

# Object-Oriented Database Development

# Objectives

- ▶ Definition of terms
- ▶ Create object-oriented database schemas in ODL
- ▶ Transform UML class diagrams to ODL schemas
- ▶ Identify type specifications for attributes, arguments, and operation return values
- ▶ Create objects and specify their attribute values
- ▶ Understand object-oriented database implementation steps
- ▶ Understand OQL syntax and semantics
- ▶ Understand object-oriented database applications

# Object Definition Language (ODL)

- ▶ Corresponds to SQL's DDL (Data Definition Language)
- ▶ Specify the logical schema for an object-oriented database
- ▶ Based on the specifications of Object Database Management Group (ODMG)

# Defining a Class

- ▶ **class** – keyword for defining classes
- ▶ **attribute** – keyword for attributes
- ▶ **operations** – return type, name, parameters in parentheses
- ▶ **relationship** – keyword for establishing relationship

```
class Student {  
    attribute string name;  
    attribute Date dateOfBirth;  
    attribute Address address;  
    attribute Phone phone;  
    // relationship between Student and CourseOffering  
    relationship set <CourseOffering> takes inverse CourseOffering::taken_by;  
    // operations  
    short age();  
    float gpa();  
    boolean register_for(string crse, short sec, string term);  
};
```

See page 620

# Defining an Attribute

- ▶ Value can be either:
  - Object identifier OR Literal
- ▶ Types of literals
  - Atomic – a constant that cannot be decomposed into components
  - Collection – multiple literals or object types
  - Structure – a fixed number of named elements, each of which could be a literal or object type
- ▶ Attribute ranges
  - Allowable values for an attribute
  - enum – for enumerating the allowable values

# Kinds of Collections

- ▶ Set – unordered collection without duplicates
- ▶ Bag – unordered collection that may contain duplicates
- ▶ List – ordered collection, all the same type
- ▶ Array – dynamically sized ordered collection, locatable by position
- ▶ Dictionary – unordered sequence of key-value pairs without duplicates

# Defining Structures

Structure = user-defined type with components

**struct** keyword

Example:

```
struct Address {  
    String street_address  
    String city;  
    String state;  
    String zip;  
};
```

# Defining Operations

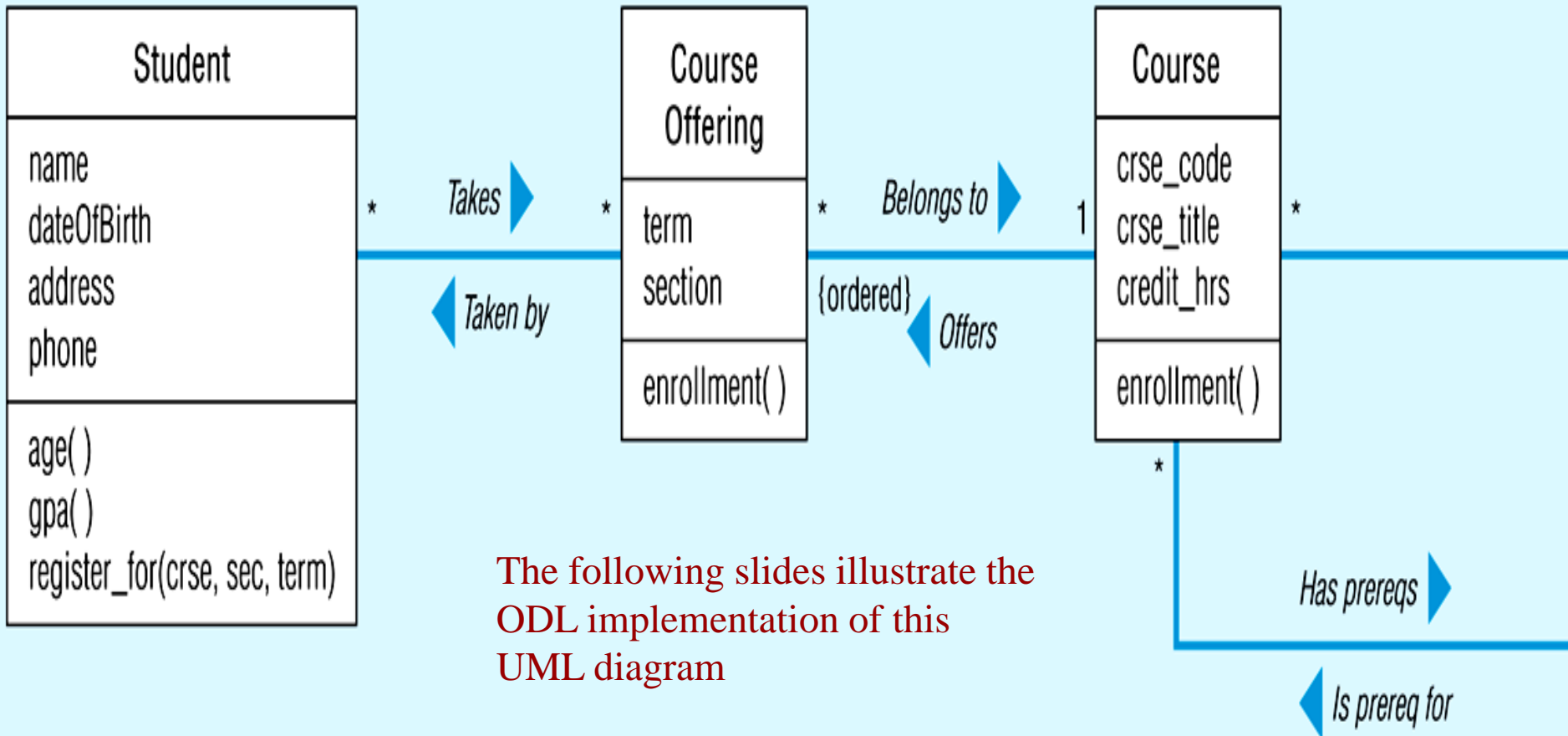
- ▶ Return type
- ▶ Name
- ▶ Parentheses following the name
- ▶ Arguments within the parentheses



