CSE 373

Review of Java

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also based on course materials by Stuart Reges
http://www.cs.washington.edu/373/

Summary

- These slides contain material about objects, classes, and object-oriented programming in Java.
- We won't be covering these slides in lecture, but they contain material you are expected to remember from CSE 142 and 143.
- For additional review material, consult Ch. 1-6 of *Core Java*.

Primitives vs. objects; value and reference semantics

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

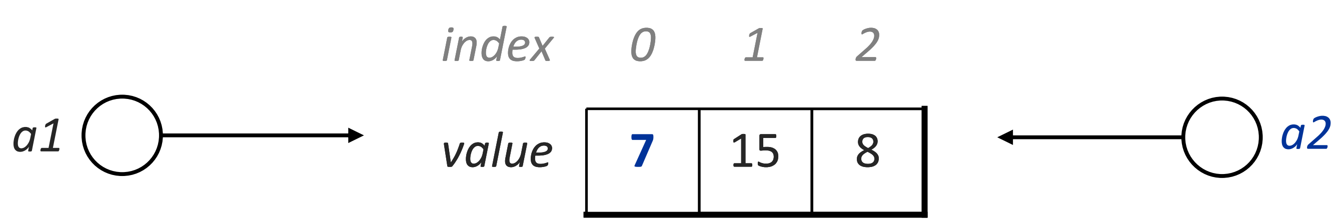
- **value semantics**: Behavior where values are copied when assigned, passed as parameters, or returned.
  - All primitive types in Java use value semantics.
  - When one variable is assigned to another, its value is copied.
  - Modifying the value of one variable does not affect others.

```
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.

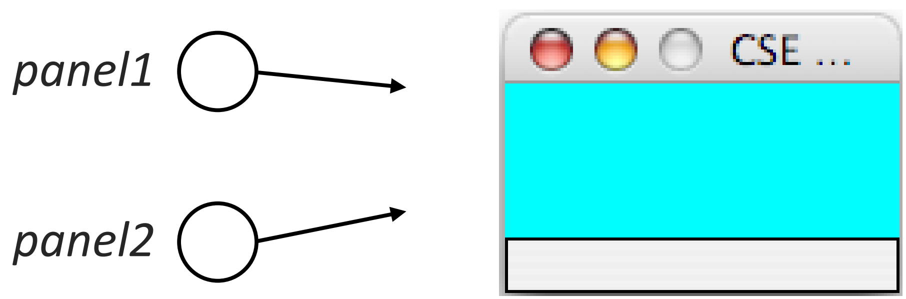
```
int[] a1 = {4, 15, 8};
int[] a2 = a1;          // refer to same array as a1
a2[0] = 7;
System.out.println(Arrays.toString(a1)); // [7, 15, 8]
```



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

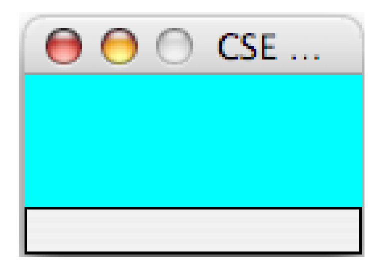
- When an object is passed as a parameter, the object is *not* copied. The parameter refers to the same object.
  - If the parameter is modified, it *will* affect the original object.

```
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);
    ...
}
```

window

panel

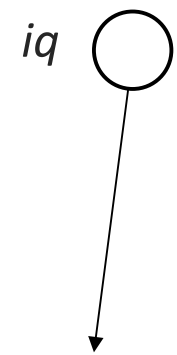


Arrays as parameters

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

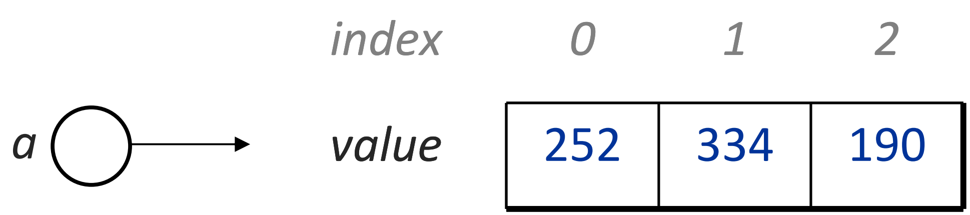
```
public static void main(String[] args) {
    int[] iq = {126, 167, 95};
    increase(iq);
    System.out.println(Arrays.toString(iq));
}

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



  - Output:

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



Arrays pass by reference

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

  - Output:

