Today's Goals

- Pointers as function arguments
- Pointers as function return value
- Arrays in terms of pointers
  - Single
  - Multi-dimensional
  - Pointer arrays

Section 1

The `NULL` Pointer

- C guarantees that zero is never a valid address for data
- A pointer that contains the address zero known as the **NULL** pointer
- It is often used as a signal for abnormal or terminal event
- It is also used as an initialization value for pointers

Section 2

Pass by Value

- All functions are pass-by-value in C
  - A copy is made of each parameter's value and then the copy is passed
- Variables supplied as parameters to a function call are protected against change
  - i.e. impossible to write a **swap(x, y)** function
- Only way to modify a variable through a function is to assign the return value to that variable

Pass by Value and Pointers

- All functions are pass-by-value in C
- Pass-by-value sill holds even if the parameter is a pointer
  - A copy of the pointer's value is made – the address stored in the pointer variable
  - The copy is then a pointer pointing to the same object as the original parameter
  - Thus modifications via de-referencing the copy STAYS.

Function Arguments

- **x** and **y** are copies of the original, and thus **a** and **b** can not be altered.

```
void swap(int x, int y) {
  int tmp;
  tmp = x; x = y; y = tmp;
}

int main() {
  int a = 1, b = 2;

  swap(a, b);
  return 0;
}
```

Wrong!

Pointers and Function Arguments

- Passing pointers – **a** and **b** are passed by reference (the pointers themselves **px** and **py** are still passed by value)

```
void swap(int *px, int *py) {
  int tmp;
  tmp = *px; *px = *py; *py = tmp;
}

int main() {
  int a = 1, b = 2;

  swap(&a, &b);
  return 0;
}
```

Use Pointers to Modify Multiple Values in a Function

```
void decompose(double d, int *i, double *frac) {
  *i = (int) d;
  *frac = d - *i;
}

int main() {
  int int_part;
  double frac_part, input;

  scanf("%lf", &input);
  decompose(input, &int_part, &frac_part);
  printf("%f decomposes to %d and %f\n",
         *int_part, *frac_part);
  return 0;
}
```


Pass by Reference

- Do not equate pass-by-reference with pass-by-pointer
- The pointer variables themselves are still passed by value
- The objects being pointed to, however, are passed by reference
- In a function, if a pointer argument is de-referenced, then the modification indirectly through the pointer will stay

Pointers are Passed by Value

```
void f(int *px, int *py) {
  px = py;
}

int main() {
  int x = 1, y = 2, *px;
  px = &x;
  f(px, &y);
  printf("%d", *px); // will print 1
}
```


Modification of a Pointer

```
void g(int **ppx, int *py) {
  *ppx = py;
}

int main() {
  int x = 1, y = 2, *px;
  px = &x;
  g(&px, &y);
  printf("%d", *px); // will print 2
}
```


Pointer as Return Value

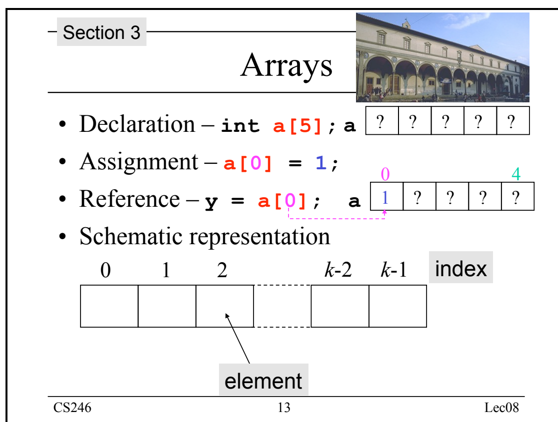
- We can also write functions that return a pointer
- Thus, the function is returning the memory address of where the value is stored instead of the value itself
- Be very careful not to return an address to a temporary variable in a function!!!

