# Object-Oriented Programming:

## The Basic Building Blocks

Zeegee Software Inc.

# TERMS AND CONDITIONS

# INTRODUCTION

- What is/isn't object-orientedness?
- The "software crisis"
- Software reuse
- The evolution of good engineering practices
- The perils of non-OO development

# What does "object-oriented" mean, anyway?

- Programs consist of entities, called ***objects***, which correspond to concepts the program will manipulate:
  - A business application might have Employee and Department objects.
- Objects are created by specifying their structure and their properties in a ***class***.
  - The Employee class is a (single) blueprint used to create (many and varying) Employee objects.
- Objects communicate by sending each other ***messages***:
  - We might ask an Employee object "what's your name?".

# What *is* object-orientedness?

- A **programming style** where concepts in your problem domain are mapped directly into your code: "object-oriented" means "concept-oriented."
- A **philosophy** of design and implementation (i.e., a way of thinking about your code) which can be employed even in non-OO programming domains.
- A **technology** to help you follow this philosophy: OO languages, OO databases, OO expert systems, etc.
- A **buzzword** used by people who want to sell you something.

# What is object-orientedness *not*?

- It is ***not*** a solution to all your design and implementation problems.
- It will ***not*** allow non-programmers to "program like the pros."
- It does ***not*** allow you to side-step the design process and begin coding applications from day zero.
- It is ***not*** inherently better than non-OO for all tasks.
- It will ***not*** grow hair, lower your cholesterol, taste as fresh as homemade, soften hands while you do the dishes, and paint any car for $99.95… *beware of sales pitches, no matter how flashy.*

# The software crisis: why we must change our ways

- Human society depending more and more on software.
- The ***software crisis***: much existing software is...
  - bug-ridden, *because*...
  - too complex to understand, *and so*...
  - difficult to maintain, *and so*...
  - difficult to extend, *and so*...
- We reinvent the wheel over and over, leading to...
  - unnecessarily high development costs
  - new and more exciting bugs...

# The goal: software reuse

- Programs tend to be "stick built" from the ground up:
  - Like making custom nails, screws, bricks, etc. for a house!
- Take our cue from the industrial revolution: *assembly lines* and *interchangeable parts*:
  - **Goal:** develop manageable, understandable, reusable software components that can be employed in a wide variety of applications, so that "new" code is specific to the problem at hand.
- Reuse is *not* the same as "cut and paste"; however...
- *Temptation* to "cut and paste" indicates useful code!

# Benefits of software reuse

- Reduces coding/testing, thereby reducing *delivery time* and *cost*.
- *Many reusers* means *many testers*: well-tested code!
- Bugs found in reusable module can be reported to source: fix is made, new module is distributed, and now *everyone* benefits.
- Application programmers don't need to be experts in a wide variety of esoteric disciplines: *easier to hire* developers, and *easier to keep them sane*.
- High visibility of code *can* improve attitude of developer, and inspire more care and forethought, rather than just "task at hand" thinking.

# Come on... how long does software last, anyway?

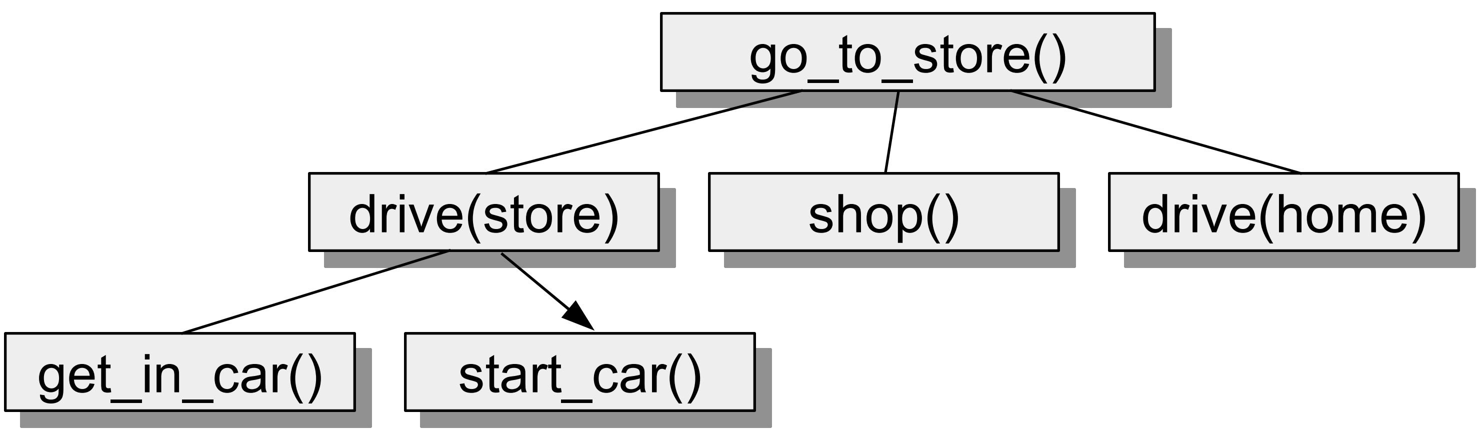
- Long enough for the Y2K bug to have been of some concern!
  - Much software written before 1990 did not have Y2K in mind.
  - Code from the 1980s is *still* in use!
  - People often "cut and paste" old code into new systems: the ghosts of programs long dead.
  - Developers are unwilling to tweak/upgrade components if they "seem to work fine as-is".
- Huge sums of money were spent to head off Y2K disaster. We'll never know if it was necessary, but we *do* know the price tag!

# Modular programming

- Break large problems down into smaller, more manageable ones by breaking large programs into smaller pieces.
- Each piece can be coded and tested individually.
- Core of modularization is the **subroutine** (invented 1950s).
- But we still need to decide...
  - What tasks are made into subroutines?
  - What are the arguments? Return values? Side effects?
- A discipline was needed...

# Structured programming

- Invented 1960s, as a means of good modularization.
- Relies on ***functional decomposition***:
  - Top-down approach.
  - Break tasks (functionality) down from top level on down, to smaller and smaller components, until you get to actual subroutines.

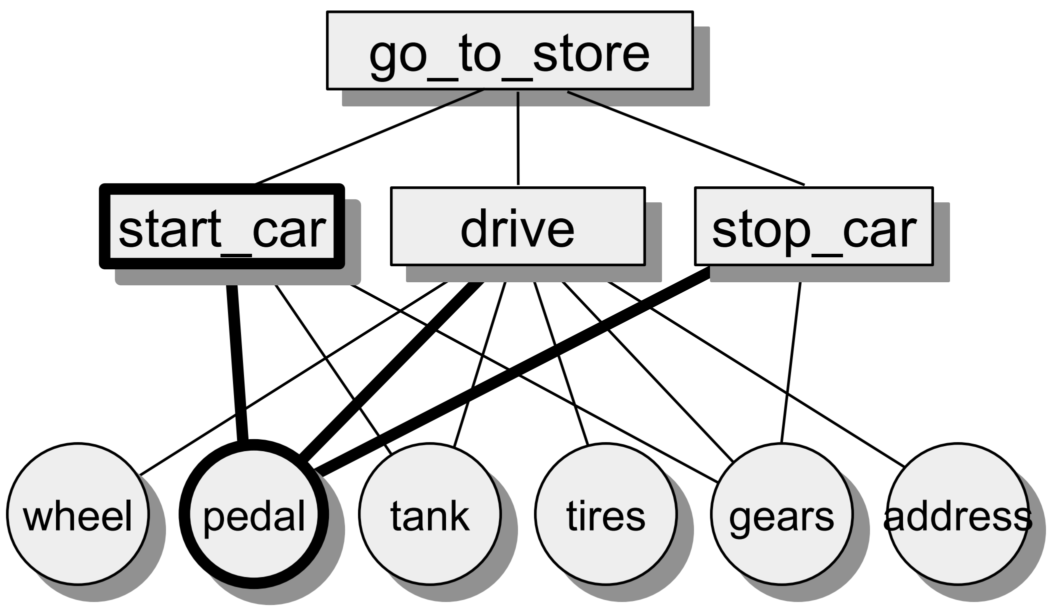


# Limitations of structured programming

- Can't always anticipate functions of evolving systems!
- The more successful a system is, the greater the chance it will be requested to handle a wider range of tasks than originally envisioned:
  - System gets "tweaked" to handle initial modifications.
  - Tweaks become "hacks" as desired functionality departs more and more from original decomposition.
  - System becomes more complex and unstable; further modifications require worse hacks or full rewrite.
  - Process stops when costs outweighs benefits.

# Global/shared data: the break in the modularity

- At some point, many programs use ***global data*** which is shared between different subroutines.
- When any subroutine affects the global data, they can affect the other **subroutines** as well, in unexpected ways!



