CS 33

Introduction to C
Part 2

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

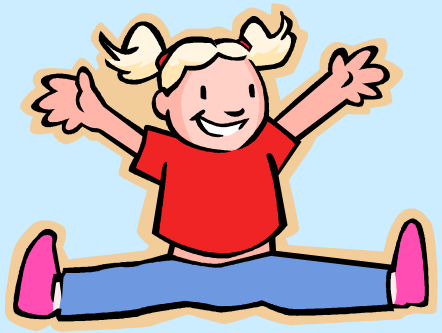
```
$ gcc -o fact fact.c
main.c:27: warning: type mismatch with previous implicit
declaration
main.c:23: warning: previous implicit declaration of
'fact'
main.c:27: warning: 'fact' was previously implicitly
declared to return 'int'
```

```
$  ./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);
}
```

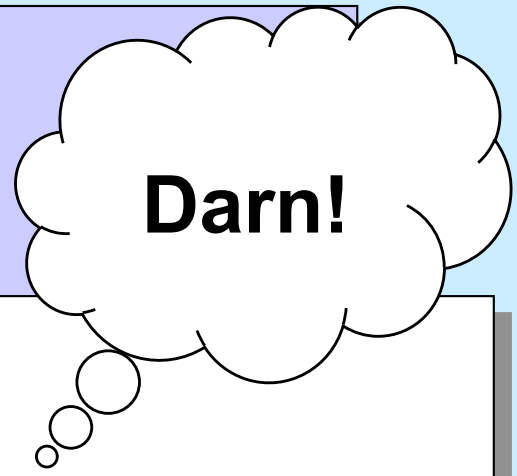
Arguments are passed by value

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);
}
```

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



Why “pass by value”?

- **Fortran, for example, passes arguments “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*.

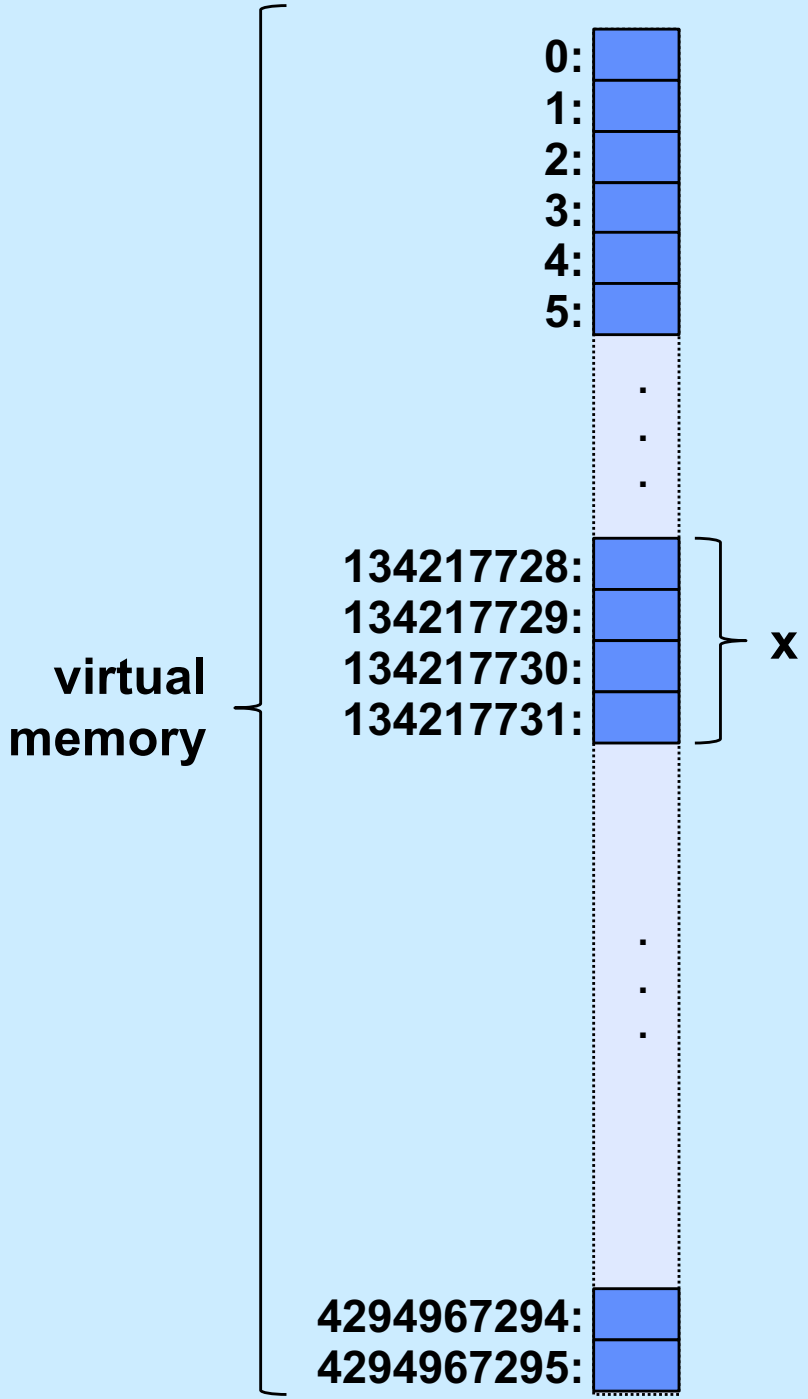
What's memory?

Memory

- "Real" memory
