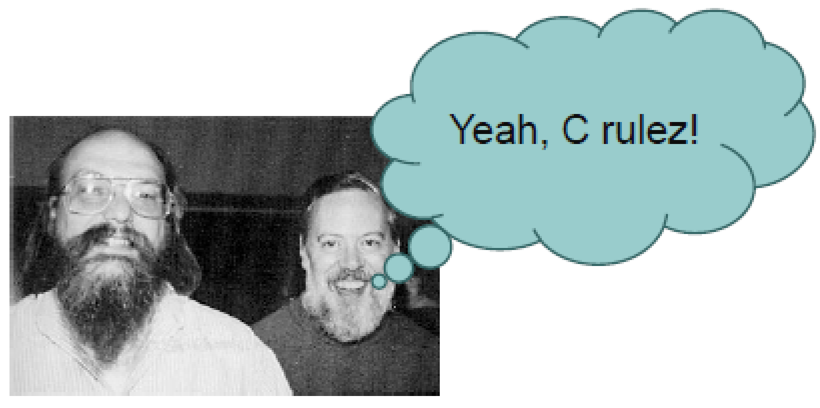
C Minicourse

Introduction to C



Because creepy, old kernel hackers use C!!!
(Ken Thompson and Dennis Richie)

Part 0: Overview

- What is C and why should I care?
- Differences from Java and C++
- Overview of a C program

This is C!

```
#include <stdio.h>

int main(int argc, char **argv) {
  printf("Hello, world!\n");
  return 0;
}
```

What is C?

- Low level programming language used primarily for implementing operating systems, compilers, etc.
- Great at:
  - interfacing with hardware
  - efficiency
  - large, entrenched user-base
- Not so great:
  - long development times
  - writing cross-platform C can be hard
  - notorious for hard-to-find bugs

Java *vs* C *vs* C++

Java	C	C++
Object-Oriented	Procedural	Object-Oriented
Memory-Managed (automatic garbage collection)	Manual memory management (very prone to bugs)	Manual memory management (still very prone to bugs)
Good for high level or quick programs	Good for very low level programs where efficiency and/or interfacing with hardware are necessary	Good for everything that C is plus some (that's where the whole "++" thing comes in..)
Cross platform by design	Can be cross-platform, but it's not always easy	Can be cross-platform, but it's not always easy
Lame 無趣	Not lame	Not lame

- As you can see, C and C++ are very similar and much more not lame than Java

Overview of a C Program

- Split into source files that are compiled separately
  - In Java, `.java` files are compiled into `.class` files
  - In C, `.c` files are compiled into `.o` (object) files
    - Generally done with the help of the `make` utility

- Define interface definitions in `.h` (header) files
- Define implementation in source files
  - Typically `.c` for C sources and `.cpp` for C++

Part 1: The Basics

- Data types
- Structs and unions
- Arrays
- Strings
- printf()
- Enums
- Typedef
- Pointers

Basic Data Types

- Variables declared with *data types*
  - e.g. int, char, float, long

```
int a, b, c;
a = b = c = 3;
```

- No boolean data type

```
while(true)  →  while(1)
```

Structs (1)

- Special data type, groups variables together

To declare:

```
struct sesamestreet {
        int    number;
        char   letter;
}; /* note the semicolon */
```

To set values:

```
struct sesamestreet st1 = { 3, 'a' };
/* the order must be correct */

struct sesamestreet st2;
st2.number = 7;
st2.letter = 'm';
```

Unions

- Like a struct, but only *one* member is allowed to have a value.
- You almost never need to use these

```
union grade {
        int     percent;
        char    letter;
} ;

union grade stud1 = {100, 'a'}; /* not allowed */

union grade stud2 = {'a'}; /* unclear */

union grade stud3;
stud3.percent = 100;   /* okay! */
```

Arrays

- Declaration is similar to Java
- Arrray size must be known at compile time (size should never be specified by a variable)

```
int nums[50];
nums[10] = 123;

/* multidimensional arrays */
int morenums[10][10];
morenums[0][3] = nums[1];

/* initialized array (size declared
implicitly) */
int somenums[] = { 1, 2, 3 };
```

Strings (or lack thereof)

- A string in C is a `char` array.

```
char firstname[10];
char fullname[20];

firstname = "george"; /* won't work! */
fullname = firstname + "bush"; /* won't work! */
```

- `char` arrays and `char*` variables are similar and can be confusing

```
const char *georgeStr = "george"; /* works fine */
const char georgeStr[] = "george"; /* won't work! */
```

- Null termination is important.

