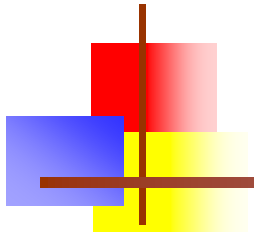
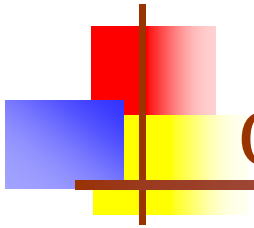


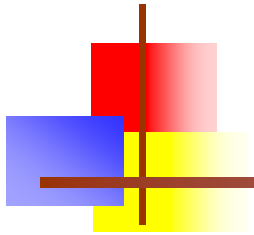
INF 212 Analysis of Prog. Langs

Basic OOP



Goal of this lecture

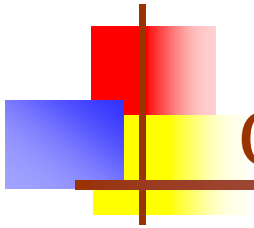
- Visit a few flavors of OOP
  - “Popular” OOP
  - Smalltalk OOP
  - JavaScript OOP
  - Objects vs. Abstract Data Types



Basic Object-Oriented Concepts

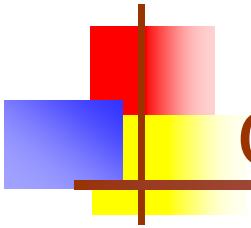
From

http://www.cis.upenn.edu/~matuszek/cit591-2003/



Concept: An object has behaviors

- ~~In old style programming, you had~~: Previously:
  - data, which was completely passive
  - functions, which could manipulate any data
- An object contains both data and methods that manipulate that data
  - An object ~~is *active*, not passive; it~~ *does* things
  - An object is *responsible* for its own data
    - But: it can *expose* that data to other objects

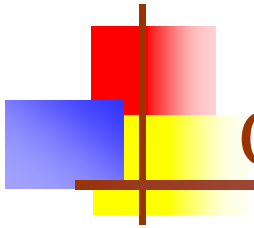


Concept: An object has state

- An object contains both data and methods that manipulate that data
  - The data represent the state of the object
  - Data can also describe the relationships between this object and other objects
- Example: A CheckingAccount might have
  - A balance (the internal state of the account)
  - An owner (some object representing a person)

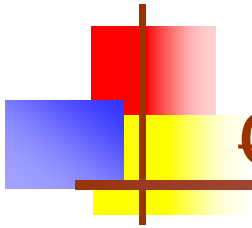
Example: A “Rabbit” object

- You could (in a game, for example) create an object representing a rabbit
- It would have data:
  - How hungry it is
  - How frightened it is
  - Where it is
- And methods:
  - eat, hide, run, dig



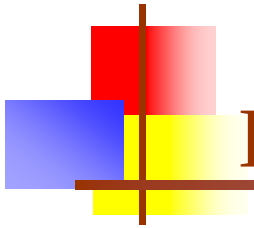
Concept: Classes describe objects

- Every object belongs to (is an instance of) a class
- An object may have fields, or variables
  - The class describes those fields
- An object may have methods
  - The class describes those methods
- A class is like a template, or cookie cutter
  - You use the class's constructor to make objects



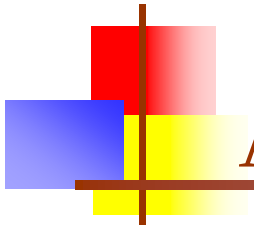
Concept: Classes are like Abstract Data Types

- An Abstract Data Type (ADT) bundles together:
  - some data, representing an object or "thing"
  - the operations on that data
- The operations defined by the ADT are the *only* operations permitted on its data
- Example: a `CheckingAccount`, with operations `deposit`, `withdraw`, `getBalance`, etc.
- Classes enforce this bundling together
  - *If* all data values are `private`, a class can also enforce the rule that its defined operations are the only ones permitted on the data



