ID2212 Network Programming with Java
Lecture 9

Java Database Connectivity (JDBC)
Java Persistence API (JPA)

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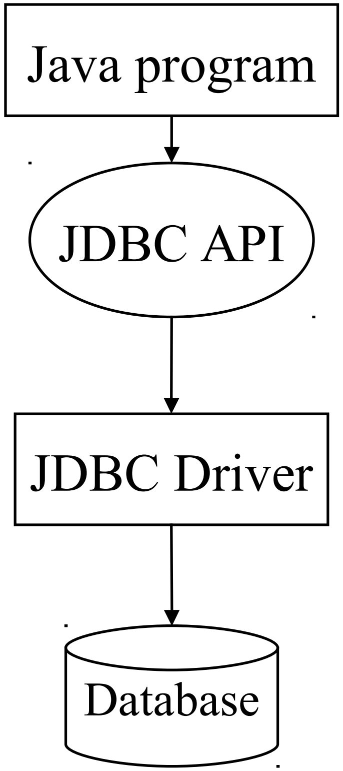
JDBC: Java Database Connectivity

`java.sql`

https://docs.oracle.com/javase/8/docs/technotes/guides/jdbc/index.html

Java Database Connectivity (JDBC)

- An API for unified connectivity to relational databases
  - Establish a connection with a data source
  - Execute SQL queries on the data source
  - Get and process results



Database

- A ***database*** is essentially a smart container for tables.
- A ***table*** is a named container comprised of rows.
- A ***row*** is (conceptually) a container comprised of columns.
- A ***column*** is a single data item having a name, type, and value.

SQL

- SQL (Structured Query Language)
  - An industry-standard language for creating, updating and, querying relational DBMS.
  - Developed by IBM in the 1970s
  - A single SQL statement can be very expressive and can initiate high-level actions, such as sorting and merging.

SQL Primer

- Create a table in SQL:

```
CREATE TABLE <table name>  (<column element> [,
  <column element>]...)
```

  - where `column element` is of the form:

```
<column name> <data type>  [DEFAULT <expression>] [<column
  constraint> [, <column constraint>]...]
```

  - where `column constraint` is of the form:

```
NOT NULL | UNIQUE | PRIMARY KEY
```

  - Example:

```
CREATE TABLE participants (ID char(5), NAME char(64), GENDER
  char(1), COUNTRY char(32), BIRTHDAY date, HEIGHT double,
  WEIGHT double, SUBJECT char(32));
```

- Drop a table:

```
DROP TABLE <table name>
```

SQL Primer (cont)

- Retrieve a set of columns from one or more tables:

```
SELECT [ALL | DISTINCT] <select list>  FROM <table reference
  list>
  WHERE <search condition list>  [ORDER BY <column
  designator>
  [ASC | DESC] [, <column designator> [ASC | DESC]]...]
```

  - Example:

```
SELECT NAME, COUNTRY from participants WHERE GENDER=‘F’;
```

SQL Primer (cont)

- Insert rows:

```
INSERT INTO <table name>  [(<column name> [, <column
  name>]...)] VALUES (<expression> [,
  <expression>]...)
```

  - Example:

```
INSERT INTO participants VALUES  (50044, ‘Wahlström,
  Robert’, ‘M’,’Sweden’, 1979-05-03, 177.0, 61.0,
  ‘Skijumping’);
```

- Update rows:

```
UPDATE <table name> SET <column name = {<expression>
  | NULL} [, <column name = {<expression> | NULL}]...
  WHERE <search condition>
```

- Delete rows:

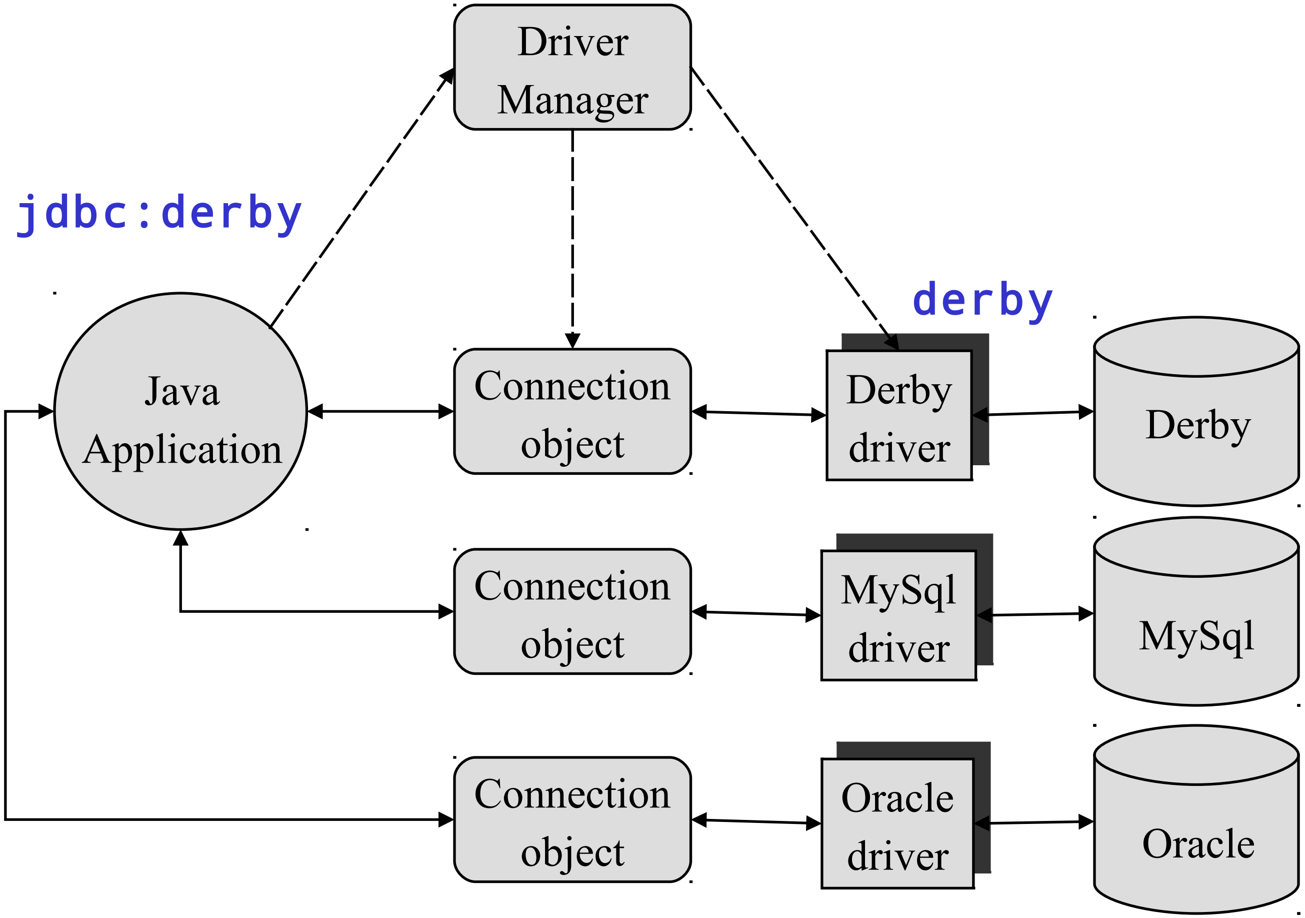
```
DELETE FROM <table name> WHERE <search condition>
```

JDBC Code Fragment

```
// Connect to the data source
Connection connection =
DriverManager.getConnection(
   “jdbc:derby://localhost:1527/mydb”, “user”,
“pass”);
// Create SQL statement
Statement stmt = connection.createStatement();
// Send a query to the data source, get results
ResultSet rs = stmt.executeQuery(“SELECT a, b, c
FROM Table1”);
// Process results
      while (rs.next()) {
              int x = rs.getInt(“a”);
              String s = rs.getString(“b”);
              float f = rs.getFloat(“c”);
      }
```