`printf()`, your new best friend

- Equivalent of `System.out.println()`

```
#include <stdio.h>

char *name = "yoda";
int age = 900;

printf("name: %s     age: %d\n", name, age);
```

OUTPUT → name: yoda   age: 900

- Use *format specifiers* for printing variables

```
%s - string
%d - int
%f - float
```

`enum`, a special type

- Used to declare and assign numerical values to a list of integer constants
- Start number defaults to ‘0’

```
enum { MON, TUE, WED, THU, FRI };
/* now, MON = 0, TUE = 1, etc.. */

enum color_t { RED = 3, BLUE = 4, YELLOW = 5 };
/* name your enum and use it as a type */

color_t myColor = BLUE;
/* can make statements like: if (myColor == RED) */

myColor = 5; /* is this allowed? */
```

`typedef` (yay for less typing)

- Giving an alternative name to a type – especially useful with `struct`s and the STL (more to come, in C++ minicourse)
- `typedef <type> <name>`
- `Example:`

```
typedef int bool_t;

bool_t happy = 1; /* 'happy' is really an int */
do {
   happy = learnMoreC();
} while(happy);
```

First look at pointers

- When a variable is declared, space in memory is reserved for it.
- A pointer represents the memory address of a variable, NOT its *value*.
- `&` ("address of" operator) gives the address of a variable
- `*` (dereference operator) evaluates to the value of the memory referred to by the pointer

Some pointer examples

```
int a, b;

a = 3;
b = a;

printf("a = %d, b = %d\n", a, b);
printf("a located at %p, b located at %p\n", &a, &b);

int *myptr = &a;

printf("myptr points to location %p\n", myptr);
printf("the value that 'myptr' points at is %d\n", *myptr);
```

Part 2: Memory Management and Functions

- more on pointers
- malloc/free
- dynamic arrays
- functions
- main arguments
- pass by: value / pointer
- function pointers

Pointers and Arrays

```
int main() {
   int array[10];
   int* pntr = array;
   for(int i=0; i < 10; i++) {
      printf("%d\n", pntr[i]);
   }
   return 0;
}
```

- We can get a pointer to the beginning of an array using the name of the array variable without any brackets.
- From then on, we can index into the array using our pointer.

Pointer Arithmetic

```
int main() {
   int array[10];
   int *pntr = NULL; // set pointer to NULL
   for(pntr = array; pntr < array + 10; pntr++) {
     printf("%d\n", *pntr); // dereference the pntr
   }
   return 0;
}
```

- We can "increment" a pointer, which has the effect of making it point to the next variable in a array.
- Instead of having an integer counter, we iterate through the array by moving the pointer itself.
- The pointer is initialized in the for loop to the start of the array. Terminate when we get the tenth index.

void *

- A pointer to nothing??
- NO!! A pointer to *anything*

```
int main() {
   char c;
   int i;
   float f;
   void *ptnr;

   pntr = &c;  //OK
   pntr = &i;  //OK
   pntr = &f;  //OK
   return 0;
}
```

- All pointers are the same size (typically 32 or 64 bits) because they all store the same kind of memory address.

when to pass by pointer

- When declaring function parameters, you can either pass by value or by reference.
- Factors to consider:
  - How much data do you have?
  - Do you “trust” the other functions that will be calling your function.
  - Who will handle memory management?

Stack vs. Heap

- Stack vs. Heap
  - Both are sources from which memory is allocated
  - Stack is automatic
    - Created for local, “in scope” variables
    - Destroyed automatically when variables go “out of scope”
  - Heap is manual
    - Created upon request
    - Destroyed upon request

Two ways to get an `int`:

- On the Stack:

```
int main() {
   int myInt; /* declare an int on the stack */
   myInt = 5; /* set the memory to five      */
   return 0;
}
```

- On the Heap:

```
int main() {
   int *myInt = (int*) malloc(sizeof(int));
                       /* allocate mem. from heap */
   *myInt = 5;         /* set the memory to five  */
   return 0;
}
```

A closer look at `malloc`

```
int main() {
   int *myInt = (int*) malloc(sizeof(int));
   *myInt = 5;
   return 0;
}
```

- `malloc` short for "memory allocation"
  - Takes as a parameter the number of bytes to allocate on the heap
  - `sizeof(int)` conveniently tells us how many bytes are in an `int` (typically 4)
  - Returns a *pointer* to the memory that was just allocated

…but we forgot something!

