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Chapter 3
DB-Gateways

Outline

- Coupling DBMS and programming languages
  - approaches
  - requirements
- Programming Model (JDBC)
  - overview
  - DB connection model
  - transactions
- Data Access in Distributed Information System Middleware
- DB-Gateways
  - architectures
    - ODBC
    - JDBC
- SQL/OLB – embedded SQL in Java
- Summary

Coupling Approaches (Examples)

- Embedded SQL
  - static
    - Example:

      ```
      exec sql declare c cursor for
                SELECT empno FROM Employees WHERE dept = :deptno_var;
      exec sql open c;
      exec sql fetch c into :empno_var;
      ```
  - dynamic
    - Example:

      ```
      strcpy(stmt, "SELECT empno FROM Employees WHERE dept = ?");
      exec sql prepare s1 from :stmt;
      exec sql declare c cursor for s1;
      exec sql open c using :deptno_var;
      exec sql fetch c into :empno_var;
      ```
- Call-Level Interface (CLI)
    - Example:

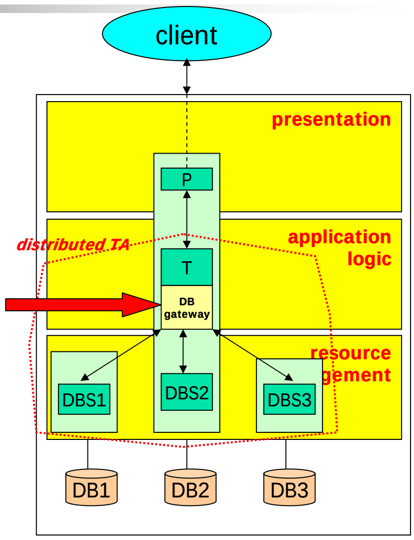
      ```
      strcpy(stmt, "SELECT empno FROM Employees WHERE dept = ?");
      SQLPrepare(st_handle, stmt, ...);
      SQLBindParam(st_handle, 1, ..., &deptno_var, ...);
      SQLBindCol(st_handle, 1, ..., &empno_var, ...);
      SQLExecute(st_handle);
      SQLFetch(st_handle);
      ```

Standard Call Level Interfaces - Requirements

- Uniform database access
  - query language (SQL)
  - meta data (both query results and DB-schema)
    - Alternative: SQL Information Schema
  - programming interface
- Portability
  - call level interface (CLI)
    - no vendor-specific pre-compiler
    - application binaries are portable
    - but: increased application complexity
  - dynamic binding of vendor-specific run-time libraries
- Dynamic, late binding to specific DB/DBS
  - late query compilation
  - flexibility vs. performance

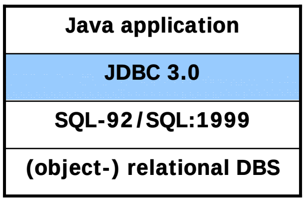
Additional Requirements for DB-Gateways

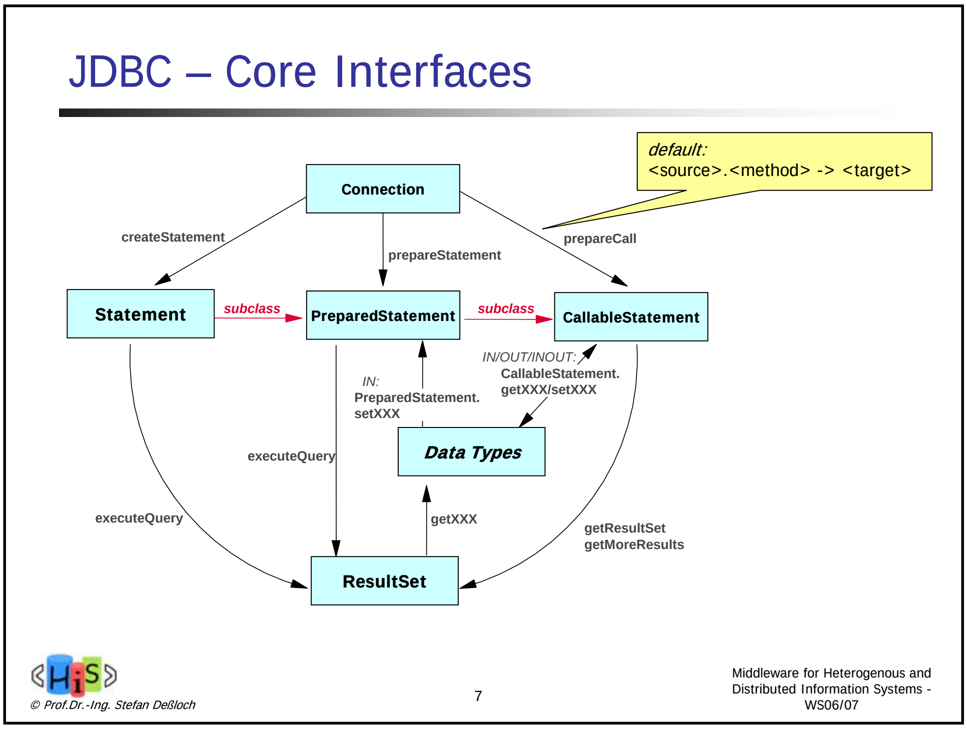
- Remote data access
- Multiple simultaneously active DB-connections within the same application thread
  - to the same DB
  - to different DBs
  - within the same (distributed) transaction
- Simultaneous access to multiple DB/DBMS
  - architecture supports use of (multiple) DBMS-specific drivers
  - coordinated by a driver manager
- Support for vendor-specific extensions



