CS 241

January 23, 2012

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Announcements

- Anonymous feedback
- Honors section
- Registration

Review: New concepts in C

- Pointers
- Memory allocation
- Arrays
- Strings

Theme:
how memory
really works

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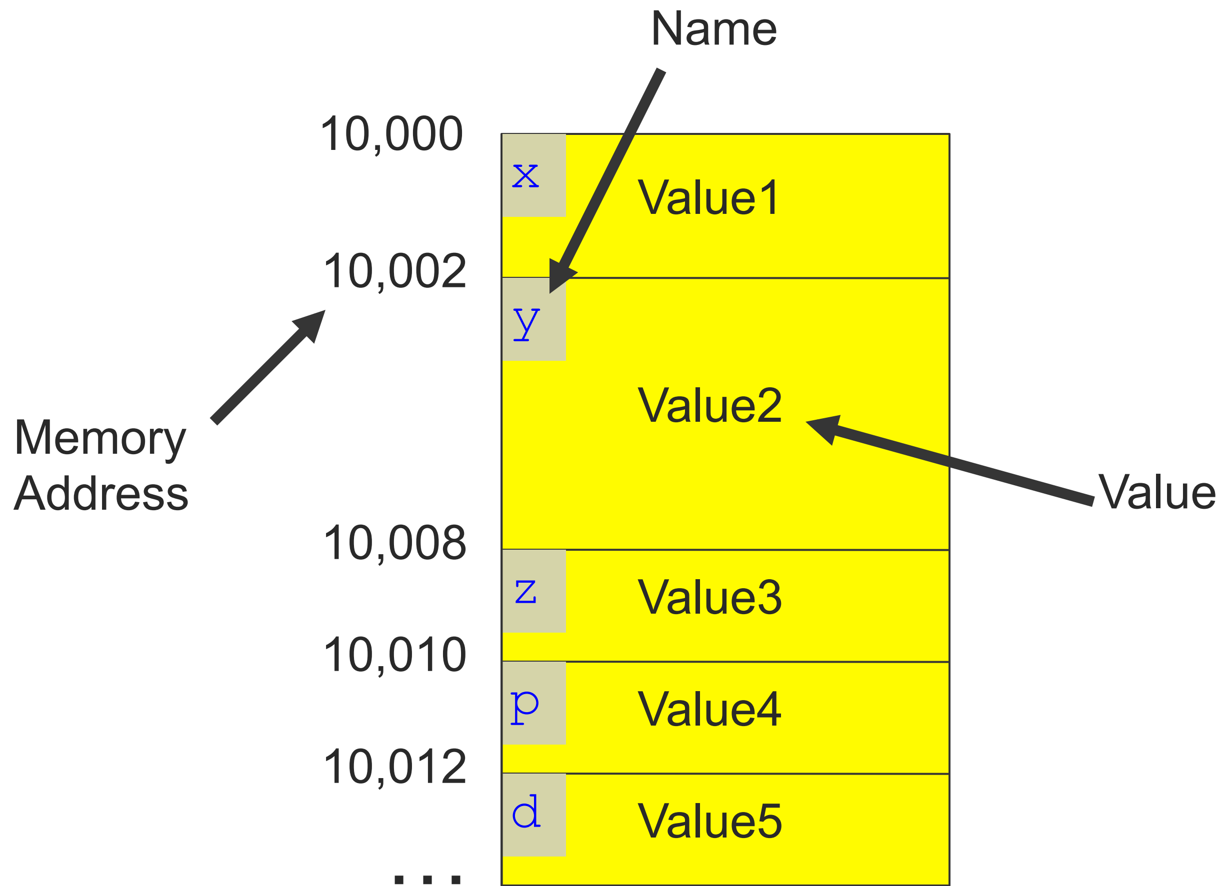
Pointers

Variables



Type of each variable
(also determines size)

```
int      x;
double   y;
float    z;
double*  p;
int      d;
```