- We requested memory but never released it!

```
int main() {
    int *myInt = (int*) malloc(sizeof(int));
    *myInt = 5;
    printf("myInt = %d\n", *myInt);
    free(myInt);  /* use free() to release memory */
    myInt = NULL;
    return 0;
}
```

- `free()` releases memory we aren't using anymore
  - Takes a *pointer* to the memory to be released
  - Must have been allocated with `malloc`
  - Should set pointer to `NULL` when done

Don’t do these things!

- `free()` memory on the stack

```
int main() {
    int myInt;
    free(&myInt);  /* very bad */
    return 0;
}
```

- Lose track of `malloc()`’d memory

```
int main() {
    int *myInt = (int*) malloc(sizeof(int));
    myInt = 0;  /* how can you free it now? */
    return 0;
}
```

- `free()` the same memory twice

```
int main() {
    int *A = (int*) malloc(sizeof(int));
    int *B = A;
    free(A);
    free(B);  /* very bad; shame on you */
    return 0;
}
```

Dynamic arrays (1)

- Review: static arrays

```
int main() {
   int array[512];                  // static array of size 512
   for(int i = 0; i < 512; i++) { // initialize the array to 0
      array[i] = 0;
   }
   /* alternative (faster) way of clearing the array to zero
   memset(array, 0, sizeof(int) * 512);
   */
   return 0;
}
```

- **Problem:** Size determined at compile time. We must explicitly declare the exact size.

Dynamic arrays (2)

- **Solution:** use `malloc()` to allocate enough space for the array at run-time

```
int main() {
   int n = rand() % 100;                       /* random number between 0 and 99 */
   int *array = (int*) malloc(n * sizeof(int));  /* allocate array of size */
   for(int i = 0; i < n; i++)       /* we can count up to (n-1) in our array */
      array[i] = 0;

   free(array);                                 /* make sure to free the array! */
   array = NULL;
   return 0;
}
```

Using `malloc` for "strings"

- Since "strings" in C are just arrays of `char`s, `malloc` can be used to create variable length "strings"

```
int main() {
   int n = rand() % 100;        // random number between 0 and 99
   char *myString = (char*) malloc(n);

   /* a char is one byte, so we don't have to use sizeof */
   for(int i = 0; i < n - 1; i++) {
      myString[i] = 'A';

   printf("myString: %s\n", string);
   myString[n - 1] = '\0';   /* must be null terminated! */
   free(myString);           /* make sure to free the string! */
   myString = NULL;
   return 0;
}
```

mallocing structs

- We can also use `malloc` to allocate space on the heap for a `struct`

```
struct foo_t {
   int     value;
   int[10] array;
};

int main() {
   /* sizeof(foo_t) gives us the size of the struct */
   foo_t *fooStruct = (foo_t*) malloc(sizeof(foo_t));
   fooStruct->value = 5;

   for(int i = 0; i < 10; i++) {
      fooStruct->array[i] = 0;
   }

   /* free the struct. DON'T need to also free the array */
   free(fooStruct);
   fooStruct = NULL;
   return 0;
}
```

Functions

- So far, we've done everything in main without the use of functions
- But we have *used* some functions
  - `printf` in "hello world"
  - `malloc` for allocating memory
- C functions are similar to methods in Java
  - In Java, all methods are associated with a particular class. In C, all functions are global
  - In Java, you can overload methods. In C, you can't

Our first function

```
int foo(int a, int b) {
   return a + b;
}

int main() {
   int sum = foo(1, 2);
   return 0;
}
```

- First we define the function "`foo`"
  - `foo` will return an `int`
  - `foo` takes two `int`s as arguments
- In `main`, we call `foo` and give it the values: 1 and 2
  - `foo` is invoked and returns the value 3

Order matters

- In Java, the order that methods are defined doesn't matter
- Not true in C. Look what happens when we flip the order around:

```
int main() {
    int sum = foo(1, 2);
    return 0;
}

int foo(int a, int b) {
    return a + b;
}
```