Historical Development

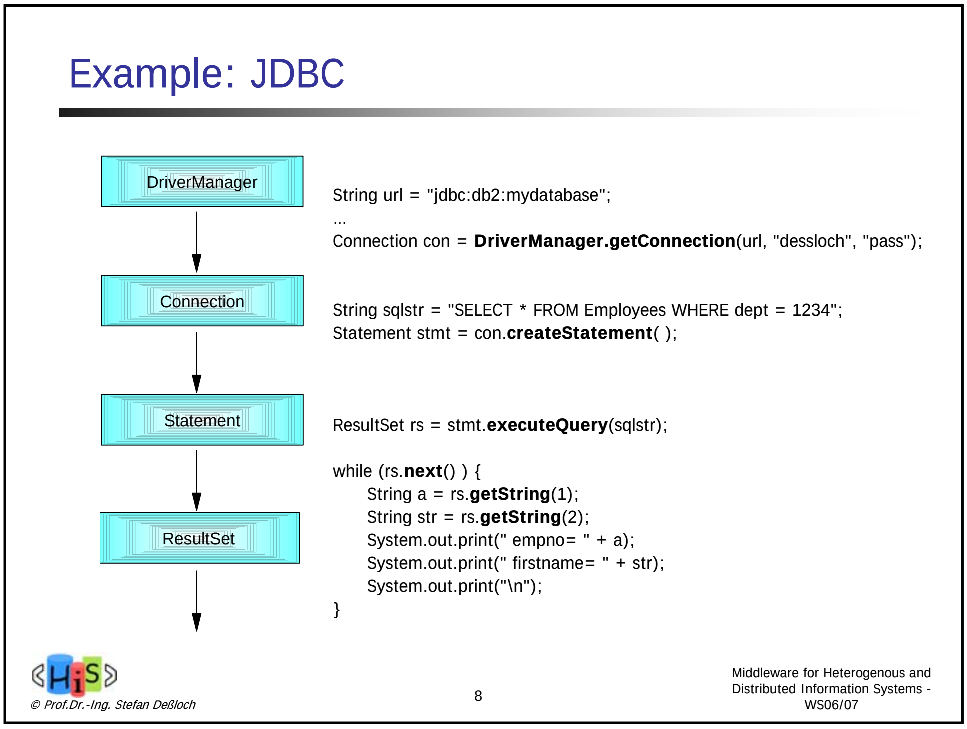
- ODBC: Open Database Connectivity
  - introduced in 1992 by Microsoft
  - quickly became a de-facto standard
    - ODBC drivers available for almost any DBMS
  - "blueprint" for ISO SQL/CLI standard
- JDBC
  - introduced in 1997, initially defined by SUN, based on ODBC approach
    - leverages advantages of Java (compared to C) for the API
  - abstraction layer between Java programs and SQL
  - current version: JDBC 3.0
    - JDBC 4.0 is expected to become final in 11/2006





