Arrays

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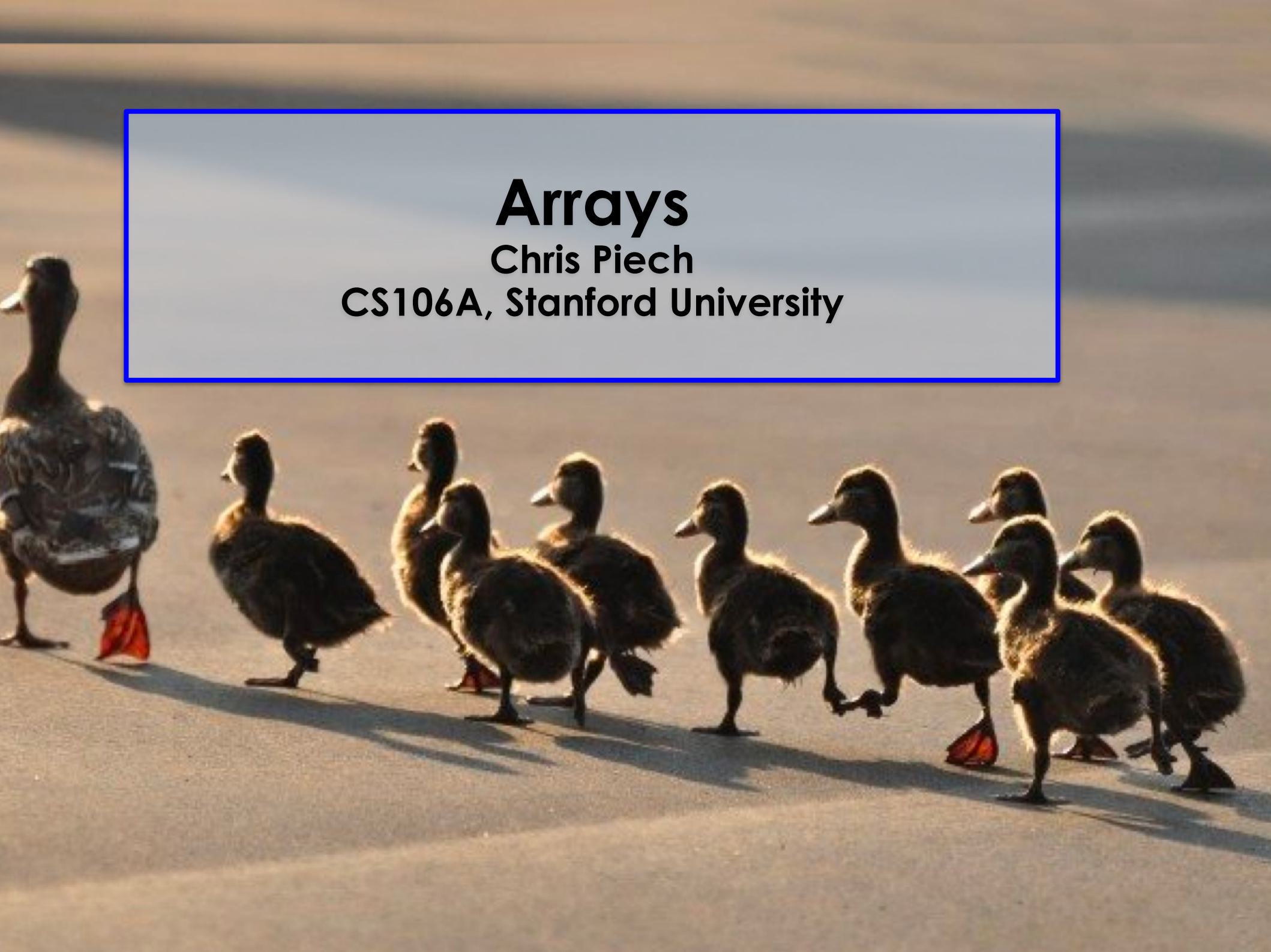


