PreProcessing

Deep C - a 3 day course
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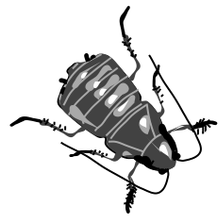
Translation Phases

1. multibyte character mapped, trigraphs replaced
2. \ newline deleted to form logical lines
3. decomposed into preprocessing tokens
4. preprocessing directives executed
   (#includes phases 1-4 recursively)



5. source character set and escape sequences mapped
6. adjacent string literals are concatenated
7. preprocessing tokens converted to tokens,

translation unit is semantically analysed and translated

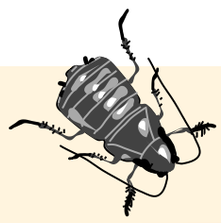
gotcha

phase 6: adjacent string literals are concatenated

```
const char * lines[] =
{
    "the boy stood on the burning deck" ,
    "his heart was all a quiver"        ,
    "he gave a cough, his leg fell off" ,
    "and floated down the river"
};
assert(sizeof(lines) / sizeof(lines[0]) == 4);
```

3 commas

```
const char * lines[] =
{
    "the boy stood on the burning deck"  ,
    "his heart was all a quiver"         ,
    "he gave a cough, his leg fell off"
    "and floated down the river"
};
assert(sizeof(lines) / sizeof(lines[0]) == 3);
```



2 commas

object macros

you can define an identifier as a macro name with a replacement list

 # define *identifier* *pp-tokens*$_{opt}$

one or more spaces after the identifier

preprocesses to...

```
#define BUFFER_SIZE (100)

char buffer[BUFFER_SIZE];
```

```
char buffer[(100)];
```

preprocesses to...

```
#define printf my_printf

printf("error: %s", message);
```

?

```
my_printf("error: %s", message);
```

predefined macros

__func__
- the name of the current function (a string literal) (c99)

__FILE__
- the name of the current source file (a string literal)

__LINE__
- the line number of the current source line (an integer constant)

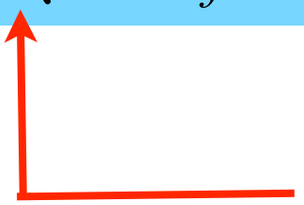
__DATE__
- the date of translation of the preprocessing translation unit (a string literal)

__TIME__
- the time of translation of the preprocessing translation unit (a string literal)

function macros

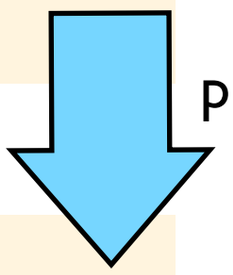
a function-like macro accepts arguments

**define** *identifier* **(** *identifier-list*$_{opt}$ **)** *pp-tokens*$_{opt}$



no space between the identifier and the left parentheses

```
#define MAX(a,b)  ((a) > (b) ? (a) : (b))

func(MAX(precision, delta + epsilon));
```



preprocesses to...

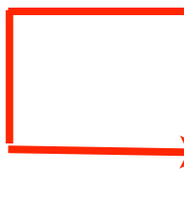
```
func(((precision) > (delta + epsilon)
    ? (precision) : (delta + epsilon)));
```

macro guidelines

macro names should use UPPERCASE and _ underscore only

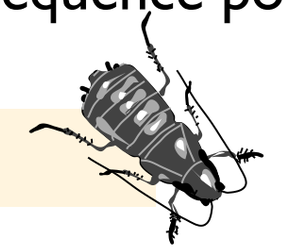
- never lowercase
- this is a very strong convention

```
#define max(a,b)  ((a) > (b) ? (a) : (b))
```

