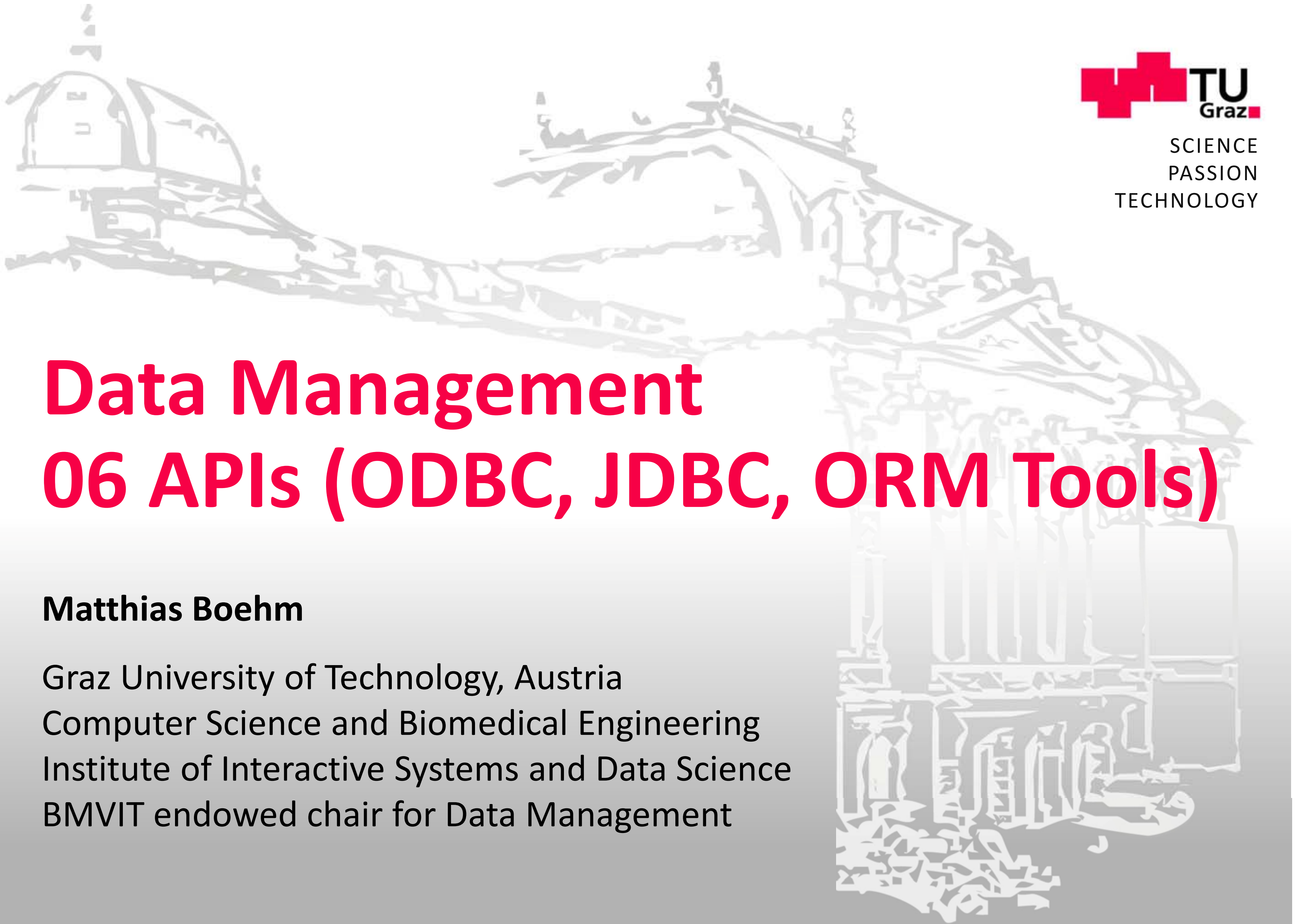

SCIENCE
PASSION
TECHNOLOGY

Data Management
06 APIs (ODBC, JDBC, ORM Tools)

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Last update: Apr 18, 2020

Announcements/Org

- **#1 Video Recording**
  - Link in **TeachCenter** & **TUbe** (lectures will be public)
  - **Live Streaming** Mo 4.10pm until end of semester (June 30)

- **#2 Reminder Communication**
  - **Newsgroup:** news://news.tugraz.at/tu-graz.lv.dbase; **no TeachCenter forum!** (https://news.tugraz.at/cgi-bin/usenet/nntp.csh?tu-graz.lv.dbase)
  - **Office hours:** Mo 1pm-2pm (https://tugraz.webex.com/meet/m.boehm)

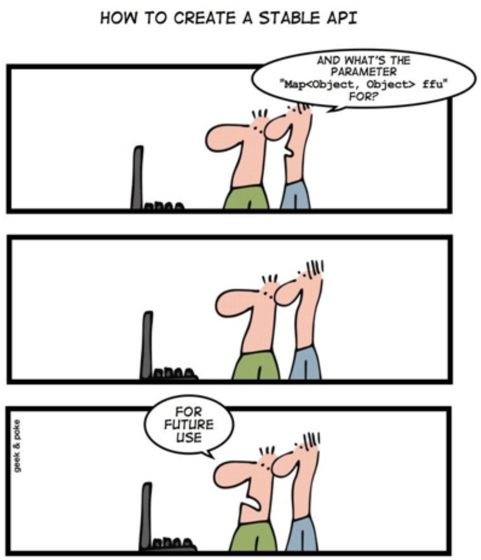
- **#3 Exercise 1 Summary**
  - **Started grading Apr 10** (after 7+3 late days)

