

# **CSCI 0330/1330**

## **Introduction to Computer Systems**

# Welcome!

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# What You'll Learn

- **Programming in C**
- **Data representation**
- **Programming in x86 assembler language**
- **High-level computer architecture**
- **Optimizing programs**
- **Linking and libraries**
- **Basic OS functionality**
- **Memory management**
- **Network programming (Sockets)**
- **Multithreaded programming (POSIX threads)**

# **Prerequisites: What You Need to Know**

- **Ability to program in an object-oriented or procedural language (e.g., Java) and knowledge of basic algorithms**
  - **CSCI 0160 or CSCI 0180 or CSCI 0200**

# What You'll Do

- **Eight 2-hour labs (may be done in pairs)**
- **Nine one- to two-week programming assignments (two may be done in pairs)**
  - most will be doable on OSX as well as on SunLab machines
- **No exams!**
- **Top Hat for in-class quizzes (sections 1 only)**
  - not anonymous: a small portion of your grade
  - full credit (A) for each correct answer
  - partial credit (B) for each wrong answer
  - NC for not answering
  - one to three or so questions per class

# CSCI 1330

- **Master's students only**
- **Weekly homeworks, just for you**
  - 10% of your grade

# Gear-Up Sessions

- **Optional weekly sessions**
  - handle questions about the week's assignment and course material
  - soon after each assignment is released
    - » first session is 8pm Monday, 9/12
    - » via zoom (link TBD)

# Take Aways

- **A few questions on lecture material on the web site after each lecture**
  - completely optional
  - not graded
- **They help you digest the lecture material**
  - you may discuss them with each other, with TAs, and with the instructor



# Collaboration Policy

- **Learn by doing**
- **You may:**
  - discuss the requirements with others
  - discuss the high-level approach with others
- **Write your own code**
- **Debug your own code**
- **If you get stuck debugging**
  - others may help you debug
  - may not give you solutions or test cases
- **Acknowledge (in README) those who assist you**
- **We run MOSS on all relevant assignments**

# Textbook

- ***Computer Systems: A Programmer's Perspective*, 3<sup>rd</sup> Edition, Bryant and O'Hallaron, Prentice Hall 2015**



# If Programming Languages Were Cars ...

- **Java would be an SUV**
  - automatic transmission
  - stay-in-lane technology
  - adaptive cruise control
  - predictive braking
  - gets you where you want to go
    - » safe
    - » boring
- **Pyret would be a Tesla**
  - you drive it like an SUV
    - » (avoid autopilot)
    - » definitely cooler
    - » but limited range



# If Programming Languages Were Cars ...

- **C would be a sports car**
  - manual everything
  - dangerous
  - **fun**
  - you really need to know what you're doing!



# **U-Turn Algorithm (Java and Pyret Version)**

- 1. Switch on turn signal**
- 2. Slow down to less than 3 mph**
- 3. Check for oncoming traffic**
- 4. Press the accelerator lightly while turning the steering wheel pretty far in the direction you want to turn**
- 5. Lift your foot off the accelerator and coast through the turn; press accelerator lightly as needed**
- 6. Enter your new lane and begin driving**

# **U-Turn Algorithm (C Version)**

- 1. Enter turn at 30 mph in second gear**
- 2. Position left hand on steering wheel so you can quickly turn it one full circle**
- 3. Ease off accelerator; fully depress clutch**
- 4. Quickly turn steering wheel either left or right as far as possible**
- 5. A split second after starting turn, pull hard on handbrake, locking rear wheels**
- 6. As car (rapidly) rotates, restore steering wheel to straight-ahead position and shift to first gear**
- 7. When car has completed 180° turn, release handbrake and clutch, fully depress accelerator**

# History of C

- **Early 1960s: CPL (Combined Programming Language)**
  - developed at Cambridge University and University of London
- **1966: BCPL (Basic CPL): simplified CPL**
  - intended for systems programming
- **1969: B: simplified BCPL (stripped down so its compiler would run on minicomputer)**
  - used to implement earliest Unix
- **Early 1970s: C: expanded from B**
  - motivation: they wanted to play “Space Travel” on minicomputer
  - used to implement all subsequent Unix OSes



