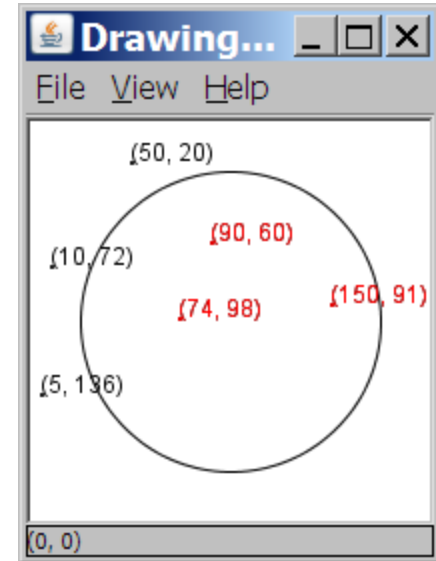# Classes

A programming problem

- Given a file of cities' (x, y) coordinates, which begins with the number of cities:

```
6
50 20
90 60
10 72
74 98
5 136
150 91
```

- Write a program to draw the cities on a `DrawingPanel`, then drop a "bomb" that turns all cities red that are within a given radius:

```
Blast site x? 100
Blast site y? 100
Blast radius? 75
Kaboom!
```

A bad solution

```
Scanner input = new Scanner(new File("cities.txt"));
int cityCount = input.nextInt();
int[] xCoords = new int[cityCount];
int[] yCoords = new int[cityCount];

for (int i = 0; i < cityCount; i++) {
    xCoords[i] = input.nextInt();   // read each city
    yCoords[i] = input.nextInt();
}
...
```

- **parallel arrays**: 2+ arrays with related data at same indexes.
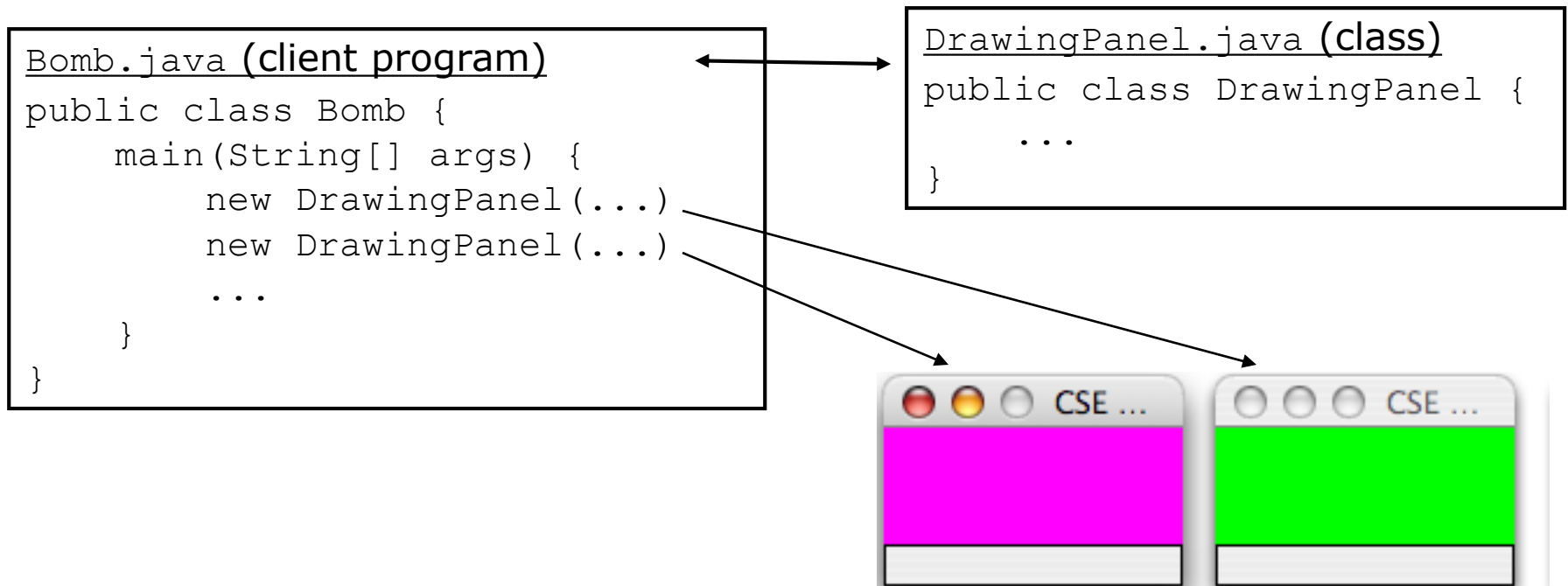 - Considered poor style.

Observations

- The data in this problem is a set of points.
- It would be better stored as `Point` objects.

  - A `Point` would store a city's x/y data.

  - We could compare distances between `Point`s to see whether the bomb hit a given city.

  - Each `Point` would know how to draw itself.

  - The overall program would be shorter and cleaner.
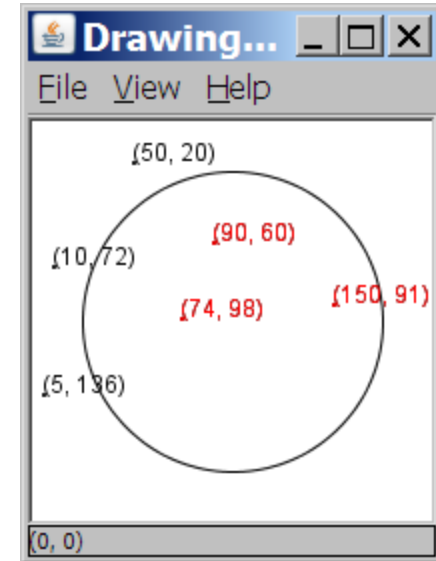
Clients of objects

- **client program**: A program that uses objects.
  - Example: `Bomb` is a client of `DrawingPanel`.

```
Bomb.java (client program)
public class Bomb {
    main(String[] args) {
        new DrawingPanel(...)
        new DrawingPanel(...)
        ...
    }
}
```

```
DrawingPanel.java (class)
public class DrawingPanel {
    ...
}
```

Classes and objects

- **class**: A program entity that represents either:
    1. A program / module, or
    2. **A template for a new type of objects.**

    - The `DrawingPanel` class is a template for creating `DrawingPanel` objects.