# Defining Relationships

- ▶ Only unary and binary relationships allowed
- ▶ Relationships are bi-directional
  - implemented through use of **inverse** keyword
- ▶ ODL relationships are specified:
  - **relationship** indicates that class is on many-side
  - **relationship set** indicates that class is on one-side and other class (many) instances unordered
  - **relationship list** indicates that class is on one-side and other class (many) instances ordered

Figure 15-1: UML class diagram for a university database



## Figure 15-2: ODL Schema for university database

```
class Student {
  ( extent students)
  attribute string name;
  attribute Date dateOfBirth;
  attribute Address address;
  attribute Phone phone;
  relationship set (CourseOffering) takes inverse CourseOffering::taken_by;
  short age( );
  float gpa( );
  boolean register_for(string crse, short sec, string term);
};

class CourseOffering {
  ( extent courseofferings)
  attribute string term;
  attribute enum section {1, 2, 3, 4, 5, 6, 7, 8};
  relationship set (Student) taken_by inverse Student::takes;
  relationship Course belongs_to inverse Course::offers;
  short enrollment( );
};

class Course {
  ( extent courses)
  attribute string crse_code;
  attribute string crse_title;
  attribute short credit_hrs;
  relationship set (Course) has_prereqs inverse Course::is_prereq_for;
  relationship set (Course) is_prereq_for inverse Course::has_prereqs;
  relationship list (CourseOffering) offers inverse CourseOffering::belongs_to;
  short enrollment( );
};
```

Figure 15-2: ODL Schema for university database (cont.)

```
class Student {  
  ( extent students)  
  attribute string name;  
  attribute Date dateOfBirth;  
  attribute Address address;  
  attribute Phone phone;  
  relationship set (CourseOffering) takes inverse CourseOffering::taken_by;  
  short age( );  
  float gpa( );  
  boolean register_for(string crse, short sec, string term);  
};
```

```
class CourseOffering {  
  ( extent courseofferings)  
  attribute string term;  
  attribute enum section {1, 2, 3, 4, 5, 6, 7, 8};  
  relationship set (Student) taken_by inverse Student::takes;  
  relationship Course belongs_to inverse Course::offers;  
  short enrollment( );  
};
```

```
class Course {  
  ( extent courses)  
  attribute string crse_code;  
  attribute string crse_title;  
  attribute short credit_hrs;  
  relationship set (Course) has_prereqs inverse Course::is_prereq_for;  
  relationship set (Course) is_prereq_for inverse Course::has_prereqs;  
  relationship list (CourseOffering) offers inverse CourseOffering::belongs_to;  
  short enrollment( );  
};
```

