Building Java Programs

Chapter 7

Lecture 16: Arrays as Parameters, Arrays for Tallying

reading: 4.3, 7.6

Why did the programmer quit his job?

Because he didn't get arrays.

Array parameter (declare)

```
public static type methodName(type[] name) {
```

- Example:

```
// Returns the average of the given array of numbers.
public static double average(int[] numbers) {
    int sum = 0;
    for (int i = 0; i < numbers.length; i++) {
        sum += numbers[i];
    }
    return (double) sum / numbers.length;
}
```

  - You don't specify the array's length (but you can examine it).

Array parameter (call)

methodName(**arrayName**);

- Example:

```
public class MyProgram {
    public static void main(String[] args) {
        // figure out the average TA IQ
        int[] iq = {126, 84, 149, 167, 95};
        double avg = average(iq);
        System.out.println("Average IQ = " + avg);
    }
    ...
```

  - Notice that you don't write the `[]` when passing the array.

Array return (declare)

```
public static type[] methodName(parameters) {
```

- Example:

```
// Returns a new array with two copies of each value.
// Example: [1, 4, 0, 7] -> [1, 1, 4, 4, 0, 0, 7, 7]
public static int[] double(int[] numbers) {
    int[] result = new int[2 * numbers.length];
    for (int i = 0; i < numbers.length; i++) {
        result[2 * i]     = numbers[i];
        result[2 * i + 1] = numbers[i];
    }
    return result;
}
```

Array return (call)

```
type[] name = methodName(parameters);
```

- Example:

```
public class MyProgram {
    public static void main(String[] args) {
        int[] iq = {126, 84, 149, 167, 95};
        int[] doubled = double(iq);
        System.out.println(Arrays.toString(doubled));
    }
    ...
```

- Output:

```
[126, 126, 84, 84, 149, 149, 167, 167, 95, 95]
```

Array reversal question

- Write code that reverses the elements of an array.
  - For example, if the array initially stores:

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

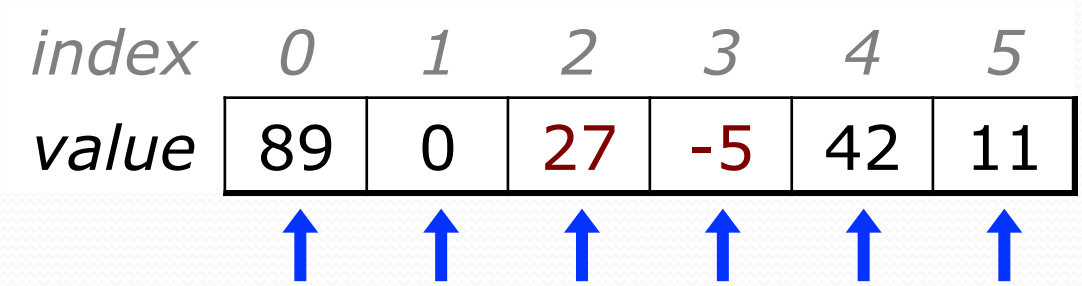
  - Then after your reversal code, it should store:

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

    - The code should work for an array of any size.
    - Hint: think about swapping various elements...

Algorithm idea

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



Swapping values

```
public static void main(String[] args) {
    int a = 7;
    int b = 35;

    // swap a with b?
    a = b;
    b = a;

    System.out.println(a + " " + b);
}
```

- What is wrong with this code? What is its output?

- The red code should be replaced with:

```
int temp = a;
a = b;
b = temp;
```

Flawed algorithm

- What's wrong with this code?

```
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;
}
```

- The loop goes too far and un-reverses the array! Fixed version:

```
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;
}
```

Array reverse question 2

- Turn your array reversal code into a `reverse` method.
  - Accept the array of integers to reverse as a parameter.

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

  - How do we write methods that accept arrays as parameters?
  - Will we need to return the new array contents after reversal?

  ...

Reference semantics

reading: 7.3

A `swap` method?

