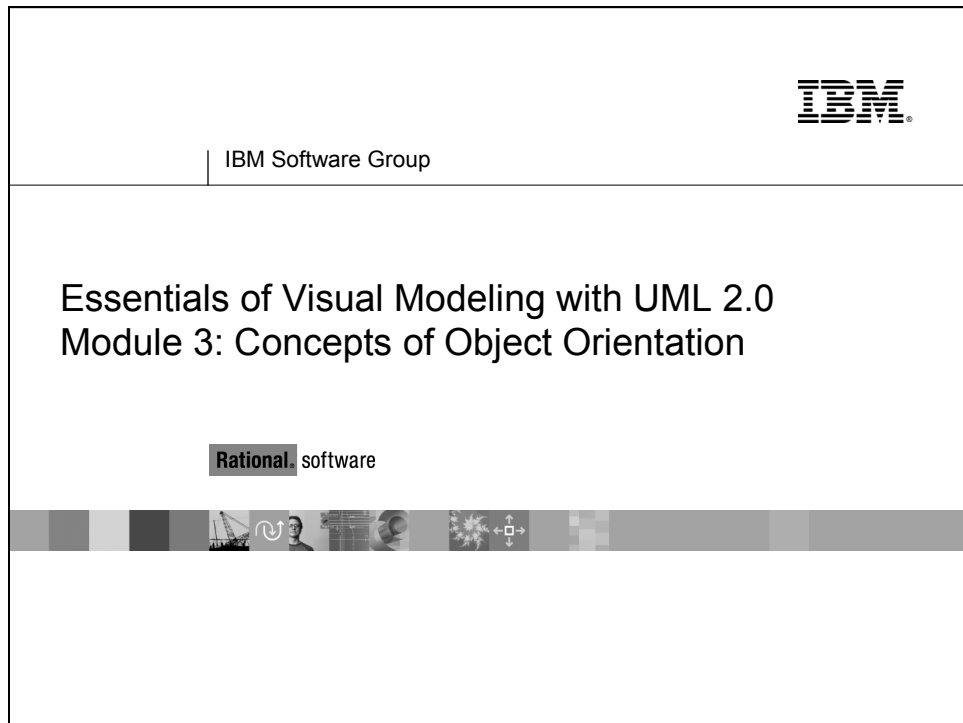


## ► ► ► Module 3

### Concepts of Object Orientation



## Topics

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What Is an Object?.....	3-4
Basic Principles of Object Orientation.....	3-10
What Is a Class?.....	3-20
The Relationship Between Classes and Objects.....	3-23
What Is a Package?.....	3-35

## Objectives

### Objectives

- ♦ Describe abstraction, encapsulation, modularity, and hierarchy.
- ♦ Describe the physical structure of a class.
- ♦ Describe the relationship between a class and an object.
- ♦ Define polymorphism and generalization.

## Where Are We?

### Where Are We?

- ☆ ♦ What is an object?
- ♦ Four principles of OO
- ♦ What is a class?
- ♦ Polymorphism and generalization
- ♦ Organizing model elements



3

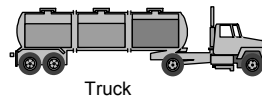
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## What Is an Object?

### What Is an Object?

- ♦ Informally, an object represents an entity, either physical, conceptual, or software.

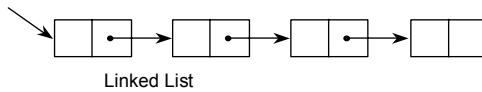
- Physical entity



- Conceptual entity



- Software entity



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Objects allow the software developer to represent real-world concepts in their software design. These real-world concepts can represent a physical entity such as a person, truck, or space shuttle.

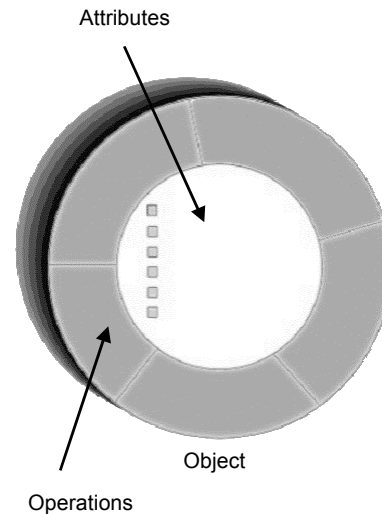
Objects can be concepts like a chemical process or algorithms.

Object can even represent software entities like a linked list.

## A More Formal Definition

### A More Formal Definition

- ♦ An object is an entity with a well-defined boundary and *identity* that encapsulates *state* and *behavior*.
  - State is represented by attributes and relationships.
  - Behavior is represented by operations, methods, and state machines.



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An **object** is an entity that has a well-defined boundary. That is, the purpose of the object should be clear.

An object has two key components: attributes and operations.

Attributes and relationships represent an object's state. Operations represent the behavior of the object.

Object behavior and state are discussed in the next few slides.

## An Object Has State

### An Object Has State

- ♦ State is a condition or situation during the life of an object, which satisfies some condition, performs some activity, or waits for some event.
- ♦ The state of an object normally changes over time.



Name: J Clark  
Employee ID: 567138  
Date Hired: July 25, 1991  
Status: Tenured  
Discipline: Finance  
Maximum Course Load: 3 classes



Professor Clark

6



The **state** of an object is one of the possible conditions in which an object may exist. State normally changes over time.

The state of an object is usually implemented by a set of properties called attributes, along with the values of the properties and the links the object may have with other objects.

State is not defined by a “state” attribute or set of attributes. Instead, state is defined by the total of an object’s attributes and links. For example, if Professor Clark’s status changed from Tenured to Retired, the state of the Professor Clark object would change.

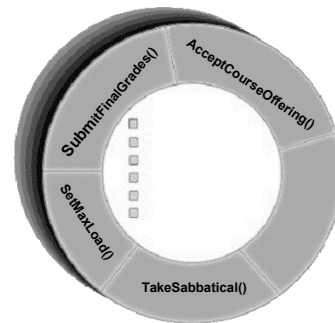
## An Object Has Behavior

### An Object Has Behavior

- ♦ Behavior determines how an object acts and reacts.
- ♦ The visible behavior of an object is modeled by a set of messages it can respond to (operations that the object can perform).



Professor Clark's behavior  
 Submit Final Grades  
 Accept Course Offering  
 Take Sabbatical  
 Set Max Load



Professor Clark



The second characteristic of an object is that it has **behavior**. Objects are intended to mirror the concepts that they are modeled after, including behavior.

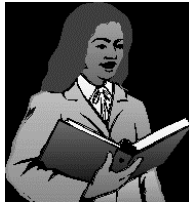
Behavior determines how an object acts and reacts to requests from other objects.