**class** keyword begins the class definition. Class components enclosed between { and }

Figure 15-2: ODL Schema for university database (cont.)

```
class Student {
  ( extent students)
  attribute string name;
  attribute Date dateOfBirth;
  attribute Address address;
  attribute Phone phone;
  relationship set (CourseOffering) takes inverse CourseOffering::taken_by;
  short age( );
  float gpa( );
  boolean register_for(string crse, short sec, string term);
};

class CourseOffering {
  ( extent courseofferings)
  attribute string term;
  attribute enum section {1, 2, 3, 4, 5, 6, 7, 8};
  relationship set (Student) taken_by inverse Student::takes;
  relationship Course belongs_to inverse Course::offers;
  short enrollment( );
};

class Course {
  ( extent courses)
  attribute string crse_code;
  attribute string crse_title;
  attribute short credit hrs;
  relationship set (Course) has_prereqs inverse Course::is_prereq_for;
  relationship set (Course) is_prereq_for inverse Course::has_prereqs;
  relationship list (CourseOffering) offers inverse CourseOffering::belongs_to;
  short enrollment( );
};
```

attribute has a data type and a name

specify allowable values using **enum**

## Figure 15-2: ODL Schema for university database (cont.)

```
class Student {
  ( extent students)
  attribute string name;
  attribute Date dateOfBirth;
  attribute Address address;
  attribute Phone phone;
  relationship set (CourseOffering) takes inverse CourseOffering::taken_by;
  short age( );
  float gpa( );
  boolean register_for(string crse, short sec, string term);
};

class CourseOffering {
  ( extent courseofferings)
  attribute string term;
  attribute enum section {1, 2, 3, 4, 5, 6, 7, 8};
  relationship set (Student) taken_by inverse Student::takes;
  relationship Course belongs_to inverse Course::offers;
  short enrollment( );
};

class Course {
  ( extent courses)
  attribute string crse_code;
  attribute string crse_title;
  attribute short credit_hrs;
  relationship set (Course) has_prereqs inverse Course::is_prereq_for;
  relationship set (Course) is_prereq_for inverse Course::has_prereqs;
  relationship list (CourseOffering) offers inverse CourseOffering::belongs_to;
  short enrollment( );
};
```

**extent** = the set of all instances of the class

Figure 15-2: ODL Schema for university database (cont.)

```
class Student {
  ( extent students)
  attribute string name;
  attribute Date dateOfBirth;
  attribute Address address;
  attribute Phone phone;
  relationship set (CourseOffering) takes inverse CourseOffering::taken_by;
  short age( );
  float gpa( );
  boolean register_for(string crse, short sec, string term);
};

class CourseOffering {
  ( extent courseofferings)
  attribute string term;
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class Course {
  ( extent courses)
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  relationship set (Course) has_prereqs inverse Course::is_prereq_for;
  relationship set (Course) is_prereq_for inverse Course::has_prereqs;
  relationship list (CourseOffering) offers inverse CourseOffering::belongs_to;
  short enrollment( );
};
```

Operation definition:  
return type, name,  
and argument list.  
Arguments include  
data types and names

# Figure 15-2: ODL Schema for university database (cont.)

```
class Student {
  ( extent students)
  attribute string name;
  attribute Date dateOfBirth;
  attribute Address address;
  attribute Phone phone;
  relationship set (CourseOffering) takes inverse CourseOffering::taken_by;
  short age( );
  float gpa( );
  boolean register_for(string crse, short sec, string term);
};

class CourseOffering {
  ( extent courseofferings)
  attribute string term;
  attribute enum section {1, 2, 3, 4, 5, 6, 7, 8};
  relationship set (Student) taken_by inverse Student::takes;
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  short enrollment( );
};

class Course {
  ( extent courses)
  attribute string crse_code;
  attribute string crse_title;
  attribute short credit_hrs;
  relationship set (Course) has_prereqs inverse Course::is_prereq_for;
  relationship set (Course) is_prereq_for inverse Course::has_prereqs;
  relationship list (CourseOffering) offers inverse CourseOffering::belongs_to;
  short enrollment( );
};
```

