CS 33

Introduction to Computer Systems

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 some reasonable language (e.g., Java)**
  - **CS15 or CS18**

What You'll Do

- Eleven 2-hour labs
- Twelve one- to two-week programming assignments
  - most will be doable on OSX as well as on SunLab machines
- No exams!
- Clickers used in class
  - 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

Gear-Up Sessions

- **Optional weekly sessions**
  - handle questions about the week's assignment and course material
  - Thursdays, 7pm – 9pm
  - Barus-Holley 166

Collaboration Policy

- Learn by doing
  - get your hands dirty!
- You may:
  - discuss the requirements
  - discuss the high-level approach
- Write your own code
- Debug your own code
- Get stuck
  - others may help you find bugs
  - may not give you solutions or test cases
- Acknowledge (in README) those who assist you

Textbook

- *Computer Systems: A Programmer's Perspective,* 2nd Edition, Bryant and O'Hallaron, Prentice Hall 2011
  - 3rd Edition is also ok
  - very definitely required


Java

If Programming Languages Were Cars …

- Java would be an SUV
  - automatic transmission
  - stay-in-lane technology
  - GPS navigation
  - traction control
  - gets you where you want to go
    - » safe
    - » boring

- Racket 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 Racket 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
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), 1st edition, published
  - de facto standard for the language
- 1989: ANSI C specification (ANSI C)
  - 1988: K&R, 2nd 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)
  - too new to affect us

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
      - much of this probably won't be objectionable to you …
  - -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

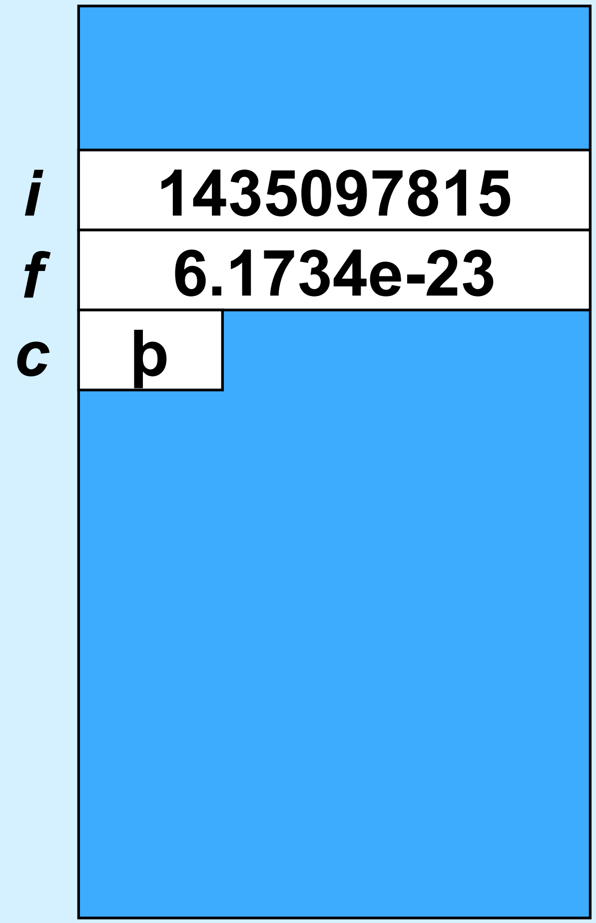
- where?