Object behavior is represented by the operations that the object can perform. For example, Professor Clark can choose to take a sabbatical once every five years. The Professor Clark object represents this behavior through the TakeSabbatical() operation.

## An Object Has Identity

### An Object Has Identity

- ♦ Each object has a unique identity, even if the state is identical to that of another object.



Professor "J Clark"  
teaches Biology



Professor "J Clark"  
teaches Biology

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In the real world, two people can share the same characteristics: name, birth date, job description. Yet, there is no doubt that they are two individuals with a unique **identity**.

The same concept holds true for objects. Although two objects may share the same state (attributes and relationships), they are separate, independent objects with their own unique identity.



## Where Are We?

### Where Are We?

- ♦ What is an object?
- ☆ ♦ Four principles of OO
- ♦ What is a class?
- ♦ Polymorphism and generalization
- ♦ Organizing model elements

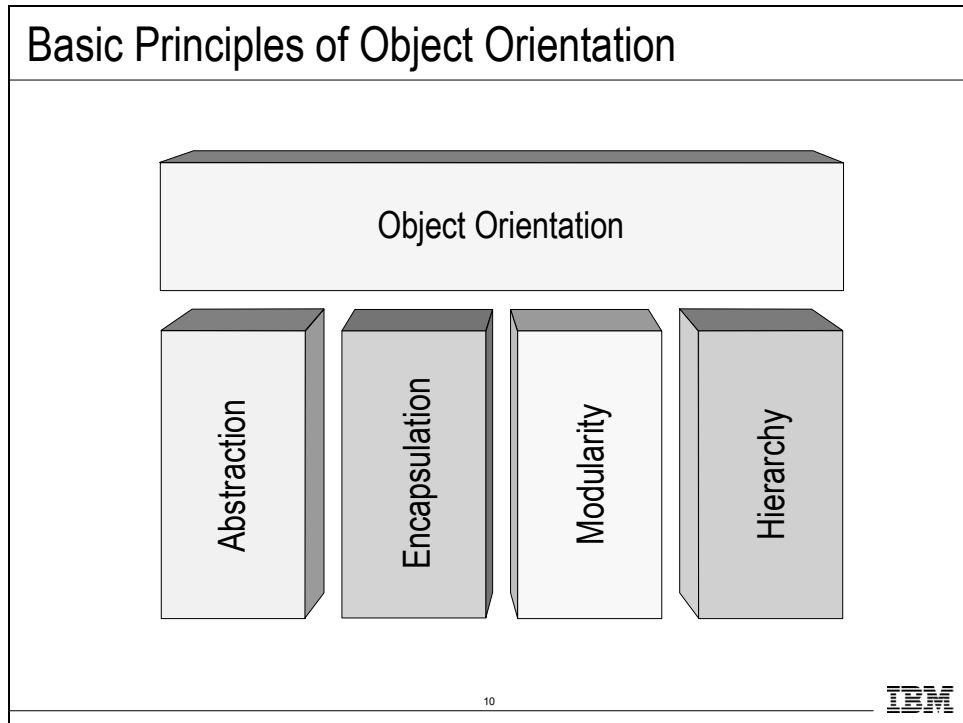


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## Basic Principles of Object Orientation

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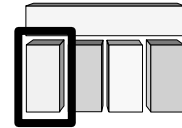
There are four basic principles of object orientation:

- Abstraction
- Encapsulation
- Modularity
- Hierarchy

## What Is Abstraction?

### What Is Abstraction?

- ♦ The essential characteristics of an entity that distinguishes it from all other kinds of entities.
- ♦ Defines a boundary relative to the perspective of the viewer.
- ♦ Is not a concrete manifestation, denotes the ideal essence of something.



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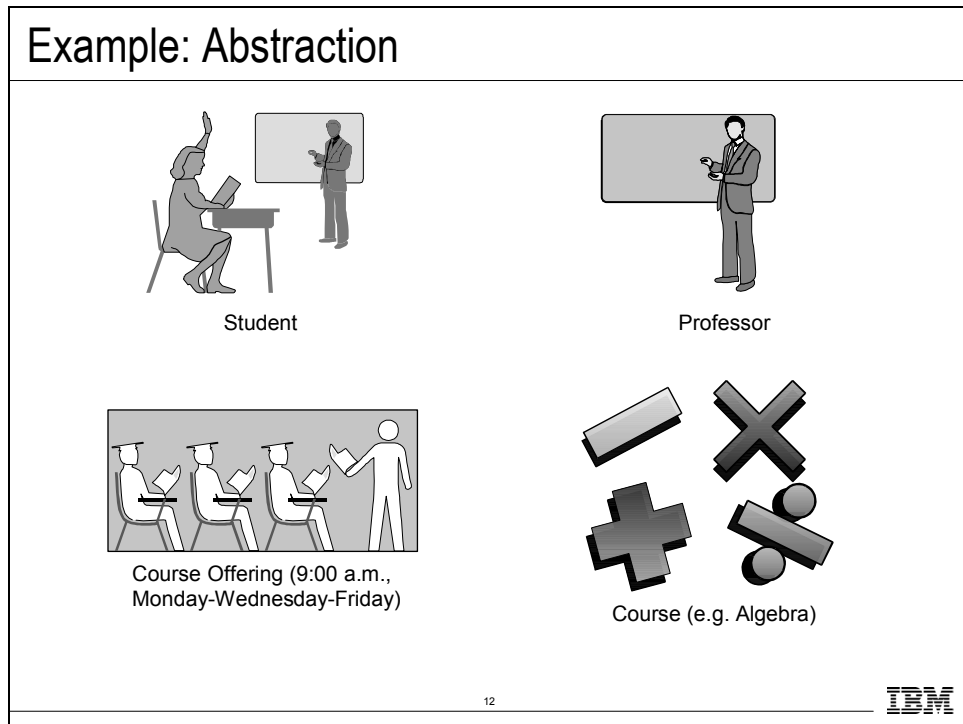


**Abstraction** can be defined as:

Any model that includes the most important, essential, or distinguishing aspects of something while suppressing or ignoring less important, immaterial, or diversionary details. The result of removing distinctions so as to emphasize commonalities. (*Dictionary of Object Technology*, Firesmith, Eykholt, 1995.)

- Abstraction allows us to manage complexity by concentrating on the essential characteristics of an entity that distinguishes it from all other kind of entities.
- An abstraction is domain and perspective dependent. That is, what is important in one context may not be in another.
- OO allows us to model our system using abstractions from the problem domain (for example, classes and objects).