  - it's complicated
  - it involves electronics, semiconductors, physics, etc.
  - it's not terribly relevant at this point
- "Virtual" memory
  - the notion of memory as used by programs
  - it involves logical concepts
  - it's how you should think about memory (most of the time)

Virtual Memory

- It's a large array of bytes
  - one byte is eight bits
  - an int is four consecutive bytes
  - so is a float
  - a char is one byte
- The array index of a byte is its *address*
  - the address of a larger item is the index of its first byte



Variables

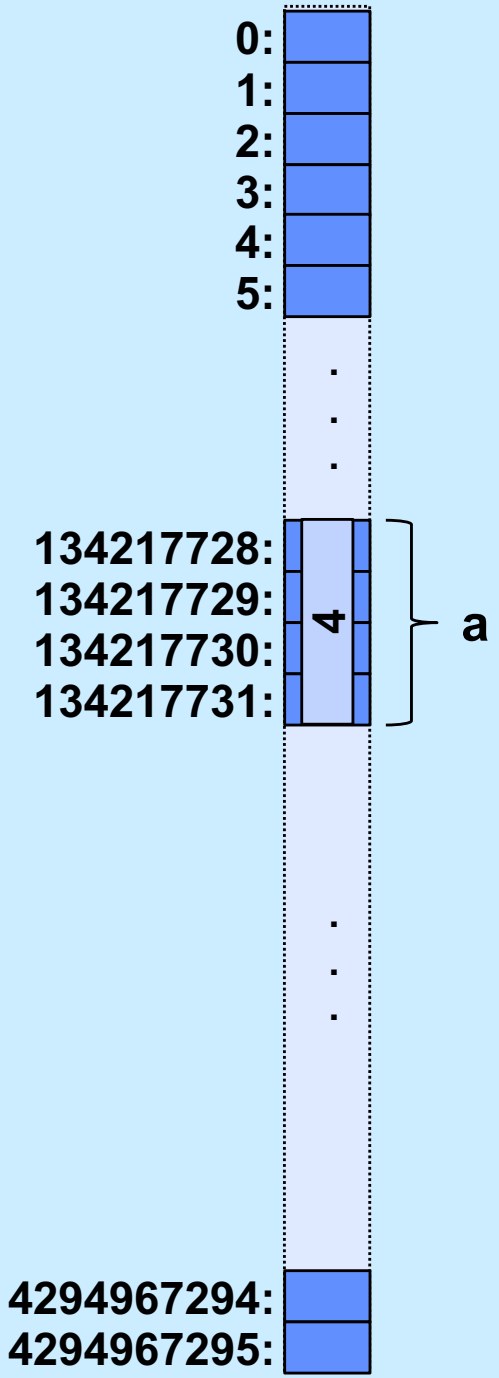
- Where
  - they refer to locations in memory
- Size
  - how much memory they refer to
- Interpretation
  - how to interpret the contents of memory

- All determined when they are declared
- None of the above change after declaration

