9 Embedding SQL into Programming languages

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Lit.: Kemper / Eickler: chap. 4.19-4.23;
Melton: chap. 12,13,17-19, Widom, Ullman, Garcia-Molina: chapt.8
Christian Ullenboom Java ist auch eine Insel, Kap. 20, Galileo Comp.

Using SQL from Programs

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- SQL is a **data sublanguage**
- Easy **data** access but no way to define "business rules"
- **Business rule**: Algorithm which implements an application specific use cases
  Example (Uni-DB): student finished her studies an leaves university

- Needs a **host language** offering

  Control structures

  User interface: output formatting, forms

  Transaction: more than one DB interaction as a unit of work for implementing business rules.

SQL and Programming Languages

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Issues

Language mismatch ("impedance mismatch")

- Set oriented operations versus manipulation of individuals -> Objects vs. Relations
- How to interconnect program variables and e.g attributes in SQL statements?
- Should an SQL-statement as part of a program be compiled, when?

SQL from Programs: Introduction

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Overview of language / DB integration concepts

Interface of standard programming languages

- **Call level interface**, proprietary library routines, API
  Standardized: SQL CLI **Open Database connection (ODBC),**
- **Embedded C / Java / ..**
  Standardized language extensions
- Standardized API
  Java DBC

Object-Relational Mapping

- JPA (Java Persistence Architecture), Hibernate

Component architectures: hiding the details of DB interaction, Enterprise Java Beans (EJB)

Using SQL from Programs:CLI

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Call level interface

Language and DBS specific library of procedures to access the DB

Example: MySQL C API

- Communication buffer for transferring commands and results
- API data types like
  `MYSQL` handle for db connections
  `MYSQL_RES` structure which represents result set
- API functions
  `mysql_real_query()`
  `mysql_real_query (MYSQL *mysql, const char * query, unsigned int length)`
  query of **`length`** of character string in buffer
  and many more....

Standard : Open Database Connection (**ODBC**)
Predecessor of Java Database Connection (**JDBC**), see below

SQL Call level interface (SQL/CLI)

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Standardized Interface to C / C++ defined by **X/OPEN** and **SQL Access group**

- Main advantages

  DBS-independent

  Application development independent from DBS
  (as opposed to Embedded SQL precompiler approach, see below)