Local variables are uninitialized

- junk
- whatever was there before

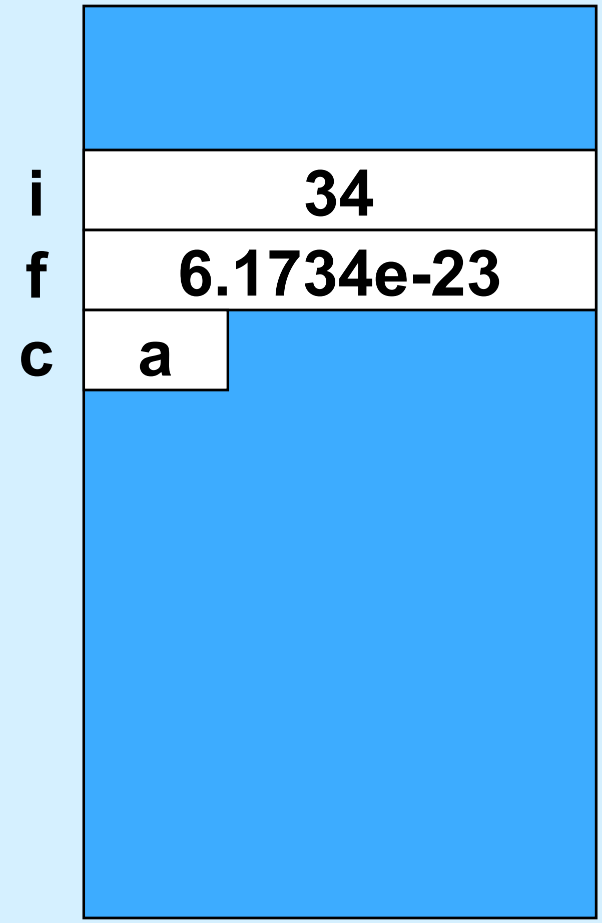
Declarations in C

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



Using Variables

```c
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
```

Formating 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 integers 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