- An **object** is an *instance* of a **class**

- **object**: An entity that combines state and behavior.
    - **object-oriented programming (OOP)**: Programs that perform their behavior as interactions between objects.
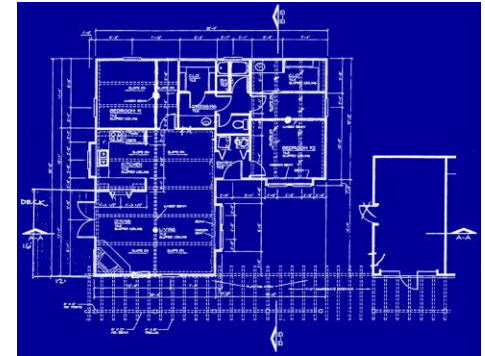
Blueprint analogy

iPod blueprint

state:
  current song
  volume
  battery life

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

creates

iPod #1

state:
  song = "1,000,000 Miles"
  volume = 17
  battery life = 2.5 hrs

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

iPod #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 #3

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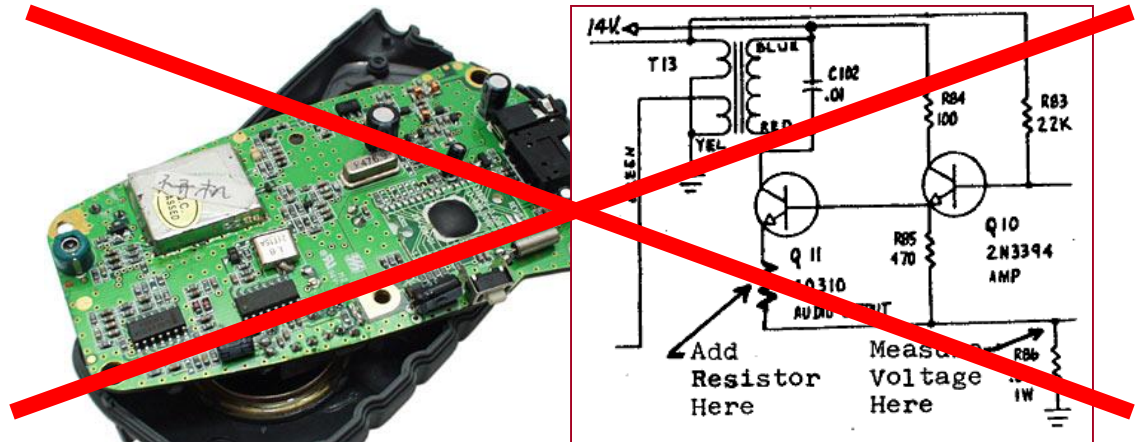 volume = 24
  battery life = 1.8 hrs

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

Abstraction

- **abstraction**: A distancing between ideas and details.
  - We can use objects without knowing how they work.

- abstraction in an iPod:
  - You understand its external behavior (buttons, screen).
  - You don't understand its inner details, and you don't need to.

Our task

- In the following slides, we will implement a `Point` class as a way of learning about defining classes.

    - We will define a type of objects named `Point`.
    - Each `Point` object will contain x/y data called **fields**.
    - Each `Point` object will contain behavior called **methods**.
    - **Client programs** will use the `Point` objects.

Point objects (desired)

```
Point p1 = new Point(5, -2);
Point p2 = new Point();        // origin, (0, 0)
```

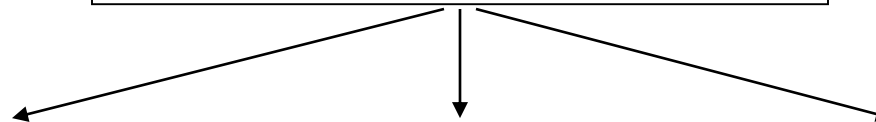- Data in each `Point` object:

Field name	Description
x	the point's x-coordinate
y	the point's y-coordinate

- Methods in each `Point` object:

Method name	Description
setLocation(**x, y**)	sets the point's x and y to the given values
translate(**dx, dy**)	adjusts the point's x and y by the given amounts
distance(**p**)	how far away the point is from point *p*
draw(**g**)	displays the point on a drawing panel

10

Point class as blueprint

Point class

state:
int x, y

behavior:
setLocation(int x, int y)
translate(int dx, int dy)
distance(Point p)
draw(Graphics g)
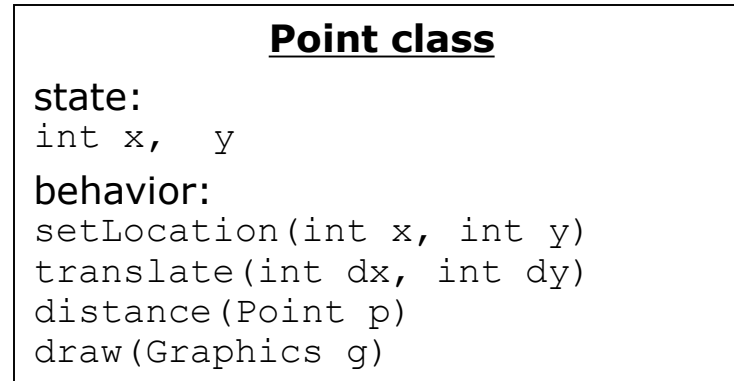
Point object #1

state:
x = 5,   y = -2

behavior:
setLocation(int x, int y)
translate(int dx, int dy)
distance(Point p)
draw(Graphics g)

Point object #2

state:
x = -245,   y = 1897

behavior:
setLocation(int x, int y)
translate(int dx, int dy)
distance(Point p)
draw(Graphics g)

Point object #3

state:
x = 18,   y = 42

behavior:
setLocation(int x, int y)
translate(int dx, int dy)
distance(Point p)
draw(Graphics g)

– The class (blueprint) will describe how to create objects.
– Each object will contain its own data and methods.

Object state: Fields

Point class, version 1

```
public class Point {
    int x;
    int y;
}
```

— Save this code into a file named `Point.java`.

- The above code creates a new type named `Point`.
  - Each `Point` object contains two pieces of data:
    - an `int` named `x`, and
    - an `int` named `y`.