JDBC Programming Concepts

- Data Source
- Driver
- Driver Manager
- Connection
- Statement
- Result set
- Metadata
- Transactions



A Data Source

- A database, a file system, a (tab-separated-value) file.
- A data source is pointed to by an URL of the form `jdbc:<Sub-Protocol>:<Datasource-Name>`
  - For example:
    - `jdbc:derby://localhost:1527/myDataBase`
    - `jdbc:mysql://localhost:3306/myDataBase`
  - A sub-protocol name
    - indicates the type of data source, e.g. `derby`
    - defines a driver to handle the data source.
    - used by DriverManager to lookup a driver.
- User name and password might be required to connect to the data source.

A JDBC Driver

- An object that opens connection to a data source and handles the connection.
- A JDBC driver class
  - implements the JDBC `Driver` interface and can convert program (and typically SQL) requests for a particular database.
- Loading a driver class. Two options
  - Put name of the driver in the jdbc.drivers System property, e.g. `jdbc.drivers=org.apache.derby.jdbc.ClientXADataSource`
    - Will be checked by the DriverManager
  - Load class explicitly, e.g.

```
Class.forName(“org.apache.derby.jdbc.ClientXADataSource”);
```

Driver Manager

- Driver Manager
  - Parses URL of a data source, look for a driver to handle the source, returns a Connection object, e.g.

```
Connection connection =
  DriverManager.getConnection (url,
  username, password);
```

Connection

- Represents a session with a data source.
- Used
  - to create and prepare SQL statements and calls,
  - to retrieve the meta data regarding the connection's database,
  - to commit or to drop (rollback) all changes made to the connection's database.
- Any number of SQL statements can be executed over the connection.
- An application can have one or more connections to a single data source or to several databases.

Connection (cont)

- To connect to a data source, you supply the following information
  - URL of a data source (database, file),
  - class names of drivers,
  - user name and password (both are optional)
- This info can be
  - "hard-coded" in the code,
  - passed as arguments to the application,
  - loaded as Properties at run time from a configuration file of the form:

```
jdbc.drivers=org.apache.derby.jdbc.ClientXADataSource
jdbc.url=jdbc:derby://localhost:1527/myDataBase
db.username=user
db.password=pass
```

Using Configuration Properties. Connecting to a Data Source.

```
FileInputStream in = new FileInputStream(configFileName);
Properties props = new Properties();
props.load(in);

String drivers = props.getProperty("jdbc.drivers");
System.setProperty("jdbc.drivers", drivers);
String url = props.getProperty("jdbc.url");
String username = props.getProperty("jdbc.username");
String password = props.getProperty("jdbc.password");
in.close();
Connection connection =
    DriverManager.getConnection(url, username, password);
```

Database Meta-Data

- If necessary, query the Connection for meta-data about the database structure:
  - tables, supported SQL grammar, stored procedures,
  - capabilities of the connection (e.g. supported isolation levels), etc.

```
DatabaseMetaData dbm = connection.getMetaData();
```

- The DatabaseMetaData interface defines various get and checking methods, e.g.

```
ResultSet rs =
    dbm.getTables(null, null, null, null);
System.out.println(“Table Name\tTable Type”);
while (rs.next()) {
   System.out.println(rs.getString(3) + “\t” +
   rs.getString(4));
}
```

Statement

- Create a SQL statement object from the Connection object for sending commands and SQL statements to the data source.
  - Statement is like an envelope for SQL,
  - Connection is like the transport to deliver the statement to the driver,
  - The driver forwards the SQL to the database and returns results.

Statement (cont'd)

- Create a statement using the `Connection` object
  - `createStatement()`
    - Creates a `Statement` object for sending SQL statements to the database
  - `prepareStatement(String sql)`
    - Creates a `PreparedStatement` object for sending parameterized SQL statements to the database.
  - `prepareCall(String sql)`
    - Creates a `CallableStatement` object for calling stored procedures.