## Example: Abstraction



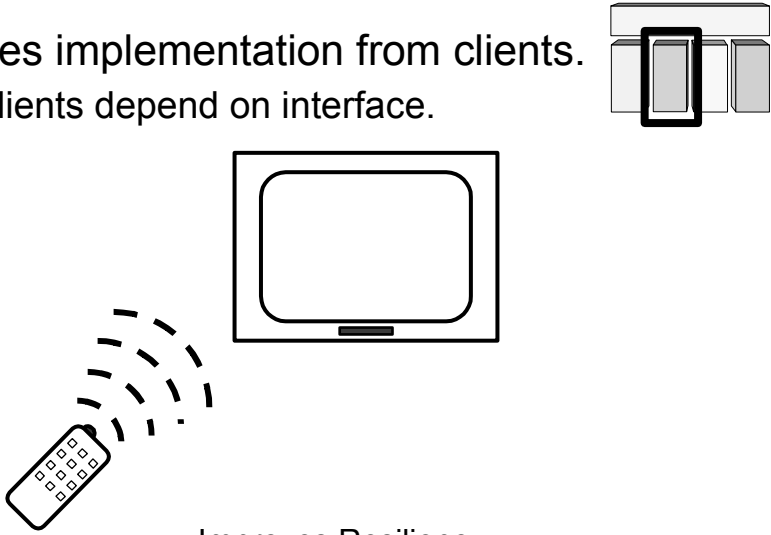
The following are examples of abstraction:

- A student is a person enrolled in classes in the university.
- A professor is a person teaching classes at the university.
- A course is a class offered by the university.
- A course offering is a specific offering for a course including the days of the week and the times.


## What Is Encapsulation?

### What Is Encapsulation?

- ◆ Hides implementation from clients.
  - Clients depend on interface.



Improves Resiliency

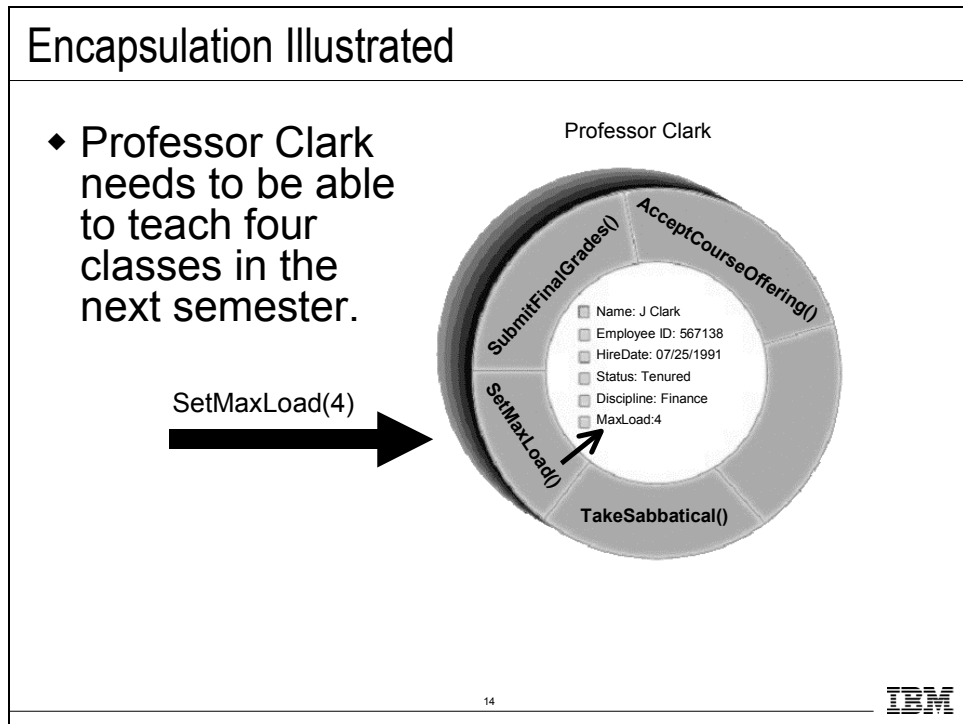


**Encapsulation** can be defined as:

The physical localization of features (for example, properties, behaviors) into a single blackbox abstraction that hides their implementation (and associated design decisions) behind a public interface. (*Dictionary of Object Technology*, Firesmith, Eykholt, 1995.)

- Encapsulation is often referred to as “information hiding,” making it possible for the clients to operate without knowing how the implementation implements the interface.
- Encapsulation eliminates direct dependencies on the implementation (clients depend on/use the interface). Thus, it’s possible to change the implementation without updating the clients as long as the interface is unchanged.
- Clients are not affected by changes in implementation, thus reducing the “ripple effect,” where a correction to one operation forces the corresponding correction in a client operation and so on. As a result of encapsulation, maintenance is easier and less expensive.
- Encapsulation offers two kinds of protection. It protects an object’s internal state from being corrupted by its clients and client code from changes in the object’s implementation.

## Encapsulation Illustrated



The key to encapsulation is an object's **message interface**. The object interface ensures that all communication with the object takes place through a set of predefined operations. Data inside the object is only accessible by the object's operations. No other object can reach inside the object and change its attribute values.

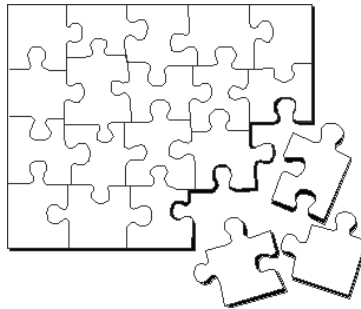
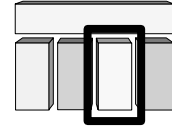
For example, Professor Clark needs to have her maximum course load increased from three classes to four classes per semester. Another object makes a request to Professor Clark to set the maximum course load to four. The attribute, MaxLoad, is then changed by the SetMaxLoad() operation.

Encapsulation is beneficial in this example because the requesting object does not need to know how to change the maximum course load. In the future, the number or variables that are used to define the maximum course load may be increased, but it doesn't affect the requesting object. It depends on the operation interface for the Professor Clark object.

## What Is Modularity?

### What Is Modularity?

- ♦ Breaks up something complex into manageable pieces.
- ♦ Helps people understand complex systems.