# Modularization of data

- Often in structured programming, each subroutine is given its "own little world" of data:
  - Arguments
  - Local variables
  - Return value

```
float hypotenuse (a, b)
   float a;
   float b;
{
   float c;
   c = sqrt((a * a) + (b * b));
   return c;
}
```

- One way structured programming helps is in modularizing *data* as well as *functionality*.
- **But sometimes, we still have to share information!**

# The status quo: non-OO programming

- Programs consist of two separate entities: **data structures** and **functions**.
- Data structures: integer, string, array, list, stack, binary tree, hashtable, person, etc.
- Data structures are **accessed and modified directly**, or else by calling functions to perform the desired operations.

```
IntStack s;

s.size = 0;
s.top = NULL;

istack_push(101, &s);
x = istack_pop(&s);
```

Modify **s** by direct assignment

Modify/access **s** by via special functions

# Problems with non-OO programming

- Functions for manipulating the same data structure can differ in naming convention, argument order, etc.: difficult to build/understand code:

```
s.size = 0;
count = s_numelems(&s);
istack_push(101, &s);
x = pop_int_stack(&s);
print_thing(INTSTACK, &s);
```

- Ability/requirement to examine/modify parts of data structure results in programs which will fail if data structure changes.
- Can never be sure we have all the functions we need to build complex applications with data structure.

# Problems with non-OO programming

- To implement something similar (but not identical) to an existing data structure, must often duplicate large amounts of code.
- Containers (arrays, lists, search trees, etc.) which can store different data types at the same time require lots of additional bookkeeping in the code:

```
for (i = 0; i < size; i++) {

        thing = slot[i];

        if (thing->type == INT_ {
                print_int(thing);
        }
        else if (thing->type == STRING) {
                print_string(thing);
        }
        else if (thing->type == CIRCLE) ...
                ...
}
```

**the switch statement of death**

# How does OO help?

- ***Message passing*** paradigm provides clear, consistent syntax for accessing/manipulating objects.
- ***Encapsulation*** provides way of making data and "helper functions" inaccessible to prying eyes and sticky fingers.
- ***Inheritance*** allows new data structures to be defined in terms of existing ones, re-using existing (and tested) code.
- ***Dynamic binding*** means that data structures keep track of their types, so users of the data structures don't have to.
- All objects come bundled with the complete set of functions that are needed to work with them.

# THE OO UNIVERSE

- Objects
- Classes
- Instance variables
- Instance methods and messages
- Pure OO environments
- Class variables/methods
- Constructors/destructors

# Objects

- An ***object*** is a bundle of information that **models some high-level concept** in the problem domain.
- Generally a 1-to-1 correspondence between "real things" in the problem domain and objects in a running OO program.
  - This is one reason that OO programs can be very intuitive to work with: they're a kind of **"virtual reality"**.
- The structure and behavior of an object is defined in the object's *class description*...

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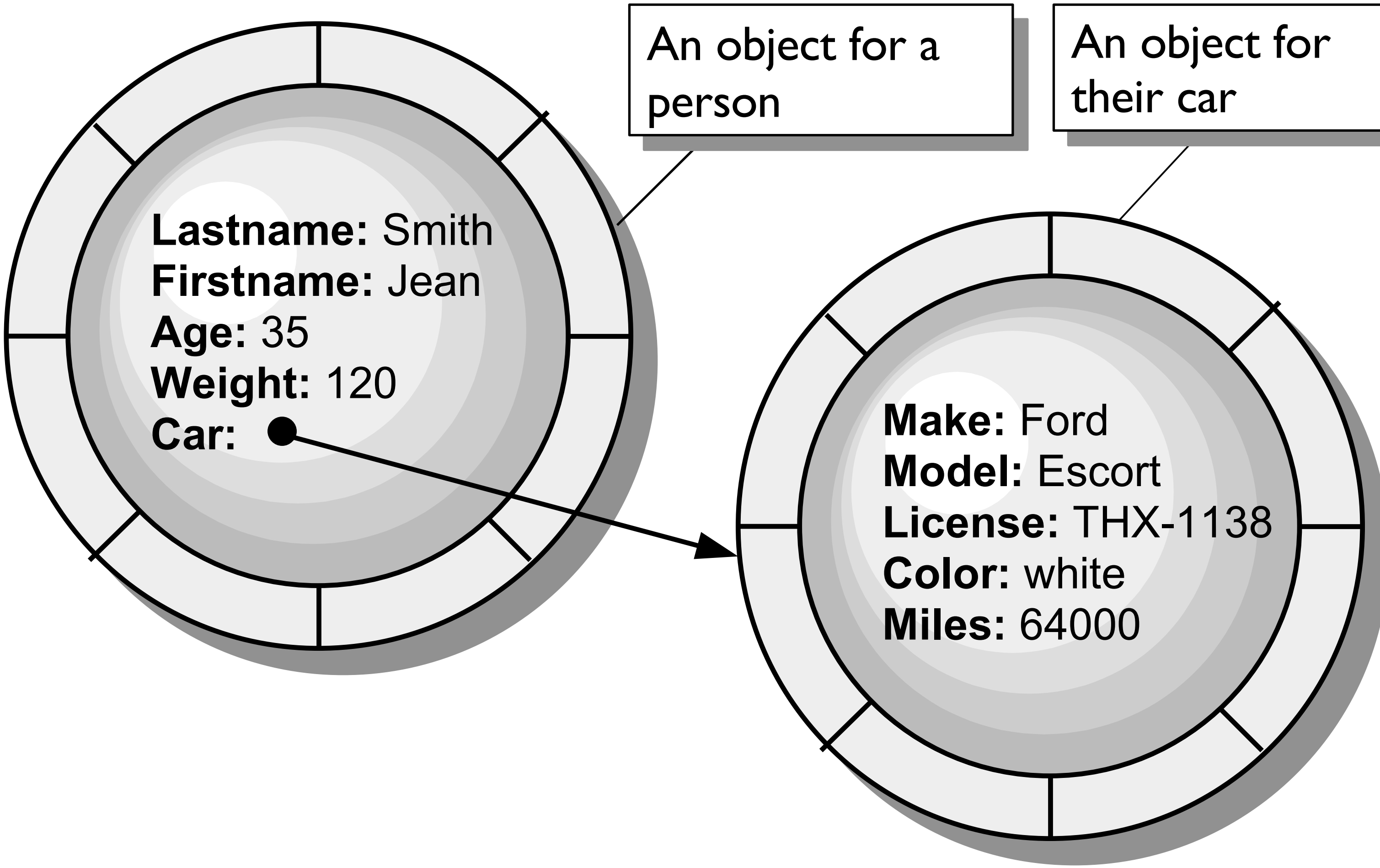
*You can think of objects as just another kind of data type, like integers and strings. For example, a boolean variable holds a very simple object which might model the state of an on/off switch...*

# Objects


An object for a person
An object for their car
Lastname: Smith
Firstname: Jean
Age: 35
Weight: 120
Car:
Make: Ford
Model: Escort
License: THX-1138
Color: white
Miles: 64000

