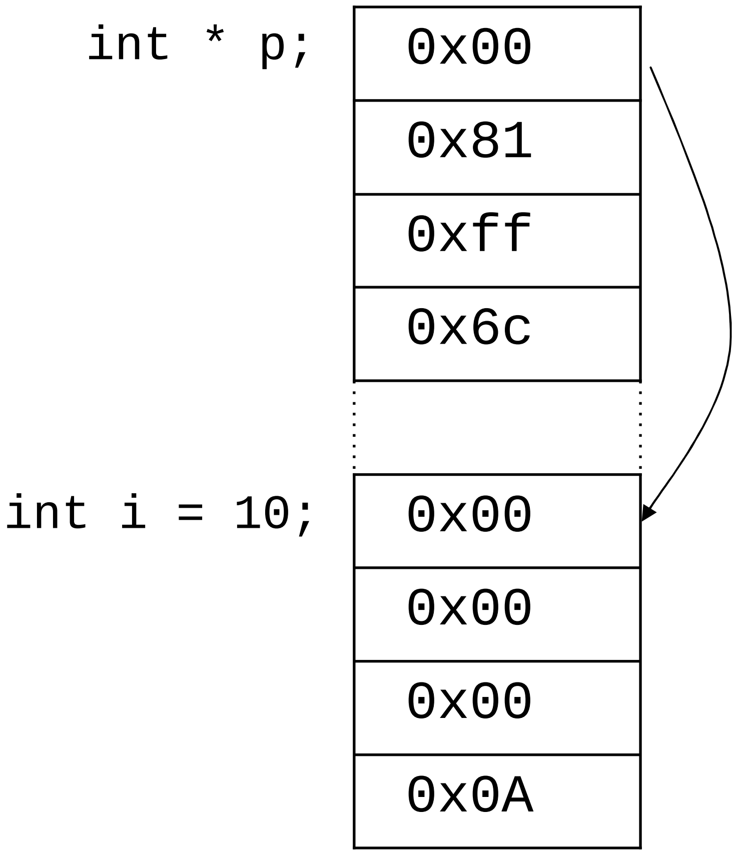
Pointers and Arrays

Introduction

- Pointers are variables that store memory addresses
- They store the address of a memory region that stores a particular type of data
- The size of a pointer is determined by the address size of the CPU

```
int * p;
int i = 10;
p = &i;
```



Pointer declaration

- A pointer variable is declared using the `*` operator

  ```
  int * p;
  ```

- `*` is called the dereferencing operator because `*p` gives the value of the variable `p` points to
- The & operator is used to recover the address of a variable in memory, it cannot be applied to expressions, constants or register variables

  ```
  p = &i;
  ```

Pointer assignment and usage

- Pointer can be assigned to one another

```
int i = 10;
int * ip = &i;
int * iq = ip; /* iq now points to i */
```

- Operator precedence in usage scenarios of `*` operator

```
*ip += 1;
++*ip;
(*ip)++;
```

  - increment value pointed to by `ip`
  - `*ip++;` would be incorrect in last example

Function arguments

- Arguments are passed to a function by value, even pointer arguments
- Pointers provide a mechanism for functions to alter the value of referenced variables
- Write a function that swaps the value of it's arguments

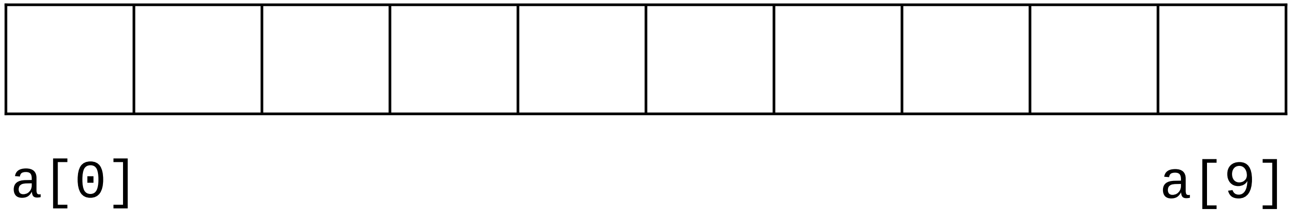
Arrays

- Arrays provide contiguous storage to several elements of the same type

  ```
  int a [10];
  ```

  declares an array of 10 integers

- Elements for external, static and automatic variables are initialized to zero
- The array index is zero based



Array initialization

- Arrays can be initialized during declaration

```
int days[] = {5, 10, 15, 25, 30};
```

  compiler fills in the size and fills the array

```
char name[] = "name";
```

  right-hand side is a string constant

```
char name[] = {'n', 'a', 'm', 'e'};
```

