Administrivia

New exercise posted this morning, due before class Wed.
- A little longer and a few more days than usual because...

No class Monday (MLK holiday)

Lecture order rearranged to finish most C topics today before the long weekend (lec 7 before lec 6)
- (Instructor is too lazy to renumber everything.)

HW1 due a week from Tuesday
- Not much discussion board traffic yet. No problems, no confusion, or nobody started?
Today’s topics:

- a few final C details
  - header guards and other preprocessor tricks
  - extern, static and visibility of symbols
  - some topics for you to research on your own
an `#include` problem

What happens when we compile foo.c?

```c
#include "ll.h"
#include "ht.h"

typedef void *HashTable;
// A hypothetical function
LinkedList HTKeyList(HashTable t);

int main(int argc, char **argv) {
  // ... do stuff here ...
  return 0;
}
```

```c
typedef void *LinkedList;
// more definitions below

#include "ll.h"
#include "ht.h"
```
an #include problem

What happens when we compile foo.c?

bash$ gcc -Wall -g -o foo foo.c

In file included from ht.h:1,
    from foo.c:2:
ll.h:1: error: redefinition of typedef ‘LinkedList’
ll.h:1: note: previous declaration of ‘LinkedList’ was here

foo.c includes ll.h twice!
- 2nd time is indirectly via ht.h
- so, typedef shows up twice!
- try using cpp to see this
header guards

A commonly used C preprocessor trick to deal with this

- uses macro definition (\#define)
- uses conditional compilation (\#ifndef and \#endif)

```
#ifndef _LL_H_
#define _LL_H_

typedef void *LinkedList;

// more definitions below
#endif  // _LL_H_
```

```
#ifndef _HT_H_
#define _HT_H_

#include "ll.h"

typedef void *HashTable;

// A hypothetical function
LinkedList HTKeyList(HashTable t);

#endif  // _HT_H_
```
Other preprocessor tricks

A way to deal with “magic constants”

```c
int globalbuffer[1000];

void circalc(float rad,
             float *circumf,
             float *area) {
  *circumf = rad * 2.0 * 3.1415;
  *area = rad * 3.1415 * 3.1415;
}
```

bad code
(littered with magic constants)

```c
#define BUFSIZE 1000
#define PI 3.14159265359
int globalbuffer[BUFSIZE];

void circalc(float rad,
             float *circumf,
             float *area) {
  *circumf = rad * 2.0 * PI;
  *area = rad * 3.1415 * PI;
}
```

better code
Macros

You can pass arguments to macros

```cpp
#define ODD(x) ((x) % 2 != 0)
void foo(void) {
   if ( ODD(5) )
     printf("5 is odd!\n");
}
```

Be careful of precedence issues; use parenthesis:

```cpp
#define ODD(x) ((x) % 2 != 0)
#define BAD(x) x % 2 != 0
ODD(5 + 1);
BAD(5 + 1);
```

```cpp
void foo(void) {
   if ( ((5) % 2 != 0) )
     printf("5 is odd!\n");
}
```

```cpp
((5 + 1) % 2 != 0);
5 + 1 % 2 != 0;
```
Conditional Compilation

You can change what gets compiled

```c
#ifndef TRACE
#define ENTER(f) printf("Entering %s
", f);
#define EXIT(f)  printf("Exiting  %s
", f);
#else
#define ENTER(f)
#define EXIT(f)
#endif

// print n
void pr(int n) {
  ENTER("pr");
  printf("n = %d
", n);
  EXIT("pr");
}
```

ifdef.c
Defining Symbols

Besides #defines in the code, preprocessor values can be given on the gcc command

```
bash$ gcc -Wall -g -DTRACE -o ifdef ifdef.c
```

assert is controlled the same way - #define NDEBUG and asserts expand to “empty” (it’s a macro - see assert.h)

```
bash$ gcc -Wall -g -DNDEBUG -o faster usesassert.c
```
Namespace problem

If I define a global variable named “counter” in foo.c, is it visible in bar.c?