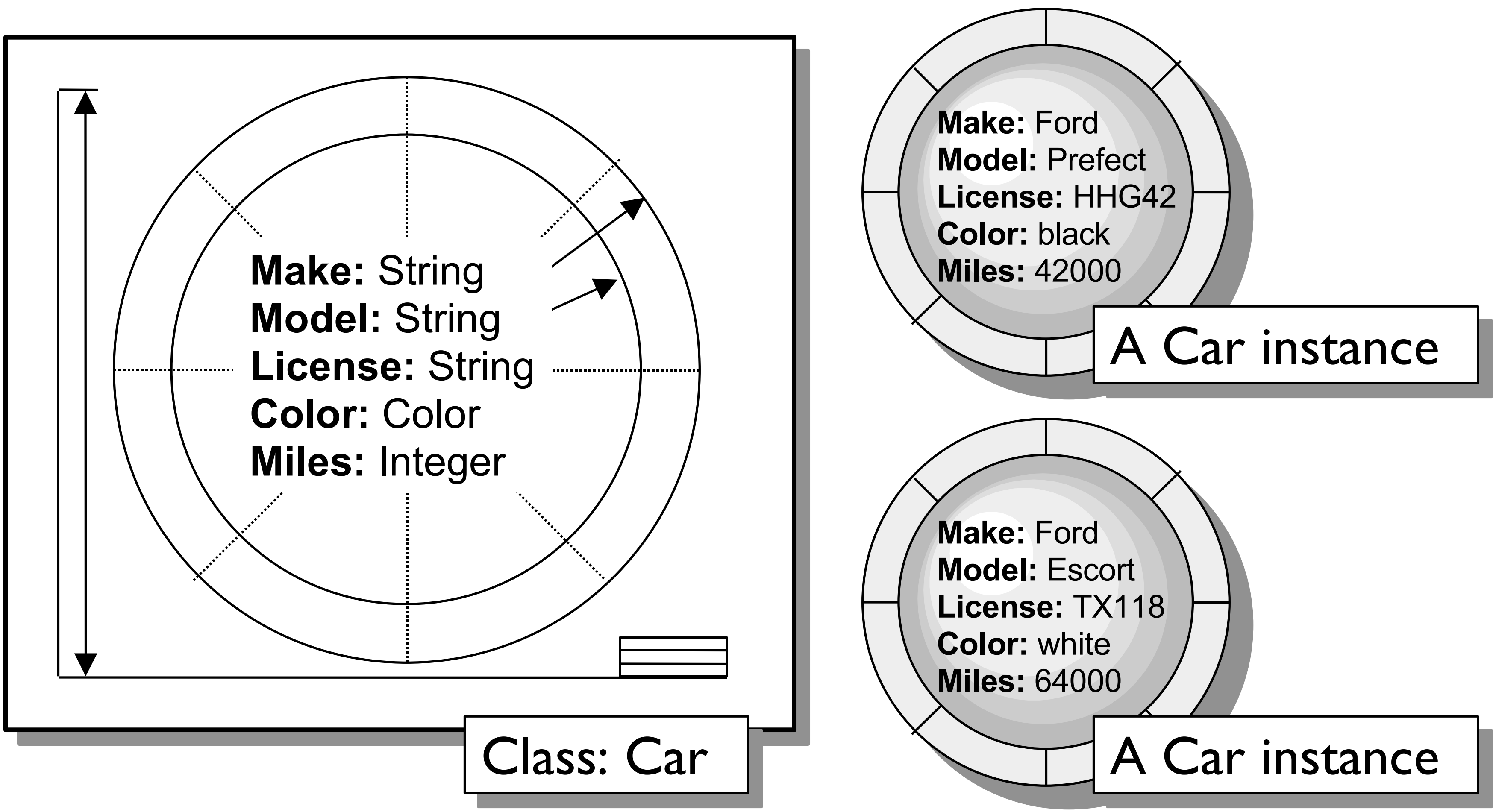
# Classes and instances

- A ***class*** is a blueprint for creating many similar objects.
- The created object is an ***instance*** of that class.
- Objects created from the same class will have the same basic **structure** and **functionality**.
  - All cars created from the same Ford Escort blueprints will look and work basically the same.
- **Many instances** can be created from a single class.
  - Just as many Ford Escorts can be created from the same set of Ford Escort blueprints.

---

*Think of objects as structs (C) or records (Pascal): there's a single type definition (the class), but many different structs/records (the instances) can be created from it.*

# Classes and instances



# Instance variables

- An ***instance variable*** (or ***attribute***) of an object is a piece of information attached to an instance (object).
  - The name of a Person object, the model and year of a Car object, etc.
- The instance variables that an object has are **defined in the object's class**: an object can usually have many instance variables, of many different types.
- **Each object is given its own private space to hold its instance variables**. Assigning a new value to an instance variable of one object does not affect the instance variables of any other object.

---

*If you think of objects as structs (C) or records (Pascal), then the instance variables are the structure elements.*

# Instance methods

- When we define objects, we usually have an idea of what we want to do with them...
  - *I'm dealing with Person objects in an employee database... I want to be able to **ask** each Person object their **name**, **weight**, and **age**.*
  - *I'm dealing with Car objects in a driving simulation... I want to be able to **start** a Car, **change its speed**, **turn its steering wheel**, etc.*
- An action that involves a single object as the "star player" is usually implemented as a special kind of function/subroutine attached to that object's class, called an ***instance method*** (or, more commonly, just a ***method***).

# Methods and messages

- A ***message*** is the *request* you send to an object in order to get it to do something: perform an action, return a value, etc.

```
someone.setName("Picard");
```

- A ***method*** is the *piece of code* which is called to perform the activity requested by the message:

```
Person::setName(String newname){
   self.name = newname;
}
```

- ***Message passing*** and ***method invocation*** usually mean the same thing: the act of sending a message to an object, and having that object do something.

# What messages look like

A message generally has three parts:

- The ***receiver:*** the object receiving the message.
- The ***method name:*** what we want the object to execute.
- The ***parameters:*** any arguments that the message takes.

receiver method parameters

```
someone.setName("Jean-Luc", "Picard");
```

# What methods look like

- Like any other function, **methods can take arguments.**
- Methods know **which object received the message** (they have to... after all, it's the star player!).

They might access the object through a special variable (C++'s this, Smalltalk's self):

```
Person::setName(String new){
   this->name = new;
}
```

Or through a special argument given to the method (Perl, Python):

```
sub setName {
   my ($self, $new) = @_;
   $self->{Name} = $new;
}
```

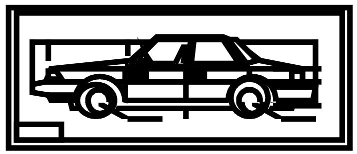
Or just access its instance variables implicitly (C++, Smalltalk):

```
Person::setName(String new){
   name = new;
}
```

# An OO bestiary

| | Real world | Software |
|---|---|---|

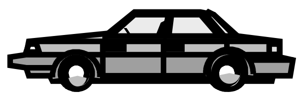
## Classes



blueprint

```
class Car {
   String itsModel;
   int    itsYear;
   Tire   itsTires[4];
   ...
}
```

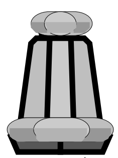
## Instances



car

| myCar | myMom'sCar | myFriend'sCar |
|---|---|---|

## Instance variables



seat

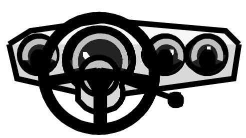
steering wheel

tires

myCar

| | | | | |
|---|---|---|---|---|
| itsModel | Escort | | | |
| itsYear | 1990 | | | |
| itsTires | tire631 | tire245 | tire898 | tire707 |

## Methods



dashboard

```
myCar.start();
myCar.shiftGear(FIRST);
myCar.accelerate();
myCar.turn(LEFT);
```

# A sample class

```
class Person {

     String  name;
     int     age;
     float   weight;

     /* Change my weight: */
     setWeight(int newWeight) {
            weight = newWeight;
     }

     /* Return my weight, if I won't mind: */
     getWeight() {
            if (weight < 150)
                   return weight;
            else
                   return -1;
     }
}
```

instance variables

method

method

# Using classes and objects

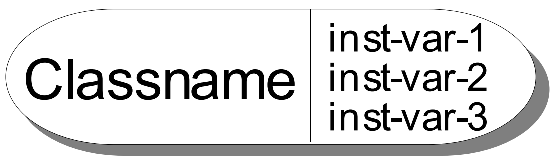
Create instance of class Person

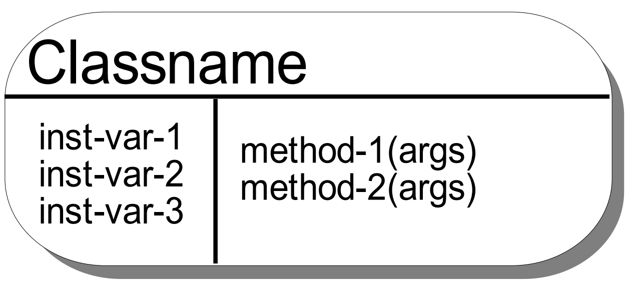
```
Person kirk("Kirk, James T.");

kirk.setWeight(190);
kirk.setAge(37);

wgt = kirk.getWeight();
```

Send messages to object "kirk"

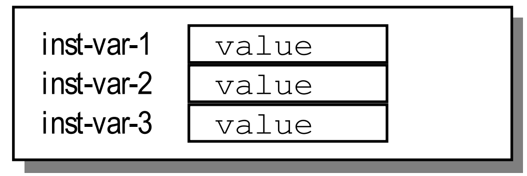
# Representing classes and objects

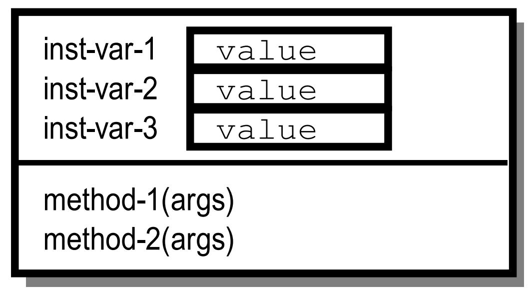
## Class


## Object



# "Pure" OO environments

- In very "pure" OO environments, ***everything is an object***!
  - Every class might be an instance of a special MetaClass class, which in turn might be an instance of itself!
  - Methods/functions might be instances of a special Code class.
- This can be taken to surprising extremes... for example, in OPAL (Smalltalk), *there is no if-then statement*: instead, you send an *ifTrue:ifFalse* message to a Boolean object:

```
method: getWeight
       (weight < 150.0)
              ifTrue: [^weight]   % okay
              ifFalse: [^-1]
       % no way!
%
```

# Class methods

*If a class is just another kind of object, then it should have its own methods and respond to messages, right?*

- Right! Because of this, we usually divide methods into:
  - ***Class methods,*** which are invoked when you send a message to a class.
  - ***Instance methods,*** which are invoked when you send a message to an instance of a "normal" class.
    We usually just call these *methods*.
- The most common class method is the ***constructor,*** which returns a new instance. It's often called "new":

```
/* Class method: */
p = Person.new("Kirk");
```

```
/* Instance method: */
p.setName("Kirk");
```

# Class methods, cont'd

**Class methods generally *do not* operate on instances!** They are intended for performing utility functions that are *strongly* associated with a class, but that don't involve any particular instance of that class!

