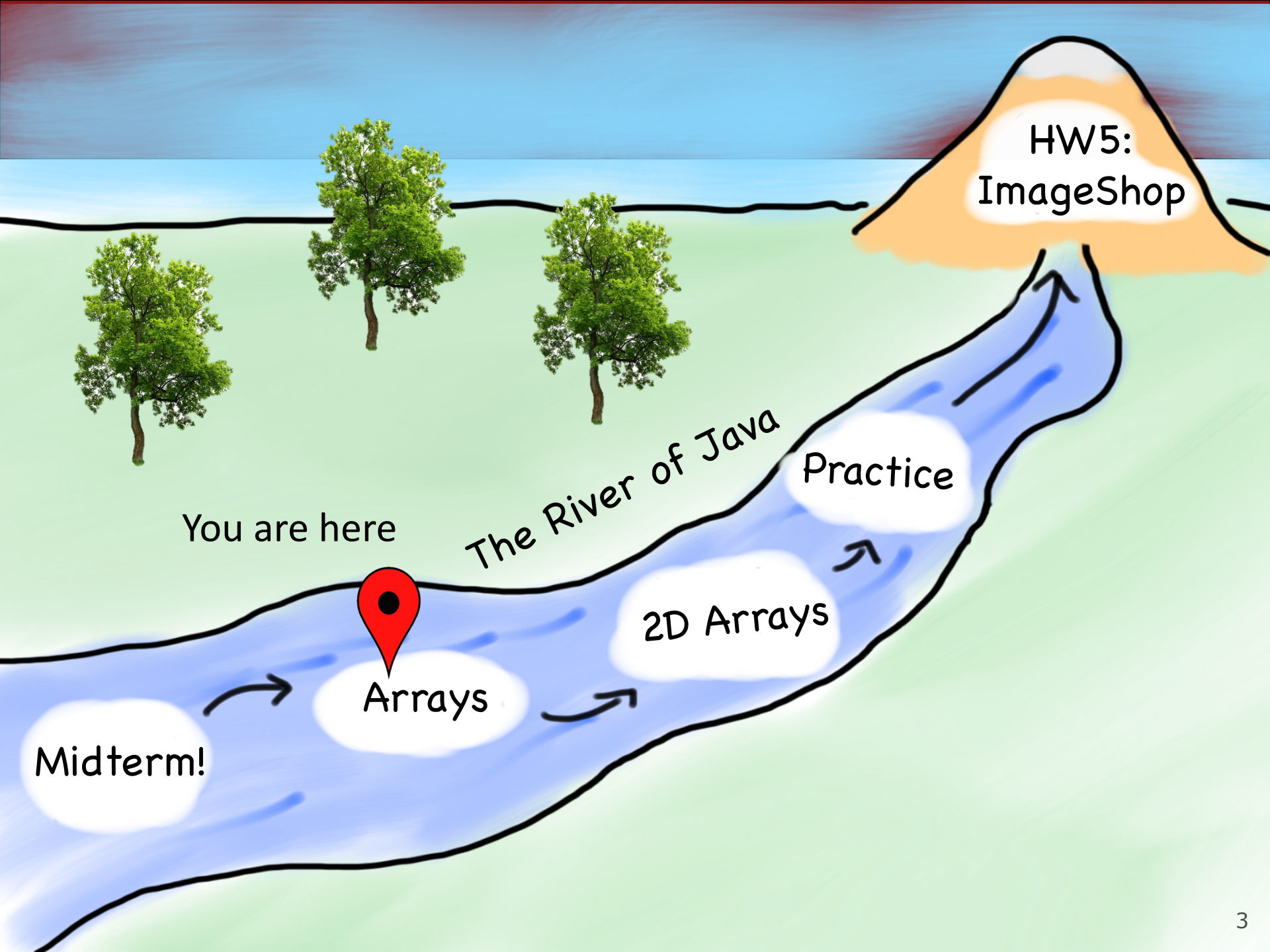
CS 106A, Lecture 16
Arrays

suggested reading:

Java Ch. 11.1-11.5

Where Are We in CS 106A?

- Karel the Robot
- Java
- Console Programs
- Text Processing
- Graphics Programs
- Data Structures
- Defining our own Variable Types
- GUIs


HW5:
ImageShop
The River of Java
Practice
You are here
2D Arrays
Arrays
Midterm!