**relationship sets** indicate 1:N relationship to an *unordered* collection of instances of the other class

**inverse** establishes the bidirectionality of the relationship

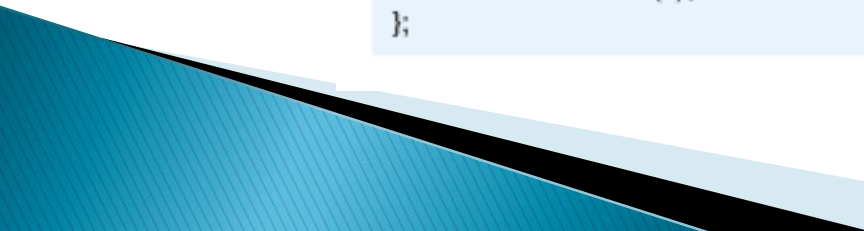




Figure 15-2: ODL Schema for university database (cont.)

```
class Student {
  ( extent students)
  attribute string name;
  attribute Date dateOfBirth;
  attribute Address address;
  attribute Phone phone;
  relationship set (CourseOffering) takes inverse CourseOffering::taken_by;
  short age( );
  float gpa( );
  boolean register_for(string crse, short sec, string term);
};

class CourseOffering {
  ( extent courseofferings)
  attribute string term;
  attribute enum section {1, 2, 3, 4, 5, 6, 7, 8};
  relationship set (Student) taken_by inverse Student::takes;
  relationship Course belongs_to inverse Course::offers;
  short enrollment( );
};

class Course {
  ( extent courses)
  attribute string crse_code;
  attribute string crse_title;
  attribute short credit_hrs;
  relationship set (Course) has_prereqs inverse Course::is_prereq_for;
  relationship set (Course) is_prereq_for inverse Course::has_prereqs;
  relationship list (CourseOffering) offers inverse CourseOffering::belongs_to;
  short enrollment( );
};
```