79.5%

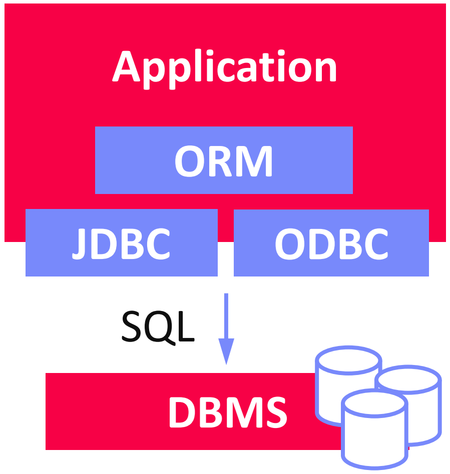
- **#4 Exercise 2 Reminder**
  - **Published Apr 7**, recommend schema **Apr 10**
  - Submission Deadline **Apr 28, 11.59 pm**

What’s an API and again, why should I care?

- **Application Programming Interface (API)**
  - Defined **set of functions or protocols** for system or component communication
  - Interface independent of concrete implementation → **decoupling of applications** from underlying libraries / systems
  - API stability of utmost importance


HOW TO CREATE A STABLE API
AND WHAT'S THE PARAMETER "Map<Object, Object> ffu" FOR?
FOR FUTURE USE
geek & poke

- **Examples**
  - **Linux:** kernel-user space API → system calls, POSIX (Portable Operating System Interface)
  - **Cloud Services:** often dedicated REST (Representational State Transfer) APIs
  - **DB Access: ODBC/JDBC and ORM frameworks**



Agenda

- Exercise 2: **Query Languages and APIs**
- **Call-level Interfaces (ODBC/JDBC) and Embedded SQL**
- **Object-Relational Mapping Frameworks**

Exercise 2:
Query Languages and APIs

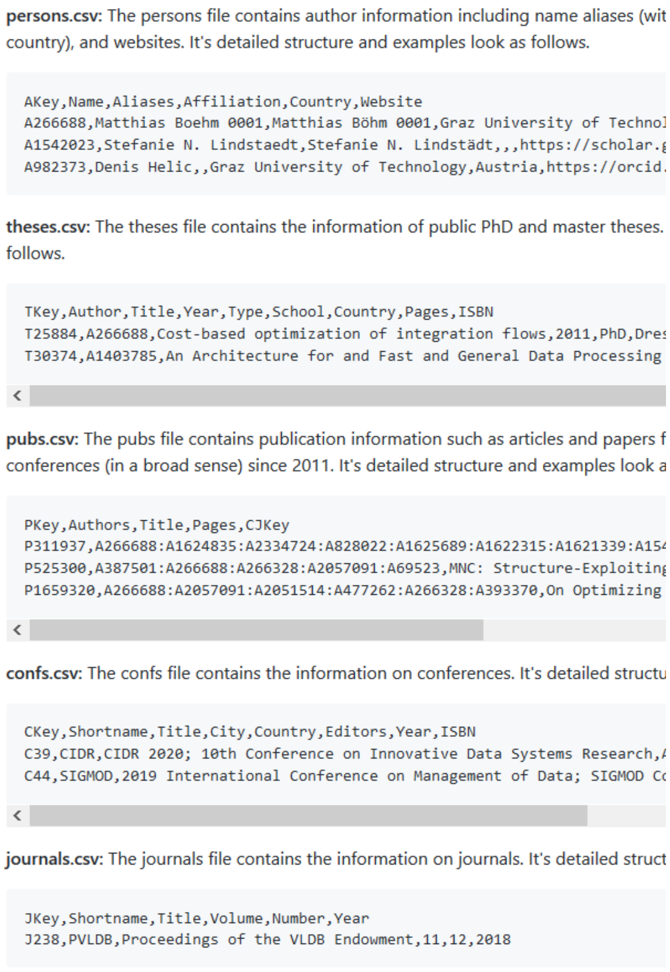
Extension of Exercise 2 Preview
from Mar 30

Published: **Apr 07, 2020**

Deadline: **Apr 28, 2020**

Exercises: DBLP Publications

- **Dataset**
  - CC0-licensed, derived (extracted, cleaned) from **DBLP** (https://dblp.org Feb 1, 2020) for publication **year ≥ 2011 + DM venues**
  - Clone or download your copy from https://github.com/tugraz-isds/datasets.git
- **Exercises**
  - **01** Data modeling (relational schema)
  - **02 Data ingestion and SQL query processing**
    - **Relational schema** + **ingestion**
    - SQL query processing + extra credit
  - **03** Physical design tuning, query processing, and transaction processing
  - **04** Large-scale data analysis (distributed data ingestions and query processing)



persons.csv: The persons file contains author information including name aliases (wit
country), and websites. It's detailed structure and examples look as follows.

```
AKey,Name,Aliases,Affiliation,Country,Website
A266688,Matthias Boehm 0001,Matthias Böhm 0001,Graz University of Technol
A1542023,Stefanie N. Lindstaedt,Stefanie N. Lindstädt,,,https://scholar.
A982373,Denis Helic,,Graz University of Technology,Austria,https://orcid.
```

theses.csv: The theses file contains the information of public PhD and master theses.
follows.

```
TKey,Author,Title,Year,Type,School,Country,Pages,ISBN
T25884,A266688,Cost-based optimization of integration flows,2011,PhD,Dres
T30374,A1403785,An Architecture for and Fast and General Data Processing
```

pubs.csv: The pubs file contains publication information such as articles and papers f
conferences (in a broad sense) since 2011. It's detailed structure and examples look a

```
PKey,Authors,Title,Pages,CJKey
P311937,A266688:A1624835:A2334724:A828022:A1625689:A1622315:A1621339:A154
P525300,A387501:A266688:A266328:A2057091:A69523,MNC: Structure-Exploitin
P1659320,A266688:A2057091:A2051514:A477262:A266328:A393370,On Optimizing
```

confs.csv: The confs file contains the information on conferences. It's detailed structu

```
CKey,Shortname,Title,City,Country,Editors,Year,ISBN
C39,CIDR,CIDR 2020; 10th Conference on Innovative Data Systems Research,
C44,SIGMOD,2019 International Conference on Management of Data; SIGMOD C
```

journals.csv: The journals file contains the information on journals. It's detailed struct

```
JKey,Shortname,Title,Volume,Number,Year
J238,PVLDB,Proceedings of the VLDB Endowment,11,12,2018
```