JDBC – Core Interfaces

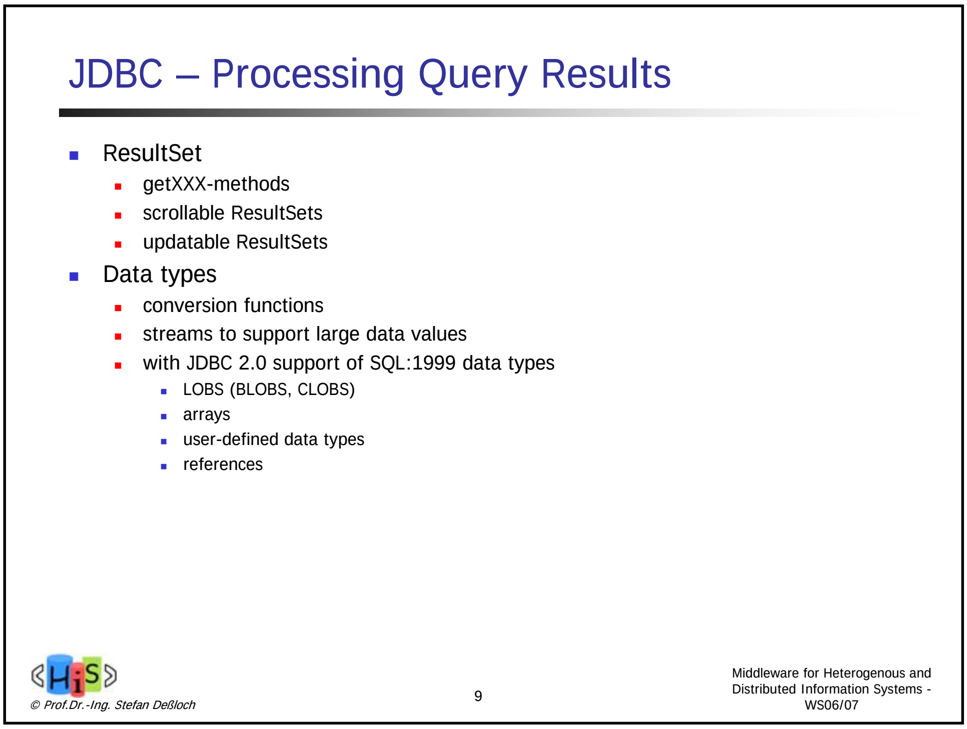
default:
<source>.<method> -> <target>



Example: JDBC

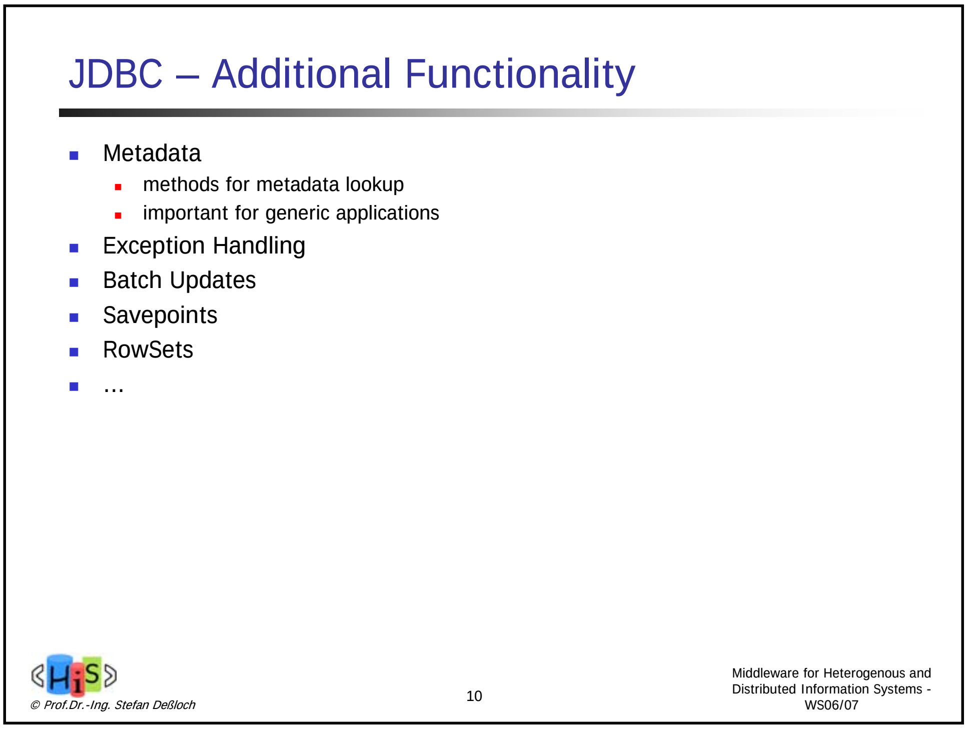
DriverManager
Connection
Statement
ResultSet

```
String url = "jdbc:db2:mydatabase";
...
Connection con = DriverManager.getConnection(url, "dessloch", "pass");

String sqlstr = "SELECT * FROM Employees WHERE dept = 1234";
Statement stmt = con.createStatement( );

ResultSet rs = stmt.executeQuery(sqlstr);

while (rs.next() ) {
      String a = rs.getString(1);
      String str = rs.getString(2);
      System.out.print(" empno= " + a);
      System.out.print(" firstname= " + str);
      System.out.print("\n");
}
```



JDBC – Processing Query Results

- ResultSet
  - getXXX-methods
  - scrollable ResultSets
  - updatable ResultSets
- Data types
  - conversion functions
  - streams to support large data values
  - with JDBC 2.0 support of SQL:1999 data types
    - LOBS (BLOBS, CLOBS)
    - arrays
    - user-defined data types
    - references



JDBC – Additional Functionality

- Metadata
  - methods for metadata lookup
  - important for generic applications
- Exception Handling
- Batch Updates
- Savepoints
- RowSets
- ...

Transactions in JDBC

- Connection interface – transaction-oriented methods for local TAs
  - *begin is implicit*
  - commit()
  - rollback()
  - get/setTransactionIsolation()
    - NONE, READ_UNCOMMITTED, READ_COMMITTED, REPEATABLE_READ, SERIALIZABLE
  - get/setAutoCommit()

Data Access in Distributed IS Middleware

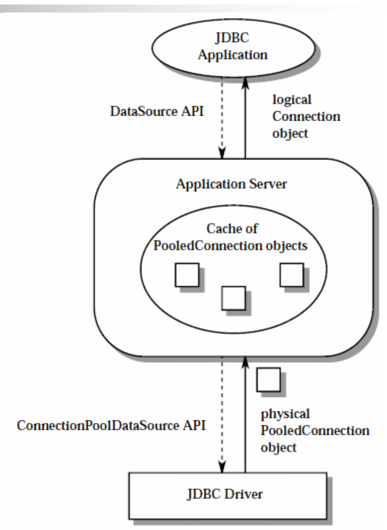
- Distributed transaction processing
- Data access from within applications/components in a managed environment (e.g., an application server)
  - "logical" database connections
  - connection pooling

