Databases

Jörg Endrullis

VU University Amsterdam

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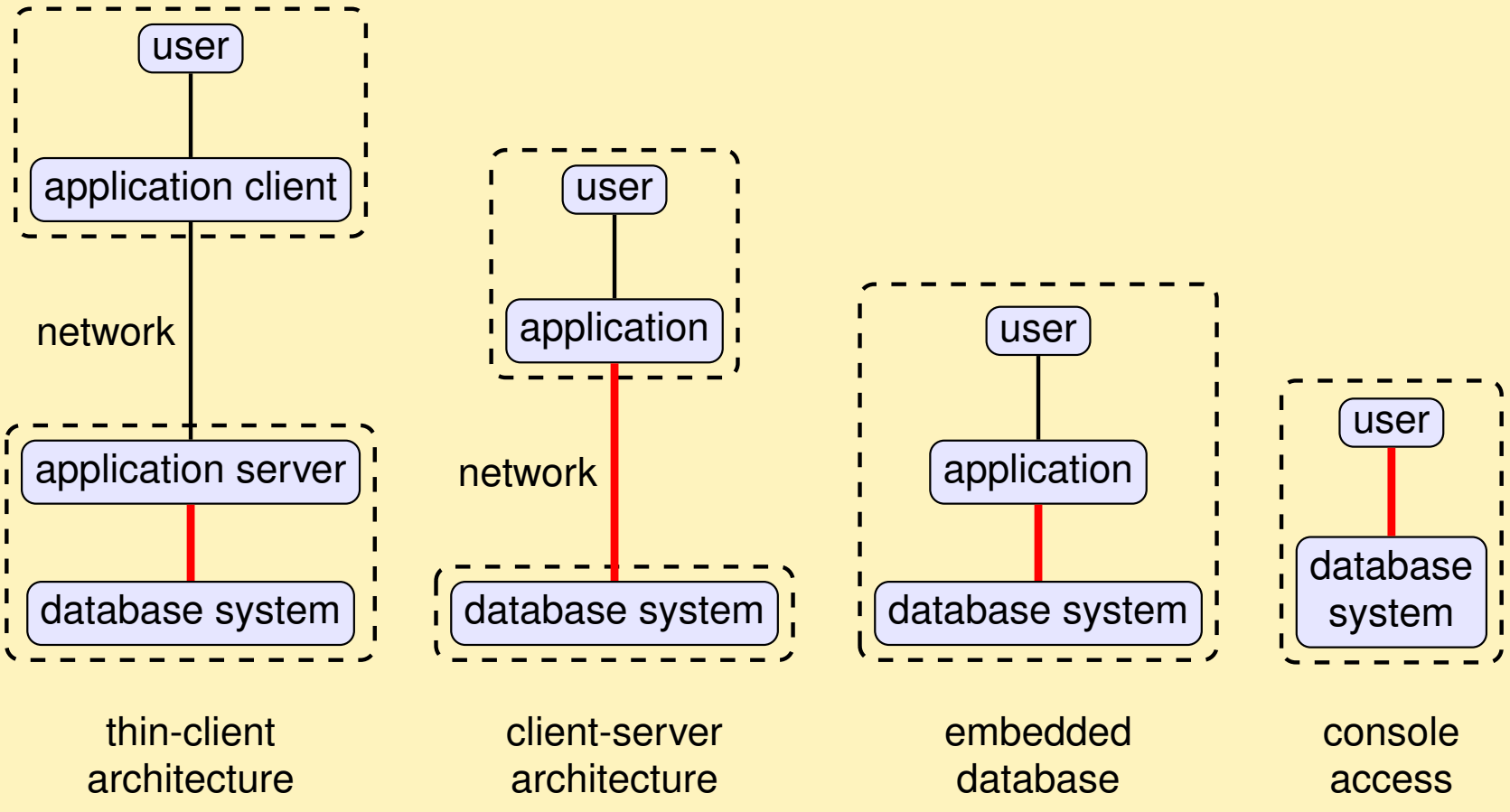
Application Architectures

Various ways of using database technology



Application Architectures

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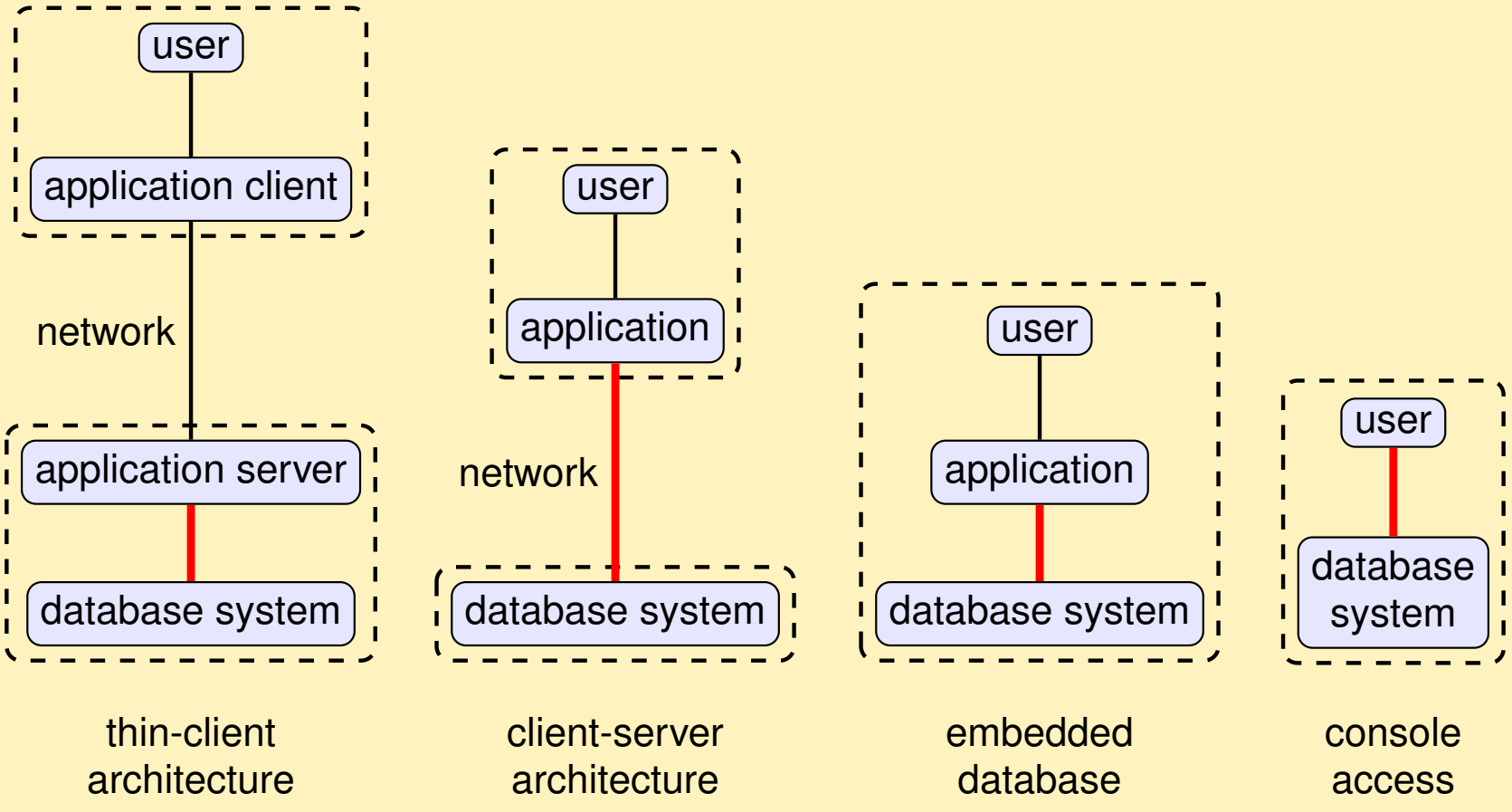

