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Introduction to JPA and Hibernate

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Web Engineering at Vienna University of Technology

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Business Informatics Group

Vienna University of Technology

Web Engineering

Introduction to JPA and Hibernate

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Outline of today's talk

- JDBC

- JPA/Hibernate
  - Relationships
  - Persistence Context/Persistence Unit
  - Entity Manager
  - JPQL
  - Hibernate Criteria API

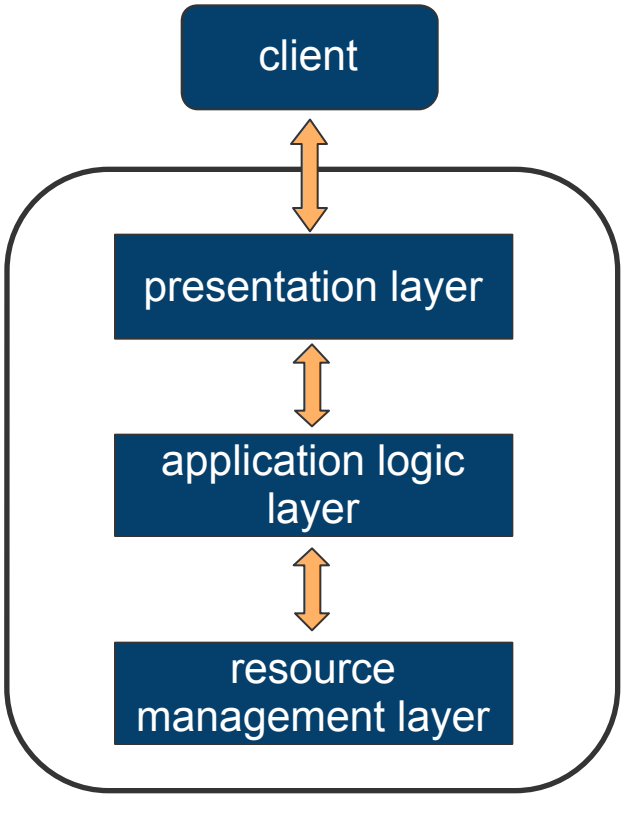
Accompanying examples

https://github.com/pliegl/we2014/tree/master/jpa-sample

Motivation

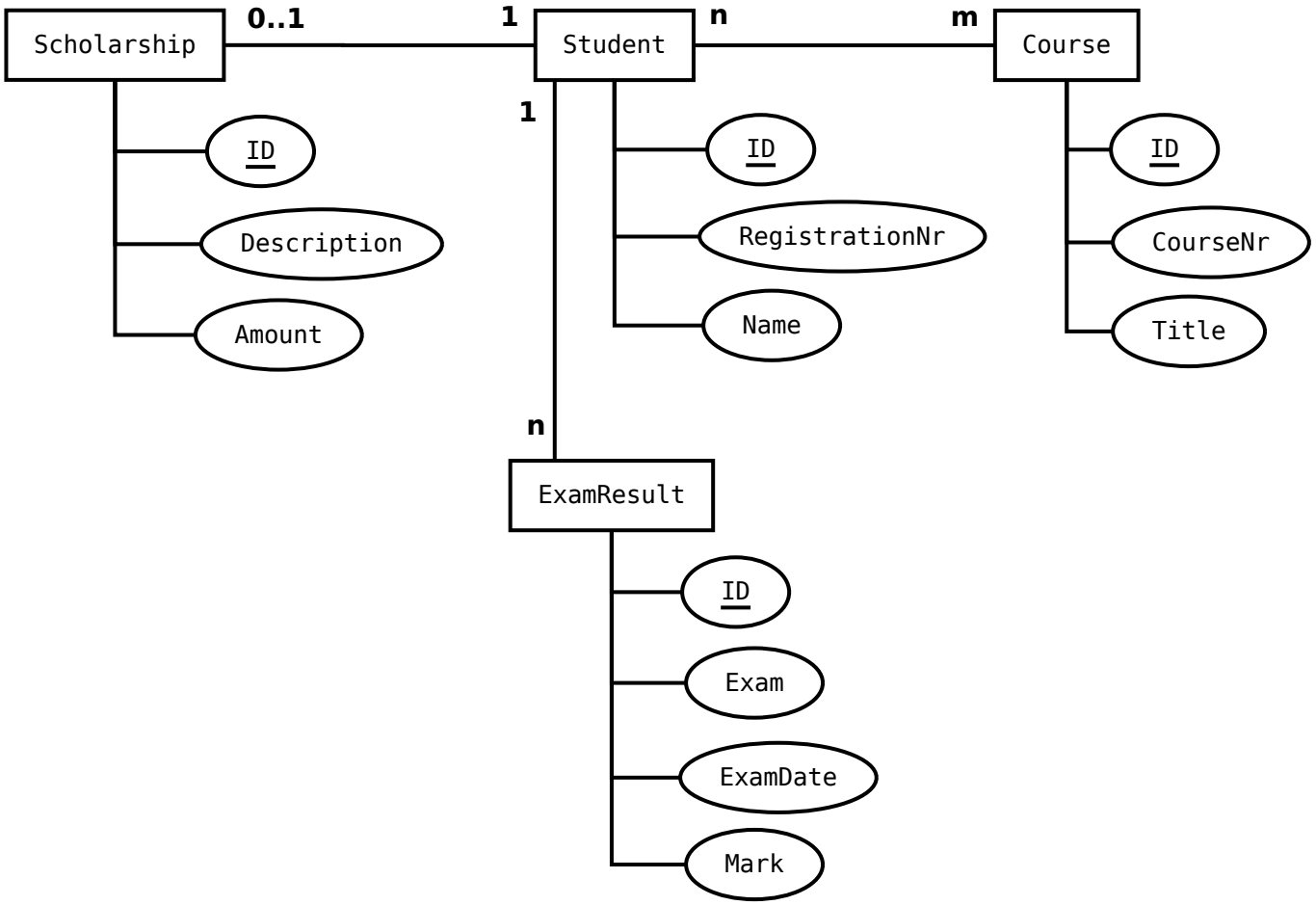
N-Tier Architectures

- Layers of an information system
  - Presentation layer
    - Communication interface to external entities
    - “View” in the model-view-controller
  - Application logic layer (service layer)
    - Implements operations requested by clients through the presentation layer
    - Represents the “business logic”
  - Resource management layer (persistence layer)
    - Deals with different data sources of an information system
    - Responsible for storing and retrieving data



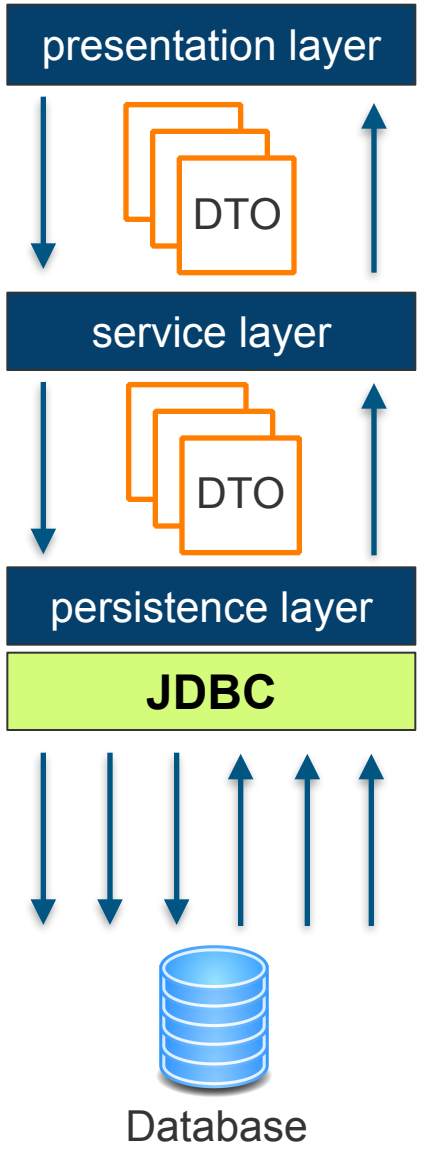
Motivation

Accompanying model



Motivation

Traditional persistence with JDBC



Motivation

JDBC - Java Database Connectivity

- Used to access relational databases from Java programs
- First version released 1996
- Ability to
  - Establish a connection to a database
  - Execute an SQL statement and return results
  - Create parameterized queries
  - Manage database transactions
- Basic Steps
  - Load driver or obtain an already defined data source
  - Establish connection using a JDBC URL
  - Create an **SQL statement** and execute SQL statement
  - If present, process results present in **result sets**
  - Close database resources
  - Commit or rollback transaction, if necessary

http://www.oracle.com/technetwork/java/overview-141217.html

JDBC example

Insert an entry

```
Connection conn = null;
PreparedStatement stmt = null;

try {
        conn = connection();
        stmt = conn.prepareStatement( "INSERT INTO student VALUES(?, ?, ?)" );
        stmt.setInt( 1, student.getId() );
        stmt.setString( 2, student.getMatrNr() );
        stmt.setString( 3, student.getName() );
        stmt.executeUpdate();
        stmt.close();
} catch (Exception e) {
        e.printStackTrace();
} finally {
        if (stmt != null) {
           stmt.close();
        }
        if (conn != null) {
           conn.close();
        }
}
```