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[252, 334, 190]
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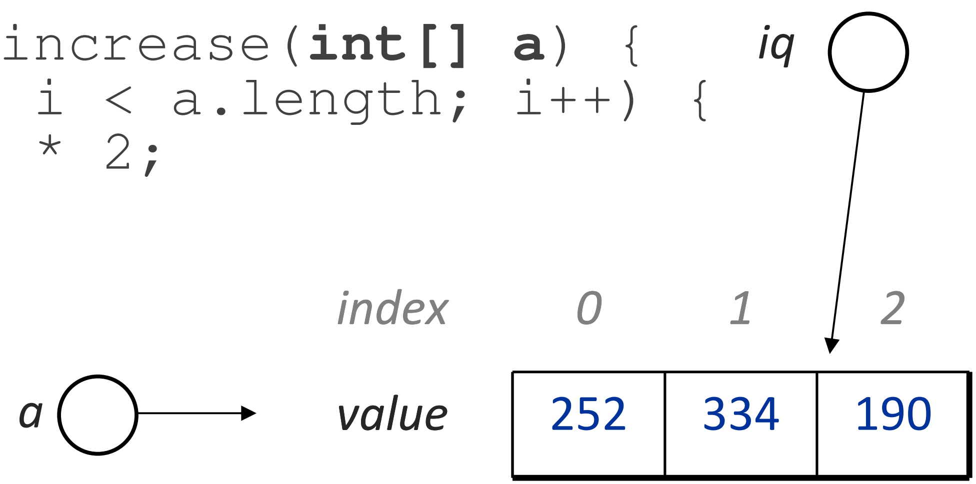
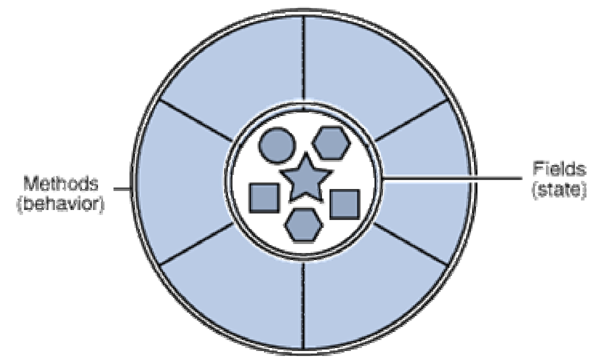


Classes and Objects

Objects

- **object:** An entity that encapsulates data and behavior.
  - *data*: variables inside the object
  - *behavior*: methods inside the object
    - You interact with the methods;
      the data is hidden in the object.



- Constructing (creating) an object:

  Type objectName = `new` **Type** (**parameters**) ;

- Calling an object's method:

  objectName . methodName (**parameters**) ;

Classes

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

– **object-oriented programming (OOP)**: Programs that perform their behavior as interactions between objects.

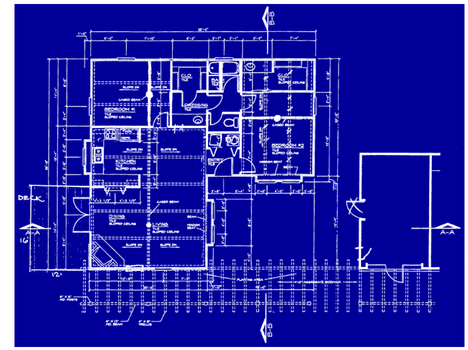
  – **abstraction**: Separation between concepts and details. Objects and classes provide abstraction in programming.

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

Point objects

```
import java.awt.*;
...
Point p1 = new Point(5, -2);
Point p2 = new Point();         // origin (0, 0)
```

- Data:

Name	Description
`x`	the point's x-coordinate
`y`	the point's y-coordinate

- Methods:

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*

`Point` class as blueprint

Point class

state each object should receive:
`int x, y`

behavior each object should receive:
```
setLocation(int x, int y)
translate(int dx, int dy)
distance(Point p)
```

Point object #1

state:
`x =` 51 `y =` -2

behavior:
```
setLocation(int x, int y)
translate(int dx, int dy)
distance(Point p)
```

Point object #2

state:
`x =` -24 `y =` 137

behavior:
```
setLocation(int x, int y)
translate(int dx, int dy)
distance(Point p)
```

Point object #3

state:
`x =` 18 `y =` 42

behavior:
```
setLocation(int x, int y)
translate(int dx, int dy)
distance(Point p)
```

- The class (blueprint) describes how to create objects.
- Each object contains its own data and methods.
  - The methods operate on that object's data.

Clients of objects

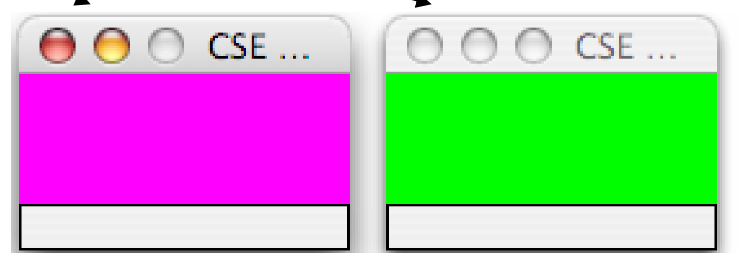
- **client program**: A program that uses objects.
  - Example: `Bomb` is a client of `DrawingPanel` and `Graphics`.