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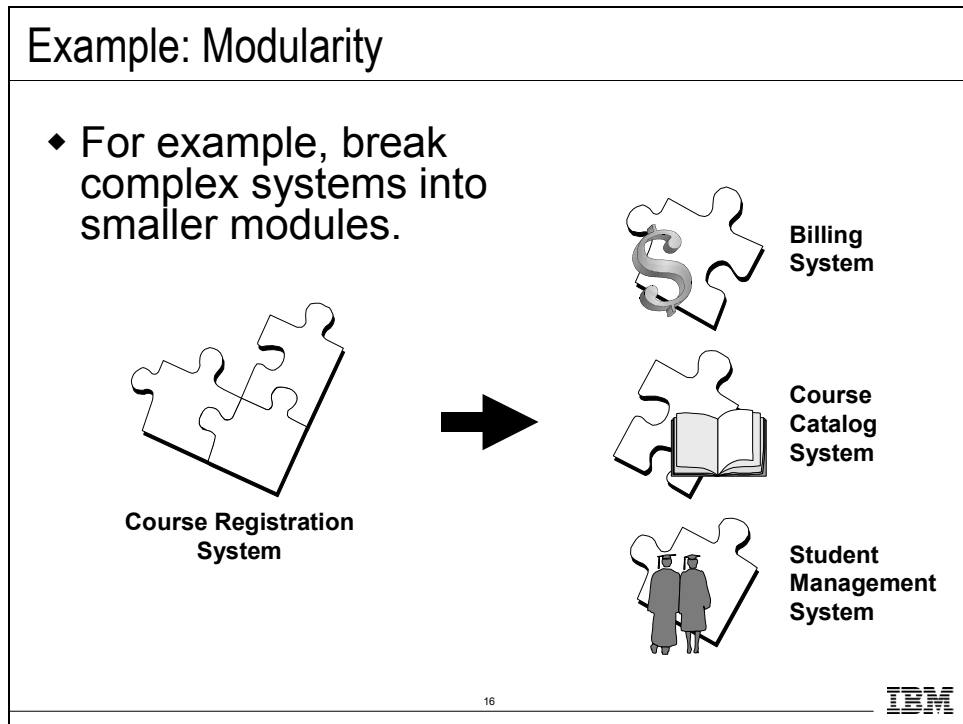
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**Modularity** can be defined as:

The logical and physical decomposition of things (for example, responsibilities and software) into small, simple groupings (for example, requirements and classes, respectively), which increase the achievements of software-engineering goals. (*Dictionary of Object Technology*, Firesmith, Eykholt, 1995.)

- Another way to manage complexity is to break something that is large and complex into a set of smaller, more manageable pieces. These pieces can then be independently developed as long as their interactions are well understood.
- Packages (described later in the course) support the definition of modular components.

## Example: Modularity



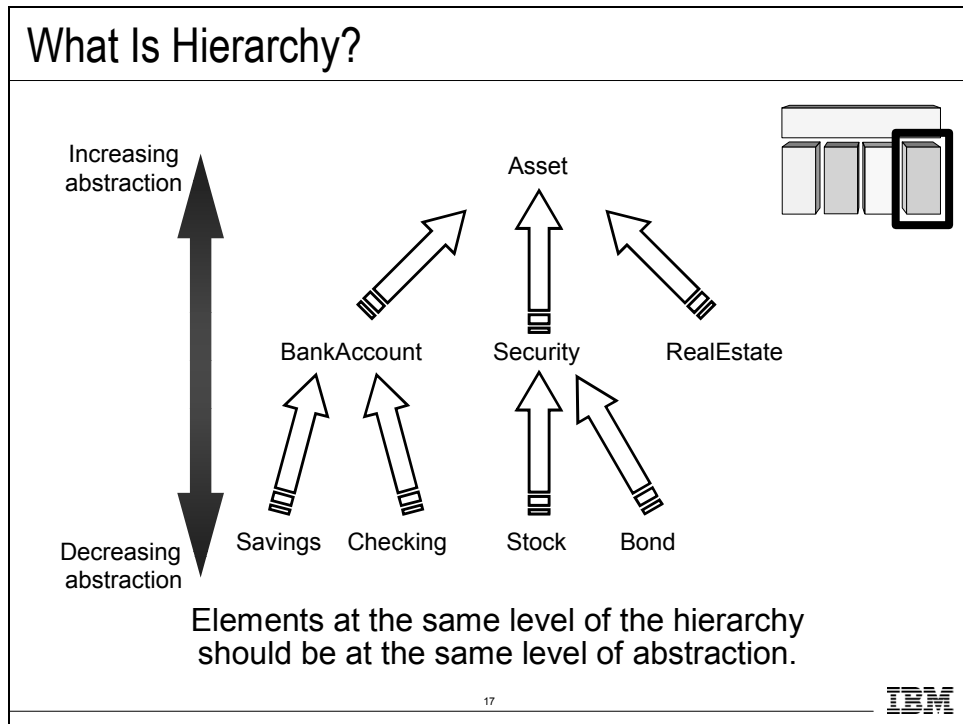
Often, the system under development is too complex to understand. To better understand this, imagine that the system is broken into smaller blocks that are maintained independently. Breaking down a system in this way is called **modularity**. It is critical for understanding a complex system.

For example, the system under development is a Course Registration System. The system itself is too large and abstract to understand the details. Therefore, the development team broke this system into three modular systems, each independent of the others.

- Billing System
- Course Catalog System
- Student Management System



## What Is Hierarchy?



**Hierarchy** can be defined as:


Any ranking or ordering of abstractions into a tree-like structure. Kinds: Aggregation hierarchy, class hierarchy, containment hierarchy, inheritance hierarchy, partition hierarchy, specialization hierarchy, type hierarchy. (*Dictionary of Object Technology*, Firesmith, Eykholt, 1995.)

- Hierarchy organizes in a particular order or rank (for example, complexity, responsibility, and so on). This organization is dependent on perspective. Using a hierarchy to describe differences or variations of a particular concept provides for more descriptive and cohesive abstractions and a better allocation of responsibility.
- In any one system, there may be multiple abstraction hierarchies (for example, a financial application may have different types of customers and accounts).
- Hierarchy is neither an organizational chart nor a functional decomposition.
- Hierarchy is a taxonomic organization. The use of hierarchy makes it easy to recognize similarities and differences. For example, botany organizes plants into families. Chemistry organizes elements into a periodic table.

## Representing Objects in the UML

### Representing Objects in the UML

- ♦ An object is represented as a rectangle with an underlined name.



Professor J Clark


J Clark : Professor

Named Object

: Professor

Anonymous Object

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An object is represented with a rectangle and the name of the class.

The name of the object is always underlined. To name an object, place its name before the colon.

An object can be either named or anonymous. To remain anonymous, do not include a name.

## Where Are We?

### Where Are We?

- ♦ What is an object?
- ♦ Four principles of OO
- ☆ ♦ What is a class?
- ♦ Polymorphism and generalization
- ♦ Organizing model elements



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## What Is a Class?

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### What Is a Class?

- ♦ A class is a description of a set of objects that share the same *attributes*, *operations*, *relationships*, and *semantics*.
  - An object is an instance of a class.
- ♦ A class is an abstraction in that it
  - Emphasizes relevant characteristics.
  - Suppresses other characteristics.