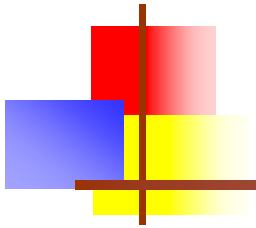
Example of a class

```
class Employee {
    // Fields
    private String name;     //Can get but not change
    private double salary;   // Cannot get or set
    // Constructor
    Employee(String n, double s) {
        name = n; salary = s;
    }
    // Methods
    void pay () {
        System.out.println("Pay to the order of " +
                                name + " $" + salary);
    }
    public String getName() { return name; } // getter
}
```



Approximate Terminology

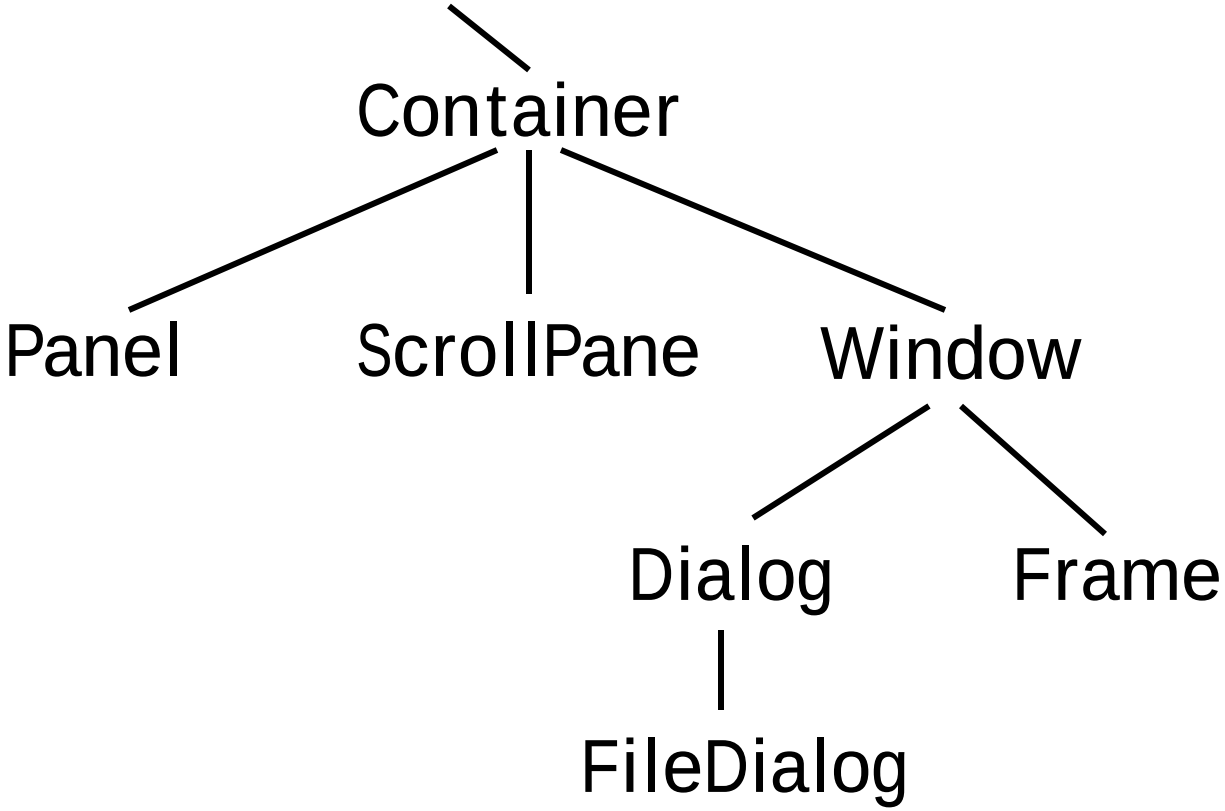
- instance = object
- field = instance variable
- method = function
- sending a message to an object = calling a function
- These are all *approximately* true



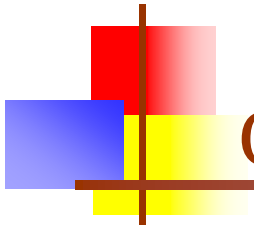
Concept: Classes form a hierarchy

- Classes are arranged in a treelike structure called a hierarchy
- The class at the root is named `Object`
- Every class, except `Object`, has a superclass
- A class may have several ancestors, up to `Object`
- When you define a class, you specify its superclass
  - If you don't specify a superclass, `Object` is assumed
- Every class may have one or more subclasses