JDBC example

Retrieve an entry

```
Connection conn = null;
PreparedStatement stmt = null;
ResultSet rs = null;
try {
        conn = connection();
        stmt = conn.prepareStatement( "SELECT id, matrnr, name FROM student
                                       WHERE id=?" );
        stmt.setInt( 1, id );
        rs = stmt.executeQuery();
        rs.next();

        Student student = new Student();
        student.setId( rs.getInt( 1 ) );
        student.setMatrNr( rs.getString( 2 ) );
        student.setName( rs.getString( 3 ) );

        rs.close();
        stmt.close();
        return student;
} catch (Exception e) {
        e.printStackTrace();
} finally {
        …
}
```


JDBC

Drawbacks

- Verbose JDBC boilerplate code for the various CRUD actions
- Manual mapping of JDBC result sets to the respective Java POJOs
  - Imagine 40 different database tables with 20 attributes each…
- Manual synchronization of Java code in case of database schema changes (e.g., a new field is added to a database table)
  - Manual adaptation of the entire related JDBC Java code necessary

Object Relational Mapping

Reasons for using ORM

- In an application we want to focus on **business concepts**, not on the relational database structure
- Abstract from the “by-hand” communication with the DB (e.g., via JDBC)
- Allow for an automatic synchronization between Java Objects and the underlying database
- Portability
  - ORM should be mostly DB independent (with the exception of some types of features, such as identifier generation)
  - Query abstractions using e.g. JPQL or HQL - the vendor specific SQL is auto-generated
- Performance
  - Object and query caching is automatically done by the ORM

Java Persistence API (JPA)

Introduction

- Specification for the management of persistence and object/relational mapping with Java
  - Persistence: Data objects shall outlive the JVM app
- Objective: provide an object/relational mapping facility for Java developers using a Java domain model and a relational database
  - Map Java POJOs to relational databases (which are one type of persistence)
- Standardized under the Java Community Process Program with contributions from Hibernate, TopLink, JDO, and the EJB community
- Hibernate: Full JPA implementation with additional “native” features, e.g.,
  - HQL (Hibernate Query Language) - similar to JPQL, but with some extensions
  - Criteria API
  - Used version in this course: Hibernate 4.2.12.Final (supports JPA 2.0)

Caveats

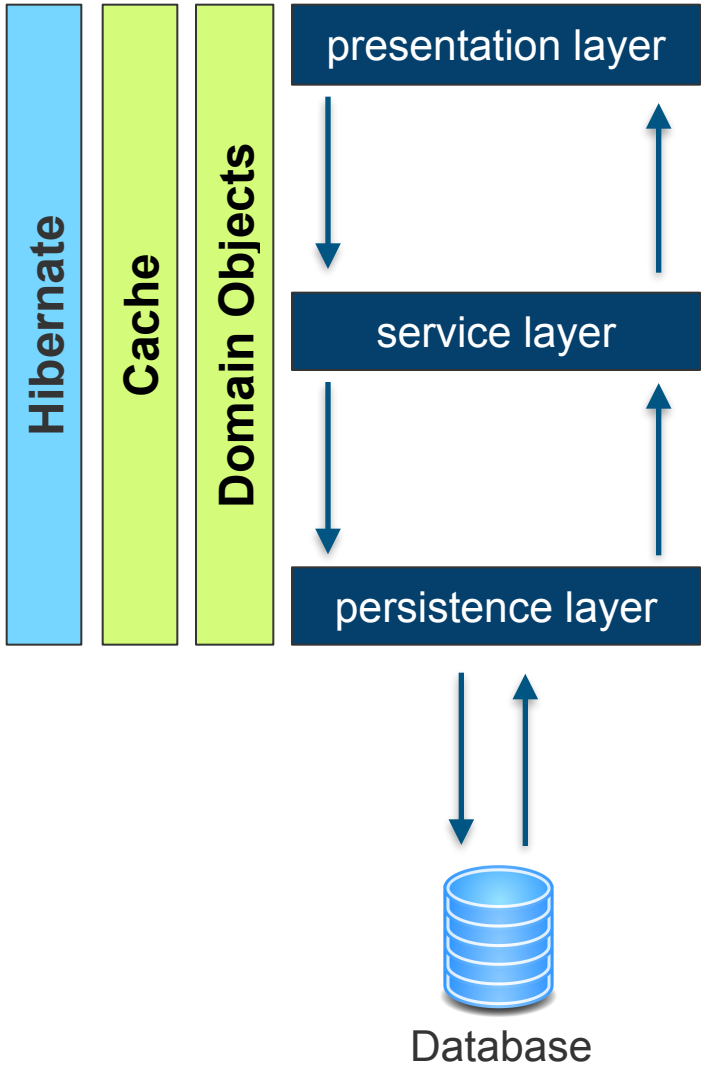
- With JPA/Hibernate lots of “magic” is done under the hood, e.g., SQL-DDL is automatically generated
- Know the database basics first (e.g., from a data engineering course), in order to fully understand what JPA is doing under the hood
- After annotating the classes and running the application check the resulting SQL-DDL (e.g., using the database explorer in IntelliJ or Eclipse)
- When executing SQL-Queries using JPA/Hibernate use the “show SQL queries” feature during development, in order to see what kind of queries are actually executed
  - Set `<property name="hibernate.show_sql" value="true" />` in persistence.xml

Persistent Entities

Basics

- Are POJOs (Plain Old Java Objects)
- Lightweight persistent domain object
- Typically represent a table in a relational database
- Each entity instance corresponds to one row in that table
- Have a persistent identity
- May have both, persistent and transient (non-persistent) state
  - Simple types (primitive data types, wrappers, enums)
  - Composite types (e.g., Address)
  - Non-persistent state (using identifier `transient` or `@Transient` annotation)

Persistence with Hibernate



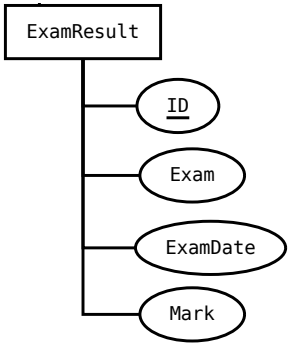
Simple Mapping

Enhance Java domain classes with JPA annotations

```
@Entity
public class ExamResult {

    @Id
    private Long id;

    @Column(name = "prufungsDatum")
    @Temporal(TemporalType.DATE)
    private Date examDate;

    private int mark;

    @Transient
    private String examLocation;
…
}
```

