

# CS 33

## Introduction to Computer Systems

# Welcome!

- Prof: Tom Doeppner
- HTAs: Jason Fischman, Daphne Li-Chen, Ethan Sattler, Star Su
- UTAs: Aalia Habib, Andrew Kopplin, Ben Smith, Charlie Gagnon, Casey Nelson, Cam Wenzel, Daniel Civita Ramirez, Floria Tsui, Hans Bala, Ian Layzer, Jusung Lee, Jian Cong Loh, James Pirozzolo, Justin Sanders, Symone Houston, Maggie Beardsley, Maya Taylor, Marina Triebenbacher, Milanca Wang, Melissa Wang, Rachel Fuller, Rachel Yan, Sharon Alexander, Shalan Billault-Lee, Ell Li, Sarah Rockhill, Selen Tumay, Trisha Ballakur

# Your CS33 TAs



Sharon



Rachel



Maggie



Aalia



Jusung



Rachel



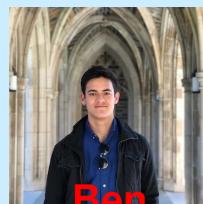
Justin



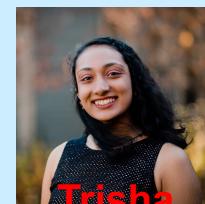
Marina



Melissa



Ben



Trisha



Shalan



Ell



Sarah



Maya



JC



Ian



Daniel



Daphne



Selen



Star



Andrew



Casey



Jason



Symone



James



Cam



Hans



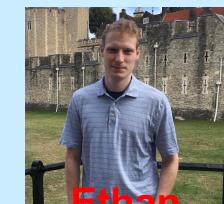
Charlie



Floria



Milanca



Ethan

# 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)**
  - CS15 or CS18

# What You'll Do

- Eight 2-hour labs (may be done in pairs)
- Nine one- to two-week programming assignments
  - most will be doable on OSX as well as on SunLab machines
- No exams!
- Top Hat for in-class quizzes (33 section 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**
  - **weekly discussion sessions (Fridays 10-10:50)**
    - » **starting September 18**

# Gear-Up Sessions

- **Optional weekly sessions**
  - handle questions about the week's assignment and course material
  - 7pm the day after each assignment is released
    - » first session is this Saturday

# Take Aways

- **A few questions on lecture material on the web site after each lecture**
  - completely optional
  - not graded
  - no solutions provided
    - » the point is not necessarily to get the right answer, but to think about the material
- **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**
  - your MOSS score will be supplied with your grade

# 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**
    - » 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

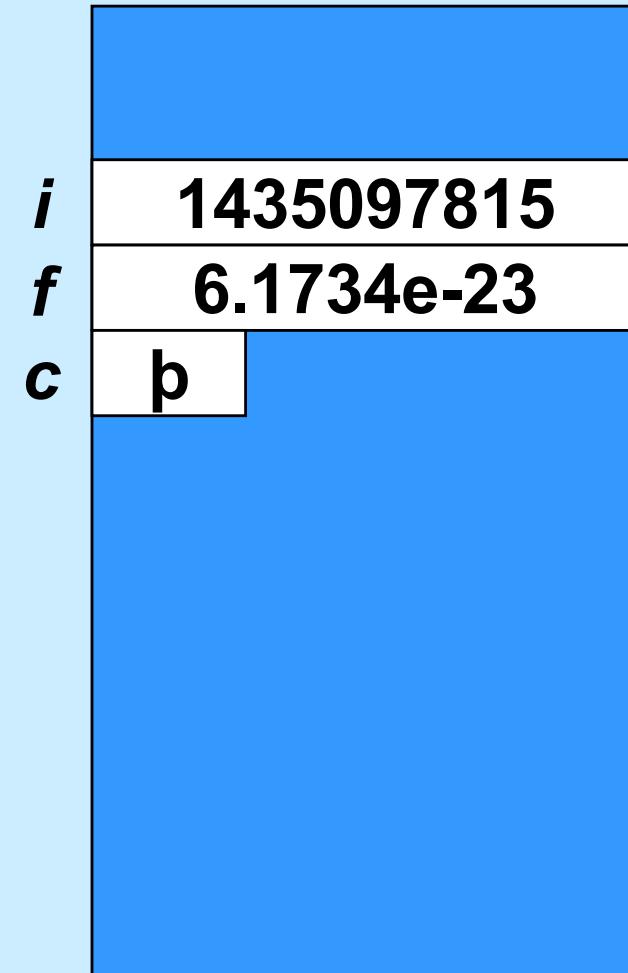
```
int main() {  
    int i;  
    float f;  
    char c;  
  
    return 0;  
}
```