- Other candidates for class methods:
  - Storing/retrieving objects of this class by some appropriate lookup key (e.g., the name).
  - Asking for information related to the class as a whole:

```
/* Get the next available license plate. */
classmethod Car::nextLicensePlate {
        CurrentLicense += 1;
        return "ABC" + CurrentLicense;
}
```

# Class variables

*If a class is just another kind of object, then it should have its own instance variables too, right?*

- Right! And these special instance variables are commonly called ***class variables***.
- In many OO environments, the only places you can access a class variable are...
  - From inside a **class method** of that class
  - From inside an **instance method** of that class
- Class variables are kind of like global variables which are associated with a particular class.

# Constructors

- As mentioned before, ***constructors*** are special functions (usually class or instance methods) used to **initialize or return a new object**.
- Most common name for a constructor is **`new()`**.
- Depending on the OO environment, a class **might have many constructors**, each of which builds an object a different way.
- Different constructors might have **different names** (Perl5, Smalltalk), or they might all have the **same name** but be distinguished by having different numbers/types of their **arguments** (C++).

# Sample constructors

- In C++, constructors are special unnamed **instance methods,** invoked when you declare object variables:

```
// Create a Person from nothing:
Person anonymous;

// Create a Person from name, age, and weight:
Person nsolo("Napoleon Solo", 35, 190.0);

// Create a Person from another Person:
Person clone(nsolo);
```

- In Perl5, constructors are **class methods**, and can be named whatever you like:

```
# Create a Person from name, age, and weight:
$nsolo = Person->new(     Name=>"Napoleon Solo",
          Age=>35,
          Weight=>190.0);
```

# Destructors

- Objects often end their lives be being *explicitly deleted* (C++), going *out of scope* (C++), or being *garbage-collected* (Java, Perl, Smalltalk).
- We sometimes want to get control of the object just before it vanishes, to clean up after it properly:
  - We may have opened files, which we want to close.
  - We may have allocated memory, which we want to free.
- The special instance method invoked just as an object is about to disappear is called the ***destructor***.
- Classes generally have **one destructor**, which takes **no arguments**.

# OO FEATURES/BENEFITS

- Encapsulation
- Polymorphism
- Subclasses and inheritance
- Class hierarchies and inheritance schemes
- Abstract/concrete classes
- Static/dynamic binding

# Encapsulation

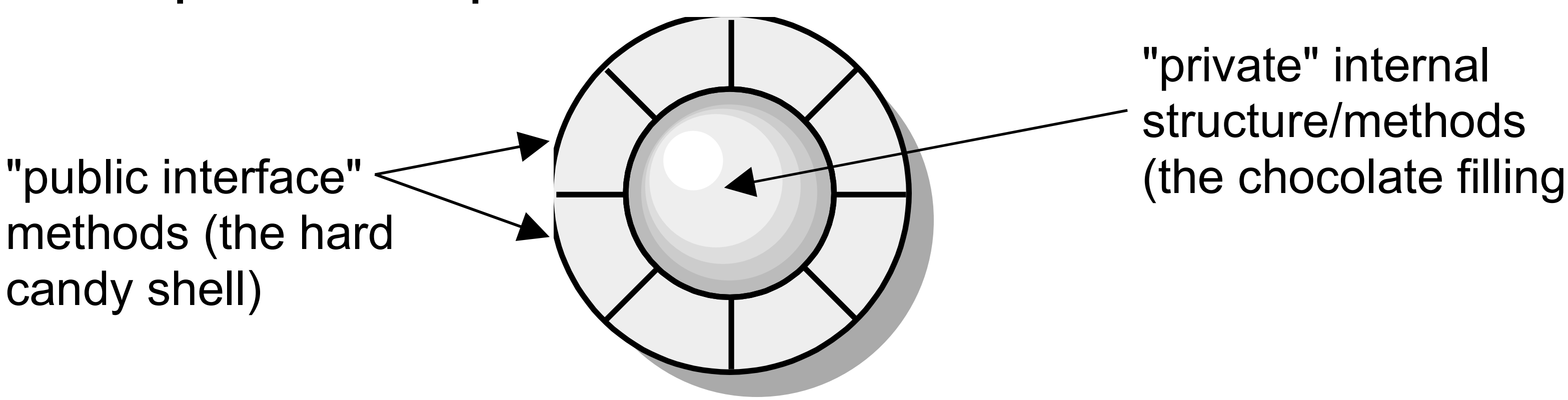
- There is a piece of wisdom which has made its way down through centuries of software development...

  *Teams work best when members of those teams know as little about each others' work as possible.*

- When one software module depends on the low-level implementation details of another module, unexplained bugs tend to appear as the system evolves.
- The "back room" metaphor.
- We need a way of not only *suggesting* that programmers stay out of the "back room", but *enforcing* it.

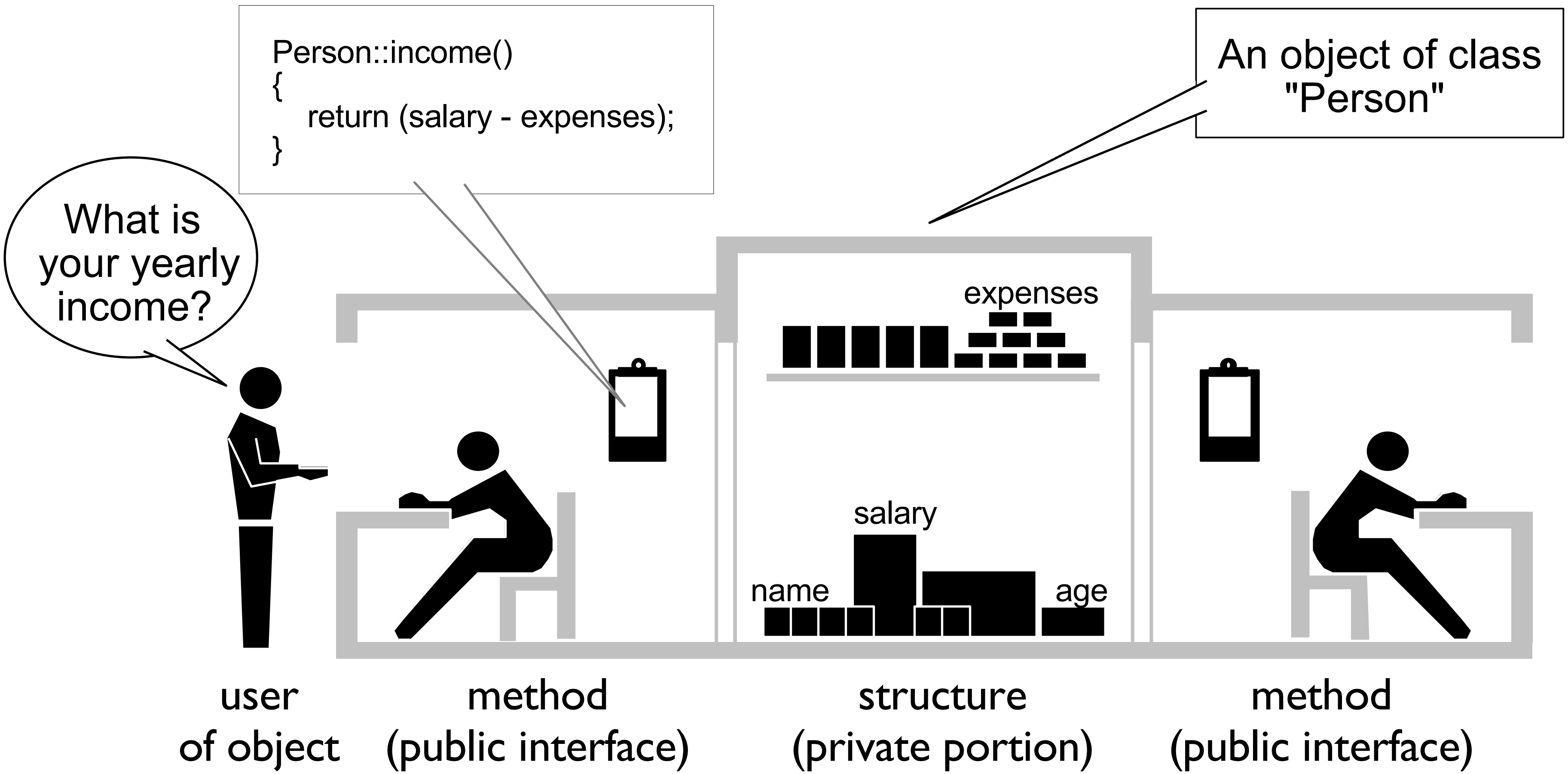
# Encapsulation

- ***Encapsulation*** means that some or all of an object's internal structure is "hidden" from the outside world.
- Hidden information may only be accessed through the object's methods, called the object's ***public interface***.
- Access to object is safe, controlled.
- Methods, like instance variables, may also be hidden to create private "helper functions".