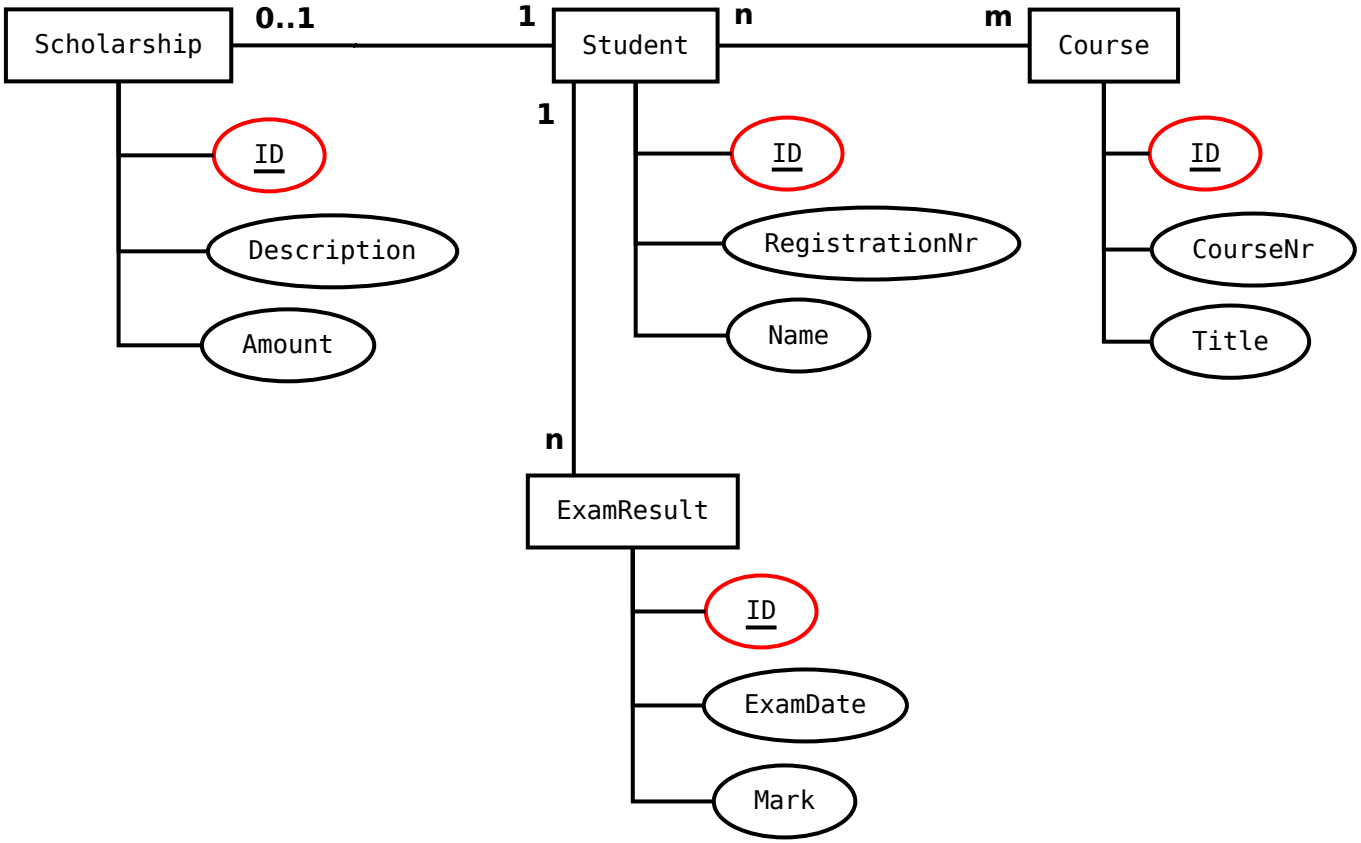
ExamResult		
id	pruefungsDatum	mark

Important annotations	
@Entity	Specifies that the class is an entity
@Id	Specifies the primary key of an entity
@Temporal	Must be specified for fields of type java.util.Date and java.util.Calendar
@TemporalType	Type used to indicate a specific mapping of java.util.Date or java.util.Calendar. Allowed values: - DATE - TIME - TIMESTAMP
@Transient	Specifies that the field is not persistent



Simple Mapping

Inheritance



Simple Mapping

Inheritance

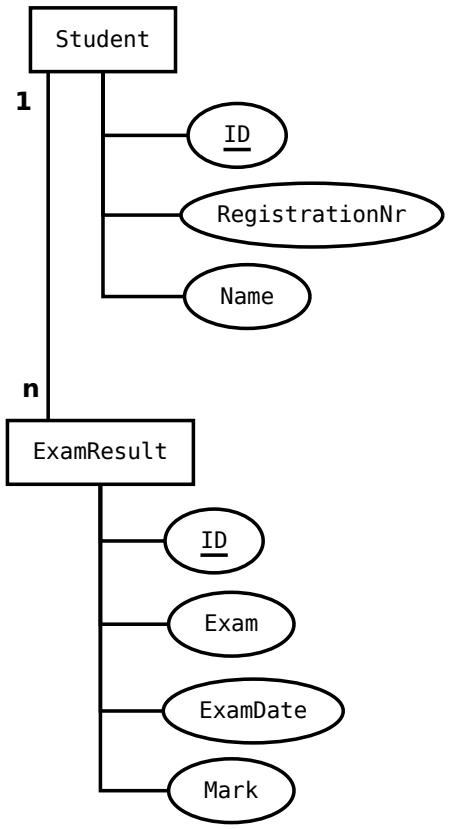
```
@MappedSuperclass
public class BaseEntity {

    @Id
    @GeneratedValue(
     strategy =
     GenerationType.AUTO)
    protected Long id;

    public Long getId() {
        return id;
    }
}
```

Important annotations	
@MappedSuperclass	Designates a class whose mapping information is applied to the entities that inherit from it. A mapped superclass has no separate table defined for it.
@GeneratedValue	The `GeneratedValue` annotation may be applied to a primary key property or field of an entity or mapped superclass in conjunction with the `Id` annotation.

```
@Entity
public class ExamResult extends BaseEntity {

    @Column(name = "prufungsDatum")
    @Temporal(TemporalType.DATE)
    private Date examDate;

    private int mark;

    @Transient
    private String examLocation;

    //Getter and setters omitted

}
```

ExamResult		
id	pruefungsDatum	mark

Object-oriented vs. SQL



OO: **Student** *owns* the **ExamResults**
Usually: no ExamResult without a student

```
public class Student extends BaseEntity {

    private String registrationNumber;
    private String name;
    private List<ExamResult> examResults;
…
}
```

Does not exist in the DB, but is simulated using an SQL query. JPA takes care of that.

```
public class ExamResult extends BaseEntity {

    private Date examDate;
    private String exam;
    private int mark;
    private Student student;
…
}
```

SQL:

- ExamResult contains a foreign key to the Student it belongs to
- The ExamResult owns (contains) the connection
- This is opposite to the OO perspective

Entity relationships

One-to-one, **one-to-many**, **many-to-many**, **many-to-one** relationships among entities

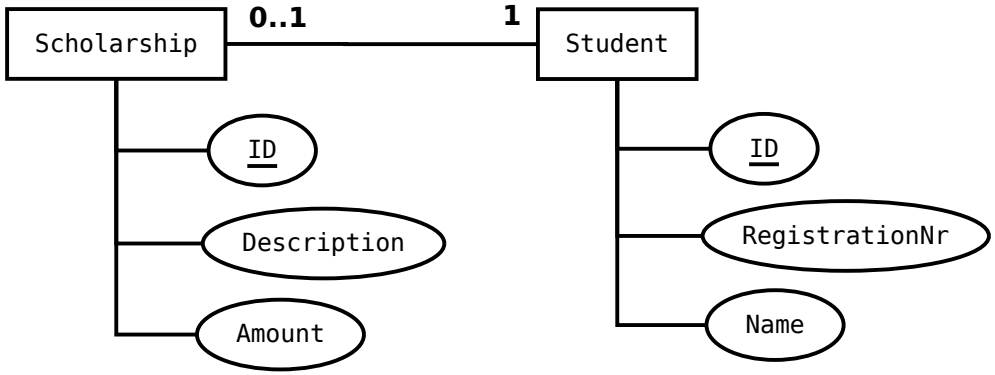
- bi-directional or uni-directional
- Support for different Collection types, e.g., List, Set, Map, etc.