**relationship list** indicates 1:N relationship to an *ordered* collection of instances of the other class

# Figure 15-2: ODL Schema for university database (cont.)

```
class Student {
  ( extent students)
  attribute string name;
  attribute Date dateOfBirth;
  attribute Address address;
  attribute Phone phone;
  relationship set (CourseOffering) takes inverse CourseOffering::taken_by;
  short age( );
  float gpa( );
  boolean register_for(string crse, short sec, string term);
};

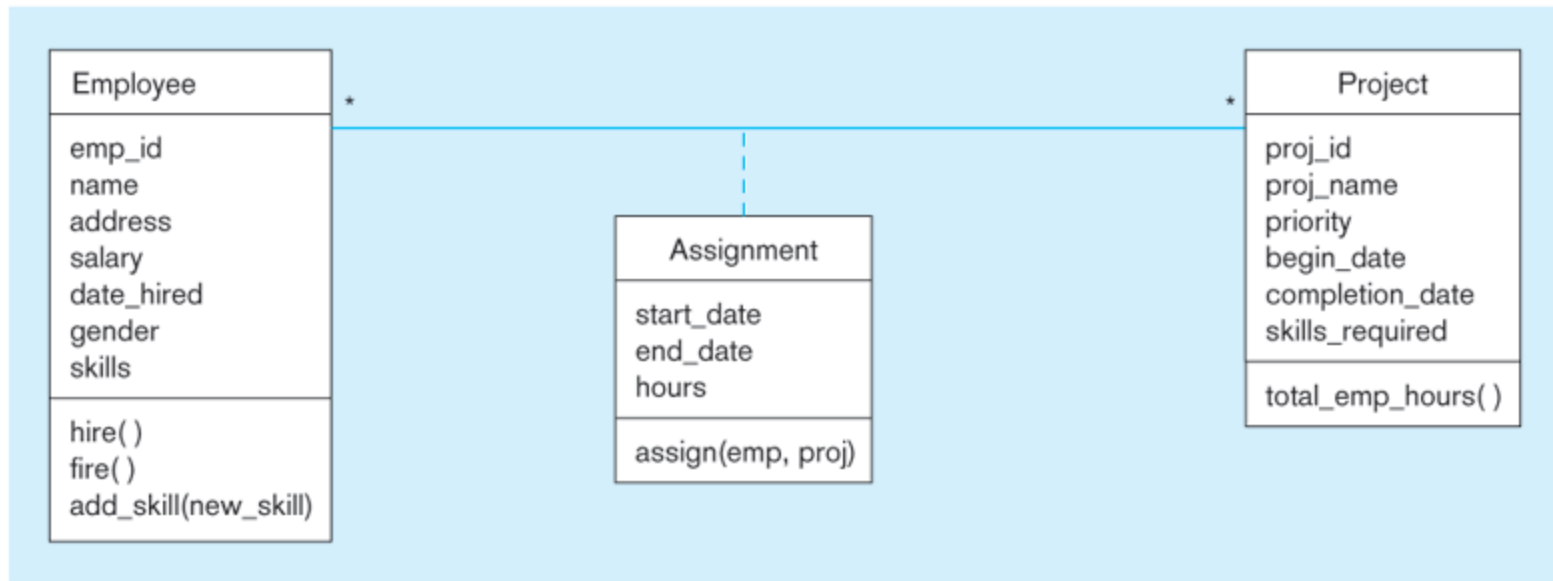
class CourseOffering {
  ( extent courseofferings)
  attribute string term;
  attribute enum section {1, 2, 3, 4, 5, 6, 7, 8};
  relationship set (Student) taken_by inverse Student::takes;
  relationship Course belongs_to inverse Course::offers;
  short enrollment( );
};

class Course {
  ( extent courses)
  attribute string crse_code;
  attribute string crse_title;
  attribute short credit_hrs;
  relationship set (Course) has_prereqs inverse Course::is_prereq_for;
  relationship set (Course) is_prereq_for inverse Course::has_prereqs;
  relationship list (CourseOffering) offers inverse CourseOffering::belongs_to;
  short enrollment( );
};
```

**relationship** indicates N:1 relationship to an instance of the other class

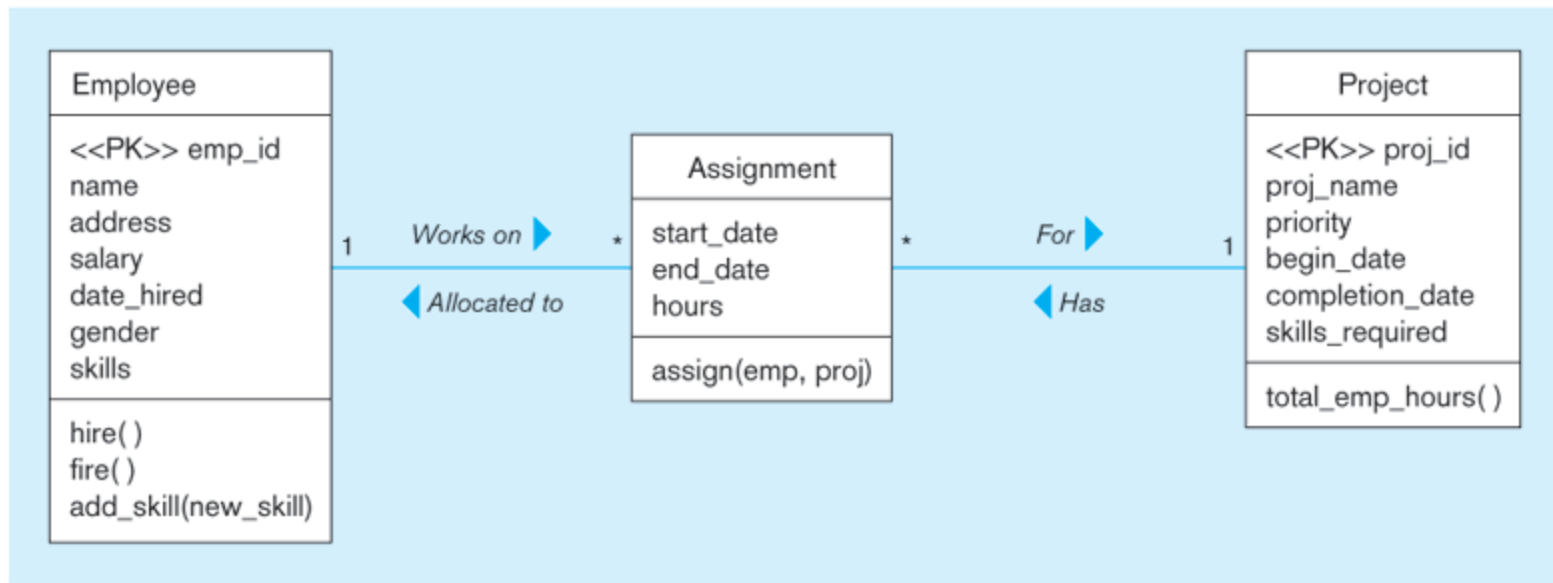
relationship Course belongs\_to inverse Course::offers;