`Bomb.java` (client program)

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

`DrawingPanel.java` (class)

```
public class DrawingPanel {
    ...
}
```



Fields

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

- Declaration syntax:

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

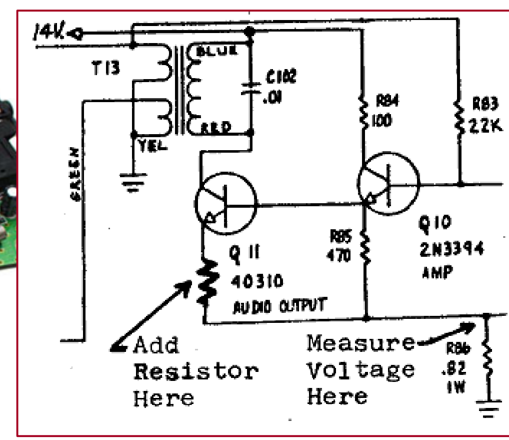
  - Example:

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

    ...
}
```

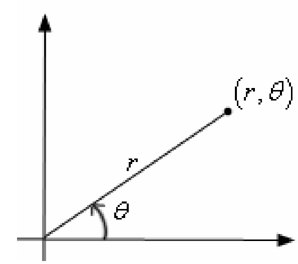
Encapsulation

- **encapsulation**: Hiding implementation details from clients.
  - Encapsulation enforces *abstraction*.
    - separates external view (behavior) from internal view (state)
    - protects the integrity of an object's data



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.

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 tranlate(int dx, int dy) {
      x += dx;
      y += dy;
}
```

The implicit parameter

- **implicit parameter**:
  The object on which an instance method is being called.
  - If we have a `Point` object `p1` and call `p1.translate(5, 3);` the object referred to by `p1` is the implicit parameter.
  - If we have a `Point` object `p2` and call `p2.translate(4, 1);` 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.
    - `translate` can refer to the `x` and `y` of the object it was called on.

Categories 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`

- **helper**: Assists some other method in performing its task.
  - often declared as private so outside clients cannot call it

The `toString` method

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

```
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 + ")";
}
```

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; implicitly "returns" the new object

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

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

Multiple constructors

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

- *Example:* 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;
}
```

The keyword `this`

- **`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 can call another: `this(`**parameters**`);`

Calling another constructor

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

    public Point() {
        this(0, 0);
    }

    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

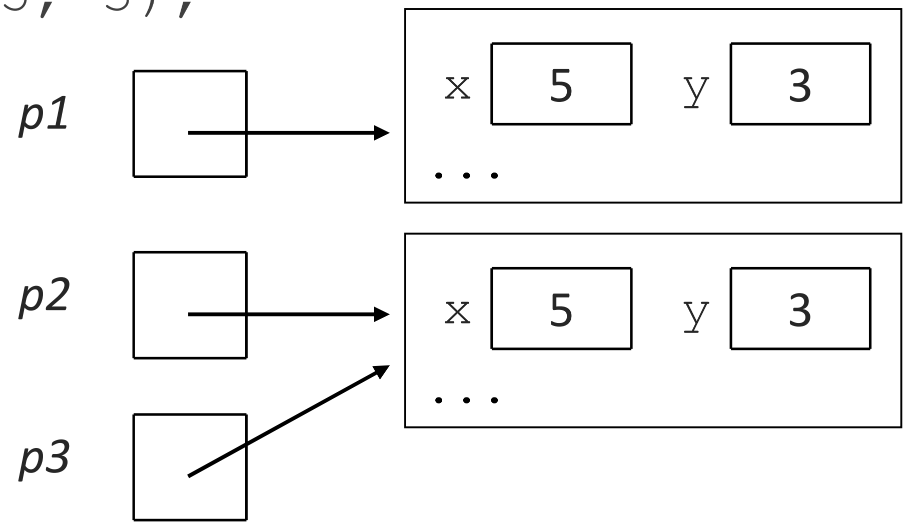
Comparing objects for equality and ordering

Comparing objects

- The == operator does not work well with objects.
  - == compares references to objects, not their state.
  - It only produces `true` when you compare an object to itself.

```
Point p1 = new Point(5, 3);
Point p2 = new Point(5, 3);
Point p3 = p2;

// p1 == p2 is false;
// p1 == p3 is false;
// p2 == p3 is true
```



The `equals` method

- The `equals` method compares the state of objects.