How do these applications talk to the database?

How to Talk to a Database?

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  - e.g. JDBC, ODBC, OLE DB, Python DB-API,...

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- **Static** embedded queries
  - e.g. SQLJ, Embedded SQL (C/C++)
  - preprocessor-based, static SQL
- **Dynamic**
  - e.g. JDBC, ODBC, OLE DB, Python DB-API,...
- **Object Relational Mappings (ORM)**, and beyond
  - hide navigational access behind objects
  - e.g. JPA/Hibernate, RubyOnRails, ADO.NET/LinQ

Dynamic: JDBC

```
import java.sql.* ;

public class ShowStudents {
  public static void main(String args[]) throws Exception {
    String url = "jdbc:mysql://localhost/db" ;
    System.setProperty("jdbc.drivers",
                       "org.gjt.mm.mysql.Driver");

    Connection conn = DriverManager.getConnection(url);

    Statement stat = conn.createStatement() ;
    ResultSet rs = stat.executeQuery(
                     "SELECT sid, name FROM students");

    while (rs.next()) {
      int sid = rs.getInt("sid");
      String name = rs.getString("name");
      System.out.println(sid + ": " + name);
    }
    conn.close();
```

fetch results row by row

getInt(...), getString(...) fetch column values by name

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Checking whether a field is `NULL` is done in JDBC by explicitly calling rs.isNull(column).

Type (mis)Match

Mapping SQL types to Java Types

SQL type	Java Type
CHAR, VARCHAR	String
NUMERICAL, DECIMAL	java.math.BigDecimal
BIT	boolean
TINYINT	byte
SMALLINT	short
INTEGER	int
BIGINT	long
REAL	float
FLOAT, DOUBLE	double
BINARY, VARBINARY	byte[]
DATE	java.sql.Date
TIME	java.sql.Time
TIMESTAMP	java.sql.Timestamp

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- **Stored procedures** to reduce #query roundtrips
  - written in DB-specific language, not portable 
  - accessed with **Connection.prepareCall()**
- Use a **driver** that is **bulk**-transfer optimised
  - when retrieving large result sets
  - driver can send several tuples in a single network packet

SQL Injection

Website with Login Screen

Name: Maria

Password: 12345

Server Side SQL

```
String userName = // name that the user has entered
String userPassword = // password that the user has entered

ResultSet rs = stat.executeQuery(
                    "SELECT balance FROM accounts " +
                    "WHERE name = '" + userName + "'" +
                    "  AND passwd = '" + userPassword + "'"
                  );
```

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The Resulting SQL Query

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SELECT balance FROM accounts
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Name: Joe' --

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SELECT balance FROM accounts
WHERE name = 'Joe' -- ' AND passwd = 'who cares'
```

SQL injection is a very common mistake! Very dangerous!

SQL Injection: How to Prevent It?

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Preventing SQL Injection

```
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PreparedStatement stat = conn.prepareStatement(
                         "SELECT balance FROM accounts " +
                         "WHERE name = ?" +
                         "  AND passwd = ?");

 // use JDBC to fill the name and password
stat.setString(1, userName);
stat.setString(2, userPassword);

ResultSet rs = stat.executeQuery();
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Can we do better?. . .

Object Relational Mapping

Logical database schemas are not always ideal

- New applications on top of existing schemas
- Not the same set of constructs and abstractions
  - objects, relations, inheritance

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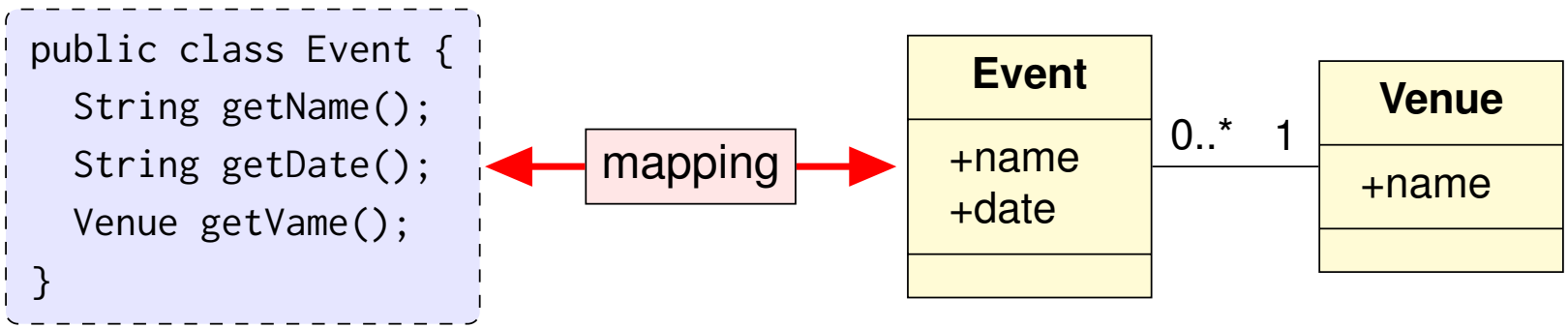
In applications we would like to work with