  Easy to connect to multiple DB

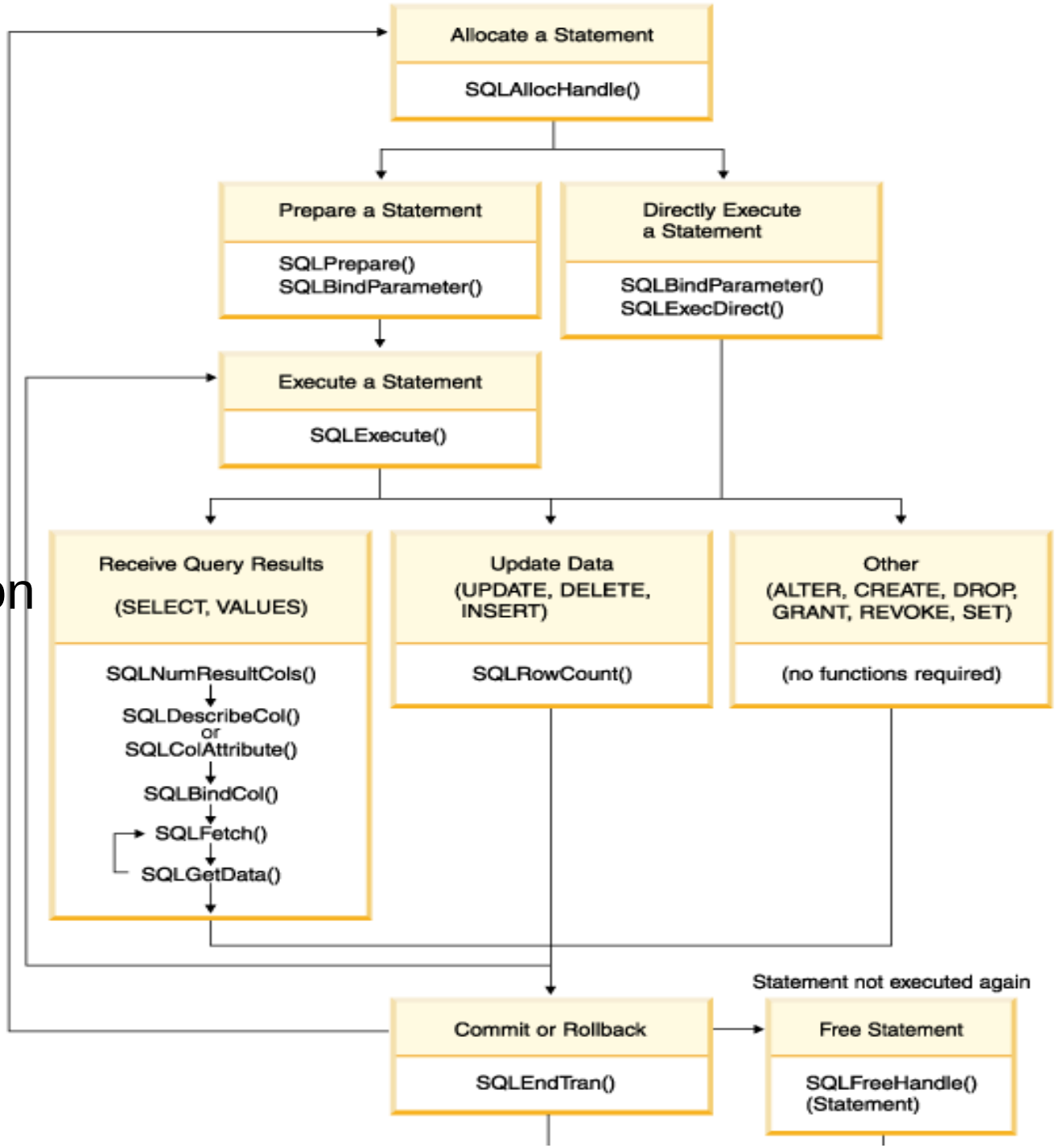
- Microsoft implementation
  ODBC (= Open Database Connectivity) de facto standard, available not only for MS products

Main cycle of transaction execution with SQL/CLI

Calls are embedded in the application program

See also JDBC

source:
IBM DB2 manual



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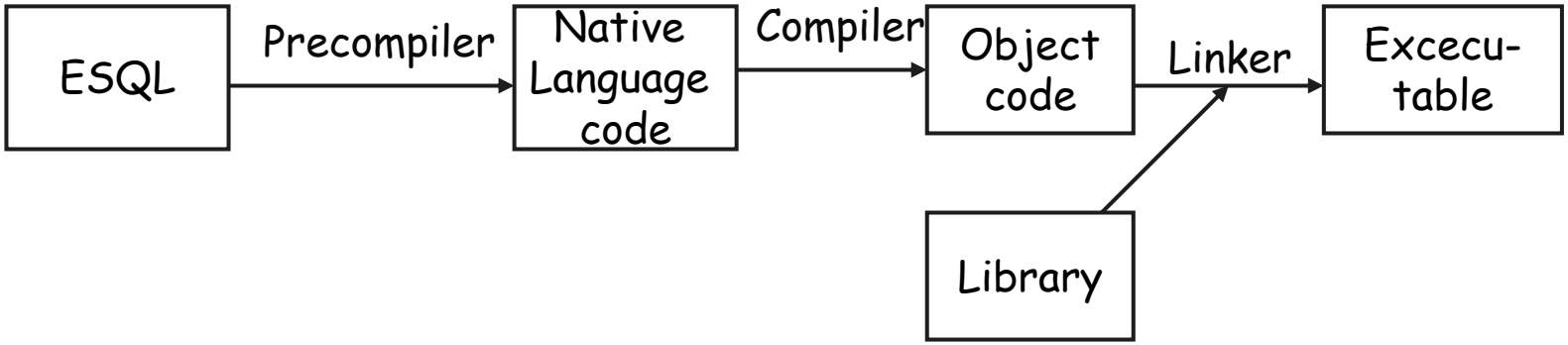
Embedded SQL – the most important(**?**) approach

Concepts

- **Program consists of "native" and SQL-like statements (e.g.** Embedded C , SQLJ)
- **Precompiler compiles it to native code, includes calls to DBS resources**
- Employs call level interface in most implementations



Embedded SQL (ESQL): what needed?