JDBC DataSource

- DataSource Interface
  - motivation: increase portability by abstracting from driver-specific connection details
  - application uses logical name to obtain connection, interacting with Java Naming and Directory Service (JNDI)
  - connections can be created, registered, reconfigured, directed to another physical DB without impacting the application
    - example: connections are set up and managed by an application server administrator
- Steps
  - DataSource object is created, configured, registered with JNDI
    - using administration capability of application server
    - outside the application component
  - application component obtains a DataSource object
    - JNDI lookup
    - no driver-specific details required
  - application obtains a Connection object using DataSource
    - DataSource.getConnection( )

Connection Pooling

- Improves performance, scalability
  - establishing a connection is expensive
    - communication/storage resources
    - authentication, creation of security context
- Server-side application components
  - DB access often in the context of few (shared) user ids
  - connection is often held only for short duration (i.e., short processing step)
- Reuse of physical DB connection desirable
  - open -> "get connection from pool"
  - close -> "return connection to pool"
- Connection pooling can be "hidden" by DataSource, Connection interfaces
  - transparent to the application

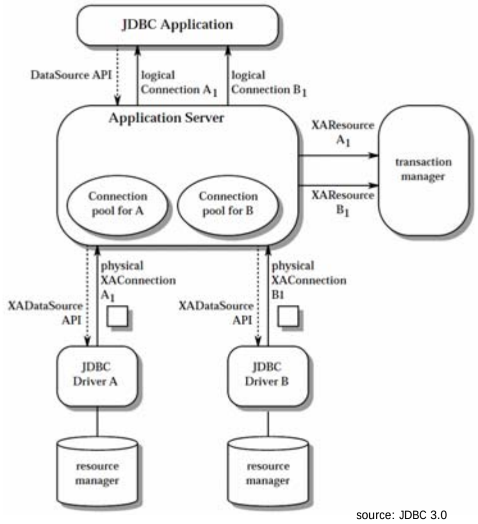

JDBC Application
DataSource API
logical Connection object
Application Server
Cache of PooledConnection objects
ConnectionPoolDataSource API
physical PooledConnection object
JDBC Driver

source: JDBC 3.0

JDBC - Distributed Transaction Support

- Requires interaction with a transaction manager (*see chapter 4*)
  - X/Open DTP, Java Transaction Service (JTS)
- Demarcation of transaction boundaries
  - Java Transaction API (JTA)
    - UserTransaction Object
  - NOT using methods of Connection interface
- JDBC defines additional interfaces to be supported by a driver implementation to interact with transaction manager
  - XADataSource, XAConnection, ...
- DataSource interface helps to make distributed transaction processing transparent to the application

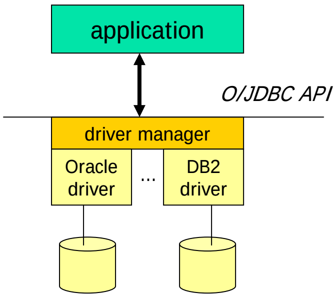
Distributed Transaction Processing with JDBC



