CS3157: Advanced Programming

Lecture #4

June 5

Shlomo Hershkop

shlomo@cs.columbia.edu

1

Announcements

- Will move makeup class from June 9 to June 23, will allow us to do any catch up necessary to wrap up C/CPP track
- Will allow more hands on during the class time
- Probably will meet 3ish

- If you are having issues with CGI, please email or see me asap
- How comfortable are you with regular expressions?

2

Announcements

- Welcome to the next phase of the course (cue dramatic music) later today
- C
- not B or A

3

Announcements

- HW1 is going to be due soon
- Office hours + email + IM
- Reading: please wrap up the perl reading and start on C (make sure you have a book (see class page for reading list)

4

Debugging process

- This is a general programming idea:
- We have some code instructions, would like to examine them as they run:

1. Output test cases for each line (hope it doesn't crash)
2. Run it within another program allowing us to fine tune control of running process and interaction with the running environment

5

Running perl debugger

- Can use a graphical based debugger
  – Demo : Eclipse debug process!
- Should learn to use the text based one…never know when it can come in usuafull (actually it will, once we start c…
- Perl –d nameofscript.pl
- Perl –d –e 0

6

What you see

- Current scope (main::)
- What line it will execute next
- No need for comma, ‘enter’ key is a signal

- Can do many things
  - Evaluate expressions
  - Check variables
  - Step through code

7

Common commands

- h
  - Get help
- x variable [, var2, var3..]
  - Examine a variable (or set)
- p
  - To print something
- V ???
  - Examine all variables in scope/package ?? (example main)
- s
  - Step through next instruction (including sub)
- n
  - Jump over subs

8

Today

- Lets wrap up perl
- Some advanced stuff
- Will intro and begin C

9

Advanced topics

- Multi threading
  - Fork processes
    - this is not an eating utensil
  - Process space
    - not parking space
- Communication between programs
  - Pipes
  - Sockets

10

Testing Environment

- One word on testing in the real world:
  - need as much as you can get!

- Large projects
- Bugs cost time and money
- Bugs hurt morale
- Human are programmers…humans make mistakes
- Formula for this actually

11

Automated testing

- Humans hate testing…
- Fast verification that new feature has not broken code
- Verify all code on a regular basis
- No grumble if test to rerun test ☺

12

packages

- There are packages out there (Test::Simple and Test::Harness) to automatically run tests
- Verify what happens on good/bad input
- Verify variables/method behavior
- Usually .t files have tests

13

Advanced Random Stuff

- $| =1
  - flushes the output to make sure you see what is being printed right away
- Can choose your own delimiters when matching
- m#shlomo#
- s!cheese!milk!
- s{something}(else)

14

Slicing

- similar to ranges, can fetch set of values from hash by preceding hash variable with @ sign

- `%phonebook;`
- `#do bunch of reads/inserts`
- `@numbers = @phonebook{$n1, $n2, $n3};`

- `@phonebook{$n1, $n2} = (718,516);`

15

What is this exactly?

```
$animals = [
        'dog', 'cat',
        'duck', 'cow',
        'pig', 'lizard'
    ];

    $sounds  = {
        dog  => 'bark',
        cat  => 'meow',
        duck => 'quack'
    };

    @domestic = @{$sounds}{@{$animals}[0,1]};
```

16

Pragma

- Like most other languages, perl allows to drop hints to the compiler which is interpreting our code

- use warnings;
- use strict;

- Can also be done lexically
- and can fine tune control of a specific pragma

17

Example

```
#beginning of code
use warnings;

#bunch of stuff
{
no warnings;
#bunch of other stuff
}
use warnings;
#bunch of other other stuff
```

18

use strict ‘vars’

- Normally Perl allows you to create variables on the fly
- Any idea of their scope ?

- One of 3 strict modes

19

Something Interesting:

- Can have a perl program with
  $name
  @name
  %name

- All in the same scope
- Perl will never mix them up (that is our job)

20

- How does he do it ?