- objects / entities
- inheritance
- relations

Object Relational Mapping

Maps rows in tables to objects:

- Table $\approx$ Class
- Row $\approx$ Object
- Foreign key navigation $\approx$ pointers / references



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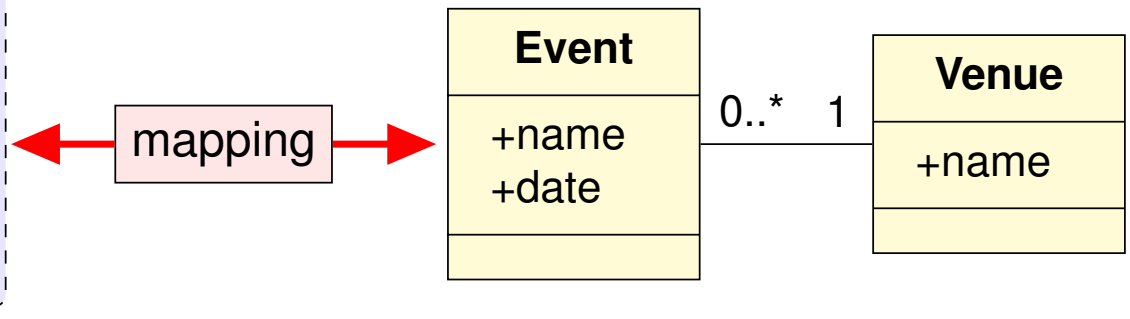

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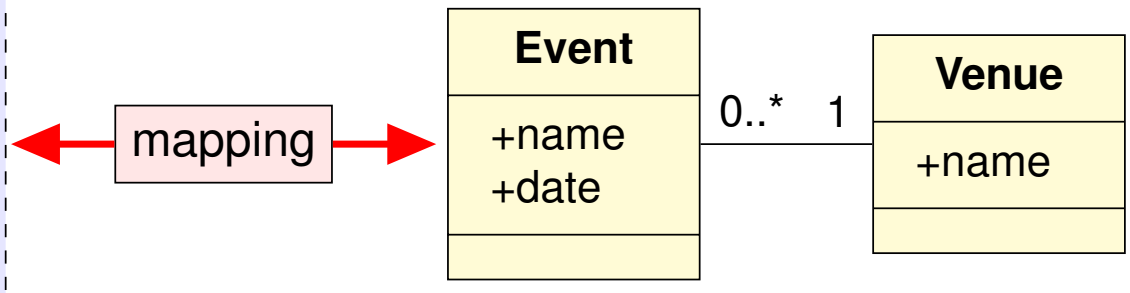

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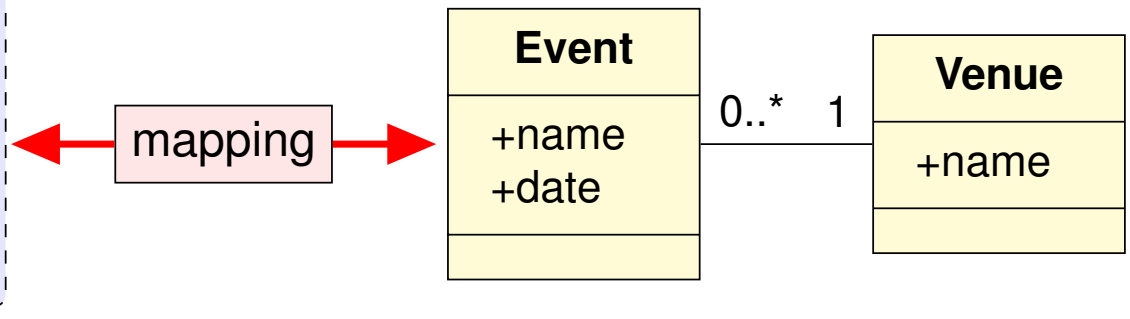

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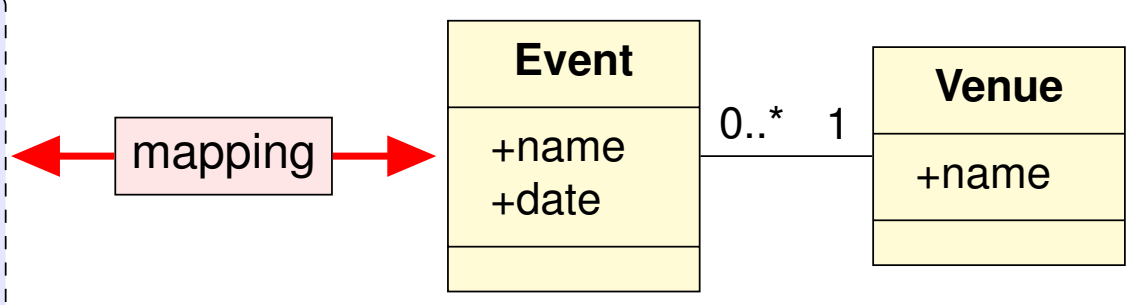