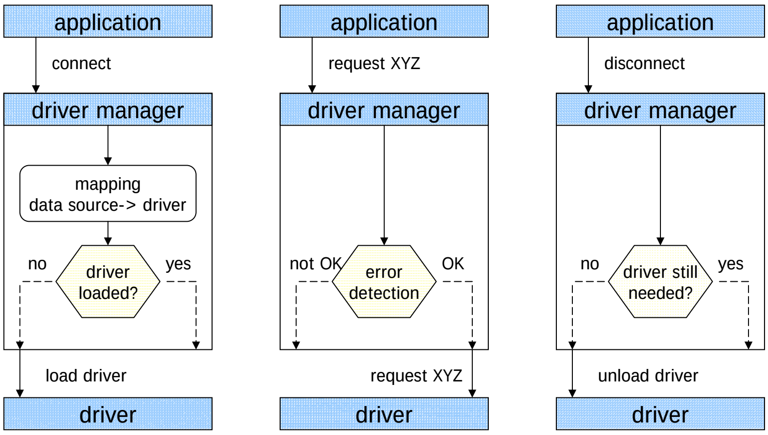
source: JDBC 3.0

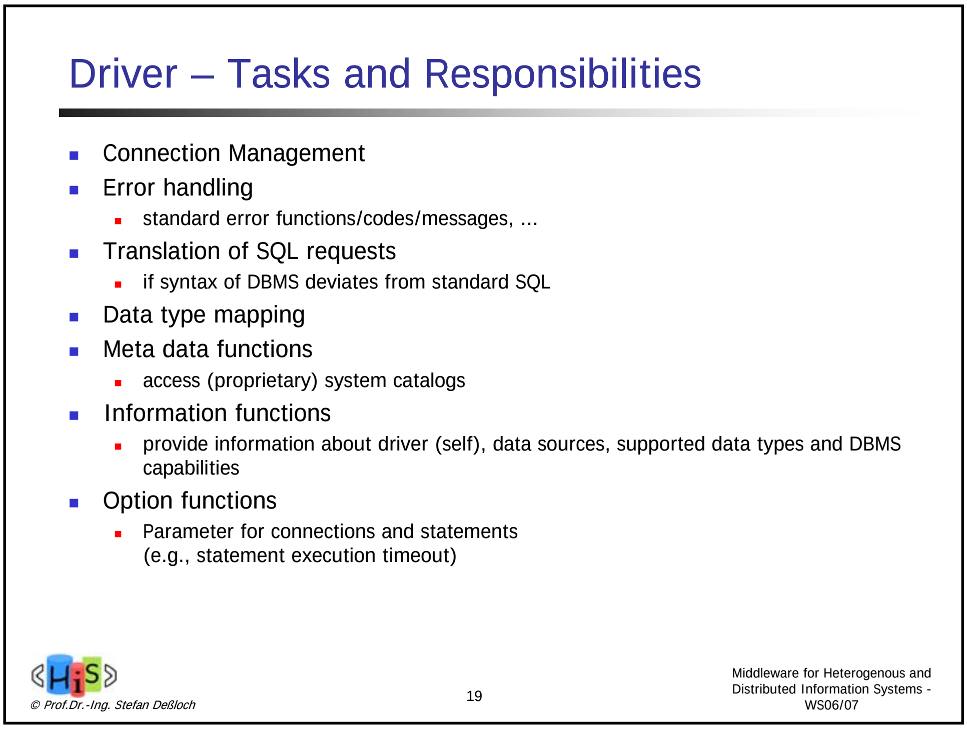
Architecture

- Applications
  - programs using DB-CLI functionality
  - usage
    - connect to data sources
    - execute SQL statements (e.g., queries) over data sources
    - receive (and process) results
- Driver
  - processes CLI calls
  - communicates SQL requests to DBMS
    - Alternative: does the entire processing of the SQL requests
  - hides heterogeneity of data sources
- Driver Manager
  - manages interactions between applications and drivers
  - realizes (n:m)-relationship between applications and drivers
  - tasks
    - load/unload driver
    - mapping data sources to drivers
    - communication/logging of function/method calls
    - simple error handling