```
int x;   // sizeof(x) == 4
float y; // sizeof(y) == 4
char z;  // sizeof(z) == 1
```

Memory addresses in C

- In C
  - you can get the memory address of any variable
  - just use the operator &




```
int main() {
    int a = 4;
    printf("%p\n", &a);
}
```

```
$ ./a.out
134217728
```

C Pointers

- What is a C pointer?
  - a variable that holds an address
- Pointers in C are “typed” (remember the promises)
  - pointer to an int
  - pointer to a char
  - pointer to a float
  - pointer to <whatever you can define>
- C has a syntax to declare pointer types
  - things start to get complicated …

C Pointers

p is a pointer to an int

if you follow p, you find an int

```
int main() {
    int *p;
    int a = 4;
    p = &a;
    printf("%p\n", p);
}
```

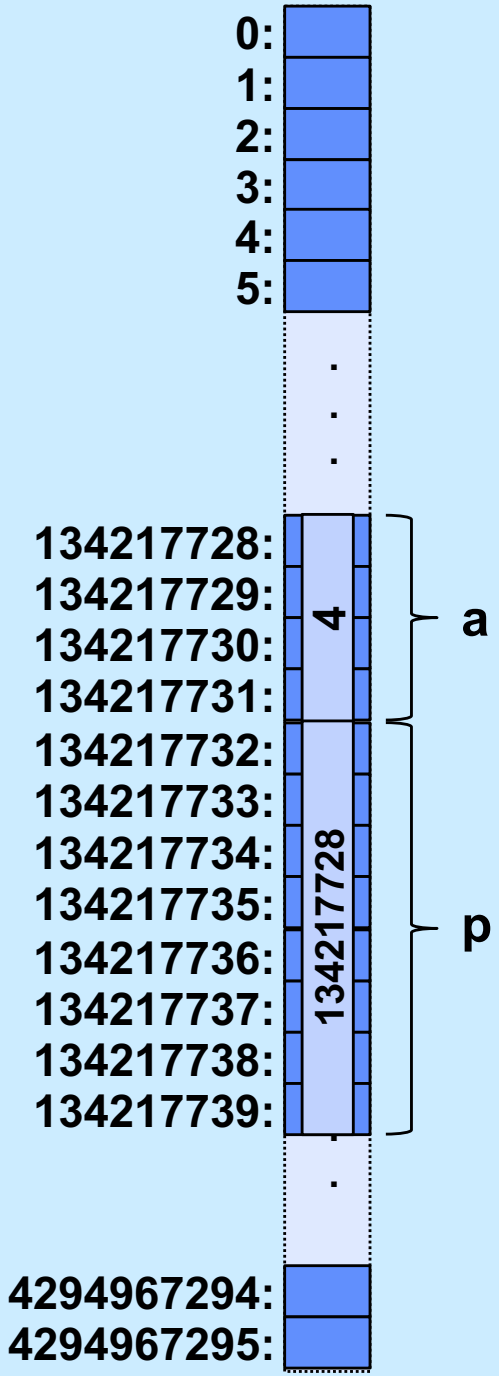
p is assigned the address of a

```
$ ./a.out
134217728
```

C Pointers

```
int main() {
    int *p;
    int a = 4;
    p = &a;
    printf("%p\n", p);
}
```

```
$ ./a.out
134217728
```



C Pointers

- **Pointers are typed**
  - **the types of the items they point to are known**
  - **there is one exception (discussed later)**
- **Pointers are first-class citizens**
  - **they can be passed to functions**
  - **they can be stored in arrays and other data structures**
  - **they can be returned by functions**
- **Pointers have the properties of all variables**

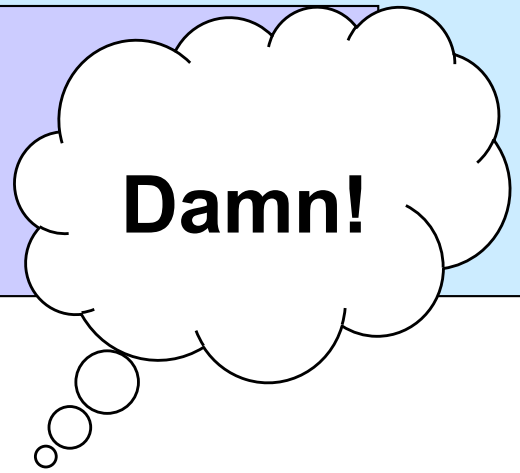
```
sizeof(int *) == sizeof(char *) == 8
```

Swapping

What does this do?

```
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\n", a, b);
}
```

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

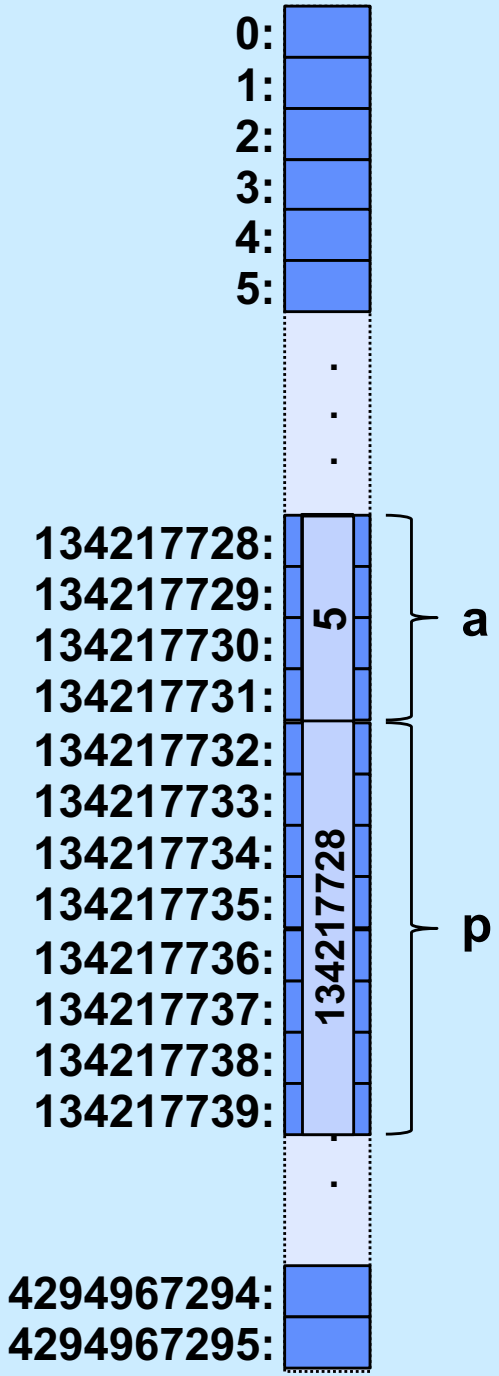


C Pointers

- **Dereferencing pointers**
  - **accessing/modifying the value pointed to by a pointer**