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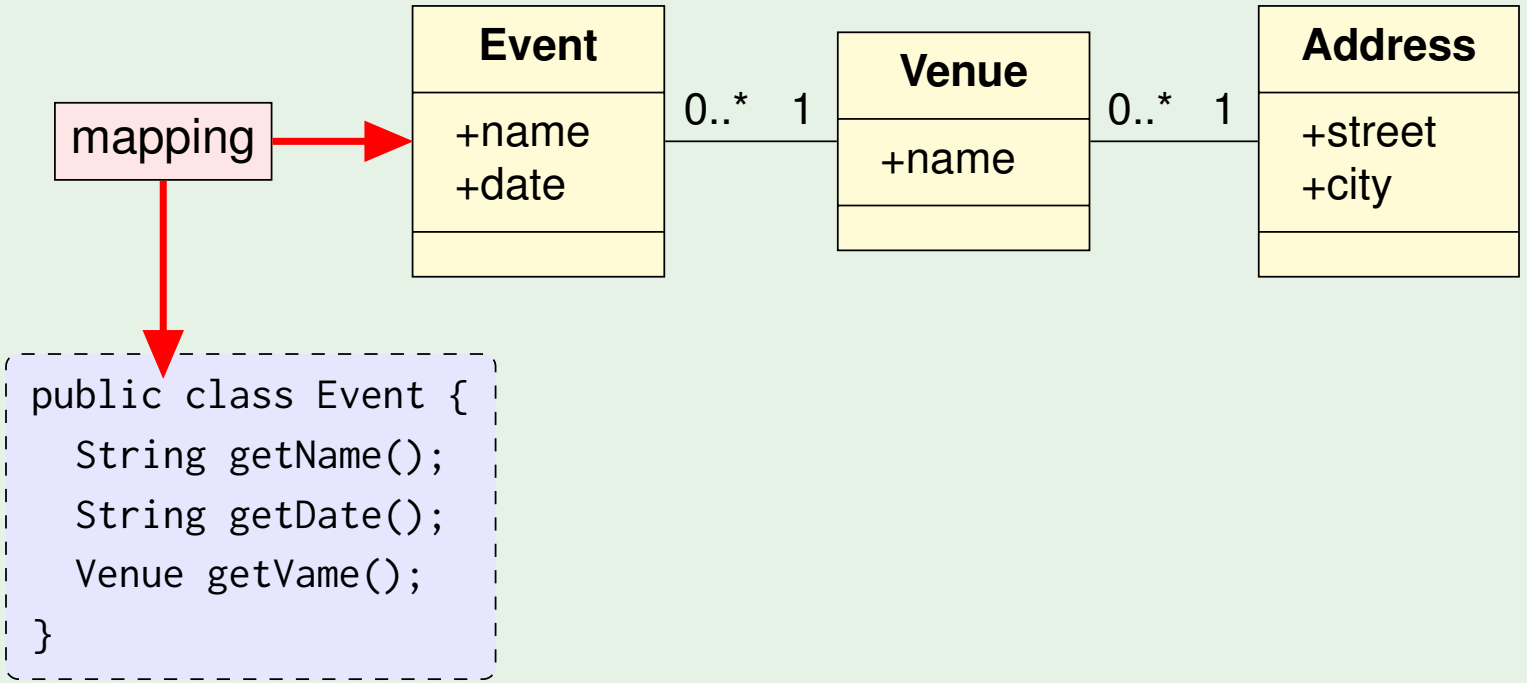
Many ORM toolkits: Hybernate, RubyOnRails, ADO.NET,. . .

Object Relational Mapping: JPA/Hibernate



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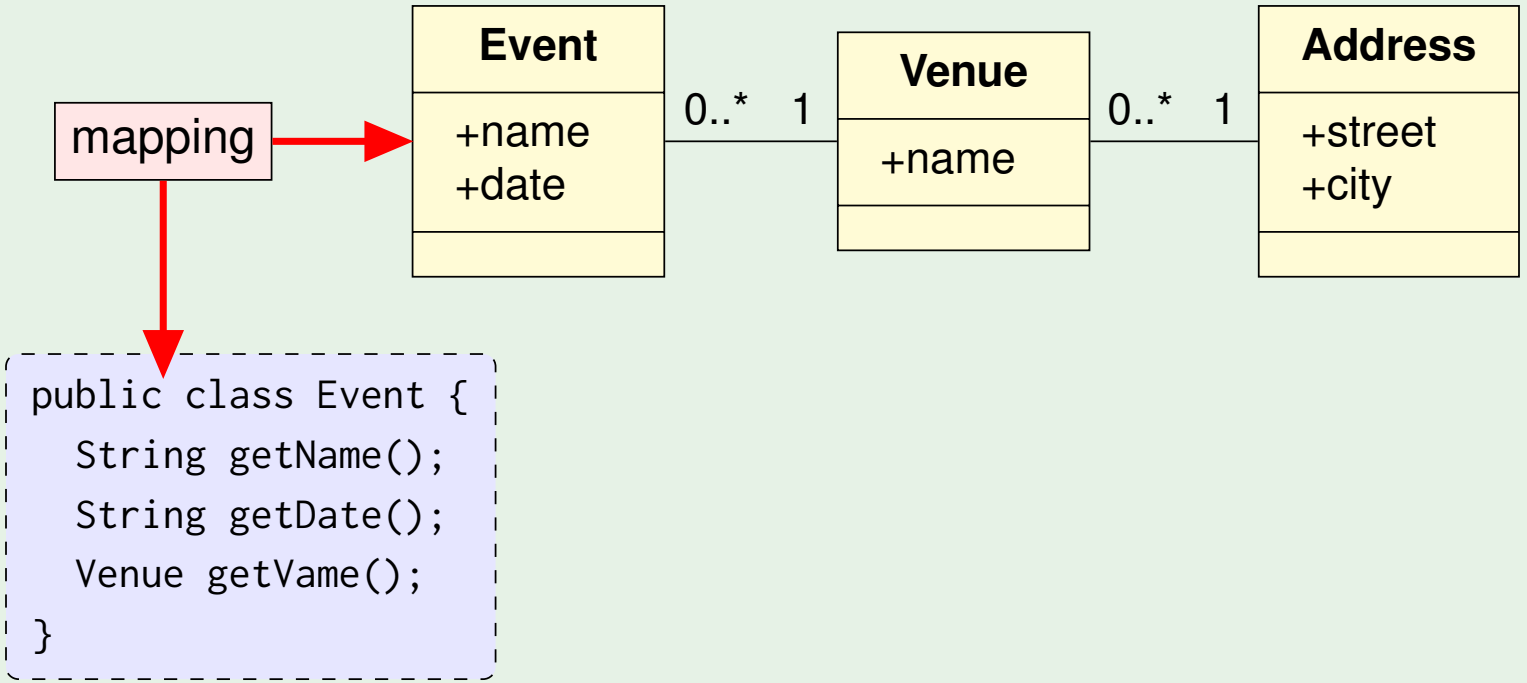

