# CS 106A, Lecture 17
# More Arrays;
# More Classes and Objects

reading:

*Art & Science of Java*, 12.4

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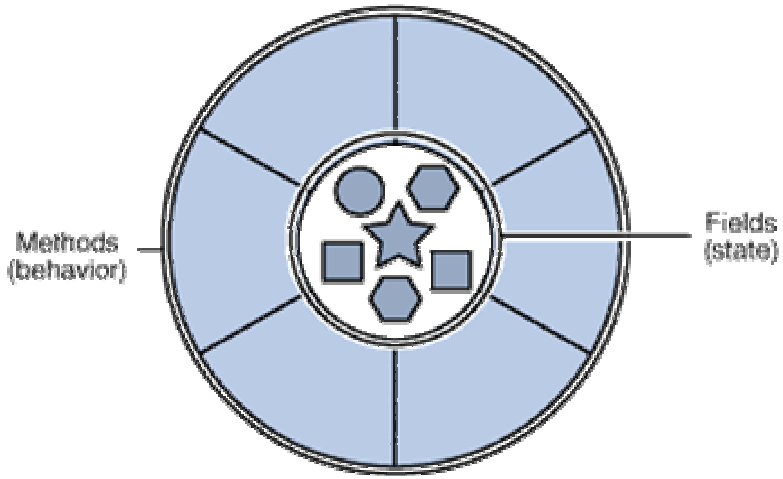
# Lecture Outline

- Today we will learn more about **arrays**.
  - We'll review arrays as **parameters and returns**.
  - We will see an important data concept called **reference semantics**.
  - We will talk about using an array to **tally** data.

- We will also revisit **classes and objects**.

| *index* | *0* | *1* | *2* | *3* | *4* | *5* | *6* |
|---|---|---|---|---|---|---|---|
| *value* | 1 | 7 | 10 | 12 | 8 | 14 | 22 |



# Array as param/return

```
public void name(type[] name) {   // parameter
public type[] name(params)    {   // return
```

– Example:

```
public int sum(int[] a) {
    int result = 0;
    for (int i = 0; i < a.length; i++) {
        result += a[i];
    }
    return result;
}
```

- Call:

```
int[] numbers = {2, -1, 4, 7};
int total = sum(numbers);       // 12
```

# Value semantics

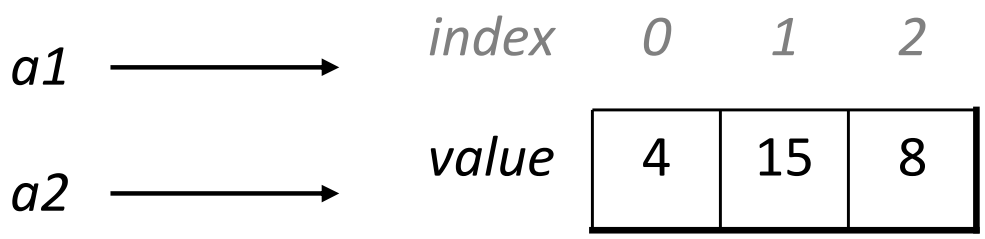
- **value semantics**: Behavior where values are copied when assigned, passed as parameters, or returned. *(used with primitive types)*
  - When a variable is assigned to another, its value is *copied*.
  - Modifying a variable does not affect others.

```
int x = 5;
int y = x;      // x =  5, y =  5   (value of x is copied)

y = 17;         // x =  5, y = 17   (x is not changed)
x = 8;          // x =  8, y = 17   (y is not changed)

x = y;          // x = 17, y = 17   (value of y is copied)
y++;            // x = 17, y = 18   (x is not changed)
x--;            // x = 16, y = 18   (y is not changed)
```