**Figure 15-3a** UML class diagram for an employee project database -  
Many-to-many relationship with an association class



In order to capture special features of assignment, this should be converted into two 1:N relationships

**Figure 15-3b** UML class diagram for an employee project database -  
Many-to-many relationship broken into two one-to-many relationships



```

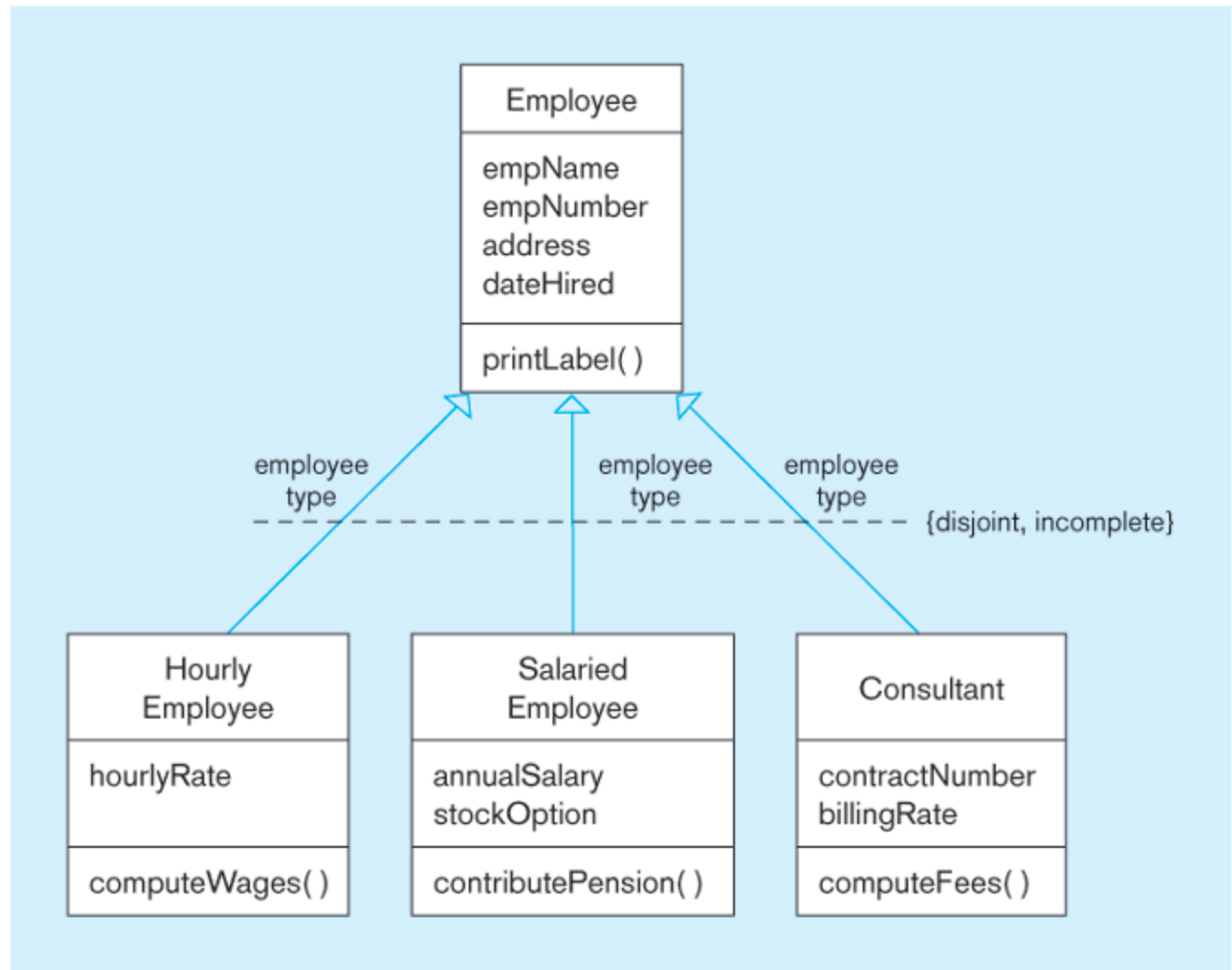
class Employee {
    (extent employees
    key emp_id)
    .....
    attribute set <string> skills_required;
};