Plan for Today

- Data Structures
- Arrays
- Arrays as Parameters and Return Values
- Announcements
- Practice: Swapping Elements
- Practice: WeatherStation
- Recap

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What are Data Structures?

Data structures are variable types that can store data in interesting ways.

Why Are Data Structures Useful?

Consider a program similar to Weather from HW2 that prompts for daily temperatures and prints averages, high/lows, etc.

– Why is this hard to write with what we've learned so far?

```
How many days' temperatures? 7
Day 1's high temp: 45
Day 2's high temp: 44
Day 3's high temp: 39
Day 4's high temp: 48
Day 5's high temp: 37
Day 6's high temp: 46
Day 7's high temp: 53

All temperatures: [45, 44, 39, 48, 37, 46, 53]
Average temp = 44.6
4 days were above average.
Two coldest days: 37, 39
Two hottest days: 53, 48
```

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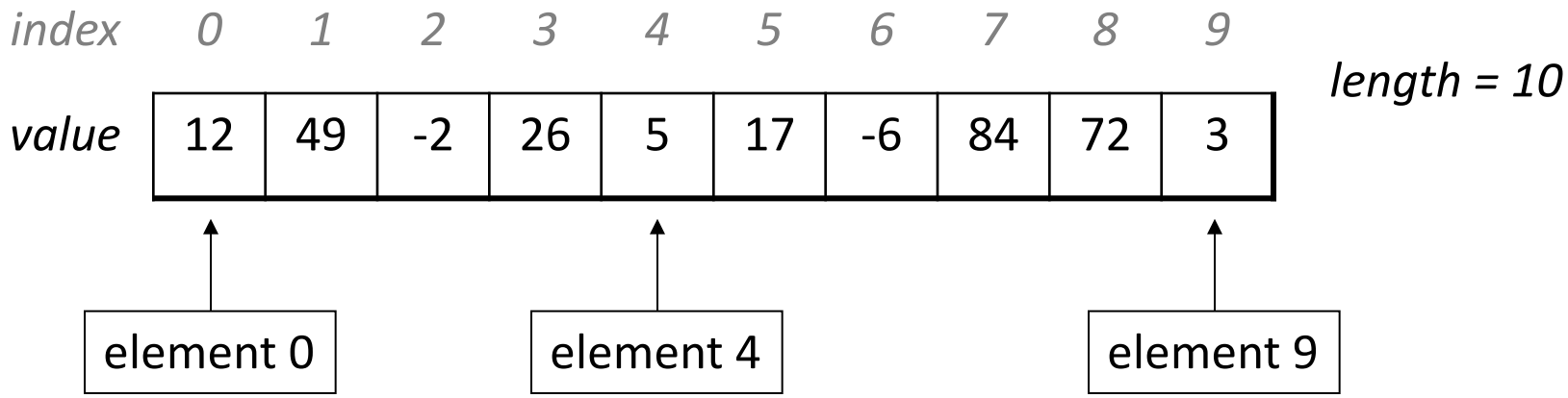
Arrays

A new variable type that is an object that represents an ordered, homogeneous list of data.

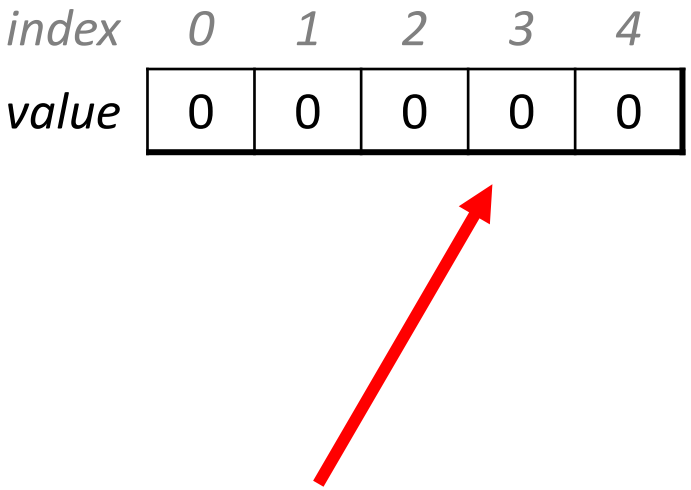
– Arrays have many *elements* that you can access using *indices*