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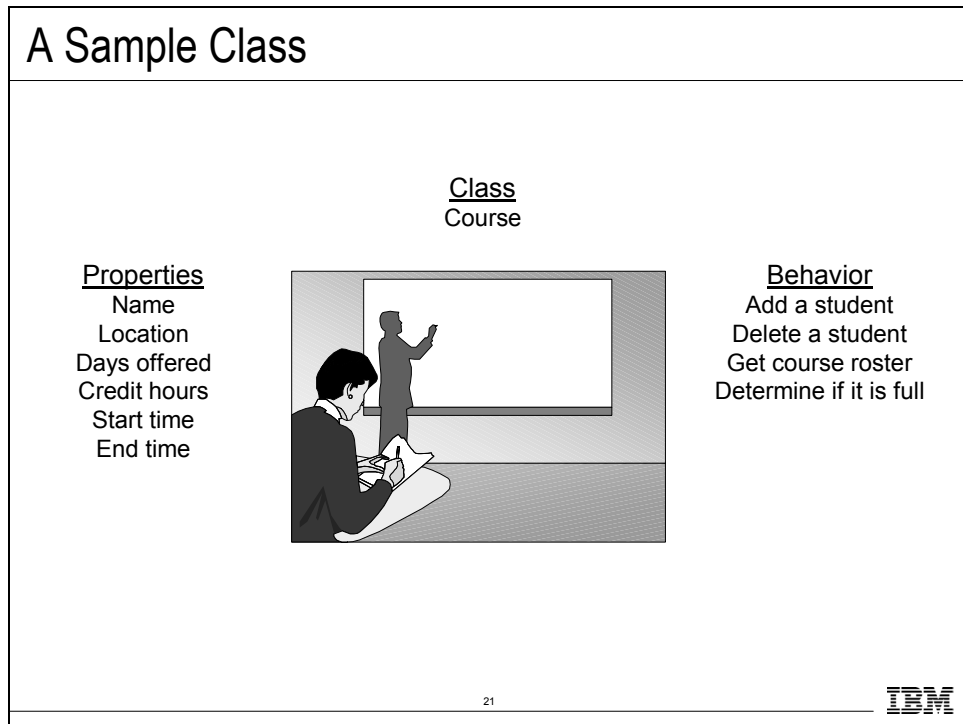


A **Class** can be defined as:

A description of a set of objects that share the same attributes, operations, relationships, and semantics. (*The Unified Modeling Language User Guide*, Booch, 1999.)

- There are many objects identified for any domain.
- Recognizing the commonalties among the objects and defining classes helps us deal with the potential complexity.
- The OO principle abstraction helps us deal with complexity.

## A Sample Class



The class “Course” is an abstraction of the real-world representation of a college course. The class has properties: name, location, days offered, credit hours, start time, and end time. It also has behavior, like adding and deleting a student to the class, retrieving a current course roster, and determining if the course is full.

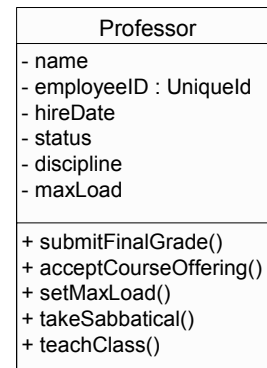
The class does not represent a specific course like Algebra 101 or Theatre Arts 102. Rather, it is a description of the types of properties and behavior a typical course may have.

## Representing Classes in the UML

### Representing Classes in the UML

- ♦ A class is represented using a rectangle with three compartments:

- The class name
- The structure (attributes)
- The behavior (operations)



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The UML notation for a class permits you to see an abstraction apart from any specific programming language, which lets you emphasize the most important parts about an abstraction – its name, attributes, and operations.

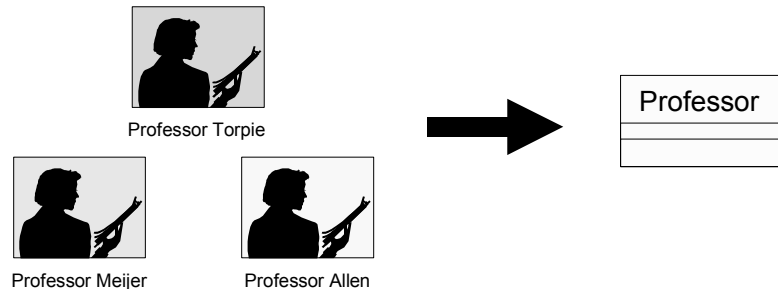
Graphically, a class is represented by a rectangle.

The UML represents public visibility with a plus (+) symbol and private visibility with a minus (-) symbol.

## The Relationship Between Classes and Objects

### The Relationship between Classes and Objects

- ♦ A class is an abstract definition of an object.
  - It defines the structure and behavior of each object in the class.
  - It serves as a template for creating objects.
- ♦ Classes are not collections of objects.



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A class is a description of a set of objects that share the same responsibilities, relationships, operations, attributes, and semantics.

A class defines an object. A class defines a template for the structure and behavior of all its objects. The objects created from a class are also called the **instances** of the class.

The class is the static description and the object is the run-time instance of that class.

Modeling is from real-world objects. Software objects are based on the real-world objects, but exist only in the context of the system.

Use real-world objects, abstract out what you don't care about. Then, take these abstractions and go through the process of classification based on what you do care about. Classes in the model are the result of this classification process.

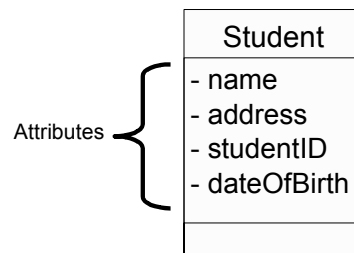
These classes are then used as templates within an executing software system to create software objects. These software objects represent the real-world objects you originally started with.

Some classes/objects may be defined that don't represent real-world objects. They are there to support the design and are "software only."

## What Is an Attribute?

### What Is an Attribute?

- ♦ An attribute is a named property of a class that describes the range of values that instances of the property may hold.
  - A class may have any number of attributes or no attributes at all.



