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The C Preprocessor

```
#define exprintf(expr,                  \
        /* optional msg... */) \
    __exprintf(#expr,   \
        (int) (expr),   \
        "%s: %d\n" msg)

#define __exprintf(str_expr, \
        expr, fmt, args...)   \
    printf(fmt, \
        str_expr, expr, ##args)
```

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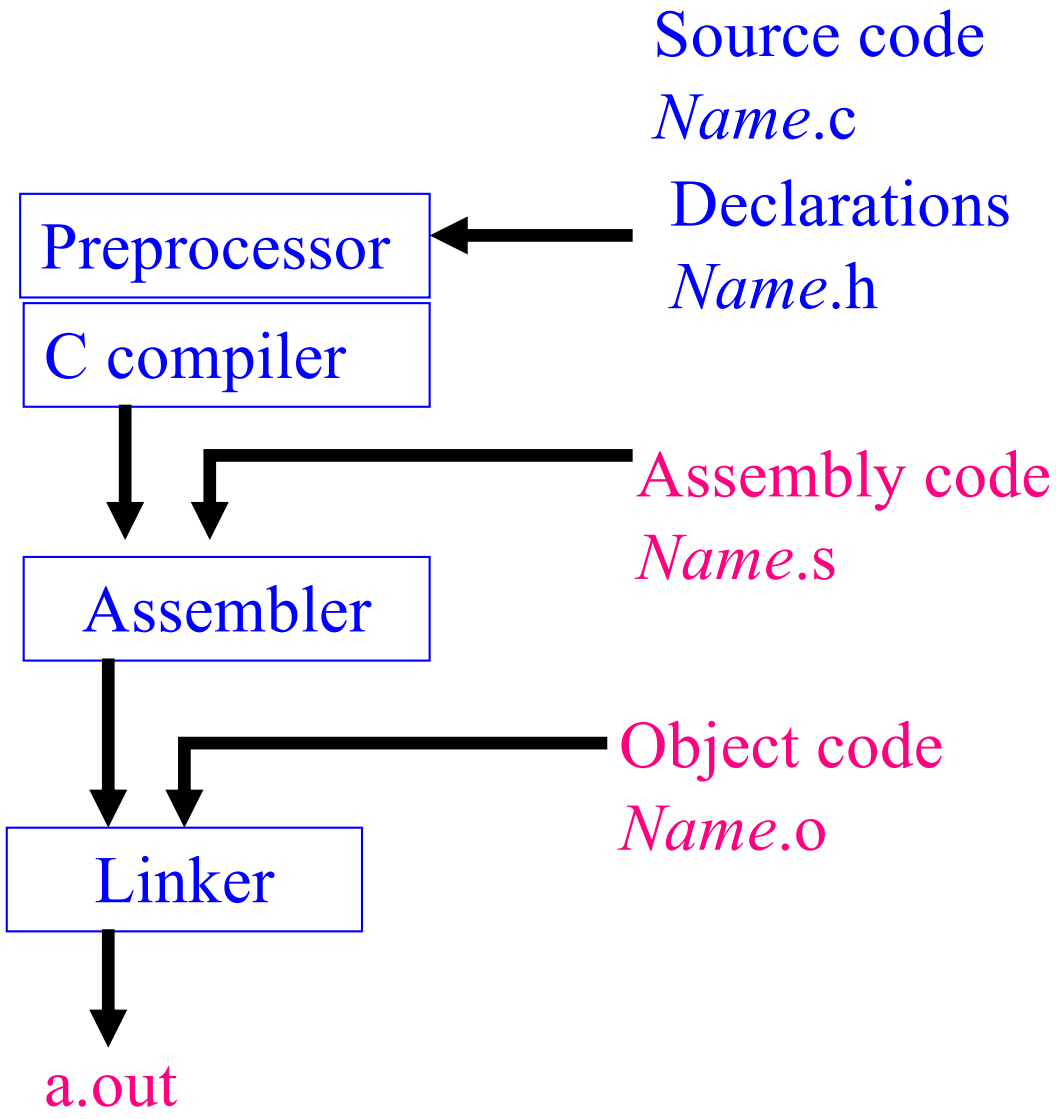
Object Code Files