Executing A Statement

- Four methods of `Statement` for sending SQL to the database and executing database calls:
  - `ResultSet executeQuery(String sql)`
    - Executes an SQL statement that returns a single ResultSet object.
  - `int executeUpdate(String sql)`
    - Executes an SQL INSERT, UPDATE or DELETE statement.

Result Set

- Result Set
  - A table of data representing a database result set, which is usually generated by executing a statement that queries the database.

```
Statement stmt = con.createStatement();
ResultSet rs =
   stmt.executeQuery("SELECT a, b FROM TABLE2”);
```

  - Organized into logical rows and columns of data.
  - Maintains a cursor to a current row

Result Set (cont'd)

- The `ResultSet` interface contains methods for
  - getting values from the set by name or position,
  - traversing to the next, previous, first, and last row of the set,
  - deleting current row, jumping to the insert row, and so on,
  - getting result set meta-data.

Result Set Meta-Data

- Result set meta-data
  - number of columns, names and types of columns.

    Get from the result set of an execute method. For example:

```
ResultSetMetaData rsmd = rs.getMetaData();
int columnCount = rsmd.getColumnCount();
// Iterate through the columns
// and print each column name
for (int i = 1; i <= columnCount; i++) {
   String columnName = rsmd.getColumnName(i);
   System.out.print(columnName +"\t");
}
System.out.println("");
```

Iterating Though A Result Set

```
// Execute a SELECT query, get result set and
// meta-data.
ResultSet rs = stmt.executeQuery(sqlStr);
ResultSetMetaData rsmd = rs.getMetaData();
// Get the column count.
int columnCount = rsmd.getColumnCount();
// Iterate through each row printing the values.
// Print a $ if the column type is CURRENCY.
while (rs.next()) {
   for (int i =1; i <= columnCount; i++) {
      if (rsmd.getColumnTypeName(i).
               equals("CURRENCY")) {
         System.out.print("$");
      }
      System.out.print(rs.getString(i) +"\t");
   }
   System.out.println("");
}
```

PreparedStatement

- Represents a precompiled SQL statement prepared using the Connection object.

```
PreparedStatement pstmt = con.prepareStatement(
"UPDATE EMPLOYEES SET SALARY = ? WHERE ID = ?”);
pstmt.setBigDecimal(1, 153833.00);
pstmt.setInt(2, 110592);
int insCount = pstmt.executeUpdate();
System.out.println( “Updated ” + insCount +“rows”);
```

PreparedStatement, Cont'd

- `PreparedStatement` has the following advantages above `Statement`:
- Faster execution since the statement is not interpreted and compiled at each call.
- More secure since SQL injection is not possible when using a prepared statement.

Summary

- Steps for accessing and working with a data source
  - Load (specify) a JDBC driver, URL of the source, username and password
  - Create a connection to the data source pointed to by the URL:

```
Connection con =
  DriverManager.getConnection(url, user, password)
```

  - If necessary query the Connection for meta-data about the database:

```
DatabaseMetaData dbm = con.getMetaData();
```

  - Create a SQL statement from the connection

```
Statement stmt = con.createStatement();
```

  - Use the statement object to execute SQL query(ies)

```
ResultSet rs =
  stmt.executeQuery("SELECT a, b FROM TABLE2”);
```

  - Check for SQLWarning, if any, or ignore

```
SQLWarning warning = stmt.getWarnings();
```

  - Get and process the results from the query
  - Finally close the database connection: `con.close();`

Transactions

- A transaction is a group of operations that are:
  - **Atomic**, either all or no of the operations are performed.
  - **Consistent**, The data is left in a valid state.
  - **Isolated**, transactions do not affect each other even if they are concurrent.
  - **Durable**, once a transaction has finished the data is saved, no matter what happens afterwards.
- These four properties are referred to as ACID.

Transactions, Cont'd

- There are two operations that can end a transaction:
  - **Commit**, all changes made during the transaction are saved permanently.
  - **Rollback**, All changes made during the transaction are unmade and the data is left in the same state it had before the transaction started.