Changing Variable Types

int to double?

```
int x = 5;
double xDbl = x;
```

int to String?

```
int x = 5;
String xStr = "" + x
```

String to int?

```
String xStr = "5";
int x = Integer.parseInt(x);
```

String to double?

```
String xStr = "5.6";
double x = Double.parseDouble(xStr);
```

Casting double to int

```
double x = 5.2;
int y = (int)x;
```

GObject to GRect

```
GObject obj = getElementAt(5, 2);
GRect objRect = (GRect)obj;
```

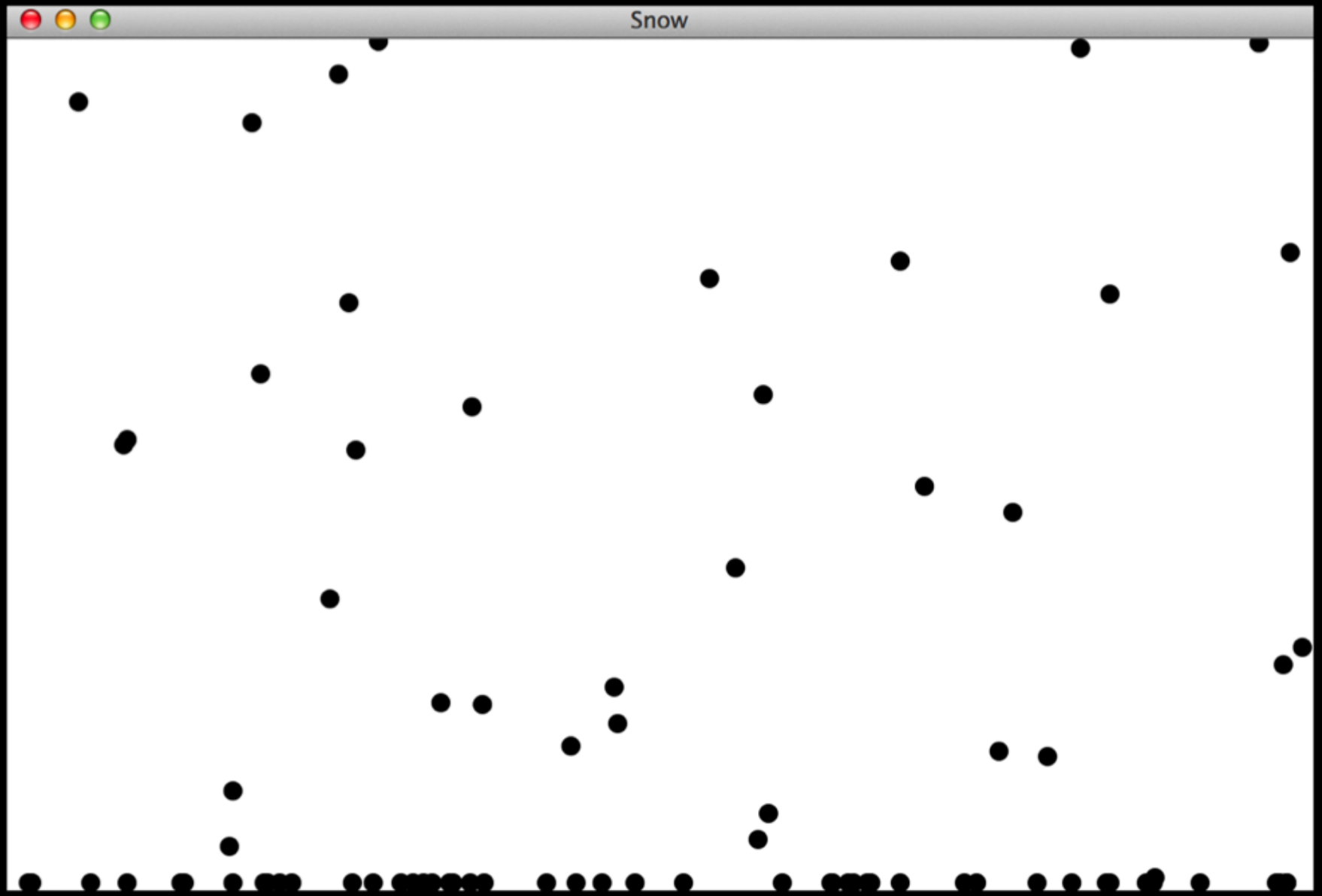
int to char

```
int diff = 'C'-'A';
char next = (char)'a' + diff;
```