Example:

- `event.getVenue().getAddress().getStreet();`

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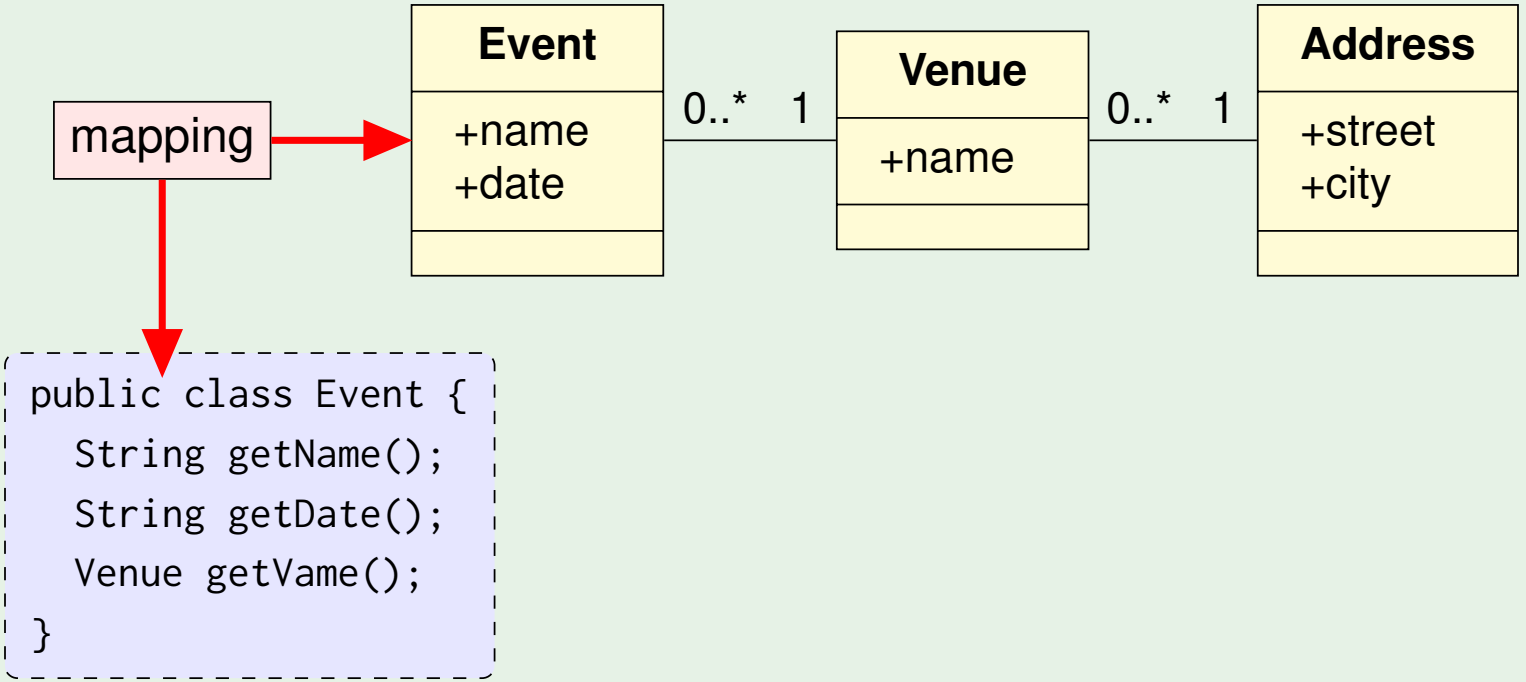

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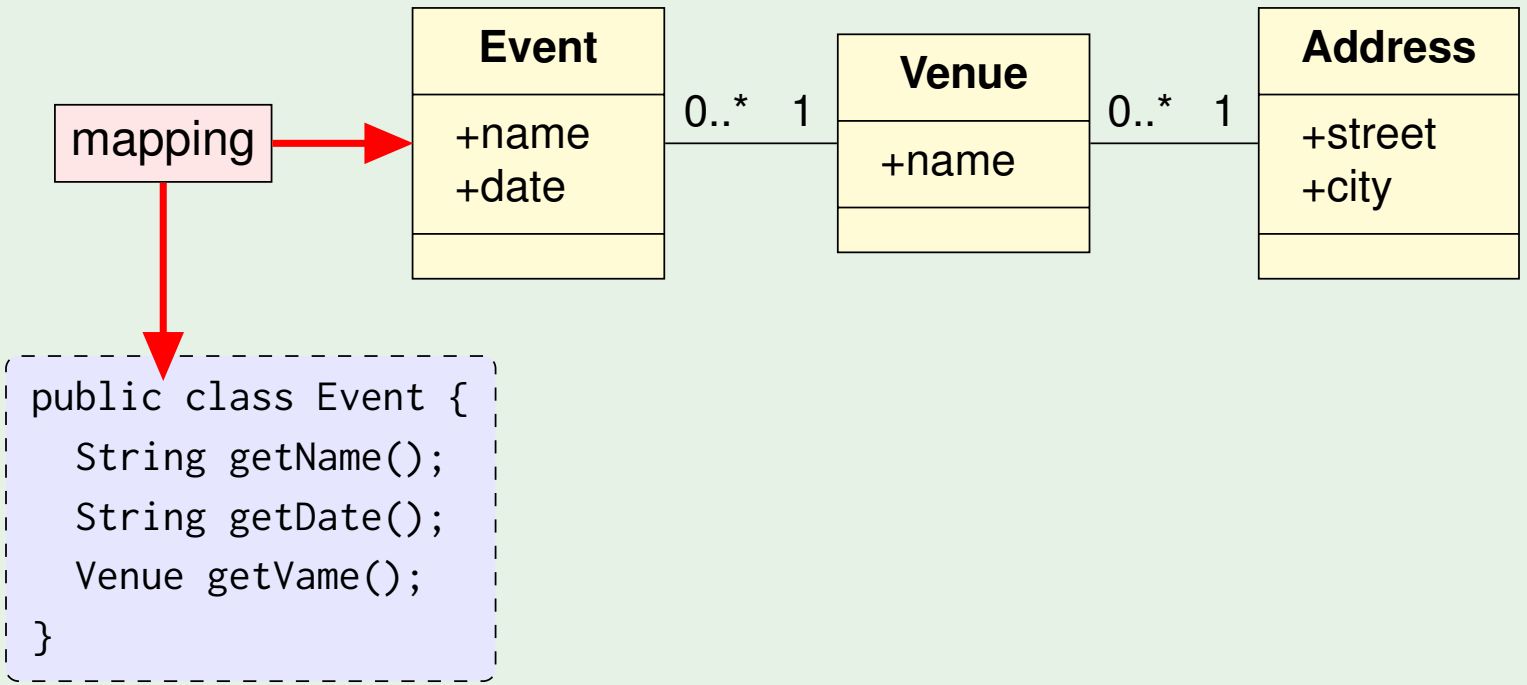