Auto Commit

- By default, an active database connection is set to ***auto commit***
  - all connection's SQL statements are executed and committed as individual transactions.
  - The commit occurs when the statement completes or the next execute occurs,
    - If a statement returns a ResultSet, the statement completes when the last row of the ResultSet has been retrieved or the ResultSet has been closed.

Managing Transactions

- To enable/disable auto commit, call on the `Connection`
  - `setAutoCommit(boolean)`
- If auto commit is disabled, call on the `Connection`
  - `rollback()`
    - To drop all changes made since the previous commit/rollback and releases any database locks currently held by the Connection.
  - `commit()`
    - To make all changes made since the previous commit/rollback permanent and releases any database locks currently held by the Connection.

Transaction Isolation Level

- Specifies to which extent transactions avoid sharing data. Different isolation levels allow different sets of the following phenomena.
  - ***Phantom read*** - finding data (in where clause) added by another transaction
  - ***Dirty read*** - reading data not committed yet by another transaction
  - ***Non-repeatable read*** - rereading different data within the same transaction

Transaction Isolation Level (cont'd)

- To control isolation level of the Connection, use
  - `getTransactionIsolation()`
  - `setTransactionIsolation(int level)`
- May use also

```
DatabaseMetaData.
  supportsTransactionIsolationLevel(int)
```

Transaction Isolation Level (cont'd)

- Levels are defined as integer constants in the `Connection` interface

`TRANSACTION_NONE`

- Transactions are not supported.

`TRANSACTION_READ_UNCOMMITTED`

- Dirty reads, non-repeatable reads and phantom reads can occur.

`TRANSACTION_READ_COMMITTED`

- Dirty reads are prevented; non-repeatable and phantom reads can occur.

`TRANSACTION_REPEATABLE_READ`

- Dirty and non-repeatable reads are prevented; phantom reads can occur.

`TRANSACTION_SERIALIZABLE`

- Dirty reads, non-repeatable reads and phantom reads are prevented.

JPA: Java Persistence API

`javax.persistence`

JPA Home Page:

`https://docs.oracle.com/javaee/7/tutorial/partpersist.htm#BNBPY`

What is JPA?

- Persists plain Java objects, no need to write SQL
- Object/relational (O/R) mapping, relations between objects are managed by JPA.
  - Possible to store and load entire object graphs with one command.
- Uses post-compilation (when needed)

The first example (1/2)

- The **`@Entity`** and **`@Id`** annotations are all that is needed to turn a plain Java object into an entity managed by JPA.

```
package account;

import javax.persistence.Entity;
import javax.persistence.Id;

@Entity
public class Account {
    @Id
    private int acctNo;
    private String firstName;
    private String lastName;
    private int balance;
```

The first example (2/2)

```
public Account() {}

public Account(int acctNo, String firstName,
               String lastName, int balance) {
   this.acctNo = acctNo;
   this.firstName = firstName;
   this.lastName = lastName;
   this.balance = balance;
}
public int getAcctNo() {
   return acctNo;
}

// More business methods.
```

Main JPA Concepts

- Entity
  - A persistent abstraction.
  - Represented as Java class in the program and (typically but not necessarily) as table in the database.
  - An *entity instance* is a Java object in the program and a row in the database table(s).
  - Either fields or properties (JavaBeans style) are persisted. If fields or properties are persisted is decided by the location of annotations (close to fields or close to properties).
  - Must have no-argument `public` or `protected` constructor.
  - Fields may not be `public` and may not be accessed by other objects than the entity instance itself.
  - Must have the `@Entity` annotation.
  - Object/Relational (O/R) mapping with annotations to map objects to underlying relational data store.