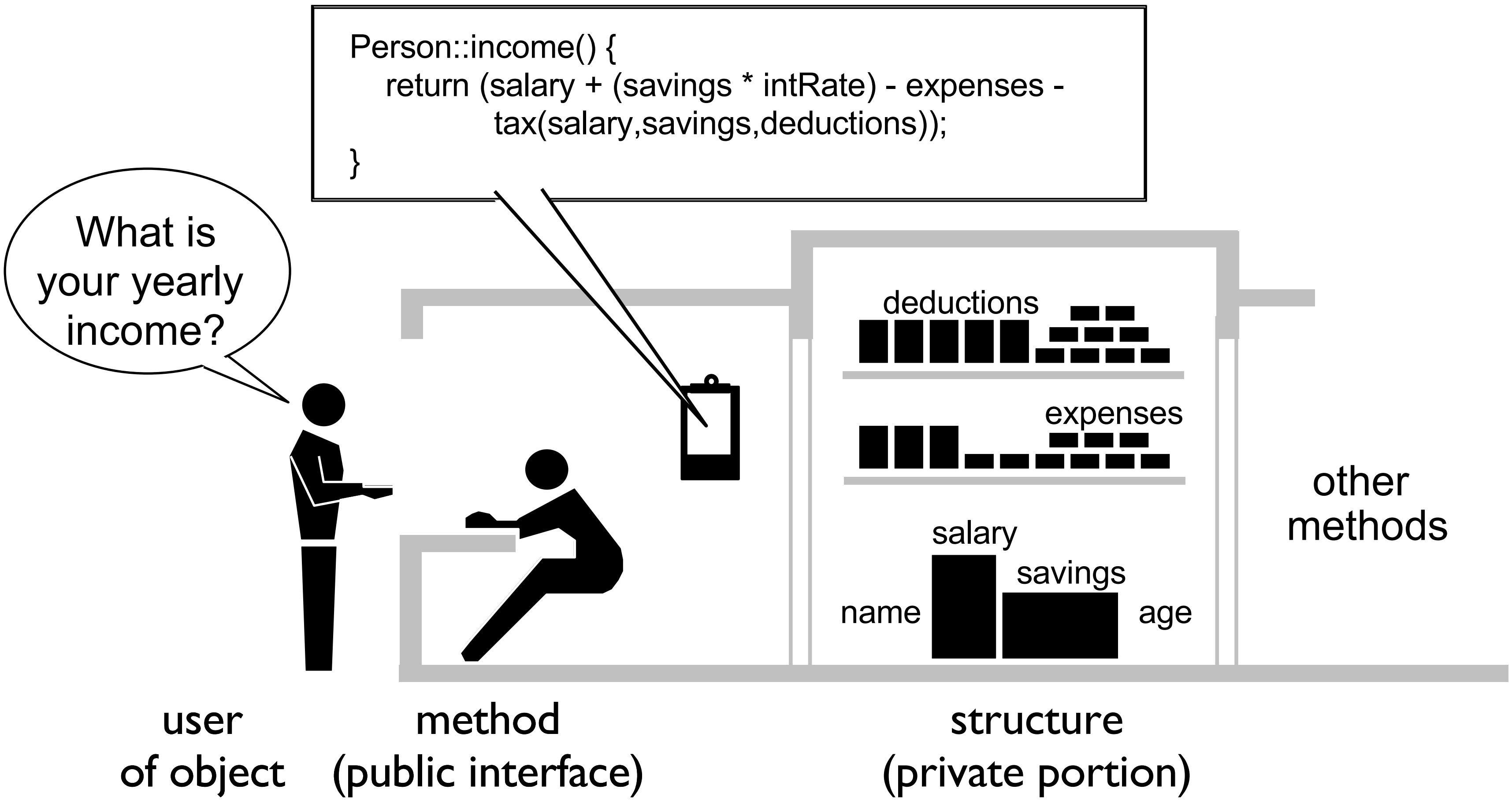


# Objects as "goods" and "services"



# Encapsulation as maintainability



# Encapsulation for class builders and class users

| | Class builder | Class user |
|---|---|---|
| **Goal** | Create a reusable, maintainable class with an understandable interface. | Quickly get and use a class. |
| **Approach** | Hide structure and implementation details from user. | Examine and use operations in class interface. |
| **Benefits** | May change structure and algorithms without affecting user. | Understandable interface; can be used without fear of "breaking" object. |
| **Costs** | Reusable classes must be carefully planned. | Access to data through operations may be slower than direct access. |

# Polymorphism

- Literally, "one entity, many forms."
- Means the **same name can be assigned to different functions/methods**: the actual function triggered by the name is determined by the types of the arguments.
- Sometimes called *overloading*.
- Allows designers to use the most "natural" and understandable names for functions:

```
/* Matrix M times vector v: */
y = M * x;

/* Matrix M times scalar: */
N = M * 2;

/* Vector x times scalar: */
y = 4 * x;
```

The multiplication operator is overloaded

# With/without polymorphism

- **Without polymorphism**, we need a unique name for every function:

```
/* Stuff with matrices, vectors, and scalars: */
mat_vec_mult(
   M,
   vec_times_scal(
      vec_cross(vec_minus(A, B), vec_plus(A, B)),
      -1)
   );
```

- **With polymorphism**, we can use natural names and operators, shrinking code and increasing readability:

```
/* Stuff with matrices, vectors, and scalars: */
M  *  (-1 * (A-B).cross(A+B))
```

# More fun with polymorphism

Overloading '+' to perform string concatenation:

```
fullname = lastname + ", " + firstname;
```

Overloading 'min' to compare different types:

```
firstInDictionary = min("astro", "zodiac");
lowerNumber =       min(42, 99);
closerToOrigin =    min(complex1, complex2);
```

Overloading 'print' to print different entities to different kinds of output:

```
aPerson.print(myFile);
aPerson.print(myScreen);
aPerson.print(myPrinter);
aPlace.print(myPrinter);
```

# Polymorphism for class builders and class users

| | Class builder | Class user |
|---|---|---|
| **Goal** | Create maintainable, reusable, class **library** with understandable interfaces. | Quickly get and use a class. |
| **Approach** | Use polymorphism to create **similarity** between class interfaces & speed learning. | Examine and use operations in class interface. |
| **Benefits** | Interfaces to new classes are already partially designed. | Learn one class, and learn a bunch! |
| **Costs** | Must pick method names and arguments carefully. Must *not* reuse names if purposes differ! | Misnamed methods which are similar *but not identical* can be confusing. |

# Subclasses

- It is often desirable to create a new class which is a special case of an existing class, possibly with some small changes in structure or methods:

```
class Person {

   String  name;
   int     age;
   float   weight;

   void setWeight(wgt) {…}
   int  getWeight() {…}
}
```

```
class Doctor {

   String  name;
   int     age;
   float   weight;
   School  medSchool;
   String  licenseNo;

   void setWeight(wgt) {…}
   int  getWeight() {…}
   void examine(patient) {…}
}
```

- To re-use the existing code, make the new class a ***subclass*** of the existing one...

# Subclasses and inheritance

- If class C is a subclass of class P, then C is a ***child class*** of P, and P is a ***parent class*** or ***superclass*** of C.
- A child class automatically ***inherits*** all the structure and functionality of its parent class. When defining a subclass, you will usually choose to:
  - **Add** new instance variables and methods.
  - **Override** some methods of the parent class, providing new methods.
  - **Exclude** some of the instance variables and methods of the parent class.

# Adding structure/behavior in subclasses

When you specify instance variables/methods in a child class that are not present in the parent class, instances of the child class get the new structure and functionality **in addition** to what they would get from the parent alone:

## Classes

```
class Person {
   int age;

   int getAge() {…}
}
```

```
class Doctor : Person {
   String licenseNo;
   void examine(patient) {…}
}
```

## Instances

a Person:

age 52

getAge()

a Doctor:

age 52
licenseNo AMA-1179150-6

getAge()
examine(patient)

# Overriding behavior in subclasses

When you specify a method in a child class that **already exists** in the parent class, the child's method ***overrides*** the parent's method: instances of the child will execute the child's method.

## Classes

```
class Person {
   String name;
   String getName() {
      return name;
   }
}
```

```
class Doctor : Person {
   String getName() {
      return "Dr. " + name;
   }
}
```

## Instances

name `Leonard McCoy`
getName()

Uses getName() of Person

name `Leonard McCoy`
getName()

Uses getName() of Doctor

# Overriding with default behavior

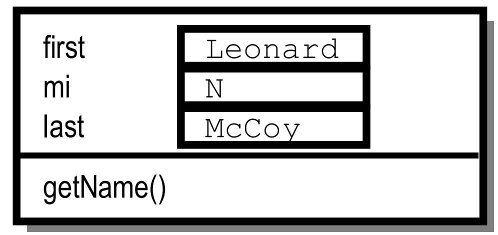
Sometimes it is desirable to override a parent's method, and yet also to **invoke the parent's method** to do some of the work:

## Classes

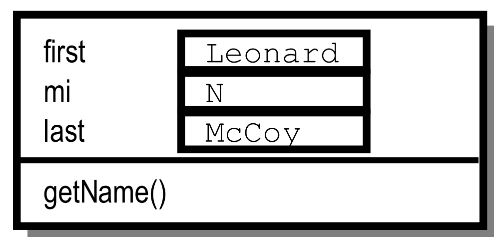
```
class Person {
   String first, mi, last;

   String getName() {
      return first + mi + last;
   }
}
```

```
class Doctor : Person {

   String getName() {
      return
         "Dr." +
         Person::getName();
   }
}
```

## Instances




getName() returns "Leonard N. McCoy"




getName() returns "Dr. Leonard N. McCoy"

# Exclusion in subclasses

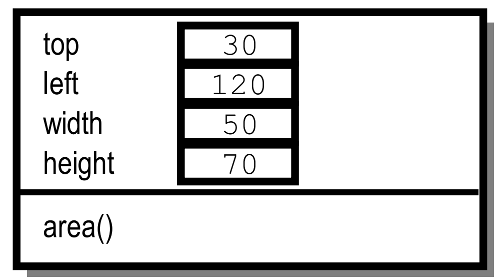
If a child class is a very special case of its parent, it may not need all the instance variables in its parent. Some languages allow variables/methods to be ***excluded*** in a subclass.