21

Symbol Table

- This is a data structure which maps variables to information needed by compiler to handle it
- Perl maps variables names to Glob type
- Glob type matches to each variable type
- Each namespace has own symbol table
- Will come back to this later

22

Short Example

```
sub dispSymbols {
    my($hashRef) = shift;
    my(%symbols);
    my(@symbols);
    %symbols = %{$hashRef};
    @symbols = sort(keys(%symbols));
    foreach (@symbols) {
        printf("%-10.10s| %s\n", $_, $symbols{$_});
    }

}

dispSymbols(\%Foo::);

package Foo;
    $bar = 2;
    sub baz {
        $bar++;
    }
```

23

perldoc

- perldoc –f function
- perldoc –q faq

- b = move up page
- space = move down
- q = quit

24

Perl Skills

- We’ve covered a lot of perl skills since beginning the course
- What you should have
- What we haven’t covered
- Where to take perl from here

25

Shift gears

- Will now start C component of the course
- This is not C#
  - any ideas why it is called C#

26

C Phase

- Intro to C
  - Background
  - *Compiling*
  - *Basic data structures*
  - *Basic I/O*
  - *Types conversion*
  - *Loops*
  - *Branching*

27

Roadmap

- How this all fits together
  - We covered perl (duct-tape programming)
  - CGI programming USING perl

  - Will now move to c, which is a more low level programming language
  - Will learn to work with c, and then CGI+c
  - Then CGI+perl+c etc
  - Get to use the best of any programming language in a project

28

Why Learn C ?

- C provides stronger control of low-level mechanisms such as memory allocation, specific memory locations

- C performance is usually better than Java and usually more predictable (very task dependant)

29

Why Learn c continued

- Java hides many details needed for writing code, but in C you need to be careful because:
  - memory management responsibility left to you
  - explicit initialization and error detection left to you
  - generally, more lines of (your) code for the same functionality
  - more room for you to make mistakes

- Most older code is written in C (if you are lucky) might need there skills if you will be hired to upgrade or interface with in place tech

30

Background

C

– Dennis Ritchie in late 1960s and early 1970s
– Systems programming language
– Goal: make OS portable across hardware platforms
– Not necessarily for real applications—could be written in Fortran or PL/I

31

Background II

C++

– Bjarne Stroustrup (Bell Labs), 1980s
– object-oriented features

Java

– James Gosling in 1990s, originally for embedded systems
– object-oriented, like C++
– ideas and some syntax from C

32

Background III

- C is early-70s, procedural language

- C advantages:
  - direct access to OS primitives (system calls)
  - more control over memory
  - fewer library issues— just execute

- C disadvantages:
  - language is portable, but APIs are not
  - no easy graphics interface
  - more control over memory (i.e., memory leaks)
  - pre-processor can lead to obscure errors

33

C vs Java

- Java program
  - collection of classes
  - class containing main method is starting class
  - running java StartClass invokes StartClass.main method
  - JVM loads other classes as required

- C program
  - collection of functions
  - one function – main() – is starting function
  - running executable (default name a.out) starts main function
  - typically, single program with all user code linked in— but can be dynamic libraries (.dll, .so)

34

C vs Java …Running

- Java programs are compiled and interpreted:
  - javac converts foo.java into foo.class
  - class file is not machine-specific— it is byte code
  - byte code is then interpreted by JVM
  - and each JVM is machine-specific

- C programs are compiled into object code and then linked into executables

(to allow for multiple object files and libraries to be compiled together into one program):
  - gcc compiles foo.c into foo.o and then links foo.o into a.out
  - you can skip writing foo.o if there is only one object file used to create your executable
  - a.out is executed by OS and hardware
  - the C compiler is machine-specific, creating code that executes on specific OS/hardware

35

Outline

- Working with C
  - Compiling
  - Basic data structures
  - Basic I/O
  - Types conversion
  - Loops
  - Branching
  - compiling
  - Control flow
  - Arrays
  - Pointers
  - strings
  - string library
  - string tokenizing
  - Memory allocation intro

- Reading
  - K & R skim 1-3.
  - Read: K & R 4.1-4.3, 7.1-7.5)
  - Deitel book: online posted!

36

Code Example

- Java

```
public class hello {
    public static void main( String[] args ) {
            System.out.println( "hello world! " );
    }
}
```

- C

```
#include <stdio.h>
    int main() {
    printf( "hello world!" );
    return 0;
    }
```

37

- #include <stdio.h> to include header file stdio.h
- # lines processed by pre-processor
- No semicolon at end of pre-processor lines
- Lower-case letters only— C is case-sensitive
- int main() { ... } is the only code executed
- printf(" /* message you want printed */ ");
- \n = newline, \t = tab
- \ (escape character) in front of other special characters

38

Brief Overview

- For the c section of the course, here are some tips

1. Write your course code
2. Try to compile
3. Debug compile bugs, goto step 1
4. Try step 2 again
5. Run debugger to catch run time bugs
6. Run memory profiler to catch memory bugs
7. Have running product
8. Add one last cool feature and jump to step 3 ☺

39

How to make your c code run

- gcc is the C compiler we'll use in this class
- it's a free compiler from Gnu (i.e., Gnu C Compiler)
- gcc translates C program into executable for some target machine platform
- default file name a.out
- behavior of gcc is controlled by command-line switches
- Will create files to help in compiling out programs

$ gcc hello.c

$. a.out

hello world!