Example of (part of) a hierarchy

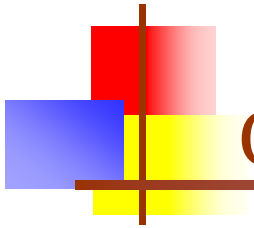


A FileDialog is a Dialog is a Window is a Container



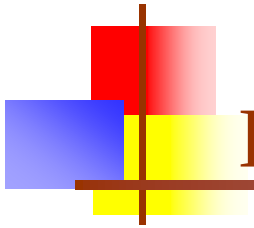
C++ is different

- In C++ there may be more than one root
  - but not in Java!
- In C++ an object may have more than one parent (immediate superclass)
  - but not in Java!
- Java has a single, strict hierarchy



Concept: Objects inherit from superclasses

- A class describes fields and methods
- Objects of that class have those fields and methods
- But an object *also* inherits:
  - the fields described in the class's superclasses
  - the methods described in the class's superclasses
- A class is *not* a complete description of its objects!

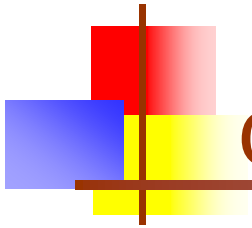


Example of inheritance

```
class Person {
   String name;
   int age;
   void birthday () {
      age = age + 1;
   }
}
```

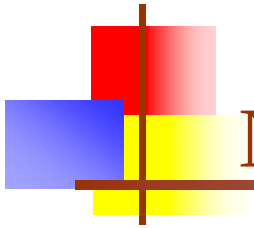
```
class Employee
        extends Person {
   double salary;
   void pay () { …}
}
```

Every Employee has name and age fields and birthday method *as well as* a salary field and a pay method.



Concept: Objects must be created

- `int n;` does two things:
  - It declares that `n` is an integer variable
  - It allocates space to hold a value for `n`
  - For a primitive, this is all that is needed
- `Employee secretary;` also does two things
  - It declares that `secretary` is type `Employee`
  - It allocates space to hold a *reference* to an Employee
  - For an object, this is ***not*** all that is needed
- `secretary = new Employee ( );`
  - This allocate space to hold a *value* for the Employee
  - Until you do this, the Employee is `null`

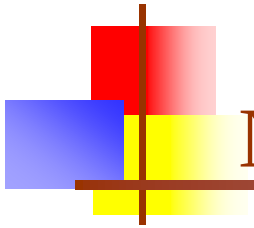


Notation: How to declare and create objects

```
Employee secretary;   // declares secretary
secretary = new Employee (); // allocates space
Employee secretary = new Employee(); // does both
```

- But the secretary is still "blank" (null)

```
secretary.name = "Adele";   // dot notation
secretary.birthday ();   // sends a message
```



Notation: How to reference a field or method

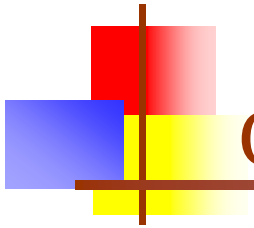
- Inside a class, no dots are necessary

```
class Person { … age = age + 1; …}
```

- Outside a class, you need to say which object you are talking to

```
if (john.age < 75) john.birthday ();
```

- If you don't have an object, you cannot use its fields or methods!



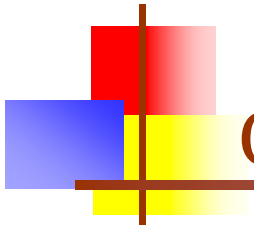
Concept: this object

- Inside a class, no dots are necessary, because
  - you are working on this object
- If you wish, you can make it explicit:

  class Person { … this.age = this.age + 1; …}
- this is like an extra parameter to the method

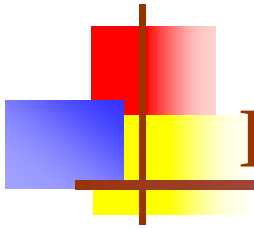
  CVL: in Python it's explicit – self
- You usually don't need to use this