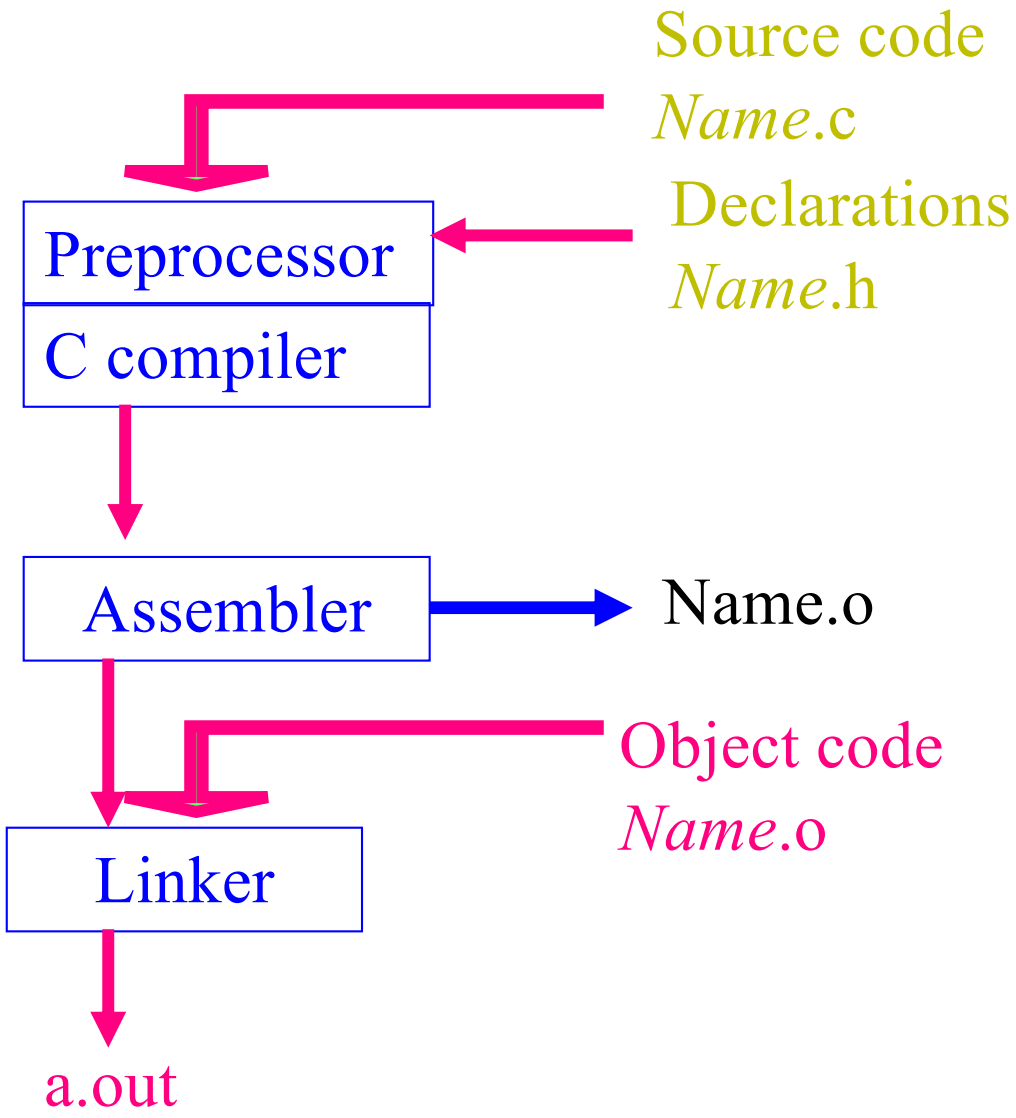
- the C compiler can produce an *object code* version of a .c file that is machine language but not linked with other parts of your program
- these *object code* files end in .o

use “gcc -c hello.c” to compile hello.c to hello.o

Compiling multi-file programs



Compiling multi-file programs



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Compiling and Linking

- the C compiler can be instructed to produce the .o file from the .c using the -c flag, eg:

```
gcc -c util.c
```

- several .c or .o files can be combined to produce an executable program:

```
gcc myprog.c util.o -o myprog
```

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- the *object code* files are linked together to form the final executable program

- after changing a .c file we only need to recompile the affected file into its object code (.o) form and then relink all the .o files to produce the executable

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Preprocessor commands

- preprocessor commands are lines starting with #

eg #include

- The C preprocessor interprets these lines

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Including Text from other files