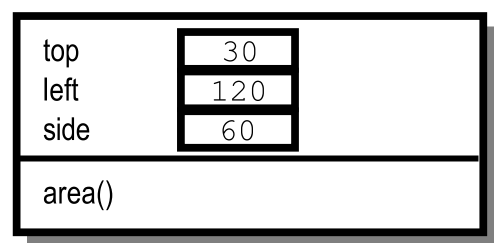
## Classes

```
class Rectangle {

   int top;
   int left;
   int width;
   int height;
}
```

```
class Square : Rectangle {

   exclude width;
   exclude height;
   int side;
}
```

## Instances



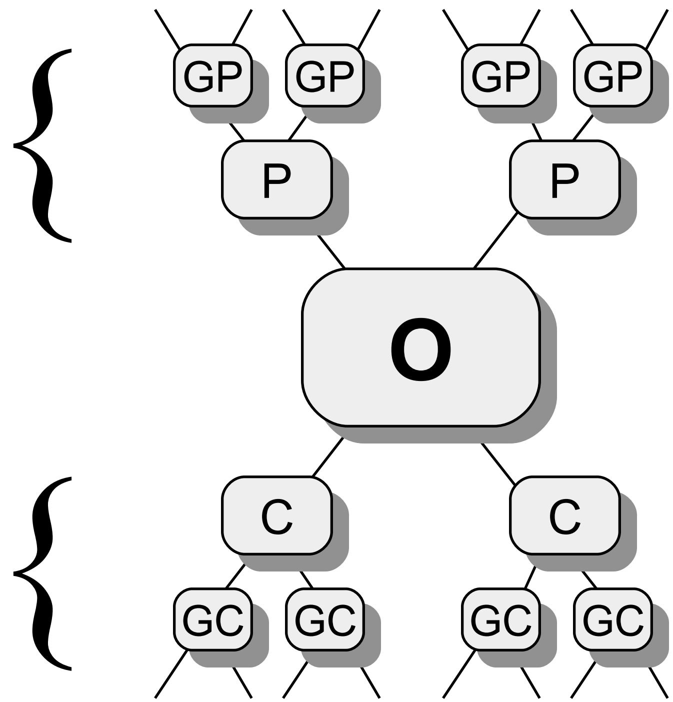



# Class hierarchies

Usually, a class can have many child classes, each of which can have their own child classes. A "family tree" of all the classes in a program is called a ***class hierarchy***...

The ***base classes*** of a given class O are those classes from which O ultimately inherits (parents, grandparents, etc.).

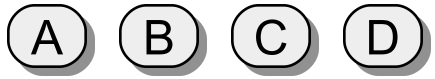
The ***derived classes*** of a given class O are those classes which ultimately inherit from O (children, grandchildren, etc.).



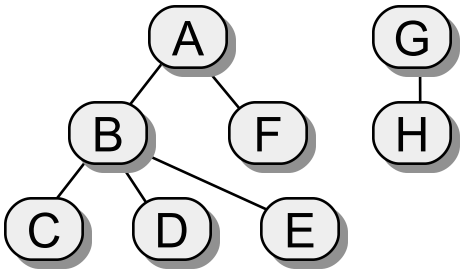
# Inheritance schemes

One important way we characterize an OO language is by the kind of inheritance we are allowed to use...

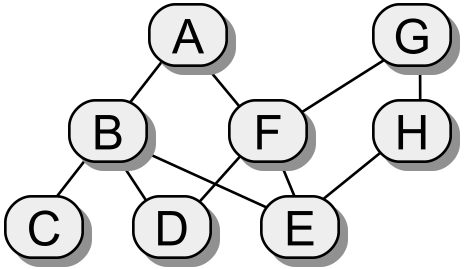
- If classes can't be derived from parents, we have a ***no-inheritance*** language. Its class hierarchies will be flat.



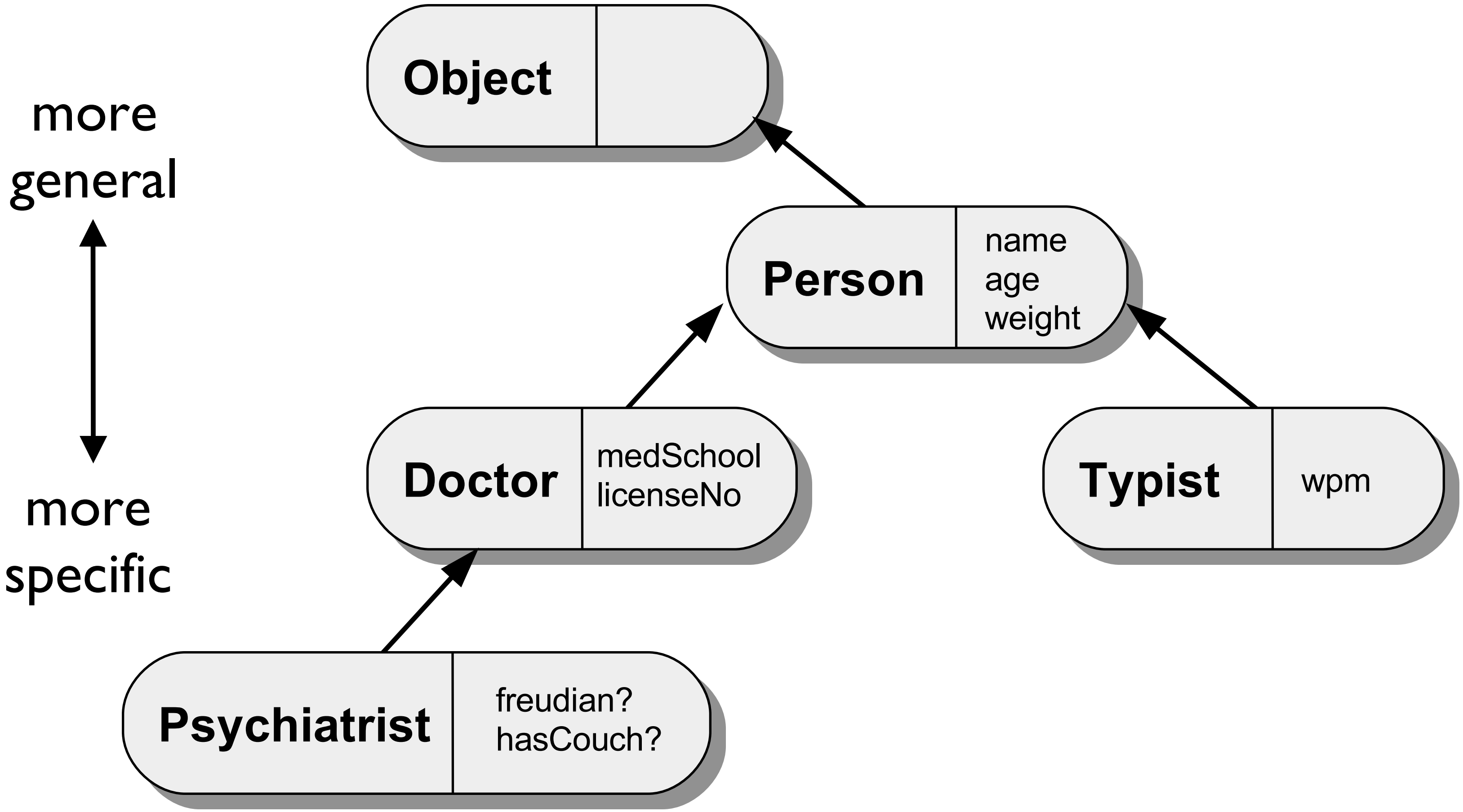

- If each class can have **at most one parent**, we have a ***single-inheritance*** language. Its class hierarchies will resemble trees.