```
if (str1.equals(str2)) {
    System.out.println("the strings are equal");
}
```

- But if you write a class, its `equals` method behaves like `==`

```
if (p1.equals(p2)) {    // false :-(
    System.out.println("equal");
}
```

  - This is the default behavior we receive from class `Object`.
  - Java doesn't understand how to compare new classes by default.

The `compareTo` method (10.2)

- The standard way for a Java class to define a comparison function for its objects is to define a `compareTo` method.
  - Example: in the `String` class, there is a method:

    `public int compareTo(String other)`

- A call of **A**`.compareTo(`**B**`)` will return:

a value <	0	if **A** comes "before" **B** in the ordering,
a value >	0	if **A** comes "after" **B** in the ordering,
or	0	if **A** and **B** are considered "equal" in the ordering.

Using `compareTo`

- `compareTo` can be used as a test in an `if` statement.

```
String a = "alice";
String b = "bob";
if (a.compareTo(b) < 0) {  // true
    ...
}
```

Primitives	Objects
`if (a < b) { ...`	`if (a.compareTo(b) < 0) { ...`
`if (a <= b) { ...`	`if (a.compareTo(b) <= 0) { ...`
`if (a == b) { ...`	`if (a.compareTo(b) == 0) { ...`
`if (a != b) { ...`	`if (a.compareTo(b) != 0) { ...`
`if (a >= b) { ...`	`if (a.compareTo(b) >= 0) { ...`
`if (a > b) { ...`	`if (a.compareTo(b) > 0) { ...`

`compareTo` and collections

- You can use an array or list of strings with Java's included binary search method because it calls `compareTo` internally.

```
String[] a = {"al", "bob", "cari", "dan",
  "mike"};
int index = Arrays.binarySearch(a, "dan");  // 3
```

- Java's `TreeSet/Map` use `compareTo` internally for ordering.

```
Set<String> set = new TreeSet<String>();
for (String s : a) {
    set.add(s);
}
System.out.println(s);
// [al, bob, cari, dan, mike]
```

`Comparable` (10.2)

```
public interface Comparable<E> {
    public int compareTo(E other);
}
```

- A class can implement the `Comparable` interface to define a natural ordering function for its objects.

- A call to your `compareTo` method should return:

a value <	0	if `this` object comes "before" the `other` object,
a value >	0	if `this` object comes "after" the `other` object,
or	0	if `this` object is considered "equal" to the `other`.

- If you want multiple orderings, use a `Comparator` instead (see Ch. 13.1)

Comparable template

```
public class name implements Comparable<name> {

    ...

    public int compareTo(name other) {
        ...
    }
}
```

Comparable example

```java
public class Point implements Comparable<Point> {
    private int x;
    private int y;
    ...

    // sort by x and break ties by y
    public int compareTo(Point other) {
        if (x < other.x) {
            return -1;
        } else if (x > other.x) {
            return 1;
        } else if (y < other.y) {
            return -1;   // same x, smaller y
        } else if (y > other.y) {
            return 1;    // same x, larger y
        } else {
            return 0;    // same x and same y
        }
    }
}
```

`compareTo` tricks

- *subtraction trick* - Subtracting related numeric values produces the right result for what you want `compareTo` to return:

```
// sort by x and break ties by y
public int compareTo(Point other) {
    if (x != other.x) {
        return x - other.x;   // different x
    } else {
        return y - other.y;   // same x; compare y
    }
}
```

  - The idea:
    - if `x > other.x`, then `x - other.x > 0`
    - if `x < other.x`, then `x - other.x < 0`
    - if `x == other.x`, then `x - other.x == 0`
      - NOTE: This trick doesn't work for `doubles` (but see `Math.signum`)

`compareTo` tricks 2

- *delegation trick* - If your object's fields are comparable (such as strings), use their `compareTo` results to help you:

```
// sort by employee name, e.g. "Jim" < "Susan"
public int compareTo(Employee other) {
    return name.compareTo(other.getName());
}
```

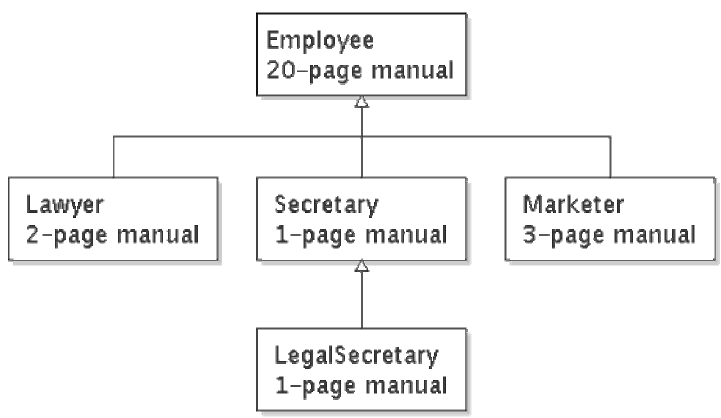
- *`toString` trick* - If your object's `toString` representation is related to the ordering, use that to help you:

```
// sort by date, e.g. "09/19" > "04/01"
public int compareTo(Date other) {
    return
  toString().compareTo(other.toString());
}
```

Inheritance

Inheritance

- **inheritance**: Forming new classes based on existing ones.
  - a way to share/**reuse code** between two or more classes
  - **superclass**: Parent class being extended.
  - **subclass**: Child class that inherits behavior from superclass.
    - gets a copy of every field and method from superclass
  - **is-a relationship**: Each object of the subclass also "is a(n)" object of the superclass and can be treated as one.



Inheritance syntax

```
public class name extends superclass {
```

- Example:

```
public class Lawyer extends Employee {
    ...
}
```

- By extending `Employee`, each `Lawyer` object now:
  - receives a copy of each method from `Employee` automatically
  - can be treated as an `Employee` by client code
- Lawyer can also replace ("override") behavior from Employee.

Overriding Methods

- **override**: To write a new version of a method in a subclass that replaces the superclass's version.
  - No special syntax required to override a superclass method. Just write a new version of it in the subclass.

```
public class Lawyer extends Employee {
    // overrides getVacationForm in Employee class
    public String getVacationForm() {
        return "pink";
    }
    ...
}
```

The `super` keyword

- A subclass can call its parent's method/constructor:

```
super.method(parameters)          // method
super(parameters);                // constructor
```

```
public class Lawyer extends Employee {
    public Lawyer(String name) {
        super(name);
    }

    // give Lawyers a $5K raise (better)
    public double getSalary() {
        double baseSalary = super.getSalary();
        return baseSalary + 5000.00;
    }
}
```

Subclasses and fields

```
public class Employee {
    private double salary;
    ...
}

public class Lawyer extends Employee {
    ...
    public void giveRaise(double amount) {
        salary += amount;   // error; salary is private
    }
}
```

- Inherited private fields/methods cannot be directly accessed by subclasses. *(The subclass has the field, but it can't touch it.)*
  - How can we allow a subclass to access/modify these fields?

Protected fields/methods

```
protected type name;    // field

protected type name(type name, ..., type name) {
    statement(s);        // method
}
```

- a **protected field** or **method** can be seen/called only by:
  - the class itself, and its subclasses
  - also by other classes in the same "package" (discussed later)
  - useful for allowing selective access to inner class implementation

```
public class Employee {
    protected double salary;
    ...
}
```

Inheritance and constructors

- If we add a constructor to the `Employee` class, our subclasses do not compile. The error:

```
Lawyer.java:2: cannot find symbol
symbol  : constructor Employee()
location: class Employee
public class Lawyer extends Employee {
       ^
```

  - The short explanation: Once we write a constructor (that requires parameters) in the superclass, we must now write constructors for our employee subclasses as well.

Inheritance and constructors

- Constructors are not inherited.
  - Subclasses don't inherit the `Employee(int)` constructor.
  - Subclasses receive a default constructor that contains:

```
public Lawyer() {
    super();          // calls Employee() constructor
}
```

- But our `Employee(int)` replaces the default `Employee()`.
  - The subclasses' default constructors are now trying to call a non-existent default `Employee` constructor.

Calling superclass constructor

```
super(parameters);
```

- Example:

```
public class Lawyer extends Employee {
    public Lawyer(int years) {
        super(years);  // calls Employee c'tor
    }
    ...
}
```

- The `super` call must be the first statement in the constructor.

Polymorphism

Polymorphism

- **polymorphism**: Ability for the same code to be used with different types of objects and behave differently with each.

  - `System.out.println` can print any type of object.
    - Each one displays in its own way on the console.

  - `CritterMain` can interact with any type of critter.
    - Each one moves, fights, etc. in its own way.

Coding with polymorphism

- A variable of type *T* can hold an object of any subclass of *T*.

```
Employee ed = new Lawyer();
```

  - You can call any methods from the `Employee` class on `ed`.

- When a method is called on `ed`, it behaves as a `Lawyer`.

```
System.out.println(ed.getSalary());        // 50000.0
System.out.println(ed.getVacationForm()); // pink
```

Polymorphic parameters

- You can pass any subtype of a parameter's type.

```
public static void main(String[] args) {
    Lawyer lisa = new Lawyer();
    Secretary steve = new Secretary();
    printInfo(lisa);
    printInfo(steve);
}

public static void printInfo(Employee e) {
    System.out.println("pay  : " + e.getSalary());
    System.out.println("vdays: " + e.getVacationDays());
    System.out.println("vform: " + e.getVacationForm());
    System.out.println();
}
```

OUTPUT:

```
pay  : 50000.0    pay  : 50000.0
vdays: 15         vdays: 10
vform: pink       vform: yellow
```

Polymorphism and arrays

- Arrays of superclass types can store any subtype as elements.