  - `Point` objects do not contain any behavior (yet).

Fields

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

- Declaration syntax:

  type name;

  - Example:

```
public class Student {
    String name;      // each Student object has a
    double gpa;       // name and a gpa field
}
```

Accessing fields

- Other classes can access/modify an object's fields.
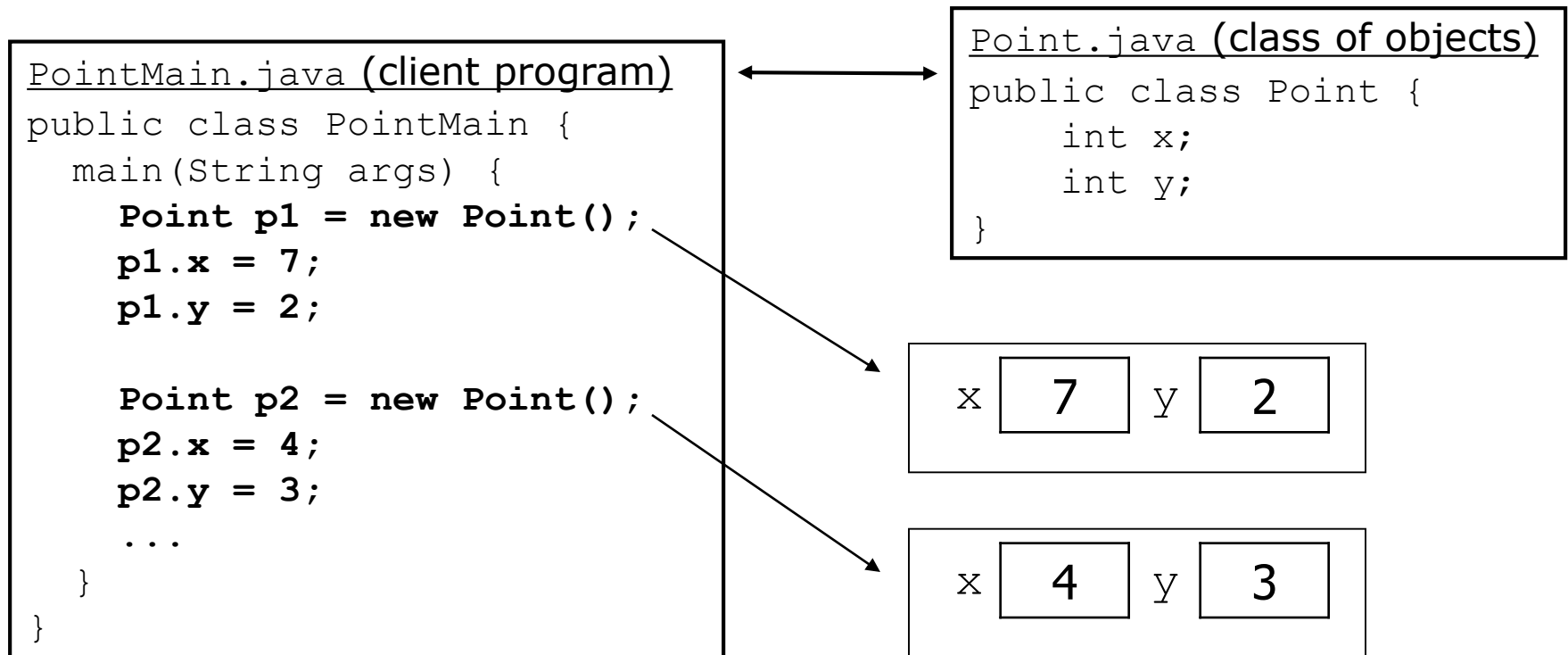
  - access: **variable**.**field**
  - modify: **variable**.**field** = **value**;

- Example:

```
Point p1 = new Point();
Point p2 = new Point();
System.out.println("the x-coord is " + p1.x);    // access
p2.y = 13;                                        // modify
```

A class and its client

- `Point.java` is not, by itself, a runnable program.
  - A class can be used by **client** programs.

<table>
<tr>
<td>

PointMain.java (client program)

```
public class PointMain {
  main(String args) {
    Point p1 = new Point();
    p1.x = 7;
    p1.y = 2;

    Point p2 = new Point();
    p2.x = 4;
    p2.y = 3;
    ...
  }
}
```

</td>
<td>

Point.java (class of objects)

```
public class Point {
    int x;
    int y;
}
```

</td>
</tr>
</table>

x 7   y 2

x 4   y 3

PointMain client example

```java
public class PointMain {
    public static void main(String[] args) {
        // create two Point objects
        Point p1 = new Point();
        p1.y = 2;
        Point p2 = new Point();
        p2.x = 4;

        System.out.println(p1.x + ", " + p1.y);   // 0, 2

        // move p2 and then print it
        p2.x += 2;
        p2.y++;
        System.out.println(p2.x + ", " + p2.y);   // 6, 1
    }
}
```
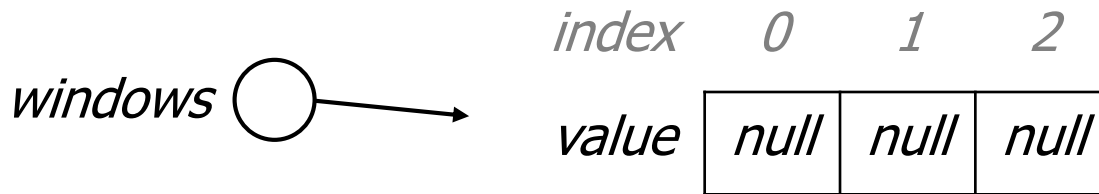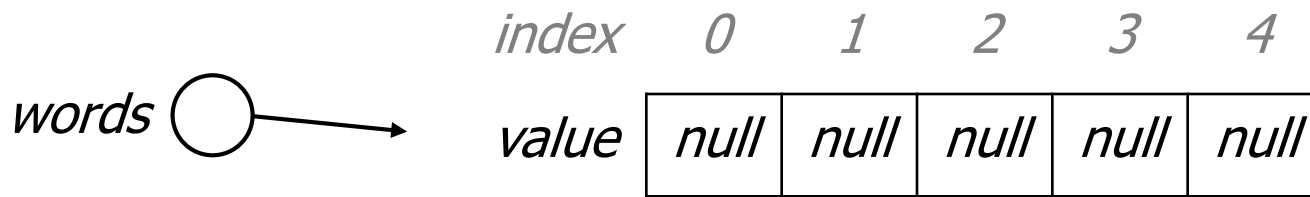
- Modify the `Bomb` program to use `Point` objects.