- The #include statement is used to include text from another file into your program file at that point
- C programs typically consist of many source code files that each contain a small number of functions
- functions work on common data structures and so need declarations of the data structure to be included in each file

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Including Text from other files

- rather than copy the declarations into every file (error prone!) we can use *include files*
- Useful for:
  - externs
  - typedefs
  - struct definitions
- can even nest the included files

Two Files: before

myprog.c

```
/* My Program */
#include "decs.h"

int main(int argc,
         char *argv[])
{
…
}
```

decs.h

```
/* Declarations */

extern  int count;

struct employee
{
…
}
```

After preprocessor:

```
extern  int count;


struct employee
{
…
}

int main(int argc,
                char *argv[])
{
…
}
```

Included text

- By convention, the names of included files end in ".h"
- So called “header” files because they tend to be included near the head of the program file

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- Why shouldn’t you include actual code?

- Why should you include relevant header files rather than simply have them in the code?

Defined Symbols

- An identifier symbol can be given a value by the preprocessor

```
#define LINES 100
```

- The preprocessor will replace the identifier LINES with the string 100 ***whenever*** it finds it in the program

Before preprocessor

myprog.c

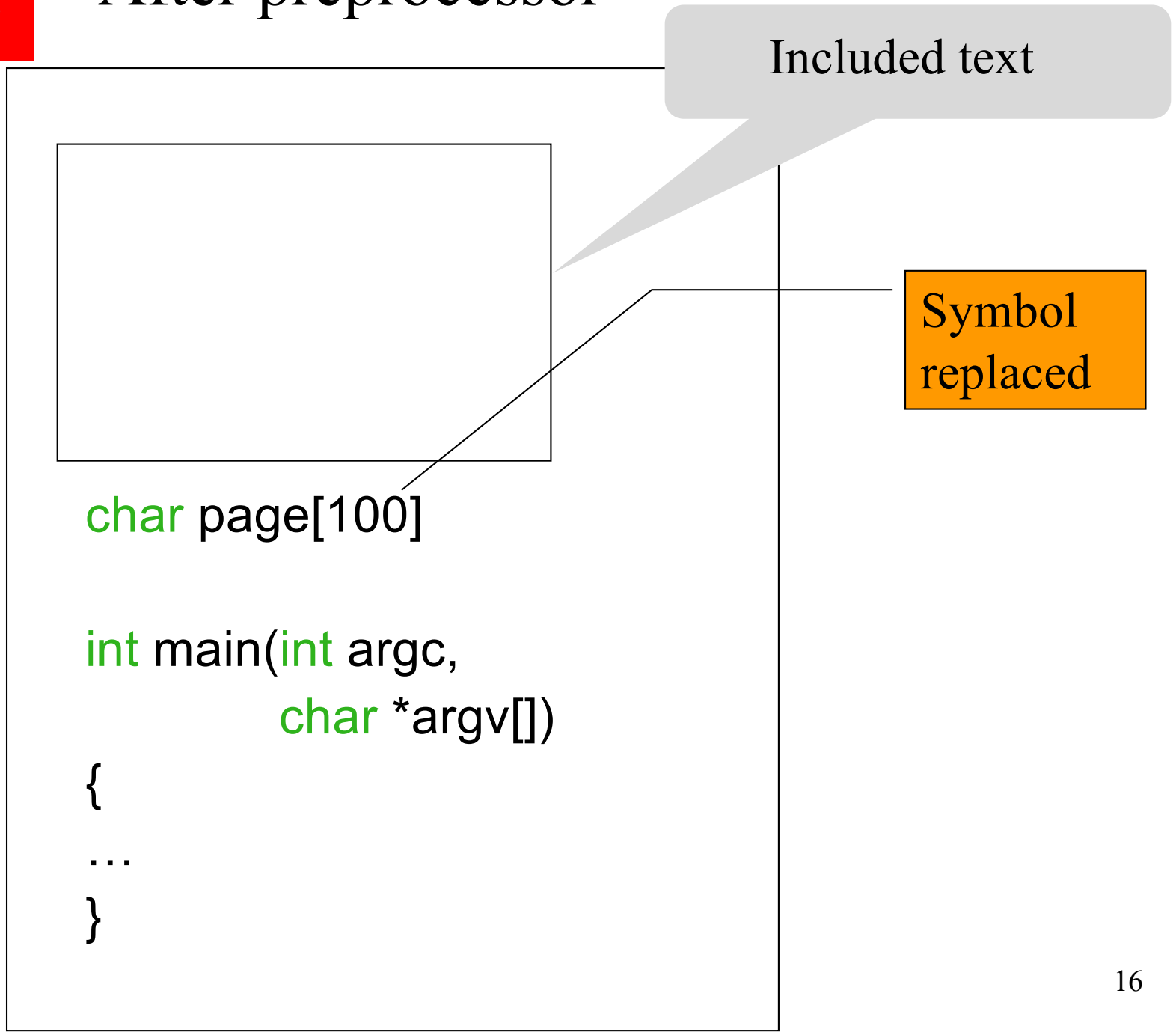
```
/* My Program */
#include "decs.h"
char page[LINES]
int main(int argc,
        char *argv[])
{
…
}
```