- Does the following `swap` method work? Why or why not?

```
public static void main(String[] args) {
    int a = 7;
    int b = 35;

    // swap a with b?
    swap(a, b);

    System.out.println(a + " " + b);
}

public static void swap(int a, int b) {
    int temp = a;
    a = b;
    b = temp;
}
```

Value semantics

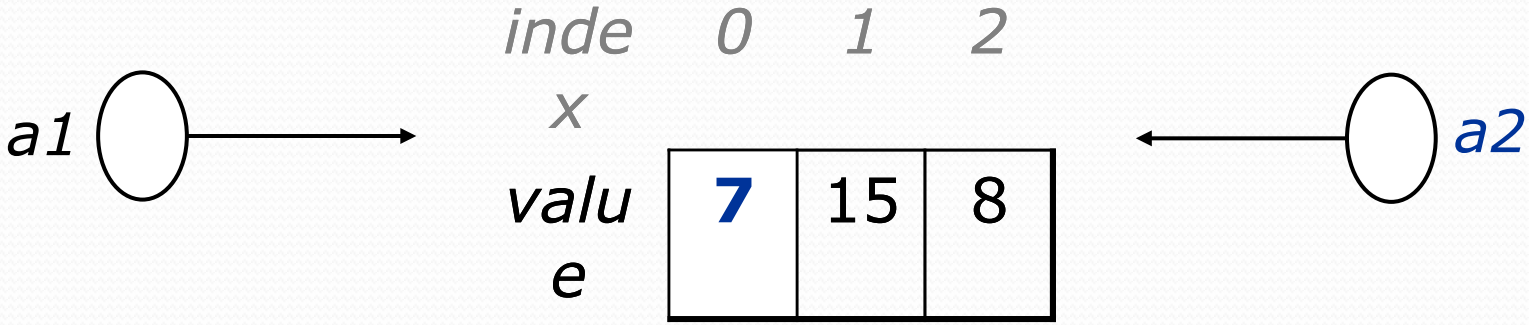
- **value semantics**: Behavior where values are copied when assigned, passed as parameters, or returned.
  - All primitive types in Java use value semantics.
  - When one variable is assigned to another, its value is copied.
  - Modifying the value of one variable does not affect others.

```
int x = 5;
int y = x;      // x = 5, y = 5
y = 17;         // x = 5, y = 17
x = 8;          // x = 8, y = 17
```

Reference semantics (objects)

- **reference semantics**: Behavior where variables actually store the address of an object in memory.
  - When one variable is assigned to another, the object is *not* copied; both variables refer to the *same object*.
  - Modifying the value of one variable *will* affect others.

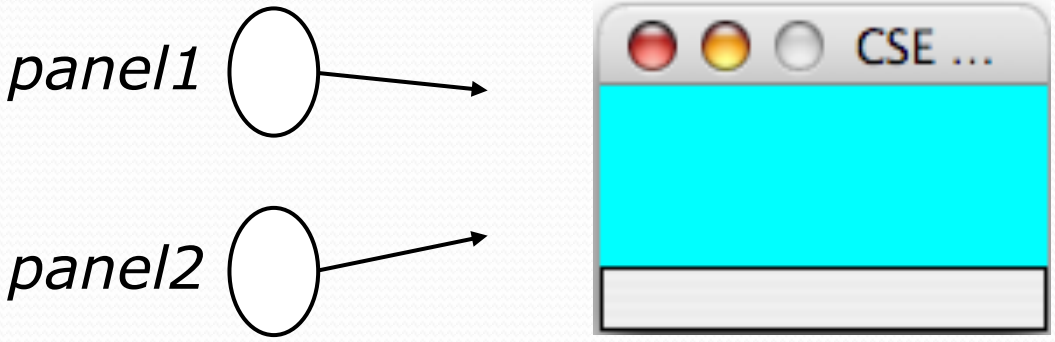
```
int[] a1 = {4, 15, 8};
int[] a2 = a1;              // refer to same array as a1
a2[0] = 7;
System.out.println(Arrays.toString(a1)); // [7, 15, 8]
```