**Declarations reserve memory space**  
– where?

**Local variables can be uninitialized**  
– junk  
– whatever was there before

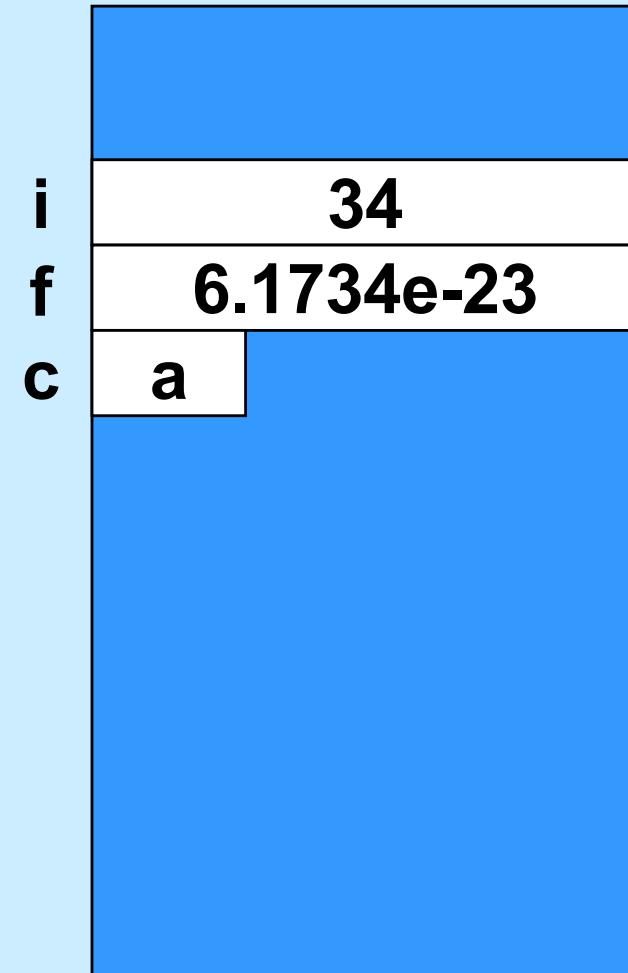
# Declarations in C

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



# 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: integers
  - %f: floating-point numbers
  - %c: characters