```
int main() {
    int *p;
    int a = 4;
    p = &a;
    printf("%d\n", *p);
    *p = *p + 1;
    printf("%d\n", *p);
}
```

```
$ ./a.out
4
5
```



Dereferencing C Pointers

```
int main() {
    int *p;
    int a = 4;
    p = &a;
    printf("%d\n", *p);
    *p = *p + 1;
    *p += 3;
    printf("%d\n", a);
}
```

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

Swapping

```
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\n", a, b);
}
```

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

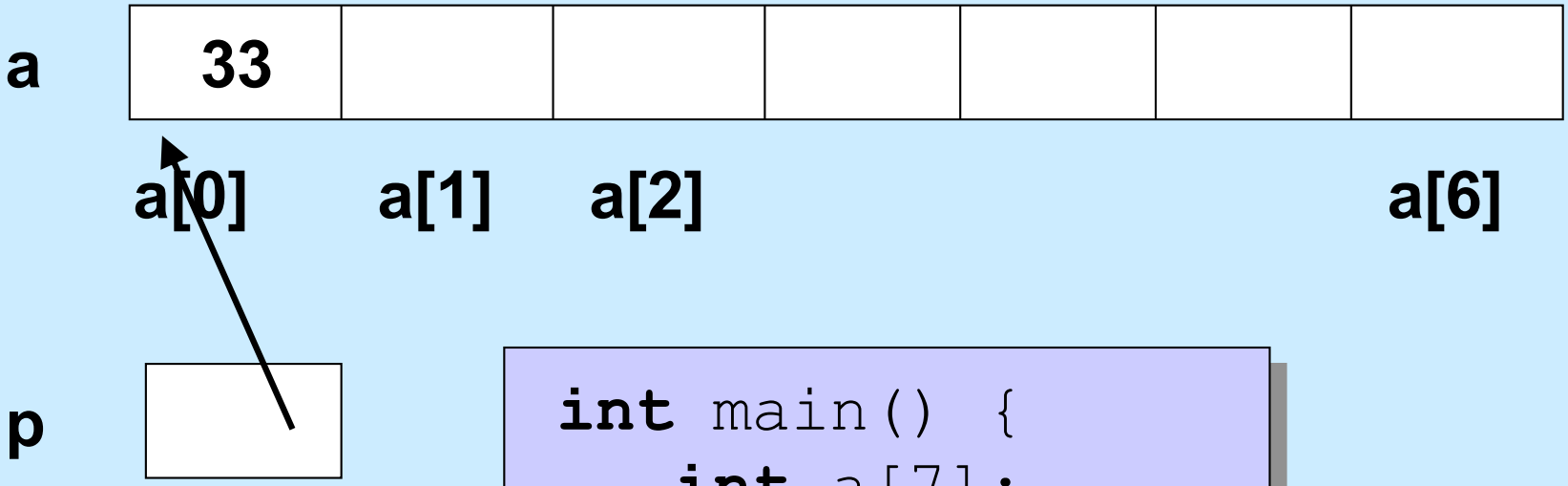
Quiz 1

```
int doubleit(int *p) {
    *p = 2*(*p);
    return *p;
}
int main() {
    int a = 4;
    int b;
    b = doubleit(&a);
    printf("%d\n", a*b);
}
```

What's printed?

a) 8
b) 16
c) 32
d) 64

Pointers and Arrays

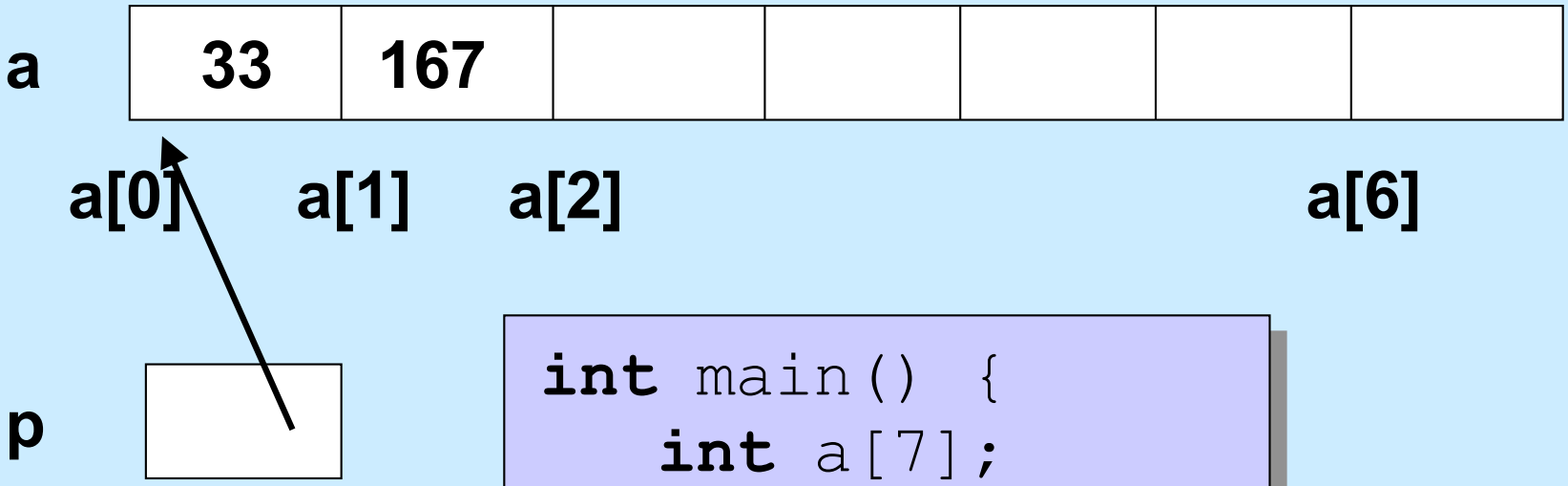