References and objects

- Arrays and objects use reference semantics. Why?
  - *efficiency.* Copying large objects slows down a program.
  - *sharing.* It's useful to share an object's data among methods.

```
DrawingPanel panel1 = new DrawingPanel(80, 50);
DrawingPanel panel2 = panel1;   // same window
panel2.setBackground(Color.CYAN);
```

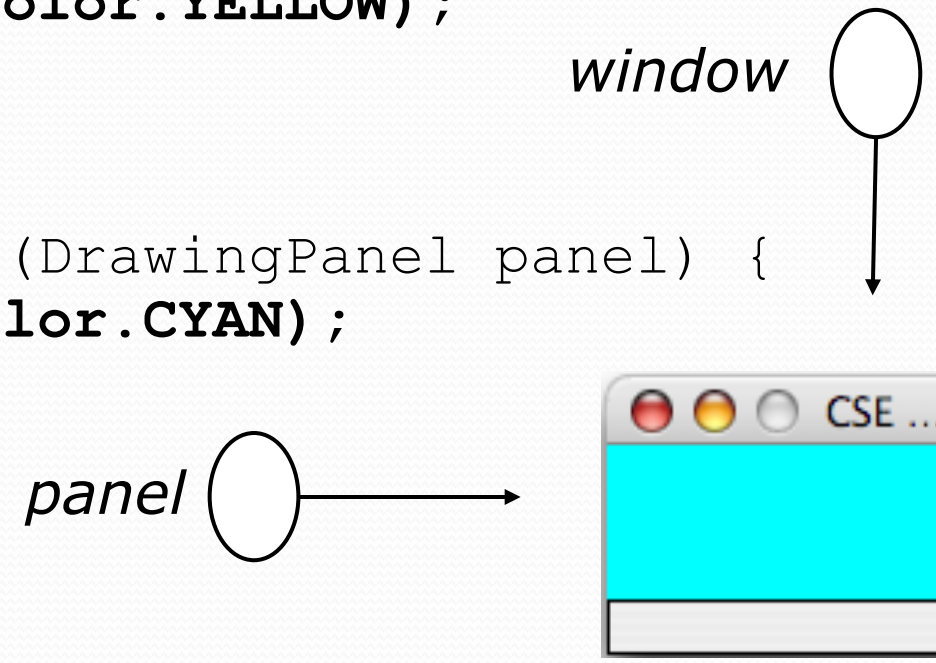


Objects as parameters

- When an object is passed as a parameter, the object is *not* copied. The parameter refers to the same object.
  - If the parameter is modified, it *will* affect the original object.

```
public static void main(String[] args) {
    DrawingPanel window = new DrawingPanel(80, 50);
    window.setBackground(Color.YELLOW);
    example(window);
}

public static void example(DrawingPanel panel) {
    panel.setBackground(Color.CYAN);
    ...
}
```

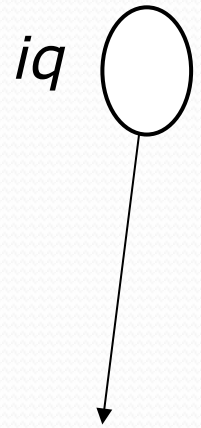


Arrays pass by reference

- Arrays are passed as parameters by *reference*.
  - Changes made in the method are also seen by the caller.