- Compiling the above code yields the following errors:

```
test.c: In function 'int main()':
test.c:2: error: 'foo' undeclared (first use of this function)
…
test.c: In function 'int foo(int, int)':
test.c:6: error: 'int foo(int, int)' used prior to declaration
```

Definition vs. declaration

- In C, we can *declare* functions using a “function prototype” without *defining* what happens when the function is called
- This tells the compiler about the existence of a function so it will expect a definition at some point later on.

```
int foo(int, int);      /* function prototype */

int main() {
   foo(1, 2);
   return 0;
}

int foo(int a, int b) {
   return a + b;
}
```

- The program will now compile

Declarations

```
int foo(int, int);
```

- In a function declaration, all that is important is the *signature*
  - function name
  - number and type of arguments
  - return type

- We do not need to give names to the arguments, although we can, and should (for clarity)

- We can also declare `struct`s and `enum`s without defining them, but this is less common

void* (*function) (point, ers);

- In C, we can treat functions just like types
- We can pass around "function pointers" just like regular pointers.
- Since all functions have memory addresses, we're really not doing anything different here.

```
int foo(int a, int b) {
   return a + b;
}

int main() {
   int (*funcPntr)(int, int) = &foo;
   int sum = funcPntr(1, 2);  /* sum is now 3 */
   return 0;
}
```

Let's break it down

```
int (*funcPntr)(int, int) = &foo;
```

- Function pointer syntax is weird, and not exactly consistent with the rest of C. You just have to get used to it.
- Starting from the left…
  - `int`: the return type
  - `(*funcPntr)`: the `*` denotes that this is a function *pointer*, not a regular function declaration. `funcPntr` is the name of the pointer we are declaring
  - `(int, int)`: the argument list
  - `= &foo`: we are assigning the address of `foo` to the pointer we just declared

…if you thought that was ugly

- What is being declared here?

```
void*(*func)(void*(*)(void*), void*);
```

- First person with the correct answer wins a delicious pack of **Skittles®**

The Answer

```
void*(*func)(void*(*)(void*), void*);
```

- We are declaring a function pointer called `func`. `func` is a pointer to a function which returns a `void*` (un-typed pointer), and takes two arguments. The first argument is a function pointer to a function that returns a `void*` and also takes a `void*` as its only argument. The second argument of the function pointed to by `func` is a `void*`.
- Inconceivably contrived way to set a pointer to null:

```
void* foo(void* pnt) {
  return pnt;
}
void* bar(void*(*func)(void*), void* pntr) {
  return func(pntr);
}
int main() {
  void* (*func)(void*(*)(void*), void*) = &bar;    /* here's the declaration */
  void* pntr = func(&foo, NULL);                    /* pntr gets set to NULL */
  return 0;
}
```

`main` arguments

- Remember those funky arguments that were passed to main in the hello world program?

```
#include <stdio.h>

int main(int argc, char **argv) {
  printf("Hello, world!\n");
  return 0;
}
```

- Main arguments are a simple way to pass information into a program (filenames, options, flags, etc.)

`argc` and `argv` ?

- `argc` stands for "argument count"
  - An `int`, representing the number of arguments passed to the program
- `argv` stands for "argument vector"
  - A `char**`, meaning an array (size `argc`) of null terminated strings.
  - The first (0^{th}) null terminated string is always the name of the executable

Here's a program which simply prints out the arguments given to it

```
#include <stdio.h>

int main(int argc, char **argv) {
    for(int i = 1; i < argc; i++) { /* start at 1, since arg 0 is name of program */
        printf("%s\n", argv[i]);
    }
    return 0;
}
```

- Enters the loop once for every argument
- Prints out each argument, adds a newline

```
> gcc printArgs.c -o printArgs
> printArgs how are you today?
how
are
you
today?
```

Part 3: Making Projects

- Header files
- Makefiles
- Input / Output functions
- `const` / `static` keywords
- `gcc` basics
- Common errors (segfaults, etc.)
- Tips for compiling code

Header Files

- Use as an interface to a particular .c file. It's always a good idea to separate interface from implementation
- Put the following in header files
  - `#define` statements
  - `extern` function prototypes
  - `typedef` statements

Example Header File

```
#ifndef __HELLO_WORLD__
#define __HELLO_WORLD__

#define TIMES_TO_SAY_HELLO 10

extern void printHello(void);

#endif // __HELLO_WORLD__
```

