

Administrivia

- Homework 5 on the Web. Nominally due next Monday (but deadline may be extended).

Slide 1

Dynamic Memory and C

- With the C89 standard, you had to decide when you compiled the program how big to make things, particularly arrays — a significant limitation.
- Variable-length arrays in C99 standard help with that, but don't solve all related problems:

Slide 2

In many implementations, space is obtained for them on “the stack”, an area of memory that's limited in size.

You can return a pointer from a function, *but* not to one of the function's local variables (because these local variables cease to exist when you return from the function).

Dynamic Memory and C, Continued

Slide 3

- “Dynamic allocation” of memory gets around these limitations — allows us to request memory of whatever size we want (well, up to limitations on total memory the program can use) and have it stick around until we give it back to the system.

(The trick here is that most implementations differentiate between two areas of memory, a “stack” used for local variables, and a “heap” used for dynamic memory allocation. Usually the former is more limited in size.)

- To request memory, use `malloc`. To return it to the system, use `free`.
(For short simple programs you can skip this, but not good practice, since in “real” programs you may eventually run out of memory.)
- Python and Scala hide most of this from you — allocating space for objects is automatic/hidden, and space is reclaimed by automatic garbage collection. Makes for easier programming but possibly-unpredictable performance.

Dynamic Memory and C, Continued

Slide 4

- Examples:

```
int * nums = malloc(sizeof(int) * 100);
char * some_text = malloc(sizeof(char) *
20);
free(nums);
```

- Some books/resources recommend “casting” value returned by `malloc`. Other references recommend the opposite! But you should check the value — if `NULL`, system was not able to get that much memory.
- (Example — improved sort program.)

Function Pointers

Slide 5

- You know from more-abstract languages that there are situations in which it's useful to have method parameters that are essentially code. Some languages make that easy (functions are "first-class objects") and others don't, but almost all of them provide some way to do it, since it's so useful — e.g., providing a "less-than" function for a generic sort.
- In C, you do this by explicitly passing a pointer to the function.

Function Pointers in C

Slide 6

- The type of a function pointer includes information about the number and types of parameters, plus the return type.
- Example — last parameter to library function `qsort` (in its man page). Call this by providing, in your code, a function with declaration

```
int my_compare(const char *, const char *);
```

and using `my_compare` as the last parameter to `qsort`.
- (Example — improved sort program.)

Pointers Versus Arrays — One More Thing

- We've said that pointers and arrays are in most contexts equivalent. One potential benefit of this is that it can make it easier to work with substrings, subarrays, etc.
- Example — one more revision of the string-length example, using recursion.

Slide 7

User-Defined Types

- So far we've only talked about representing very simple types — numbers, characters, text strings, arrays, and pointers. You might ask whether there are ways to represent more complex objects, such as one can do with classes in object-oriented languages.
- The answer is “yes, sort of” — C doesn't provide nearly as much syntactic help with object-oriented programming, but you can get something of the same effect. But first, some simpler user-defined types . . .

Slide 8

User-Defined Types in C — typedef

- typedef just provides a way to give a new name to an existing type, e.g.:

```
typedef charptr char *;
```

- This can make your code more readable, or allow you to isolate things that might be different on different platforms (e.g., whether to use `float` or `double` in some application) in a single place.

Slide 9

User-Defined Types in C — enum

- In C (and in some other programming languages) an *enumeration* or an *enumerated type* is just a way of specifying a small range of values, e.g.

```
enum basic_color { red, green, blue, yellow };  
enum basic_color color = red;
```

This can make code more readable, and sometimes combines nicely with `switch` constructs.

- Under the hood, C enumerated types are really just integers, though, and they can be ugly to work with in some ways (e.g., no nice way to do I/O with them).

Slide 10

User-Defined Types in C — struct

- More complex (interesting?) types can be defined with `struct`, which lets you define a new type as a collection of other types — something like a class in an object-oriented language, but with no methods and no way to hide fields/variables.
- Two versions of syntax (next slide) ...

Slide 11

User-Defined Types in C — struct

- One way to define uses `typedef`:

```
typedef struct {
    int dollars;
    int cents;
} money;
money bank_balance;
```
- Another way doesn't:

```
struct money {
    int dollars;
    int cents;
};
struct money bank_balance;
```

Slide 12

User-Defined Types in C — struct, Continued

- Either way you define a struct, how you access its fields is the same:

. if what you have is a struct itself:

```
struct money bank_balance;  
bank_balance.dollars = 100;  
bank_balance.cents = 100;
```

-> if what you have is a pointer to a struct:

```
struct money * bank_balance_ptr = &bank_balance;  
bank_balance_ptr->dollars = 100;  
bank_balance_ptr->cents = 100;
```

Slide 13

User-Defined Types in C — union

- For completeness, we should mention that C also provides a way of defining a structure that can contain one of several alternatives (“this OR that”, as opposed to the “this AND that” of struct) — union.
- See discussion in textbook about this; it can be useful, but can also make code more difficult to understand.

Slide 14

Slide 15

Example — Singly-Linked List

- Now we have enough tools to do a low-level version of something probably familiar to you — linked list. Idea is the same as in higher-level languages, but must explicitly deal with many details.
- We could write some code, using two types of `structs`, one for the nodes in the list and one for the list itself. (Example on “sample programs” page. Textbook also has somewhat simpler code for list — single data structure, iterative rather than recursive.)

Slide 16

Separate Compilation and Makefiles — Review

- C (like many languages) lets you split large programs into multiple source-code files. Typical to put function and other declarations in files ending `.h`, function definition in files ending `.c`. Compilation process can be separated into “compile” (convert source to object code) and “link” (combine object and library code to make executable) steps.
- UNIX utility `make` can help manage compilation process. Can also be useful as a convenient way to always compile with preferred options.

Minute Essay

- Anything about C that you'd like to hear more about next time?

Slide 17