Arrays of objects

- **null:** A value that does not refer to any object.

  - The elements of an array of objects are initialized to `null`.

    ```
    String[] words = new String[5];
    DrawingPanel[] windows = new DrawingPanel[3];
    ```

index	0	1	2	3	4
value	null	null	null	null	null

words ⃝ →

index	0	1	2
value	null	null	null

windows ⃝ →

Things you can do w/ `null`

- store `null` in a variable or an array element
  ```
  String s = null;
  words[2] = null;
  ```

- print a `null` reference
  ```
  System.out.println(s);        // null
  ```

- ask whether a variable or array element is `null`
  ```
  if (words[2] == null) { ...
  ```

- pass `null` as a parameter to a method
  ```
  System.out.println(null);     // null
  ```

- return `null` from a method (often to indicate failure)
  ```
  return null;
  ```

Null pointer exception

- **dereference**: To access data or methods of an object with the dot notation, such as `s.length()` .
  - It is illegal to dereference `null` (causes an exception).
  - `null` is not any object, so it has no methods or data.

```
String[] words = new String[5];
System.out.println("word is: " + words[0]);
words[0] = words[0].toUpperCase();    // ERROR
```

index	0	1	2	3	4
value	null	null	null	null	null

Output:
```
word is: null
Exception in thread "main"
java.lang.NullPointerException
        at Example.main(Example.java:8)
```

Looking before you leap

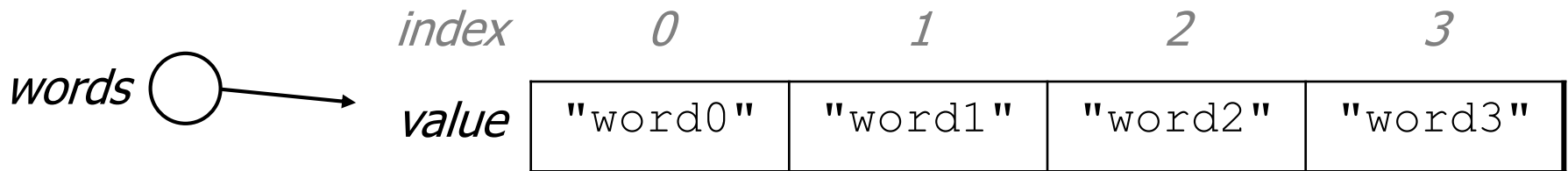- You can check for `null` before calling an object's methods.

```java
String[] words = new String[5];
words[0] = "hello";
words[2] = "goodbye";    // words[1], [3], [4] are null

for (int i = 0; i < words.length; i++) {
    if (words[i] != null) {
        words[i] = words[i].toUpperCase();
    }
}
```

index	0	1	2	3	4
words → value	"HELLO"	*null*	"GOODBYE"	*null*	*null*

Two-phase initialization

1) initialize the array itself (each element is initially `null`)

2) initialize each element of the array to be a new object

```
String[] words = new String[4];              // phase 1
for (int i = 0; i < words.length; i++) {
    words[i] = "word" + i;                   // phase 2
}
```

index	0	1	2	3

words ◯ ⟶

value | `"word0"` | `"word1"` | `"word2"` | `"word3"` |

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

// Displays a set of cities and simulates dropping a "bomb" on them.
public class Bomb {
    public static void main(String[] args) throws FileNotFoundException {
        DrawingPanel panel = new DrawingPanel(200, 200);
        Graphics g = panel.getGraphics();

        Scanner input = new Scanner(new File("cities.txt"));
        Point[] cities = readCities(input, g);

        // drop the "bomb"
        Scanner console = new Scanner(System.in);
        Point bomb = new Point();
        System.out.print("Blast site x? ");
        bomb.x = console.nextInt();
        System.out.print("Blast site y? ");
        bomb.y = console.nextInt();
        System.out.print("Blast radius? ");
        int radius = console.nextInt();
        boom(bomb, radius, cities, g);
    }
    ...
```

Bomb answer 2

```java
// Reads input file of cities and returns them as array of Points.
public static Point[] readCities(Scanner input, Graphics g) {
    int numCities = input.nextInt();    // first line = # of cities
    Point[] cities = new Point[numCities];
    for (int i = 0; i < cities.length; i++) {
        cities[i] = new Point();
        cities[i].x = input.nextInt();   // read city x/y from file
        cities[i].y = input.nextInt();
        g.fillOval(cities[i].x, cities[i].y, 3, 3);
        g.drawString("(" + cities[i].x + ", " + cities[i].y + ")",
                cities[i].x, cities[i].y);
    }
    return cities;
}

// Simulates dropping a bomb at the given location on the given cities.
public static void boom(Point bomb, int radius, Point[] cities, Graphics g) {
    g.setColor(Color.RED);
    g.drawOval(bomb.x - radius, bomb.y - radius, 2 * radius, 2 * radius);
    for (int i = 0; i < cities.length; i++) {
        int dx = cities[i].x - bomb.x;
        int dy = cities[i].y - bomb.y;
        double distance = Math.sqrt(dx * dx + dy * dy);
        if (distance <= radius) {
            g.fillOval(cities[i].x, cities[i].y, 3, 3);
            g.drawString("(" + cities[i].x + ", " + cities[i].y + ")",
                    cities[i].x, cities[i].y);
        }
    }
    System.out.println("Kaboom!");
}
}
```

Object behavior: Methods

Client code redundancy

- Our client program wants to draw `Point` objects:

```
// draw each city
g.fillOval(cities[i].x, cities[i].y, 3, 3);
g.drawString("(" + cities[i].x + ", " + cities[i].y + ")",
             cities[i].x, cities[i].y);
```

- To draw them in other places, the code must be repeated.
  - We can remove this redundancy using a method.

Eliminating redundancy, v1

- We can eliminate the redundancy with a static method:

```
// Draws the given point on the DrawingPanel.
public static void draw(Point p, Graphics g) {
    g.fillOval(p.x, p.y, 3, 3);
    g.drawString("(" + p.x + ", " + p.y + ")", p.x, p.y);
}
```

- `main` would call the method as follows:

```
// draw each city
draw(cities[i], g);
```

Problem with static method

- We are missing a major benefit of objects: code reuse.
  - Every program that draws `Point`s would need a `draw` method.

- The syntax doesn't match how we're used to using objects.