- if you use **external linkage**: yes
  - the name “counter” refers to the same variable in both files
  - the variable is defined in one file, declared in the other(s)
  - when the program is linked, the symbol resolves to one location

- if you use **internal linkage**: no
  - the name “counter” refers to different variables in each file
  - the variable must be defined in each file
  - when the program is linked, the symbols resolve to two locations
External linkage

```
#include <stdio.h>

// A global variable, defined and initialized here in foo.c.
// It has external linkage by default.
int counter = 1;

int main(int argc, char **argv) {
  printf("%d\n", counter);
  bar();
  printf("%d\n", counter);
  return 0;
}
```

```
#include <stdio.h>

// "counter" is defined and initialized in foo.c.
// Here, we declare it, and specify external linkage by using the extern specifier.
extern int counter;

void bar(void) {
  counter++;
  printf("(b): counter %d\n", counter);
}
```

foo.c

bar.c
Internal linkage

#include <stdio.h>

// A global variable, defined and initialized here in foo.c.
// We force internal linkage by using the static specifier.
static int counter = 1;

int main(int argc, char **argv) {
  printf("%d\n", counter);
  bar();
  printf("%d\n", counter);
  return 0;
}

#include <stdio.h>

// A global variable, defined and initialized here in bar.c.
// We force internal linkage by using the static specifier.
static int counter = 100;

void bar(void) {
  counter++;
  printf("(b): counter %d\n", counter);
}

foo.c

bar.c
Some gotchas

Every global (variables and functions) is extern by default

- unless you specify the static specifier, if some other module uses the same name, you’ll end up with a collision!
  ‣ best case: compiler error
  ‣ worst case: stomp all over each other

- it’s good practice to:
  ‣ use static to defend your globals (hide your private stuff!)
  ‣ place external (i.e., global) declarations in a module’s header file
Extern, static functions

// By using the static specifier, we are indicating
// that foo() should have internal linkage. Other
// .c files cannot see or invoke foo().
static int foo(int x) {
    return x*3 + 1;
}

// Bar is "extern" by default. Thus, other .c files
// could declare our bar() and invoke it.
int bar(int x) {
    return 2*foo(x);
}

#include <stdio.h>
extern int bar(int);
int main(int argc, char **argv) {
    printf("%d\n", bar(5));
    return 0;
}
Somebody should get fired

C has a second, different use for the word “static”

- to declare the extent of a local variable
- if you declare a static local variable, then:
  - the storage for that variable is allocated when the program loads, in either the program’s .data or .bss segment
  - the variable retains its value across multiple function invocations

(see static_extent.c for an example)
Additional C topics

Teach yourself

- bit-level manipulation in C (cf CSE 351): \( \sim | \& << >> \)

- string library functions provided by the C standard library
  - #include <string.h>
    - strlen(), strcpy(), strdup(), strcat(), strcmp(), strchr(), strstr(), ...
  - learn why \texttt{strncat} is safer (in the security sense) than \texttt{strcat}, etc.
  - #include <stdlib.h> or #include <stdio.h>
    - atoi(), atof(), sprintf(), sscanf()

- \texttt{man} pages are your friend!
Additional C topics

Teach yourself

- the syntax for function pointers, including passing as args
- how to declare, define, and use a function that accepts a variable-lengthed number of arguments (varargs)
- unions and what they are good for
- what argc and argv are for in main

```c
#include <stdio.h>
int main(int argc, char **argv) {
  int i;
  for (i = 0; i < argc, i++) {
    printf("%d: %s\n", i, argv[i]);
  }
  return 0;
}
```

```
bash$ gcc -o argv argv.c
bash$ ./argv
0: ./argv
bash$ ./argv foo bar
0: ./argv
1: foo
2: bar
bash$
```
Additional C topics

Teach yourself:

- the difference between pre-increment (++v) and post-increment (v++)

- the meaning of the “register” storage class
  - Might see it in code, but compilers often ignore it these days since they can often do a better job without it

- harder: the meaning of the “volatile” storage class
  - pages 91, 92 of CARM, much more precise in C11
Exercise 1

Write a program that:

- prompts the user to input a string (use fgets( ))
  - assume the string is a sequence of whitespace-separated integers
  - e.g., "5555 1234 4 5543"
- converts the string into an array of integers
- converts an array of integers into an array of strings
  - where each element of the string array is the binary representation of the associated integer
- prints out the array of strings
Exercise 2

Modify the linked list code from last lecture / exercise 1

- add static declarations to any internal functions you implemented in linkedlist.h
- add a header guard to the header file
- write a Makefile
  ‣ use Google to figure out how to add rules to the Makefile to produce a library (liblinkedlist.a) that contains the linked list code
See you on Wednesday!