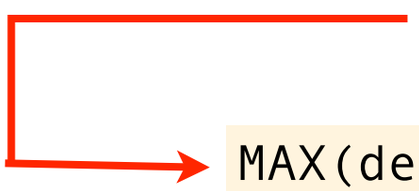


this looks like a function call (with a sequence point)
but it's not, it's a macro :-(

```
max(delta, precision);
```



```
#define MAX(a,b)  ((a) > (b) ? (a) : (b))
```



this looks like a function MACRO (without a sequence point)
and it is indeed a MACRO

```
MAX(delta, precision);
```

macro guidelines

```
#define MAX(a,b)  a > b ? a : b;
```

don't include a trailing semi-colon

better

```
#define MAX(a,b)  a > b ? a : b
```

put each argument in parentheses

better

```
#define MAX(a,b)  (a) > (b) ? (a) : (b)
```

if the replacement tokens form an expression
put the whole replacement text in parentheses

better

```
#define MAX(a,b)  ((a) > (b) ? (a) : (b))
```

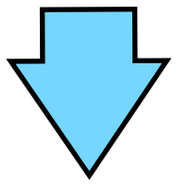
macro side effects

Macro arguments with side effect can happen multiple times

- Surprising enough even without considering sequence points!

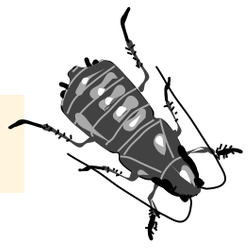
```
#define MAX(a,b)  ((a) > (b) ? (a) : (b))
```

```
f(MAX(n++, limit));
```



preprocesses to...

```
f(((n++) > (limit) ? (n++) : (limit)));
```



macro guidelines

c99

Consider if you can replace the macro with an inline function

```
#define IS_ODD(n)  ((n) % 2 == 1)
```

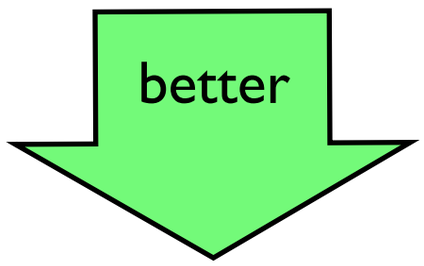
```
static inline bool is_odd(int n)
{
    return n % 2 == 1;
}
```

logical lines

A backslash followed immediately by a newline is deleted (phase 2)

- Allows multiple physical lines to form one logical line
- Used to increase readability of macro replacement

```
#define TRACE(msg)  do { if (dbg_mode) puts(msg); } while (0)
```




```
#define TRACE(msg)  do {                  \¬
                        if (dbg_mode)  \¬
                            puts(msg); \¬
                    } while (0)
```

where ¬ is being used to represent a newline character

macro problem

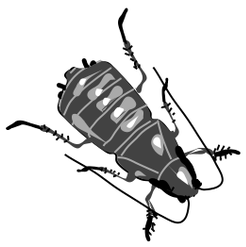
macros bigger than a single expression…

- can easily interfere with their surrounding context

```
#define LOG(msg)  if (in_log_mode) \¬
                        puts(msg)
```

??

```
if (toggled())
   LOG("on");
else
   LOG("off");
```



preprocessess to...

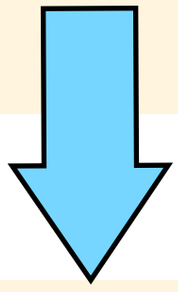
```
if (toggled())
    if (in_log_mode)
        puts("on");
    else if (in_log_mode)
        puts("off");
```

macro solution 1

rephrase the logic in a single expression

```
#define LOG(msg) \¬
    ((void) (in_log_mode && puts(msg)))
```

```
if (toggled())
   LOG("on");
else
   LOG("off");
```



preprocessess to...

```
if (toggled())
    ((void) (in_log_mode && puts("on")));
else
    ((void) (in_log_mode && puts("off")));
```

macro solution 2

embed the macro replacement inside a do-while(0) loop

```
#define LOG(msg)  do {                          \¬
                      if (in_log_mode)  \¬
                          puts(msg);    \¬
                  } while (0)
```

don't include a trailing semi-colon here

instead put it here at each point of use

```
if (toggled())
   LOG("on");
else
   LOG("off");
```

preprocessess to...

```
if (toggled())
     do { if (in_log_mode) puts("on");  } while (0);
else
     do { if (in_log_mode) puts("off"); } while (0);
```

variadic function macros

c99

can accept a variable number of arguments
__VA_ARGS__ expands to the elided arguments

 # define *identifier* **(** *identifier-list*$_{opt}$ **, . . .)** *pp-tokens*$_{opt}$

no space between the identifier and the left parentheses

```
#define DEBUG(...)  fprintf(stderr, __VA_ARGS__)

DEBUG("error: %s", message);
```

preprocesses to...

```
fprintf(stderr, "error: %s", message);
```

Here's an amazing c99 macro to count how many arguments a function macro is called with!