Task 2.1: Schema Creation via SQL (3/25 points)

- **Schema creation via SQL**
  - Relies on lectures **04 Relational Algebra** and **05 Query Languages (SQL)**
  - Setup DBMS PostgreSQL
  - Create database `db<studentID>` and setup relational schema
    - **Ignore** (1) **person aliases**, and (2) **conference editors**
    - Primary keys, foreign keys, `NOT NULL`, `UNIQUE`, specific `CHECK`s
    - `CreateSchema.sql`

- **Recommended Schema (published Apr 10)**

Task 2.2 Data Ingestion via CLI (8/25 points)

- **Data Ingestion Program via ODBC/JDBC**
  - Relies on lectures **05 Query Languages (SQL)** and **06 APIs (ODBC, JDBC)**
  - Write a program that performs **deduplication and data ingestion**
  - Programming language of your choosing (Python, Java, C#, C++ recommended)

- **Data Ingestion Process**
  - Data: https://github.com/tugraz-isds/datasets/tree/master/dblp_publications
  - Invoke your ingestion program as follows → script to compile and run

```
IngestData ./confs.csv ./journals.csv \
  ./persons.csv ./pubs.csv ./theses.csv \
  <host> <port> <database> <user> <password>
```

Task 2.3: SQL Query Processing (9/25 points)

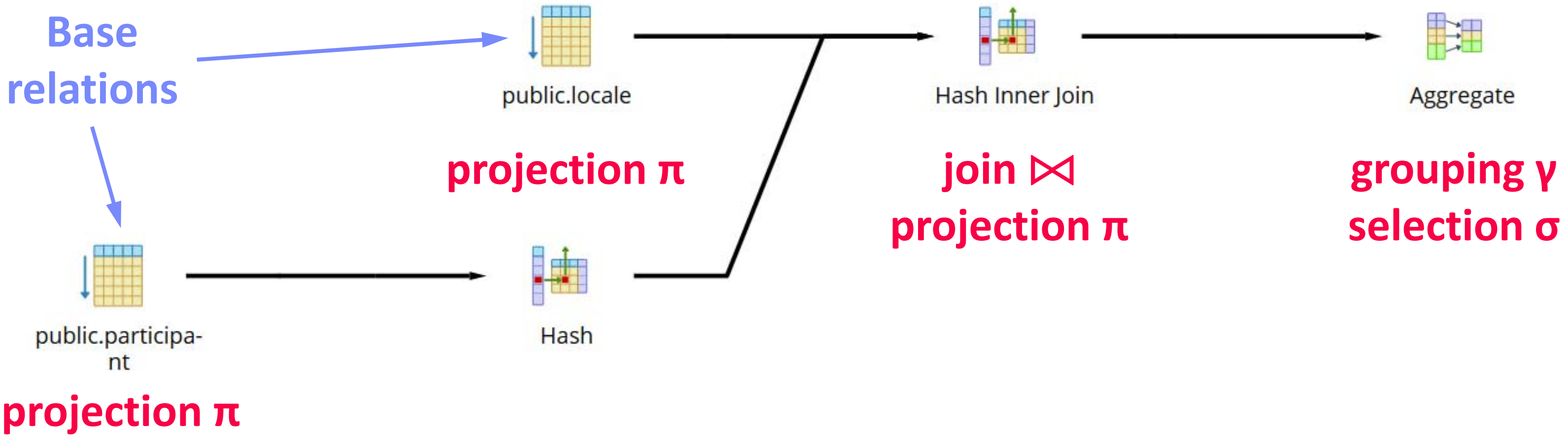
- **SQL Query Processing**
  - Relies on lecture **05 Query Languages (SQL)**
  - Write SQL queries (w/ results in comments) → `Queries.sql`

- **Example Queries**
  - **Q01:** Where did the conference SIGMOD 2019 (short name, year) take place? (return city and country)
  - **Q02:** Which persons are affiliated with Graz University of Technology? (return name, website; sorted ascending by name)
  - **Q05:** Which cities hosted more than 2 conferences? (return city, country, count; sorted decreasing by count)
  - **Q06:** Create a histogram that counts the number of papers for all groups of papers with equal #authors. (return #authors, #papers; sorted asc # authors)
  - **Q07:** How many distinct theses and papers did persons currently affiliated with Austrian institutions publish? (return single count)

Task 2.4: Query Plans (5/25 points)

- **Explain Query Plans**
  - Relies on lecture **04 Relational Algebra** and **05 Query Languages (SQL)**
  - Obtain and **analyze execution plans** of at least two queries
  - `ExplainQueries.sql`
- **Example: Recap: Participants/Locations from Lecture 04**
  - Text Explain

```
EXPLAIN VERBOSE SELECT L.location, count(*)
  FROM Participant P, Locale L WHERE P.lid = L.lid
  GROUP BY L.location HAVING count(*)>1
```