# Reference semantics

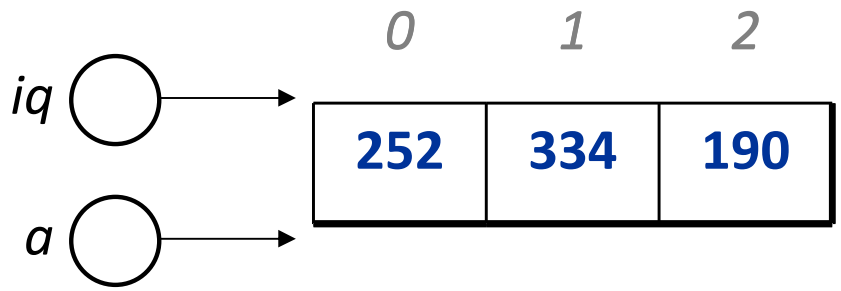
- **reference semantics**: Behavior where variables actually store the address of an object in memory. *(used with arrays/objects)*
  - When a variable is assigned to another, both refer to the *same object*.
  - Modifying the value of one variable ***will*** affect others.

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



# Pass by reference

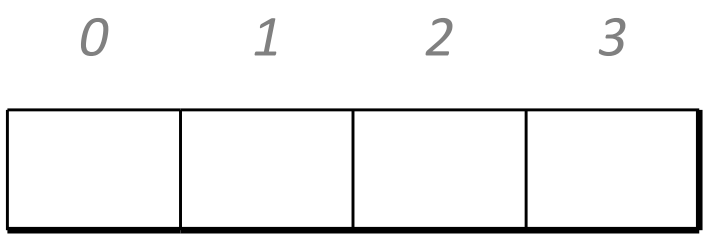
```
// Increases the values in the array by 2x.
public void doubleAll(int[] a) {
    for (int i = 0; i < a.length; i++) {
        a[i] = a[i] * 2;
    }
}

public void run() {
    int[] iq = {126, 167, 95};
    doubleAll(iq);
    println(Arrays.toString(iq));
}   // [252, 334, 190]
```



# Output parameter

- **output parameter**: One passed in by reference to be changed.
  - Its original value is unimportant and will be replaced.

```
// generate a random "password" of digits
public void run() {
    int[] pw = new int[4];
    fillWithRandomDigits(pw);
    println(Arrays.toString(pw));
}

// fills the given array with random values from 0-9
public void fillWithRandomDigits(int[] a) {
    RandomGenerator rg = RandomGenerator.getInstance();
    for (int i = 0; i < a.length; i++) {
        a[i] = rg.nextInt(0, 9);
    }
}
```



# References to objects

- Java objects are stored as **references** (as are arrays).
  - If two variables store the same object, they share that object's data.

```
BankAccount ba1 = new BankAccount("Marty", 1.00);
BankAccount ba2 = new BankAccount("Keith", 3.14);
BankAccount ba3 = ba1;
// ba3 refers to Marty's account

ba3.deposit(4.00);
println(ba1);        // Marty $5.00
println(ba3);        // Marty $5.00
ba1.deposit(2.00);
println(ba1);        // Marty $7.00
println(ba3);        // Marty $7.00
```

ba1 ba3

```
name    = "Marty"
balance = 1.00

deposit(amount) {
    balance += amount;
}
```