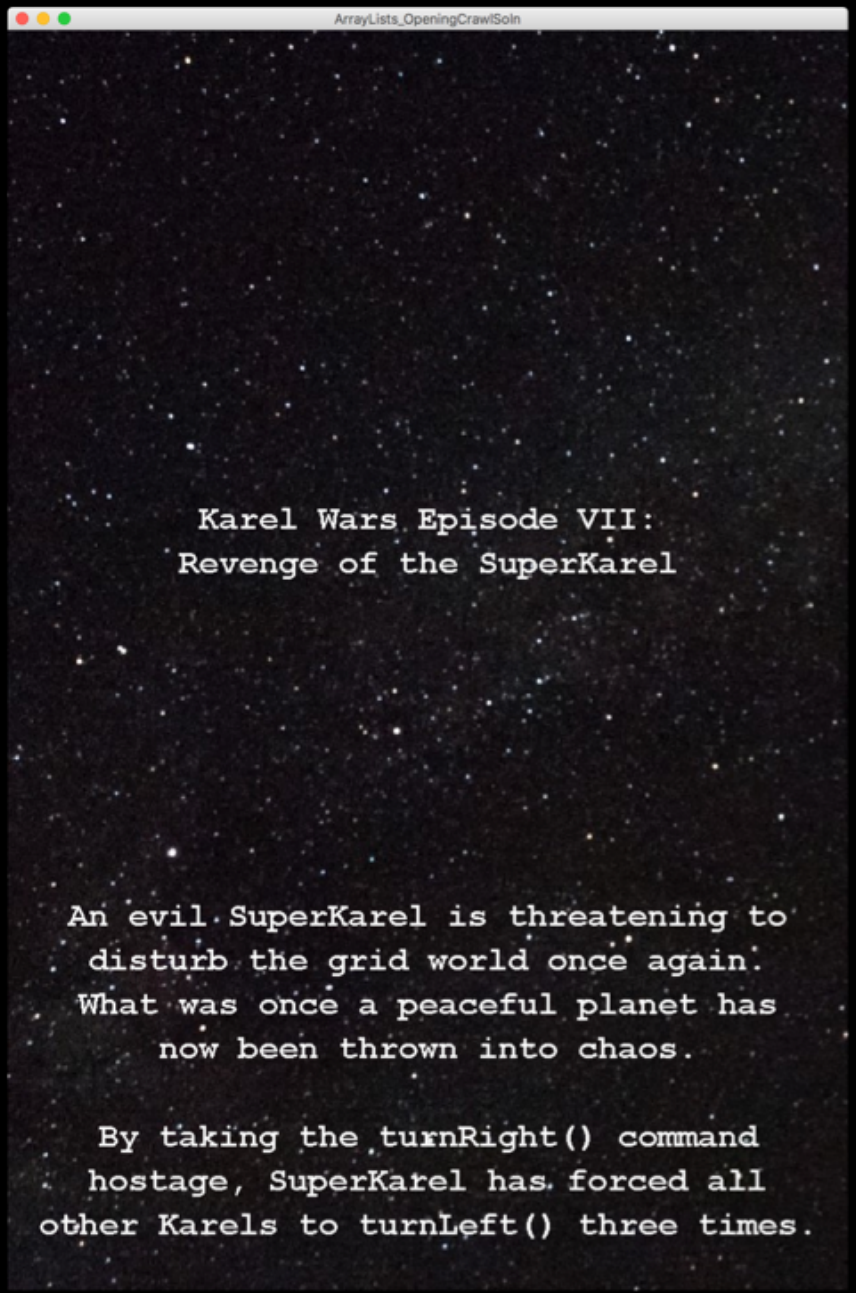
Where are we?