Need to specify the **owning** side in relationships

- Owning side table has the foreign key
- OneToOne relationship - the side where the foreign key is specified
- OneToMany, ManyToOne - the “many” side

Relationship mapping

Example using a unidirectional mapping

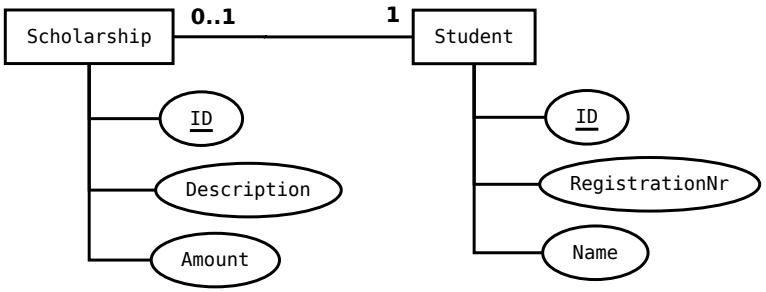


Four different options:

1. Using an embedded table, where Scholarship is the embedded table. (see example)
2. Scholarship and Student are separate tables. The primary key of Scholarship has a foreign key constraint on the primary key of the “owning” Student (using @PrimaryKeyJoinColumn annotation)
3. Scholarship and Student are separate tables. Student holds a foreign key which references the primary key of Scholarship. The foreign key has a unique constraint.
4. Scholarship and Student are separate tables. Scholarship holds a foreign key which references the primary key of Student. The foreign key has a unique constraint. (see example)

Relationship mapping

Unidirectional OneToOne using an embedded table



Important annotations	
@Embedded	Defines a persistent field or property of an entity whose value is an instance of an embeddable class. The embeddable class must be annotated as `Embeddable`.
@Embeddable	Defines a class whose instances are stored as an intrinsic part of an owning entity and share the identity of the entity. Each of the persistent properties or fields of the embedded object is mapped to the database table for the entity.

```
@Entity
public class EmbeddedStudent extends BaseEntity {

    @Column(name = "matrikelNummer", unique = true)
    private String registrationNumber;

    private String name;

    @Embedded
    private EmbeddedScholarship scholarship;

    @Transient
    private DateTime loginTime;

…
}
```

```
@Embeddable
public class EmbeddedScholarship {

    private String description;

    private Integer amount;

}
```

Might be an issue with legacy databases, where the DB schema already exists and must not be altered.

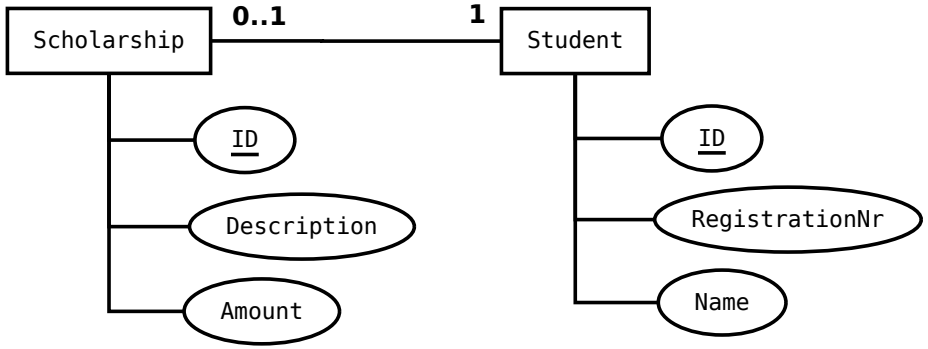
Relationship mapping

Unidirectional OneToOne using an embedded table - resulting SQL DDL

```java
@Entity
public class EmbeddedStudent extends BaseEntity {

    @Column(name = "matrikelNummer", unique = true)
    private String registrationNumber;

    private String name;

    @Embedded
    private EmbeddedScholarship scholarship;

    @Transient
    private DateTime loginTime;

…
}
```

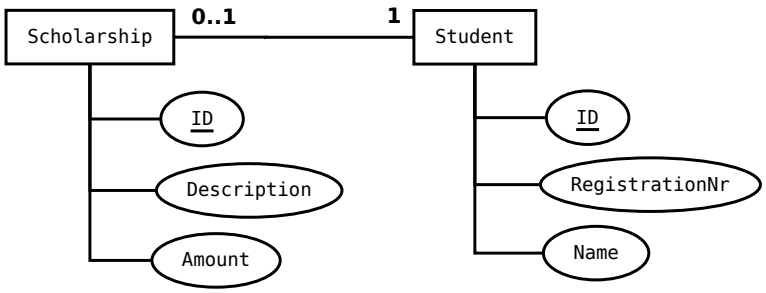
```java
@Embeddable
public class EmbeddedScholarship {

    private String description;

    private Integer amount;

}
```

```sql
CREATE TABLE EMBEDDEDSTUDENT
(
    ID BIGINT PRIMARY KEY NOT NULL,
    NAME VARCHAR(255),
    MATRIKELNUMMER VARCHAR(255),
    AMOUNT INTEGER,
    DESCRIPTION VARCHAR(255)
);
CREATE UNIQUE INDEX anIndexName
ON EMBEDDEDSTUDENT ( MATRIKELNUMMER );
```



Relationship mapping

Bidirectional OneToOne using foreign key



The “non-owning” side

```
@Entity
public class Student extends BaseEntity {

    @Column(name = "matrikelNummer",
            unique = true)
    private String registrationNumber;

    private String name;

    @OneToOne(fetch = FetchType.LAZY,
              cascade = CascadeType.ALL,
              mappedBy="grantedTo")
    private Scholarship scholarship;

    @Transient
    private DateTime loginTime;
…
}
```

Important annotations	
@OneToOne	Defines a single-valued association to another entity that has one-to-one multiplicity.
@FetchType	LAZY = do not load referenced entity, until it is accessed for the first time EAGER = load referenced entity immediately
@CascadeType	Defines the set of cascadable operations that are propagated to the associated entity. ALL is equivalent to cascade={PERSIST, MERGE, REMOVE, REFRESH, DETACH}
mappedBy	References the field that “owns” the relationship in the referenced entity. Required unless the relationship is unidirectional.

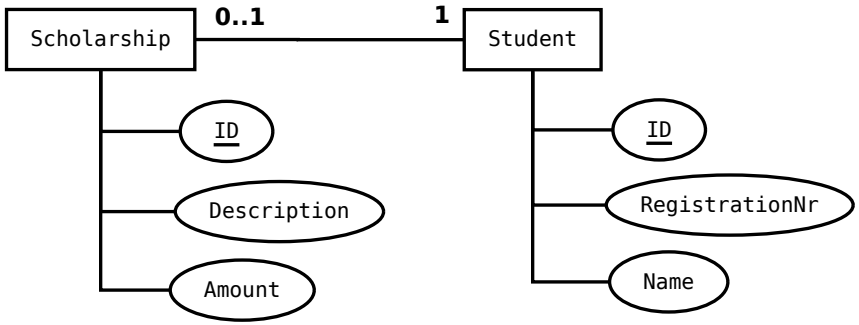
Relationship mapping

Bidirectional OneToOne using foreign key cont'd

The "owning" side

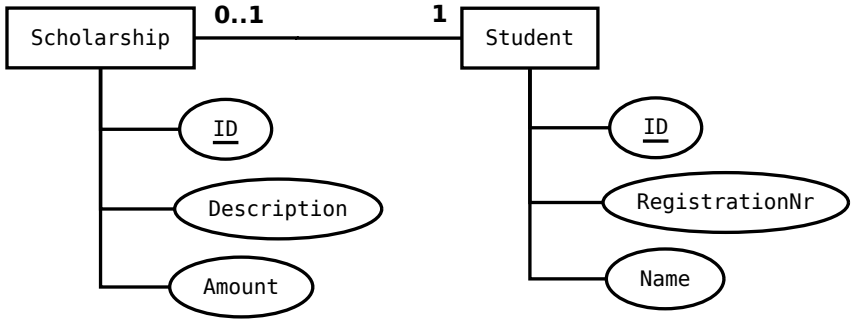
```
@Entity
public class Scholarship extends BaseEntity {

    private String description;

    private Integer amount;

    @JoinColumn(name="student_id", unique=true)
    @OneToOne
    private Student grantedTo;

…
}
```

Important annotations	
@JoinColumn	Specifies a column for joining an entity association or element collection. In this case: the name of the column, where the foreign key will be stored.