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

char

– a single byte

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));
}
```

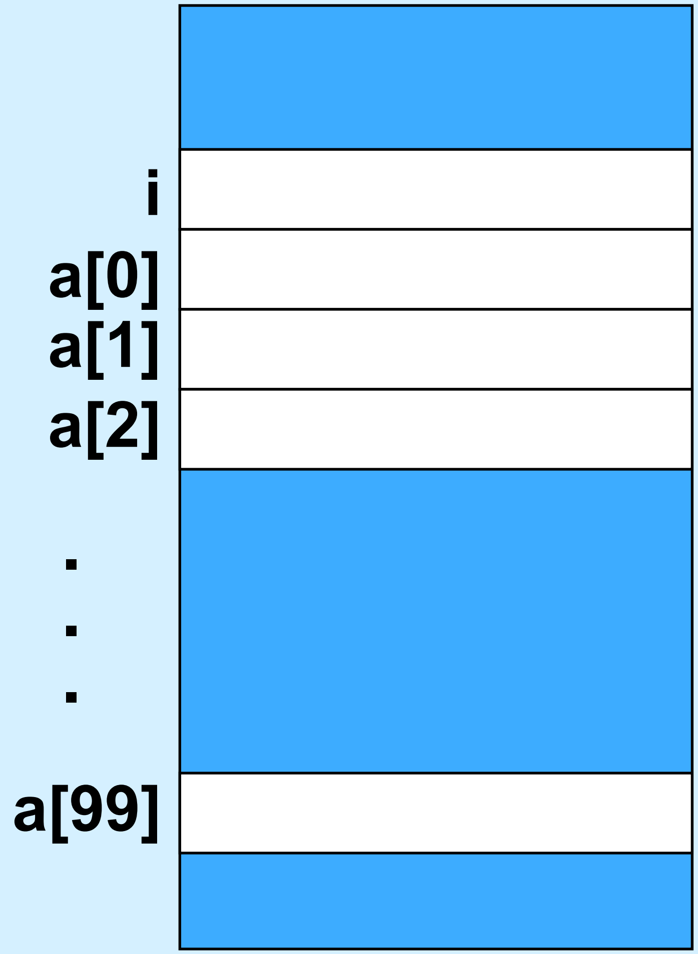
```
$ ./a.out
4
```

`sizeof`

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

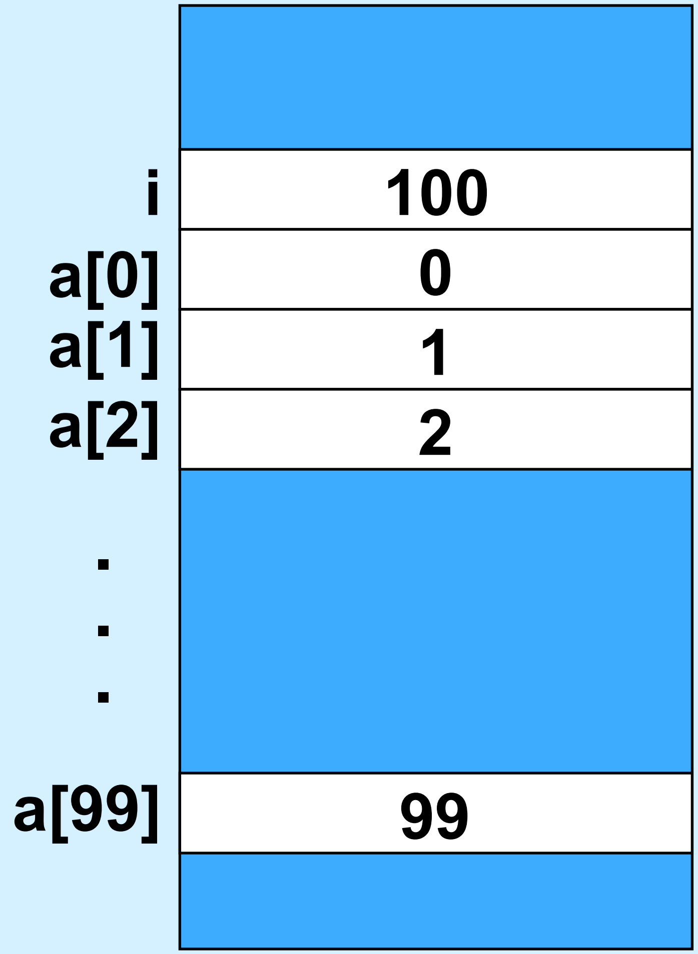
Arrays

