CSE 303:
Concepts and Tools for Software Development

Dan Grossman

Spring 2007

Lecture 12— C: The C Preprocessor; printf/scanf

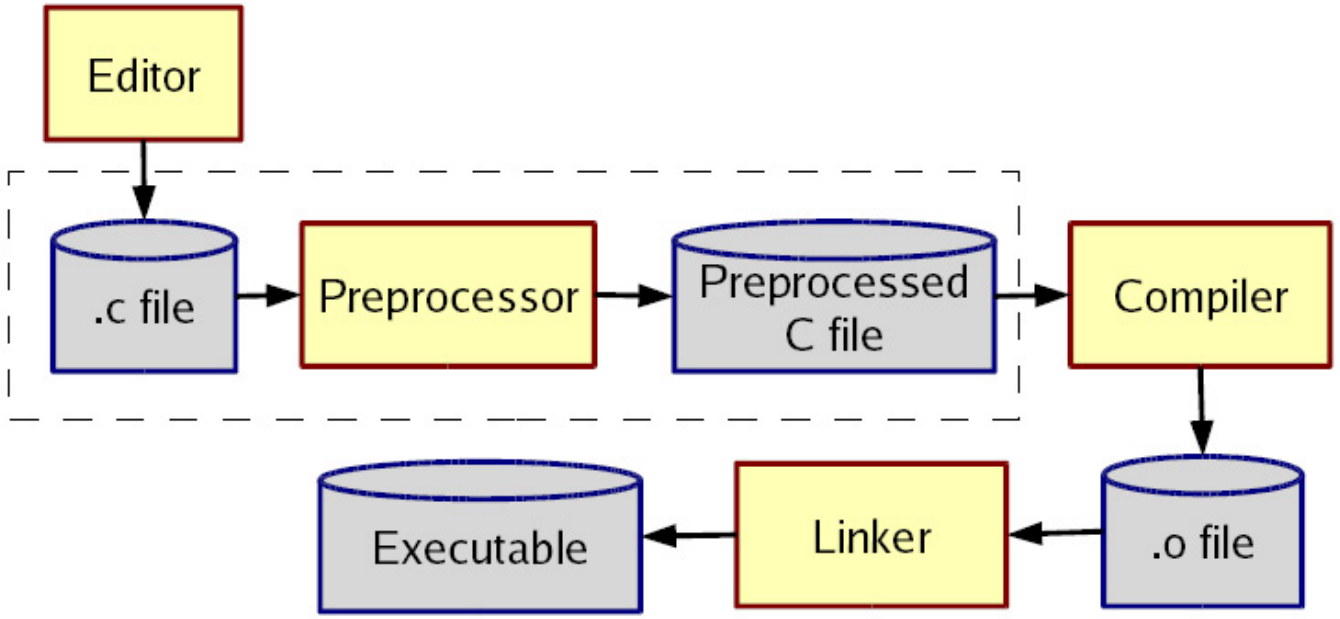
Where are We

Two important "sublanguages" used a lot in C (almost every program)

- The preprocessor: runs even before the compiler (hence the name)
- printf/scanf: interpret certain strings funny at run-time
  - Really just a library though

Two lectures in one (preprocessor a bigger topic).

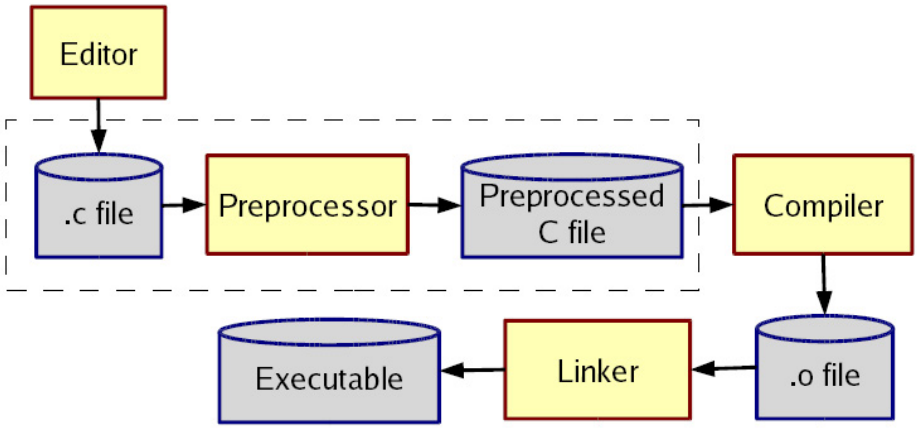
The compilation picture



gcc does all this for you

- `-E` to only preprocess, put result on stdout (rare)
- `-c` to stop with `.o` (common; for part of a program)

More about multiple files



Typical usage:

- Preprocessor `#include` to get a file describing *prototypes* (just types of functions/variables, *not* code)
- Linker is passed your `.o` and other *code*
  - By default, the "standard C library"
  - Other `.o` and `.a` files (hence `-lm` in homework 3)

Whole lecture on the linker and libraries later.

The Preprocessr

Rewrites your `.c` file *before* the compiler gets at the code.

- Lines *starting* with # tell it what to do.

Can do crazy things (please don't); uncrazy things are:

1. Including contents of *header* files (see previous slide)
2. Defining *constants* and *parameterized macros* (textual-replacements)
   - Actually token-based (to be explained)
   - Easy to misdefine and misuse
3. Conditional compilation
   - Include/exclude part of a file
   - Example uses: code for debugging, code for some computers, "the trick" for including header files only once

File inclusion

`#include <foo.h>`

- Search for file `foo.h` in "system include directories" (on attu `/usr/include` and subdirs) for `foo.h` and include its *preprocessed* contents (recursion!) at this place.
  - Typically lots of nested includes, so result is a mess nobody looks at.
  - Idea is simple: declaration for `fgets` is in stdio.h (use `man` for what file to include)
- `#include "foo.h"` the same but *first* look in current directory.
  - How you break your program into smaller files and still make calls to other files.
- `gcc -I dir1 -I dir2 ...` look in these directories for all header files first (keeps paths out of your code files).