Base relations

projection π

join ⋈
projection π

grouping γ
selection σ

projection π

Task 2.5 Extra Credit (5 extra points)

- **Data Ingestion Program via ODBC/JDBC**
  - Relies on lectures **05 Query Languages (SQL)** and **06 APIs (ODBC, JDBC)**
  - Write a program that reconstructs and **prints a person's publication list**
  - Programming language of your choosing (Python, Java, C#, C++ recommended)

- **Invocation**
  - Print pub list for person to **stdout**

```
PrintPubs <person_name> \
<host> <port> <database> <user> <password>
```

- **Example Output**

```
* Johanna Sommer, Matthias Boehm 0001, Alexandre V. Evfimievski, Berthold Reinwald,
Peter J. Haas; MNC: Structure-Exploiting Sparsity Estimation for Matrix Expressions;
SIGMOD; 2019; 1607-1623.

* Matthias Boehm 0001, Berthold Reinwald, Dylan Hutchison, Prithviraj Sen, Alexandre V.
Evfimievski, Niketan Pansare; On Optimizing Operator Fusion Plans for Large-Scale Machine
Learning in SystemML; PVLDB; 2018; 1755-1768.

* Ahmed Elgohary, Matthias Boehm 0001, Peter J. Haas, Frederick R. Reiss, Berthold
Reinwald; Compressed Linear Algebra for Large-Scale Machine Learning; PVLDB; 2016; 960-971.

* Matthias Boehm 0001, Benjamin Schlegel, Peter Benjamin Volk, Ulrike Fischer, Dirk Habich,
Wolfgang Lehner; Efficient In-Memory Indexing with Generalized Prefix Trees; BTW; 2011;
227-246.
```

Call-level Interfaces (ODBC/JDBC) and Embedded SQL

Call-level Interfaces vs Embedded SQL

- **#1 Call-level Interfaces**
  - Standardized in ISO/IEC SQL – Part 3: CLI
  - **API of defined functions for dynamic SQL**
  - **Examples:** ODBC (C/C++), JDBC (Java), DB-API (Python)

- **#2 Embedded SQL**
  - Standardized in ISO/IEC SQL – Part 2: Foundation / Part 10 OLB
  - **Embedded SQL in host language** (typically static)
  - **Preprocessor** to compile CLI protocol handling
    ➔ **SQL syntax and type checking**, **but static** (SQL queries, DBMS)
  - **Examples:** ESQL (C/C++), SQLJ (Java)

Embedded SQL

- **Overview**
  - Mix host language constructs and SQL in data access program ➔ simplicity?
  - Precompiler translates program into valid host language program
  - Primitives for creating cursors, queries and updates, etc

➔ In practice, limited relevance

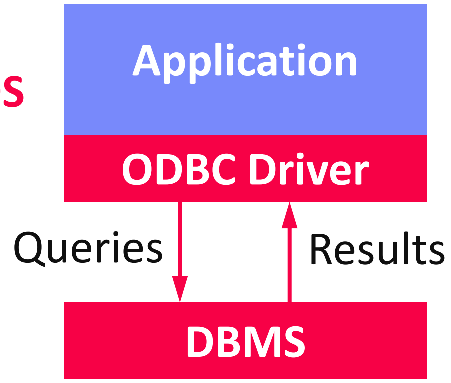
- **Example SQLJ**
  - Cursors with and without explicit variable binding

```
#sql iterator StudIter
   (int sid, String name);
StudIter iter;
#sql iter = {SELECT * FROM Students};

while( iter.next() )
   print(iter.sid, iter.name);

iter.close();
```

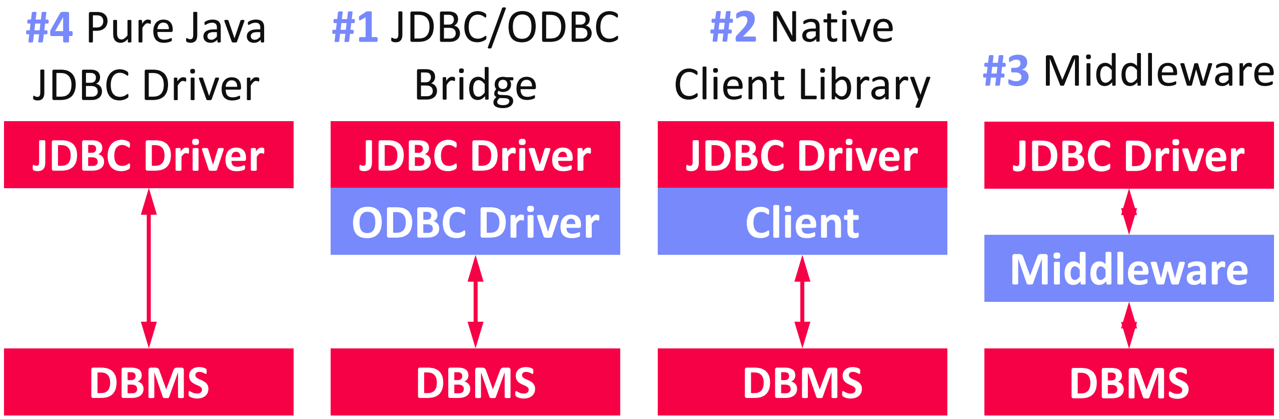
```
int id = 7;
String name;

#sql {SELECT LName INTO :name
   FROM Students WHERE SID=:id};

print(id, name);
```

CLI: ODBC and JDBC Overview

- **Open Database Connectivity (ODBC)**
  - **API for accessing databases independent of DBMS and OS**
  - Developed in the **early 1990s → 1992** by Microsoft (superset of ISO/IEC SQL/CLI and Open Group CLI)
  - **All relational DBMS have ODBC implementations**, good programming language support