```

Note:  
key indicates identifier  
(candidate key)

Note: attribute set indicates a  
multivalued attribute

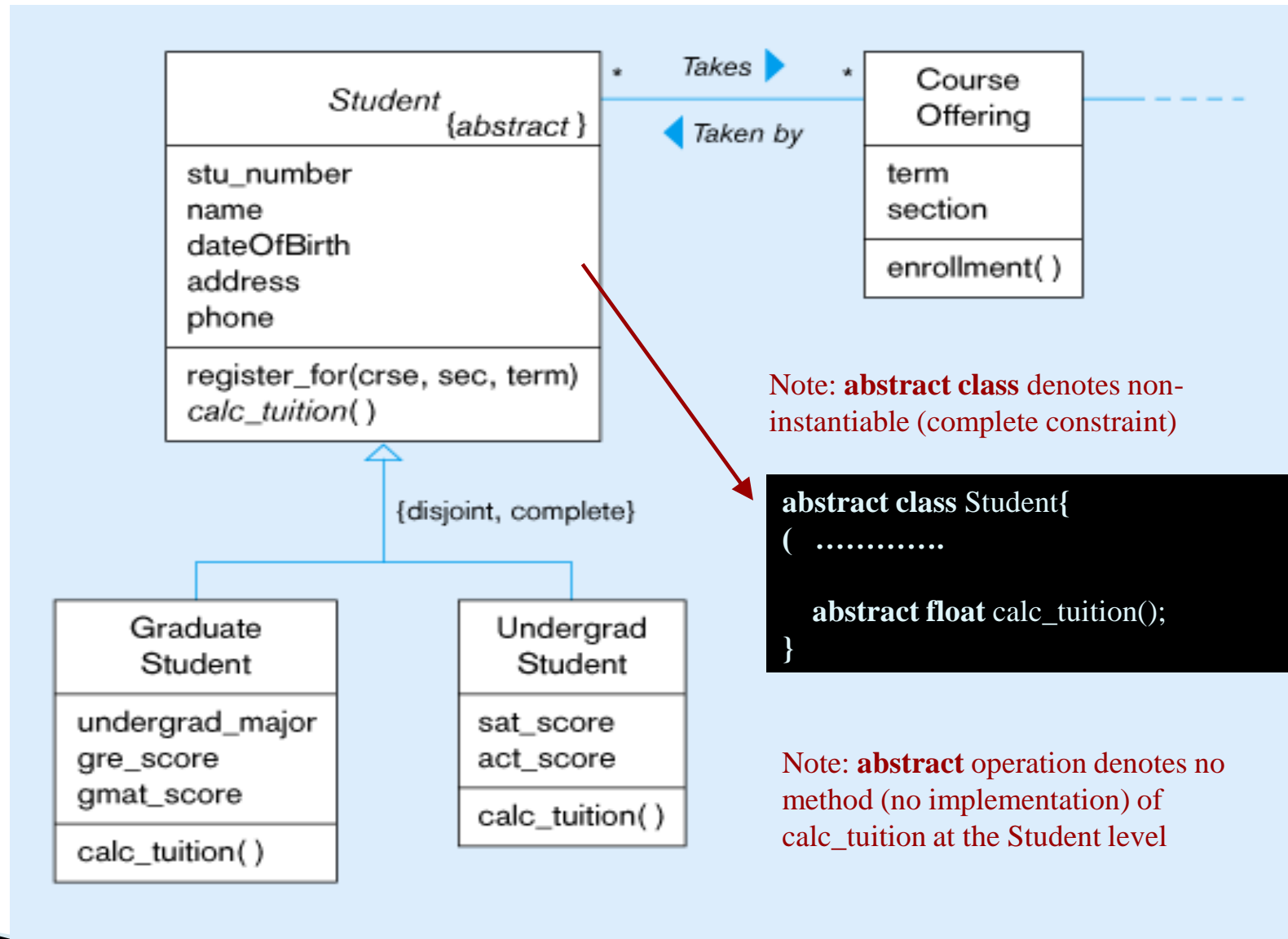
**Figure 15-4** UML class diagram showing employee generalization