```
public static void main(String[] args) {
    Employee[] e = {new Lawyer(),   new Secretary(),
                    new Marketer(), new LegalSecretary()};

    for (int i = 0; i < e.length; i++) {
        System.out.println("pay  : " + e[i].getSalary());
        System.out.println("vdays: " + i].getVacationDays());
        System.out.println();
    }
}
```

Output:

```
pay  : 50000.0      pay  : 60000.0
vdays: 15           vdays: 10

pay  : 50000.0      pay  : 55000.0
vdays: 10           vdays: 10
```

Casting references

- A variable can only call that type's methods, not a subtype's.

```
Employee ed = new Lawyer();
int hours = ed.getHours();   // ok; in Employee
ed.sue();                    // compiler error
```

  - The compiler's reasoning is, variable `ed` could store any kind of employee, and not all kinds know how to `sue` .

- To use `Lawyer` methods on `ed`, we can type-cast it.

```
Lawyer theRealEd = (Lawyer) ed;
theRealEd.sue();             // ok

((Lawyer) ed).sue();         // shorter version
```

More about casting

- The code crashes if you cast an object too far down the tree.

```
Employee eric = new Secretary();
((Secretary) eric).takeDictation("hi");     // ok
((LegalSecretary) eric).fileLegalBriefs(); // error
//   (Secretary doesn't know how to file briefs)
```

- You can cast only up and down the tree, not sideways.

```
Lawyer linda = new Lawyer();
((Secretary) linda).takeDictation("hi");    // error
```

- Casting doesn't actually change the object's behavior.
  It just gets the code to compile/run.