40

Compiling your program

two-stage compilation
1. pre-process and compile: gcc -c hello.c
2. link: gcc -o hello hello.o

linking several modules:

```
>gcc -c a.c
    == a.o
>gcc -c b.c
    == b.o
>gcc -o hello a.o b.o
    == hello
```

using a library, for example the “math” library (libm):

```
>gcc -o calc calc.c -lm
```

41

C control flow

- blocks are enclosed in curly brackets
- functions are blocks
- main() is a function
- blocks have two parts:
  - variable declaration (“data segment”)
  - code segment
- in C, variables have to be declared before they are used
- initializations can occur at the end of the declaration section, but before the code section

42

Break down of running program

- A program is a collection of functions
- The function named main is launched first
- when main ends, your program is done
  – or can crash the system earlier ☺

43

First c program

```
/* First c program */

int main(void){

  printf("Hello Everyone\n”);

  return 0;
}
```

44

compile

- gcc –o test simple.c
- ./test

45

Steps to running program

- Write code
  – Platform independent (for the most part)
- Preprocess the code
  – Understand and reinterpret parts
- Compile the code generate object files
  – Turn it into machine code, use optimizers
- Link object files to executable
- Load executable to running code

46

Your Own Environment

- Windows:
  - can use cygwin (free) with gcc (free)
  - gcc 3.4.4.1
- Mac
  - get gcc
- Unix:
  - cunix has it already
  - gcc 4.1.1

47

Split personalities

- In c and cpp normal to divide definition of code (header files .h) and working code (.c files)

- So will have function declaration
- `int foo();`
- And function definitions
- `int foo(){. . . . . }`

48

A macro

- A macro is a section of code, which has been given a name
- Can do a lot with macros

- When you use the name, the preprocessor will replace it with the code contents
- Compiler only sees changed code

49

c pre-processor

- the C pre-processor (cpp) is a macro-processor which
  - manages a collection of macro definitions
  - reads a C program and transforms it for the compiler
  - pre-processor directives start with # at beginning of line
- used to:
  - include files with C code (typically, “header” files containing definitions; file names end with .h)
  - define new macros
  - conditionally compile parts of file (later – not today)
- gcc -E shows output of pre-processor
- Can be used independently of compiler

50

Example

- `#define BUFFER_SIZE 1024`

- Convention to use upper case
- Will be replaced exactly with the stuff after the name

- `int x = BUFFER_SIZE;`

- Why would this be useful ?

51

pre-processor II

- file inclusion

```
#include "filename.h"
#include <filename>
```

- inserts contents of filename into file to be compiled
- "filename.h" relative to current directory
- <filename> relative to /usr/include or in default path (specified by -I compiler directive); note that file is named verb+filename.h+

- import function prototypes (in contrast with Java import) examples:

```
#include <stdio.h>
#include "mydefs.h"
#include "/home/shlomo/programs/defs.h"
```

52

Comments

/* any text until this */

- convention for longer comments:

```
/*
* AverageGrade()
* Given an array of grades, compute the average.
*/
```

- Don’t get carried away with comment boxed
- **** boxes - hard to edit, usually look ragged.

53

Where to begin?

- Lets talk about what are the primitive data types:

54

Data Types

- Very important when trying to resource memory/cpu
- float has 6 bits precision
- double has 15 bits precision
- Range can change depending on machine type, generally int is native to the machine type

Type	Bits
char	8
short	16
int	32
long	32
float	32
double	64

55

Types II

- unsigned char
- unsigned short
- unsigned int
- unsigned long

- Byte size is the same, but can now have greater range
- Can look at /usr/include/limits.h

56

Use in functions

- Variables must be declared in the beginning of the function to be used

- Common mistake: forgetting to declare at top of function

57

Intro arrays

- An array is a group of memory locations with the same name and type
- To get to a particular element in the array we need
  - data type
  - name
  - Length or position
- Array length can be determined:
  - statically— at compile time (when we code)
    - e.g., char str1[10];
  - dynamically— at run time (more on this later)
    - e.g., char *str2;

58

- Defining a variable is called “allocating memory” to store that variable
- Defining an array means allocating memory for a group of bytes,
- Individual array elements are indexed
  - starting with 0
  - ending with length -1
- Indices follow array name, enclosed in square brackets ([ ])

  e.g., name[25]

59

- Initializing the arrays are your problem

int a[3];

….