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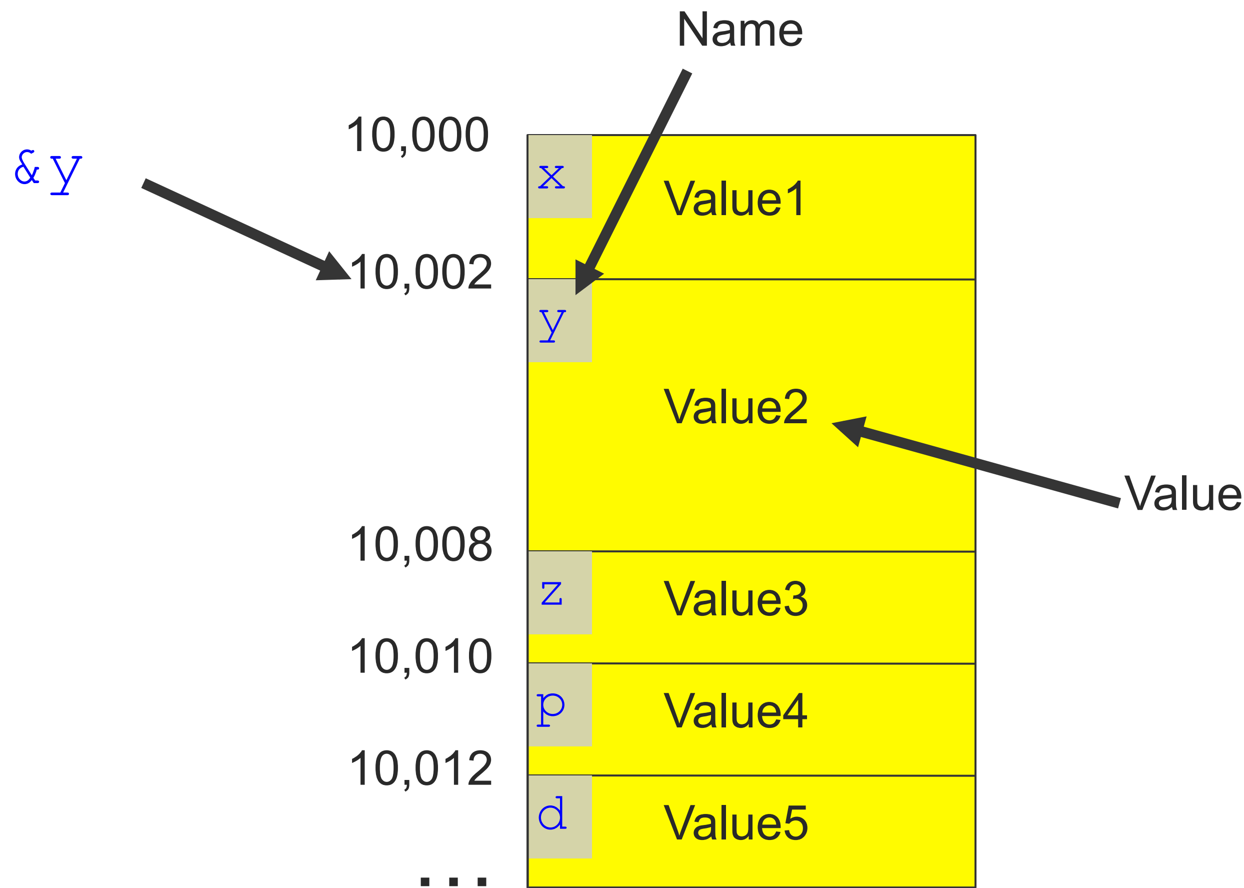
The "&" Operator: Reads "Address of"



