these quantities.

```
void print_stats(void)
{
    puts("\\nMemory\\usage\\statistics:");
    printf("%td\\names\\(out\\of\\ld)\\n", (ptrdiff_t)(name_ptr - name_dir), (long) max_names);
    printf("%td\\cross-references\\(out\\of\\ld)\\n", (ptrdiff_t)(xref_ptr - xmem), (long) max_refs);
    printf("%td\\bytes\\(out\\of\\ld)\\n", (ptrdiff_t)(byte_ptr - byte_mem), (long) max_bytes);
    puts("Parsing:");
    printf("%td\\scraps\\(out\\of\\ld)\\n", (ptrdiff_t)(max_scr_ptr - scrap_info), (long) max_scraps);
    printf("%td\\texts\\(out\\of\\ld)\\n", (ptrdiff_t)(max_text_ptr - tok_start), (long) max_texts);
    printf("%td\\tokens\\(out\\of\\ld)\\n", (ptrdiff_t)(max_tok_ptr - tok_mem), (long) max_toks);
    printf("%td\\levels\\(out\\of\\ld)\\n", (ptrdiff_t)(max_stack_ptr - stack), (long) stack_size);
    puts("Sorting:");
    printf("%td\\levels\\(out\\of\\ld)\\n", (ptrdiff_t)(max_sort_ptr - scrap_info), (long) max_scraps);
}
```


270. Index. If you have read and understood the code for Phase III above, you know what is in this index and how it got here. All sections in which an identifier is used are listed with that identifier, except that reserved words are indexed only when they appear in format definitions, and the appearances of identifiers in section names are not indexed. Underlined entries correspond to where the identifier was declared. Error messages, control sequences put into the output, and a few other things like “recursion” are indexed here too.

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<code>*:</code> 96.	<code>\MM:</code> 198.
<code>\,:</code> 129, 133, 142, 145, 163, 174, 196, 198, 236.	<code>\MOD:</code> 196.
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- attr*: [20](#), [34](#), [107](#), [110](#), [111](#), [121](#), [128](#), [138](#), [141](#), [143](#), [149](#), [176](#), [178](#), [179](#).
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