# More History of C

- **1978: Textbook by Brian Kernighan and Dennis Ritchie (K&R), 1<sup>st</sup> edition, published**
  - de facto standard for the language
- **1989: ANSI C specification (ANSI C)**
  - 1988: K&R, 2<sup>nd</sup> edition, published, based on draft of ANSI C
- **1990: ISO C specification (C90)**
  - essentially ANSI C
- **1999: Revised ISO C specification (C99)**
- **2011: Further revised ISO C specification (C11)**
  - not widely used

# CS 33

## Introduction to C

# A C Program

```
int main( ) {  
    printf("Hello world!\n");  
    return 0;  
}
```

# Compiling and Running It

```
$ ls
hello.c
$ gcc hello.c
$ ls
a.out      hello.c
$ ./a.out
Hello world!
$ gcc -o hello hello.c
$ ls
a.out      hello      hello.c
$ ./hello
Hello world!
$
```

# What's gcc?

- **gnu C compiler**
  - **it's actually a two-part script**
    - » **part one compiles files containing programs written in C (and certain other languages) into binary machine code (known as object code)**
    - » **part two takes the just-compiled object code and combines it with other object code from libraries to create an executable**
      - **the executable can be loaded into memory and run by the computer**

# gcc Flags

- **gcc [-Wall] [-g] [-std=gnu99]**
  - **-Wall**
    - » provide warnings about pretty much everything that might conceivably be objectionable
  - **-g**
    - » provide extra information in the object code, so that gdb (gnu debugger) can provide more informative debugging info
      - discussed in lab
  - **-std=gnu99**
    - » use the 1999 version of C syntax, rather than the 1990 version

# Declarations in C

```
int main() {  
    int i;  
    float f;  
    char c;  
    return 0;  
}
```

**Types are promises**

- promises can be broken

**Types specify memory sizes**

- cannot be broken

# Declarations in C

```
int main() {  
    int i;  
    float f;  
    char c;  
    return 0;  
}
```

**Declarations reserve memory space**

- where?

**Local variables can be uninitialized**

- junk

- whatever was there before



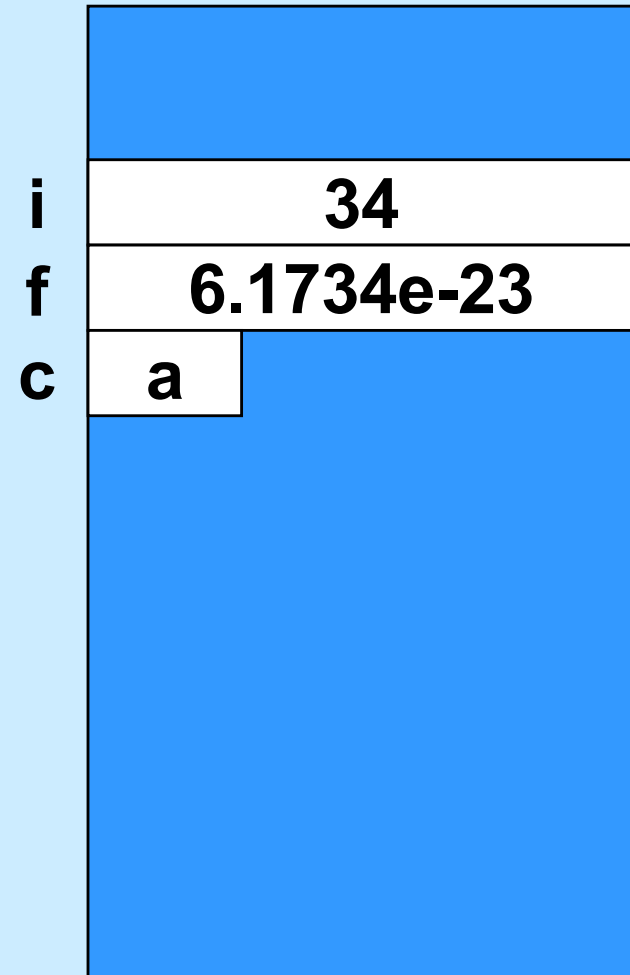
# Declarations in C

```
int main() {  
    int i;  
    float f;  
    char c;  
    return 0;  
}
```