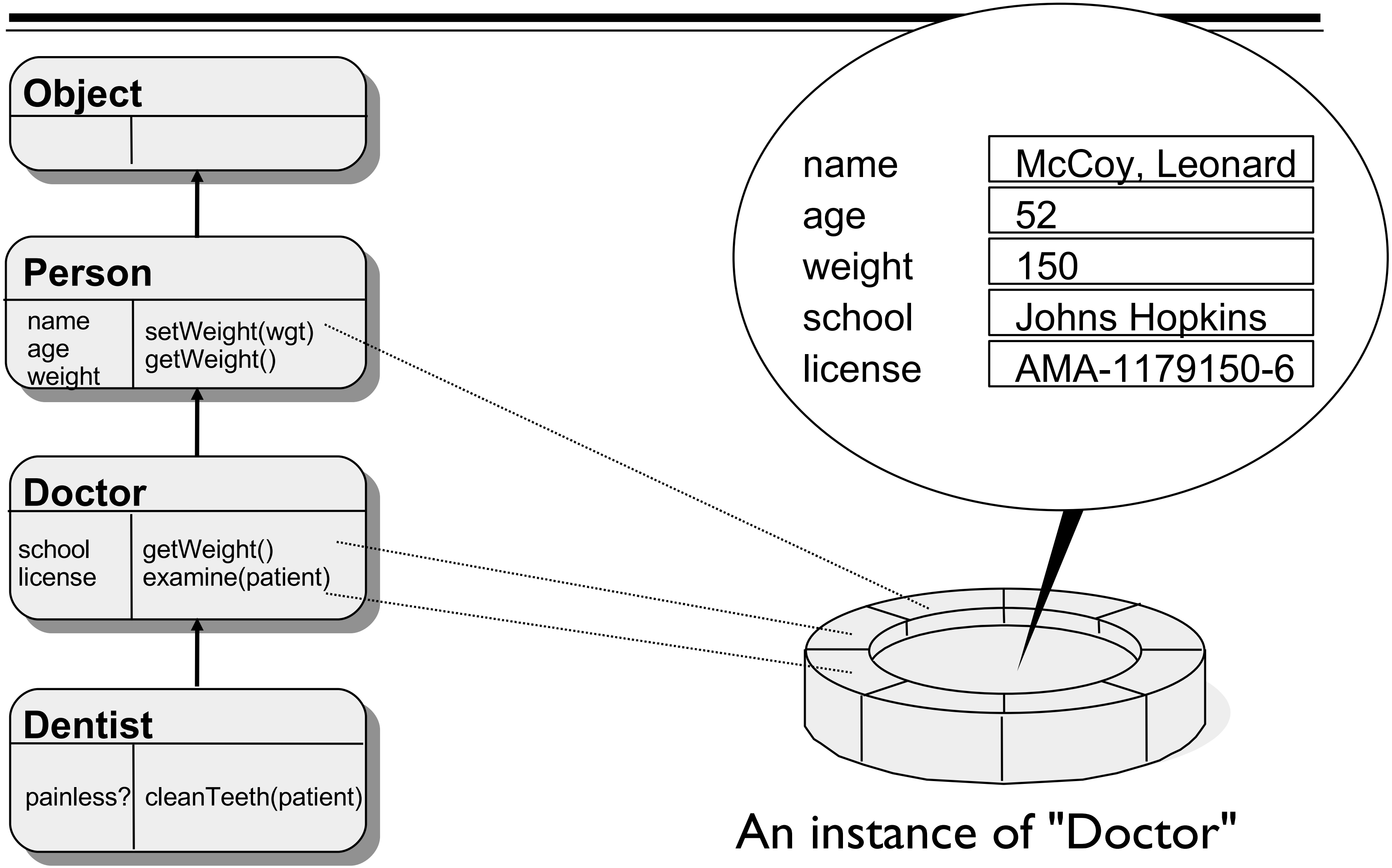

- If each class to can have **more than one parent** class, we have a ***multiple-inheritance*** language. Its class hierarchies will be graphs (DAGs).



# A single-inheritance class hierarchy

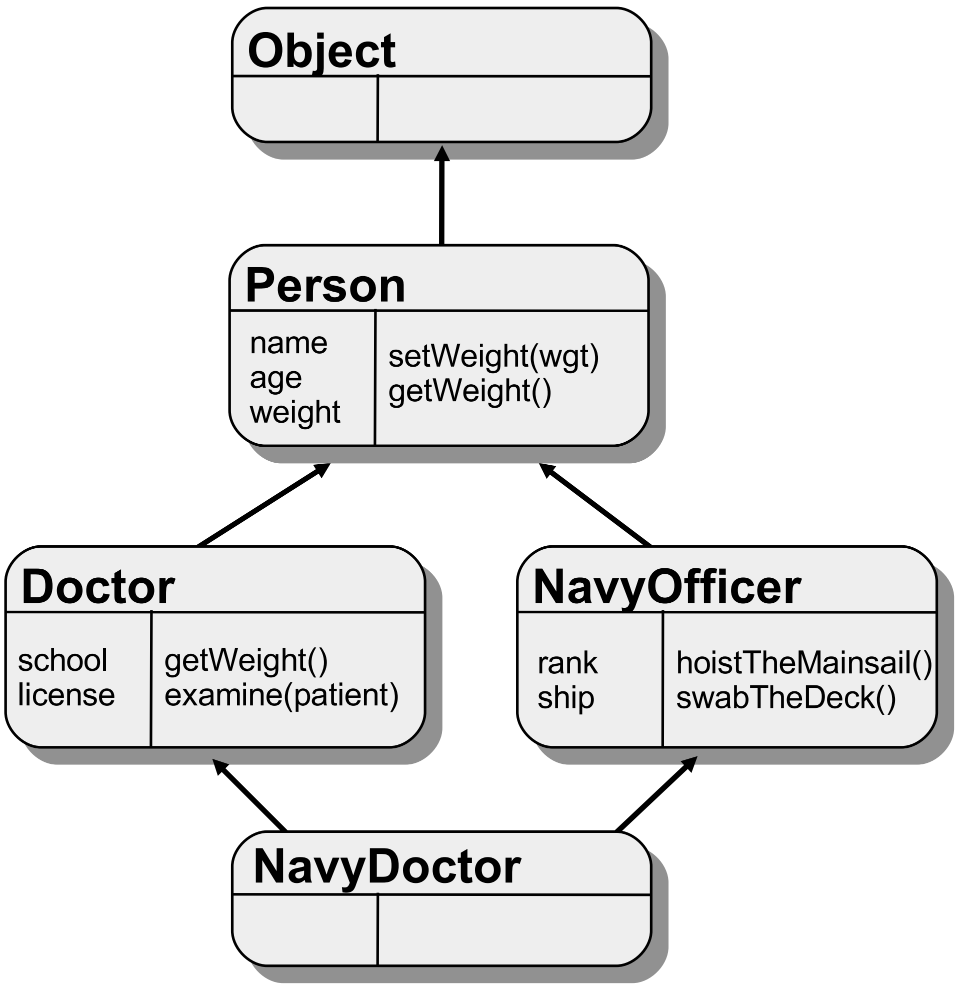


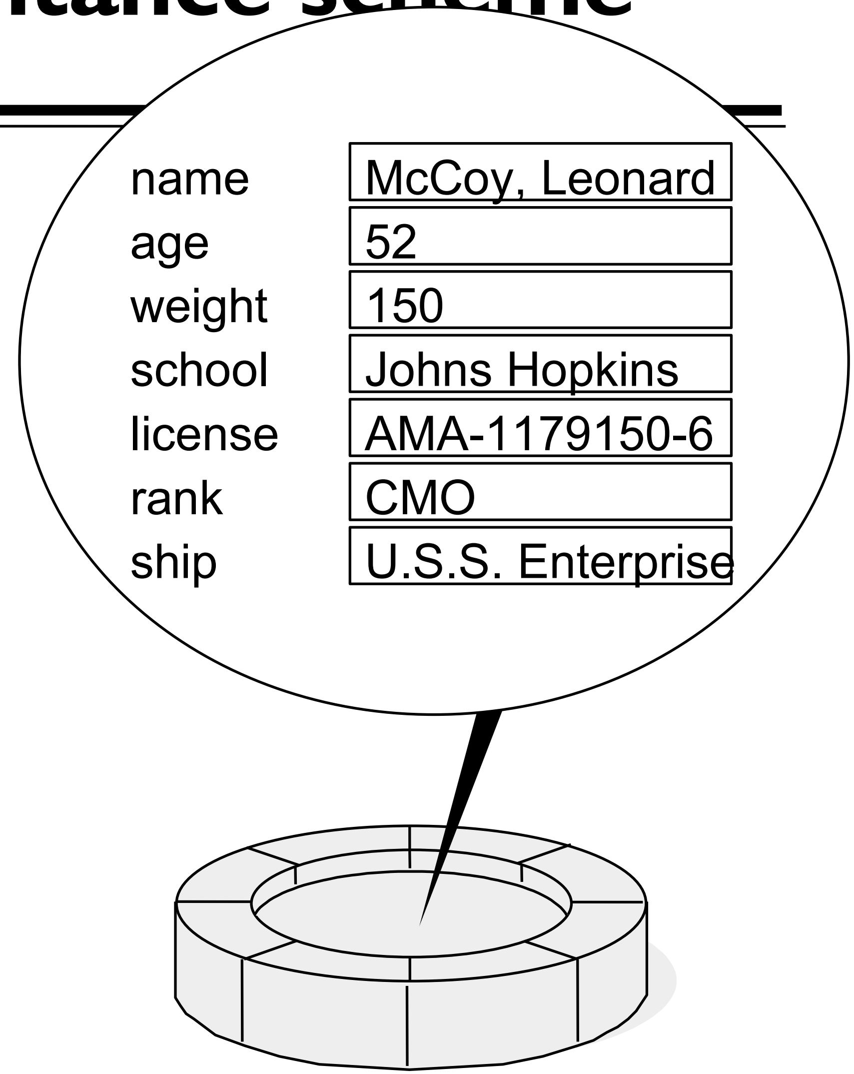
# A single-inheritance scheme




An instance of "Doctor"