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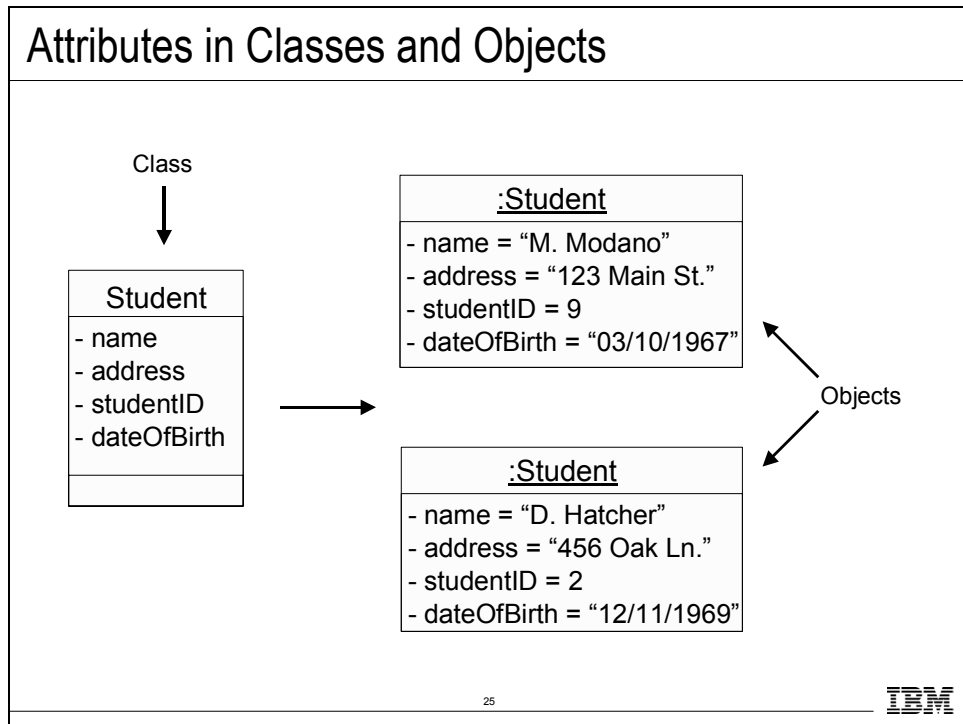
An **Attribute** can be defined as:

A named property of a class that describes the range of values that instances of the property may hold. (*The Unified Modeling Language User Guide*, Booch, 1999.)

- A class may have any number of attributes or no attributes at all. At any time, an object of a class has specific values for every one of its class's attributes.
- An attribute defined by a class represents a named property of the class or its objects. An attribute defines the type of its instances.
- An attribute has a **type**, which tells us what kind of attribute it is. Typical attributes are integer, Boolean, real, and enumeration. These are called **primitive** types. An attribute does not need to be a primitive type though.



## Attributes in Classes and Objects



At the class level, the Student class attributes indicate that the Students have names, addresses, studentIDs, and a date of birth.

At the object level, the attributes indicate the values for the name, address, studentID, and date of birth.

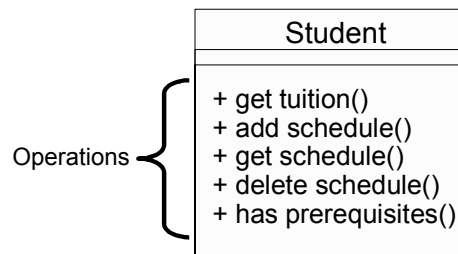
Only the class instance (objects) should be able to change the value of the attributes.

The state of an object is defined by the value of its attributes and the existence of links to other objects.

## What Is an Operation?

### What Is an Operation?

- ♦ A service that can be requested from an object to effect behavior. An operation has a signature, which may restrict the actual parameters that are possible.
- ♦ A class may have any number of operations or none at all.



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An **Operation** can be defined as:

A service that can be requested from an object to effect behavior. An operation has a signature, which may restrict the actual parameters that are possible.

- The operations in a class describe what the class can do.
- An operation can either be a command or a question. A question should never change the state of the object. Only a command can change the state of the object.
- An operation is described with a return-type, name, and zero or more parameters. Together, the return-type, name, and parameters are called the **signature** of the operation.
- The outcome of the operation depends on the current state of the object. Often, but not always, invoking an operation on an object changes the object's data or state.

## Where Are We?

### Where Are We?

- ♦ What is an object?
- ♦ Four principles of OO
- ♦ What is a class?
- ☆ ♦ Polymorphism and generalization
- ♦ Organizing model elements



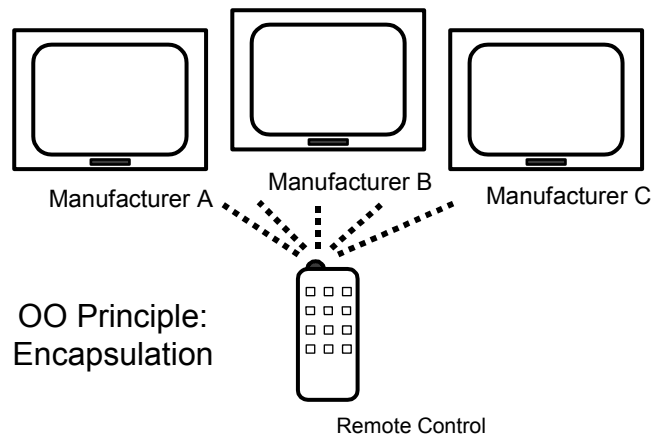
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## What Is Polymorphism?

### What Is Polymorphism?

- ♦ The ability to hide many different implementations behind a single interface.



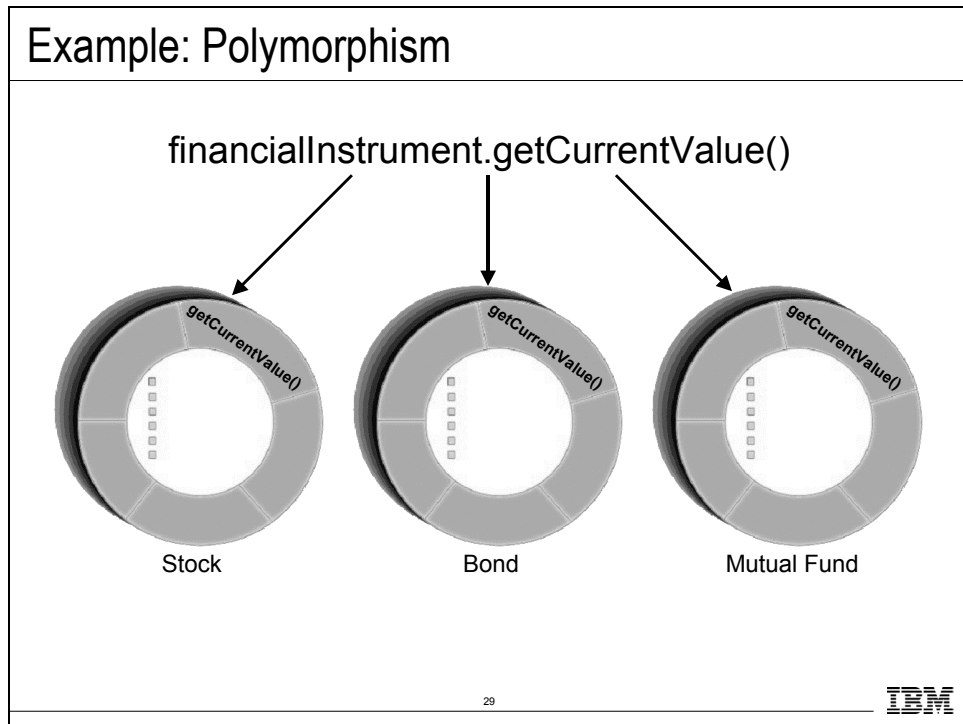
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The Greek term *polymorphos* means “having many forms.” Every implementation of the interface must include at least the interface. In some cases, the implementation can include more than the interface.