Main JPA Concepts (cont)

- Primary key
  - Identifies an entity instance, must be unique for each instance.
  - A simple (non-composite) primary key must correspond to a single persistent field or property of the entity class.
  - The `@Id` annotation is used to denote a simple primary key.
- Context
  - A set of managed entity instances that exist in a particular data store.
  - The scope under which entity instances exist.
- Entity manager
  - An interface that defines the methods used to interact with the context, for example `create`, `remove` and `find`.
  - Each `EntityManager` instance is associated with a single context.

Main JPA Concepts (cont)

- Persistence unit
  - Defines the entities that are managed by an entity manager.
  - Defines where to store the entities persistently.
- Relation
  - A relation between entity instances that is persisted together with the entity instances.
- Query
  - The data store can be searched for entity instances using the `find` method in `EntityManager` or using the JPA Query Language (JPQL).
- Transaction
  - JPA is transaction aware. Transaction can be either container-managed or application-managed.

How to Start JPA

Applications that are not container-managed, for example Java SE applications, must use the classes `javax.persistence.Persistence` and `javax.persistence.EntityManagerFactory` to create an entity manager:

```
EntityManagerFactory emf =
  Persistence.createEntityManagerFactory("MyPU");
EntityManager em = emf.createEntityManager();
```

Entity Instance's Life cycle

- The life cycle of an entity instance is managed by the **`EntityManager`**.
- Entity instances are in one of four states: *new*, *managed*, *detached*, or *removed*.

Entity Instance's Life cycle (cont)

- ***New*** entity instances have no persistent identity and are not yet associated with a persistence context.
- ***Managed*** entity instances have a persistent identity and are associated with a persistence context.

Entity Instance's Life cycle (cont)

- ***Detached*** entity instances have a persistent identify and are not currently associated with a persistence context.
- ***Removed*** entity instances have a persistent identity, are associated with a persistent context, and are scheduled for removal from the data store.

How to Create a New Entity

```
@PersistenceContext
  EntityManager em;
  ...
  public LineItem createLineItem(Order order, Product product,
                                 int quantity) {
      LineItem li = new LineItem(order, product,
                                 quantity); // new
      order.getLineItems().add(li);
      em.persist(li); // managed
  }
```

The entity (`li`) is *new* after this statement.

The entity is *managed* after this statement.

How to Find and Remove an Existing Entity

```
public void removeOrder(Integer orderId) {
  try {
      Order order = em.find(Order.class,
                                   orderId);
      em.remove(order);
  }
```

- Entities are looked up with the **`EntityManager`** method **`find`** (more on queries below).
- Entities are removed with the **`EntityManager`** method **`remove`**.

Container-Managed Transactions

- The preferred way.
- Can only be used when JPA entities stays in a transaction aware container (e.g EJB or Spring)
- Transactions propagate from the calling container and are not handled by JPA code.
- Use declarative transaction demarcation in the container.

Application-Managed Transactions

- The only choice when there is no transaction aware container. This is the case with plain Java SE applications.
- Transaction must be started and stopped programmatically through the `EntityTransaction` interface.
- Easy to make mistakes!

Application-Managed Transaction Example

```
EntityManager em = emFactory.createEntityManager();
EntityTransaction transaction = em.getTransaction();
transaction.begin();

// Update entities here.

em.getTransaction().commit();
```

Synchronization With Database

- The state of persistent entities is synchronized to the database when the transaction with which the entity is associated commits.
- To force synchronization of the managed entity to the database before transaction commit, invoke the `flush` method of the `EntityManager`.

Relationships

- Relationships are persisted by JPA and recreated when an entity instance is read from the database.
- Can be unidirectional or bidirectional.
- Can be one-to-one, one-to-many, many-to-one or many-to-many
- Entity updates (adding/removing entities or changing entity state) can cascade along relations when synchronizing with the database.