```
draw(cities[i], g);      // static (bad)
```

- The point of classes is to combine state and behavior.
  - The `draw` behavior is closely related to a `Point`'s data.
  - The method belongs *inside* each `Point` object.

```
cities[i].draw(g);       // inside object (better)
```

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;
}
```

 – same syntax as static methods, but without `static` keyword

Example:

```
public void shout() {
    System.out.println("HELLO THERE!");
}
```

Instance method example

```
public class Point {
    int x;
    int y;

    // Draws this Point object with the given pen.
    public void draw(Graphics g) {
        ...
    }
}
```

- The `draw` method no longer has a `Point p` parameter.
- How will the method know which point to draw?
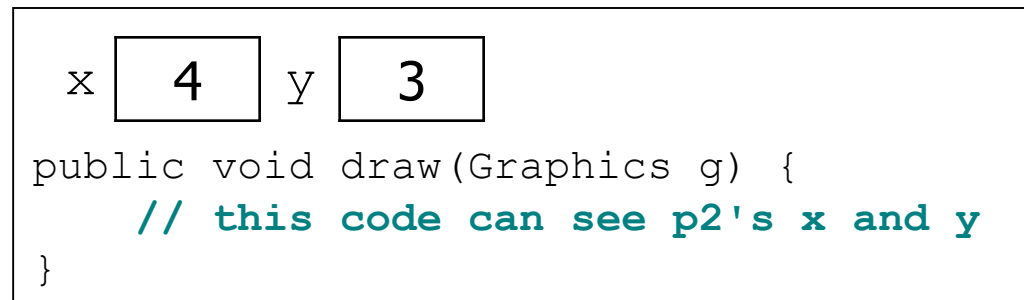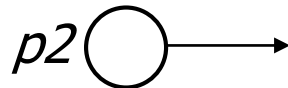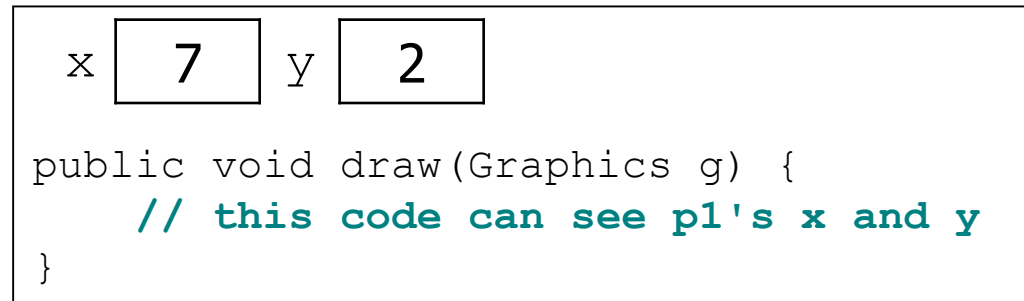 - How will the method access that point's x/y data?

Point objects w/ method

- Each `Point` object has its own copy of the `draw` method, which operates on that object's state:

```
Point p1 = new Point();
p1.x = 7;
p1.y = 2;

Point p2 = new Point();
p2.x = 4;
p2.y = 3;

p1.draw(g);
p2.draw(g);
```

p1

```
x  7   y  2

public void draw(Graphics g) {
    // this code can see p1's x and y
}
```

p2

```
x  4   y  3

public void draw(Graphics g) {
    // this code can see p2's x and y
}
```
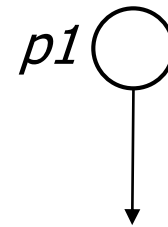
The implicit parameter

- **implicit parameter**:
  The object on which an instance method is called.

  - During the call `p1.draw(g);`
    the object referred to by `p1` is the implicit parameter.

  - During the call `p2.draw(g);`
    the object referred to by `p2` is the implicit parameter.

  - The instance method can refer to that object's fields.
    - We say that it executes in the *context* of a particular object.
    - `draw` can refer to the `x` and `y` of the object it was called on.

Point class, version 2

```
public class Point {
    int x;
    int y;


public void draw(Graphics g) {
        g.fillOval(x, y, 3, 3);
        g.drawString("(" + x + ", " + y + ")", x, y);
    }
}
```

- Each `Point` object contains a `draw` method that draws that point at its current `x`/`y` position.

Kinds of methods

- **accessor**: A method that lets clients examine object state.
  - Examples: `distance, distanceFromOrigin`
  - often has a non-`void` return type

- **mutator**:   A method that modifies an object's state.
  - Examples: `setLocation, translate`

Mutator method questions

- Write a method `setLocation` that changes a `Point`'s location to the (*x*, *y*) values passed.

- Write a method `translate` that changes a `Point`'s location by a given *dx*, *dy* amount.

  - Modify the `Point` and client code to use these methods.

Mutator method answers

```java
public void setLocation(int newX, int newY) {
    x = newX;
    y = newY;
}


public void translate(int dx, int dy) {
    x = x + dx;
    y = y + dy;
}

// alternative solution that utilizes setLocation
public void translate(int dx, int dy) {
    setLocation(x + dx, y + dy);
}
```

Accessor method questions

- Write a method `distance` that computes the distance between a `Point` and another `Point` parameter.

  Use the formula: $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$

- Write a method `distanceFromOrigin` that returns the distance between a `Point` and the origin, (0, 0).

  – Modify the client code to use these methods.