- Arrays can be initialized using assignment statements or using loops

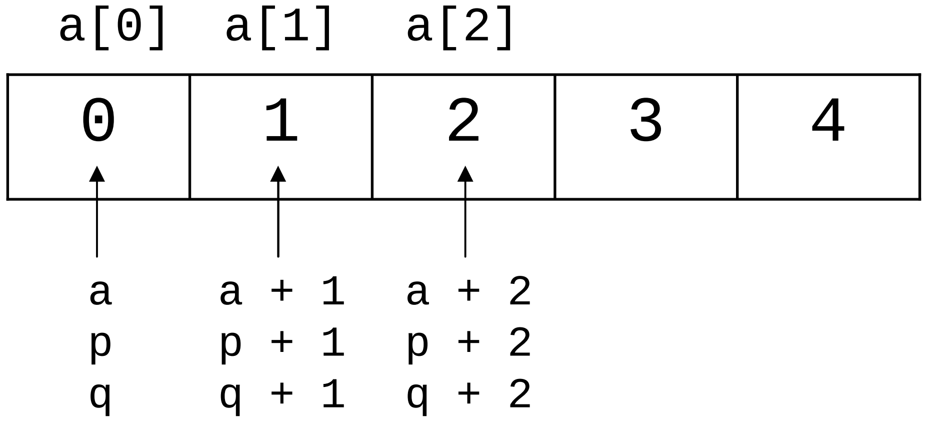
```
int days[5];
days[0] = 5;
```

Pointers and Arrays

- Arrays and pointers are related

```
int a[5] = {0 , 1, 2, 3, 4};
int * p = &a[0];
int * q = a;
```

`a` always points to the start of the array and cannot be changed



Pointer operations

- Pointers can be incremented in integer steps
- `p++` points to the next element

  what does `*p++ = 10` do? (hint – see operator precedence table)
- `p--` points to the previous element

  what does `*--p = 10` do? (hint – see operator precedence table)
- `p+=i` points to i elements beyond the current position

Strings

- Strings constants are arrays of `char`

```
 char name [] = "name";
```

- Since an array of `char` can be assigned to a pointer to `char`, a pointer to `char` can refer to a string constant

```
 char * name = "name";
```

- `strlen` can be used to calculate length of a string

 `strlen(name)` returns `4`

Multi-dimensional Arrays

- Declaration

```
int a[10][20];
```

  10 rows and 20 columns, *contiguous* storage for 200 integers

- Initialization

```
int a[][2] = {{1,2}, {3}};
int (a[])[2] = {{1,2}, {3}};
```

  The number of columns (length of each row) needs to be known beforehand, try printing `a[1][1]`, what do you get?

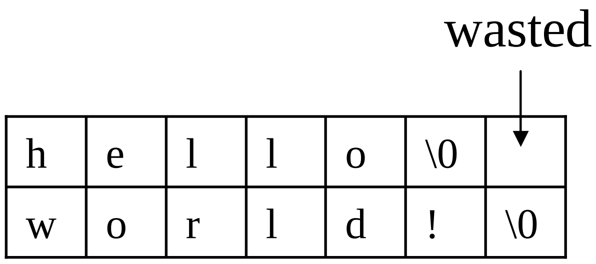
Array of Pointers

- This is how you would construct an array of string constants

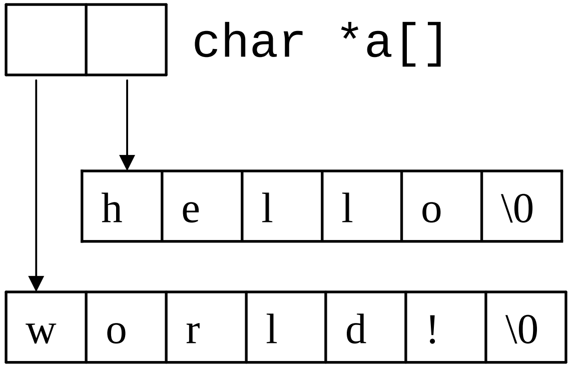
```
char a[][7] = {"hello",
  "world!"};
printf("%s %s\n", a[0],
  a[1]);
```

- The multi-dimensional array above is similar to an array of pointers to char

```
char * a[] = {"hello",
  "world!"};
printf("%s %s\n", a[0],
  a[1]);
```