c99

```c
#include <stdio.h>

#define PP_NARG(...) \¬
    PP_NARG_(__VA_ARGS__, PP_REV_SEQ_N())

#define PP_NARG_(...) \¬
    PP_ARG_N(__VA_ARGS__)

#define PP_ARG_N( \¬
    _1, _2, _3, _4, _5, _6, N, ...)    (N)

#define PP_REV_SEQ_N() \¬
    6,5,4,3,2,1,0

int main(void)
{
    printf("%d", PP_NARG(a,b,c,d));
    printf("%d", PP_NARG(a+b,c+d));
    return 0;
}
```

```
4
2
```

Don't use this.

#include

the most common directive

- #include X is replaced by the entire contents of X
- >50% of compilation is typically for #inclusions!
- three forms

h-char == any character except > or newline

```
# include < h-chars >
```

q-char == any character except " or newline

```
# include " q-chars "
```

must expand to < > or " " form

```
# include   pp-tokens
```

is this a tab character?

" " for local headers

< > for system headers

rare

```
#include "widget\table.h"
#include <stdio.h>
#include INCFILE
```

this is *not* a string literal

include order

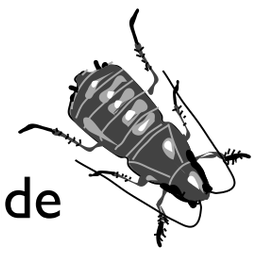
a source file should #include its own header before any other header

- this helps to ensure they don't accidentally compile because of a previous #include
- consider ensuring each header compiles individually as part of the build

eg.h

```
FILE * eg(void);
...
```

this should #include <stdio.h> itself



eg.c

```
#include <stdio.h>
#include "eg.h"
...
```

eg.c

```
#include "eg.h"
#include <stdio.h>
...
```

operator

the # operator converts its argument to a string literal

• if the argument is a string literal or character constant \ is inserted before " and \

```
#define REPORT(test, ...)  \¬
    ((test)                \¬
    ? puts(#test)          \¬
    : printf(__VA_ARGS__))

REPORT(x > y, "x is %d but y is %d", x, y);
```

preprocesses to...

```
((x > y)
   ? puts("x > y")
   : printf("x is %d but y is %d", x, y));
```

The point of the # operator is to create a string representation of its argument *as the developer sees it*

```c
#include <stdio.h>

#define STR(arg)   #arg

int main(void)
{
    puts("x\ty");
    puts(STR("x\ty"));
    return 0;
}
```

```
x       y
x\ty
```

For example

`"x\ty"` **is** `{ 'x','\t','y','\0' }`

but

`STR("x\ty")` **is** `{ 'x', '\\', 't', 'y', '\0' }`

operator

operator concatenates two arguments

```
#define DEBUG(s, t)  printf("x" # s "= %d, "  \¬
                           "x" # t "= %s",   \¬
                            x ## s, x ## t)

DEBUG(1, 2);
```

preprocesses to...

```
printf("x" "1" "= %d, " "x" "2" "= %s", x1, x2);
```

phase 6 string literal concatenation

preprocesses to...

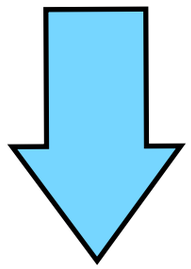
```
printf("x1= %d, x2= %s", x1, x2);
```

#define #undef

you can define and undefine an identifier as a macro name

```
# define identifier   ...
# undef   identifier
```

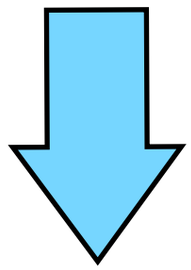
preprocesses to...



```
#define BUFFER_SIZE /*nothing*/

char buffer[BUFFER_SIZE];
```

```
char buffer[];
```

preprocesses to...



```
#define BUFFER_SIZE (100)
#undef  BUFFER_SIZE

char buffer[BUFFER_SIZE];
```

```
char buffer[BUFFER_SIZE];
```

anonymous enums

- consider anonymous enums as an alternative to #defines

```
#define MAX_SIZE (1024)

char buffer[MAX_SIZE];
```

```
enum { MAX_SIZE = 1024 };

char buffer[MAX_SIZE];
```

```
enum { max_size = 1024 };

char buffer[max_size];
```

conditionals

sections of code can be conditionally included/excluded from preprocessing (and hence from translation)