decs.h

```
/* Declarations */

#define LINES 100
```

After preprocessor



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Any replacement string

- The replacement string can be any string of characters:

```
#define LINES 5*10*20
```

Before preprocessor

myprog.c

```
/* My Program */
#include "decs.h"
char page[LINES]
int main(int argc,
        char *argv[])
{
…
}
```

decs.h

```
/* Declarations */

#define LINES 5*10*20
```

After preprocessor

Symbol replaced

```
char page[5*10*20]

int main(int argc,
         char *argv[])
{
…
}
```

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Warning!

- The replacement string can be any string of characters and replaces the symbol exactly

```
#define LINES 10+10
```

Before preprocessor

myprog.c

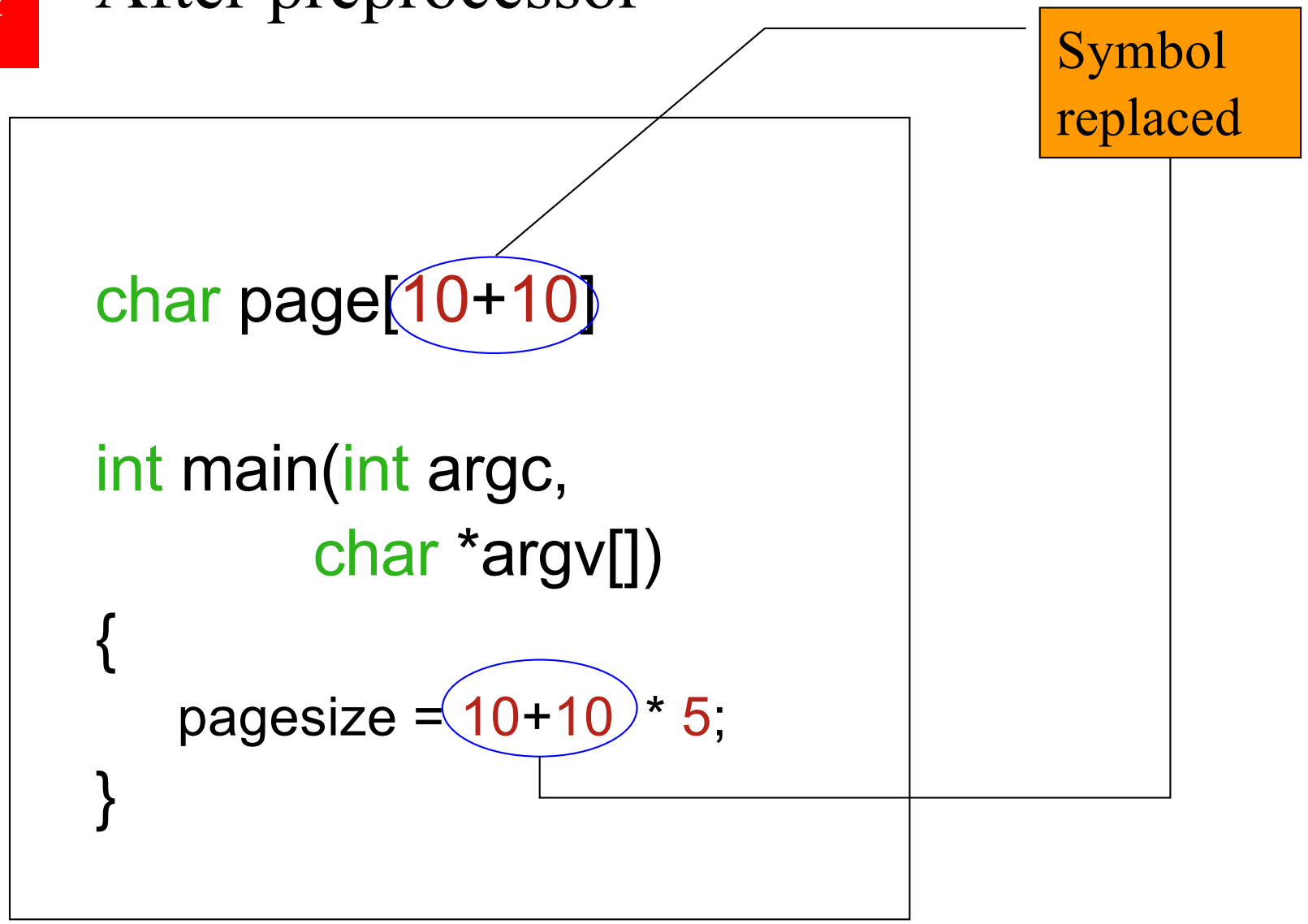
```
/* My Program */
#include "decs.h"
char page[LINES]
int main(int argc,
         char *argv[])
{
    pagesize = LINES * 5;
}
```