Creating an Array

```
type[] name = new type[length];
```

```
int[] numbers = new int[5];
```



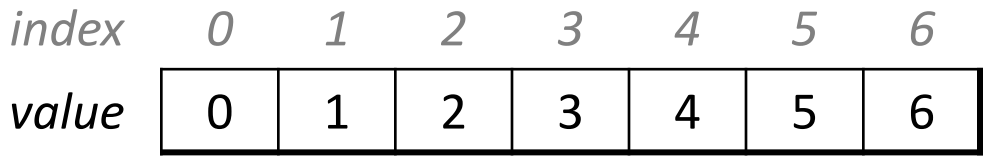
Java automatically initializes elements to **0**.

Accessing Data In An Array

```
name[index]    // get element at index
```

- Like Strings, indices go from **0** to the **array's length - 1**.

```
for (int i = 0; i < 7; i++) {
    println(numbers[i]);
}
println(numbers[9];    // exception
println(numbers[-1]);  // exception
```



Putting Data In An Array

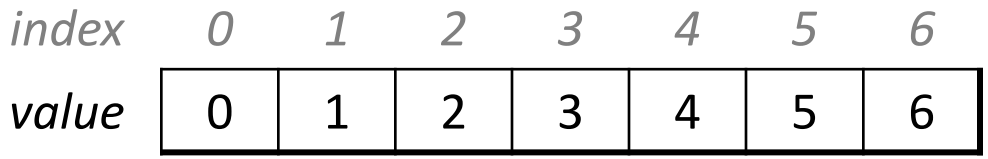
```
name[index] = value;    // set element at index
```

Putting Data In An Array

```
name[index] = value;    // set element at index
```

- Like Strings, indices go from **0** to the **array's length - 1**.

```
int[] numbers = new int[7];
for (int i = 0; i < 7; i++) {
    numbers[i] = i;
}
numbers[8] = 2;    // exception
numbers[-1] = 5;   // exception
```



Practice

Q: What are the contents of `numbers` after executing this code?

```
int[] numbers = new int[8];
numbers[1] = 3;
numbers[4] = 7;
numbers[6] = 5;
int x = numbers[1];
numbers[x] = 2;
numbers[numbers[4]] = 9;
```

```
//  0  1  2  3  4  5  6  7
```

A. {0, 3, 0, 2, 7, 0, 5, 9}
B. {0, 3, 0, 0, 7, 0, 5, 0}
C. {3, 3, 5, 2, 7, 4, 5, 0}
D. {0, 3, 0, 2, 7, 6, 4, 4}

Arrays Of Other Types

You can create arrays of any variable type. For example:

```
double[] results = new double[5];

String[] names = new String[3];

boolean[] switches = new boolean[4];

GRect[] rects = new GRect[5];
```

- Java initializes each element of a new array to its *default value*, which is **0** for `int` and `double`, '\0' for `char`, **`false`** for `boolean`, and **`null`** for objects.

Array Length

Similar to a String, you can get the length of an array by saying

```
myArray.length
```

Note that there are *no parentheses* at the end!

Practice:

- What is the index of the *last element* of an array in terms of its length?
- What is the index of the *middle element* of an array in terms of its length?

Arrays + For Loops = ❤️

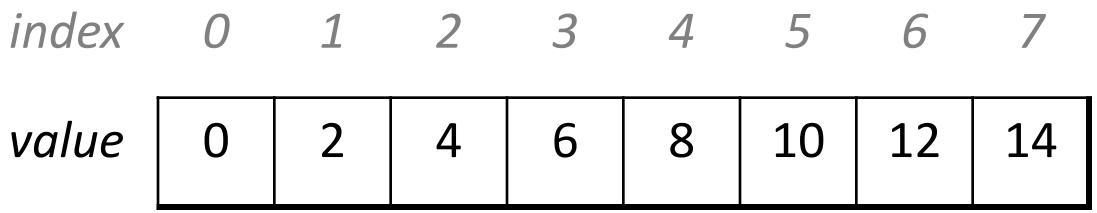
Just like with Strings, we can use an array's length, along with its indices, to perform cool operations.

