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CSE 374

# Programming Concepts & Tools

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(Thanks to Hal Perkins)

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Lecture 8 – C: Miscellanea

Control, Declarations, Preprocessor, printf/scanf

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# The story so far...

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- The low-level execution model of a process (one address space)
- Basics of C:
  - Language features: functions, pointers, arrays
  - Idioms: Array-lengths, strings as arrays with '\0' terminators
- Today – a collection of core C idioms/ideas:
  - Control Constructs, ints as booleans
  - Declarations & Definitions
  - Source file structure
  - Two important “sublanguages” used a lot in C
    - The **preprocessor**: runs even before the compiler
      - Simple #include and #define for now; more later
    - printf/scanf: **formatted I/O**
      - Really just a library though
- Next time: lvalues, rvalues, arrays & pointers; then structs & memory allocation

# Control constructs

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- while, if, for, break, continue, switch: much like Java
- **Key difference: No built-in boolean type; use ints (or pointers)**
  - Anything but 0 (or NULL) is “true”
  - 0 and NULL are “false”
  - C99 did add a bool library but not widely used (particularly in old code)
- goto much maligned, but makes sense for some tasks (more general than Java’s labeled break)
- **Gotcha:** switch cases fall-through unless there is an explicit transfer (typically a break), just like Java

# Declarations and Definitions (1)

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- C makes a careful distinction between these two
- *Declaration*: introduces a name and describes its properties (type, # parameters, etc), but does not create it
  - ex. Function prototype: `int twice(int x);`
  - also works (not as good style?): `int twice(int);`
- *Definition*: the actual thing itself
  - ex. Function implementation:  
`int twice(int x) { return 2*x; }`

# Declarations and Definitions (2)

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- An item may be *declared* as many times as needed
  - although normally at most once per scope or file (i.e., can't declare the same name twice in a scope)
  - Declarations of shared things are often #included (read) from header files (e.g., `stdio.h`)
- An item must be *defined exactly once*
  - e.g., there must be a single definition of each function in only one file no matter how many files contain a declaration of it (or #include a declaration) or actually use it

# Forward References

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- No forward references allowed:
  - A function must be defined or declared in a source file **before it is used**. (Lying: “implicit declaration” warnings, return type assumed int, ...)
  - Linker error if something is used but not defined in some file somewhere (including main)
    - Use -c to not link yet (more later)
  - To write mutually recursive functions, you just need a (forward) declaration

# Some (more) glitches

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- Declarations must precede statements in a “block”
  - But any statement can be a block, so use { ... } if you need to
  - Or use --std=c99 gcc compiler option
- **Array variables in code must have a constant size**
  - So the compiler knows how much space to allocate
  - (C99 has an extension to relax this – rarely used)
  - Arrays whose size depends on runtime information are allocated on the heap (next time)
  - Large arrays are best allocated on the heap also, even if constant size, although not required

# More gotchas

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- Declarations in C are funky:
  - You can put multiple declarations on one line, e.g., `int x, y;` or `int x=0, y;` or `int x, y=0;`, or ...
  - But `int *x, y;` means `int *x; int y;` – you usually mean (want) `int *x, *y;`
  - **Common style rule: one declaration per line (clarity, safety, easier to place comments)**
- Variables holding arrays have super-confusing (but convenient) rules...
  - Array types in function arguments are pointers(!)
  - Referring to an array doesn't mean what you think (!)
    - “implicit array promotion” (later)



# The preprocessor

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- Rewrites (processes) your .c file before (pre) 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 (now)
  2. Defining constants (now) and parameterized macros (textual-replacements) (later)
  3. Conditional compilation (later)

# File inclusion

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`#include <foo.h>`

- Search for file `foo.h` in “system include directories” (on Fedora `/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 (use `gcc -E` if you want a look!)
  - Idea is simple: e.g., 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 functions other files**
- `gcc -I dir1 -I dir2 ...` look in these directories for header files first (keeps paths out of your code files) – we probably won't need to use this

# Simple macros & symbolic constants

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```
#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)
}
```

# Typical file layout

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- Not a formal rule, but good conventional style

```
// includes for functions & types defined elsewhere
#include <stdio.h>
#include "localstuff.h"
```

```
// symbolic constants
#define MAGIC 42
```

```
// global variables (if any)
static int days_per_month[ ] = { 31, 28, 31, 30, ...};
```

```
// function prototypes (to handle "declare before use")
void some_later_function(char, int);
```

```
// function definitions
void do_this( ) { ... }
char * return_that(char s[ ], int n) { ... }
int main(int argc, char ** argv) { ... }
```

# printf and scanf

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- “Just” two library functions in the standard library
  - Prototypes (**declarations**) in <stdio.h>
- Example: `printf("%s: %d %g\n", p, y+9, 3.0)`
- They can take any number of arguments
  - You can define functions like this too, but it is rarely useful, arguments are usually not checked and writing the function definition is a pain
    - Writing these not covered in this course
- The “f” in printf is for “format” – crazy characters in the format string control formatting (%s string, %d decimal/integer, %f floating point, \n newline, etc.)

# The rules

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- 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 must 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\*\*)  
int n; char \*s;  
...  
scanf(“%d %s”, &n, s);

# More funny characters

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- Between the % and the letter (e.g., d) can be other things that control formatting (look them up; we all 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

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- Check for errors (scanf returns number of % successfully 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)`

(better have room for  $\geq 20$  characters)