X = a[1]; ……

- Bound checking is your problem

printf(“%d”,a[100]); …..

60

int C[5]

C[0]	-45
C[1]	0
C[2]	17
C[3]	4
C[4]	82

We can say for example

X = C[4] / 5;

Declarations:

int b[100],v[3];

61

More arrays

- Can also create arrays in the following manners

1. int a[] = {1,2,3};
2. int b[3] = {6,3,7};
3. int n[10] = {0};

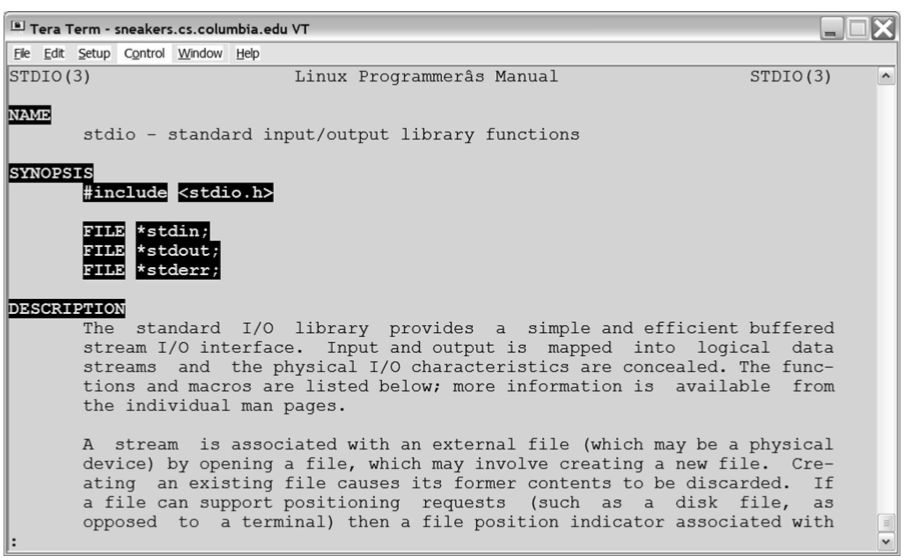
Note you need to initialize the array elements, 3 is a trick case.

62

Library

- Access libraries using the include statement
- Generally include header files
- Compiler links them automatically
- Example:
  - Standard input/output: stdio.h
  - To look up information use the man page: `man stdio`

63



Tera Term - sneakers.cs.columbia.edu VT

File Edit Setup Control Window Help

```
STDIO(3)                   Linux Programmerâs Manual                  STDIO(3)

NAME
       stdio - standard input/output library functions

SYNOPSIS
       #include <stdio.h>

       FILE *stdin;
       FILE *stdout;
       FILE *stderr;

DESCRIPTION
       The  standard  I/O  library  provides  a  simple and efficient buffered
       stream I/O interface.  Input and output is  mapped  into  logical  data
       streams  and  the physical I/O characteristics are concealed. The func-
       tions and macros are listed below; more information is  available  from
       the individual man pages.

       A  stream  is associated with an external file (which may be a physical
       device) by opening a file, which may involve creating a new file.  Cre-
       ating  an existing file causes its former contents to be discarded.  If
       a file can support positioning  requests  (such  as  a  disk  file,  as
       opposed  to  a terminal) then a file position indicator associated with
:
```

64

stdio.h

- Access stdio functions by
  - using #include <stdio.h>
  - compiler links it automatically

- defines stdin, stdout, stderr
- use for character, string and file I/O (later)

- printf

65

printf Function

- The way printf works is it takes a format to print out and then the data to add to the format

- One or more of the following:
  - %[flags][width][.precision][modifiers]type

  - “%d”
    - Means a single number
  - “%d %d %d”
    - ??