Arrays + For Loops = ❤️

Just like with Strings, we can use an array's length, along with its indices, to perform cool operations.

For instance, we can efficiently initialize arrays.

```
int[] numbers = new int[8];
for (int i = 0; i < numbers.length; i++) {
    numbers[i] = 2 * i;
}
```



Arrays + For Loops = ❤️

Just like with Strings, we can use an array's length, along with its indices, to perform cool operations.

For instance, we can read in numbers from the user:

```
int length = readInt("# of numbers? ");
int[] numbers = new int[length];
for (int i = 0; i < numbers.length; i++) {
    numbers[i] = readInt("Elem " + i + ": ");
}
```

Arrays + For Loops = ❤️

Just like with Strings, we can use an array's length, along with its indices, to perform cool operations.

For instance, we can *sum up* all of an array's elements.

```
int sum = 0;
for (int i = 0; i < numbers.length; i++) {
     sum += numbers[i];
}
println(sum);
```

Brief Aside: Creating Arrays

Sometimes, we want to hardcode the elements of an array.

```
int numbers = new int[7];
numbers[0] = 5;
numbers[1] = 32;
numbers[3] = 12;
...

// This is tedious!
```

Brief Aside: Creating Arrays

Sometimes, we want to hardcode the elements of an array.

Luckily, Java has a special syntax for initializing arrays to hardcoded numbers.

```
type[] name = { elements };
```

```
// Java infers the array length
int[] numbers = {5, 32, 12, 2, 1, -1, 9};
```

Limitations of Arrays

- An array's length is **fixed**. You cannot resize an existing array:

```
int[] a = new int[4];
a.length = 10;                          // error
```

- You cannot compare arrays with == or `equals` :

```
int[] a1 = {42, -7, 1, 15};
int[] a2 = {42, -7, 1, 15};
if (a1 == a2) {  ... }                  // false!
if (a1.equals(a2)) {  ... }             // false!
```

- An array does not know how to print itself:

```
println(a1);                          // [I@98f8c4]
```

Arrays Methods To The Rescue!

- The class `Arrays` in package `java.util` has useful methods for manipulating arrays:

Method name	Description
`Arrays.binarySearch(`***`array, value`***`)`	returns the index of the given value in a *sorted* array (or < 0 if not found)
`Arrays.copyOf(`***`array, length`***`)`	returns a new copy of array of given length
`Arrays.equals(`***`array1, array2`***`)`	returns `true` if the two arrays contain same elements in the same order
`Arrays.fill(`***`array, value`***`);`	sets every element to the given value
`Arrays.sort(`***`array`***`);`	arranges the elements into sorted order
`Arrays.toString(`***`array`***`)`	returns a string representing the array, such as `"[10, 30, -25, 17]"`

Example: Arrays.toString

`Arrays.toString` accepts an array as a parameter and returns a string representation of its elements.

```
int[] e = {0, 2, 4, 6, 8};
e[1] = e[3] + e[4];
println("e is " + Arrays.toString(e));
```

Output:

```
e is [0, 14, 4, 6, 8]
```

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Passing Arrays Between Methods

- Arrays are just another variable type, so methods can take arrays as parameters and return an array.

```
private int sumArray(int[] numbers) {
    ...
}

private int[] makeSpecialArray(...) {
    ...
    return myArray;
}
```

Passing Arrays Between Methods

- Arrays are just another variable type, so methods can take arrays as parameters and return an array.
- However, arrays are **objects**, so per A Variable Origin Story, an array variable box actually stores its *location*.
- This means changes to an array passed as a parameter *affect the original array*!

Arrays: Pass By Reference

```
public void run() {
     int[] numbers = new int[7];
     fillArray(numbers);
     println(Arrays.toString(numbers));
}

private void fillArray(int[] arr) {
     for (int i = 0; i < arr.length; i++) {
          arr[i] = 2 * i;
     }
}
```

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Practice: Swapping Elements

Let's write a method called **swapElements** that swaps two elements of an array. How can we do this?