# 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));  
}
```

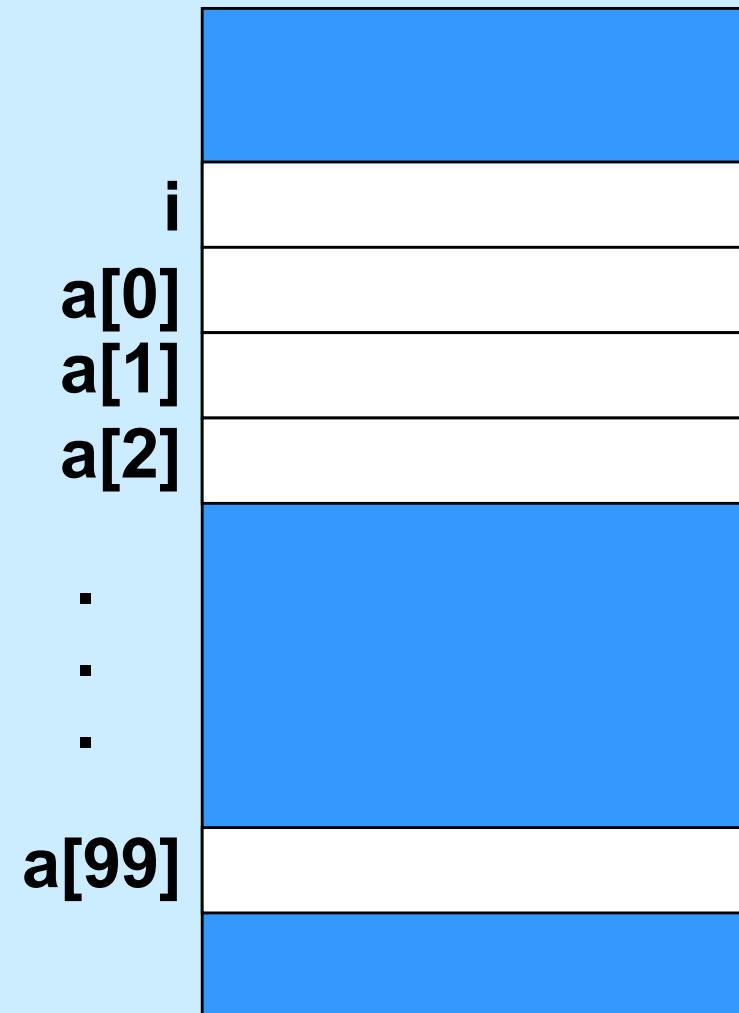
```
$ ./a.out  
4
```

## sizeof

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

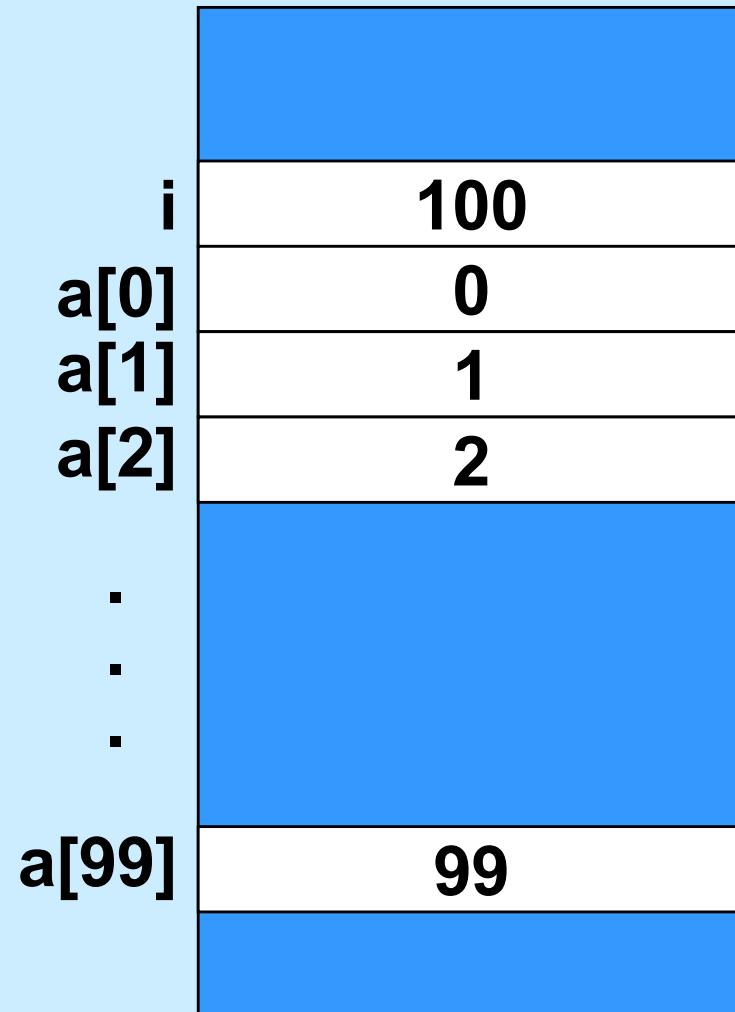
# Arrays

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



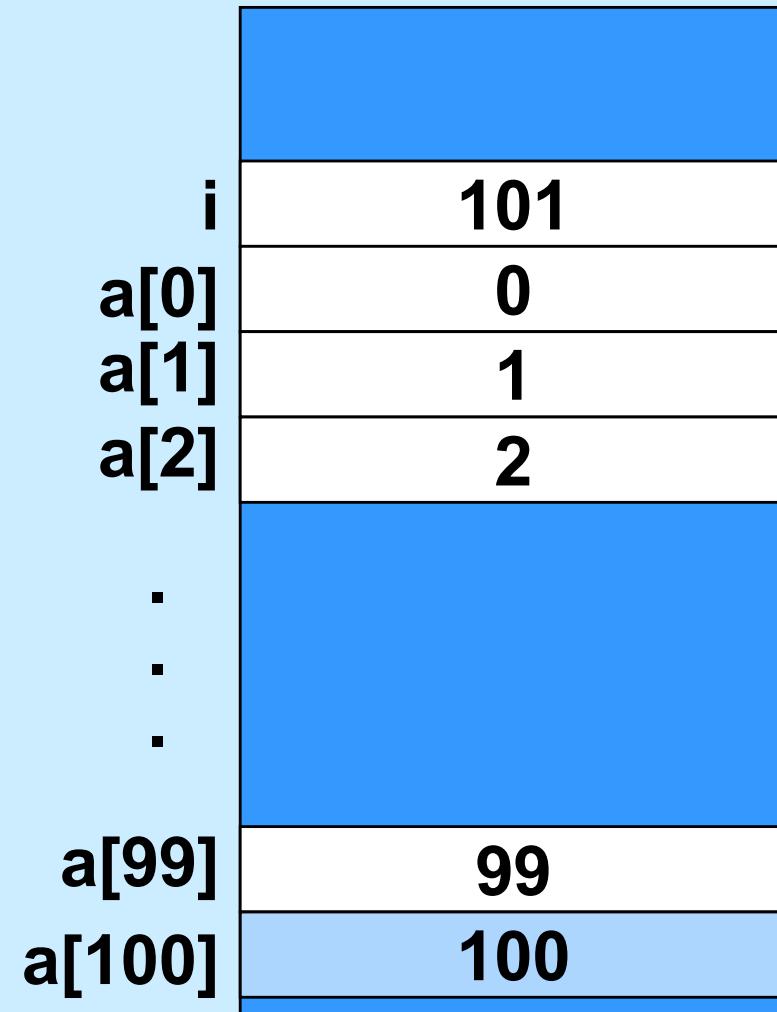