  CVL: in Python you do



Concept: A variable can hold subclass objects

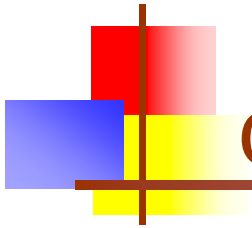
- Suppose B is a subclass of A
  - A objects can be assigned to A variables
  - B objects can be assigned to B variables
  - B objects can be assigned to A variables, but
  - A objects can *not* be assigned to B variables
    - Every B is also an A *but* not every A is a B
- You can cast: `bVariable = (B) aObject;`
  - In this case, Java does a runtime check



Example: Assignment of subclasses

```
class Dog { … }
class Poodle extends Dog { … }
Dog myDog;
Dog rover = new Dog ();
Poodle yourPoodle;
Poodle fifi = new Poodle ();

myDog = rover;                    // ok
yourPoodle = fifi;                // ok
myDog = fifi;                     //ok
yourPoodle = rover;               // illegal
yourPoodle = (Poodle) rover;      //runtime check
```

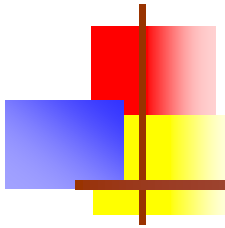


Concept: Methods can be overridden

```
class Bird extends Animal {
   void fly (String destination) {
      location = destination;
   }
}

class Penguin extends Bird {
   void fly (String whatever) { }
}
```

- So birds can fly. Except penguins.



Concept: Don't call functions, send messages

(CVL: sort of... This is called dynamic dispatch)

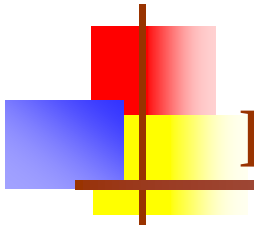
```
Bird someBird = pingu;
someBird.fly ("South America");
```

- Did pingu actually go anywhere?
  - You sent the message fly(…) to pingu
  - If pingu is a penguin, he ignored it
  - Otherwise he used the method defined in Bird
- You did *not* directly call any method
  - You cannot tell, without studying the program, which method actually gets used
  - The same statement may result in different methods being used at different times

From: http://courses.cs.washington.edu/courses/cse413/08au

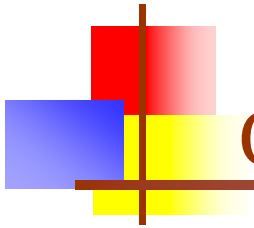
DYNAMIC DISPATCH

CSE 413 Autumn 2008



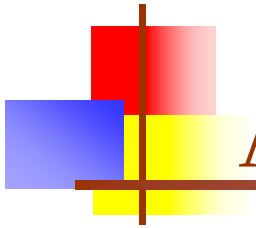
Dynamic Dispatch

- Recall: In an object-oriented language, a subclass can override (redefine) a method
- When a message is sent to an object, the actual method called depends on the type of the *object*, not the type of the variable that references it
- How?



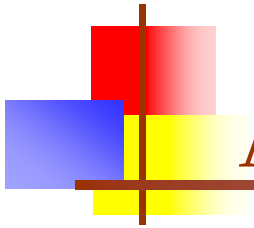
Conceptual Model

- An object consists of
  - State (instance variables, …)
  - Behavior (methods, messages)
- So we can implement an object as something that contains data and procedures
- But… Not good engineering – multiple copies of method code in each object



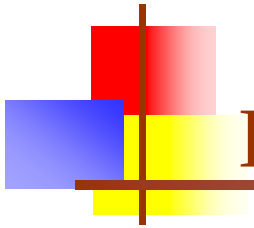
Attempt #2

- Instead of replicating the methods in each object, include a set of pointers to the applicable methods
- But… Lots of duplicate pointers per object