Header File Do's

- Always enclose header files with `#ifndef`, `#define`, and `#endif` preprocessor commands (called header guards)
  - This makes it ok to include the header file in multiple places. Otherwise, the compiler will complain about things being redefined.
- Make sure function prototypes match functions
- Double-check semi-colons; they are necessary after function prototypes

Header File Don'ts

- Don't `#include` files if you can avoid it; you should use `#include` in .c files instead
- Never `#include` a .c file
- Don't ***define*** functions inside your header file unless you have a good reason.
- Don't use a single header file for multiple .c files

Makefiles

- Makefiles save you typing
- Can reduce compile time by only compiling changed code
- Can be extremely complicated
- But existing Makefiles are easy to edit
- And it's easy to write quick-n-dirty ones

Sample Makefile

```
EXEC_NAME = helloWorld

all: main.o
	gcc -g -o $(EXEC_NAME) main.o

main.o: main.c
	gcc -g -c main.c -o main.o

clean:
	rm -rf main.o $(EXEC_NAME)
```

More Makefiles

- Rule names like “all” and “clean” and “main.o”
- “all” and “clean” are special – most rule names should be filenames
- Dependencies are listed after the colon following the rule name
- Operations are listed underneath; must be preceded by <u>a tab</u>

Input / Output functions

- `printf` – takes a format string and an “unlimited” number of variables as arguments; prints to `stdout`
- `scanf` – similar to `printf`, but it takes pointers to variables and fills them with values received from `stdin`
- `read` / `write` – lower level system calls for getting and printing strings

printf/scanf example

```
#include <cstdio>

int main ()
{
   char  name[100];    /* to hold the name entered */
   int   age;          /* to hold the age entered */

   printf("Enter your name: ");
   scanf("%s", name);
   printf("Enter your age: ");
   scanf("%d", &age);
   printf("%s is %d years old\n", name, age);

   return 0;
}
```

`printf/scanf` example cont.

(bold represents data typed in by the user)

> > ./printfScanfExample
> > Enter your name: **Andy**
> > Enter your age: **1000000**
> > Andy is 1000000 years old

`const`/`static` keywords

- Declaring a variable `const` tells the compiler its value will not change
- `static` limits the usage of a variable or function to a particular .c file
  - `static` functions cannot be declared extern in header files
  - `static` variables retain their values between function calls

gcc basics

- gcc is C compiler
  - -Wall turns on all warnings
  - -g adds debugging info
  - -o specifies output filename
  - -c just builds a .o (object) file
    - does not link symbols into an executable

```
gcc -Wall hello.c -o helloWorld
```

Common errors

- Segfault
  - Indicates a problem with memory access; dereferencing a `NULL` pointer can cause this
- Linker error
  - Usually a problem with a Makefile and / or `gcc` commands. Can often occur if you declare, but fail to define a function
- Multiple definitions of functions
  - Often caused by failure to include header guards (`#ifndef, #define, #endif`) in header files

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A Crash Course in C++:
Procedural (not Object-Oriented) Part

- In general, C++ was designed to be highly compatible with existing C programs.
- Keywords: addition of **class**, **const**, **delete**, **friend**, **inline**, **new**, **operator**, **private**, **protected**, **public**, **template**, **this**, **virtual**, etc.

Comments

- Any text from // to the end of the current line is ignored.
- Use /* … */ for multi-line comments.
- The /* … */ comments do not nest.

Input / Output

- The iostream header file must be included in all source code using stream input and output operations.
- The special object endl prints a newline character and flushes the stream buffer.
- Operations to the same stream can be chained.

Input / Output (2)

- ***#include <iostream.h>***
  int i = 5;
  cout << i;
  cout << "i has the value " << i << "\n";
  is the equivalent of
  printf("i has the value %d\n", i);
- ***int i;***
  char array[80];
  cin >> i >> array;
  works like
  scanf("%d%s", &i, array);

Input / Output (3)

- Data can be sent to a file instead of standard output.

```
#include <fstream.h>
ofstream os(“output.dat”);
os << “The value of pi is approxi. “
    << 3.14159 << endl;
```

Type and Var Declarations

- A type or variable declaration in C++ can go anywhere that a statement can go. It does not have to be at the ***top*** of a block.
- Constants are prefixed by const.