<i>i</i>	1435097815
<i>f</i>	6.1734e-23
<i>c</i>	p

# Using Variables

```
int main() {  
    int i;  
    float f;  
    char c;  
    i = 34;  
    c = 'a';  
}
```



# printf Again

```
int main() {  
    int i;  
    float f;  
    char c;  
    i = 34;  
    c = 'a';  
    printf("%d\n", i);  
    printf("%d\t%c\n", i, c);  
}
```

```
$ ./a.out  
34  
34      a
```

# printf Again

```
int main() {  
    ...  
    printf("%d\t%c\n", i, c);  
}
```

```
$ ./a.out  
34      a
```

## Two parts

- **formatting instructions**
- **arguments**

# printf Again

```
int main() {  
    ...  
    printf("%d\t%c\n", i, c);  
}
```

```
$ ./a.out  
34      a
```

## Formatting instructions

- **Special characters**
  - **\n** : newline
  - **\t** : tab
  - **\b** : backspace
  - **\"** : double quote
  - **\\** : backslash

# printf Again

```
int main() {  
    ...  
    printf("%d\t%c", i, c);  
}
```

```
$ ./a.out  
34      a
```

## Formatting instructions

- **Types of arguments**
  - %d: integer
  - %f: floating-point number
  - %c: character

# printf Again

```
int main() {  
    ...  
    printf("%6d%3c", i, c);  
}
```

```
$ ./a.out  
    34  a
```

## Formatting instructions

- **%6d**: decimal integer at least 6 characters wide
- **%6f**: floating point at least 6 characters wide
- **%6.2f**: floating point at least 6 wide, 2 after the decimal point

# printf Again

```
int main() {  
    int i;  
    float celsius;  
    for(i=30; i<34; i++) {  
        celsius = (5.0/9.0)*(i-32.0);  
        printf("%3d %6.1f\n", i, celsius);  
    }  
}
```

```
$ ./a.out  
30      -1.1  
31      -0.6  
32       0.0  
33       0.6
```



# For Loops

before the loop

should loop continue?

```
int main() {  
    int i;  
    float celsius;  
    for (i=30 ; i<34 ; i=i+1) {  
        celsius = (5.0/9.0)*(i-32.0);  
        printf("%3d %6.1f\n", i, celsius);  
    }  
}
```

after each iteration

# Some Primitive Data Types

## **char**

- a single byte: interpreted as either an 8-bit integer or a character

## **short**

- integer: 16 bits

## **int**

- integer: 16 bits or 32 bits (implementation dependent)