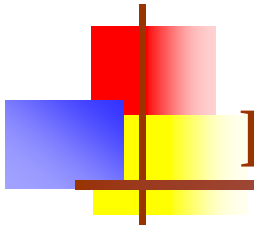
Attempt #3

- Instead of having method pointers in each object, have one set of method pointers per class
  - Each object contains a pointer to a “class object”
  - Method calls are indirect to the actual methods in the class object
- A little bit of time overhead per method call
- Need some tweaks for something as dynamic as Ruby



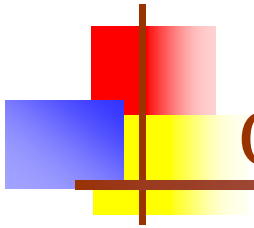
Dynamic Dispatch in Ruby

- Complicatons
  - Modules (mixins) as well as classes
  - Can add or change methods dynamically as the program runs
  - Can include per-object methods as well as per-class methods



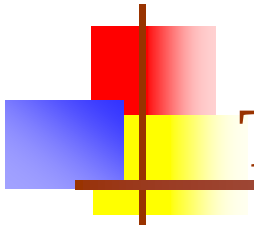
Ruby Data Structures

- Every object has a pointer to its class
- A class is represented by a “class object”
  - Every class object contains a hash table with method names and code
- Every class object has a pointer to its superclass
- Search for applicable methods starting in the object and moving up
  - If you hit the top without finding it, “message not understood”



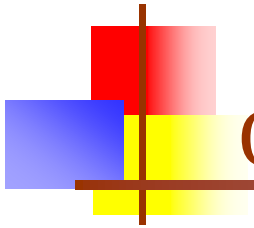
Complications

- Mixins
  - One object per mixin, searched after the class object and before the superclass
- Per-object methods
  - Define a “virtual class” of methods for that object that is searched first
- What is the class of a class object?
  - Interesting question… left as an exercise



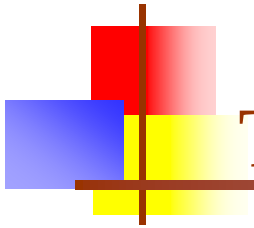
Types for O-O Languages

- Java, C++, and others are *strongly typed*
- Purpose of the type system: prevent certain kinds of runtime errors by compile-time checks (i.e., static analysis)



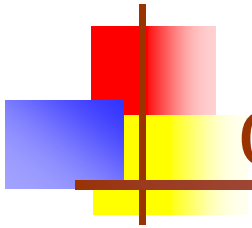
O-O Type Systems

- "Usual" guarantees
  - Program execution won't
    - Send a message that the receiver doesn't understand
    - Send a message with the wrong number of arguments
- "Usual" loophole
  - Type system doesn't try to guarantee that a reference is not null



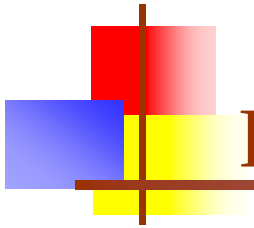
Typing and Dynamic Dispatch

- The type system allows us to know in advance what methods exist in each class, and the potential type(s) of each object
  - Declared (static) type
  - Supertypes
  - Possible dynamic type(s) because of downcasts
- Use this to engineer fast dynamic type lookup



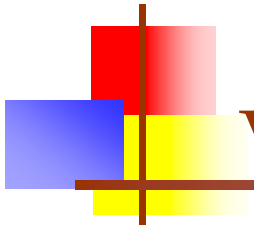
Object Layout

- Whenever we execute “new Thing(…)”
  - We know the class of Thing
  - We know what fields it contains (everything declared in Thing plus everything inherited)
- We can guarantee that the initial part of subclass objects matches the layout of ones in the superclass
  - So when we up- or down-cast, offsets of inherited fields don’t change



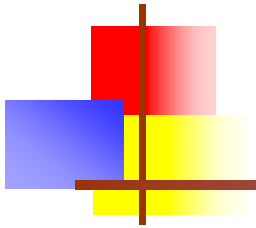
Per-Class Data Structures

- As in Ruby, an object contains a pointer to a per-class data structure
  - (But this need not be a first-class object in the language)
- Per-class data structure contains a table of pointers to appropriate methods
  - Often called “virtual function table” or vtable
  - Method calls are indirect through the object’s class’s vtable