Relationship mapping

Bidirectional OneToOne using foreign key - resulting SQL DDL

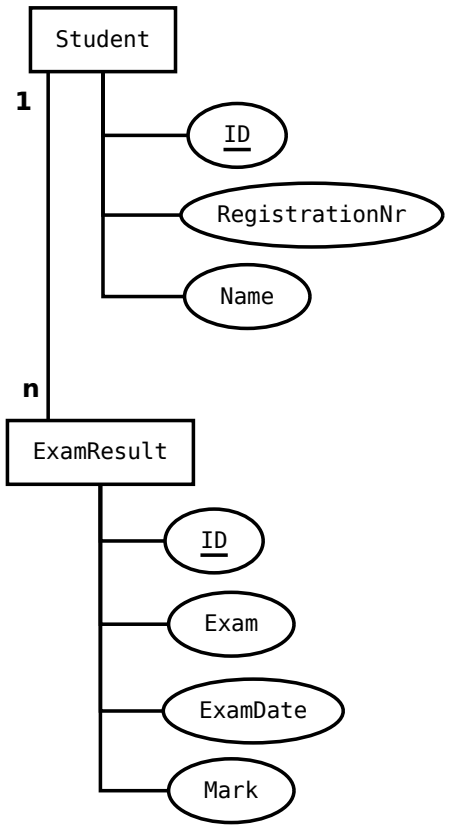



```
CREATE TABLE SCHOLARSHIP
(
    ID BIGINT PRIMARY KEY NOT NULL,
    AMOUNT INTEGER,
    DESCRIPTION VARCHAR(255),
    STUDENT_ID BIGINT,
    FOREIGN KEY ( STUDENT_ID )
    REFERENCES STUDENT ( ID )
);
CREATE UNIQUE INDEX uniqueIndexName
ON SCHOLARSHIP ( STUDENT_ID );
```

```
CREATE TABLE STUDENT
(
    ID BIGINT PRIMARY KEY NOT NULL,
    NAME VARCHAR(255),
    MATRIKELNUMMER VARCHAR(255)
);
CREATE UNIQUE INDEX anIndexName
ON STUDENT ( MATRIKELNUMMER );
```

Relationship mapping

Bidirectional OneToMany



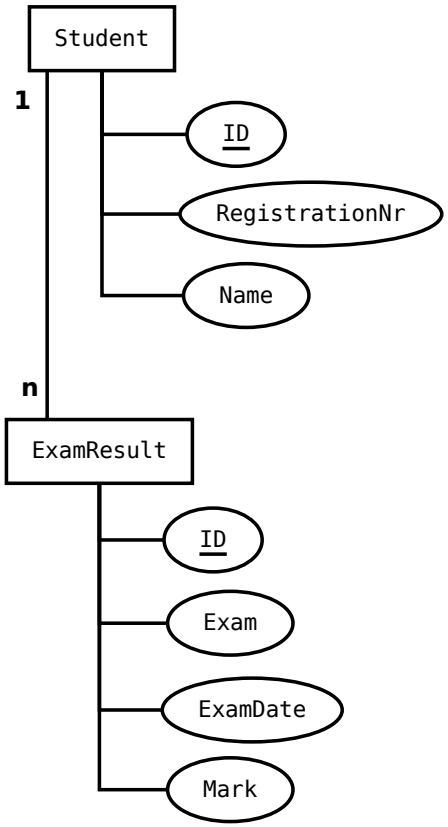
The “non-owning” side

```
@Entity
public class Student extends BaseEntity {

    @Column(name = "matrikelNummer", unique = true)
    private String registrationNumber;

    private String name;

    @OneToOne(fetch = FetchType.LAZY, cascade = CascadeType.ALL,
              mappedBy = "grantedTo")
    private Scholarship scholarship;

    @OneToMany(cascade = CascadeType.ALL, mappedBy = "student")
    private List<ExamResult> examResults;

    @Transient
    private DateTime loginTime;
…
}
```

Important annotations	
@OneToMany	Defines a many-valued association with one-to-many multiplicity.

Relationship mapping

Bidirectional OneToMany cont'd



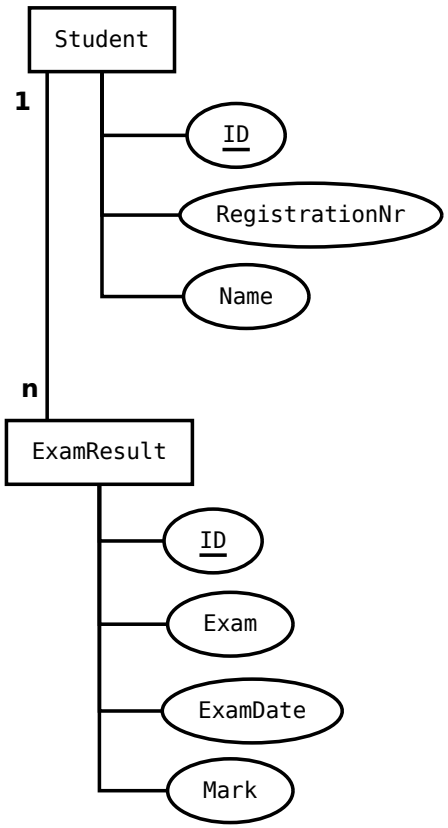
The "owning" side

```
@Entity
public class ExamResult extends BaseEntity {

    @Column(name = "prufungsDatum")
    @Temporal(TemporalType.DATE)
    private Date examDate;

    private String exam;

    private int mark;

    @ManyToOne
    private Student student;


    @Transient
    private String examLocation;
…
}
```

Important annotations	
@ManyToOne	Defines a single-valued association to another entity class that has many-to-one multiplicity.

Relationship mapping

Bidirectional OneToMany - resulting SQL DDL

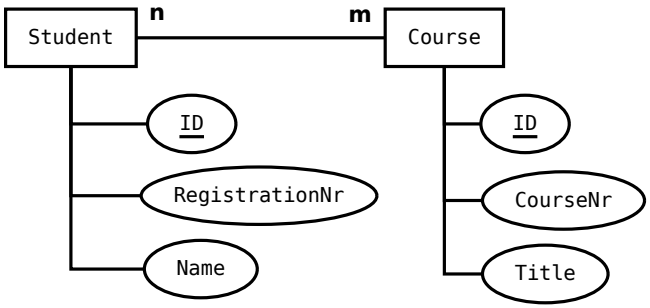



```
CREATE TABLE STUDENT
(
    ID BIGINT PRIMARY KEY NOT NULL,
    NAME VARCHAR(255),
    MATRIKELNUMMER VARCHAR(255)
);
CREATE UNIQUE INDEX anIndexNameB
ON STUDENT ( MATRIKELNUMMER );
```

```
CREATE TABLE EXAMRESULT
(
    ID BIGINT PRIMARY KEY NOT NULL,
    EXAM VARCHAR(255),
    PRUFUNGSDATUM DATE,
    MARK INTEGER NOT NULL,
    STUDENT_ID BIGINT,
    FOREIGN KEY ( STUDENT_ID ) REFERENCES STUDENT ( ID )
);
```

Relationship mapping

ManyToMany

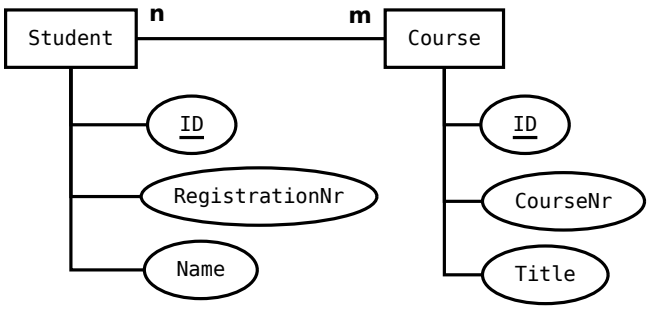


Important annotations	
@ManyToMany	Defines a many-valued association with many-to-many multiplicity.

```
@Entity
public class Student extends BaseEntity {

    @Column(name = "matrikelNummer", unique = true)
    private String registrationNumber;

    private String name;

    @OneToOne(fetch = FetchType.LAZY,
              cascade = CascadeType.ALL,
              mappedBy = "grantedTo")
    private Scholarship scholarship;

    @OneToMany(cascade = CascadeType.ALL,
               mappedBy = "student")
    private List<ExamResult> examResults;

    @ManyToMany(mappedBy = "students")
    private List<Course> courses;

    @Transient
    private DateTime loginTime;

...
}
```