decs.h

```
/* Declarations */

#define LINES 10+10
```

After preprocessor



- Always bracket expressions in defined symbols:

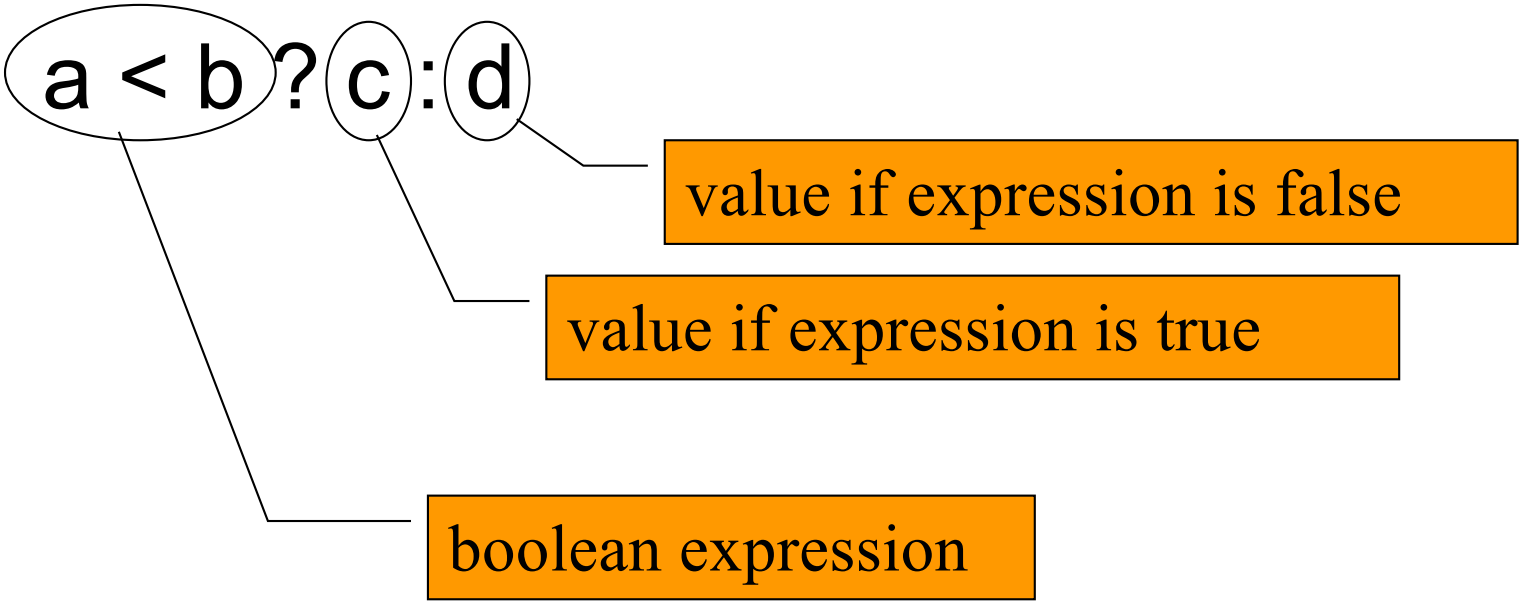
```
#define LINES (10+10)
```

Defined symbols: macros with parameters

- A macro looks like a function with parameters
- A macro is processed by the preprocessor: replacing symbols in the body by parameters

```
#define min(a,b) ((a) < (b) ? (a):(b))
```