Note:  
**extends**  
denotes  
subclassing

```
class HourlyEmployee
  extends Employee{
  ( .....
  .....
  }
```

Figure 15-5: UML class diagram showing student generalization



Note: **abstract class** denotes non-instantiable (complete constraint)

```

abstract class Student{
( .....
    abstract float calc_tuition();
}
  
```

Note: **abstract operation** denotes no method (no implementation) of `calc_tuition` at the Student level

# Creating Object Instances

- ▶ Specify a tag that will be the object identifier
  - MBA699 course ();
- ▶ Initializing attributes:
  - Cheryl student (name: “Cheryl Davis”, dateOfBirth:4/5/77);
- ▶ Initializing multivalued attributes:
  - Dan employee (emp\_id: 3678, name: “Dan Bellon”, skills {“Database design”, “OO Modeling”});
- ▶ Establishing links for relationship
  - Cheryl student (takes: {OOAD99F, Telecom99F, Java99F});

# Querying Objects in the OODB

- ▶ Object Query Language (OQL)
- ▶ ODMG standard language
- ▶ Similar to SQL-92
- ▶ Some differences:
  - Joins use class's relationship name:
    - Select x.enrollment from courseofferings x, *x.belongs\_to* y where y.crse\_course = "MBA 664" and x.section = 1;
  - Using a set in a query
    - Select emp\_id, name from employees where *"Database Design" in skills;*



# Current ODBMS Products

- ▶ Rising popularity due to:
  - CAD/CAM applications
  - Geographic information systems
  - Multimedia
  - Web-based applications
  - Increasingly complex data types
- ▶ Applications of ODBMS
  - Bill-of-material
  - Telecommunications navigation
  - Health care
  - Engineering design
  - Finance and trading

**Table 15-1** ODBMS Products

<i>Company</i>	<i>Product</i>	<i>Website</i>
GemStone Systems	GemStone	<a href="http://www.gemstone.com">www.gemstone.com</a>
neoLogic	NeoAccess	<a href="http://neologic.com">neologic.com</a>
Object Design	ObjectStore	<a href="http://www.odi.com">www.odi.com</a>
Objectivity	Objectivity/DB	<a href="http://www.objectivity.com">www.objectivity.com</a>
POET Software	POET Object Server	<a href="http://www.poet.com">www.poet.com</a>
Versant	Versant ODBMS	<a href="http://www.versant.com">www.versant.com</a>
<i>Other Links Related to ODBMS Products</i>		
Barry & Associates		<a href="http://www.odbmsfacts.com">www.odbmsfacts.com</a>
Doug Barry's <i>The Object Database Handbook</i>		<a href="http://wiley.com">wiley.com</a>
Object database newsgroup		<a href="mailto:news://comp.databases.object">news://comp.databases.object</a>
Rick Cattell's <i>The Object Database Standard ODMG 3.0</i>		<a href="http://www.mkp.com">www.mkp.com</a>
Object Database Management Group		<a href="http://www.odmg.org">www.odmg.org</a>
Chaudhri and and Zicarl's <i>Succeeding with Object Databases</i>		<a href="http://www.wiley.com/compbooks/chaudhri">www.wiley.com/compbooks/chaudhri</a>