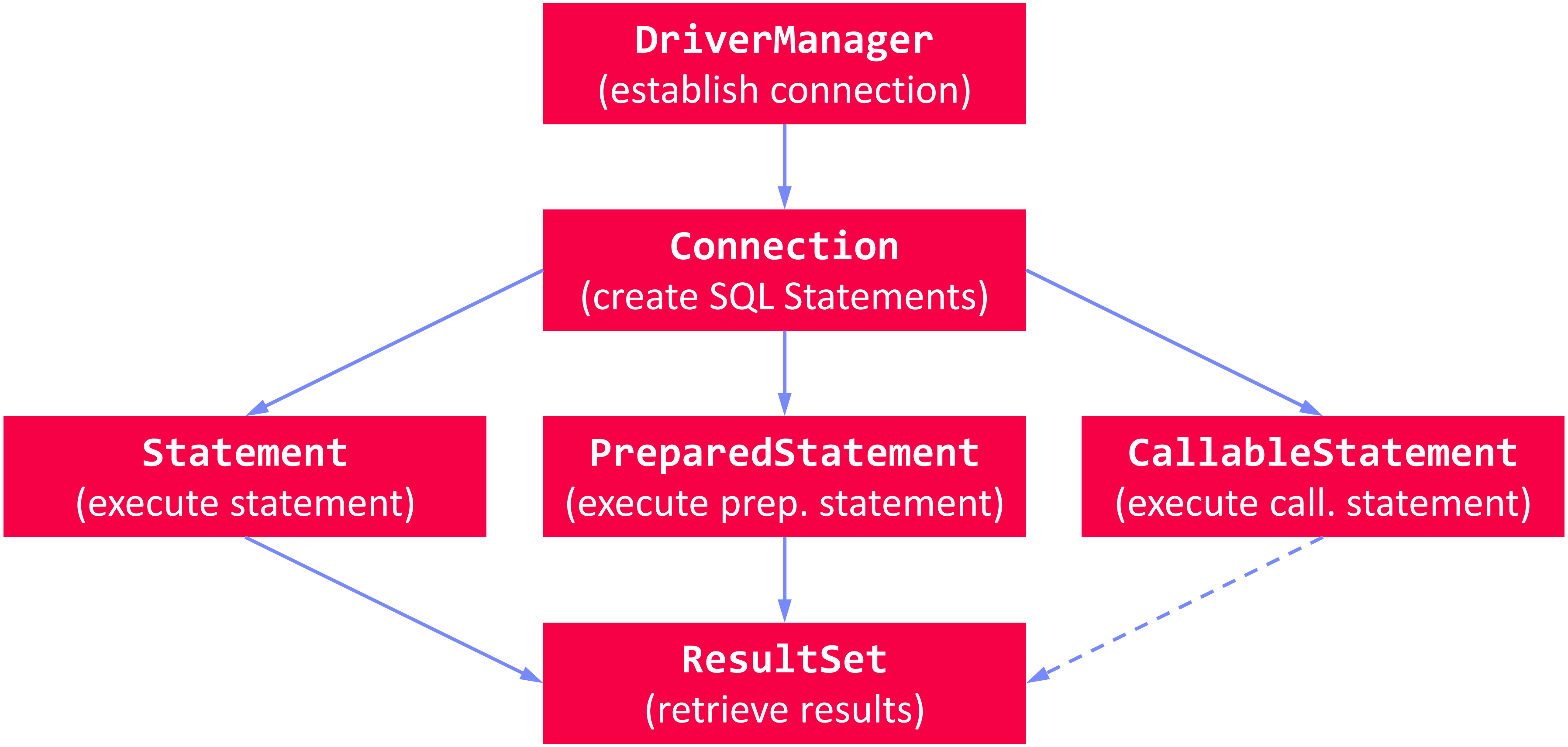


- **Java Database Connectivity (JDBC)**
  - **API for accessing databases independent of DBMS from Java**
  - Developed and released by Sun in **1997**, JDBC 4.0 (2006), JDBC 4.3 in Java 9
  - Most relational DBMS have JDBC implementations
  - Types of Drivers



Note: Reuse of drivers from open source DBMS

JDBC Components and Flow



JDBC Connection Handling

- **Establishing a Connection**
  - **DBMS-specific URL strings** including host, port, and database name

```
Connection conn = DriverManager
    .getConnection(“jdbc:postgresql:”+
    ”//localhost:5432/db1234567”,
    username, password);
```

  - Stateful handles representing user-specific DB sessions
  - JDBC driver is usually a jar on the class path
  - **Connection and statement pooling** for performance

```
META-INF/services/
java.sql.Driver
```

- **JDBC 4.0**
  - **Explicit driver class loading and registration no longer required**

```
Class.forName(
    "org.postgresql.Driver");
```

  - Improved connection management (e.g., status of DB connections)
  - Other: XML, Java classes, row ID, better exception handling

JDBC Statements

- **Execute Statement**
  - Use for simple SQL statements w/o parameters
  - **Beware of SQL injection**
  - API allows fine-grained control over fetch size, fetch direction, batching, and multiple result sets

```
Statement stmt = conn.createStatement();
ResultSet rs = stmt.executeQuery(sql1);
...
int rows = stmt.executeUpdate(sql2);
stmt.close();
```