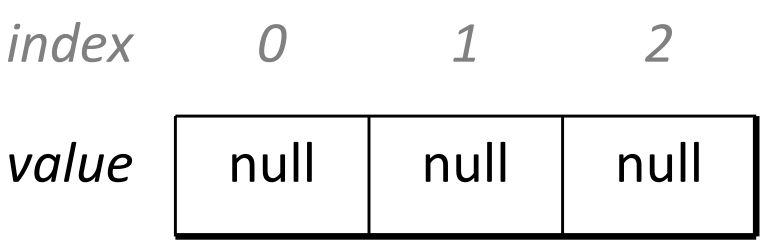
ba2

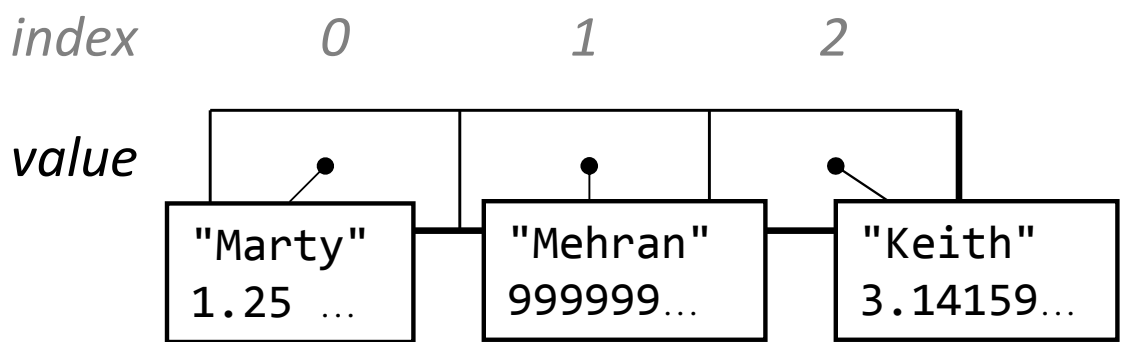
```
name    = "Keith"
balance = 3.14

deposit(amount) {
    balance += amount;
}
```

# Array of objects

- When you make a new array of objects, each element is **`null`**.
  - null is not any object. Can't call methods e.g. `deposit`.
  - Must also initialize each element of the array to store an object.

```
BankAccount[] accounts = new BankAccount[3];
println(Arrays.toString(accounts));  // [null, null, null]

// initialize each account in the array
accounts[0] = new BankAccount("Marty", 1.25);
accounts[1] = new BankAccount("Mehran", 999999.00);
accounts[2] = new BankAccount("Keith", 3.14159);
```



# Array param exercise

switchPairs

- Write a method **`switchPairs`** that accepts an arrays of strings and swaps the values of each neighboring pair of elements.
  - Swap elements 0-1, and 2-3, and 4-5, and ...
  - If the array length is odd, leave the last element untouched.

```
String[] names = {"Ash", "Em", "Nick", "Stu", "Tim"};
switchPairs(names);
println(Arrays.toString(names));

                    //    0      1       2       3        4
                    // {"Em", "Ash", "Stu", "Nick", "Tim"}
```

# Array parameter answer

```
// Swaps the values of neighboring elements.
public void switchPairs(String[] a) {
    for (int i = 0; i < a1.length - 1; i += 2) {
        String temp = a1[i];
        a[i] = a[i + 1];
        a[i + 1] = temp;
    }
}
```

# Array exercise…?



- Write a method **`mostFrequentDigit`** that accepts an integer and returns the digit value from 0-9 that appears most frequently.
  - example:

    **`mostFrequentDigit(340331378)  returns 3`**

# Idea: Array of counters

- For problems like this, where we want to keep count of many things, a *lookup array* (or *tally array*) can be a clever solution.
  - *Idea:* The element at index *i* will store a counter for the digit value *i*.
  - example: count of digits in 340331378:

| *index* | *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* |
|---|---|---|---|---|---|---|---|---|---|---|
| *value* | 1 | 1 | 0 | **4** | 1 | 0 | 0 | 1 | 1 | 0 |

# Classes and Objects, continued

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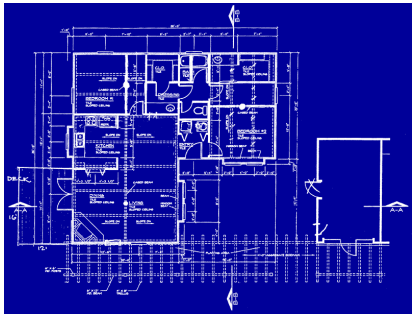
# Classes and objects

- **class**: A template for a new type of objects.
- **object**: An entity that combines state and behavior.

**iPod blueprint (class)**

**state:**
current song
volume
battery life

**behavior:**
power on/off
change station/song
change volume
choose random song



*constructs*

**iPod (object) #1**

**state:**
song = "10000 Miles"
volume = 17
battery life = 2.5 hrs

**behavior:**
power on/off
change station/song
change volume
choose random song

**iPod (object) #2**

**state:**
song = "Letting You"
volume = 9
battery life = 3.41 hrs

**behavior:**
power on/off
change station/song
change volume
choose random song

**iPod (object) #3**

**state:**
song = "Discipline"
volume = 24
battery life = 1.8 hrs

**behavior:**
power on/off
change station/song
change volume
choose random song

# Fields

- **field**: A variable inside an object that is part of its state.
  - Each object gets *its own copy* of each field.