```
((Employee) linda).getVacationForm()        // pink
```

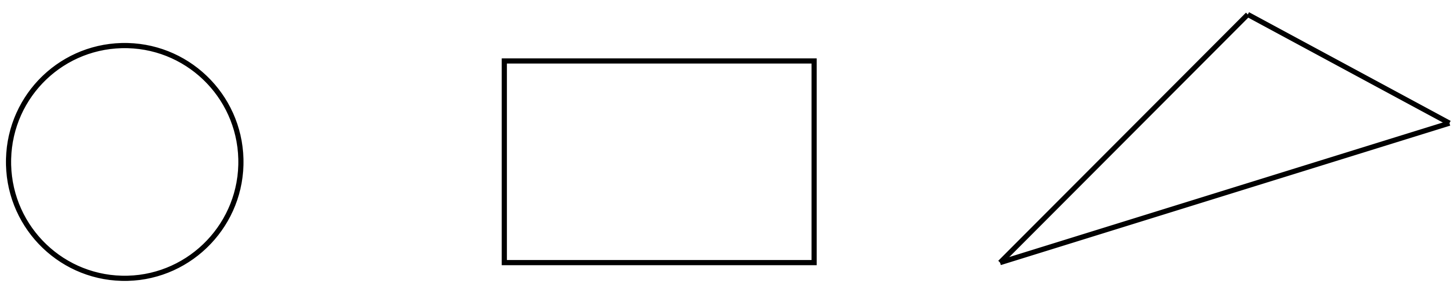
Interfaces

Shapes example

- Consider the task of writing classes to represent 2D shapes such as `Circle`, `Rectangle`, and `Triangle`.

- Certain operations are common to all shapes:
  - perimeter: distance around the outside of the shape
  - area: amount of 2D space occupied by the shape

  - Every shape has these, but each computes them differently.

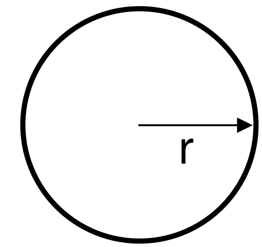


Shape area and perimeter

- Circle (as defined by radius r):

  area = πr^2

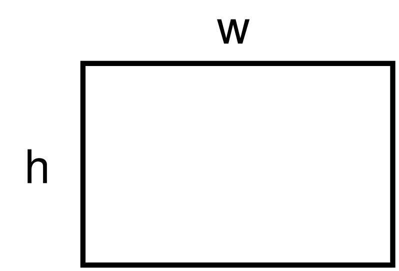
  perimeter = $2 \pi r$



- Rectangle (as defined by width w and height h):

  area = $w h$

  perimeter = $2w + 2h$

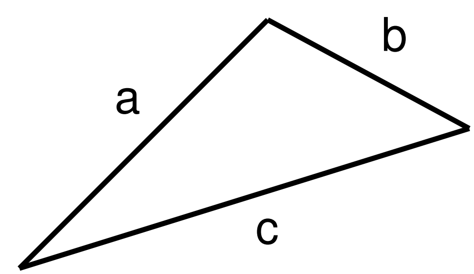


- Triangle (as defined by side lengths a, b, and c)

  area = $\sqrt{s (s - a) (s - b) (s - c)}$

  where $s = \frac{1}{2} (a + b + c)$

  perimeter = $a + b + c$



Common behavior

- Suppose we have 3 classes `Circle`, `Rectangle`, `Triangle`.
  - Each has the methods `perimeter` and `area`.

- We'd like our client code to be able to treat different kinds of shapes in the same way:
  - Write a method that prints any shape's area and perimeter.
  - Create an array to hold a mixture of the various shape objects.
  - Write a method that could return a rectangle, a circle, a triangle, or any other kind of shape.
  - Make a `DrawingPanel` display many shapes on screen.

Interfaces

- **interface**: A list of methods that a class can promise to implement.
  - Inheritance gives you an is-a relationship *and* code sharing.
    - A `Lawyer` can be treated as an `Employee` and inherits its code.
  - Interfaces give you an is-a relationship *without* code sharing.
    - A `Rectangle` object can be treated as a `Shape` but inherits no code.
  - Analogous to non-programming idea of roles or certifications:
    - "I'm certified as a CPA accountant.
      This assures you I know how to do taxes, audits, and consulting."
    - "I'm 'certified' as a Shape, because I implement the Shape interface.
      This assures you I know how to compute my area and perimeter."

Interface syntax

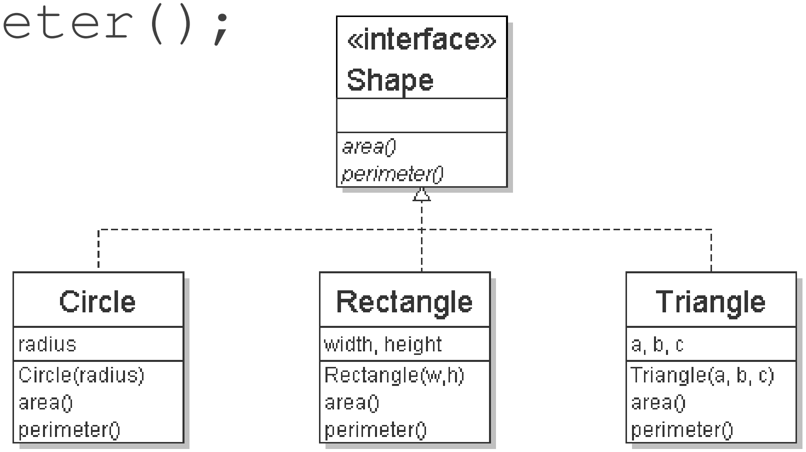
```
public interface name {
    public type name(type name, ..., type name);
    public type name(type name, ..., type name);
    ...
    public type name(type name, ..., type name);
}
```

Example:

```
public interface Vehicle {
    public int getSpeed();
    public void setDirection(int direction);
}
```

Shape interface

```
// Describes features common to all shapes.
public interface Shape {
    public double area();
    public double perimeter();
}
```



- Saved as `Shape.java`

- **abstract method**: A header without an implementation.
  - The actual bodies are not specified, because we want to allow each class to implement the behavior in its own way.

Implementing an interface

```
public class name implements interface {
      ...
}
```

- A class can declare that it "implements" an interface.
  - The class promises to contain each method in that interface.
    (Otherwise it will fail to compile.)
  - Example:
    ```
    public class Bicycle implements Vehicle {
          ...
    }
    ```

Interface requirements

```
public class Banana implements Shape {
    // haha, no methods! pwned
}
```

- If we write a class that claims to be a `Shape` but doesn't implement `area` and `perimeter` methods, it will not compile.

```
Banana.java:1: Banana is not abstract and does
not override abstract method area() in Shape
public class Banana implements Shape {
             ^
```

Interfaces + polymorphism

- Interfaces benefit the *client code* author the most.
  - they allow **polymorphism**
    (the same code can work with different types of objects)