Note: PostgreSQL does not support fetch size but sends entire result

- **Process ResultSet**
  - Iterator-like cursor (app-level) w/ on-demand fetching
  - Scrollable / updatable result sets possible
  - Attribute access via column names or positions

```
ResultSet rs = stmt.executeQuery(
   “SELECT SID, LName FROM Students”);

List<Student> ret = new ArrayList<>();
while( rs.next() ) {
   int id = rs.getInt(“SID”);
   String name = rs.getString(“LName”);
   ret.add(new Student(id, name));
}
```

JDBC Prepared Statements

- **Execute `PreparedStatement`**
  - Use for precompiling SQL statements w/ input params
  - Inherited from Statement
  - **Precompile SQL once**, and execute many times w/ different parameters
  - → **Performance**
  - → **No danger of SQL injection**

```
PreparedStatement pstmt =
   conn.prepareStatement(
     “INSERT INTO Students VALUES(?,?)”);

for( Student s : students ) {
   pstmt.setInt(1, s.getID());
   pstmt.setString(2, s.getName());
   pstmt.executeUpdate();
}

pstmt.close();
```

- **Queries and Updates**
  - Queries → `executeQuery()`
  - Insert, delete, update → `executeUpdate()`

JDBC Callable Statements

- **Recap: (Stored Procedures, see 05 Query Languages (SQL))**
  - Can be **called standalone via CALL** <proc_name>(<args>);
  - Procedures return no outputs, but might have **output parameters**

- **Execute `CallableStatement`**
  - Create prepared statement for call of a procedure
  - Explicit registration of output parameters
  - Example

```
CallableStatement cstmt = conn.prepareCall(
   “{CALL prepStudents(?, ?)}”);

cstmt.setInt(1, 2019);
cstmt.registerOutParameter(2, Types.INTEGER);
cstmt.executeQuery();

int rows = cstmt.getInt(2);
```

Psycopg (Python PostgreSQL Adapter)

- **Overview Psycopg**
  - Implements **Python Database API Specification v2.0**
  - Call-level interface for dynamic SQL, very similar to JDBC

- **Establish Connection**

```
conn = psycopg2.connect(
    host=“localhost”, port=“5432”,
    database=“db1234567”, user=username,
    password=password)
```

- **Execute Statements**
  - Use local cursors

```
cur = conn.cursor()
cur.execute(“INSERT INTO Students VALUES(...)”)
```

- **Process Result Sets**

```
cur.execute(“SELECT SID, LName FROM Students”)
students = cur.fetchall()
for row in students:
    print(“SID = ”, row[0], end = ‘’)
    print(“Lname = ”, row[1])
```

Psycopg (Python PostgreSQL Adapter), cont.

- **Execute Prepared Statements**

```
cur = conn.cursor()
sql = “INSERT INTO Students VALUES(%s, %s)”
for s in students:
    cur.execute(sql, (s.getID(),s.getName()))
conn.commit()
```

- **Execute Callable Statement**
  - Result set
  - No output parameters

```
cur = conn.cursor()
cur.callproc(“prepStudents”, (2019, 2))
cur.fetchone()
```

- **Close Connection**

```
cur.close()
conn.close()
```

Preview Transactions

- **Database Transaction**
  - A transaction (TX) is a **series of steps** that brings a database from a **consistent state** into another (not necessarily different) **consistent state**
  - **ACID properties** (atomicity, consistency, isolation, durability)
  - See lecture **08 Transaction Processing and Concurrency**

- **Example**
  - Transfer 100 Euros from Account 107 to 999

```
START TRANSACTION ISOLATION LEVEL SERIALIZABLE;
   UPDATE Account SET Balance=Balance-100
      WHERE AID = 107;
   UPDATE Account SET Balance=Balance+100
      WHERE AID = 999;
COMMIT TRANSACTION;
```

- **Transaction Isolation Level**
  - **Tradeoff:** isolation (and related guarantees) vs performance
  - READ UNCOMMITTED (~~lost update~~, dirty read, unrepeatable read, phantom R)
  - READ COMMITTED (~~lost update~~, ~~dirty read~~, unrepeatable read, phantom R)
  - REPEATABLE READ (~~lost update~~, ~~dirty read~~, ~~unrepeatable read~~, phantom R)
  - SERIALIZABLE (~~lost update~~, ~~dirty read~~, ~~unrepeatable read~~, ~~phantom R~~)

JDBC Transaction Handling

- **JDBC Transaction Handling**
  - Isolation levels (incl NONE) and (auto) commit option
  - Savepoint and rollback (undo till begin or savepoint)
  - **Note:** TX handling on connection not statements

- **Beware of Defaults**
  - DBMS-specific default isolation levels

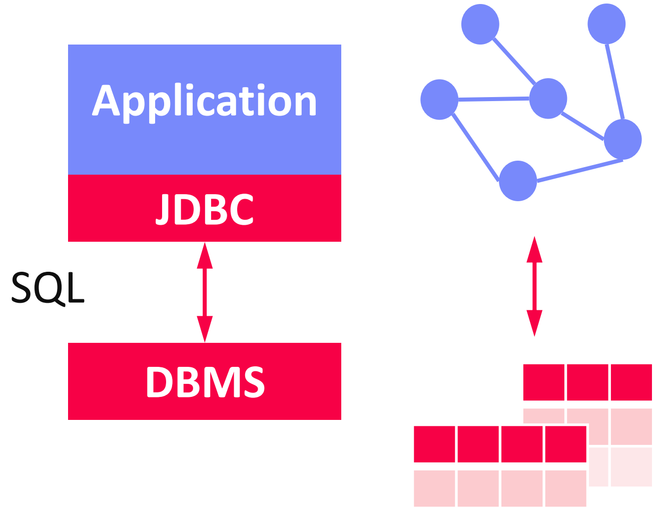
(SQL Standard: **SERIALIZABLE**, PostgreSQL: **READ COMMITTED**)

```
conn.setTransactionIsolation(
   TRANSACTION_SERIALIZABLE);
conn.setAutoCommit(false);

PreparedStatement pstmt = conn
   .prepareStatement(“UPDATE Account
   SET Balance=Balance+? WHERE AID = ?”);

Savepoint save1 = conn.setSavepoint();

pstmt.setInt(1,-100); pstmt.setInt(107);
pstmt.executeUpdate();

if( rand()<0.1 )
   conn.rollback(save1);

pstmt.setInt(1,100); pstmt.setInt(999);
pstmt.executeUpdate();

conn.commit();
```