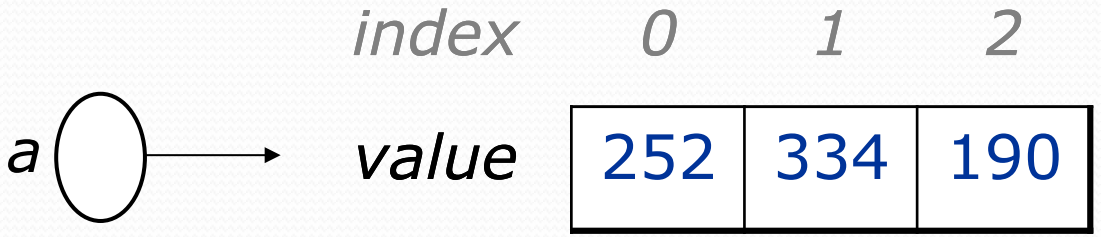
```
public static void main(String[] args) {
    int[] iq = {126, 167, 95};
    increase(iq);
    System.out.println(Arrays.toString(iq));
}

public static void increase(int[] a) {
    for (int i = 0; i < a.length; i++) {
        a[i] = a[i] * 2;
    }
}
```



  - Output:

```
[252, 334, 190]
```



Array reverse question 2

- Turn your array reversal code into a `reverse` method.
  - Accept the array of integers to reverse as a parameter.

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

- Solution:

```
public static void reverse(int[] numbers) {
    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;
    }
}
```

Array parameter questions

- Write a method `swap` that accepts an arrays of integers and two indexes and swaps the elements at those indexes.

```
int[] a1 = {12, 34, 56};
swap(a1, 1, 2);
System.out.println(Arrays.toString(a1));  // [12, 56, 34]
```

- Write a method `swapAll` that accepts two arrays of integers as parameters and swaps their entire contents.
  - Assume that the two arrays are the same length.

```
int[] a1 = {12, 34, 56};
int[] a2 = {20, 50, 80};
swapAll(a1, a2);
System.out.println(Arrays.toString(a1));  // [20, 50, 80]
System.out.println(Arrays.toString(a2));  // [12, 34, 56]
```

Array parameter answers

```
// Swaps the values at the given two indexes.
public static void swap(int[] a, int i, int j) {
    int temp = a[i];
    a[i] = a[j];
    a[j] = temp;
}

// Swaps the entire contents of a1 with those of a2.
public static void swapAll(int[] a1, int[] a2) {
    for (int i = 0; i < a1.length; i++) {
        int temp = a1[i];
        a1[i] = a2[i];
        a2[i] = temp;
    }
}
```

Array return question

- Write a method `merge` that accepts two arrays of integers and returns a new array containing all elements of the first array followed by all elements of the second.

```
int[] a1 = {12, 34, 56};
int[] a2 = {7, 8, 9, 10};

int[] a3 = merge(a1, a2);
System.out.println(Arrays.toString(a3));
// [12, 34, 56, 7, 8, 9, 10]
```

- Write a method `merge3` that merges 3 arrays similarly.

```
int[] a1 = {12, 34, 56};
int[] a2 = {7, 8, 9, 10};
int[] a3 = {444, 222, -1};

int[] a4 = merge3(a1, a2, a3);
System.out.println(Arrays.toString(a4));
// [12, 34, 56, 7, 8, 9, 10, 444, 222, -1]
```

Array return answer 1

```
// Returns a new array containing all elements of a1
// followed by all elements of a2.
public static int[] merge(int[] a1, int[] a2) {
    int[] result = new int[a1.length + a2.length];

    for (int i = 0; i < a1.length; i++) {
        result[i] = a1[i];
    }
    for (int i = 0; i < a2.length; i++) {
        result[a1.length + i] = a2[i];
    }

    return result;
}
```

Array return answer 2

```
// Returns a new array containing all elements of a1,a2,a3.
public static int[] merge3(int[] a1, int[] a2, int[] a3) {
    int[] a4 = new int[a1.length + a2.length + a3.length];

    for (int i = 0; i < a1.length; i++) {
        a4[i] = a1[i];
    }
    for (int i = 0; i < a2.length; i++) {
        a4[a1.length + i] = a2[i];
    }
    for (int i = 0; i < a3.length; i++) {
        a4[a1.length + a2.length + i] = a3[i];
    }

    return a4;
}

// Shorter version that calls merge.
public static int[] merge3(int[] a1, int[] a2, int[] a3) {
    return merge(merge(a1, a2), a3);
}
```