Relationship Example

```
@Entity
public class Employee {
  private Cubicle assignedCubicle;

  @OneToOne
  public Cubicle
getAssignedCubicle() {
    return assignedCubicle;
  }

  public void setAssignedCubicle(
     Cubicle cubicle) {
        assignedCubicle = cubicle;
  }
    ...
}
```

```
@Entity
public class Cubicle {
private Employee residentEmployee;

@OneToOne(mappedBy="assignedCubicle")
public Employee getResidentEmployee()
{
    return residentEmployee;
}

public void setResidentEmployee(
  Employee employee) {
        residentEmployee = employee;
}
    ...
}
```

Relationship Direction

- Unidirectional relationships can only be navigated in one direction.
  - Have relationship annotation only on one side.
- Bidirectional relationships can be navigated in both directions.
  - Have relationship annotations on both sides.
  - Inverse (not owning) side specifies that it is mapped by the property or field on the owning side: `@OneToOne(mappedBy="assignedCubicle")`

Persisting Relationships

- The relationship is persisted based on the owning side.
- The owning side has the foreign key.

Relationship Multiplicities

- The following annotations exist:
  - `OneToOne`
  - `OneToMany`
  - `ManyToOne`
  - `ManyToMany`
- For `OneToOne` and `ManyToMany` relationships, any side may be the owning side.
- For `OneToMany` and `ManyToOne` relationships, the many side must be the owning side.

OneToMany/ManyToOne Example (1/2)

```
@Entity
public class Employee {
    private Department department;

    @ManyToOne
    public Department getDepartment() {
        return department;
    }

    public void setDepartment(Department department)
{
        this.department = department;
    }
    ...
}
```

OneToMany/ManyToOne Example (2/2)

```
@Entity
public class Department {
    private Collection<Employee> employees = new HashSet();

    @OneToMany(mappedBy="department")
    public Collection<Employee> getEmployees() {
        return employees;
    }

    public void setEmployees(Collection<Employee> employees) {
        this.employees = employees;
    }
    ...
}
```

Cascading Updates

- Updates to the database may cascade along relationships.
  - Specified by the `cascade` element of the relationships annotations. The following cascade types can be specified:
  - `ALL`, Cascade all operations
  - `MERGE`, Cascade merge operation
  - `PERSIST`, Cascade persist operation
  - `REFRESH`, Cascade refresh operation
  - `REMOVE`, Cascade remove operation

Cascading Updates Example

```
@OneToMany(cascade=ALL,
           mappedBy="customer")
public Set<Order> getOrders() {
    return orders;
}
```

Queries

- Query methods are in the `EntityManager`.
- The `find` method can be used to find instances by primary key:

```
em.find(Order.class, orderId);
```

Java Persistence Query Language, JPQL

- JPQL is a language with many similarities to SQL.
- JPQL is used to create, search, update or delete JPA entities.
- Has object-like syntax, the query below declares the variable `c`, which has the type `Customer` (must be an entity). Then searches for all instances of `Customer` that has the property `name` equal to the parameter `custName`. The `custName` parameter must be assigned a value before the query is executed.

```
SELECT c FROM Customer c
WHERE c.name LIKE :custName
```

JPQL Example 1

- The `createQuery` method is used to create dynamic queries, queries that are defined directly within an application's business logic.

```
public EntityManager em;

public List findWithName(String name) {
   Query query = em.createQuery(
      "SELECT c FROM Customer c WHERE c.name LIKE :custName");
   query.setParameter("custName", name);
   return query.getResultList();
}
```

JPQL Example 2

- The `createNamedQuery` method is used to create static queries, queries that are defined in meta data using the `NamedQuery` annotation.

```
@NamedQuery(
    name="findCustomersByName",
    query="SELECT c FROM Customer c WHERE c.name LIKE :custName"
)

public EntityManager em;

public List findWithName(String name) {
   Query query = em.createNamedQuery("findCustomersByName");
   query.setParameter("custName", name);
   return query.getResultList();
}
```

Criteria API

- The criteria API provides a way to generate queries in an object-oriented way with ordinary method calls, as opposed to the string manipulation used by JPQL.
- The advantage over JPQL is that it is type safe and that it is not required to know field names at compile time.
- The disadvantage is that notably more code is required to generate queries and that it is harder to read the queries.
- The Criteria API is not part of this course.