- Declaration syntax:

  `private` ***`type name`***`;`

  - access level is typically `private`, but can be `public` or others

  - Example:

```
public class BankAccount {
    private String name;      // each account object has
    private double balance;   // a name and balance field
    ...
```

# Instance methods

- **instance method** (or **object method**): Exists inside each object of a class, and gives behavior to each object.

```
public type name(parameters) {
    statements;
}
```

  - access level is usually `public`, but can be `private` or others

  – Example (in `BankAccount` class):

```
public void deposit(double amount) {
    balance += amount;
}
```

# Using object methods

```
BankAccount ba1 = new BankAccount();
ba1.name = "Marty";
ba1.balance = 1.25;

BankAccount ba2 = new BankAccount();
ba2.name = "Mehran";
ba2.balance = 900000.00;

ba1.deposit(0.20);
ba2.deposit(1000.00);
```

ba1

```
name    = "Marty"
balance = 1.45

deposit(amount) {
    balance += amount;
}
```

ba2

```
name    = "Mehran"
balance = 901000.00

deposit(amount) {
    balance += amount;
}
```

- When you call an object's method:
  - It executes <u>that object's copy</u> of the code from the class.
  - If that code refers to fields, it means <u>that object's copy</u> of those fields.
  - So calling the method on different objects has different effects.

# Constructors

- **constructor**: Initializes the state of new objects as they are created.
  - The constructor runs when the client says new `ClassName(...);`

```
public ClassName(parameters) {
    statements;
}
```

  - <u>no return type</u> is specified; it "returns" the new object being created

  - If a class has no constructor, Java gives it a *default constructor* with no parameters that sets all fields to default values like `0` or `null`.

# Using constructors

```
BankAccount ba1 =
    new BankAccount("Marty", 1.25);
```

ba1

```
name    = "Marty"
balance = 1.25

BankAccount(nm, bal) {
    name = nm;
    balance = bal;
}
```

```
BankAccount ba2 =
    new BankAccount("Mehran", 900000.00);
```

ba2

```
name    = "Mehran"
balance = 900000.00

BankAccount(nm, bal) {
    name = nm;
    balance = bal;
}
```

- When you call a constructor (with new):
  - Java creates a new object of that class.
  - The constructor runs, with that new object as the implicit parameter.
  - The newly created object is returned to your program.

# Array as field

```
private type[] name;        // declare
...
name = new type[length];    // initialize (in constructor)
```

– Example:

```
// Represents a hand in the card game Uno.
public class UnoHand {
    private String[] cards;

    public UnoHand() {
        cards = new String[7];
        ...
    }
}
```

# Printing objects

- By default, Java doesn't know how to print objects.

```
// ba1 is BankAccount@9e8c34
BankAccount ba1 = new BankAccount("Marty", 1.25);
println("ba1 is " + ba1);


// better, but cumbersome to write
// ba1 is Marty with $1.25
println("ba1 is " + ba1.getName() + " with $"
        + ba1.getBalance());


// desired behavior
println("b1 is " + ba1);   // ba1 is Marty with $1.25
```

# The toString method

*tells Java how to convert an object into a string*

```
BankAccount ba1 = new BankAccount("Marty", 1.25);
println("ba1 is " + ba1);

// the above code is really calling the following:
println("ba1 is " + ba1.toString());
```

- Every class has a `toString`, even if it isn't in your code.
  - Default: class's name @ object's memory address (base 16)

```
BankAccount@9e8c34
```

# toString syntax

```
public String toString() {
    code that returns a String
    representing this object;
}
```

– Method name, return, and parameters must match exactly.

– Example:

```
// Returns a String representing this account.
public String toString() {
    return name + " has $" + balance;
}
```

# The keyword this

- **`this`** : A reference to the implicit parameter.
  - *implicit parameter:* object on which a method is called

- Syntax for using `this` :
  - To refer to a field:

    `this.`***`field`***

  - To call a method:

    `this.`***`method`***`(`***`parameters`***`);`

  - To call a constructor from another constructor:

    `this(`***`parameters`***`);`

# Variable names/scope

- Usually illegal to have 2 variables in same scope with same name:

```
public class BankAccount {
    private double balance;
    private String name;
    ...

    public void setName(String newName) {
        name = newName;
    }
}
```

  – The parameter to `setName` is named `newName` to be distinct from the object's field `name` .