66

- printf (“%d %d”,a,b);

67

stdio.h : printf, type specifier

- int printf(const char *format, ...) formatted output to stdout

c	Character	a
d or i	Signed decimal integer	392
e	Scientific notation (mantise/exponent) using e character	3.9265e2
E	Scientific notation (mantise/exponent) using E character	3.9265E2
f	Decimal floating point	392.65
g	Use shorter %e or %f	392.65
G	Use shorter %E or %f	392.65
o	Signed octal	610
s	String of characters	sample
u	Unsigned decimal integer	7235
x	Unsigned hexadecimal integer	7fa
X	Unsigned hexadecimal integer (capital letters)	7FA
p	Address pointed by the argument	B800:0000
n	Nothing printed. The argument must be a pointer to integer where the number of characters written so far will be stored.	

68

printf flags

- %[flags][width][.precision][modifiers]type

-	Left align within the given width. (right align is the default).
+	Forces to preceed the result with a sign (+ or -) if signed type. (by default only - (minus) is printed).
Blank	If the argument is a positive signed value, a blank is inserted before the number.
#	Used with o, x or X type the value is preceeded with 0, 0x or 0X respectively if non-zero.
	Used with e, E or f forces the output value to contain a decimal point even if only zeros follow.
	Used with g or G the result is the same as e or E but trailing zeros are not removed

69

example

```
int class_size = 35;
char class_name[15] = “3157 adv prog”;

printf(“Welcome to our test program\n”);


printf( “the %s class size is %d”,
        class_name, class_size);
```

70

int array

```
#include <stdio.h>
#define MAX 6

int main( void ) {
int arr[MAX] = { -45, 6, 0, 72, 1543, 62 };
int i;

for ( i=0; i<MAX; i++ ) {
    printf( "[%d] = %d \n", i, arr[i] );
}

} /* end of main() */
```


stdio.h: scanf

- `int scanf(const char *format, ...)`

Example: scanf/printf

```
#include <stdio.h>
void main( void ) {
int n = 0; /* initialization required */
printf( "how much wood could a woodchuck chuck\n" );
printf( "if a woodchuck could chuck wood?" ); /* prompt user
   */
scanf( "%d",&n ); /* read input */
printf( "the woodchuck can chuck %d pieces of wood!\n",n
   );
return;
}
```

73

output

```
$ a.out
how much wood could a woodchuck chuck
if a woodchuck could chuck wood? 12345
the woodchuck can chuck 12345 pieces of
   wood!
```

74

Loops

- loops in C are just like in Java
- there are 2 methods for looping:
  - counter-controlled (loop for a fixed number of times)
  - sentinal-controlled (loop while a condition is true)
- there are 3 statements for implementing the 2 methodologies:
  - for
  - while
  - do...while
- as always: beware the infinite loop!
- Ctrl-C interrupts your executing C program

75

Branching

- branching in C is just like in Java
- there are 2 ways to do branching:
  - if/else
  - switch
- questions:
  - which is more flexible and powerful?
  - one can always be translated into the other, but not the other way around— which is which?

76

Pointer power

- Variables that contain memory addresses as their values
- Data types we've learned about in C use direct addressing
- Pointers facilitate indirect addressing
- Declaring pointers:
  - pointers indirectly address memory where data of the types we've already discussed is stored (e.g., int, char, float, etc.)
  - declaration uses asterisks (*) to indicate a pointer to a memory location storing a particular data type
  - Called dereferencing a pointer
- example:

```
int *count;
float *avg;
```

77

Pointers: nitty gritty

- ampersand & is used to get the address of a variable (dereference a pointer)

- example:

int count = 12;

int *countPtr = &count;

- &count returns the address of count and stores it in the pointer variable countPtr

78

Another example

- here's another example:

```
int i = 3, j = -99;
int count = 12;
int *countPtr = &count;
printf ( “%d”, *countPtr);
```

- Here is the memory picture:

79

Arrays as pointers

- an array is some number of contiguous memory locations
- an array definition is really a pointer to the starting memory location of the array
- and pointers are really integers
- so you can perform integer arithmetic on them
- e.g., +1 increments a pointer, -1 decrements
- you can use this to move from one array element to another

80

Code

```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
int main() {
int i, *j, arr[5];
srand( time ( NULL ));
for ( i=0; i<5; i++ )
arr[i] = rand() % 100;
printf( "arr=%p\n",arr );
for ( i=0; i<5; i++ ) {
printf( "i=%d arr[i]=%d &arr[i]=%p\n",i,arr[i],&arr[i] );
}
j = &arr[0];
printf( "\nj=%p *j=%d\n",j,*j );
j++;
printf( "after adding 1 to j:\n j=%p *j=%d\n",j,*j );
}
```