## **long**

- integer: either 32 bits or 64 bits, depending on the architecture

## **long long**

- integer: 64 bits

## **float**

- single-precision floating point

## **double**

- double-precision floating point

# What is the size of my int?

```
int main() {  
    int i;  
    printf("%d\n", sizeof(i));  
}
```

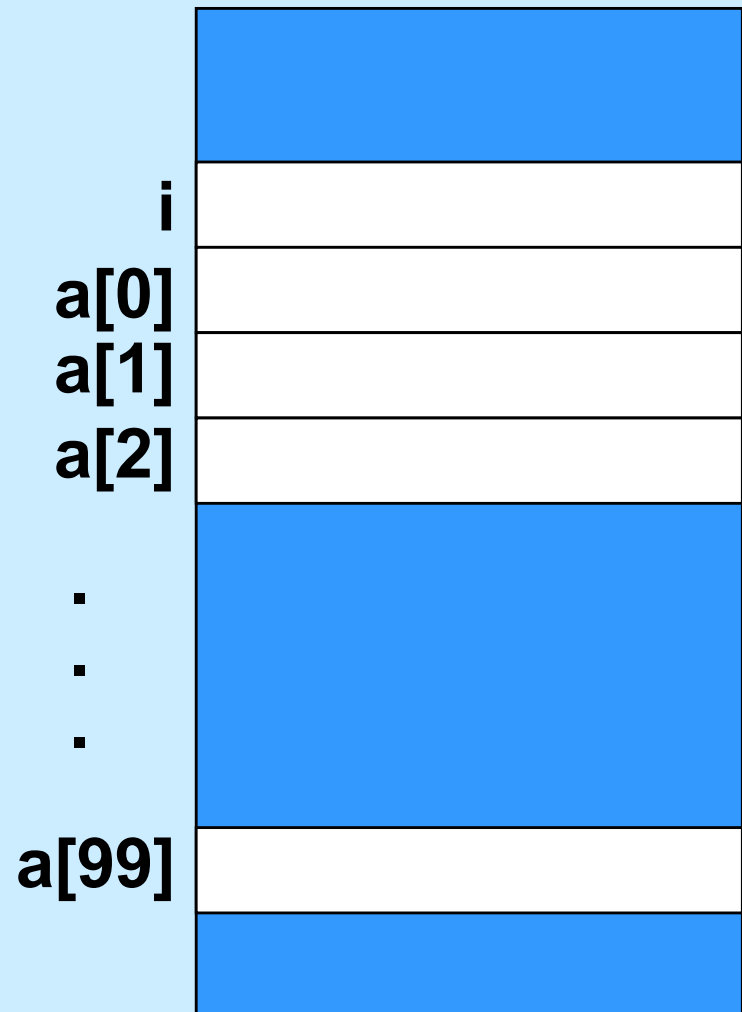
```
$ ./a.out  
4
```

## sizeof

- returns the size of a variable in bytes
- very very very very very very important function in C