```
public static void printInfo(Shape s) {
    System.out.println("The shape: " + s);
    System.out.println("area : " + s.area());
    System.out.println("perim: " + s.perimeter());
    System.out.println();
}
...
Circle circ = new Circle(12.0);
Triangle tri = new Triangle(5, 12, 13);
printInfo(circ);
printInfo(tri);
```

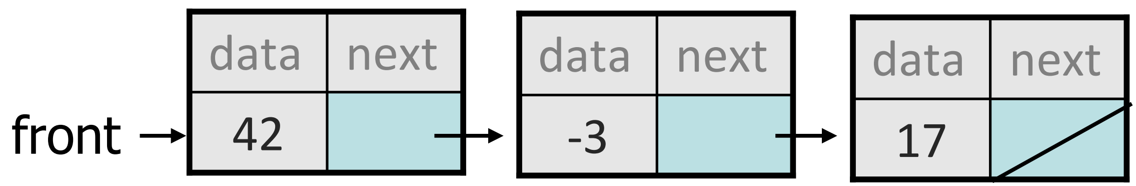
Abstract Classes

List classes example

- Suppose we have implemented the following two list classes:
  - `ArrayList`

index	0	1	2
value	42	-3	17

  - `LinkedList`



  - We have a `List` interface to indicate that both implement a List ADT.
  - Problem:
    - Some of their methods are implemented the same way (redundancy).

Common code

- Notice that some of the methods are implemented the same way in both the array and linked list classes.
  - `add(`**value**`)`
  - `contains`
  - `isEmpty`

- Should we change our interface to a class? Why / why not?
  - How can we capture this common behavior?

Abstract classes (9.6)

- **abstract class**: A hybrid between an interface and a class.
  - defines a superclass type that can contain method declarations (like an interface) and/or method bodies (like a class)
  - like interfaces, abstract classes that cannot be instantiated (cannot use `new` to create any objects of their type)

- What goes in an abstract class?
  - implementation of common state and behavior that will be inherited by subclasses (parent class role)
  - declare generic behaviors that subclasses implement (interface role)

Abstract class syntax

```
// declaring an abstract class
public abstract class name {
    ...

    // declaring an abstract method
    // (any subclass must implement it)
    public abstract type name(parameters);

}
```

- A class can be `abstract` even if it has no abstract methods
- You can create variables (but not objects) of the abstract type

Abstract and interfaces

- Normal classes that claim to implement an interface must implement all methods of that interface:

```
public class Empty implements List {}  // error
```

- Abstract classes can claim to implement an interface without writing its methods; subclasses must implement the methods.

```
public abstract class Empty implements List {} // ok
public class Child extends Empty {}            // error
```

An abstract list class

```
// Superclass with common code for a list of integers.
public abstract class AbstractList implements List {
    public void add(int value) {
        add(size(), value);
    }

    public boolean contains(int value) {
        return indexOf(value) >= 0;
    }

    public boolean isEmpty() {
        return size() == 0;
    }
}


public class ArrayList extends AbstractList { ...

public class LinkedList extends AbstractList { ...
```

Abstract class vs. interface

- Why do both interfaces and abstract classes exist in Java?
  - An abstract class can do everything an interface can do and more.
  - So why would someone ever use an interface?

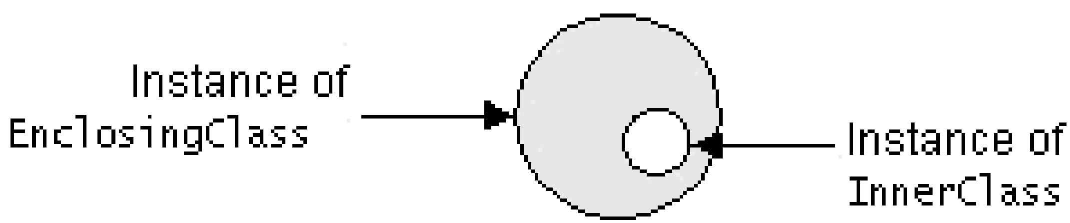
- Answer: Java has single inheritance.
  - can extend only one superclass
  - can implement many interfaces
  - Having interfaces allows a class to be part of a hierarchy (polymorphism) without using up its inheritance relationship.

Inner Classes

Inner classes

- **inner class**: A class defined inside of another class.
  - can be created as `static` or non-static
  - we will focus on standard non-static ("nested") inner classes

- usefulness:
  - inner classes are hidden from other classes (encapsulated)
  - inner objects can access/modify the fields of the outer object



Inner class syntax

```
// outer (enclosing) class
public class name {
    ...

    // inner (nested) class
    private class name {
        ...
    }
}
```

- Only this file can see the inner class or make objects of it.
- Each inner object is associated with the outer object that created it, so it can access/modify that outer object's methods/fields.
  - If necessary, can refer to outer object as **OuterClassName**.`this`

Example: Array list iterator

```
public class ArrayList extends AbstractList {
    ...
    // not perfect; doesn't forbid multiple removes in a row
    private class ArrayIterator implements Iterator<Integer> {
        private int index;   // current position in list

        public ArrayIterator() {
            index = 0;
        }

        public boolean hasNext() {
            return index < size();
        }

        public E next() {
            index++;
            return get(index - 1);
        }

        public void remove() {
            ArrayList.this.remove(index - 1);
            index--;
        }
    }
}
```