```
int main() {
    int a[7];
    int *p;
    p = &a[0];
    *p = 33;
}
```

Pointer Arithmetic

Pointers can be incremented/decremented

- **what this does depends on its type**

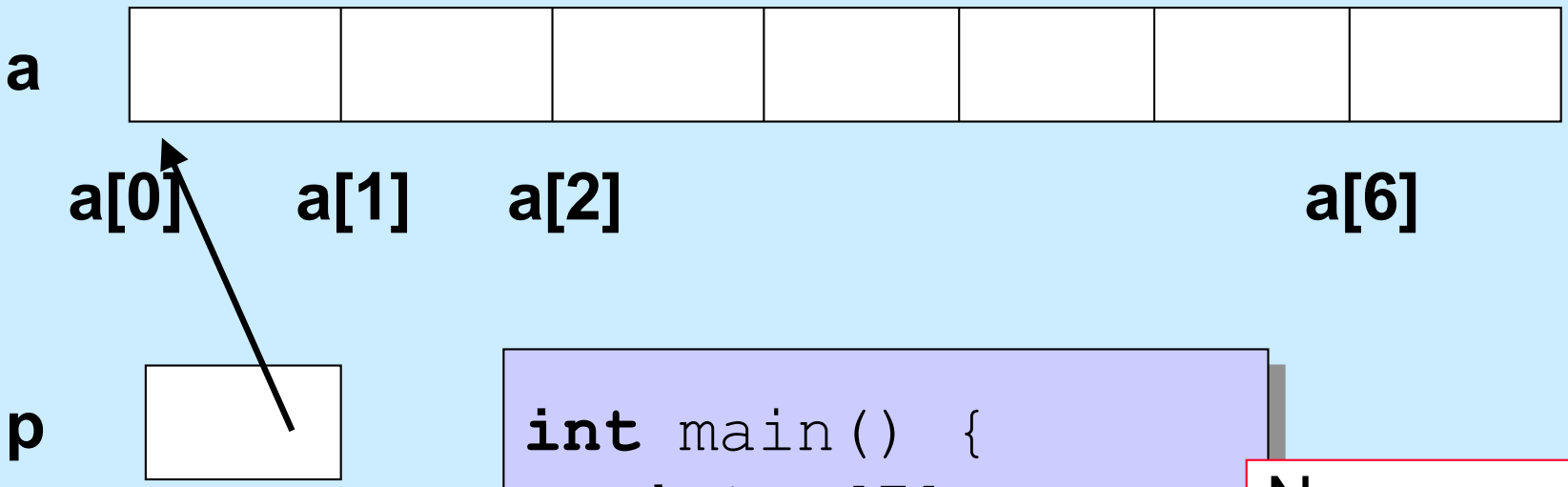



```
int main() {
    int a[7];
    int *p;
    p = &a[0];
    *p = 33;
    *(p+1) = 167;
}
```

Pointer Arithmetic

Pointers can be incremented/decremented

- **what this does depends on its type**



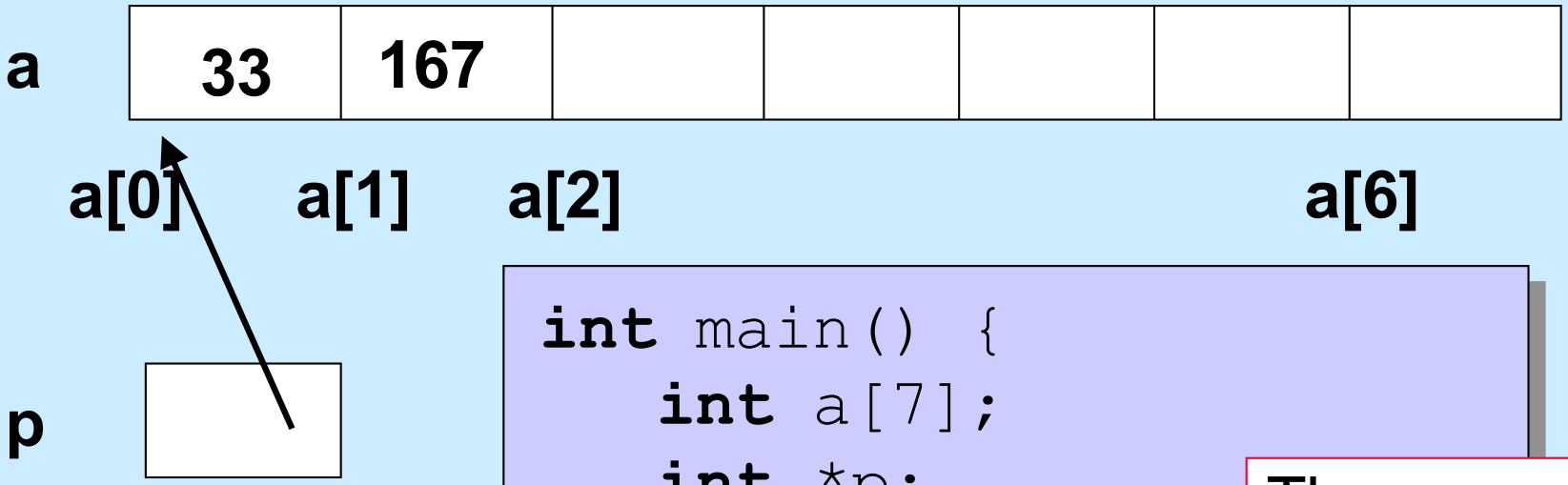