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

Winter is Coming!



Karel Wars



Thanks to Nick Troccoli for the awesome example

A Quick Review of ArrayLists

- In Java, an ***array list*** is an abstract type used to store a linearly ordered collection of similar data values.
- When you use an array list, you specify the type **`ArrayList`**, followed by the element type enclosed in angle brackets, as in **`ArrayList<String>`** or **`ArrayList<Integer>`**. In Java, such types are called ***parameterized types***.
- Each element is identified by its position number in the list, which is called its ***index***. In Java, index numbers always begin with 0 and therefore extend up to one less than the size of the array list.
- Operations on array lists are implemented as methods in the **`ArrayList`** class, as shown on the next slide.

Common ArrayList methods

`list.size()` Returns the number of values in the list.
`list.isEmpty()` Returns **`true`** if the list is empty.
`list.set(i, value)` Sets the **`i`**th entry in the list to **`value`**.
`list.get(i)` Returns the **`i`**th entry in the list.
`list.add(value)` Adds a new value to the end of the list.
`list.add(index, value)` Inserts the value before the specified index position.
`list.remove(index)` Removes the value at the specified index position.
`list.clear()` Removes all values from the list.

Arrays in Java

- The Java **`ArrayList`** class is derived from an older, more primitive type called an ***array***, which is a collection of individual data values with two distinguishing characteristics:
  1. *An array is ordered.* You must be able to count off the values: here is the first, here is the second, and so on.
  2. *An array is homogeneous.* Every value in the array must have the same type.
- As with array lists, the individual values in an array are called ***elements***, the type of those elements (which must be the same because arrays are homogeneous) is called the ***element type***, and the number of elements is called the ***length*** of the array. Each element is identified by its position number in the array, which is called its ***index***.

Arrays have fewer capabilities

`list.size()` Returns the number of values in the list.	**`array.length`**
`list.isEmpty()` Returns **`true`** if the list is empty.	
`list.set(i, value)` Sets the **`i`**th entry in the list to **`value`**.	**`array[i] = value`**
`list.get(i)` Returns the **`i`**th entry in the list.	**`array[i]`**
`list.add(value)` Adds a new value to the end of the list.	
`list.add(index, value)` Inserts the value before the specified index position.	
`list.remove(index)` Removes the value at the specified index position.	
`list.clear()` Removes all values from the list.	

Why use arrays?

- Arrays are built into the Java language and offer a more expressive selection syntax.
- You can create arrays of primitive types like **`int`** and **`double`** and therefore don't need to use wrapper types like **`Integer`** and **`Double`**.
- It is much easier to create arrays of a fixed, predetermined size.
- Java makes it easy to initialize the elements of an array.
- Many methods in the Java libraries take arrays as parameters or return arrays as a result. You need to understand arrays in order to use those methods.

1. Fantastic style
2. You will be a better programmer if you understand your roots

What does this say?