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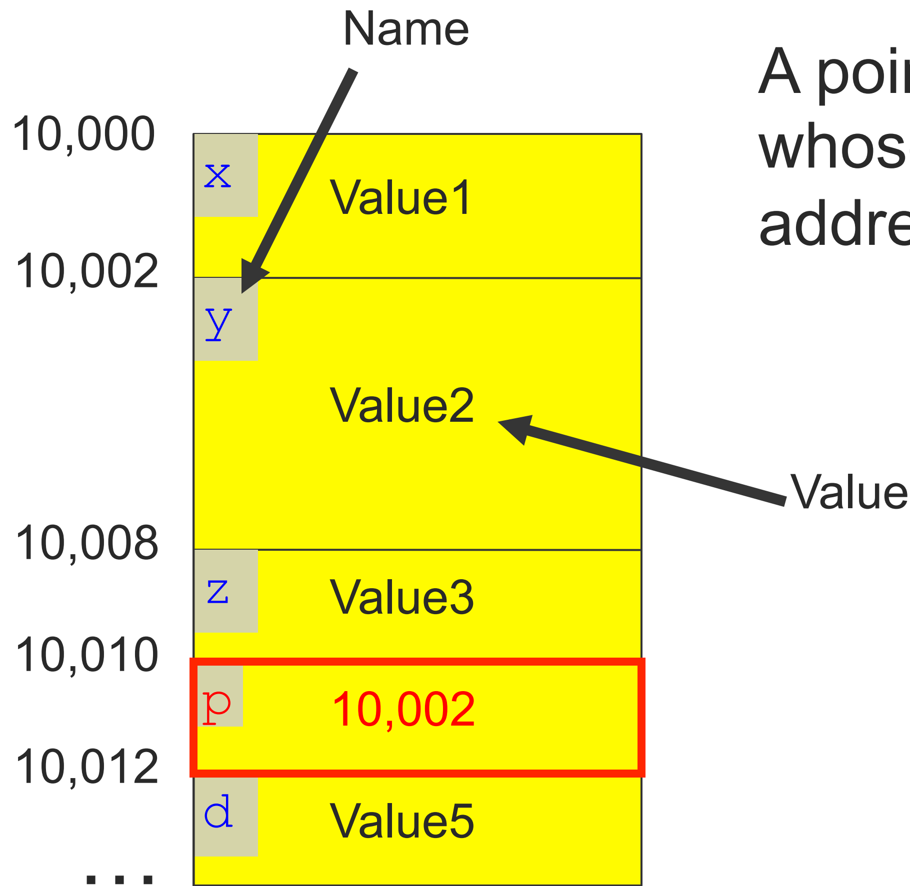
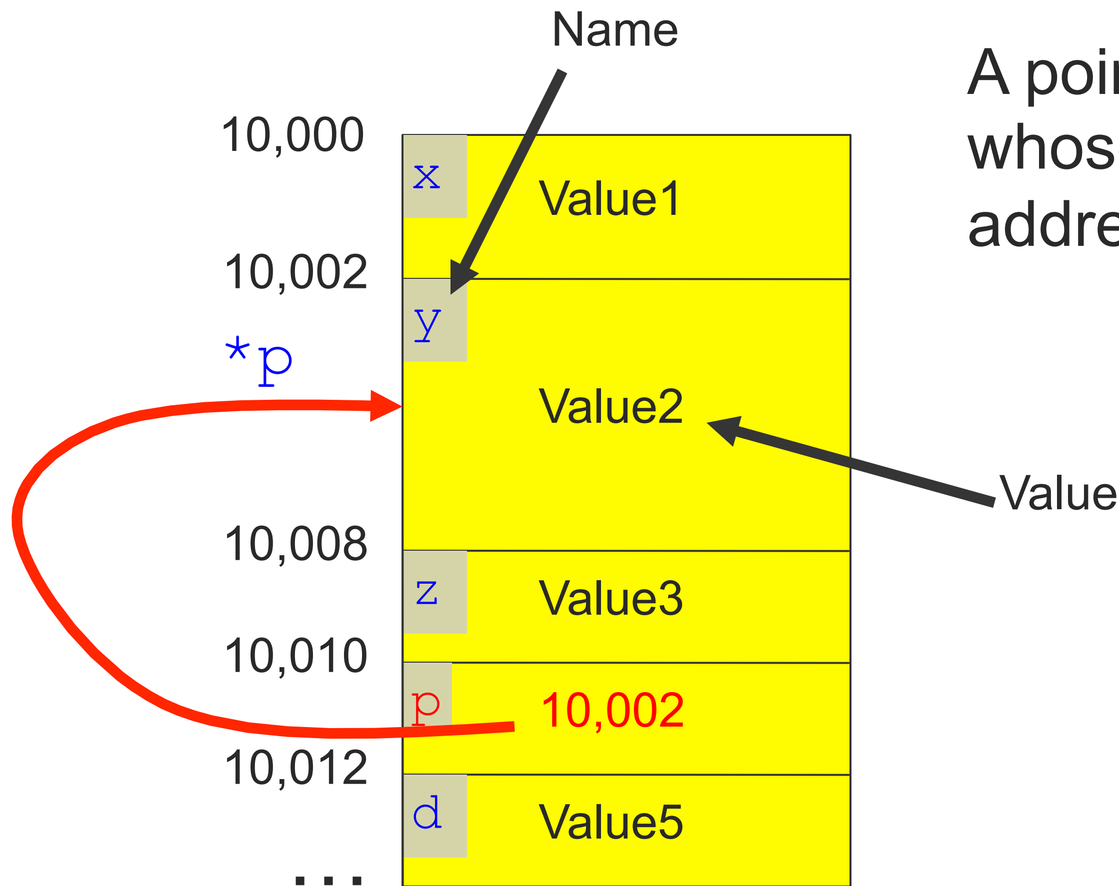
Pointers