81

Output

```
arr=0xbffff4f0
i=0 arr[i]=29 &arr[i]=0xbffff4f0
i=1 arr[i]=8 &arr[i]=0xbffff4f4
i=2 arr[i]=18 &arr[i]=0xbffff4f8
i=3 arr[i]=95 &arr[i]=0xbffff4fc
i=4 arr[i]=48 &arr[i]=0xbffff500
j=0xbffff4f0 *j=29
after adding 1 to j:
j=0xbffff4f4 *j=8
```

82

Pointer operations

- Difference between
  - ptr++
  - *ptr++
- int b[5] ….
  int *bPtr;

  bPtr = b   //or
  bPtr = &b[0]

83

- Careful when moving pointers

- bPTr += 2;

  the memory location isn't simply incremented by 2…..depends on size of type being pointed to.

84

Strings

- storing multiple characters in a single variable
- data type is still char
- BUT it has a length
- last character the is terminator: ’\0’, aka NULL
- string constants are surrounded by double quotes: "
- example:
  – char s[6] = "ABCDE";

85

String II

- char s[6] = “ABCDE”;
- Memory storage looks like:

A	B	C	D	E	\0

- Need to remember that you are really accessing indices 0 – (*length*-2) since the value at *length*-1 is always \0

86

Using strings

- printing strings
- format sequence: %s
- example:

```
#include <stdio.h>
int main() {
char str[6] = "ABCDE";
printf( "str = %s\n", str );
} /* end of main() */
```

87

String Library

- to use the string library, include the header in your C source file:

```
#include <string.h>
```

- string length function:

```
int strlen( char *s );
```

- this function returns the number of characters in s; note that this is NOT the same thing as the number of characters allocated for the string array

- string comparison function:

```
int strcmp( const char *s1, const char *s2 );
```

- “This function returns an integer greater than, equal to, or less than 0, if the string pointed to by s1 is greater than, equal to, or less than the string pointed to by s2 respectively. The sign of a non-zero return value is determined by the sign of the difference between the values of the first pair of bytes that differ in the strings being compared.”

man strcmp

88

copying functions:

```
char *strcpy( char *dest, char
  *source );
```

- copies characters from source array into dest array up to NULL

```
char *strncpy( char *dest, char
  *source, int num );
```

- copies characters from source array into dest array; stops after num characters (if no NULL before that); appends NUL

89

Search

```
char *strchr( const char
  *source, const char ch );
```

- returns pointer to first occurrence of ch in source; NULL if none

```
char *strstr( const char
  *source, const char *search );
```

- return pointer to first occurrence of search in source

90

String Parsing

```
char *strtok( char *s1, const char
  *s2 );
```

- breaks string s1 into a series of tokens, delimited by s2
- called the first time with s1 equal to the string you want to break up
- called subsequent times with NULL as the first argument
- each time is called, it returns the next token on the string
- returns null when no more tokens remain

91

Example

```
char inputline[1024];
char *name, *rank, *serial_num;
printf( "enter name+rank+serial number: " );
scanf( "%s", inputline );
name = strtok( inputline,"+" );
rank = strtok( null,"+" );
serial_num = strtok( null,"+" );
```

92

Formatting functions

```
int sscanf(char *string, char *format, ...)
```

- parse the contents of string according to format
- placed the parsed items into 3rd, 4th, 5th, ... argument
- return the number of successful conversions

```
int sprintf(char *buffer, char *format, ...)
```

- produce a string formatted according to format
- place this string into the buffer
- the 3rd, 4th, 5th, ... arguments are formatted
- return number of successful conversions

- format characters are like printf and scanf (see notes from earlier lectures)

93

Memory allocations

- One of the most powerful features of c is the ability of the programmer to create more memory space during the execution of the program.
- Limited by physical machine memory
- If you want to be able to create memory, you also need to free it manually

94

malloc /sizeof / free

- charPtr = malloc (sizeof (…));

- free (charPtr)

95

Compiling problems

- errors can come from multiple sources:
  - *pre-processor*: missing include files
  - *parser*: syntax errors
  - *assembler*: rare
  - *linker*: missing libraries and references
  - e.g., undefined names will be reported when linking:

```
undefined symbol first referenced in file
_print program.o
ld fatal: Symbol referencing errors
No output written to file.
```

- if gcc gets confused, there can be hundreds of messages!
  - fix first message first, and then retry— ignore the rest
- gcc will produce an executable with warnings
- gcc is more forgiving than javac!

96

For Next Time

- Do Reading
- Do Homework!!