#elif == #else #if

```
# if  constant-expression
...
# elif  constant-expression
...
# else
...
# endif
```

```
#if VERSION == 1
#  define INCFILE "version1.h"
#elif VERSION == 2
#  define INCFILE "version2.h"
#else
#  define INCFILE "versionN.h"
#endif
```

```
#if 0
...
#endif
```

how to exclude code when the excluded code contains /*comments*/(remember / * comments */ do not nest)

conditionals

the #if expression can determine if a macro token has been #defined or not

```
# if defined ( identifier )
# if !defined ( identifier )
```

```
# ifdef identifier
# ifndef identifier
```

equivalent

This is the idiomatic way to make header files idempotent †

widget_table.h

```
#ifndef WIDGET_TABLE_INCLUDED
#define WIDGET_TABLE_INCLUDED
...
...
...
#endif
```

in a single translation
make sure every
source
file has a unique token

† idempotent basically means "once-only"

#error

the #error directive

- issues the specific diagnostic message
- terminates the translation as a failure
- useful when conditional

 # error *pp-tokens*$_{opt}$

diagnostic message

```
#if TARGET == 1
#  define INCFILE "version1.h"
#elif TARGET == 2
#  define INCFILE "version2.h"
#else
#  error "TARGET must be 1 or 2"
#endif
```

#pragma

c99

causes implementation-defined behaviour

 # pragma *pp-tokens*$_{opt}$

also available via the _Pragma operator

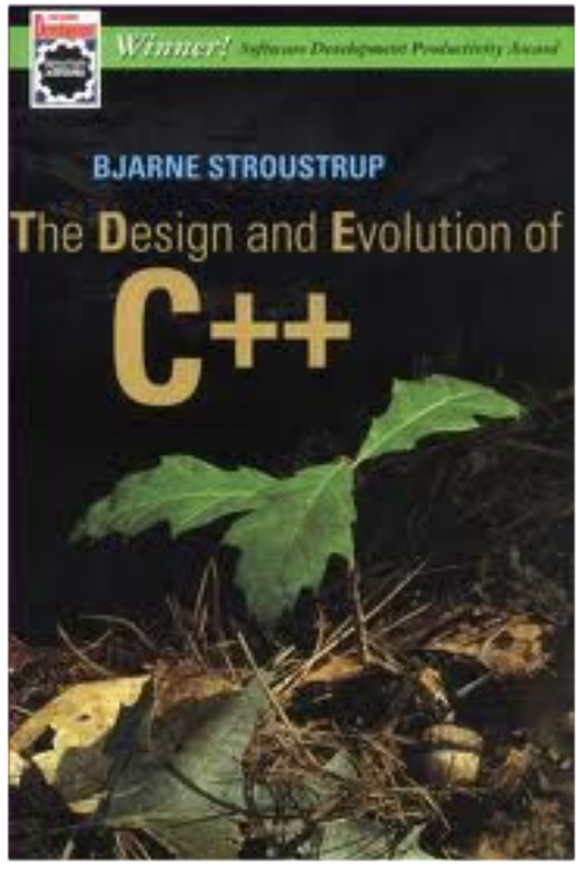
_Pragma *pp-tokens*$_{opt}$

```
#pragma ivdep /* vectorization hint */

while (n-- > 0)
  ...
```

```
#define VECTOR_HINT _Pragma("ivdep")

VECTOR_HINT
while (n-- > 0)
  ...
```

summary

- be wary of the preprocessor
- it knows practically nothing about C
- it silently changes the source being compiled
- header guards and includes are unavoidable
- but for other #directives consider alternatives
- function-like macro → inline function
- object-like macro → const variable
- object-like int macro → enumerator

"I'd like to see Cpp [the C pre processor] abolished."
p426

"In retrospect, maybe the worst aspect of Cpp is that it has stifled the development of programming environments for C."
p424