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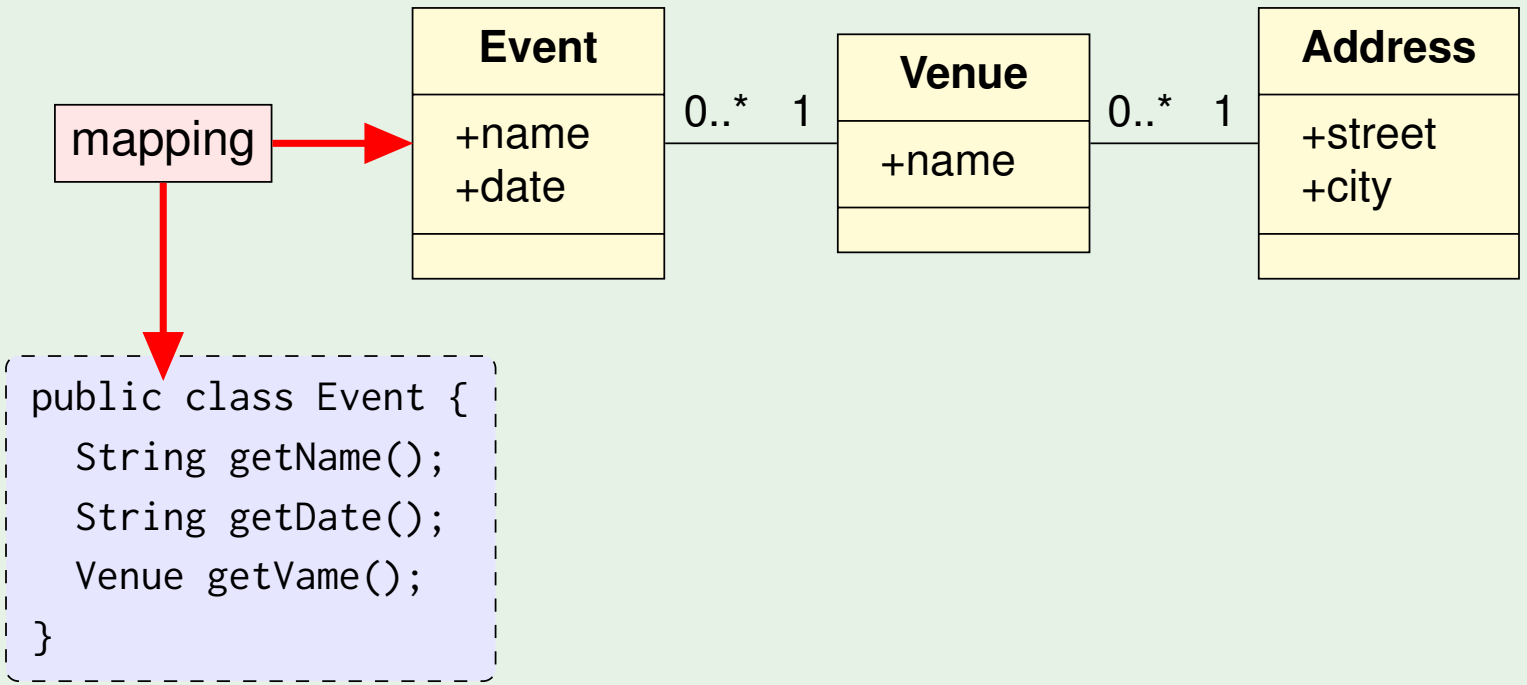

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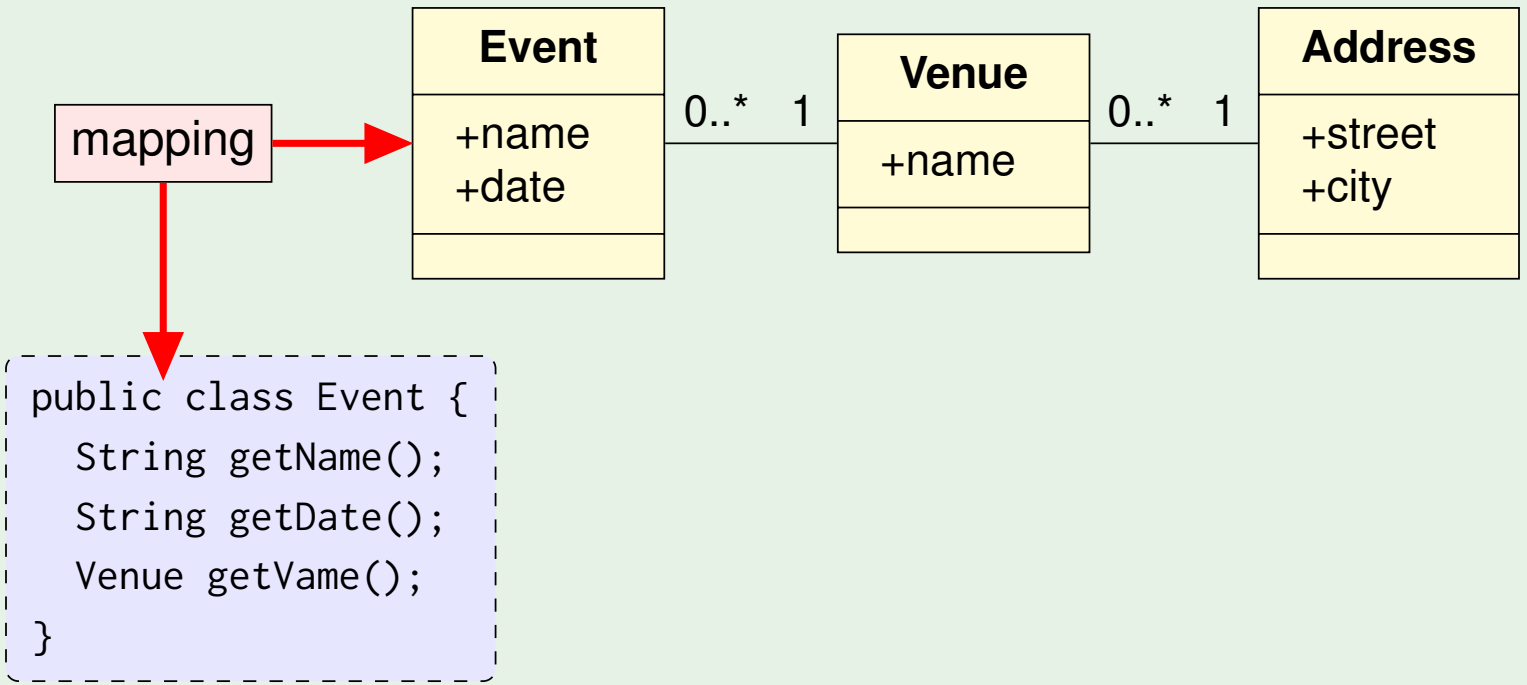