A pointer is a variable whose value is the address of another

*p = "Variable p points to"



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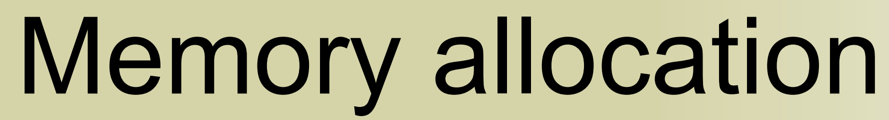

Memory allocation

Memory allocation

- Two ways to dynamically allocate memory
- Stack
  - Named variables in functions
  - Allocated for you when you call a function
  - Deallocated for you when function returns
- Heap
  - Memory on demand
  - You are responsible for all allocation and deallocation

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Sample layout for program image in main memory

High address	Command-line arguments and environment variables	← `argc, argv`, environment
	stack ↓	← Activation record for function calls (return address, parameters, saved registers, automatic variables)
	↑ heap	
	Uninitialized static data	← Allocations from `malloc` family
	Initialized static data	
Low address	Program text	

Processes have three segments: text, data, stack

Allocating and deallocating heap memory

- Dynamically **allocating** memory
  - Programmer explicitly requests space in memory
  - Space is allocated dynamically on the heap
  - E.g., using “malloc” in C, “new” in Java

- Dynamically **deallocating** memory
  - Must reclaim or recycle memory that is never used again
  - To avoid (eventually) running out of memory
  - Either manual or via automatic “garbage collection”

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Heap memory allocation

- C++:
  - `new` and `delete` allocate memory for a whole object
- C:
  - `malloc` and `free` deal with unstructured blocks of bytes

```
void* malloc(size_t size);
void free(void* ptr);
```

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Example

```
int* p;

p = (int*) malloc(sizeof(int));

*p = 5;

free(p);
```

How many bytes do you want?

Cast to the right type

Manual deallocation can lead to bugs

- **Dangling pointers**
  - Programmer frees a region of memory
  - … but still has a pointer to it
  - Dereferencing pointer reads or writes nonsense values

```
int main(void) {
      int *p;
      p = malloc(sizeof(int));
      …
      free(p);
      …
      printf("%d\n",*p);
}
```

May print nonsense

Manual deallocation can lead to bugs

- **Memory leak**
  - Programmer neglects to free unused region of memory
  - So, the space can never be allocated again
  - Eventually may consume all of the available memory

```
void f(void) {
     int *d;
     d = malloc(sizeof(int));
}

int main(void) {
     while (1) f();
}
```

Eventually, malloc() returns NULL

Manual deallocation can lead to bugs

- **Double free**
  - Programmer mistakenly frees a region more than once
  - Leading to corruption of the heap data structure
  - … or premature destruction of a different object

```
int main(void) {
      int *p, *q;
      p = malloc(sizeof(int));
      …
      free(p);
      q = malloc(sizeof(int));
      free(p);
}
```

Might free space allocated by **q**!

I’m hungry. More bytes plz.

```
int* p = (int*) malloc(10 * sizeof(int));
```

- Now I have space for 10 integers, laid out contiguously in memory. What would be a good name for that...?

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Arrays

Arrays

- Contiguous block of memory
  - Fits one or more elements of some type
- Two ways to allocate
  - named variable

```
int x[10];
```

  - dynamic

```
int* x = (int*) malloc(10*sizeof(int));
```

Is there a difference?