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- Well defined type mapping (for different languages)
- Syntax for embedded SQLJ statements

  #sql [[<context>]] { <SQL-Anweisung> }

- Binding to host language variables

```
#sql  {SELECT m# FROM M
        WHERE titel = :titleString};}...
#sql {FETCH ...INTO :var1}
```

hypothetical syntax, like SQLJ

- Exception handling (**WHENEVER condition action**)
  SQLSTATE, SQLCODE (deprecated)

ESQL

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C / Java embedding

ESQL/C

```
EXEC SQL UPDATE staff SET job = 'Clerk'
   WHERE job = 'Mgr';
 if ( SQLCODE < 0  printf( "Update Error: ... );
```

SQLJ

```
try { #sql { UPDATE staff SET job = 'Clerk'
      WHERE job = 'Mgr' }; }
catch (SQLException e)
 { println( "Update Error: SQLCODE = " + ... );
```

ESQL Static / dynamic embedding

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Static versus dynamic SQL:

Static: all SQL commands are known in advance, SQL-compilation and language binding at precompile time

Dynamic

(i) SQL-String executed by DBS:
Operator tree, optimization, code binding....

(ii) SQL-String *prepared* (compiled) at runtime.
Performance gain in loops etc.

ESQL Cursors

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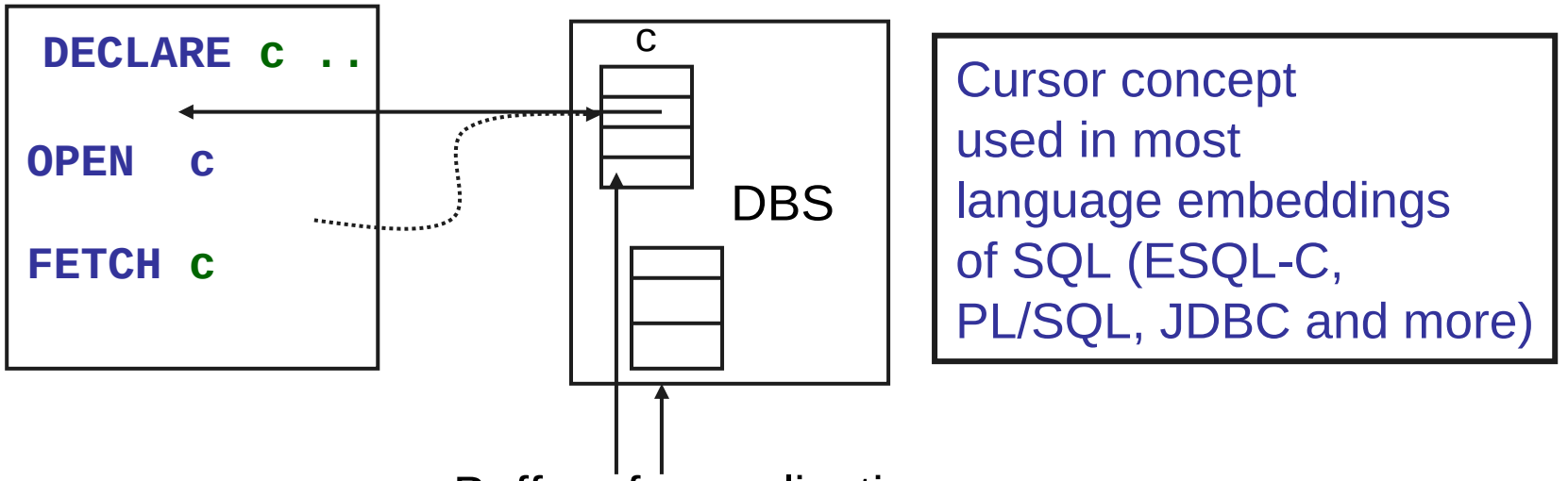
Cursor concept

How to process a result set one tuple after the other?