```
int main() {
    int a[7];
    int *p;
    p = &a[0];
}
```

Now `p` and `a` have the same value

Pointer Arithmetic

Pointers can be incremented/decremented

- **what this does depends on its type**




```
int main() {
    int a[7];
    int *p;
    p = a;
    *p = 33;
    p[1] = 167;
}
```

The array name represents a pointer to its first element

Pointers and Arrays

```
p = &a[0];
```

can also be written as

```
p = a;
```

```
a[i];
```

really is

```
*(a+i)
```

- **This makes sense, yet is weird ...**
  - `p` **is of type** `int *`
    - **it can be assigned to**

```
int *q;
p = q;
```

  - `a` **sort of behaves like an** `int *`
    - **but it can't be assigned to in the same way**

```
a = q;
```

Non-Array Variables

- **`int` `i`**
  - **four bytes of memory are allocated for `i`**

    ```
    sizeof(i) == 4
    ```

  - **`i` represents the contents of this memory, interpreted as an `int`**
  - **it makes sense to do, for example**

    ```
    i = 7; // changes the contents of i
    ```

- **`int` `*p`**
  - **8 bytes of memory are allocated for p**

    ```
    sizeof(p) == 8
    ```

  - **`p` represents the contents of this memory, interpreted as an `int *`**
  - **it makes sense to do, for example**

    ```
    p = &i; // changes the contents of p
    ```

Array Variables

- `int A[6]`
  - **24 bytes of memory are allocated for** `A`

    ```
    sizeof(A) == 24
    ```
  - `A` **represents the address of the first byte**
  - `*A` **is the value of the first int (as if** `A` **were an** `int *`**)**
  - **it does not make sense to do**

    ```
    A = &i; // would change the location of A
    ```
- `int *p = A;`
  - **8 bytes of memory are allocated for** `p`

    ```
    sizeof(p) == 8
    ```
  - `p` **represents the contents of this memory**
  - `*p` **is the same as** `A[0]`
  - **it makes sense to do, for example**

    ```
    p = &i;
    ```

Arrays and Functions

```
int func(int *a, int nelements) {
    int i;
    for (i=0; i<nelements; i++) {
        *(a+i) = i;
    }
    return nelements;
}

int main() {
    int array[1000000000] = ... ;
    printf("result = %d\n", func(array, 1000000000));
    return 0;
}
```

initialized with a copy of the argument

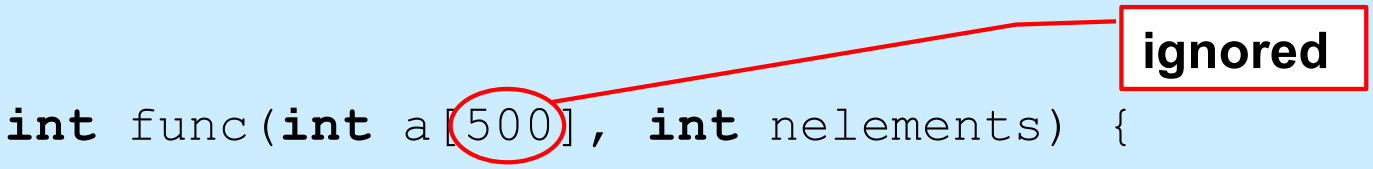
Equivalently

```
int func(int a[], int nelements) {
    int i;
    for (i=0; i<nelements; i++) {
        a[i] = i;
    }
    return nelements;
}

int main() {
    int array[1000000000] = ... ;
    printf("result = %d\n", func(array, 1000000000));
    return 0;
}
```

initialized with a copy of the argument

Equivalently




```
int func(int a[500], int nelements) {
    int i;
    for (i=0; i<nelements; i++) {
        a[i] = i;
    }
    return nelements;
}

int main() {
    int array[1000000000] = ... ;
    printf("result = %d\n", func(array, 1000000000));
    return 0;
}
```

Parameter passing

Passing arrays to a function