# Arrays

```
int main() {  
    int a[100];  
    int i;  
}
```



# Arrays

```
int main() {  
    int a[100];  
    int i;  
    for (i=0; i<100; i++)  
        a[i] = i;  
}
```

	i	100
a[0]		0
a[1]		1
a[2]		2
	.	
	.	
	.	
a[99]		99

# Array Bounds

```
int main() {  
    int a[100];  
    int i;  
    for (i=0; i<=100; i++)  
        a[i] = i;  
}
```

	i	101
a[0]		0
a[1]		1
a[2]		2
	.	
	.	
	.	
a[99]		99
a[100]		100

# Arrays in C

## C Arrays = Storage + Indexing

- no bounds checking
- no initialization

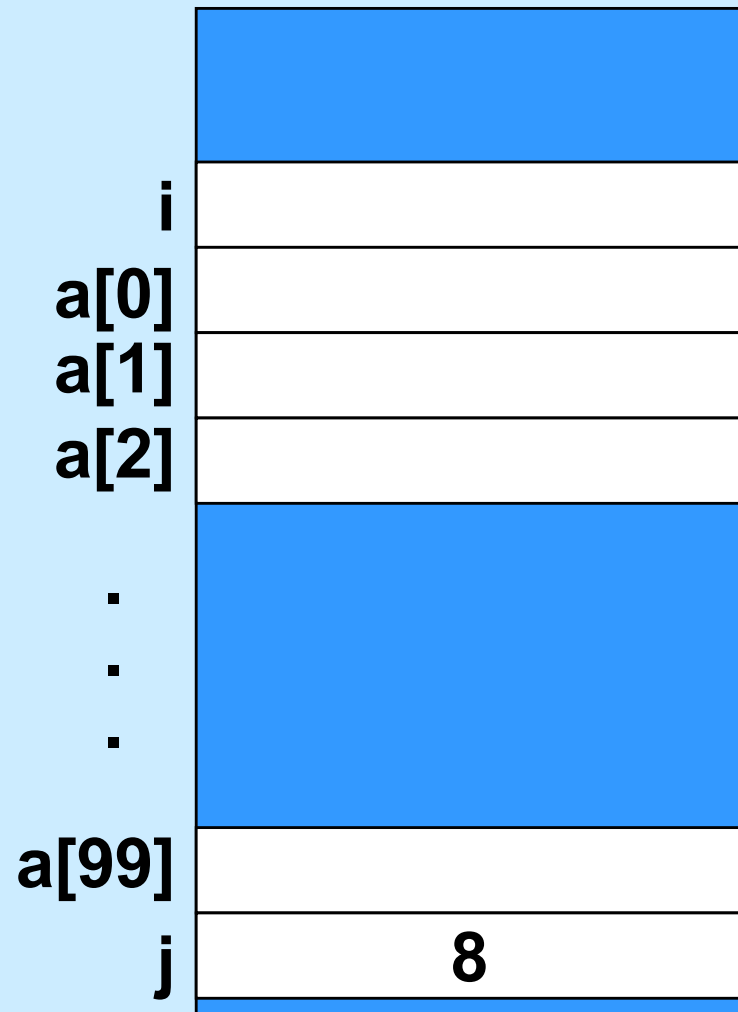


WELCOME TO THE JUNGLE

# Welcome to the Jungle

```
int main() {  
    int j=8;  
    int a[100];  
    int i;  
    for (i=0; i<=100; i++)  
        a[i] = i;  
    printf("%d\n", j);  
}
```

```
$ ./a.out  
????
```





# Quiz 1

- What is printed for the value of j when the program is run?
  - a) 0
  - b) 8
  - c) 100
  - d) indeterminate

# Welcome to the Jungle

```
int main() {  
    int j=8;  
    int a[100];  
    int i;  
    for (i=0; i<=100; i++)  
        a[i] = i;  
    printf("%d\n", j);  
}
```

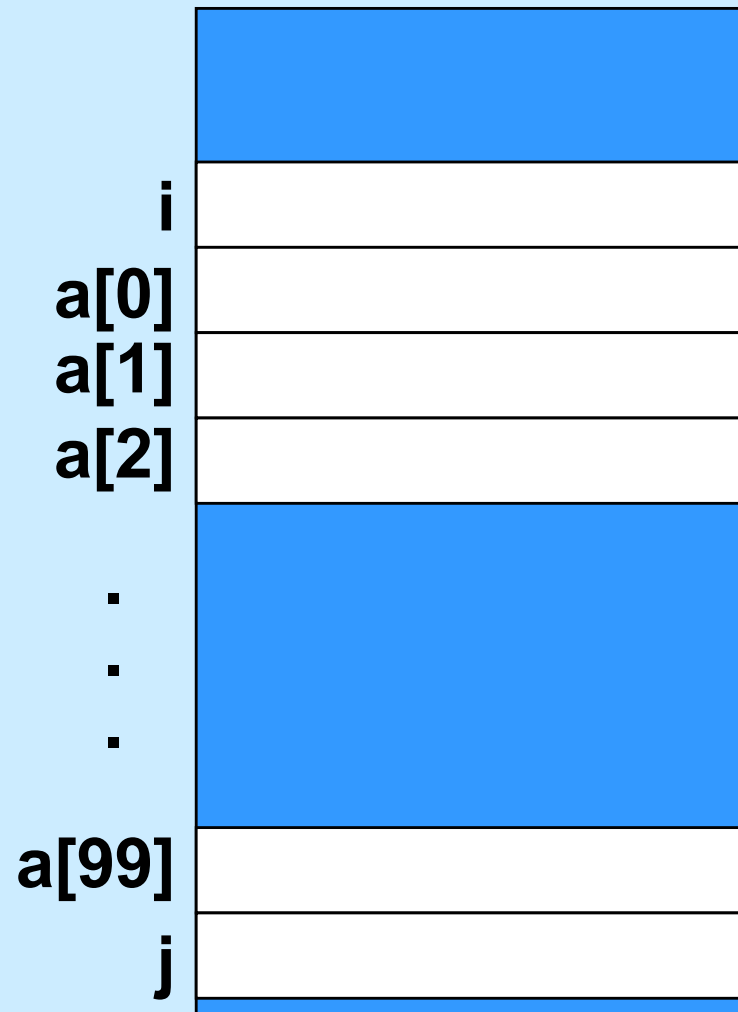
```
$ ./a.out  
100
```

i		101
a[0]		0
a[1]		1
a[2]		2
.		
.		
.		
a[99]		99
j		100

# Welcome to the Jungle

```
int main() {  
    int j;  
    int a[100];  
    int i;  
    for (i=0; i<100; i++)  
        a[i] = i;  
    printf("%d\n", j);  
}
```

```
$ ./a.out  
???
```



# Quiz 2

- What is printed for the value of j when the program is run?
  - a) 0
  - b) 8
  - c) 100
  - d) indeterminate