CURSOR: name of an SQL statement and a handle for processing the result set record by record

Cursor is defined, opened at runtime (= SQL-statement is excecuted) and used for **FETCHing** single result records



Buffers for application program cursors
DBS may determine result set in a lazy or eager way

ESQL Cursors

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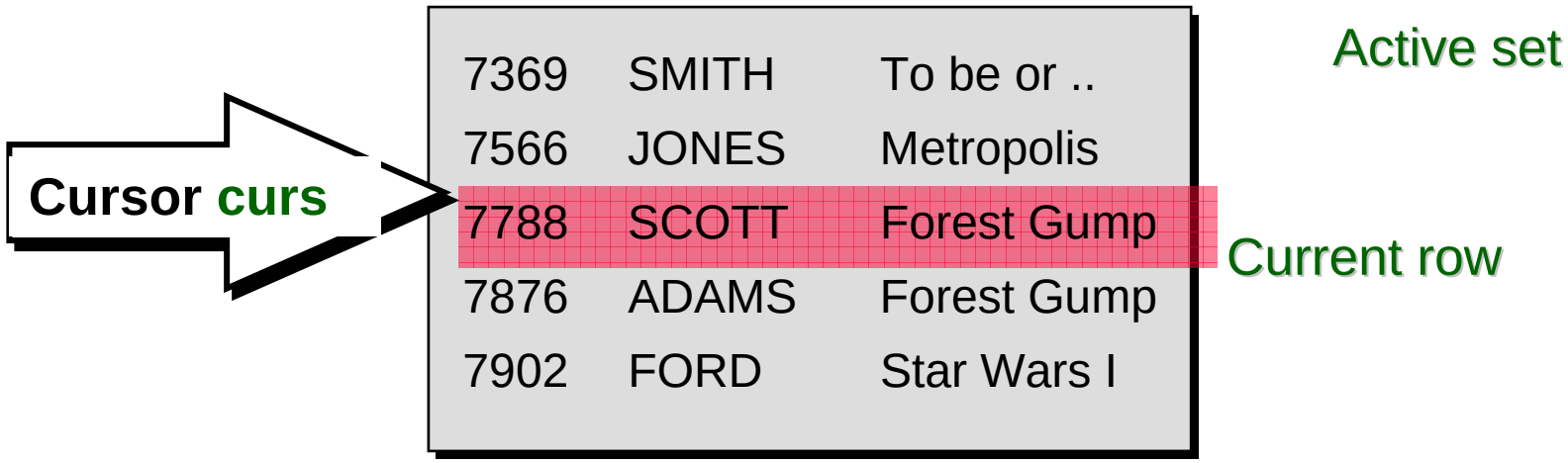
Cursor : just like cursors in PL/xxSQL,
but typically more positioning operations

```
Declare curs for Select c#, lname, m.title
                 from C, R, M where  ....
```



Cursors

Fetch

```
FETCH curs INTO :x, :nameVar, :titleVar;
```

Cursor scrolling (Declare c SCROLL cursor.. in SQL 92):

FETCH [NEXT | PRIOR | FIRST | LAST |
[ABSOLUTE | RELATIVE expression]]
FROM cursor INTO target-variables

```
FETCH curs PRIOR INTO :x, :nameVar, :titleVar;
```

=

```
FETCH curs RELATIVE –1  INTO :x, :nameVar, :titleVar;
```

Single row SELECT does not need a FETCH but result is bound to variables: SELECT a,b FROM... INTO :x,:y WHERE

SQLJ - Example

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```
#sql private static iterator EmployeeIterator(String,
   String, BigDecimal);
...
EmployeeIterator iter;
 #sql [ctx] iter = {
   SELECT LASTNAME , FIRSTNME , SALARY
        FROM DSN879.EMP
        WHERE SALARY
        BETWEEN :min AND :max };
 while (true)
 { #sql {
        FETCH :iter
        INTO :lastname, :firstname, :salary };
 if (iter.endFetch())
        break;  ..... }
 iter.close();
```

Cursors

Opening