# Arrays

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



# Array Bounds

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



# Arrays in C

**C Arrays = Storage + Indexing**

- no bounds checking
- no initialization

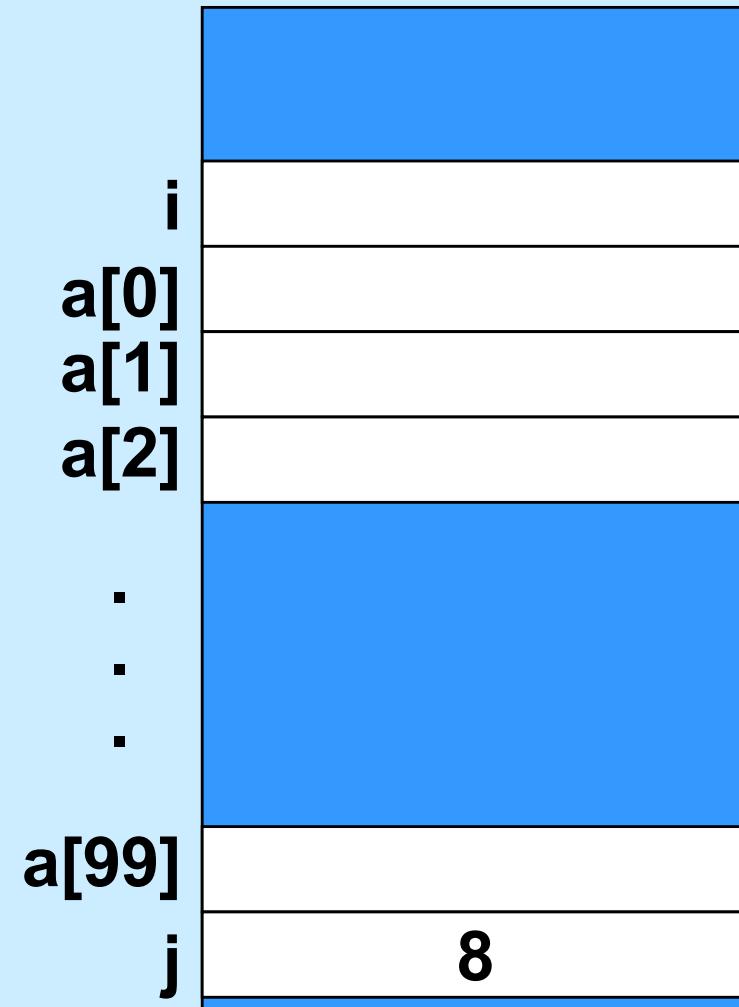


**WELCOME TO THE JUNGLE**

# 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  
????
```