What parameters should it take (if any)? What should it return (if anything)?

```
private ??? swapElements(???) {
    ...
}
```

Swap: Take 1

```
public void run() {
      int[] array = new int[5];
      ...
      swapElements(array[0], array[1]);
      ...
}

private void swapElements(int x, int y) {
      int temp = x;
      x = y;
      y = temp;
}
```

Swap: Take 1

```
public void run() {
    int[] array = new int[5];
}
```

Ints are primitives, so they are passed by **value**! Their variable boxes store their *actual values*. So changes to the parameter *do not affect the original*.

```
private void swapElements(int x, int y) {
    int temp = x;
    x = y;
    y = temp;
}
```

Swap: Take 2

```
public void run() {
        int[] array = new int[5];
        ...
        swapElements(array, 0, 1);
        ...
}


private void swapElements(int[] arr, int pos1, int pos2) {
        int temp = arr[pos1];
        arr[pos1] = arr[pos2];
        arr[pos2] = temp;
}
```

Swap: Take 2

```
public void run() {
        int[] array = new int[5];
}
```

Arrays are **objects**, so they are passed by **reference**! Their variable boxes store their *location*. So changes to the parameter *do affect the original*.

```
private void swapElements(int[] arr, int pos1, int pos2) {
        int temp = arr[pos1];
        arr[pos1] = arr[pos2];
        arr[pos2] = temp;
}
```

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WeatherStation

- Write a **`WeatherStation`** program that prompts the user to enter daily temperatures, and uses an array to produce this output:

```
How many days' temperatures? 7
Day 1's high temp: 45
Day 2's high temp: 44
Day 3's high temp: 39
Day 4's high temp: 48
Day 5's high temp: 37
Day 6's high temp: 46
Day 7's high temp: 53

All temperatures: [45, 44, 39, 48, 37, 46, 53]
Average temp = 44.6
4 days were above average.
Two coldest days: 37, 39
Two hottest days: 53, 48
```

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Recap: Arrays

- An array is an ordered, homogeneous list of data.
- Arrays can store both primitives and objects
- An array's length *cannot be changed* once it is created.
- There are no methods you can call on an array; however, there is the helpful **Arrays** class, with methods such as **Arrays.toString**.

Recap

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Next time: 2D Arrays

Extra Slides

Array reverse exercise

- Write a **`reverse`** method that reverses the elements of an array.
  - Example:

```
int[] numbers = {11, 42, -5, 27, 0, 89};
reverse(numbers);
```

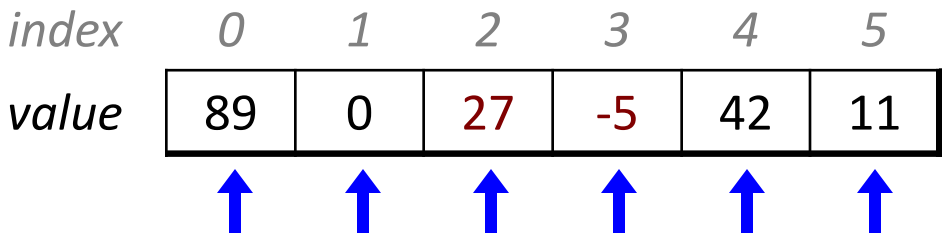
  - After the call, it should store:

```
[89, 0, 27, -5, 42, 11]
```

  - The code should work for an array of any size.

Algorithm idea

- Swap pairs of elements from the edges; work inwards:



Possible algorithm

- **Q:** What is the effect of the code below? Does it reverse the array?

```
int[] numbers = {11, 42, -5, 27, 0, 89};

// reverse the array
for (int i = 0; i < numbers.length; i++) {
    int temp = numbers[i];
    numbers[i] = numbers[numbers.length - 1 - i];
    numbers[numbers.length - 1 - i] = temp;
}
```

  - **A.** Code is correct and reverses the array properly.
  - **B.** Elements are reversed, but some are lost/missing.
  - **C.** Indexes are off-by-1.
  - **D.** Array contents are the same at the end; the code does nothing.
  - **E.** None of the above

Correct algorithm

- Corrected version:

```
int[] numbers = {11, 42, -5, 27, 0, 89};
// reverse the array
for (int i = 0; i < numbers.length / 2; i++) {
    int temp = numbers[i];
    numbers[i] = numbers[numbers.length - 1 - i];
    numbers[numbers.length - 1 - i] = temp;
}
```