# Welcome to the Jungle

```
int main() {  
    int j;  
    int a[100];  
    int i;  
    for (i=0; i<100; i++)  
        a[i] = i;  
    printf("%d\n", j);  
}
```

```
$ ./a.out  
-1880816380
```

i		100
a[0]		0
a[1]		1
a[2]		2
.		
.		
.		
a[99]		99
j		-1880816380

# Welcome to the Jungle

```
int main() {  
    int a[100];  
    int i;  
    a[-3] = 25;  
    printf("%d\n", a[-3]);  
}
```

```
$ ./a.out  
25
```

# Welcome to the Jungle

```
int main() {  
    int a[100];  
    int i;  
    a[-3] = 25;  
    a[11111111] = 6;  
    printf("%d\n", a[-3]);  
}
```



```
$ ./a.out  
Segmentation fault
```

**What is a segmentation fault?**

- attempted access to an invalid memory location

# Function Definitions

```
int main() {  
    printf("%d\n", fact(5));  
    return 0;  
}  
  
int fact(int i) {  
    int k;  
    int res;  
    for(res=1, k=1; k<=i; k++)  
        res = res * k;  
    return res;  
}
```

## **main**

- **is just another function**
- **starts the program**

## **All functions**

- **have a return type**



# Compiling It

```
$ gcc -o fact fact.c  
$ ./fact  
120
```

# Function Definitions

```
int main() {  
    printf("%f\n", fact(5));  
    return 0;  
}  
float fact(int i) {  
    int k;  
    float res;  
    for(res=1, k=1; k<=i; k++)  
        res = res * k;  
    return res;  
}
```

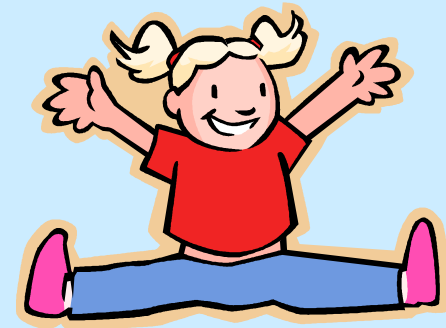
# Function Definitions



```
$ gcc -o fact fact.c
main.c:27: warning: type mismatch with previous implicit
declaration
main.c:23: warning: previous implicit declaration of
'fact'
main.c:27: warning: 'fact' was previously implicitly
declared to return 'int'
```

```
$ ./fact
1079902208
```

# Function Declarations



**Declares the function**

```
float fact(int i);  
  
int main() {  
    printf("%f\n", fact(5));  
    return 0;  
}  
  
float fact(int i) {  
    int k;  
    float res;  
    for(res=0, k=1; k<=i; k++)  
        res = res * k;  
    return res;  
}
```

```
$ ./fact  
120.000000
```

# Methods



- **C has functions**
- **Java has methods**
  - methods implicitly refer to objects
  - C doesn't have objects
- **Don't use the “M” word**
  - it's just wrong

# Swapping

Write a function to swap two ints

```
void swap(int i, int j) {
```



Parameters are  
passed by value

```
}
```

```
int main() {  
    int a = 4;  
    int b = 8;  
    swap(a, b);  
    printf("a:%d b:%d", a, b);  
}
```

# Swapping

Write a function to swap two ints

```
void swap(int i, int j) {  
    int tmp;  
    tmp = j; j = i; i = tmp;  
}  
  
int main() {  
    int a = 4;  
    int b = 8;  
    swap(a, b);  
    printf("a:%d b:%d", a, b);  
}
```



**Darn!**

```
$ ./a.out  
a:4 b:8
```

# Why “pass by value”?

- Fortran, for example, passes parameters “by reference”
- Early implementations had the following problem (shown with C syntax):

```
int main() {  
    function(2);  
    printf("%d\n", 2);  
}  
void function(int x) {  
    x = 3;  
}
```

```
$ ./a.out  
3
```



# Variables and Memory

What does

```
int x;
```

do?

- It tells the compiler:  
I want *x* to be the name of an area of memory  
that's big enough to hold an *int*.

## What's memory?

---

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