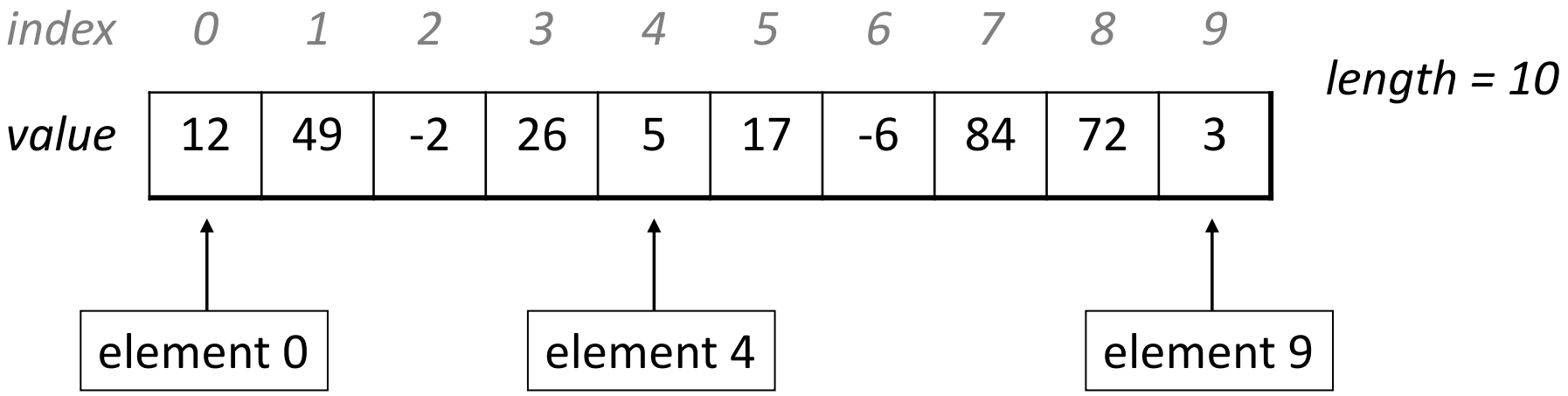
```
53‡‡†305))6*;4826)4‡•)4‡);806*;48†8¶
60))85;1‡(;:‡*8†83(88)5*†;46(;88*96*
?;8)*‡(;485);5*†2:*‡(;4956*2(5*–4)8¶
8*;4069285);)6†8)4‡‡;1(‡9;48081;8:8‡
1;48†85;4)485†528806*81(‡9;48;(88;4(
‡?34;48)4‡;161;:188;‡?;
```

Arrays

#majorkey of the day

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

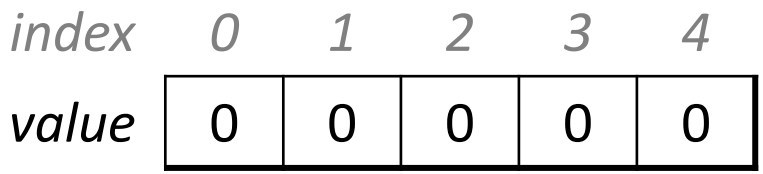
– Arrays have many *elements* that you can access using *indices*



Creating Arrays

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

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



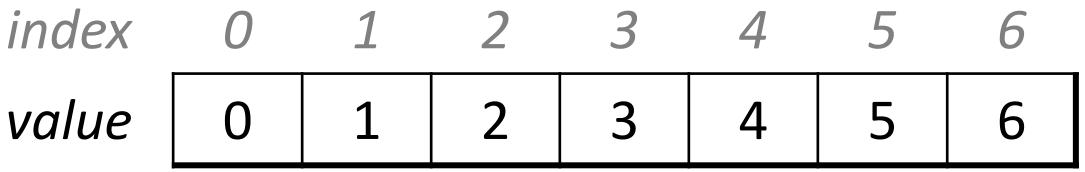
Java automatically initializes elements to **0**.

Getting values

```
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
```



Setting values

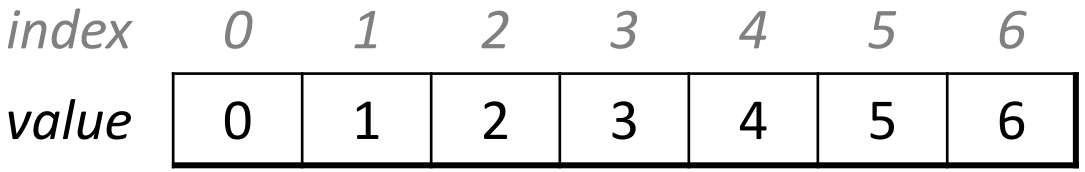
```
name[index] = value;    // set element at index
```

Setting values

```
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}
```

Many flavors of arrays

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.