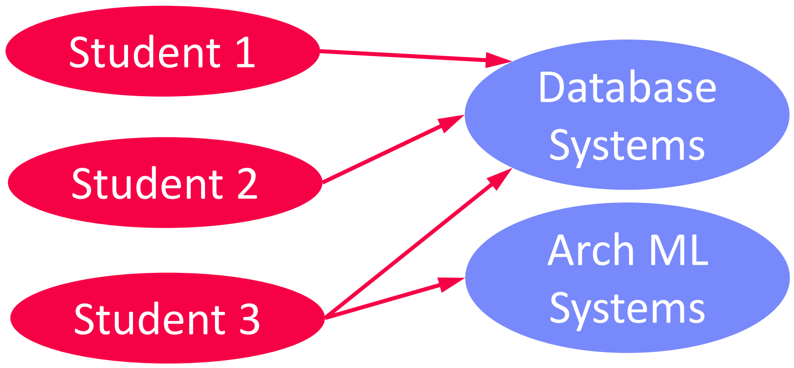
Object-Relational Mapping Frameworks

The “Impedance Mismatch” Argument

- **Problem Description**
  - Applications rely on **object-oriented programming languages** with hierarchies or graphs of objects
  - Data resides in **normalized “flat” tables** (note: ~~OODBMS~~, object-relational)
  - Application is responsible for **bridging this structural/behavioral gap**



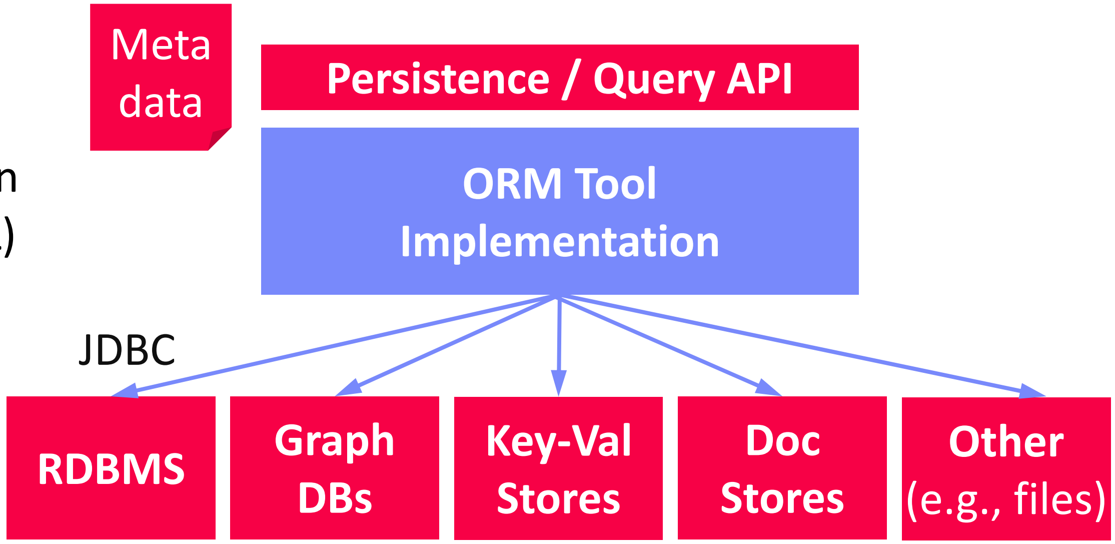
- **Example**
  - **SELECT** * **FROM** Students
  -
    ```
    SELECT C.Name, C.ECTS FROM
      Courses C, Attendance A
      WHERE C.CID = A.CID
         AND A.SID = 7;
    ```
  - … A.SID = 8;



Overview Object-Relational Mapping

- **Goals of ORM Tools**
  - Automatic **handling of object persistence lifecycle** and querying of the underlying data stores (e.g., RDBMS)
  - Reduced development effort ➔ **developer productivity**
  - Improved testing and independence of DBMS

- **Common High-Level Architecture**
  - **#1** Persistence definition (meta data → e.g., XML)
  - **#2** Persistence API
  - **#3** Query language / query API



Meta data

Persistence / Query API

ORM Tool Implementation

JDBC

RDBMS

Graph DBs

Key-Val Stores

Doc Stores

Other (e.g., files)

History and Landscape

- **History of ORM Tools** (aka persistence frameworks)
  - Since 2000 J2EE EJB **Entity Beans** (automatic persistence and TX handling)
  - Since 2001 **Hibernate** framework (close to ODMG specification)
  - Since 2002 **JDO** (Java Data Objects) via class enhancement
  - 2006 **JPA** (**Java Persistence API**), reference implementation **TopLink**
  - 2013 JPA 2, reference implementation **EclipseLink**
  - Late 2000s/early 2010s: **explosion of ORM alternatives, but criticism**
  - **2012 - today:** ORM tools just part of a much more diverse eco system

- **Example Frameworks**
  - http://java-source.net/open-source/persistence
  - Similar lists for .NET, Python, etc

JPA – Class Definition and Meta Data

- **Entity Classes**
  - **Define persistent classes** via annotations
  - Add details for IDs, relationship types, and specific behavior on updates
  - Some JPA implementations require enhancement process as post compilation step

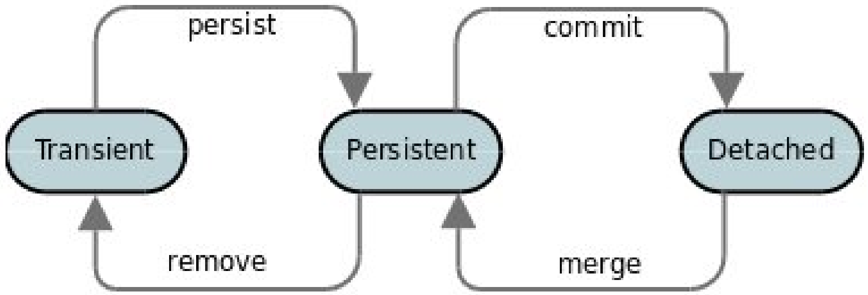
```
@Entity
public class Student {
    @Id
    private int SID = -1;
    private String Fname;
    private String Lname;
    @ManyToMany
    private List<Course> ...
}
```

- **Persistence Definition**
  - **Separate XML meta data** `META-INF/persistence.xml`
  - Includes connection details