For example, a remote control can be used to monitor/support any type of television that relates to a specific interface (the specific interface the remote was designed to be used with).

## Example: Polymorphism



In this example, a requesting object would like to know the current value of a financial instrument. However, the current value for each financial instrument is calculated in a different fashion. The stock needs to determine the current asking price in the financial market that it is listed under. The bond needs to determine the maturity timelines and interest rates. A mutual fund needs to check the day's closing price from the fund management company.

In a non object-oriented development environment, you would write code that may look something like this:

```
IF financialInstrument = Stock THEN
    calcStockValue()
ELSEIF financialInstrument = Bond THEN
    calcBondValue()
ELSEIF financialInstrument = MutualFund THEN
    calcMutualFundValue()
```

With object technology, each financial instrument can be represented by a class, and each class would know how to calculate its own value. The requesting object simply needs to ask the specific object (for example, Stock) to get its current value. The requesting object does not need to keep track of three different operation signatures. It only needs to know one. Polymorphism allows the same message to be handled in different ways depending on the object that receives it.

## What Is Generalization?

### What Is Generalization?

- ♦ A relationship among classes where one class shares the structure and/or behavior of one or more classes.
- ♦ Defines a hierarchy of abstractions in which a subclass inherits from one or more superclasses.
  - Single inheritance.
  - Multiple inheritance.
- ♦ Is an “is a kind of” relationship.

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**Generalization** can be defined as:

A specialization/generalization relationship, in which objects of the specialized element (the child) are substitutable for objects of the generalized element (the parent). (*The Unified Modeling Language User Guide*, Booch, 1999.)

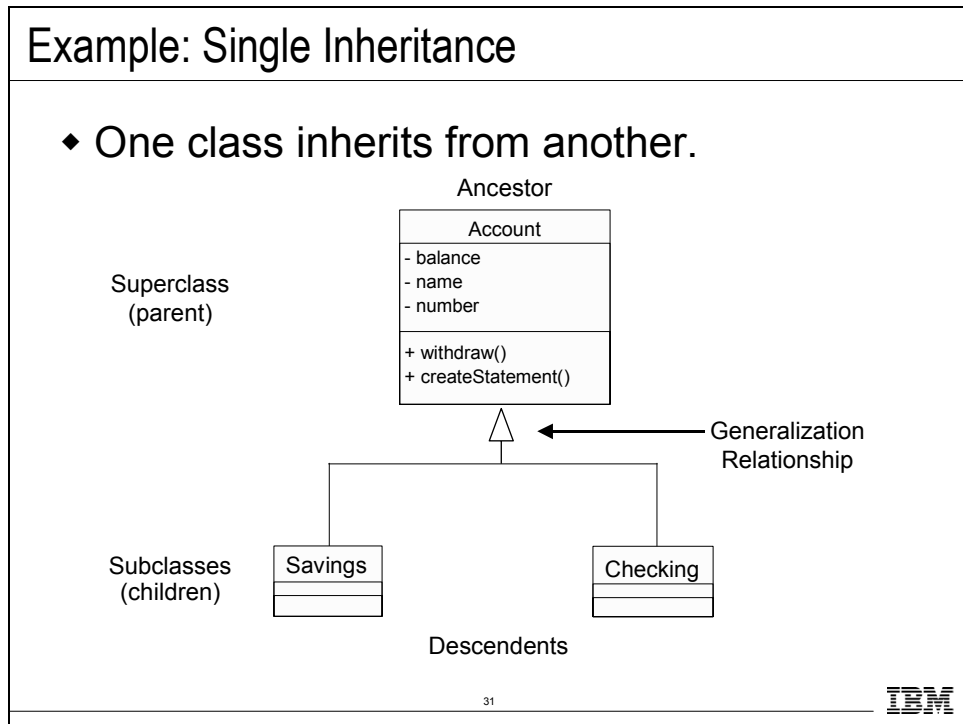
- The subclass may be used where the superclass is used, but not vice versa.
- The child inherits from the parent.
- Generalization is transitive. You can always test your generalization by applying the “is a kind of” rule. You should always be able to say that your generalized class “is a kind of” the parent class.
- The terms “generalization” and “inheritance” are generally interchangeable, but if you need to distinguish, generalization is the name of the relationship. Inheritance is the mechanism that the generalization relationship represents/models.

**Inheritance** can be defined as:

The mechanism by which more specific elements incorporate the structure and behavior of more general elements. (*The Unified Modeling Language User Guide*, Booch, 1999.)

- Single inheritance: The subclass inherits from only one superclass (has only one parent).
- Multiple inheritance: The subclass inherits from more than one superclass (has multiple parents).

## Example: Single Inheritance



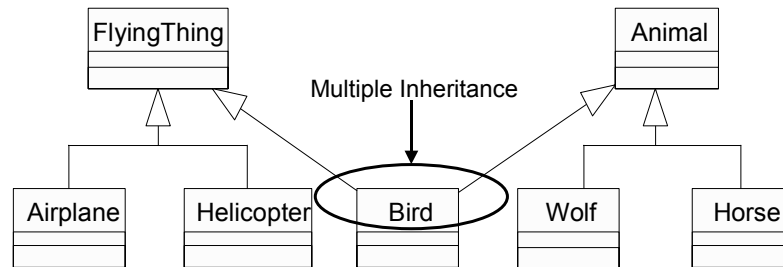
The generalization is drawn from the subclass class to the superclass/parent class.

The terms “ancestor” and “descendent” may be used instead of “superclass” and “subclass.”

## Example: Multiple Inheritance

### Example: Multiple Inheritance

- ♦ A class can inherit from several other classes.



Use multiple inheritance only when needed and  
always with caution!

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Multiple inheritance means that a class can inherit several other classes. For example, Bird inherits from both FlyingThing and Animal.

Multiple inheritance is conceptually straight forward and may be needed to model the real world accurately. However, there are potential implementation problems when you use multiple inheritance, as not all implementation languages support it. Thus, be judicious with your use of multiple inheritance. Use it only where it accurately describes the concept and reduces the complexity of your model. Be aware, however, that this representation probably needs to be adjusted in design and implementation.