Ternary operator ?:



Before preprocessor

myprog.c

```
/* My Program */
#include "decs.h"
int main(int argc,
         char *argv[])
{
   y = min(size,100)
}
```

decs.h

```
/* Declarations */

#define min(a,b) ((a)<(b)?(a):(b))
```

After preprocessor

```
/* My Program */
#include "decs.h"
int main(int argc,
         char *argv[])
{
    y = ((size)<(100)?(size):(100))
}
```

Beware of side-effects

```
y = min(a++,b)  /* before */
```

```
y = ((a++)<(b) ? (a++):(b)  /* after */
```

Beware of side-effects

```
y = min(a++,b)  /* before */
```

```
y = ((a++)<(b) ? (a++):(b)  /* after */
```

a is incremented twice

General form of macro

#define *identifier(identifier,…..) token-string*

How can you tell a function from a macro?

examples:

```
if (isupper(ch)) …

if (ch = getchar())…
if (ch = getc(stdin)) …
if (ch = fgetc(stdin)) …
```

How can you tell a function from a macro?

stdio.h

```
/* The C standard explicitly says this is a
macro, so we always do the optimization for it.
*/
#define getc(_fp) _IO_getc (_fp)
```

libio.h

```
extern int _IO_getc (_IO_FILE *__fp);
```

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The C Preprocessor:

conditional inclusion

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Conditional inclusion

- the preprocessor allows you to select text to be included or not
- very useful for debugging: include debug printouts or not - controlled by preprocessor command

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Conditional inclusion

#ifdef

#if

#ifndef

#else

#elif

#undef

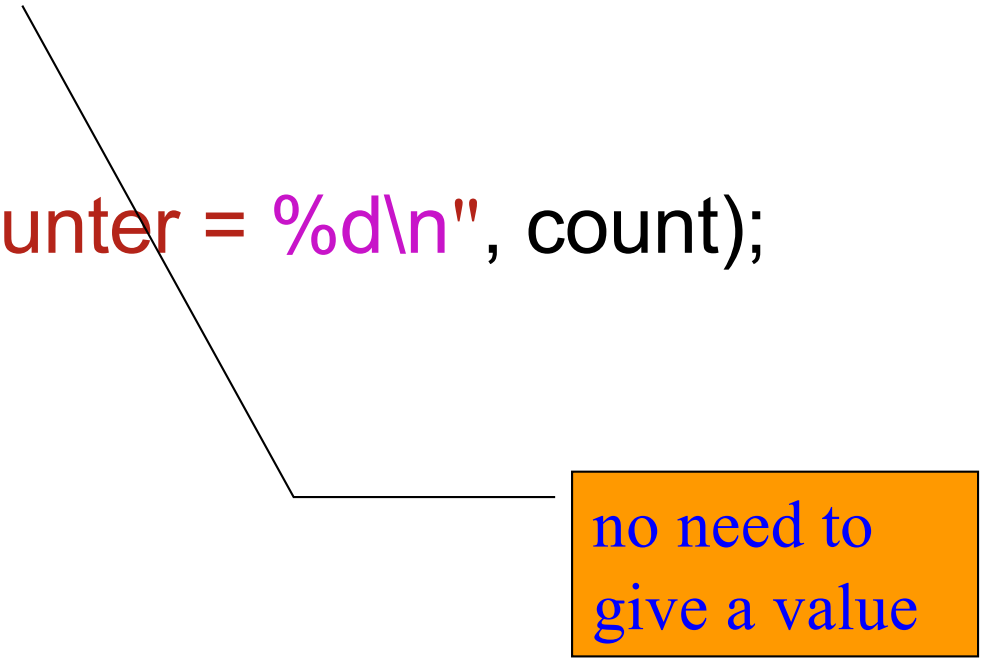
#endif

Conditional inclusion

#ifdef tests if a preprocessor symbol is defined

eg

```
#define DEBUG
#ifdef DEBUG
    printf("loop counter = %d\n", count);
#endif
```