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



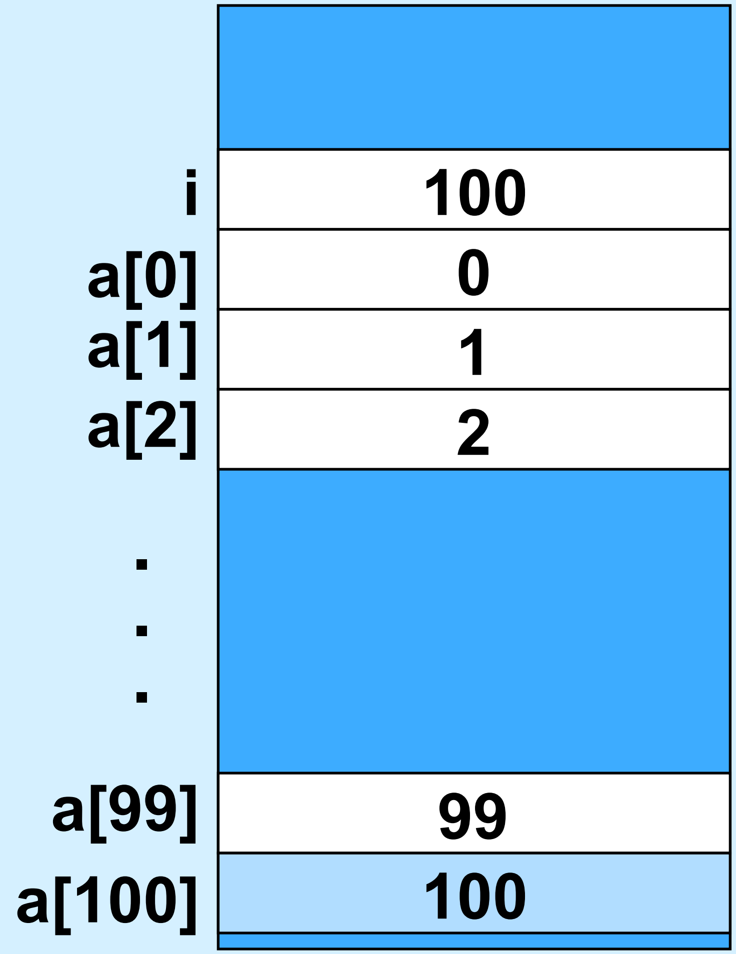
Arrays

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



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

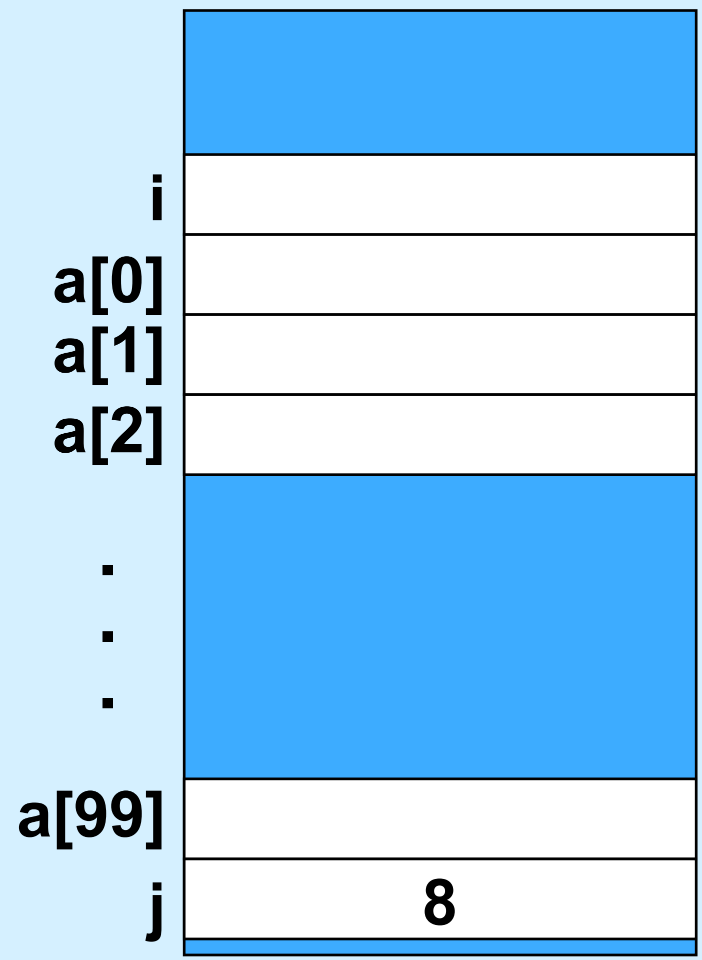
- no bounds checking
- no initialization

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
????
```