Relationship mapping

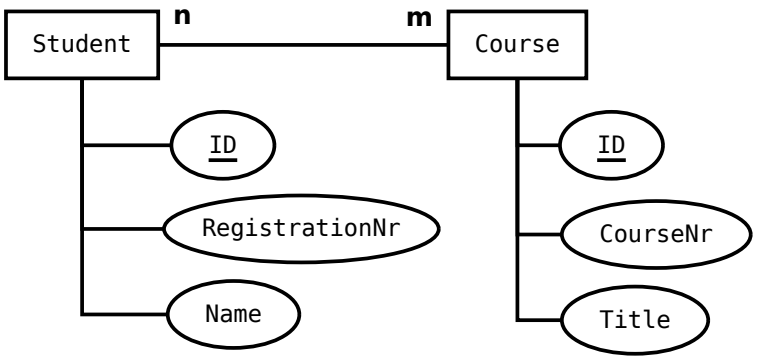
ManyToMany cont'd




```
@Entity
public class Course extends BaseEntity {

    private String courseNumber;

    private String title;

    @ManyToMany
    private List<Student> students;
…
}
```

Relationship mapping

ManyToMany - resulting SQL DDL




```
CREATE TABLE COURSE
(
    ID BIGINT PRIMARY KEY NOT NULL,
    COURSENUMBER VARCHAR(255),
    TITLE VARCHAR(255)
);
```

```
CREATE TABLE STUDENT
(
    ID BIGINT PRIMARY KEY NOT NULL,
    NAME VARCHAR(255),
    MATRIKELNUMMER VARCHAR(255)
);
CREATE UNIQUE INDEX anIndexNameB
ON STUDENT ( MATRIKELNUMMER );
```

```
CREATE TABLE COURSE_STUDENT
(
    COURSES_ID BIGINT NOT NULL,
    STUDENTS_ID BIGINT NOT NULL,
    FOREIGN KEY ( COURSES_ID )
    REFERENCES COURSE ( ID ),
    FOREIGN KEY ( STUDENTS_ID )
    REFERENCES STUDENT ( ID )
);
```

Cascade and Fetch

- Cascade Types
  - All four relationship annotations may specify operations cascaded to associated entities
  - ALL, PERSIST, MERGE, REMOVE, REFRESH, DETACH
  - Default is none
- Orphan Removal
  - For @OneToOne and @OneToMany relationships
  - Default is false
- Fetching Strategies
  - Define how object hierarchies are loaded
  - EAGER = load all related objects immediately
  - LAZY = load the related objects only if they are accessed for the first time
  - Be careful with EAGER, as large object graphs may be loaded unintentionally!

Persistence Concepts

- Persistence Unit (PU)
  - Defines a set of entity classes managed by the EntityManager instance in an application
  - Maps the set of entity classes to a relational database
- Persistence Context (PC)
  - Set of managed entity instances that exist in a particular data store
  - Runtime context
- Entity Manager (EM)
  - API for interaction with the persistence context
  - Manipulates and controls the lifecycle of a persistence context
  - Creates and removes persistent entity instances
  - Finds entities using primary keys
  - Runs queries on entities

Persistence Unit

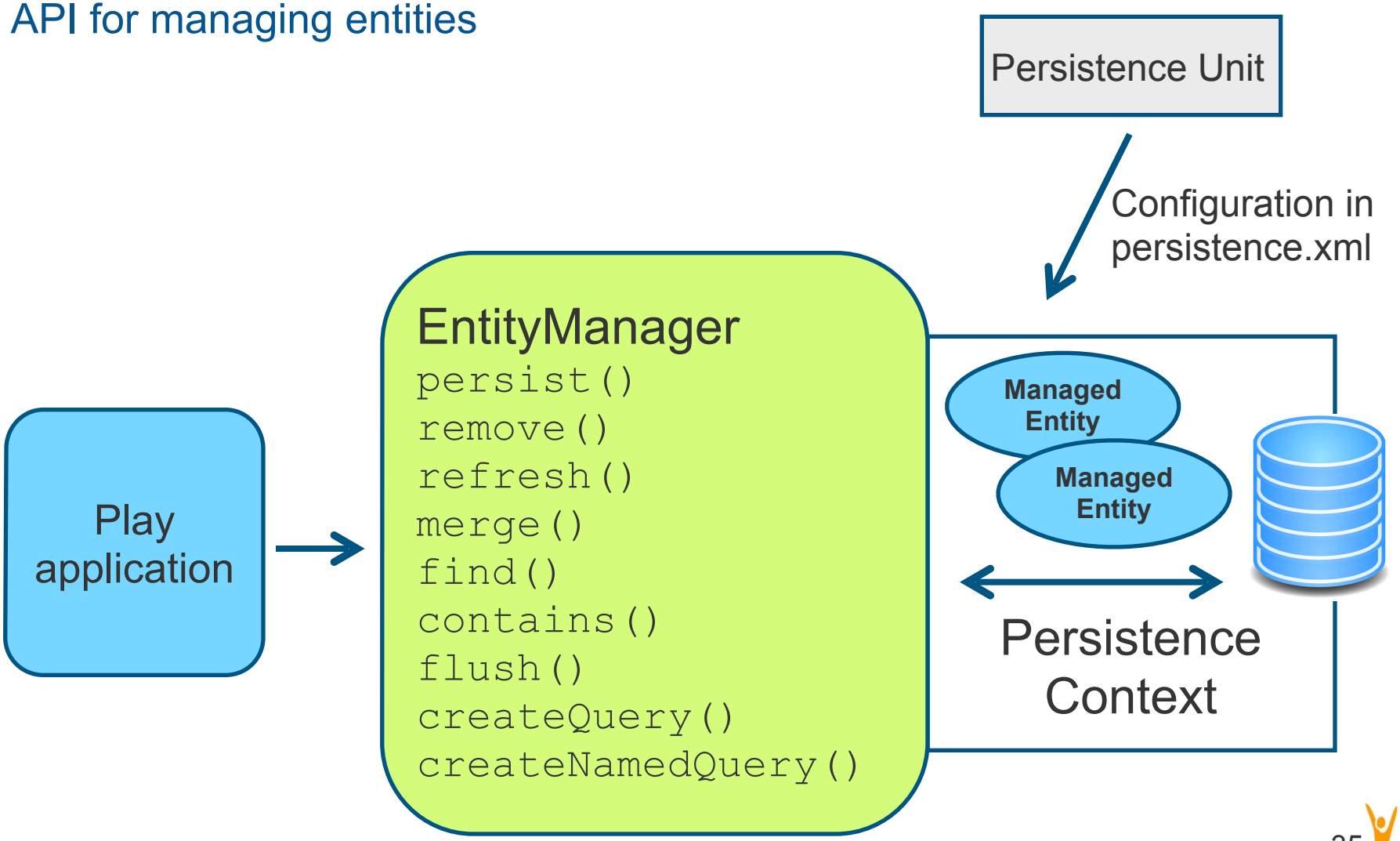
- Persistence Unit
  - Configuration to map entity classes in an application to a relational database
- persistence.xml defines one or more persistence units
  - Defined under /conf/META-INF/persistence.xml
  - Classes with JPA annotations are automatically detected upon start of the application