```
OPEN  cursor_name;
```

In a compiled language environment (e.g. embedded C):

- bind input variables
- execute query
- put (first) results into communication (context) area
- no exception if result is empty
  has to be checked when fetching the results
- positions the cursor before the first row of the result set (" –1 ")

First steps in an interpreted language (e.g. 4GL PL/SQL) :

- allocate context area
- parse query

9.2.3 ESQL

```
#include <stdio.h>

/* declare host variables
*/
char userid[12] =
"ABEL/xyz";
char emp_name[10];
int  emp_number;
int  dept_number;
char temp[32];
void sql_error();

/* include the SQL
Communications Are
*/ #include <sqlca.h>
```

```
main()
{  emp_number = 7499;
/* handle errors */
   EXEC SQL WHENEVER SQLERROR
    do sql_error("Oracle
error");

/* connect to Oracle */
   EXEC SQL CONNECT :userid;

/* declare a cursor */
   EXEC SQL DECLARE
emp_cursor CURSOR FOR
   SELECT ename
       FROM emp
       WHERE deptno =
              :dept_number;
```

ESQLExample: Embedded C

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```
printf("Department number? ");
   gets(temp);
   dept_number = atoi(temp);
/* open the cursor and identify the active
set */
   EXEC SQL OPEN emp_cursor; …
/* fetch and process data in a loop
   exit when no more data */
   EXEC SQL WHENEVER NOT FOUND DO break;
   while (1)
   {EXEC SQL FETCH emp_cursor INTO
   :emp_name; ..
}
   EXEC SQL CLOSE emp_cursor;
   EXEC SQL COMMIT WORK RELEASE;
   exit(0); }
```

Close cursor before another SC
statement is executed

ESQL Exception handling

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Exception handling: error routine (C)

```
void  sql_error(msg)
char *msg;
{
   char buf[500];
   int buflen, msglen;
   EXEC SQL WHENEVER
            SQLERROR CONTINUE;
   EXEC SQL ROLLBACK WORK
                     RELEASE;
   buflen = sizeof (buf);
   sqlglm(buf, &buflen, &msglen);
   printf("%s\n", msg);
   printf("%*.s\n", msglen, buf);
   exit(1);
}
```

ESQL Exception handling

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```
EXEC SQL WHENEVER SQLERROR GOTO sql_error;
...
sql_error:
    EXEC SQL WHENEVER SQLERROR CONTINUE;
    EXEC SQL ROLLBACK WORK RELEASE;
  …
```

Without the WHENEVER SQLERROR CONTINUE statement, a ROLLBACK error would invoke the routine again, starting an infinite loop.

Positioned Update

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Update / Delete statements in general use search predicates to determine the rows to be updated

```
Update M
 set price_Day = price_Day+1 where price_Day <= 1
```

Often useful: step through a set of rows and update some of them ⇨ positioned update

```
DECLARE myCurs  FOR SELECT ppd, title FROM M
    FOR UPDATE ON ppd
UPDATE M SET ppd = ppd + 1
   WHERE CURRENT OF  myCurs     /* delete in a
                                /*similar way
```

A cursor may declared FOR READ ONLY
- which basically results in some performance gains

ESQL Cursor sensitivity

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Which state has the database during processing?