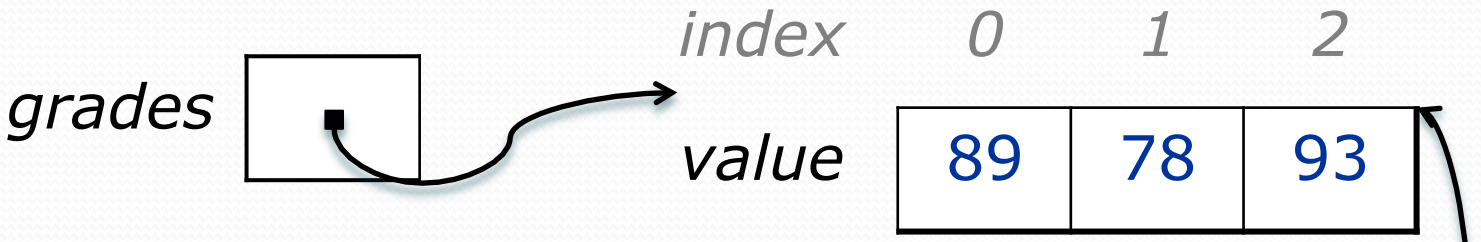
Value/Reference Semantics

- Variables of primitive types store values directly:

- Values are copied from one variable to another:

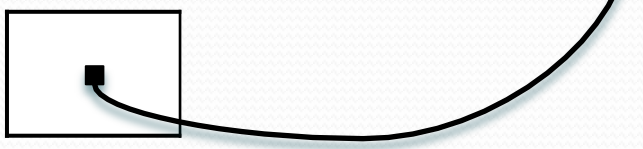
```
cats = age;
```

- Variables of object types store references to memory:



- References are copied from one variable to another:

```
scores = grades;
```



Text processing

reading: 7.2, 4.3

String traversals

- The `char`s in a `String` can be accessed using the `charAt` method.
  - accepts an `int` index parameter and returns the `char` at that index

```
String food = "cookie";
char firstLetter = food.charAt(0);   // 'c'
System.out.println(firstLetter + " is for " + food);
```

- You can use a `for` loop to print or examine each character.

```
String major = "CSE";
for (int i = 0; i < major.length(); i++) {     // output:
    char c = major.charAt(i);                  // C
    System.out.println(c);                     // S
}                                              // E
```

A multi-counter problem

- Problem: Write a method `mostFrequentDigit` that returns the digit value that occurs most frequently in a number.
  - Example: The number 669260267 contains:
    one 0, two 2s, four 6es, one 7, and one 9.

    `mostFrequentDigit(669260267)` returns 6.
  - If there is a tie, return the digit with the lower value.

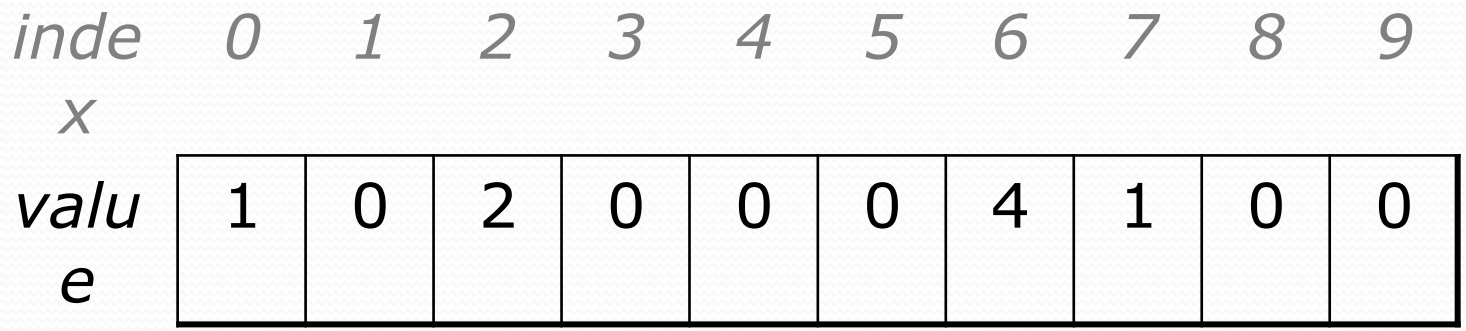
    `mostFrequentDigit(57135203)` returns 3.