Names must be referenced in application.conf

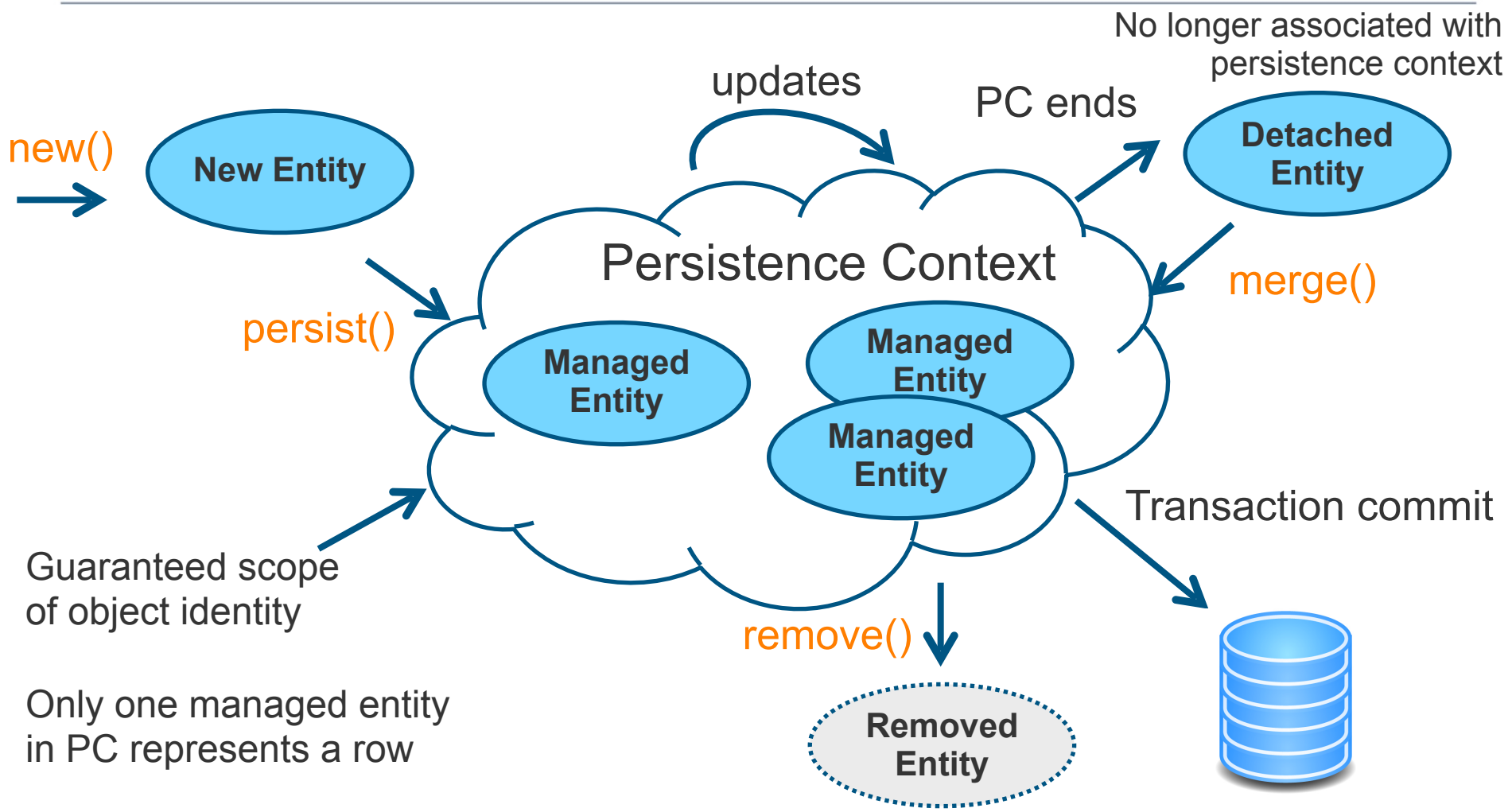
```
<persistence xmlns="http://java.sun.com/xml/ns/persistence"
             xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
             xsi:schemaLocation="http://java.sun.com/xml/ns/persistence http://
java.sun.com/xml/ns/persistence/persistence_2_0.xsd"
             version="2.0">
    <persistence-unit name="defaultPersistenceUnit" transaction-type="RESOURCE_LOCAL">
        <provider>org.hibernate.ejb.HibernatePersistence</provider>
        <non-jta-data-source>DefaultDS</non-jta-data-source>
        <properties>
            <property name="hibernate.dialect" value="org.hibernate.dialect.H2Dialect"/>
            <property name="hibernate.hbm2ddl.auto" value="create" />
        </properties>
    </persistence-unit>
</persistence>
```

Entity Manager

API for managing entities



Entity lifecycle



Entities in managed/persistent state may be manipulated by the application and any changes will be **automatically detected and persisted** when the persistence context is flushed. There is no need to call a particular method to make your modifications persistent.

Entity manager samples

Typically one addresses the entity manager from a dedicated persistence service class

```
public void persist(BaseEntity entity) {
    em().persist(entity);
}
```

Make an entity instance managed and persistent. Throws EntityExistsException, if the entity instance already exists.

```
public <T extends BaseEntity> T merge(T entity) {
    return em().merge(entity);
}
```

Make an entity instance managed and persistent. If it does not exist yet, persist it. If it already exists, the entity instance is updated.

```
public <T extends BaseEntity> T findEntity(Long id,
                                           Class<T> entityClazz) {
    return em().find(entityClazz, id);
}
```

Find the entity instance using the primary key.

```
public void remove(BaseEntity entity) {
    em().remove(entity);
}
```

Remove the instance.

Finding Entities

- Find entity by primary key using EntityManager

```
<T> T find(Class<T> entityClass, Object primaryKey)
```

- Example:

```
Student student = entityManager.find(Student.class, id);
```

- For complex queries use
  - Java Persistence Query Language (JPQL) or Hibernate Query Language (HQL)
    - Both are object model focused query languages similar in nature to SQL. JPQL is a heavily-inspired-by subset of HQL. A JPQL query is always a valid HQL query, the reverse is not true however.
  - Criteria API
  - Native Queries
- EntityManager provides methods for creating Query objects
  - createQuery
  - createNativeQuery (using plain SQL - not recommended)

JPQL/HQL

- Similar to SQL
- Works with entities as defined in the application and *not* with SQL table names and attribute names
- Portable (they abstract from vendor-specific SQL)
- Returns entities (no need to worry about result sets and their manual conversion to POJOs)
- Select, update, delete

- Support for
  - Joins
  - Conditional Expressions
  - Functional Expressions
  - Subqueries
  - Order by, group by, having
  - …

Querying Entities with JPQL

- Dynamic Query
  - Use parameter substitution and do not concatenate the JPQL string with the parameter values

```
public List<Student> getStudentByName(String studentName) {
    TypedQuery<Student> studentTypedQuery =
        em().createQuery("SELECT s FROM Student s WHERE s.name LIKE :studentName",
        Student.class);

    studentTypedQuery.setParameter("studentName", studentName);

    return studentTypedQuery.getResultList();
}
```

Querying Entities with JPQL

- Static Query
  - Named Query
  - Recommended, as it may leverage use of query cache

```
@NamedQuery(name="findAllStudents",
            query="SELECT s FROM Student s")
@Entity
public class Student extends BaseEntity {
…
}
```

```
public List<Student> getAllStudents() {
    List<Student> students = em().createNamedQuery("findAllStudents",
                                 Student.class).getResultList();
    return students;
}
```

Further reading: http://www.kumaranuj.com/2013/06/jpa-2-dynamic-queries-vs-named-queries.html

Criteria API

- Alternative to JPQL, same scope
- Dynamic Queries only

- Clauses are set using Java programming language objects
  - the query can be created in a typesafe manner

- Obtain a `CriteriaBuilder` instance by using the `EntityManager.getCriteriaBuilder` method

Querying Entities with Criteria API

```
public Student getStudent(String registrationNumber) {

    CriteriaBuilder cb = em().getCriteriaBuilder();
    CriteriaQuery<Student> criteriaQuery = cb.createQuery(Student.class);
    Root<Student> s = criteriaQuery.from(Student.class);
    ParameterExpression<String> parameter = cb.parameter(String.class);
    criteriaQuery.select(s).where(cb.equal(s.get("registrationNumber"), parameter));

    TypedQuery<Student> typedQuery = em().createQuery(criteriaQuery);
    typedQuery.setParameter(parameter, registrationNumber);
    return typedQuery.getSingleResult();

}
```

Querying entities with Hibernate Criteria

```
public List<ExamResult> getNegativeExamResults(Student student) {
    Criteria c = ((Session) JPA.em().getDelegate()).createCriteria(Student.class);
    c.createCriteria("examResults").add(Restrictions.eq("mark", 5));
    return c.list();
}
```