Accessor method answers

```java
public double distance(Point other) {
    int dx = x - other.x;
    int dy = y - other.y;
    return Math.sqrt(dx * dx + dy * dy);
}



public double distanceFromOrigin() {
    return Math.sqrt(x * x + y * y);
}

// alternative solution that uses distance
public double distanceFromOrigin() {
    Point origin = new Point();
    return distance(origin);
}
```

Printing objects

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

```
Point p = new Point();
p.x = 10;
p.y = 7;
System.out.println("p is " + p);   // p is Point@9e8c34



// better, but cumbersome;         p is (10, 7)
System.out.println("p is (" + p.x + ", " + p.y + ")");



// desired behavior
System.out.println("p is " + p);   // p is (10, 7)
```

The `toString` method

tells Java how to convert an object into a `String`

```
Point p1 = new Point(7, 2);
System.out.println("p1: " + p1);

// the above code is really calling the following:
System.out.println("p1: " + p1.toString());
```

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

```
Point@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 Point.
public String toString() {
    return "(" + x + ", " + y + ")";
}
```

Object initialization: constructors

Initializing objects

- Currently it takes 3 lines to create a `Point` and initialize it:

```
Point p = new Point();
p.x = 3;
p.y = 8;                          // tedious
```

- We'd rather specify the fields' initial values at the start:

```
Point p = new Point(3, 8);    // better!
```

  – We are able to do this with most types of objects in Java.

Constructors

- **constructor**: Initializes the state of new objects.

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

- – runs when the client uses the `new` keyword
- – no return type is specified;
  it implicitly "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 0.

Constructor example

```java
public class Point {
    int x;
    int y;

    // Constructs a Point at the given x/y location.
    public Point(int initialX, int initialY) {
        x = initialX;
        y = initialY;
    }


    public void translate(int dx, int dy) {
        x = x + dx;
        y = y + dy;
    }

    ...
}
```

Tracing a constructor call

- What happens when the following call is made?

```
Point p1 = new Point(7, 2);
```

p1 ⚪⟶

x ▢   y ▢

```
public Point(int initialX, int initialY) {
    x = initialX;
    y = initialY;
}

public void translate(int dx, int dy) {
    x += dx;
    y += dy;
}
```

Client code, version 3

```java
public class PointMain3 {
    public static void main(String[] args) {
        // create two Point objects
        Point p1 = new Point(5, 2);
        Point p2 = new Point(4, 3);

        // print each point
        System.out.println("p1: (" + p1.x + ", " + p1.y + ")");
        System.out.println("p2: (" + p2.x + ", " + p2.y + ")");

        // move p2 and then print it again
        p2.translate(2, 4);
        System.out.println("p2: (" + p2.x + ", " + p2.y + ")");
    }
}
```

OUTPUT:
```
p1: (5, 2)
p2: (4, 3)
p2: (6, 7)
```

Multiple constructors

- A class can have multiple constructors.
  - Each one must accept a unique set of parameters.

- *Exercise:* Write a `Point` constructor with no parameters that initializes the point to (0, 0).

```
// Constructs a new point at (0, 0).
public Point() {
    x = 0;
    y = 0;
}
```

Common constructor bugs

1. Re-declaring fields as local variables ("shadowing"):

```
public Point(int initialX, int initialY) {
    int x = initialX;
    int y = initialY;
}
```

- This declares local variables with the same name as the fields, rather than storing values into the fields. The fields remain 0.

2. Accidentally giving the constructor a return type:

```
public void Point(int initialX, int initialY) {
    x = initialX;
    y = initialY;
}
```

- This is actually not a constructor, but a method named `Point`

Encapsulation

Encapsulation

- **encapsulation**: Hiding implementation details from clients.

    – Encapsulation forces *abstraction*.
    - separates external view (behavior) from internal view (state)
    - protects the integrity of an object's data
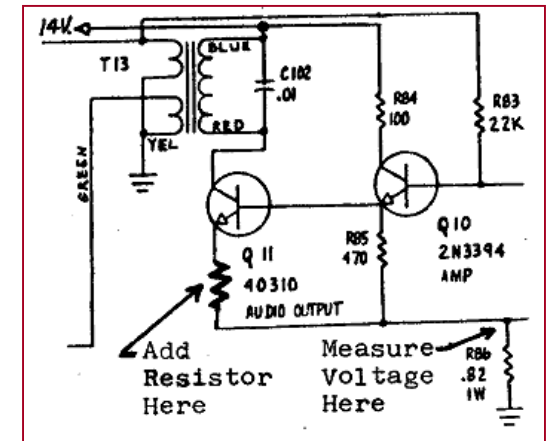
Private fields

A field that cannot be accessed from outside the class

```
private type name;
```

- – Examples:

```
private int id;
private String name;
```

- • Client code won't compile if it accesses private fields:

```
PointMain.java:11: x has private access in Point
System.out.println(p1.x);
                      ^
```

Accessing private state

```java
// A "read-only" access to the x field ("accessor")
public int getX() {
    return x;
}

// Allows clients to change the x field ("mutator")
public void setX(int newX) {
    x = newX;
}
```

– Client code will look more like this:

```java
System.out.println(p1.getX());
p1.setX(14);
```

Point class, version 4

```java
// A Point object represents an (x, y) location.
public class Point {
    private int x;
    private int y;

    public Point(int initialX, int initialY) {
        x = initialX;
        y = initialY;
    }

    public int getX() {
        return x;
    }

    public int getY() {
        return y;
    }

    public double distanceFromOrigin() {
        return Math.sqrt(x * x + y * y);
    }

    public void setLocation(int newX, int newY) {
        x = newX;
        y = newY;
    }

    public void translate(int dx, int dy) {
        setLocation(x + dx, y + dy);
    }
}
```

Benefits of encapsulation

- Abstraction between object and clients

- Protects object from unwanted access
  - Example: Can't fraudulently increase an `Account`'s balance.

- Can change the class implementation later
  - Example: `Point` could be rewritten in polar coordinates (r, θ) with the same methods.

- Can constrain objects' state (**invariants**)
  - Example: Only allow `Account`s with non-negative balance.
  - Example: Only allow `Date`s with a month from 1-12.
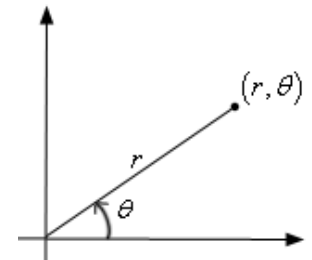
The `this` keyword

- **`this`** : Refers to the implicit parameter inside your class.

  (a variable that stores the object on which a method is called)

  – Refer to a field: `this.`**field**

  – Call a method: `this.`**method**(**parameters**)`;`

  – One constructor   `this`(**parameters**)`;`
  can call another:

Variable shadowing

- **shadowing**: 2 variables with same name in same scope.
  - Normally illegal, except when one variable is a field.