# Variable shadowing

- An instance method parameter name can match a field name:

```
public class BankAccount {
    private double balance;
    private String name;
    ...

    public void setName(String name) {
        this.name = name;
    }
}
```

  - Field name is *shadowed* by the parameter with the same name.
  - Any code inside `setName` that refers to name will use the parameter, not the field. To refer to the field, say `this.name` .

# Multiple constructors

- It is legal to have more than one constructor in a class.
  - The constructors must accept different parameters.

```
public class BankAccount {
    private double balance;
    private String name;

    public BankAccount(String name) {
        this.name = name;
        balance = 0.00;
    }

    public BankAccount(String name, double bal) {
        this.name = name;
        balance = bal;
    }
    ...
}
```

# Multiple constructors

- One constructor can call another using `this` :

```
public class BankAccount {
    private double balance;
    private String name;

    public BankAccount(String name) {
        this(name, 0.00); // call other constructor
    }

    public BankAccount(String name, double bal) {
        this.name = name;
        balance = bal;
    }
    ...
}
```

# Overflow (extra) slides

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# Swapping values

```
public void run() {
    int a = 7;
    int b = 35;

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

    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;
```

# A swap method?

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

```
public void run() {
    int a = 7;
    int b = 35;

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

    println(a + " " + b);
}

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

# Array param questions

swap
swapAll

- 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);
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);
println(Arrays.toString(a1));  // [20, 50, 80]
println(Arrays.toString(a2));  // [12, 34, 56]
```

# Array parameter answers

```
// Swaps the values at the given two indexes.
public 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 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);
println(Arrays.toString(a3));
// [12, 34, 56, 7, 8, 9, 10]
```

# Array return answer 1

```
// Returns a new array containing all elements of a1
// followed by all elements of a2.
public 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;
}
```

# Histogram question



- Given a file of integer exam scores, such as:

```
82
66
79
63
83
```

- Write a **`Histogram`** program that will print a histogram of stars indicating the # of students who earned each unique exam score.

```
85: *****
86: ************
87: ***
88: *
91: ****
```

# Idea: Array of counters

- For problems like this, where we want to keep count of many things, a *lookup array* (or *tally array*) can be a clever solution.
  - *Idea:* The element at index *i* will store a counter for the digit value *i*.
  - Example: myArray[87] stores number of people who scored 87.
  - Example: If myArray[93] stores 4, that means 4 people scored 93.

| *index* | *0* | *1* | *2* | *...* | *91* | *92* | *93* | *94* | *95* | *96* | *97* | *98* | *99* | *100* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *value* | 4 | 0 | 0 | ... | 0 | 2 | 4 | 1 | 0 | 3 | 1 | 0 | 7 | 2 |

# Histogram solution 1

```
public class Histogram extends ConsoleProgram {
    public void run() {
        int[] counts = readScores("midterm.txt");
        displayHistogram(counts);
    }

    /* Reads integer scores from the given file and returns
     * an array histogram where index [i] stores how many people
     * got a score of 'i' on the exam. */
    public int[] readScores(String filename) {
        int[] counts = new int[101];     // count scores 0-100
        try {
            Scanner input = new Scanner(new File(filename));
            while (input.hasNextInt()) {     // read into array
                int score = input.nextInt();
                counts[score]++;
            }
        } catch (FileNotFoundException fnfe) {
            println("I/O error: " + fnfe);
        }
        return counts;
    }
    ...
```

# Histogram solution 2

```
    ...

    /* Prints a histogram of stars, one for each student who
     * got a given score on the exam. */
    public void displayHistogram(int[] counts) {
        for (int i = 0; i < counts.length; i++) {
            // print a star for each student who scored 'i'
            if (counts[i] > 0) {
                print(i + ": ");
                for (int j = 0; j < counts[i]; j++) {
                    print("*");
                }
                println();
            }
        }
    }
}
```