```
<?xml version="1.0" encoding="UTF-8" ?>
<persistence
      xmlns="http://xmlns.jcp.org/xml/ns/persistence"
      xmlns:xsi=... xsi:schemaLocation=...>
   <persistence-unit name="UniversityDB">
      <class>org.tugraz.Student</class>
      <class>org.tugraz.Course</class>
      <exclude-unlisted-classes/>
      <properties> ... </properties>
   </persistence-unit>
</persistence>
```

JPA – Object Modification

- **CRUD Operations**
  - Insert by making objects persistent
  - Update and delete objects according to object lifecycle states
- **Lifecycle States**
  - Lifecycle state transitions via specific persistence contexts
  - Explicit and implicit transitions



[**Credit:** Data Nucleus, JPA Persistence Guide (v5.2), http://www.datanucleus.org/products/accessplatform/jpa/persistence.html#lifecycle]

```
EntityManager em = factory
   .createEntityManager();

tx.begin();

Student s = new
   Student(7,”Jane”,”Smith”);
s.addCourse(new Course(...));
s.addCourse(new Course(...));

em.persist(s);

tx.commit();
em.close
```

JPA – Query Languages

- **JPQL: Java Persistence Query Language**
  - SQL-like object-oriented query language
  - Parameter binding similar to embedded SQL

```
EntityManager em = factory
   .createEntityManager();
Query q = pm.createQuery(
   "SELECT s FROM Student s
      WHERE s.age > :age");
q.setParameter(“age”, 35);

Iterator iter = q
   .getResultList().iterator();
while( iter.hasNext() )
   print((Student)iter.next());
```

- **JPQL Criteria API**
  - JPQL syntax and semantics with a programmatic API

  -
    ```
    CriteriaQuery<Student> q = bld.createQuery(Student.class);
    Root<Student> c = q.from(Student.class);
    q.select(c).where(bld.gt(c.get(“age”), bld.parameter(...)));
    ```

- **Native SQL Queries**
  - Run native SQL queries if necessary

```
em.createNativeQuery(“SELECT *
   FROM Students WHERE Age > ?1”);
```

Jdbi (Java Database Interface)

[http://jdbi.org/]

- **Jdbi Overview**
  - Fluent API built on top of JDBC w/ same functionality exposed
  - Additional simplifications for row to object mapping

- **Example**

```
Jdbi jdbi = Jdbi.create(“jdbc:postgresql://.../db1234567”);
Handle handle = jdbi.open();

jdbi.registerRowMapper(Student.class, (rs, ctx)
  -> new Student(rs.getInt(“sid"), rs.getString(“lname"));

List<Student> ret = handle
  .createQuery("SELECT * FROM Students WHERE LName = :name")
  .bind(0, "Smith")
  .map(Student.class)
  .list();
```

A Critical View on ORM

- **Advantages**
  - **Simple CRUD operations** (insert/delete/update) and simple queries
  - **Application-centric development** (see boundary crossing)
- **Disadvantages**
  - **Unnecessary indirections** and complexity (meta data, mapping)
  - **Performance problems** (hard problem and missing context knowledge)
  - **Application-centric development** (schema ownership, existing data)
  - **Dependence** on evolving framework APIs
- **Sentiments** (additional perspectives)
  - Omar Rayward: Breaking Free From the ORM: Why Move On?, 2018 medium.com/building-the-system/**dont-be-a-sucker-and-stop-using-orms**-190add65add4
  - Vedra Bilopavlović: Can we talk about ORM Crisis?, 2018 linkedin.com/pulse/**can-we-talk-orm-crisis**-vedran-bilopavlovi%C4%87
  - Martin Fowler: ORM Hate, 2012 martinfowler.com/bliki/**OrmHate**.html

➔ **Awareness of strength and weaknesses / hybrid designs**

Conclusions and Q&A

- **Summary**
  - **Call-level Interfaces (ODBC/JDBC)** as fundamental access technology
  - **Object-Relational Mapping (ORM)** frameworks existing (**pros and cons**)
- **Exercise Reminder**
  - Exercise 2: Submission opened Apr 07, deadline: **Apr 28 11.59pm**
- **Next Lectures**
  - **07 Physical Design and Tuning** [Apr 27]
  - **08 Query Processing** [May 04]
  - **09 Transaction Processing and Concurrency** [May 11]