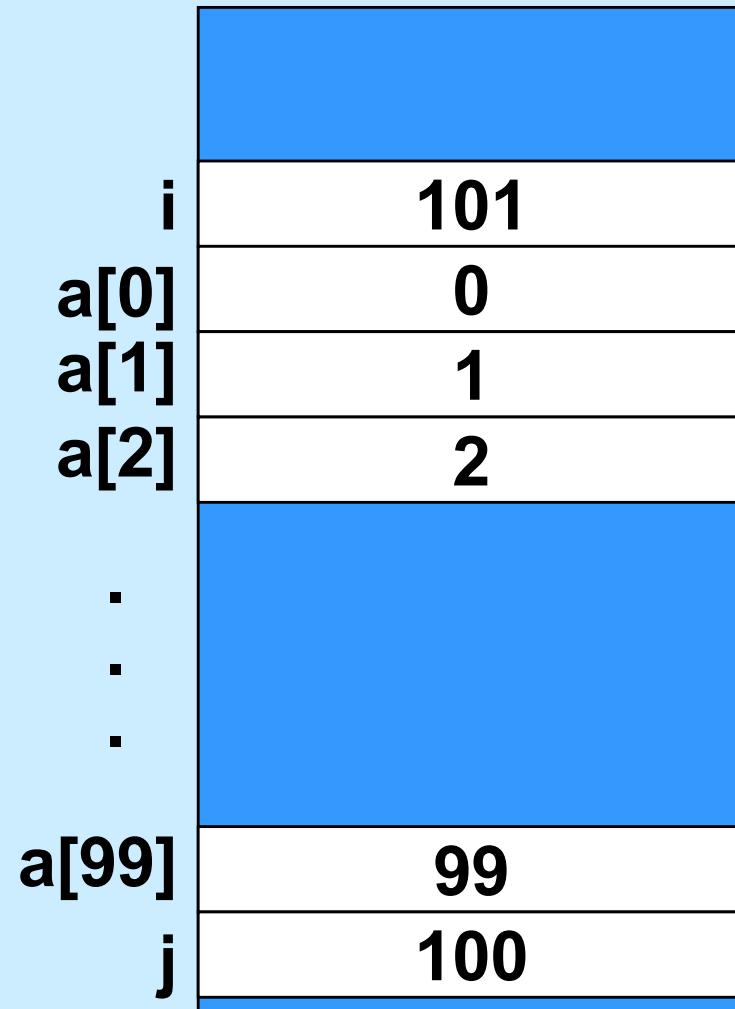
# Quiz 1

- 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);  
}
```

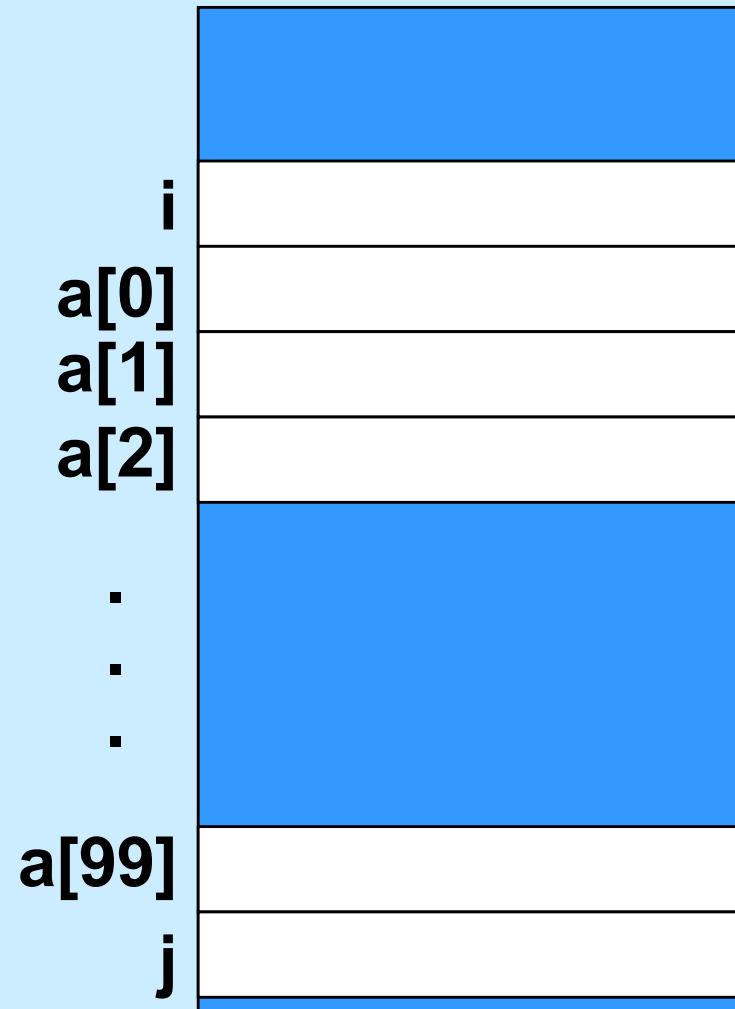
```
$ ./a.out  
100
```



# 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

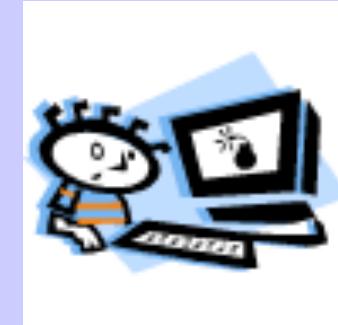
# Welcome to the Jungle

```
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[111111111] = 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

```
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;  
}
```



**Declares the function**

```
$ ./fact  
120.000000
```

d.

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

Parameters are  
passed by value

# 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?

# CS Town Hall Meeting!

- CIT 3<sup>rd</sup>-floor atrium
- 5pm Thursday (tomorrow)
- Hear about:
  - new faculty
  - new courses
  - research opportunities
  - and more!

# Industry Partners Program (IPP)

- Find and apply for job and internship postings in CS
- Learn about IPP employer tech talks & challenges
- Attend resumé reviews with industry professionals
- **[cs.brown.edu/about/partners](http://cs.brown.edu/about/partners)**
- To sign up for notifications about upcoming events:
  - <http://bit.ly/brownipp>
- Questions? Contact [Lauren\\_Clarke@brown.edu](mailto:Lauren_Clarke@brown.edu)