Conditional inclusion

#ifndef tests if a preprocessor symbol is *NOT* defined

eg

```
#ifndef FASTLINK
    …. /* code for slow links */
#endif
```

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Conditional inclusion

#if allows more complex expressions to be used

eg

```
#if WINDOWWIDTH > 600
    …. /* code for wide windows */
#endif
```

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Conditional inclusion

Both #ifdef and #if can have an #else

eg

```
#ifdef DEBUG
    …. /* Debugging version */
#else
    … /* production version */
#end
```

Conditional inclusion

#if can have an #elif

eg

```
#if WIDTH > 600
    …. /* wide version */
#elif WIDTH > 400
    … /* medium version */
#else
    … /* narrow version */
#endif
```

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Before preprocessor

```
#include "declarations.h"
int main(int argc, char *argv[])
{
#ifdef DEBUG
    printf("MyProg (debug version)\n");
#else
    printf("MyProg (production version)\n");
#endif
    return 0;
}
```

declarations.h

```
#define DEBUG
```

After preprocessor

```
int main(int argc, char *argv[])
{

    printf("MyProg (debug version)\n");

}
```

Controlling the preprocessor from the gcc command

gcc -DWIDTH=600 prog.c

has the same effect as

#define WIDTH 600

at the beginning of the program

#define or #undef **within** the program overrides the command line setting

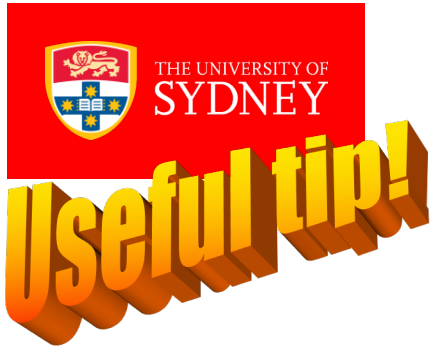
gcc -Didentifier

is equivalent to

#define identifier

multiple -D arguments can be used:

gcc -DWIDTH=600 -DTEST prog.c



Useful for debugging

gcc -DEBUG prog.c

prog.c:

```
#ifdef EBUG
#define DEBUG(m) printf("debug: %s\n", (m))
#else
#define DEBUG(m)  /* null statement */
#endif

...
   DEBUG("called proc fn");
...
```

Alternatives

```
#ifdef DEBUG
    printf(…)
#endif
```

compared with

```
enum {DEBUG = 0}
…
if (DEBUG)
   printf(…)
```

Pre-defined Symbols

- the preprocessor defines several symbols automatically
- the most useful of these are:

__LINE__ contains the current line number at any point

__FILE__ contains the name of the current program file

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When would you need them?

- __LINE__?
- __FILE__?

Debug example revisited

gcc -DEBUG prog.c

continuation indicator

prog.c:

```
#ifdef EBUG
#define DEBUG(m) \
  printf("debug: %s at line %d in file %s\n", \
                          (m), __LINE__, __FILE__)
#else
#define DEBUG(m) /* null statement */
#endif
…
    DEBUG("called doit function");
…
```

#include revisited

- the normal form of #include has a file name in double quotes - this specifies a relative or absolute path for the file
- if the file name is enclosed in <> the file is searched for in /usr/include
- the preprocessor can be instructed to look in other directories using the -I directory flag
- this allows you to have your own directory for include files

Example

```
#include <defs.h>
```

- the preprocessor will look in

  /usr/include for the defs.h file

- if we use the command

  gcc -I/home/john/include myprog.c

the preprocessor will look in

/home/john/include for the file

Caution!

```
#define IF          if(
#define THEN        )
#define BEGIN       {
#define END         }
```

```
IF a == 1 THEN
BEGIN
        dothis()
        dothat();
END
```

A new language!
Unreadable for the next programmer.

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Preprocessor as a tool

- gcc -E …..

- runs just the preprocessor
- can be used as a tool exploiting
  - #define call by name
  - #ifdef for conditional generation

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Example: hack templates

- Generate text in different forms as required:
  - #include parts
  - #define to replace parts

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Role of preprocessor

- lots of it around, especially for
  - machine-dependencies
  - OS versions
- pretty hard to read code with lots of conditional compilation through it
- how to debug the conditional compilations proprocessor “code”?

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- the preprocessor is very useful for configuring programs
  - different versions
  - debugging
- not found in Java

- image: https://packagecontrol.io/packages/C%20Improved