Generally, a class inherits from only one class.



## What Is Inherited?

### What Is Inherited?

- ♦ A subclass inherits its parent's attributes, operations, and relationships.
- ♦ A subclass may:
  - Add additional attributes, operations, relationships.
  - Redefine inherited operations. (Use caution!)
- ♦ Common attributes, operations, and/or relationships are shown at the highest applicable level in the hierarchy.

Inheritance leverages the similarities among classes.

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Generalization is more than finding common attributes, operations, and relationships. It is more about the responsibilities and essence of the classes.

## Where Are We?

### Where Are We?

- ♦ What is an object?
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- ☆ ♦ Organizing model elements



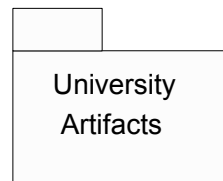
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## What Is a Package?

### What Is a Package?

- ♦ A general purpose mechanism for organizing elements into groups.
- ♦ A model element that can contain other model elements.
- ♦ A package can be used:
  - To organize the model under development.
  - As a unit of configuration management.



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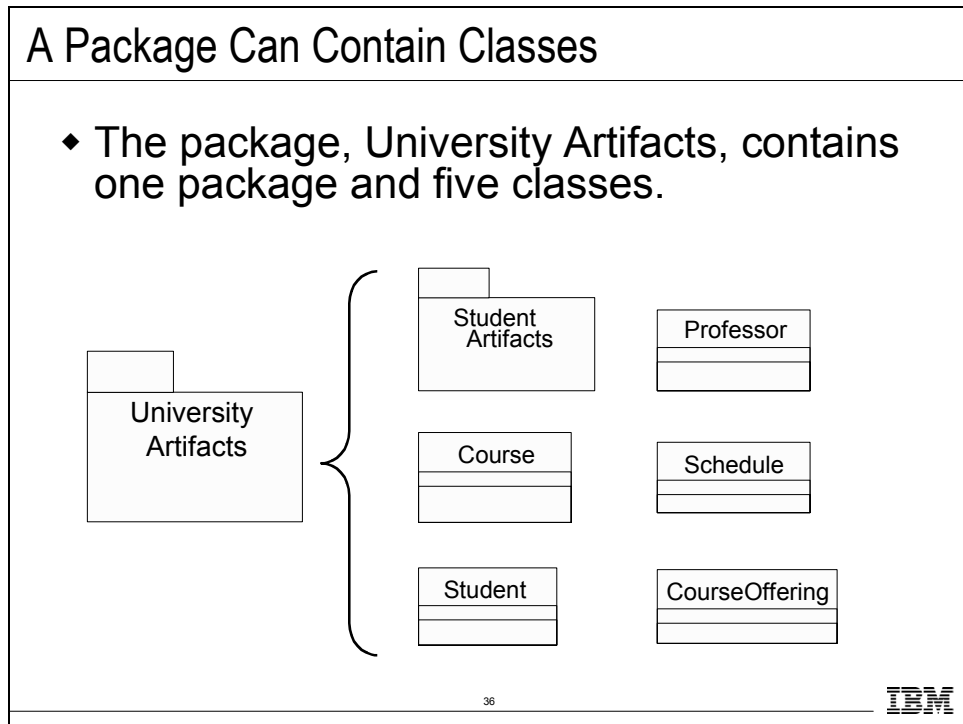


A **Package** can be defined as:

A general purpose mechanism for organizing elements into groups. (*The Unified Modeling Language User Guide*, Booch, 1999.)

- Models can contain hundreds and even thousands of model elements. The sheer number of these elements can quickly become overwhelming. Therefore, it's critical to group model elements into logical collections to maintain and easily read the model (application of modularity and hierarchy).
- Packages are a general grouping mechanism for grouping elements into semantically related groups. A package contains classes that are needed by a number of different packages, but are treated as a "behavioral unit."
- A package is simply a grouping mechanism. No semantics are defined for its instances. Thus, packages do not necessarily have a representation in implementation, except maybe to represent a directory.
- In the UML, a package is represented as a tabbed folder.
- Package diagrams depict dependencies between packages and are now formalized in UML 2.

## A Package Can Contain Classes



A package owns its elements and can even own other packages.

Owning is a **composite** relationship, meaning that the element is declared in the package. If the package is destroyed, the element is destroyed.

Every element is uniquely owned by exactly one package. For example, the package UniversityArtifacts owns the following classes: Course, Student, Schedule, Professor, and Course Offering. If the UniversityArtifacts package is destroyed then all of these classes are also destroyed. If you move the package to a different location in your model (architecturally speaking), then the classes move, too.

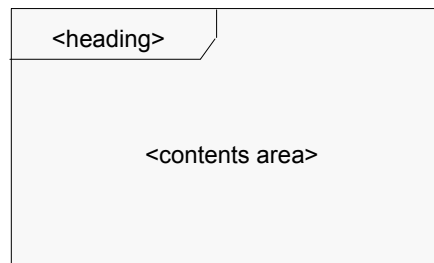
A package is an important mechanism for dealing with scale. Without packages, you would end up with large, flat models where all elements would be uniquely named.

Packages help you control the elements that compose your system as they evolve at different rates over time.

## Diagram Depiction

### Diagram Depiction

- ♦ Each diagram has a frame, a heading compartment in the upper left corner, and a contents area.
  - If the frame provides no additional value, it may be omitted and the border of the diagram area provided by the tool will be the implied frame.



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A heading compartment is a string contained in a name tag (a rectangle with cutoff corner) in the upper leftmost corner with the following syntax:

[<kind>]<name>[<parameters>]

This <kind> can be:

- activity - activity diagram
- package - class diagram, package diagram
- communication - communication diagram
- component - component diagram
- class - composite structure diagram
- deployment - deployment diagram
- intover - interaction overview diagram
- object - object diagram
- state machine - state machine diagram
- sd - sequence diagram
- timing - timing diagram
- use case - use case diagram

## Review

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- ♦ What is an object?
- ♦ What are the four principles of object orientation? Describe each.
- ♦ What is a class? How are classes and objects related?
- ♦ What is an attribute? An operation?
- ♦ Define polymorphism. Provide an example of polymorphism.
- ♦ What is generalization?
- ♦ Why use packages?



## Exercise: Principles of Object Orientation

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- ◆ The “OO Quiz Show” Rules
  - Everyone in the class is assigned a number.
  - The instructor displays a question.
  - The instructor calls out a number.
  - If the student answers the question correctly, the class continues to the next question.
  - If the student does not answer the question correctly, the class goes back to the beginning.
  - The game is over when all questions have been answered correctly.