  const double pi = 3.14159265358979323846;

Scope Resolution Operator ::

- Bypass the search in the local and class scope and refer to a global name.

```
int x = 0;
main() {
        int x = 1; printf("::x = %d\n", ::x);           // 0
        {
                int x = 2; printf("::x = %d\n", ::x);   // 0
        }
}
```

"inline" Functions

- **For the sake of efficiency, generally with short functions.**
- **Unlike a macro, an inline does not have side effects.**

#define toupper(c) { islower(c) ? c + 'A' - 'a' : c }

toupper(*p++) expands to

{ islower(*p++) ? *p++ + 'A' - 'a' : *p++ }

inline toupper(int c) { return islower(c) ? c + 'A' - 'a' : c; }

"inline" Functions (cont)

- “inline” functions are of internal linkage (i.e., definition scope is local to that file).

“void” Pointers

*char *cp;* // integer pointer

*void *vp;* // generic pointer

cp = vp; // legal in C, illegal in C++

*cp = (char *) vp;*

int foo(); is equivalent in C++ to *int foo(void);*

“struct”

```
struct tree {
    struct tree *next;      // in C
};

struct tree {
    tree *next;             // in C++
};

struct A { struct B *p; };  // legal in C
struct B { struct A *q; };
```

“struct” (cont)

```
struct A { B *p; };      // illegal in C++
struct B { A *q; };
```

solving the problem by

```
struct B;   // tell the compiler that B is a struct
struct A { B *p; };
struct B { A *q; };
```

“union”

- ***struct {***
```
struct {
	union {
		int    i;
		double f;
	}
} num;
```
- Refer *"num.i"* and *"num.f"* without calling a name for the union field, as would be required in C.

Dynamic Memory Allocation

- Using the "**new**" and "**delete**" keywords. You can call "malloc" and "free", but you should not.

int *ip = new int; delete ip;

int *ia = new int [10]; delete [10] ia;

or delete [] ia; /* not recommended */

Default Arguments

- ***int foo(int a = 1, int b = 2);***

  /* a call to *foo()* is the same as *foo(1, 2);*

  a call to *foo(3)* is the same as *foo(3, 2);*

  a call to *foo(3, 4)* is just what it says */

- Only trailing arguments can be supplied in this way. Therefore,

  int foo(int a = 1, int b); is illegal.

References

- ***int x;*** // an int
  int &rx = x; // a reference to an int
  /* translated as "reference to" rather than "pointer to". */

- All reference variables must be made to reference a real variable at declaration time when using the ***assignment-like*** syntax.

References (cont)

int *p = ℞ // puts the address of *x* into *p*

int *p = rx; // illegal

int *q = p;

int *&rp = p;