    ```
    public class Point {
        private int x;
        private int y;

        ...

        // this is legal
        public void setLocation(int x, int y) {
            ...
        }
    ```

  - In most of the class, `x` and `y` refer to the fields.
  - In `setLocation`, `x` and `y` refer to the method's parameters.

Fixing shadowing

```
public class Point {
    private int x;
    private int y;

    ...

    public void setLocation(int x, int y) {
        this.x = x;
        this.y = y;
    }
}
```

- Inside `setLocation`,
  - To refer to the data field `x`,   say `this.x`
  - To refer to the parameter `x`,   say `x`

Calling another constructor

```java
public class Point {
    private int x;
    private int y;

    public Point() {
        this(0, 0);      // calls (x, y) constructor
    }

    public Point(int x, int y) {
        this.x = x;
        this.y = y;
    }

    ...
}
```

- Avoids redundancy between constructors
- Only a constructor (not a method) can call another constructor

Static methods/fields

Multi-class systems

- Most large software systems consist of many classes.
  - One main class runs and calls methods of the others.

- Advantages:
  - code reuse
  - splits up the program logic into manageable chunks

```
Main Class #1
main
method1
method2
```

```
Class #2
method3
method5
```

```
Class #3
method4
method6
```
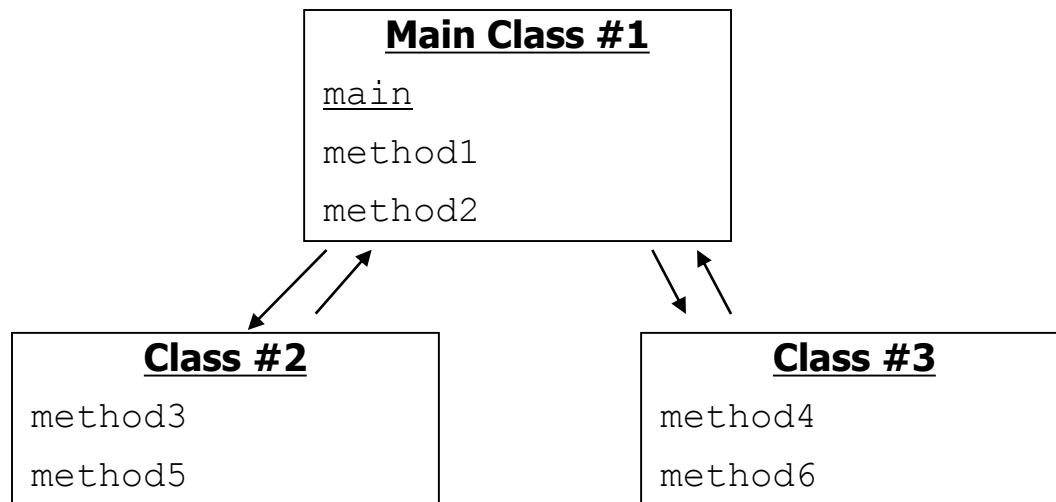
Redundant program 1

```java
// This program sees whether some interesting numbers are prime.
public class Primes1 {
    public static void main(String[] args) {
        int[] nums = {1234517, 859501, 53, 142};
        for (int i = 0; i < nums.length; i++) {
            if (isPrime(nums[i])) {
                System.out.println(nums[i] + " is prime");
            }
        }
    }

    // Returns the number of factors of the given integer.
    public static int countFactors(int number) {
        int count = 0;
        for (int i = 1; i <= number; i++) {
            if (number % i == 0) {
                count++;   // i is a factor of the number
            }
        }
        return count;
    }

    // Returns true if the given number is prime.
    public static boolean isPrime(int number) {
        return countFactors(number) == 2;
    }
}
```

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Redundant program 2

```java
// This program prints all prime numbers up to a maximum.
public class Primes2 {
    public static void main(String[] args) {
        Scanner console = new Scanner(System.in);
        System.out.print("Max number? ");
        int max = console.nextInt();
        for (int i = 2; i <= max; i++) {
            if (isPrime(i)) {
                System.out.print(i + " ");
            }   }
        System.out.println();
    }

    // Returns true if the given number is prime.
    public static boolean isPrime(int number) {
        return countFactors(number) == 2;
    }

    // Returns the number of factors of the given integer.
    public static int countFactors(int number) {
        int count = 0;
        for (int i = 1; i <= number; i++) {
            if (number % i == 0) {
                count++;    // i is a factor of the number
        }   }
        return count;
    }
}
```

Classes as modules

- **module**: A reusable piece of software, stored as a class.
  - Example module classes: `Math, Arrays, System`

```
// This class is a module that contains useful methods
// related to factors and prime numbers.
public class Factors {
    // Returns the number of factors of the given integer.
    public static int countFactors(int number) {
        int count = 0;
        for (int i = 1; i <= number; i++) {
            if (number % i == 0) {
                count++;    // i is a factor of the number
            }
        }

        return count;
    }

    // Returns true if the given number is prime.
    public static boolean isPrime(int number) {
        return countFactors(number) == 2;
    }
}
```

More about modules

- A module is a partial program, not a complete program.

  - It does not have a `main`. You don't run it directly.
  - Modules are meant to be utilized by other *client* classes.