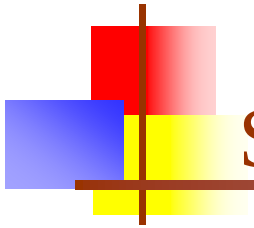


Vtables and Inheritance

- Key to making overriding work
  - Initial part of vtable for a subclass has the same layout as its superclass
    - So we can call a method indirectly through the vtable using a known offset fixed at compile-time *regardless of the actual dynamic type of the object*
  - Key point: offset of a method pointer is the same, but it can refer to a different method in the subclass, not the inherited one

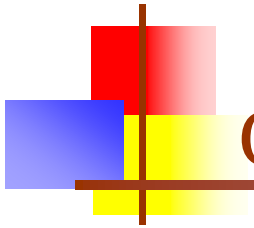


BACK TO THE ORIGINAL PRESENTATION



Sneaky trick: How to use overridden methods

```
class FamilyMember extends Person {
   void birthday () { // override birthday() in Person
      super.birthday ();  // call overridden method
      givePresent ();     // and add your new stuff
   }
}
```

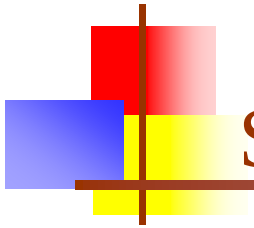


Concept: Constructors make objects

- Every class has a constructor to make its objects
- Use the keyword new to call a constructor

```
secretary = new Employee ( );
```

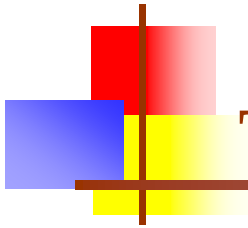
- You can write your own constructors; but if you don't,
- Java provides a default constructor with no arguments
  - It sets all the fields of the new object to zero
  - If this is good enough, you don't need to write your own
- The syntax for writing constructors is almost like that for writing methods



Syntax for constructors

- *Do not* use a return type and a name; use *only* the class name
- You can supply arguments

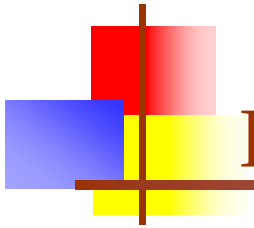
```
Employee (String theName, double theSalary) {
   name = theName;
   salary = theSalary;
}
```



Trick: Give field and parameter the same name

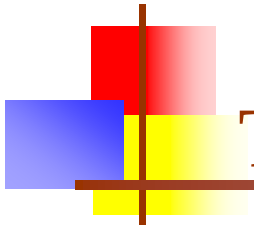
- A parameter overrides a field with the same name
- But you can use this.***name*** to refer to the field
- ```
  class Person {
      String name;
      int age;

      Person (String name, int age) {
          this.name = name;
          this.age = age;
      }
  }
  ```
- Using the same name is a common and useful convention
  ```



Internal workings: Constructor chaining

- If an Employee is a Person, and a Person is an Object, then when you say new Employee ()
  - The Employee constructor calls the Person constructor
  - The Person constructor calls the Object constructor
  - The Object constructor creates a new Object
  - The Person constructor adds its own stuff to the Object
  - The Employee constructor adds its own stuff to the Person



The case of the vanishing constructor

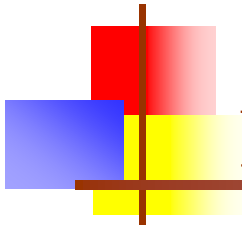
- If you don't write a constructor for a class, Java provides one (the default constructor)
  - The one Java provides has no arguments
- If you write *any* constructor for a class, Java does *not* provide a default constructor
- Adding a perfectly good constructor can break a constructor chain
- You may need to fix the chain

Example: Broken constructor chain

```
class Person {
   String name;
   Person (String name) {
        this.name = name;
    }
}
class Employee extends Person {
   double salary;
      Employee ( ) {
          super();
          salary = 12.50;
      }
 }
```

Java tries to execute an implicit super() at this point

- cannot resolve symbol – constructor Person()

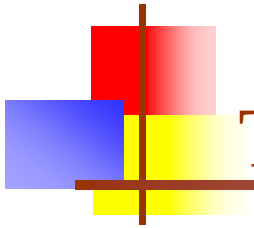


Fixing a broken constructor chain

- Special syntax: `super(…)` calls the superclass constructor
- When one constructor calls another, that call *must be first*