// *rp* is a reference to an int pointer

int &*rp; // illegal

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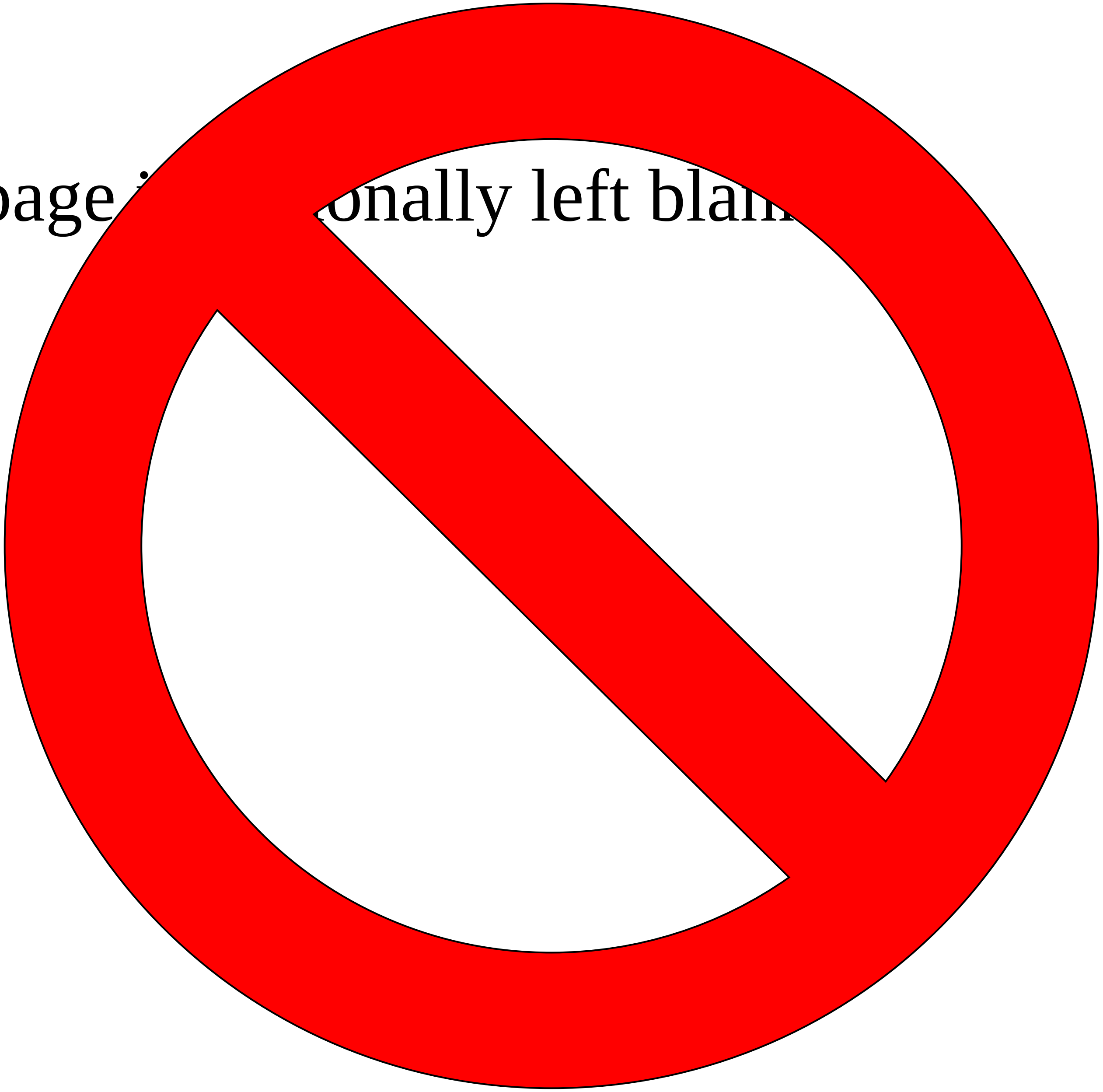

Chapter 2 - C++ As A "Better C"

2.1 Introduction

– Object based programming (classes, objects, encapsulation)
– Object oriented programming (inheritance, polymorphism)
– Generic programming (class and function templates)

2.2 C++

- C++
  - Improves on many of C's features
  - Has object-oriented capabilities
  - Superset of C
    - Can use a C++ compiler to compile C programs

2.3 A Simple Program: Adding Two Integers

- Differences
  - **`<iostream>`** - input/output stream header file
  - Return types - all functions must declare their return type
    - C does not require it, but C++ does

2.3 A Simple Program: Adding Two Integers (II)

- Output
  - **`std::cout << "hi";`**
    - Puts **`"hi"`** to **`std::cout`**, which prints it on the screen
- Input
  - **`std::cin >> myVariable;`**
    - Gets stream from keyboard and puts it into **`myVariable`**

2.3 A Simple Program: Adding Two Integers (III)

- **`std::endl`**
  - Stream manipulator - prints a newline and flushes output buffer
- Cascading
  - Can have multiple **`<<`** or **`>>`** operators in a single statement

```
std::cout << "Hello " << "there" << std::endl;
```

2.4 C++ Standard Library

- C++ programs built from
  - Functions
  - Classes

```cpp
// Fig. 15.1: fig15_01.cpp
// Addition program
#include <iostream>

int main()
{
   int integer1, integer2, sum;           // declaration

   std::cout << "Enter first integer\n";  // prompt
   std::cin >> integer1;                  // read an integer
   std::cout << "Enter second integer\n"; // prompt
   std::cin >> integer2;                  // read an integer
   sum = integer1 + integer2;             // assignment of sum
   std::cout << "Sum is " << sum << std::endl; // print sum

   return 0;   // indicate that program ended successfully
}
```

```
Enter first integer
45
Enter second integer
72
Sum is 117
```