```
int average(int a[], int size) {
    int i; int sum;
    for(i=0,sum=0; i<size; i++)
       sum += a[i];
    return sum/size;
}
int main() {
    int a[100];
    …
    printf("%d\n",average(a,100));
}
```

Swapping

Write a function to swap two entries of an array

```
void swap(int a[], int i, int j) {
    int tmp;
    tmp = a[j];
    a[j] = a[i];
    a[i] = tmp;
}
```

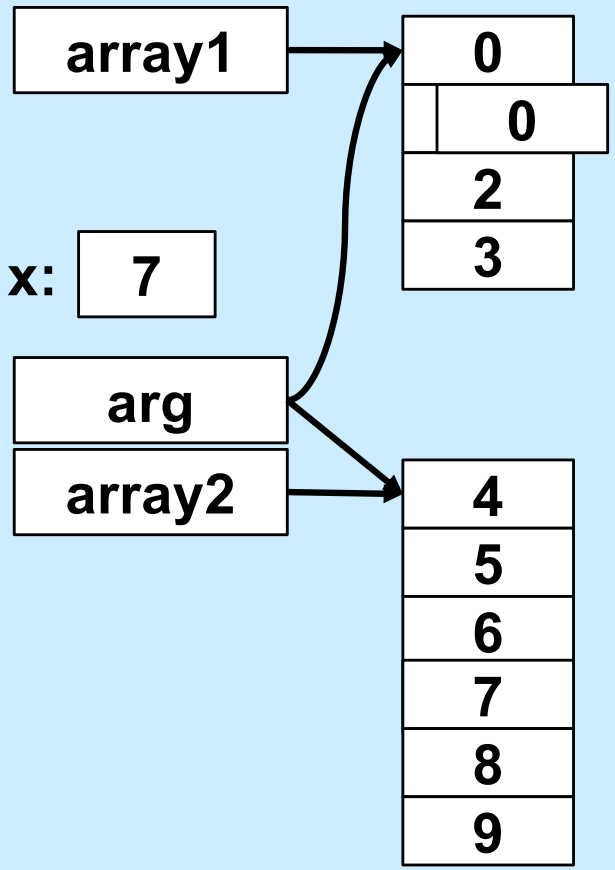
Selection Sort

```
void selectsort(int array[], int length){
  int i, j, min;
  for (i = 0; i < length; ++i){
    /* find the index of the smallest item from i onward */
    min = i;
    for (j = i; j < length; ++j) {
      if (array[j] < array[min])
        min = j;
    }
    /* swap the smallest item with the i-th item */
    swap(array, i, min);
  }
  /* at the end of each iteration, the first i slots have the i
     smallest items */
}
```

Arrays and Arguments

```
int func(int arg[]) {
    int array2[6] = {4, 5, 6, 7, 8, 9};
    arg[1] = 0;
    arg = array2;
    return arg[3];
}

int main() {
    int array1[4] = {0, 1, 2, 3};
    int x = func(array1);
    printf("%d, %d\n", x, array1[1]);
    return 0;
}
```




```
$ ./a.out
7 0
```

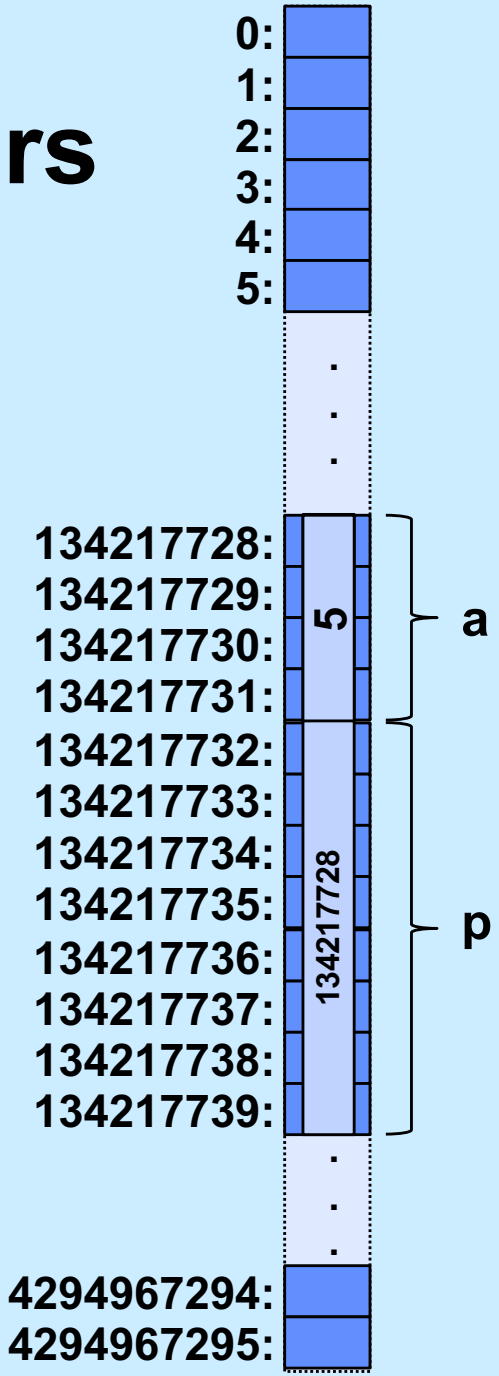
Arrays and Arguments