```
class Employee {
 double salary;
    Employee (String name) {
        super(name);   // must be first
        salary = 12.50;
    }
}
```

- Now you can only create Employees with names
- This is fair, because you can only create Persons with names

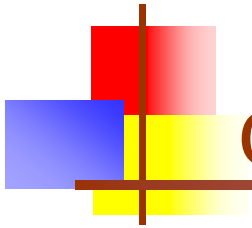


Trick: one constructor calling another

- this(…) calls another constructor for this same class

```
class Something {
   Something (int x, int y, int z) {
      // do a lot of work here
    }
   Something ( ) { this (0, 0, 0);  }
}
```

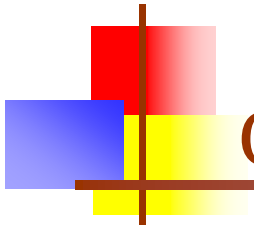
- It is poor style to have the same code more than once
- If you call this(…), that call *must be the first thing* in your constructor



Concept: You can control access

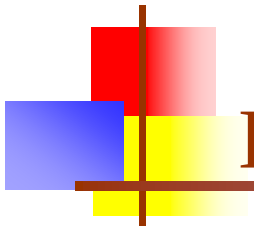
```
class Person {
    public String name;
    private String age;
    protected double salary;
    public void birthday { age++; }
}
```

- Each object is responsible for its own data
- Access control lets an object protect its data *and* its methods
- Access control is the subject of a different lecture



Concept: *Classes* can have fields and methods

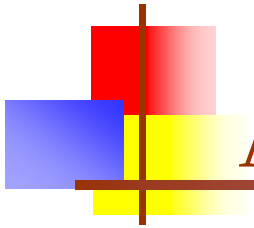
- Usually a class describes fields (variables) and methods for its objects (instances)
  - These are called instance variables and instance methods
- A class can have its own fields and methods
  - These are called class variables and class methods
- There is exactly *one* copy of a class variable, not one per object
- Use the special keyword `static` to say that a field or method belongs to the class instead of to objects



Example of a class variable

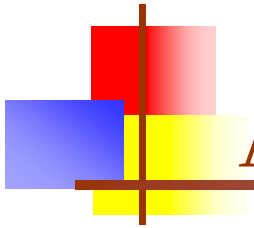
```
class Person {
    String name;
    int age;
    static int population;

    Person (String name) {
        this.name = name;
        this.age = 0;
        population++;
    }
}
```



Advice: Restrict access

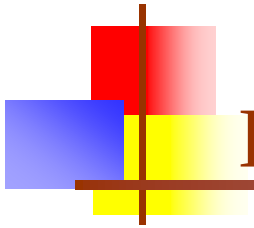
- Always, *always* strive for a narrow interface
- Follow the principle of information hiding:
  - the caller should know as little as possible about how the method does its job
  - the method should know little or nothing about where or why it is being called
- Make as much as possible private
- Your class is responsible for it's own data; don't allow other classes to screw it up!



Advice: Use setters and getters

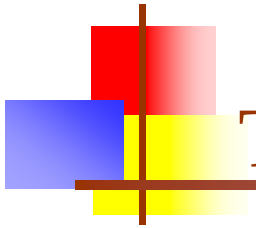
```
class Employee extends Person {
   private double salary;
   private boolean male;
   public void setSalary (double newSalary) {
      salary = newSalary;
   }
   public double getSalary () { return salary; }
   public boolean isMale() { return male; }
}
```

- This way the object maintains control
- Setters and getters have conventional names: set***DataName***, get***DataName***, is***DataName*** (booleans only)



Kinds of access

- Java provides four levels of access:
  - public: available everywhere
  - protected: available within the package (in the same subdirectory) and to all subclasses
  - [default]: available within the package
  - private: only available within the class itself
- The default is called package visibility
- In small programs this isn't important...right?



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