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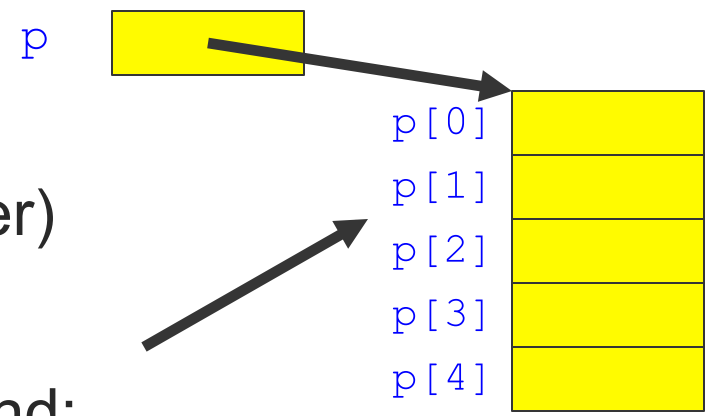
Arrays

```
int p[5];
```

Name of array (is a pointer)



Shorthand:

```
*(p+1) is called p[1]
*(p+2) is called p[2]
```

etc..

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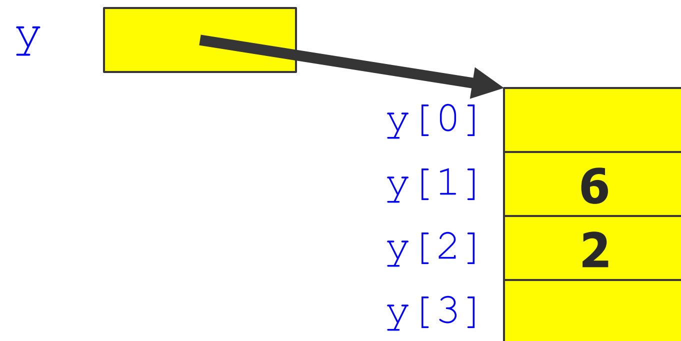
Adding integers to pointers (pointer arithmetic)

- Compiler uses the type information
  - `long *p;`
  - `p` ▶ `[long][long][long]`
- What address is `p + 2`?
  - … `p + sizeof(long) * 2`

Example

```
int y[4];
y[1]=6;
y[2]=2;
```



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Array Name as Pointer

- What's the difference between the examples?

- Example 1:

```
int z[8];
int *q;
q=z;
```

- Example 2:

```
int z[8];
int *q;
q=&z[0];
```

Questions

- What's the difference between

```
int* q;
int q[5];
```

- What's wrong with

```
int ptr[2];
ptr[1] = 1;
ptr[2] = 2;
```

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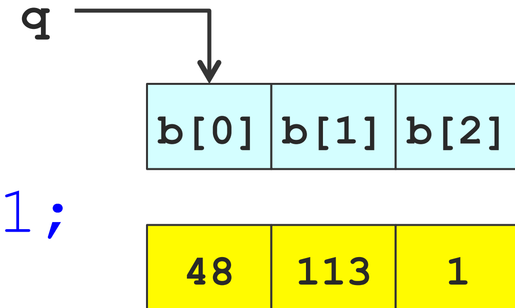
Questions

- What is the value of `b[2]` at the end?

```
int b[3];
int* q;

b[0]=48; b[1]=113; b[2]=1;

q=b;

*(q+1)=2;

b[2]=*b;

b[2]=b[2]+b[1];
```



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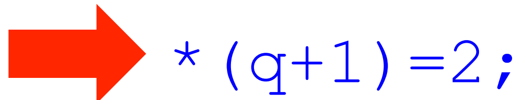
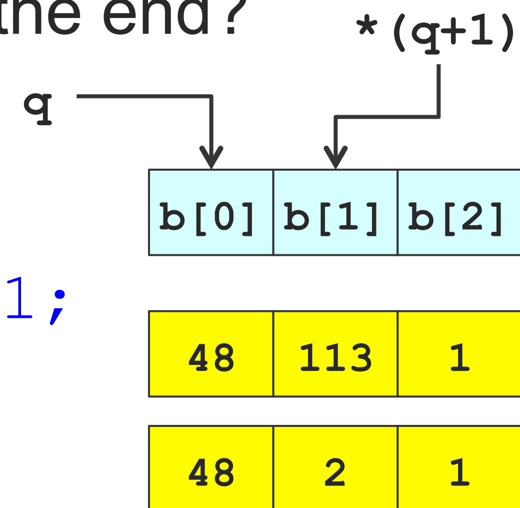


```
*(q+1)=2;

b[2]=*b;

b[2]=b[2]+b[1];
```