A multi-counter problem

- We could declare 10 counter variables ...

```
int counter0, counter1, counter2, counter3, counter4,
    counter5, counter6, counter7, counter8, counter9;
```

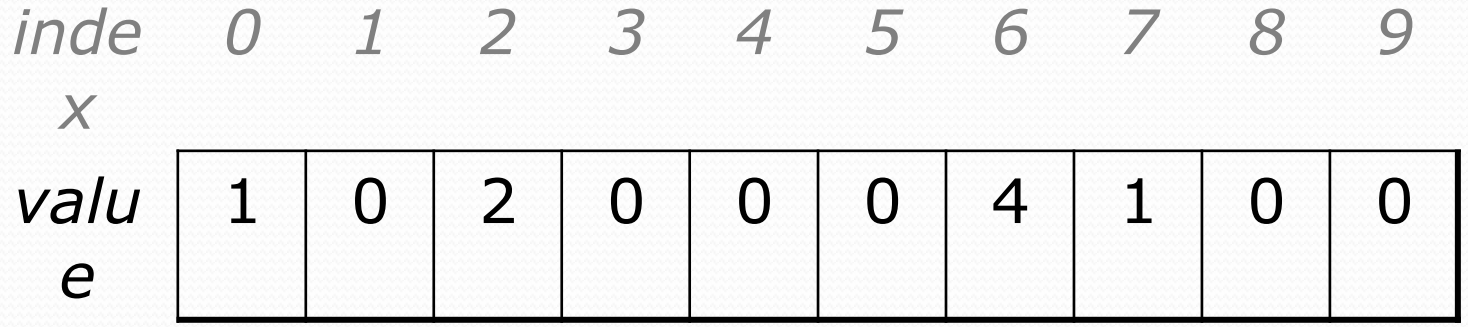
- But a better solution is to use an array of size 10.
  - The element at index *i* will store the counter for digit value *i*.
  - Example for 669260267:



  - How do we build such an array? And how does it help?

Creating an array of tallies

```
// assume n = 669260267
int[] counts = new int[10];
while (n > 0) {
    // pluck off a digit and add to proper counter
    int digit = n % 10;
    counts[digit]++;
    n = n / 10;
}
```



Tally solution

```
// Returns the digit value that occurs most frequently in n.
// Breaks ties by choosing the smaller value.
public static int mostFrequentDigit(int n) {
    int[] counts = new int[10];
    while (n > 0) {
        int digit = n % 10;  // pluck off a digit and tally it
        counts[digit]++;
        n = n / 10;
    }

    // find the most frequently occurring digit
    int bestIndex = 0;
    for (int i = 1; i < counts.length; i++) {
        if (counts[i] > counts[bestIndex]) {
            bestIndex = i;
        }
    }

    return bestIndex;
}
```

Section attendance question

- Read a file of section attendance (*see next slide*):

```
yynyyynayayynyyyayanyyyaynayyayyanayyyanyayna
ayyanyyyyayanaayyanayyyananayayaynyayayynynya
yyayaynyyayyanynnyyyayyanayaynannnyyayyayayny
```

- And produce the following output:

```
Section 1
Student points: [30, 27, 29, 24, 19]
Student grades: [100.0, 90.0, 96.7, 80.0, 63.3]

Section 2
Student points: [27, 30, 24, 24, 14]
Student grades: [90.0, 100.0, 80.0, 80.0, 46.6]

Section 3
Student points: [27, 26, 27, 30, 24]
Student grades: [90.0, 86.7, 90.0, 100.0, 80.0]
```

  - Students earn 5 points for each section attended up to 30.