```
void func(int arg[]) {
   /* arg points to the caller's array */
   int local[7];     /* seven ints */
   ++arg;            /* legal */
   arg = local;      /* legal */
   ++local;          /* illegal */
   local = arg;      /* illegal */
}
```

Dereferencing C Pointers

```
int main() {
    int *p; int a = 4;
    p = &a;
    ++(*p);
    printf("%d %p\n", *p, p);
}
```

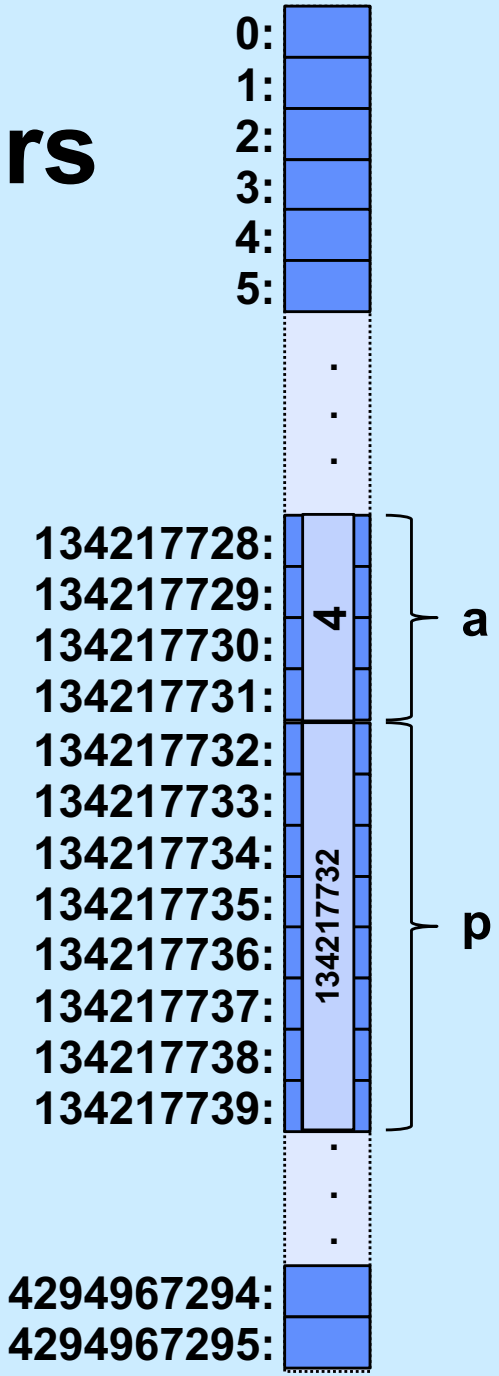
```
$ ./a.out
5 134217728
```



Dereferencing C Pointers

```
int main() {
    int *p; int a = 4;
    p = &a;
    *(++p);
    printf("%d %p\n", *p, p);
}
```

```
$ ./a.out
134217732 134217732
```



Quiz 2

```
int func(int arg[]) {
    ++arg;
    return arg[0];
}

int main() {
    int A[3]={10, 11, 12};
    printf("%d\n",
      func(A));
}
```

What's printed?

a) 9
b) 10
c) 11
d) 12

Quiz 3

```
int func(int a[]) {
    int b[5] = {10, 11, 12, 13, 14};
    a = b;
    return a[1];
}

int main() {
    int array[50];
    array[1] = 0;
    printf("result = %d\n",
        func(array));
    return 0;
}
```

This program prints:

a) 0
b) 10
c) 11
d) nothing: it doesn't compile because of a syntax error

Quiz 4

```
int func(int a[]) {
    int b[5] = {10, 11, 12, 13, 14};
    a = b;
    return a[1];
}

int main() {
    int array[5] = {9, 8, 7, 6, 5};
    func(array);
    printf("%d\n", array[1]);
    return 0;
}
```

This program prints:

a) 7
b) 8
c) 10
d) 11

The Preprocessor

`#include`

- calls the preprocessor to include a file

What do you include?

- your own *header* file:

```
#include "fact.h"
```

  - look in the current directory

- standard *header* file:

```
#include <assert.h>
#include <stdio.h>
```

  - look in a standard place

Contains declaration of *printf* (and other things)

Function Declarations

fact.h

```
float fact(int i);
```

main.c

```
#include "fact.h"
int main() {
  printf("%f\n", fact(5));
  return 0;
}
```

#define

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

#define

- **defines a substitution**
- **applied to the program by the preprocessor**

#define

```
#define forever for(;;)
int main() {
    int i;
    forever {
      printf("hello world\n");
    }
}
```

assert

```
#include <assert.h>
float fact(int i) {
  int k, res;
  assert(i >= 0);
  for(res=1,k=1; k<=i; k++)
    res = res * k;
  return res;
}
int main() {
  printf("%f\n", fact(-1));
```

assert

- **verify that the assertion holds**
- **abort if not**

```
$ ./fact
main.c:4: failed assertion 'i >= 0'
Abort
```