Conventions

Conventions to always follow:

1. Give included files names ending in `.h`; only include these *header* files.
2. Do *not* put functions in a header file; only `struct` definitions, prototypes, and other includes
3. Do all your `#include` at the beginning of a file.
4. For header file `foo.h` start it with:

   ```
   #ifndef FOO_H
   #define FOO_H
   ```

   and end it with:

   ```
   #endif
   ```

   (We will learn why soon.)

Simple macros

```
#define M_PI 3.14 // capitals a convention to avoid problems

#define DEBUG_LEVEL 1

#define NULL 0 // already in standard library
```

Replace all matching *tokens* in the rest of the file

- Knows where "words" start and end (unlike `sed`)
- Has no notion of scope (unlike C compiler)
- (Rare: can shadow with another `#define` or use `#undef`)

```
#define foo 17
void f() {
  int food = foo; // becomes int food = 17 (ok)
  int foo = 9+foo+foo; // becomes int 17 = 9+17+17 (nonsense)
}
```

Macros with parameters

```
#define TWICE_AWFUL(x) x*2
#define TWICE_BAD(x) ((x)+(x))
#define TWICE_OK(x) ((x)*2)
double twice(double x) { return x+x; } // my preference
```

Replace all matching "calls" with "body" but with *text of arguments* where the formals are.

Gotchas (understand why!):

- `y=3; z=4; w=TWICE_AWFUL(y+z);`
- `y=7; z=TWICE_BAD(++y); z=TWICE_BAD(y++);`

Common misperception: Macros a good idea to avoid performance overhead of a function call.

Macros can be more flexible though (`TWICE_OK` works on ints and doubles without conversions (which could round))

Justifiable uses

Parameterized macros are generally to be avoided (use functions), but there are things functions cannot do:

```
#define NEW_T(t,cnt) ((t*)malloc((cnt)*sizeof(t))

#define PRINT(x) printf("%s:%d %s\n",__FILE__,__LINE__,x)
```

Conditional compilation

`#ifdef FOO` (matching `#endif` later in file)

`#ifndef FOO` (matching `#endif` later in file)

`#if FOO > 2` (matching `#endif` later in file)

(You can alse have a `#else` inbetween somewhere.)

Simple use:

```
#ifdef DEBUG // do following only when debugging
    printf(...);
#endif
```

Fancier:

```
#ifdef DEBUG // use DBG_PRINT for debugging-prints
#define DBG_PRINT(x) printf("%s",x)
#else
#define DBG_PRINT(x) // replace with nothing
#endif
```

Note: `gcc -D FOO` makes `FOO` "defined"

Back to header files

Now we know what this means:

```
#ifndef SOME_HEADER_H
#define SOME_HEADER_H
... rest of some_header.h ...
#endif
```

Assuming nobody else defines `SOME_HEADER_H` (convention), the first `#include "some_header.h"` will do the define and include the rest of the file, but the second will skip everything.

- More efficient than copying the prototypes over and over again.
- In presence of circular includes, necessary to avoid "creating" an infinitely large result of preprocessing.

So we always do this.

C preprocessor summary

A few easy to abuse features and a bunch of conventions (for overcoming C's limitations).

- `#include` (cycles fine with "the trick", the way you say what other definitions you need)
- `#define` (avoids magic constants, parameterized macros have a few justifiable uses, token-based text replacement)
- `#if...` (for showing the compiler less code)

printf and scanf

"Just" two library functions in the standard library

- Prototypes in `stdio.h`

Example: `printf("%s: %d %g ", x, y+9, 3.0)`

They can take any number of arguments.

- You can define functions like that too, but it is rarely useful, arguments are not checked for any types, and writing the function definition is a pain.
  - Not covered in 303.

The `f` is for "format" – crazy characters in the format string control formatting.

The rules

To avoid HYCSBWK:

- Number of arguments better match number of %
- Corresponding arguments better have the right types (%d,int %f,float, %e,float (prints scientific), %s,\0-terminated char*, ... (look them up))

For `scanf`, arguments should be *pointers to* the right type of thing (reads input and assigns to the variables).

- So `int*` for %d, but still `char*` for %s (not `char**`)

More funny characters

Between the % and the letter (e.g., `d`) can be other things that control formatting (look them up; I do).

- Padding (width) `%12d` `%012d`
- Precision ...
- Left/right justification ...

Know what is possible; know that other people's code may look funny.

More on scanf

- Check for errors (returns number of % sucessfully matched)
  - maybe the input does not match the text
  - maybe some "number" in the input does not parse as a number
- Always bound your strings
  - Or some external data could lead to arbitrary behavior (common source of viruses; input a long string containing evil code)
  - Remember there must be room for the `\0`
  - `%s` reads up to the next whitespace

Example: `scanf("%d:%d:%d",&hour,&minutes,&seconds);`
Example: `scanf("%20s",buf)` (buf better have room for 20 characters)

Useful, bizarre sublangage

This is yet another funky little collection of characters with strange meaning.

- Pretty useful for reading/writing files (and the screen)
  - See `fprintf`, `fscanf`
- Also useful for reading/writing regular old strings
  - See `snprintf`, `sscanf`
  - (Do not use `sprintf` unless you enjoy danger.)