Outline

1. Load <iostream>

2. main

2.1 Initialize variables integer1, integer2, and sum

2.2 Print "Enter first integer"

2.2.1 Get input

2.3 Print "Enter second integer"

2.3.1 Get input

2.4 Add variables and put result into sum

2.5 Print "Sum is"

2.5.1 Output sum

2.6 exit (return 0)

Program Output

2.6 Inline Functions

- Function calls
  - Cause execution-time overhead
  - Qualifier **`inline`** before function return type "advises" a function to be inlined
    - Puts copy of function's code in place of function call
  - Speeds up performance but increases file size
  - Compiler can ignore the **`inline`** qualifier
    - Ignores all but the smallest functions

```
inline double cube( const double s )
   { return s * s * s; }
```

- Using statements
  - By writing **`using std::cout;`** we can write **`cout`** instead of **`std::cout`** in the program
  - Same applies for **`std::cin`** and **`std::endl`**

2.7 References and Reference Parameters

- Reference parameter alias for argument
  - Use **&**

```
void change(int &variable)
  {
        variable += 3;
  }
```

  - Adds 3 to the original variable input

2.7 References and Reference Parameters (II)

- Dangling references
  - If a function returns a reference to a variable, make sure the variable is **`static`**
    - Otherwise, it is automatic and destroyed after function ends

2.8 Default Arguments and Empty Parameter Lists

- If function parameter omitted, gets default value
  - If not enough parameters specified, rightmost go to their defaults

- Set defaults in function prototype

```
int myFunction( int x = 1, int y = 2, int z = 3 );
```

2.8 Default Arguments and Empty Parameter Lists (II)

- Empty parameter lists
  - In C, empty parameter list means function takes any argument
    - In C++ it means function takes no arguments
  - To declare that a function takes no parameters:
    - Write **`void`** in parentheses
    - Prototypes:

```
void print1( void );
void print2();
```

2.9 Unary Scope Resolution Operator

- Unary scope resolution operator (**`::`**)
  - Access global variables if a local variable has same name
  - Instead of **`variable`** use **`::variable`**
- Stream manipulators
  - Can change how output is formatted
  - **`setprecision`** - set precision for **`float`**s (default 6 digits)
  - **`setwidth`** - set field width

```
// Fig. 15.9: fig15_09.cpp
// Using the unary scope resolution operator
#include <iostream>

using std::cout;
using std::endl;


#include <iomanip>

using std::setprecision;

using std::setw;

const double PI = 3.14159265358979;

int main()
{


   cout << setprecision( 20 )
        << "  Local float value of PI = " << PI
        << "\nGlobal double value of PI = " << ::PI << endl;

   cout << setw( 28 ) << "Local float value of PI = "

        << setprecision( 10 ) << PI << endl;
   return 0;
}
```

Outline

1. Initialize global const PI

1.1 cast global PI to a local float

2. Print local and global values of PI

2.1 Vary precision and print local PI

Outline

```
  Local float value of PI = 3.141592741012573242
Global double value of PI = 3.141592653589790007
  Local float value of PI = 3.1415927410
```

Program Output

2.10 Function Overloading

- Function overloading:
  - Functions with same name and different parameters
  - Overloaded functions should perform similar tasks
    - Function to square **`int`**s and function to square **`float`**s

```
int square( int x) {return x * x;}
float square(float x) { return x * x; }
```

  - Program chooses function by signature
    - Signature determined by function name and parameter types

```
// Fig. 15.10: fig15_10.cpp
// Using overloaded functions
#include <iostream>

using std::cout;
using std::endl;

int square( int x ) { return x * x; }

double square( double y ) { return y * y; }

int main()
{
   cout << "The square of integer 7 is " << square( 7 )
        << "\nThe square of double 7.5 is " << square( 7.5 )
        << endl;

   return 0;
}
```

Outline

1. Define overloaded function

2. Function calls

```
The square of integer 7 is 49
The square of double 7.5 is 56.25
```

Program Output

2.11 Function Templates

- Function templates
  - Compact way to make overloaded functions
  - `template < class T >  // or template< typename T >`

```
T square( T value1)
{
   return value1 * value1;
}
```

  - **`T`** replaced by type parameter in function call

```
int x;
int y = square(x);
```

    - If **`int`** parameter, all **`T`**'s become **`int`**s
    - Can use **`float`**, **`double`**, **`long`**...