```
EXEC SQL DECLARE myCurs  FOR SELECT price_Day, title
  FROM M  FOR UPDATE ON price_Day
                WHERE price_Day < 2
EXEC SQL OPEN...
...
EXEC SQL FETCH myCurs INTO .....
UPDATE M SET price_Day = price_Day + 2
          WHERE CURRENT OF  myCurs /* similar for
                                   /* delete
```

Is the row under the cursor still in the result set?

Yes and No !

A cursor declared INSENSITIVE does not make visible any changes (update, delete) until the cursor is closed and reopened.

9.3 SQL and Java

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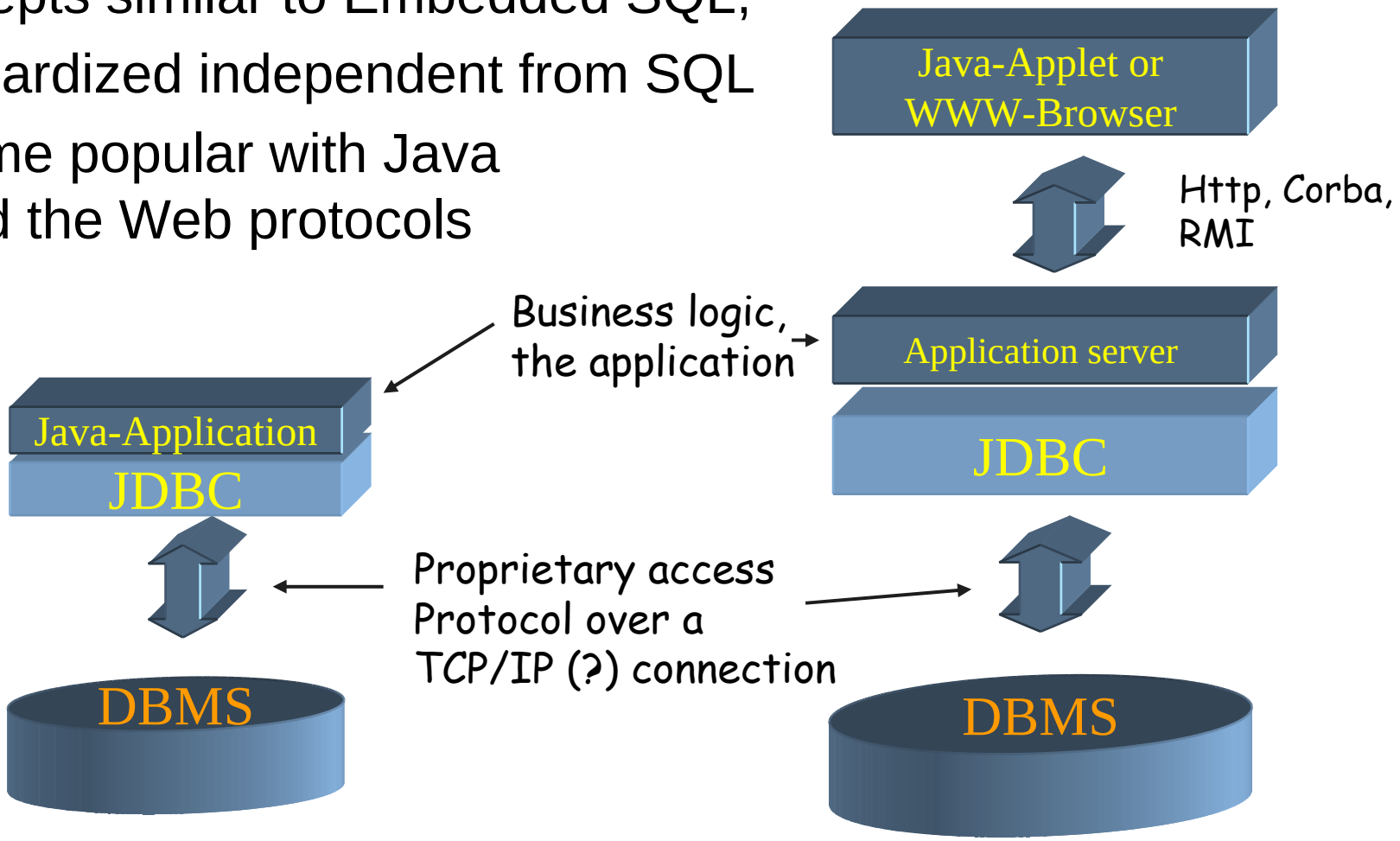
Concepts similar to Embedded SQL,

Standardized independent from SQL

became popular with Java
and the Web protocols



SQL & Java: JDBC und SQLJ

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SQLJ

- essentially embedded SQL for Java
- Compiles to JDBC method call, more interveaved with programming langugage.
- Defined and implemented by major DBS companies (Oracle in particular)

JDBC

- Java call-level interface (API) for SQL DBS
- API DB vendor independent, but often not implemented fully
- Supports static and dynamic SQL
- Implemented by nearly all DB vendors

9.4.1 JDBC

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Preparation