# A multiple-inheritance scheme




An instance of "NavyDoctor"

# Advantages/disadvantages of using inheritance

## Advantages

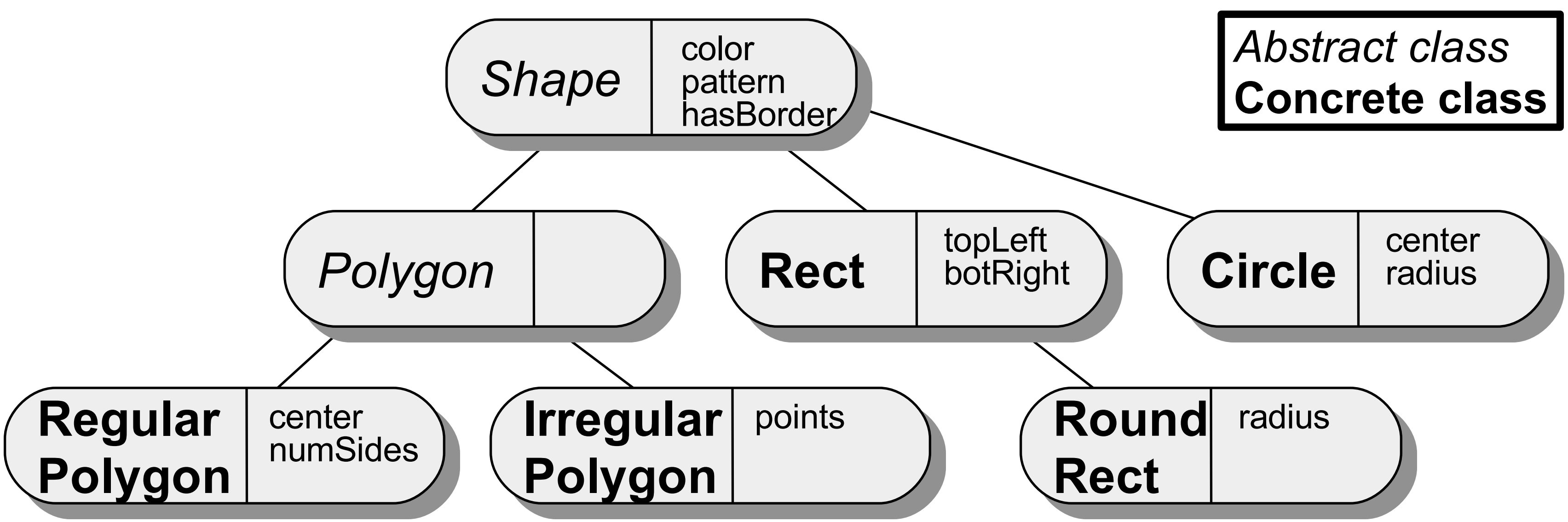
- Code sharing.
- Software reusability without disturbing working code.
- Overloading helps develop standard class interfaces.
- Encourages design by extensions/refinements, rather than mass re-implementation.

## Disadvantages

- Requires an OO programming environment.
- Can inherit attributes and operations that are not desired.
- Too many subclasses makes debugging difficult.
- Performance may be degraded.

# Abstract classes vs. concrete classes

- ***Abstract classes*** are classes which **do not have instances** of their own: they exist solely so that their child classes may inherit structure and/or functionality.
- ***Concrete classes*** are classes which **may have instances**. A concrete class may also have child classes.



# Static binding vs. dynamic binding

In some OO languages, objects don't keep track of their types:

- An object's class (and, therefore, its behavior) is **determined at compile-time** by the class of the variable it's placed in (or referenced through).

this is called ***static binding***

In other OO languages, objects know their types:

- An object's class is **determined at run-time**.  Not affected by the class of the variable the object it's placed in (or referenced through).

this is called ***dynamic binding***

# Behavior under static vs. dynamic binding

Recall our example where Doctor overrode the getName() method of Person. Now consider the following program:

```
Doctor julian("Bashir");
Person someone = julian;

print(someone.getName());
```

If we get...

```
Bashir
```

...then the Doctor behaves like a Person after being stored in a variable of type Person: we've got static binding.

If we get...

```
Dr. Bashir
```

...then the Doctor behaves like a Doctor even after being stored in a variable of type Person: we've got dynamic binding.

# Containers with static vs. dynamic binding

```
for (i = 0; i < size; i++) {
   Object *thing = slot[i];

   switch (*thing.type) {
   case INT:
      (*(IntObject *)thing).print();
      break;
   case STRING:
      (*(StringObject *)thing).print();
      break;
   case CIRCLE:
      (*(CircleObject *)thing).print();
      break;
      ...
   }
}
```

**static binding**
(yuck… just like non-OO!)

```
for (i = 0; i < size; i++) {

   slot[i].print()
}
```

**dynamic binding**
(code it just once!)

# Static binding vs. dynamic binding

| Static binding | Dynamic binding |
| --- | --- |
| Type of object fixed at compile time, by type of variable containing it. | Type of object determined at run time, so objects "know what they are". |
| Often results in "case" and "if" statements. | Eliminates complex "case" and "if" statements. |
| Heterogeneous collections difficult to implement. | Heterogeneous collections greatly simplified. |
| Easier to debug. | Harder to debug. |
| No overhead at run-time. | Slower from run-time lookups. |

# What we've been leading up to: software reuse

The most important benefit of the OO approach is that by...

- Hiding implementation details (*encapsulation*)
- Reducing the number of different things you need to remember (*polymorphism*)
- Minimizing the amount of redundant code that needs to be built, tested, and maintained (*subclassing*)
- Helping existing code to not break just because someone has added a new data type (*dynamic binding*)

...it makes it far easier for you to reuse software components.

# OO DATABASES

- What they are
- How they compare with Relational Databases

# What is a database?

- A ***database*** is a repository for ***persistent*** information: information that exists even when no program is active, usually on disk.
- A good ***database management system***...
  - Lets us **model** information in our problem domain accurately.
  - Allow **fast** insert, update, and query of the information.
  - Gives multiple users concurrent and reliable access to the information (*transaction management*).
  - Allows the information to be managed by **application programs** (not just through a user interface).

# Relational databases

- Been around for decades.
- Information placed in ***tables***:
  - Rows are individual data records.
  - Columns are the attributes of those records.
- Different tables are ***joined*** on common values of particular attributes:

Table: Person

| Name | Age | Car |
|---|---|---|
| Arthur | 36 | ZZ9ZA |
| Trillian | 32 | |
| Zaphod | 34 | HOG121 |

Table: Car

| Make | Color | License |
|---|---|---|
| Sirius | gold | HOG121 |
| Nash | white | ZZ9ZA |

# Object-oriented databases

- An ***OO database*** (OODB) is like a running OO program, except that the objects are *persistent:* they are stored on disk rather than in memory.
- The objects in an OO database can send messages to each other, just as objects in OO programs can: message-sending can be used to perform queries, create and install new objects, send mail to users in a user database, etc.
- Ability to design and implement custom container classes allows developers to optimize database structure based on queries to be supported.

# Benefits of Relational DBs over OODBs

| OO | Relational | |
|---|---|---|
| ☐ | ☑ | • Strong support in academic and commercial communities? |
| ☐ | ☑ | • Declarative vs. procedural query language? |
| ☐ | ☑ | • Underlying mathematical formalism for query optimization? |
| ☐ | ☑ | • Existing natural-language and GUI interface packages? |
| ? | ☑ | • Easy schema modification of large, populated databases? |

# Benefits of OODBs over Relational DBs

| OO | Relational | |
|---|---|---|
| ✓ | ? | Allows modeling of complex entities? |
| ✓ | | Allows modeling of custom collections/indexes (such as quadtrees for fast spatial search)? |
| ✓ | | Does *not* require duplication of data? |
| ✓ | ? | Scalable performance: will queries be fast for very large, complex databases? |
| ✓ | ? | Scalable storage: can database easily be distributed across many physical storage devices? |
| ✓ | ? | Smooth interface to external environment (other databases, math libraries, email)? |

# When is OO good to use?

- Experience has shown that not all problem domains are perfectly suited for OO implementations. Things which can indicate OO as a **good** choice...
  - Need to manage complex information.
  - Need to model real-world concepts and processes (e.g., simulations).
  - Large number of developers to be coordinated.
  - Correctness, maintainability, and evolvability more important than blinding speed.
  - Rapid/evolutionary prototyping environment.

# *PROJECT: SIM*

Many of you have played computer games where a realistic world is being modelled and maybe simulated: SimCity, Zork, Trinity, etc.

Ever wonder how people built those things?

Ever try to yourself?

Imagine that you want to create a swords-and-sorcery-style text adventure. Of course you're going to do an OO implementation. :-)

What classes will you need? What attributes and methods will they have? How will they interact? How "real" can/should the physics of your world be?