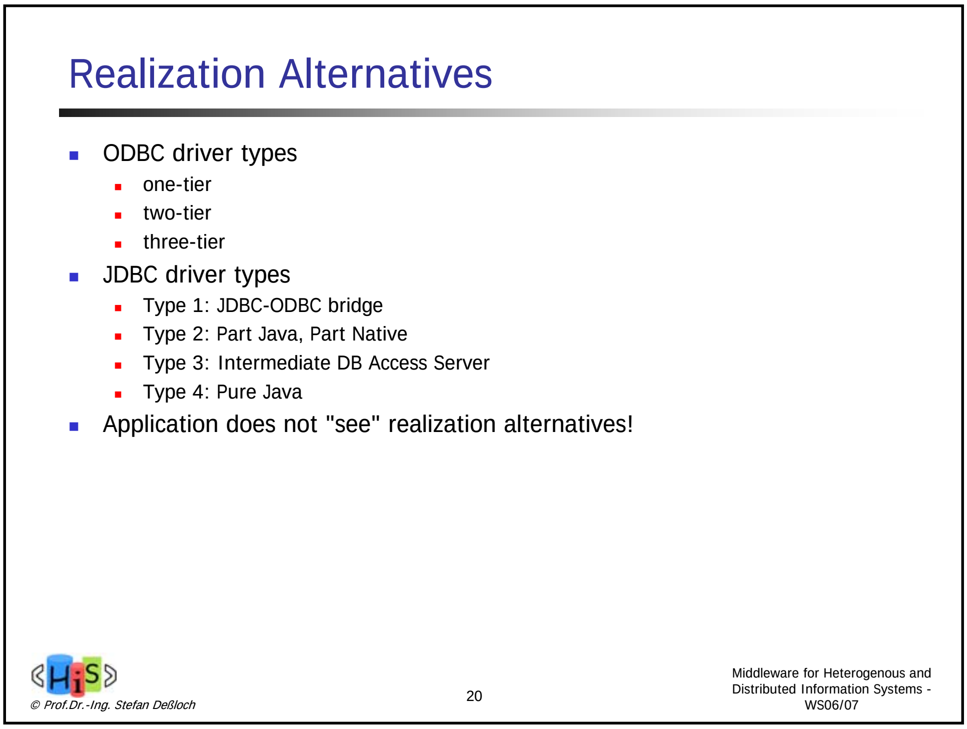
Driver Manager Tasks





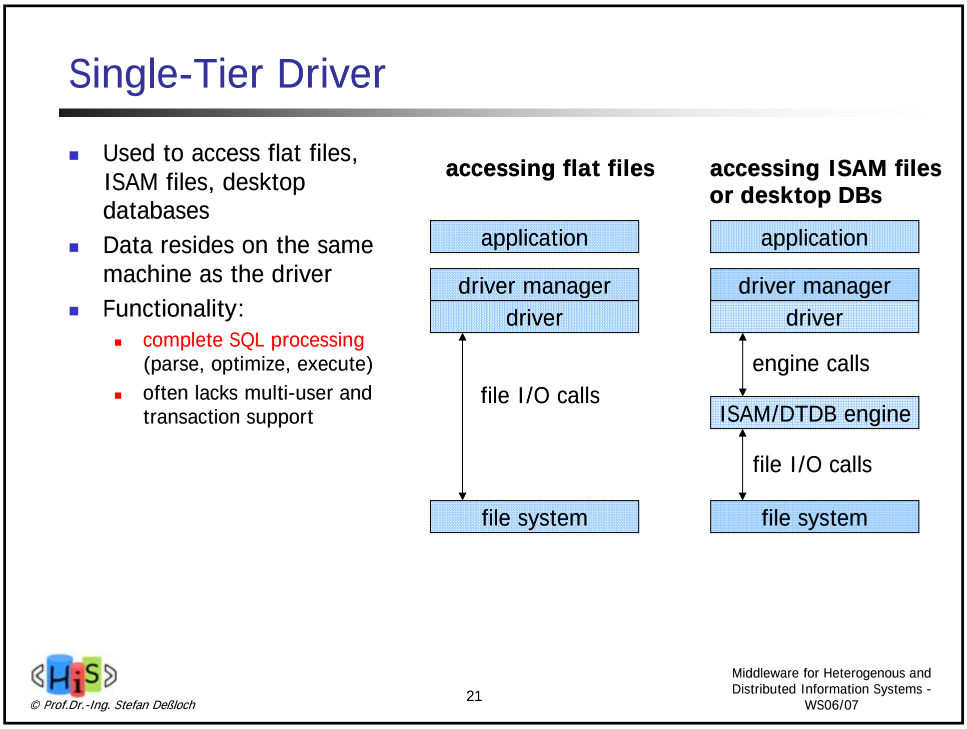
Driver – Tasks and Responsibilities

- Connection Management
- Error handling
  - standard error functions/codes/messages, ...
- Translation of SQL requests
  - if syntax of DBMS deviates from standard SQL
- Data type mapping
- Meta data functions
  - access (proprietary) system catalogs
- Information functions
  - provide information about driver (self), data sources, supported data types and DBMS capabilities
- Option functions
  - Parameter for connections and statements
    (e.g., statement execution timeout)



Realization Alternatives

- ODBC driver types
  - one-tier
  - two-tier
  - three-tier
- JDBC driver types
  - Type 1: JDBC-ODBC bridge
  - Type 2: Part Java, Part Native
  - Type 3: Intermediate DB Access Server
  - Type 4: Pure Java
- Application does not "see" realization alternatives!



Single-Tier Driver

- Used to access flat files, ISAM files, desktop databases
- Data resides on the same machine as the driver
- Functionality:
  - complete SQL processing (parse, optimize, execute)
  - often lacks multi-user and transaction support

accessing flat files

application

driver manager

driver

file I/O calls

file system

accessing ISAM files or desktop DBs

application

driver manager

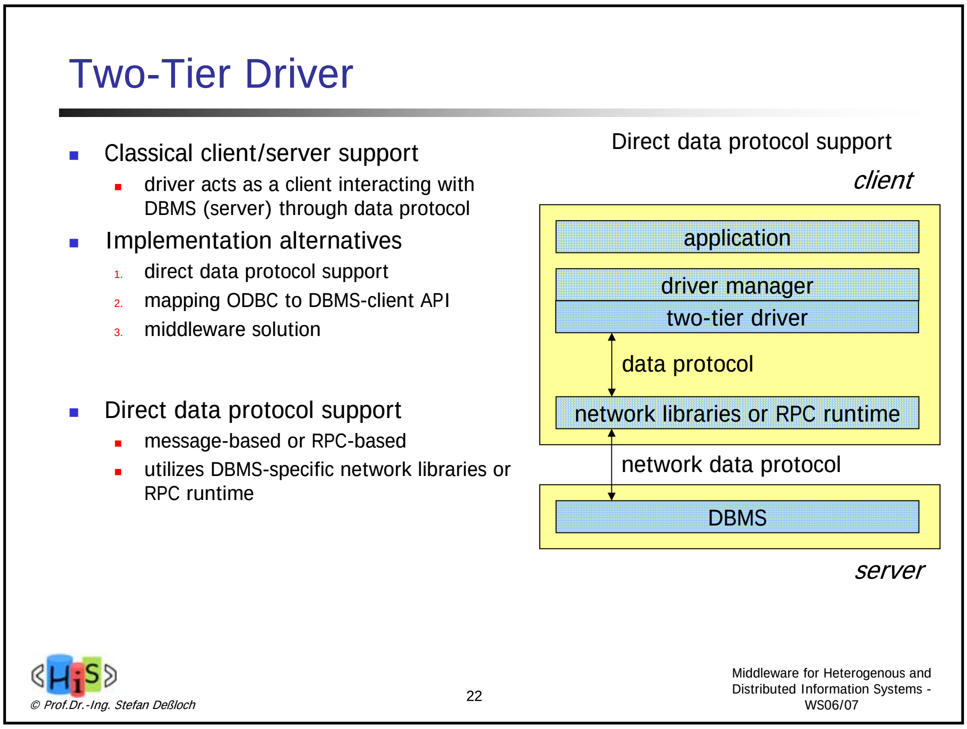
driver

engine calls

ISAM/DTDB engine

file I/O calls

file system



Two-Tier Driver

- Classical client/server support
  - driver acts as a client interacting with DBMS (server) through data protocol
- Implementation alternatives
  1. direct data protocol support
  2. mapping ODBC to DBMS-client API
  3. middleware solution
- Direct data protocol support
  - message-based or RPC-based
  - utilizes DBMS-specific network libraries or RPC runtime