Wrap up

Lessons learned today

- JPA/Hibernate provide a powerful ORM feature for Java-based applications
- Lot's of magic happens under the hood - know the data engineering basics first!
- Before putting your persistence layer into production, thoroughly test it using unit test

References

1. Sun Microsystems. JSR 220: Enterprise JavaBeans™, Version 3.0 – Java Persitence API, 2006
2. Carol McDonald. Java Persistence API: Best Practices, Sun Tech Days 2008-2009 http://de.slideshare.net/caroljmcdonald/td09jpabestpractices2
3. Carol McDonald. Enterprise JavaBean 3.0 & Java Persistence APIs: Simplifying Persistence, Sun Tech Days 2006-2007 http://de.slideshare.net/caroljmcdonald/persistencecmcdonaldmainejug3
4. The Java EE 6 Tutorial, http://docs.oracle.com/javaee/6/tutorial/doc/bnbpy.html
5. https://www.codecentric.de/files/2011/05/flush-und-clear-or-mapping-anti-patterns.pdf (in German)

Backup

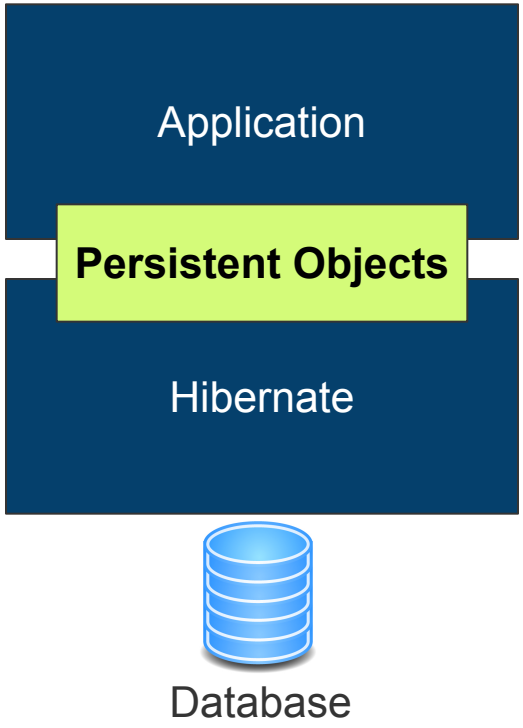
Further background information for the interested

Object relational mapping (ORM)

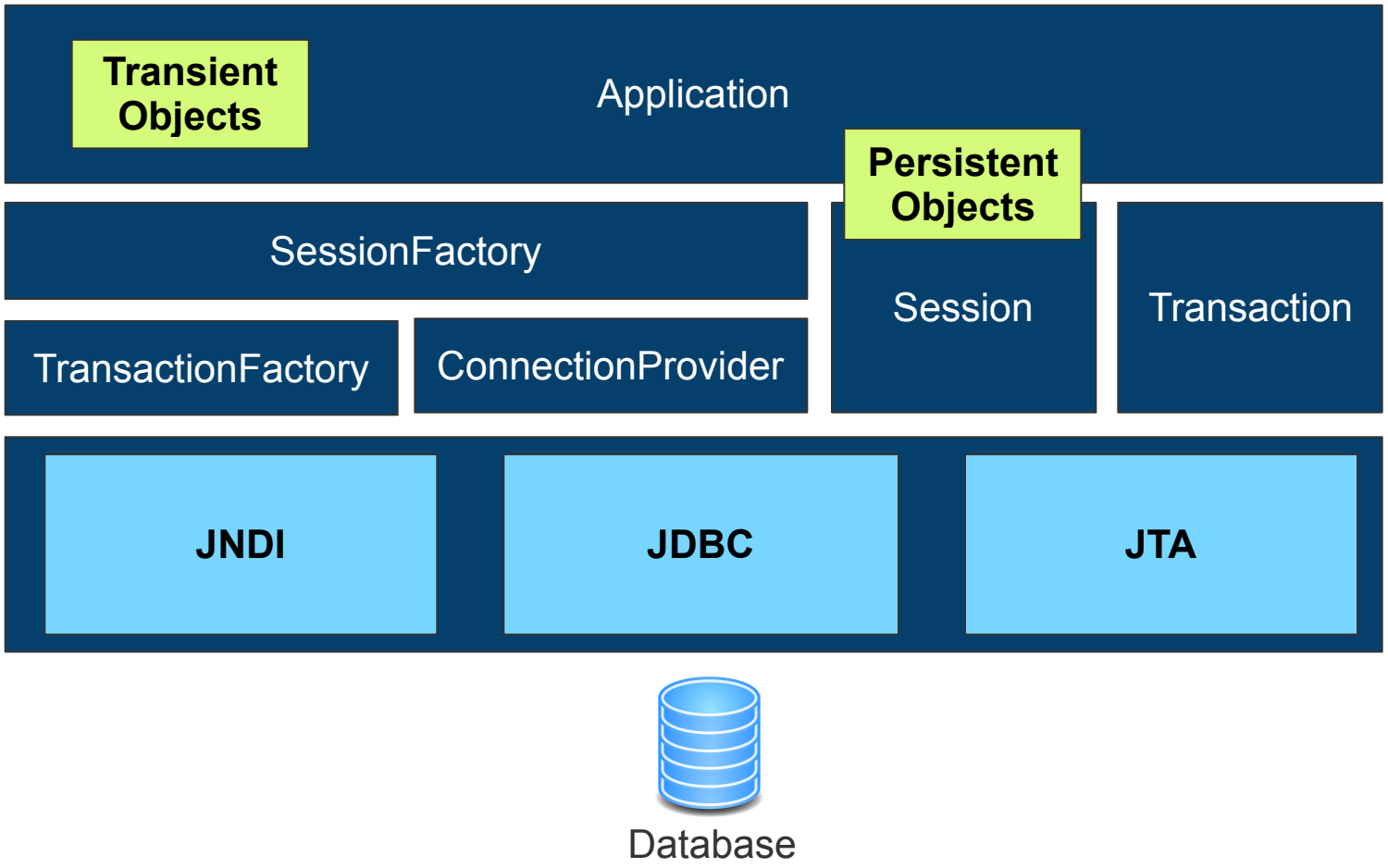
Why objects and databases do not play well together

- **Object-Relational Impedance Mismatch (or paradigm mismatch)**
  - RDBMS represent data in tabular format
  - Object-oriented languages such as Java present data in an interconnected graph of objects
- **Loading and storing objects using a tabular relational database exposes different problems:**
  - **Granularity**
    Oftentimes the object model will contain more classes, than the number of corresponding tables in the database
  - **Subtypes**
    Inheritance is an integral part of object-oriented programming. RDBMS usually do not foresee an inheritance mechanism.
  - **Identity**
    A RDMS defines a single notion of sameness: the primary key. Java, however, defines both, object identity `a==b` and object equality `a.equals(b)`
  - **Associations**
    Associations are represented as unidirectional references in an Object Oriented Language such as Java. An RDMS uses the concept of foreign keys. If one requires bidirectional relationships in Java, an association must be defined twice.
  - **Data navigation**. Association style navigation (Java), vs. SQL JOINs.

High-level overview of the Hibernate architecture



Detailed view of the Hibernate architecture



http://docs.jboss.org/hibernate/core/3.2/reference/en/html/architecture.html

Transaction

What exactly makes a database transaction?

- A transaction is a sequence of operations, performed as a single logical unit of work. The single logical unit of work must have four properties in order to qualify it as a transaction.
  - **Atomicity**
    A transaction must be an atomic unit of work, i.e., all of its data modifications are performed, or no modification is performed at all.
  - **Consistency**
    After a transaction is completed, all data must be left in a consistent state. The written data must confirm to the defined rules such as constraints, triggers, cascades, etc.
    All internal data structures, such as indexes, must be correct at the end of the transaction.

Transaction cont'd

What exactly makes a database transaction?

- **Isolation**
  Modifications of a given transaction must be isolated from modifications made by other concurrent transactions. A transaction never recognizes data in an intermediate state, which was potentially caused by another concurrent transaction.

- **Durability**
  After a transaction has been completed, its effects are permanently stored in the system. Modifications persist even in the case of a system failure.