- Syntax:

  class.**method**(**parameters**);

- Example:

  `int factorsOf24 = `**`Factors.countFactors(24);`**

Using a module

```java
// This program sees whether some interesting numbers are prime.
public class Primes {
    public static void main(String[] args) {
        int[] nums = {1234517, 859501, 53, 142};
        for (int i = 0; i < nums.length; i++) {
            if (Factors.isPrime(nums[i])) {
                System.out.println(nums[i] + " is prime");
            }
        }
    }
}

// This program prints all prime numbers up to a given maximum.
public class Primes2 {
    public static void main(String[] args) {
        Scanner console = new Scanner(System.in);
        System.out.print("Max number? ");
        int max = console.nextInt();
        for (int i = 2; i <= max; i++) {
            if (Factors.isPrime(i)) {
                System.out.print(i + " ");
        }   }
        System.out.println();
    }
}
```

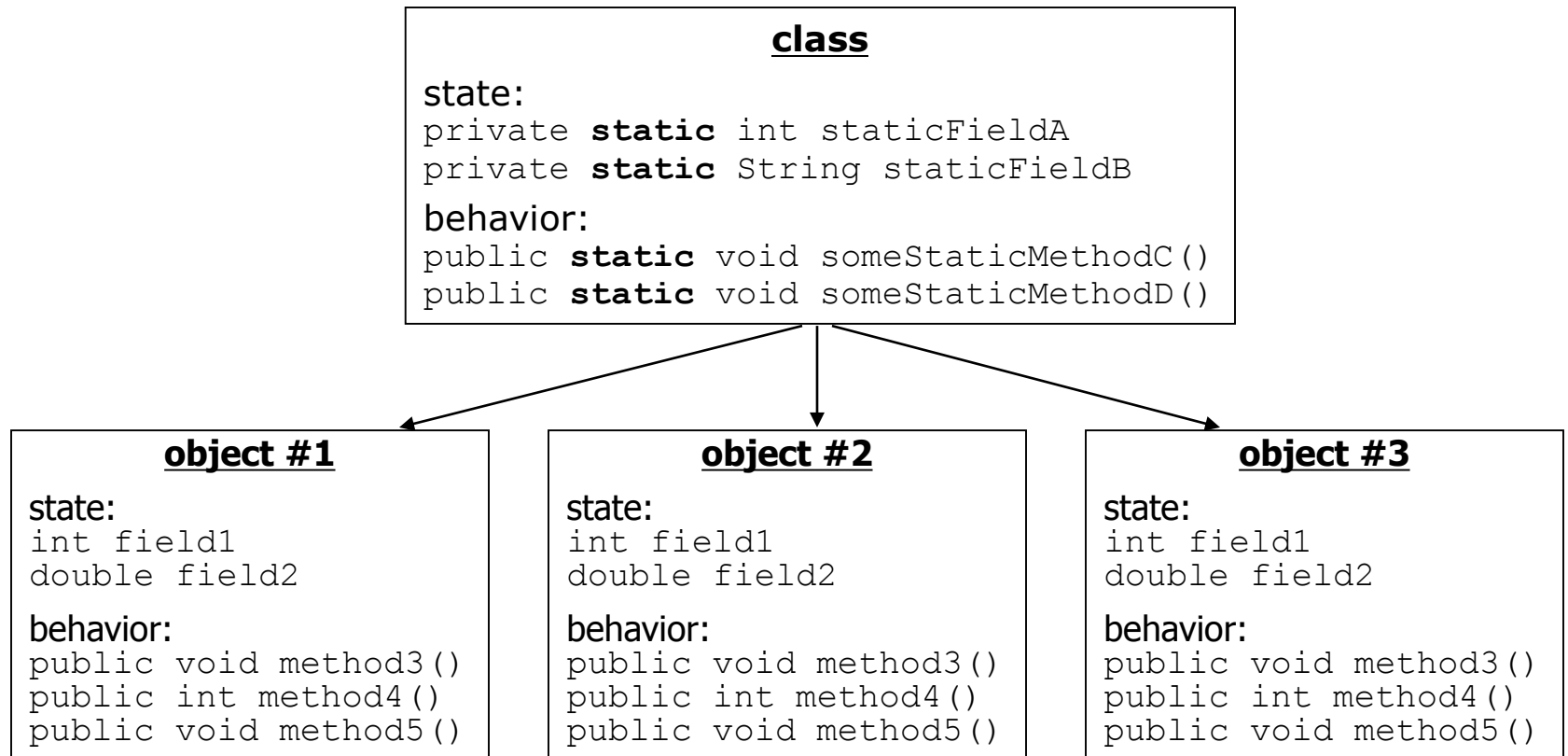# Modules in Java libraries

```java
// Java's built in Math class is a module
public class Math {
    public static final double PI = 3.14159265358979323846;

    ...

    public static int abs(int a) {
        if (a >= 0) {
            return a;
        } else {
            return -a;
        }
    }

    public static double toDegrees(double radians) {
        return radians * 180 / PI;
    }
}
```

Static members

- **static**: Part of a class, rather than part of an object.
  - Object classes can have static methods *and fields*.
  - Not copied into each object; shared by all objects of that class.

```
                        class
state:
private static int staticFieldA
private static String staticFieldB

behavior:
public static void someStaticMethodC()
public static void someStaticMethodD()
```

```
        object #1
state:
int field1
double field2

behavior:
public void method3()
public int method4()
public void method5()
```

```
        object #2
state:
int field1
double field2

behavior:
public void method3()
public int method4()
public void method5()
```

```
        object #3
state:
int field1
double field2

behavior:
public void method3()
public int method4()
public void method5()
```

Static fields

```
private static type name;
or,
private static type name = value;
```

– Example:

```
private static int theAnswer = 42;
```

- **static field**: Stored in the class instead of each object.
  – A "shared" global field that all objects can access and modify.
  – Like a class constant, except that its value can be changed.

Accessing static fields

- From inside the class where the field was declared:

  fieldName   `// get the value`
  fieldName = **value**;   `// set the value`

- From another class (if the field is `public`):

  ClassName.**fieldName**   `// get the value`
  ClassName.**fieldName** = **value**;   `// set the value`

  – generally static fields are not `public` unless they are `final`

Static methods

```
// the same syntax you've already used for
methods
public static type name(parameters) {
    statements;
}
```

- **static method**: Stored in a class, not in an object.

  - Shared by all objects of the class, not replicated.
  - Does not have any *implicit parameter*, `this`;
    therefore, cannot access any particular object's fields.

Summary of Java classes

- A class is used for any of the following in a large program:

  - a *program* : Has a main and perhaps other static methods.
    - example: `GuessingGame`, `Birthday`, `MadLibs`, `CritterMain`
    - does not usually declare any static fields (except `final`)

  - an *object class* : Defines a new type of objects.
    - example: `Point`, `BankAccount`, `Date`, `Critter`, `FratGuy`
    - declares object fields, constructor(s), and methods
    - might declare static fields or methods, but these are less of a focus
    - should be encapsulated (all fields and static fields `private`)

  - a *module* : Utility code implemented as static methods.
    - example: `Math`