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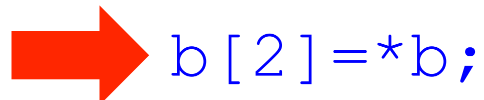

```
b[2]=*b;

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```

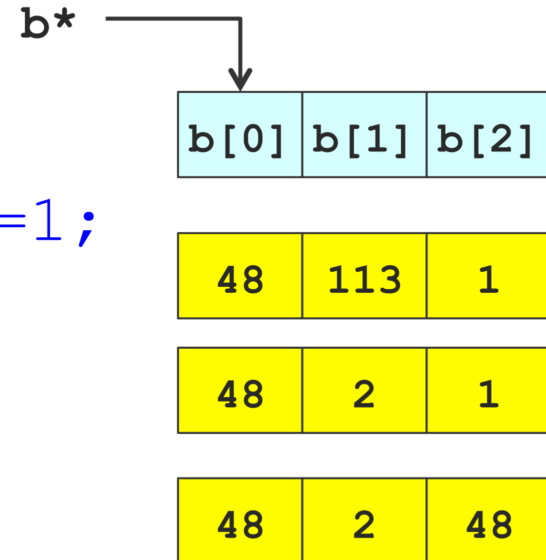

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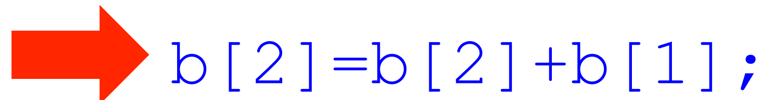

```
b[2]=b[2]+b[1];
```

b[0]	b[1]	b[2]
48	113	1
48	2	1
48	2	48
48	2	50

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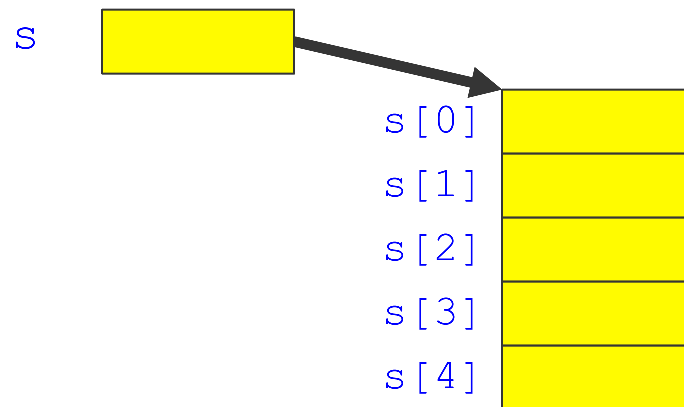
Strings

Strings (Null-terminated Arrays of Char)

- String = array of `char` followed by a "Null" character `'\0'` to indicate end
  - Do not forget to leave room for the null character
- Example
  - `char s[5];`



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String and character literals

- Strings
  - `"this is a string"`
  - `"c"`
- Characters
  - `'c'`
  - `'X'`
- Example
  - `printf("x = %c", 'x');`

Typecasting

Typecasting

- Syntax: type name in parentheses in front of another expression

```
main() {
    float a;
    a = (float)5 / 3;
}
```

- Result is a = 1.666666
  - Integer 5 is converted to floating point value before division and the operation between float and integer results in float
- What would `a` be without the `(float)`?

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Typecasting

- Take care about using typecast
- If used incorrectly, may result in loss of data
  - e.g., truncating a `float` when casting to an `int`

Typecasting pointers

```
int* p = 500;

printf("%p %p\n",
        p+1,
        ((char*) p) + 1
      );
```

- Does not change pointer value
- Does affect pointer arithmetic
- Avoids compiler warnings

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Typecasting pointers

```
int* p = (int*) 500;

printf("%p %p\n",
       p+1,
       ((char*) p) + 1
      );
```

- Does not change pointer value
- Does affect pointer arithmetic
- Avoids compiler warnings

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A puzzler

Can we make this work?!

```
int x;
```

```
printf("%s is awesome!\n", &x);
```

```
241 is awesome!
```

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Wednesday

- Lecture: OS structures
- Homework due 11 a.m. via SVN