Direct data protocol support

client

application

driver manager

two-tier driver

data protocol

network libraries or RPC runtime

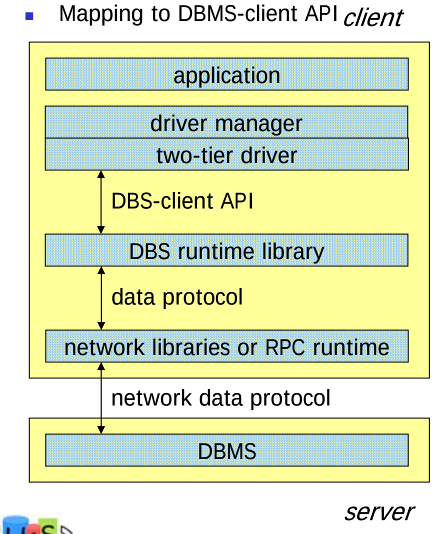
network data protocol

DBMS

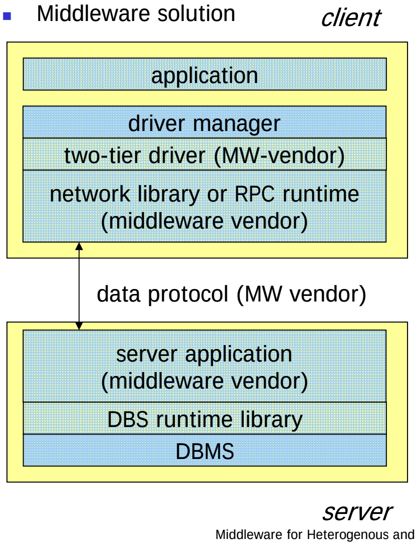
server

Two-Tier Driver (continued)

- Mapping to DBMS-client API

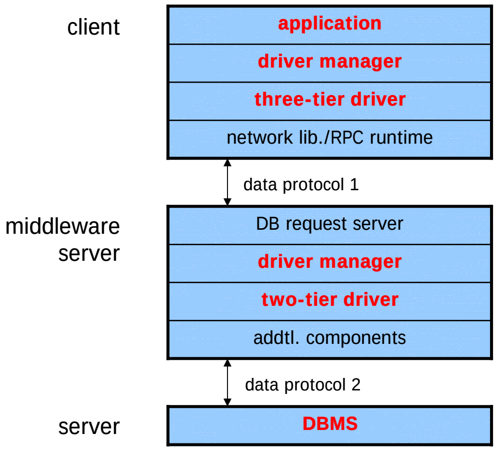


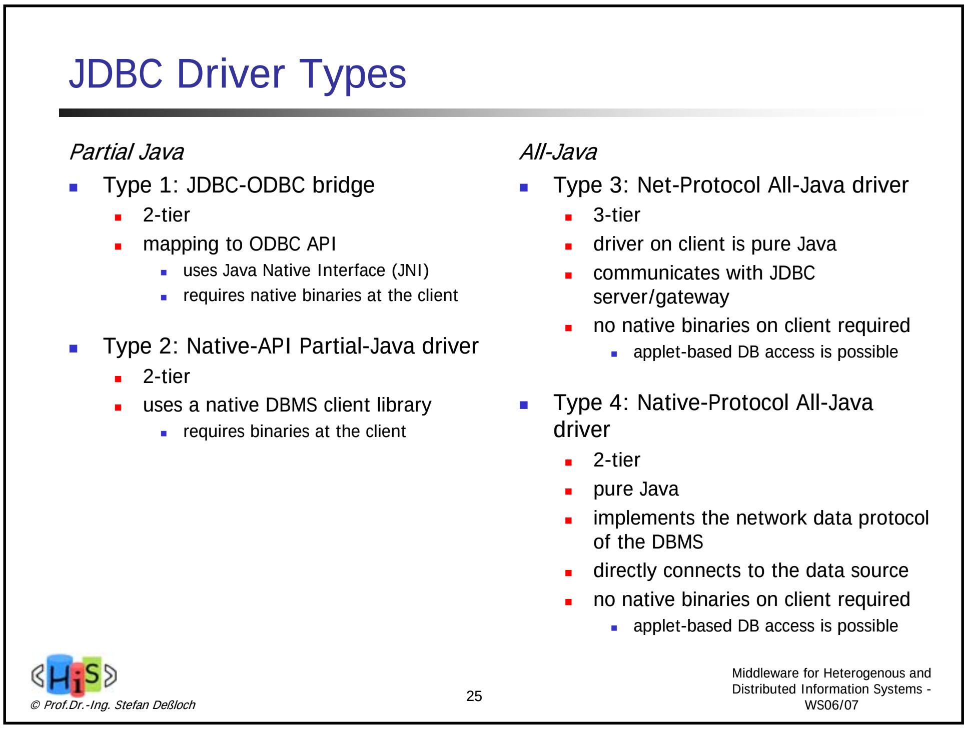
- Middleware solution



Three-Tier Driver

- Middleware Server
  - connects and relays requests to one or more DBMS servers
- Moves the complexity from the client to the middleware server
  - client requires only a single driver (for the middleware server)
- Arbitrary number of tiers possible