```
import java.sql.*;
```

(1) Load a driver (included in java.sql.*), many vendor products

```
Class.forName("oracle.jdbc.driver.OracleDriver");
```

url is a variable holding the JDBC-Driver and host information

(2) Set up the connection to one or more database(s)

```
Connection con = DriverManager.getConnection(
  "jdbc:oracle:thin:@tarent.mi.fu-
   berlin.de:1521:hstarent", username,  password);
```

Several connections at a time may be used.

Opening a connection takes time! A solution… see below.

Creating a connection

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(3a) Create a statement object

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

something like a channel, through which queries are sent to the DB

Note: `stmt` this is NOT a statement, but a "statement channel".

Executing a query from Java

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Processing

Queries may now be "sent through the statement channel" of a connection to the DBS and executed:

```
ResultSet rs = stmt.executeQuery("Select * from myTab")
```

Note: Only `String` (The SQL query as a string) is allowed no parameters within SQL command!

`ResultSet` object manages result table:
`boolean next(), boolean last(), boolean previous(),...` similar to cursor in ESQL, but cursor is "hidden".

Many methods for extracting column values from
`int getInt(int ColumnIndex), String getString(...),`

SQL & Java: JDBC

Processing

"

```
ResultSet rs = stmt.executeQuery("SELECT * FROM
Movies WHERE pricePD > 2" );
```

Process the results one after the other

```
while (rs.next())
{  // Loop through each column, get the
   // column data and display
        for (i = 1; i <= numCols; i++)
        {
             if (i > 1) System.out.print(",");
             System.out.print(rs.getString(i));
        }
}
```

Variable binding by position

JDBC: variable binding, result set iterator

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Variable binding by name

```
java.sql.Statement stmt = con.createStatement();
  ResultSet r = stmt.executeQuery("SELECT a, b, c
                                   FROM Table1");
    while (r.next())
    {
    // print the values for the current row.
      int i = r.getInt("a");
      String s = r.getString("b");
      float f = r.getFloat("c");
      System.out.println("ROW = " + i + " " + s + " " + f);
```

Compare variable binding by position

SQL and Java Excecptions

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```
try {
 // Code that could generate an exception goes here.
 // If an exception is generated, the catch block below
 // will print out information about it. }
catch(SQLException ex) {
   System.out.println("\n--- SQLException caught ---\n");
   while (ex != null) { System.out.println("Message: " +
   ex.getMessage ()); System.out.println("SQLState: " +
   ex.getSQLState ()); System.out.println("ErrorCode: " +
   ex.getErrorCode ()); ex = ex.getNextException();
  System.out.println(""); }
 }
```

process all execptions

```
--- SQLException caught ---
Message: There is already an object named 'Meier' in the database.
Severity 16,
State 1, Line 1
SQLState: 42501      -- Defined as X/Open standard
ErrorCode: 2714      -- Vendor specific
```

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Accessing columns

The class ResultSet has methods for each type to access result data by position or by name

By position:

```
String s = rs.getString(2); // the second
attribute to be bound.
```

By name:

```
String rs.getString ("b") ;
// get the value of the attribute b of the
// row under the (implicit) cursor
```

Input parameters for queries**?** (... where attr = :val**)**

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Prepared statements

Subclass of statement

will be compiled,
? Indicates parameter

```
 String mTitle; ....
try {
   java.sql.PreparedStatement prepStmt =
         con.prepareStatement("SELECT count(*)
         FROM M,T where M.title = ? and T.mId = M.mId);
    prepStmt.setString(1, mTitle);
    ResultSet r = prepStmt.executeQuery() ;
    while (r.next())
    {
     int i = r.getInt(1);
    // must get by position, no name available
      System.out.println("Number of tapes for  " +
      movieTitle + " is: " +i)
    }
  } catch(SQLEception {…}
```

Bind value to position (!)
in statement and excecute

Prepared vs non-prepared

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- Prepared statement have IN parameters
- Overhead for compiling SQL-statement basically constant
- Ratio of compile Time / processing time for queries important
- Simple queries: prepare when executed frequently – e.g. in a loop
- Complex queries in a loop: no performance gain
- Many more factors to be analyzed