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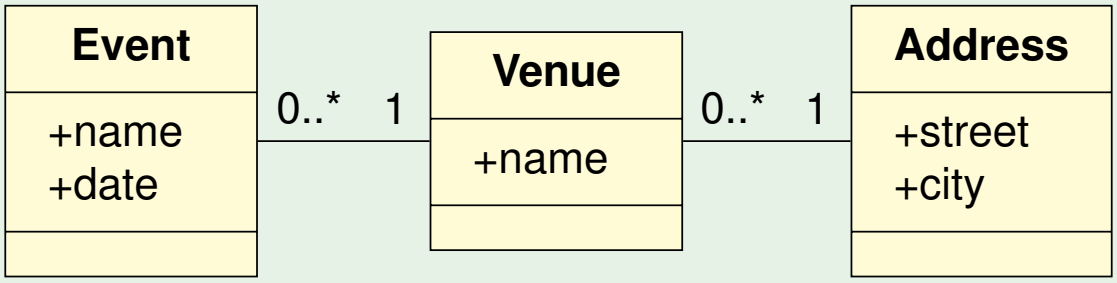

We want all events in Amsterdam:

```
List<Event> eventList = // get all events
for (Event event : eventList) {
  Address address = event.getVenue().getAddress();
  if ("Amsterdam".equals(address.getCity())) {
    System.out.println(event.getName());
  }
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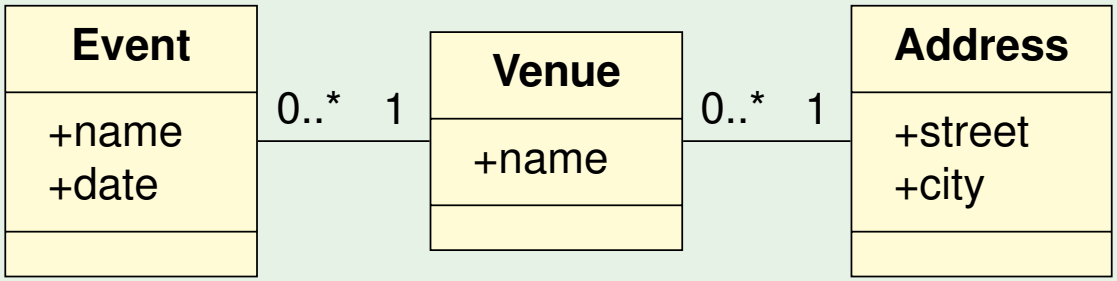

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Instead of loading just the events with city "Amsterdam":

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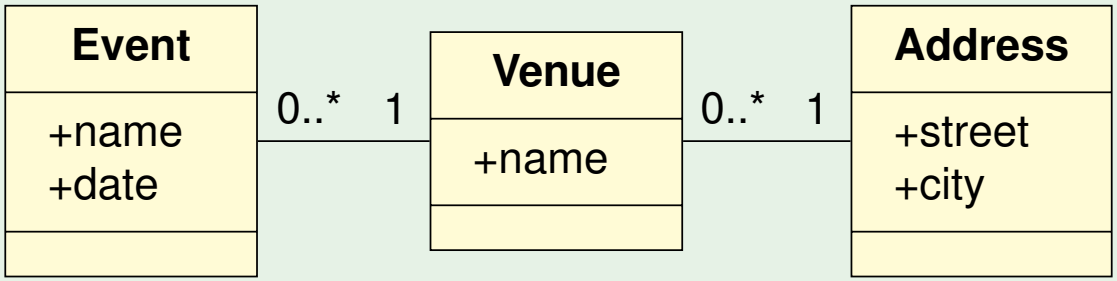

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- also each call to getVenue() will result in an SQL query

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  ... something ...
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Many queries do not return a full object!
E.g. what is the type of "select name,date from Events"?

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- Fetch strategies
  - danger of implementing queries in Java 
  - object caching

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  - can be difficult to debug
- Performance analysis is problematic because:
  - database queries are under the hood
  - sometimes very complex SQL queries are generated
  - difficult to understand what caused the complex queries

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  (ANSI-SPARC model has views on server side)
- Powerfull
  - Broad set of views that are updatable.
  - Updatability can be statically verified.

ADO.NET Entity Framework

Entity Data Model (EDM)

Data representation on client side: Entity Data Model.

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- Allows to query all collection structures.
  (lists, sets, . . . ; not restricted to databases)

LinQ

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LinQ stands for Language INtegrated Query. Allows developers to query data structures using an SQL-like syntax.

Advantages of LinQ

- Queries are first-class citizens (not strings).
- Full type-checking and error checking for queries.
- Allows to query all collection structures.
  (lists, sets, . . . ; not restricted to databases)

Problem

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Luckily. . .

Similar frameworks in other programming languages.

LinQ: Querying an array