Getting “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 ❤️ loops

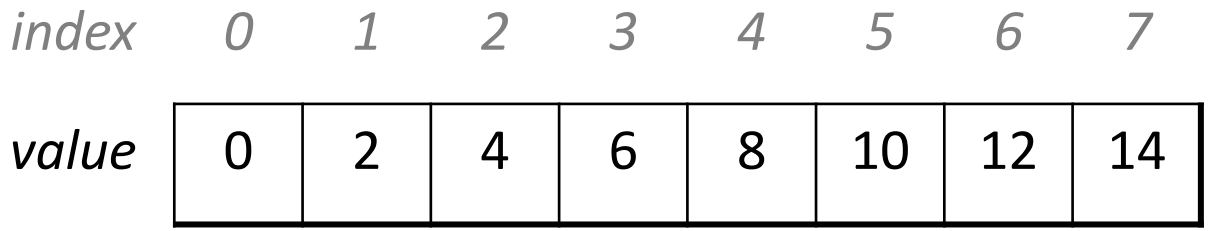
Just like with Strings, we can use an array's length, along with its indices, to perform cool operations.

Arrays ❤️ 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 ❤️ 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 ❤️ loops

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

Try it out! *sum up* all of an array's elements.

```
// assume that the user has created int[] numbers
int sum = 0;
for (int i = 0; i < numbers.length; i++) {
    sum += numbers[i];
}
println(sum);
```

Annoying initialization

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!
```

Fancy initialization

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]
```

Array 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]"`

Array Methods to the Rescue!

`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]
```

Arrays as Parameters

- 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;
}
```

- 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*!

```
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;
    }
}
```

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(???) {
    ...
}
```

Swapping: 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;
}
```

Swapping: 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;
}
```

Swapping: 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;
}
```

Swapping: Take 2

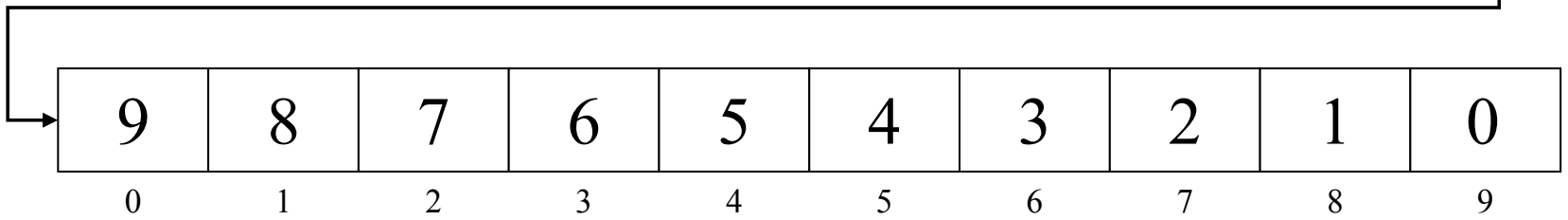
```
public void run() {
        int[] array = new int[5];
}
```

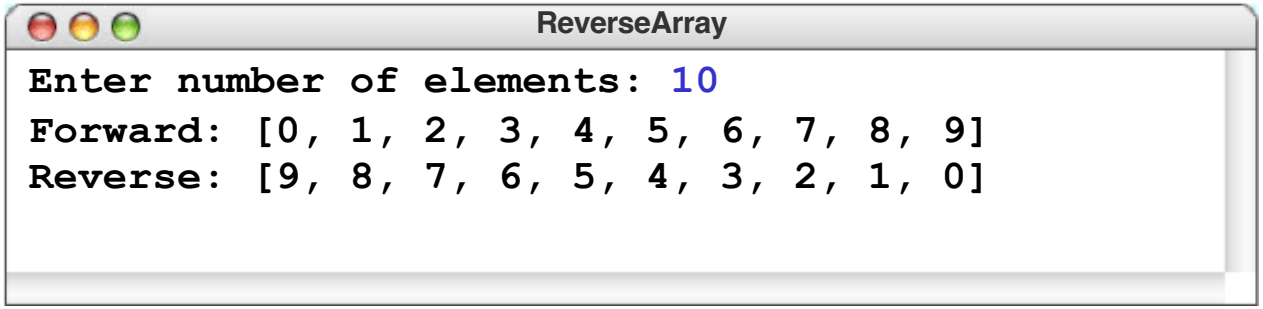
Arrays are **objects**, so they are passed by **reference**! Their variable boxes store their *location*. So changes to the parameter *do affect the original*.