wasted

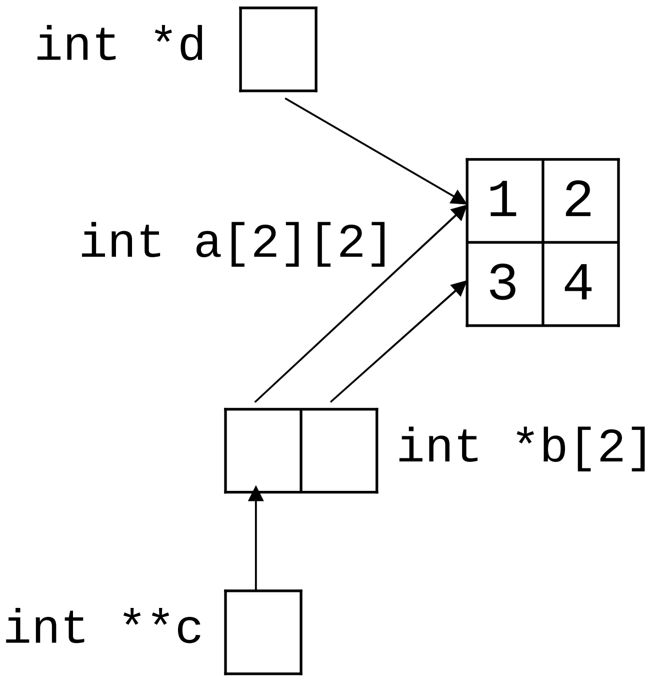
h	e	l	l	o	\0	
w	o	r	l	d	!	\0



h	e	l	l	o	\0	
w	o	r	l	d	!	\0

Pointers v. multi-dimensional arrays

```
int a[2][2] = {{1,2},{3,4}};
int *b[2], **c, *d;
b[0] = a[0]; b[1] = a[1];
c = b; d = (int *)a;
printf("%d\n", a[1][1]);
printf("%d\n", *(*(a + 1) + 1));
printf("%d\n", b[1][1]);
printf("%d\n", *(*(b + 1) + 1));
printf("%d\n", c[1][1]);
printf("%d\n", *(*(c + 1) + 1));
printf("%d\n", d[3]);
printf("%d\n", *(d + 3));
```



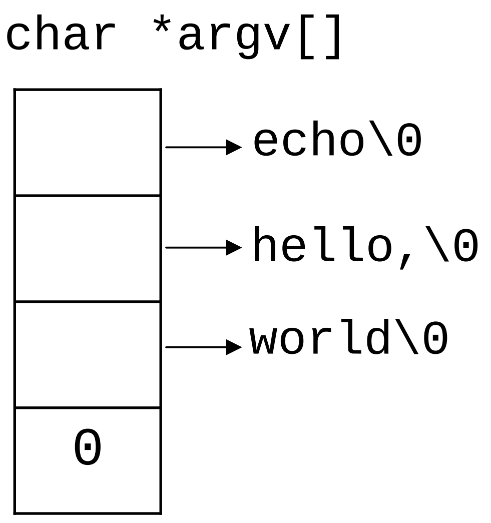
Command line arguments

```
main (int argc, char *
  argv[])
```

`argc` is the number of arguments in the command-line that invoked the program, always at least 1 because the program name is itself an argument

`argv` is an array of pointers to char, each element points to a string

```
echo hello, world
```



argv[argc] required to be a NULL pointer

Pointers to Functions

- Pointers can point to functions, although functions are very different from variables, they do have an address where they begin
- Declare a pointer to a function

```
int (*p)(int * a, int * b)
```

- Assign a function

```
p = add;
```

- Call the function

```
int a = b = 2;
(*p)(&a, &b);
```

void pointer

- Any pointer type can be assigned to, or passed to a function as, a void pointer

  ```
  int * ip;
  void * vp = ip;
  ```

- void pointer can be cast to any pointer type

  ```
  char * cp = (char *) vp;
  ```

- Useful for making generic functions that apply to various types
- Be careful with casting `void *` to another type, know what you are doing

Dynamic memory allocation

- Pointers not yet initialized are dangerous if they are not NULL pointers
- Pointers can be initialized to point to storage dynamically allocated using `malloc` and `calloc`
- `free` must be used to release the memory allocated using the above functions

malloc

```
void * malloc(size_t n)
```

- Allocates `n` bytes of storage and returns a void pointer to it

```
int * ip = (int *)malloc(10 * sizeof(int));
free(ip);
```

- `sizeof` is an operator that returns the size of the object or type specified

calloc

```
void * calloc(size_t n, size_t size)
```

- Allocates memory for `n` objects of size `size` and returns a void pointer to it
- The memory assigned is initialized to zeros

```
int * ip = (int *)calloc(10, sizeof(int));
free(ip);
```

Memory problems

- Using an unallocated pointer
- Writing to memory outside the allocated region (buffer overflow)
- Freeing memory not allocated using malloc or calloc
- Not freeing memory allocated using malloc and calloc (memory leak)

Detecting using memwatch

- memwatch [1] is distributed as a single source file `memwatch.c` and it's accompanying header file `memwatch.h`
- Source files you want to watch for memory problems must include `memwatch.h` and be recompiled using the following compiler options:

  ```
   -DMEMWATCH -DMW_STDIO
  ```
- memwatch prints an error message in the standard output and produces a detailed log file listing the memory problems it encounters

Exercise

- Write a program that sorts an array of strings. Use your favorite sorting algorithm (bubble sort, insertion sort, etc). Write your own replacement for `strcmp` to compare the strings. Write a generic sort function that can work with arrays of other types

Tools and References

1. memwatch – http://www.linkdata.se/sourcecode.html