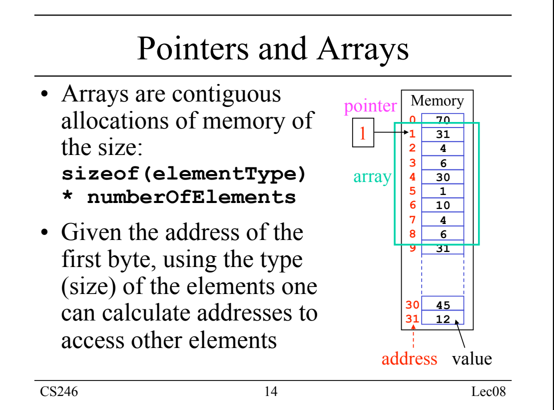
Example

- **x** and **y** are copies of the original, and thus what is **&x** and **&y**?

```
int* max(int *x, int *y) {
  if (*x > *y)
    return x;
  return y;
}

int main() {
  int a = 1, b = 2, *p;

  p = max(&a, &b);
  return 0;
}
```

```
int* max(int x, int y) {
  if (x > y)
    return &x;
  return &y;
}

p = max(a, b);
```





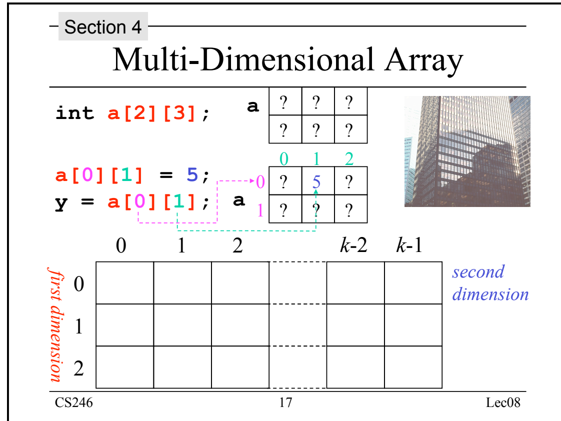
Name of an Array

- The variable name of an array is also a pointer to its first element.

- `a == &a[0]`
- `a[0] == *a`

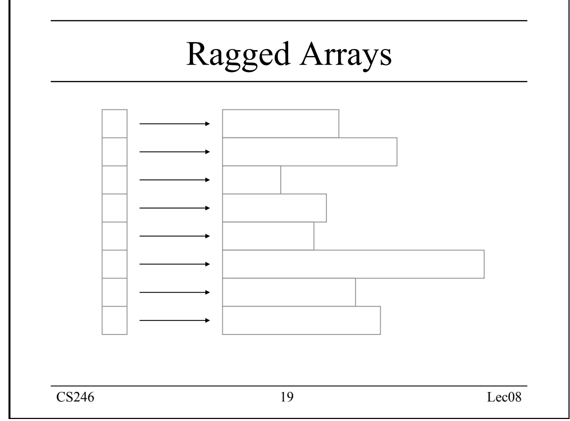
Pointer Arithmetic

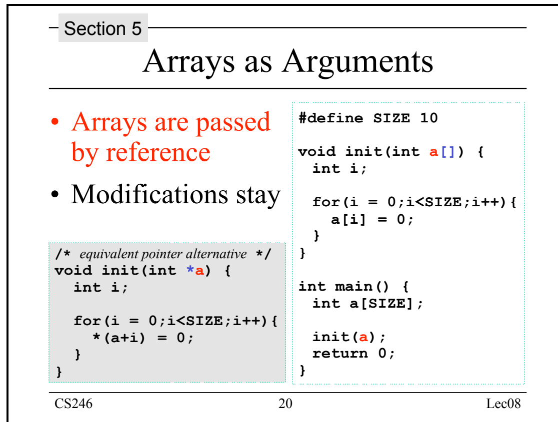
- One can add/subtract an integer to/from a pointer
- The pointer advances/retreats by that number of *elements (of the type being pointed to)*
  - `a+i == &a[i]`
  - `a[i] == *(a+i)`
- Subtracting two pointers yields the number of *elements* between them



Pointer Arrays: Pointer to Pointers

- Pointers can be stored in arrays
- Two-dimensional arrays are just arrays of pointers to arrays.
  - `int a[10][20]; int *b[10];`
  - Declaration for b allows 10 **int** pointers, with no space allocated.
  - Each of them can point to an array of 20 integers
  - `int c[20]; b[0] = c;`
  - What is the type of **b**?





Combining `*` and `++`/`--`

- `++` and `--` has precedence over `*`
  - `a[i++] = j;`
  - `p=a; *p++ = j; <==> *(p++) = j;`
  - `*p++; value: *p, inc: p`
  - `(*p)++; value: *p, inc: *p`
  - `++(*p); value: (*p)+1, inc: *p`
  - `*++p; value: *(p+1), inc: p`

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Summary

- Understand the relationship between arrays and pointers
- Understand the relationship between two-dimensional arrays and pointer arrays
- Arrays are passed by reference to functions
- Pointer arithmetic is powerful but dangerous!

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