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

Example: Reverse Array Program

```
public void run() {
   int n = readInt("Enter number of elements: ");
   int[] intArray = createIndexArray(n);
   println("Forward: " + arrayToString(intArray));
   reverseArray(intArray);
   println("Reverse: " + arrayToString(intArray));
}
```

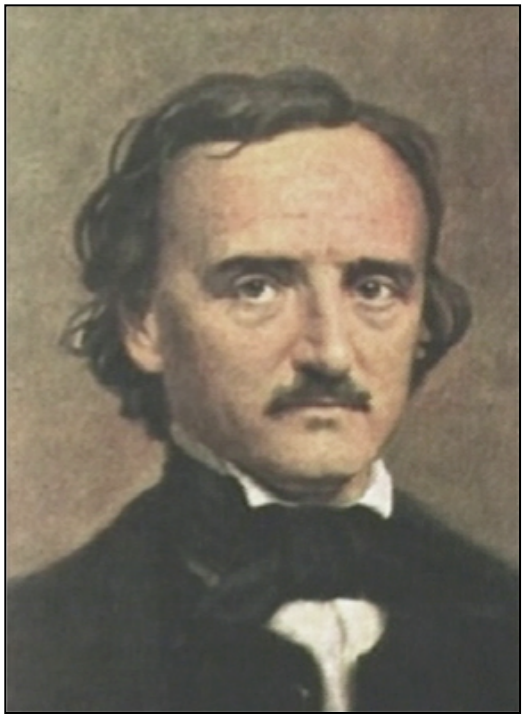




skip simulation

Cryptogram

- A ***cryptogram*** is a puzzle in which a message is encoded by replacing each letter in the original text with some other letter. The substitution pattern remains the same throughout the message. Your job in solving a cryptogram is to figure out this correspondence.
- One of the most famous cryptograms was written by Edgar Allan Poe in his short story "The Gold Bug."
- In this story, Poe describes the technique of assuming that the most common letters in the coded message correspond to the most common letters in English, which are E, T, A, O, I, N, S, H, R, D, L, and U.



I hkev Epper Tsi ,5<4=15<8=-

Poe's Cryptographic Puzzle

```
53‡‡†305))6*;4826)4‡•)4‡);806*;48†8¶
60))85;1‡(;:‡*8†83(88)5*†;46(;88*96*
?;8)*‡(;485);5*†2:*‡(;4956*2(5*–4)8¶
8*;4069285);)6†8)4‡‡;1(‡9;48081;8:8‡
1;48†85;4)485†528806*81(‡9;48;(88;4(
‡?34;48)4‡;161;:188;‡?;
```