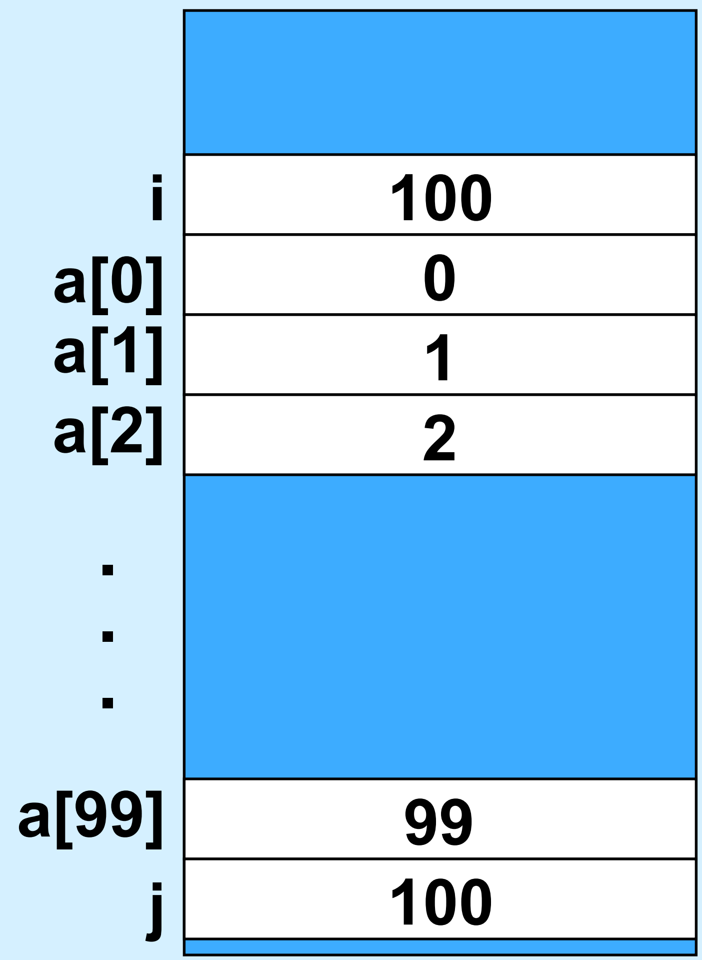
Quiz 1

- **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

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

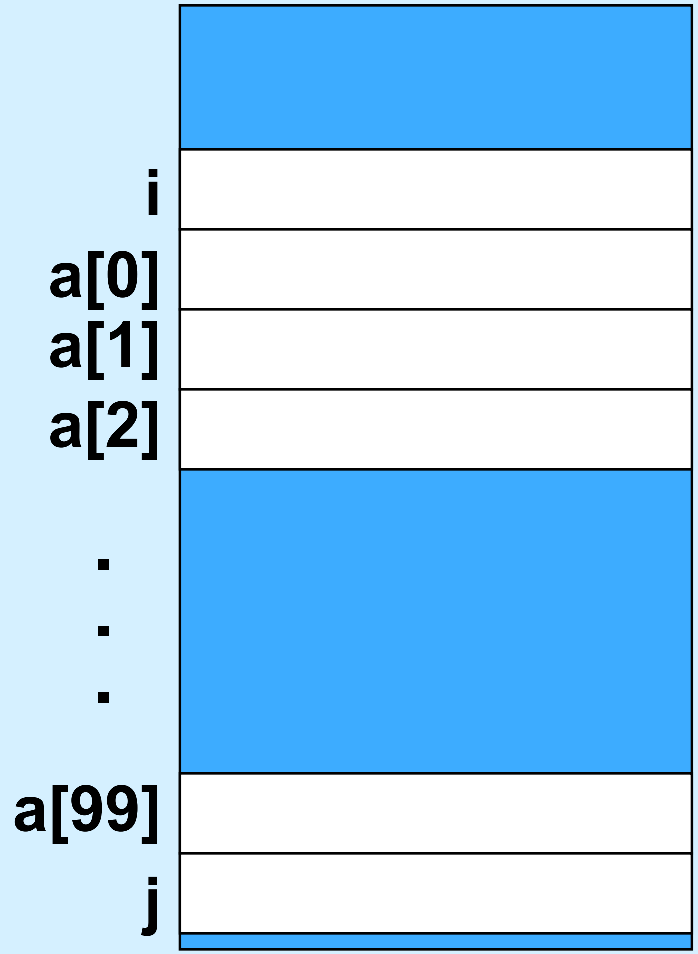
```
$ ./a.out
100
```



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
???
```



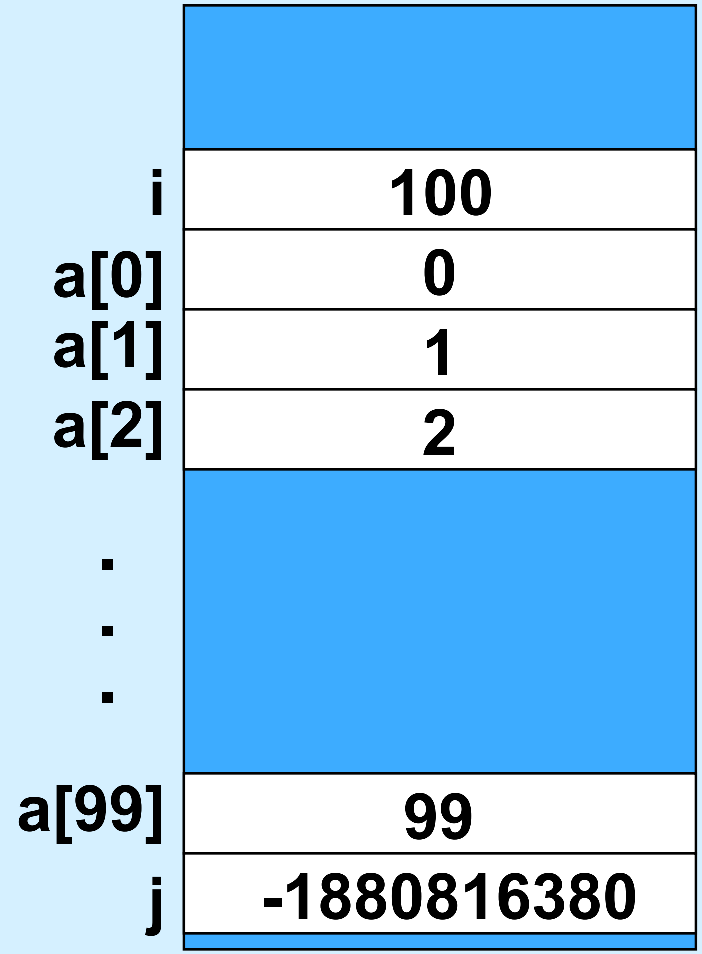
Quiz 2

- **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

```c
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
```



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**