```
//Create an array of integers
int[] myarray = new int[] { 49, 28, 20, 15, 25, 23, 24, 10, 7 };

//Create a a query for odd numbers,
var oddNumbers = from i in myarray where i \% 2 == 1 select i;

//Odd numbers in descending order
var sorted = from i in oddNumbers orderby i descending select i;

//Display the results of the query
foreach (int i in oddNumbers)
  Console.WriteLine(i);
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- LinQ to XML

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- LinQ to XML
- LinQ to SQL (interact with logical database model)

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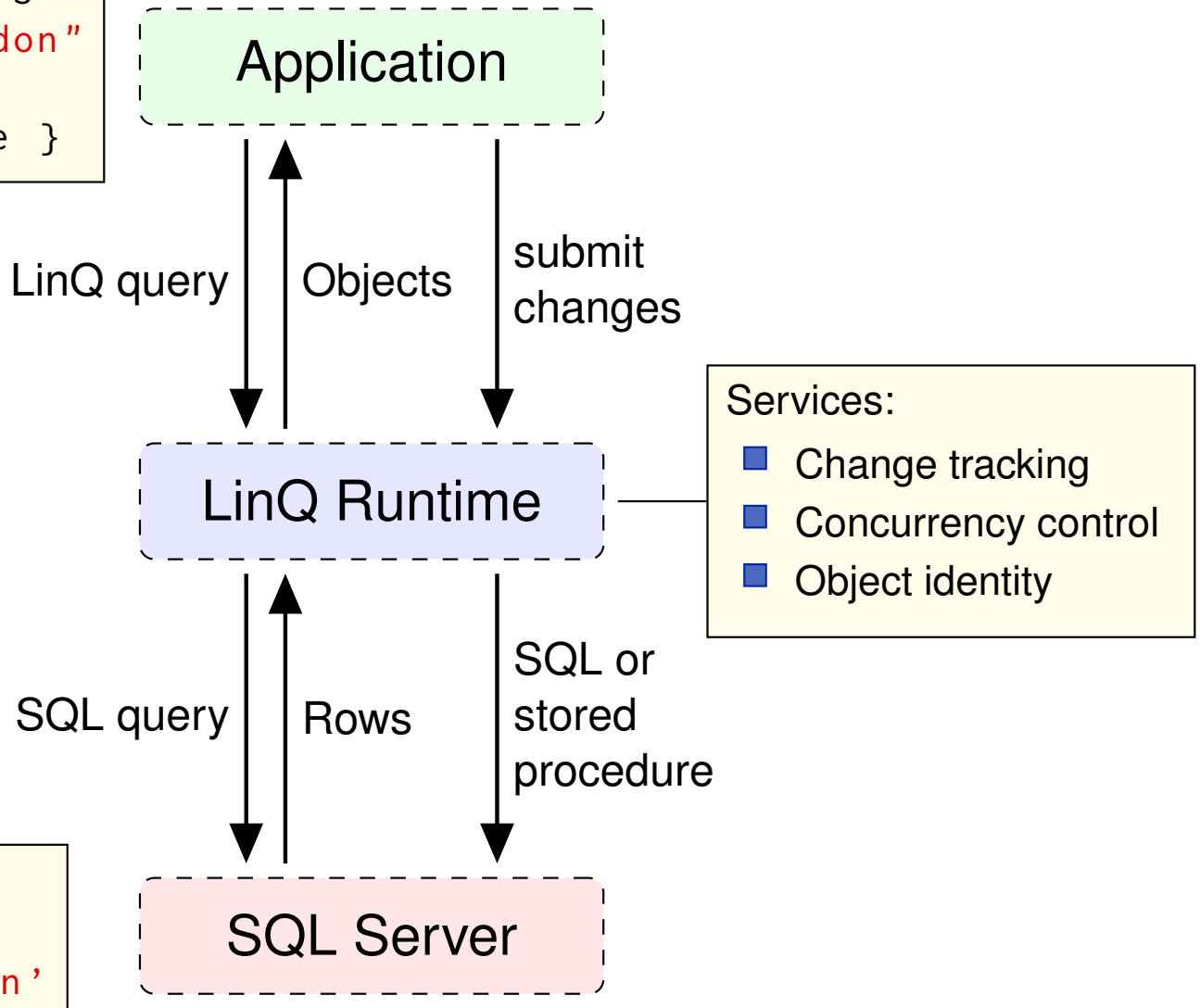
- LinQ to DataSet (querying data sets like lists)
- LinQ to XML
- LinQ to SQL (interact with logical database model)
- **LinQ to Entities** (interact with conceptual/object model)

LinQ: What the Runtime Module Does

```
from c in db.Customers
where c.City == "London"
select
new { c.Name, c.Phone }
```




```
select Name, Phone
from customers
where city = 'London'
```

LinQ: Query Comprensions

Syntactic sugar...

```
var contacts =
  from c in customers
  where c.State == "WA"
  select new { c.Name, c.Phone };
```

Syntactic sugar for an expression with lambda expressions:

Query operations with lambda expressions

```
var contacts =
  customers
  .Where(c => c.State == "WA")
  .Select(c => new{c.Name, c.Phone});
```

LinQ: Querying Collections

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var contacts =
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Here customers is of type **IEnumerable<Customer>** !

IEnumerable<...> provides methods for querying:

```
public static IEnumerable<T>
         Where<T>(this IEnumerable<T> src,
                  Func<T, bool>> p);
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Note: `Func<T, bool>> p` can be converted on-the-fly in an expression tree (a delegate) `Expression<Func<T, bool>> p`. This can then be translated into an SQL expression...

Database APIs

After this lecture, you should be able to:

- Explain the problem of **impedance mismatch**.
- Be able to classify DB application interfaces:
  - static, dynamic, object-relational mapping
- Discuss advantages and disadvantages of an API in terms of object **navigation** and complex **query execution**.
- Understand object-relational mappings:
  - **Hibernate** for Java
  - **Entity Framework** for .NET

  Relate these to the ANSI SPARC 3-layer model and the concepts of logical and physical data independence
- Explain advantages of **LinQ** and how it relates to impedance mismatch.