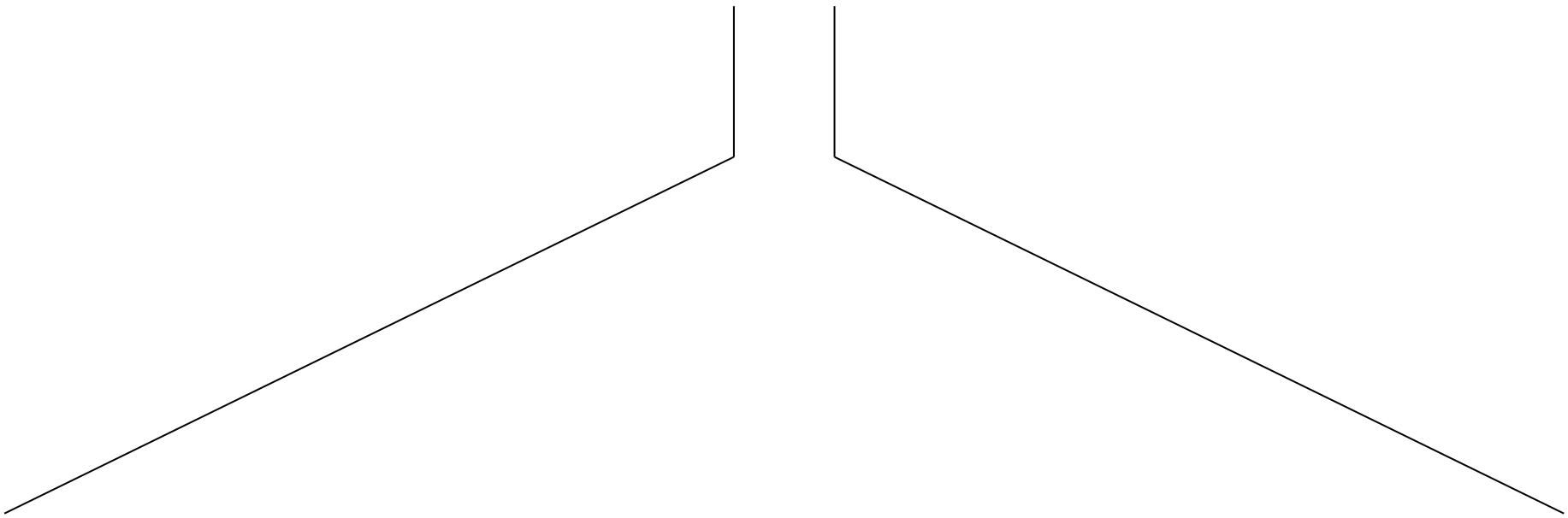
```
A good glass in the bishop's hostel in the devil's seat
forty one degrees and thirteen minutes northeast and by north
main branch seventh limb east side shoot from the left eye of
the death's head a bee line from the tree through the shot
fifty feet out
```

8	33
;	26
4	19
‡	16
)	16
*	13
5	12
6	11
(	10
†	8
1	8
0	6
9	5
2	5
:	4
3	4
?	3
¶	2
–	1
•	1

Implementation Strategy

The basic idea behind the program to count letter frequencies is to use an array with 26 elements to keep track of how many times each letter appears. As the program reads the text, it increments the array element that corresponds to each letter.

T[EWFVM1LPNK



1	1	0	0	0	0	1	0	2	0	0	2	0	0	0	0	0	1	1	1	0	0	1	0	0	0
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

To the code!

Count Letter Frequencies

```
import acm.program.*;

/**
 * This program creates a table of the letter frequencies in a
 * paragraph of input text terminated by a blank line.
 */
public class CountLetterFrequencies extends ConsoleProgram {

/* Private instance variables */
   private int[] frequencyTable;

   public void run() {
      println("This program counts letter frequencies.");
      println("Enter a blank line to indicate the end of the text.");
      initFrequencyTable();
      while (true) {
         String line = readLine();
         if (line.length() == 0) break;
         countLetterFrequencies(line);
      }
      printFrequencyTable();
   }

/* Initializes the frequency table to contain zeros */
   private void initFrequencyTable() {
      frequencyTable = new int[26];
      for (int i = 0; i < 26; i++) {
         frequencyTable[i] = 0;
      }
   }
```

Count Letter Frequencies

```
/* Counts the letter frequencies in a line of text */
   private void countLetterFrequencies(String line) {
      for (int i = 0; i < line.length(); i++) {
         char ch = line.charAt(i);
         if (Character.isLetter(ch)) {
            int index = Character.toUpperCase(ch) - 'A';
            frequencyTable[index]++;
         }
      }
   }

/* Displays the frequency table */
   private void printFrequencyTable() {
      for (char ch = 'A'; ch <= 'Z'; ch++) {
         int index = ch - 'A';
         println(ch + ": " + frequencyTable[index]);
      }
   }


}
```