Section input file

```
student      123451234512345123451234512345123451234512345123
week           1    2    3    4    5    6    7    8    9
section  1   yynyyynayayynyyyayanyyyaynayyayyanayyyanyay
section  2   ayyanyyyyayanaayyyanayyyananayayaynyayayynyn
section  3   yyayayaynyyayyanynnyyyayyyanayaynannnyyayyayay
```

- Each line represents a section.
- A line consists of 9 weeks' worth of data.
  - Each week has 5 characters because there are 5 students.
- Within each week, each character represents one student.
  - `a` means the student was absent (+0 points)
  - `n` means they attended but didn't do the problems (+2 points)
  - `y` means they attended and did the problems (+5 points)

Section attendance answer

```
import java.io.*;
import java.util.*;

public class Sections {
    public static void main(String[] args) throws FileNotFoundException {
        Scanner input = new Scanner(new File("sections.txt"));
        int section = 1;
        while (input.hasNextLine()) {
            String line = input.nextLine();      // process one section
            int[] points = new int[5];
            for (int i = 0; i < line.length(); i++) {
                int student = i % 5;
                int earned = 0;
                if (line.charAt(i) == 'y') {     // c == 'y' or 'n' or 'a'
                    earned = 5;
                } else if (line.charAt(i) == 'n') {
                    earned = 2;
                }
                points[student] = Math.min(30, points[student] + earned);
            }

            double[] grades = new double[5];
            for (int i = 0; i < points.length; i++) {
                grades[i] = 100.0 * points[i] / 20.0;
            }

            System.out.println("Section " + section);
            System.out.println("Student points: " + Arrays.toString(points));
            System.out.println("Student grades: " + Arrays.toString(grades));
            System.out.println();
            section++;
        }
    }
}
```

Data transformations

- In many problems we transform data between forms.
  - Example: digits → count of each digit → most frequent digit
  - Often each transformation is computed/stored as an array.
  - For structure, a transformation is often put in its own method.

- Sometimes we map between data and array indexes.
  - by position (store the *i* th value we read at index *i*)
  - tally (if input value is *i*, store it at array index *i*)
  - explicit mapping (count `'J'` at index 0, count `'X'` at index 1)

- *Exercise:* Modify our Sections program to use static methods that use arrays as parameters and returns.

Array param/return answer

```
// This program reads a file representing which students attended
// which discussion sections and produces output of the students'
// section attendance and scores.

import java.io.*;
import java.util.*;

public class Sections2 {
    public static void main(String[] args) throws FileNotFoundException {
        Scanner input = new Scanner(new File("sections.txt"));
        int section = 1;
        while (input.hasNextLine()) {
            // process one section
            String line = input.nextLine();
            int[] points = countPoints(line);
            double[] grades = computeGrades(points);
            results(section, points, grades);
            section++;
        }
    }

    // Produces all output about a particular section.
    public static void results(int section, int[] points, double[] grades) {
        System.out.println("Section " + section);
        System.out.println("Student scores: " + Arrays.toString(points));
        System.out.println("Student grades: " + Arrays.toString(grades));
        System.out.println();
    }

    ...
```

Array param/return answer

```
    ...
    // Computes the points earned for each student for a particular section.
    public static int[] countPoints(String line) {
        int[] points = new int[5];
        for (int i = 0; i < line.length(); i++) {
            int student = i % 5;
            int earned = 0;
            if (line.charAt(i) == 'y') {      // c == 'y'  or  c == 'n'
                earned = 3;
            } else if (line.charAt(i) == 'n') {
                earned = 2;
            }
            points[student] = Math.min(20, points[student] + earned);
        }
        return points;
    }

    // Computes the percentage for each student for a particular section.
    public static double[] computeGrades(int[] points) {
        double[] grades = new double[5];
        for (int i = 0; i < points.length; i++) {
            grades[i] = 100.0 * points[i] / 20.0;
        }
        return grades;
    }
}
```