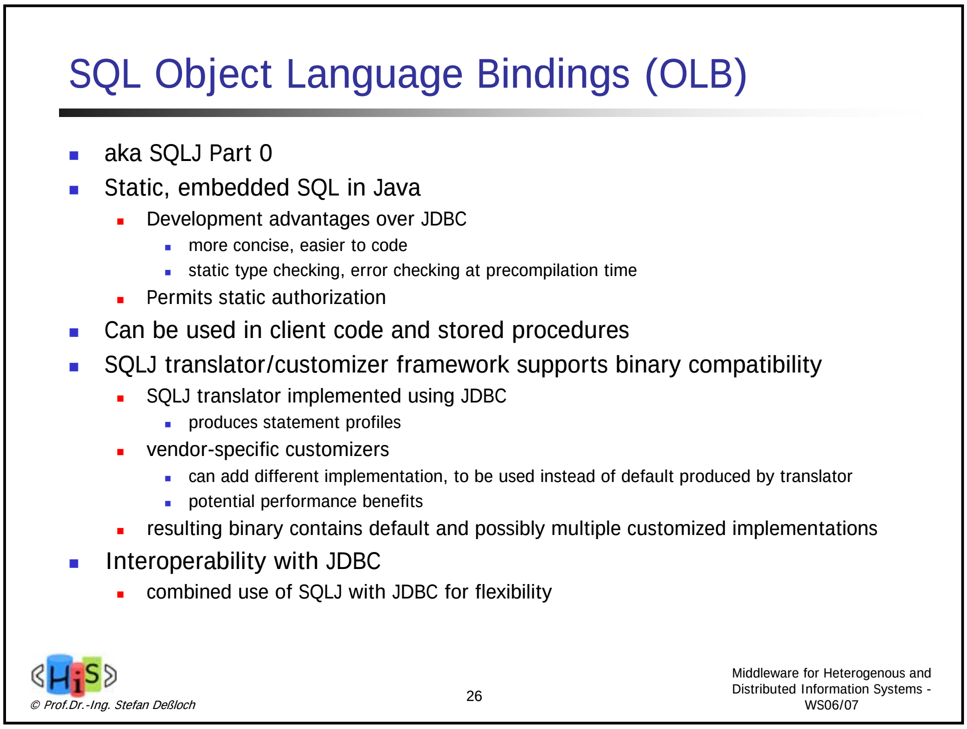
JDBC Driver Types

Partial Java

- Type 1: JDBC-ODBC bridge
  - 2-tier
  - mapping to ODBC API
    - uses Java Native Interface (JNI)
    - requires native binaries at the client
- Type 2: Native-API Partial-Java driver
  - 2-tier
  - uses a native DBMS client library
    - requires binaries at the client

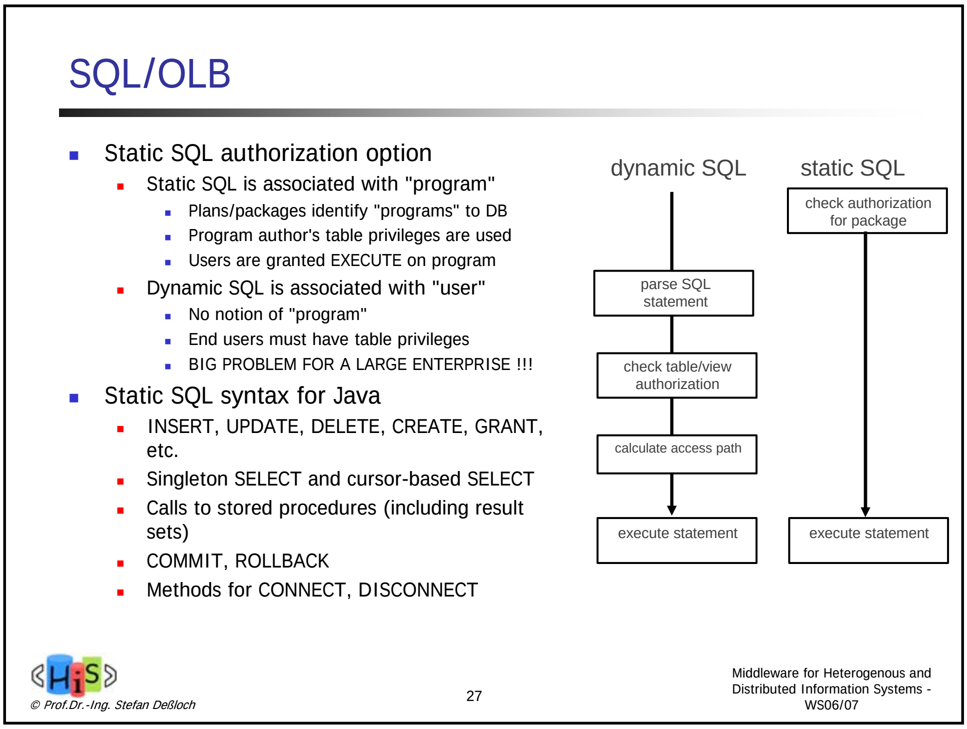
All-Java

- Type 3: Net-Protocol All-Java driver
  - 3-tier
  - driver on client is pure Java
  - communicates with JDBC server/gateway
  - no native binaries on client required
    - applet-based DB access is possible
- Type 4: Native-Protocol All-Java driver
  - 2-tier
  - pure Java
  - implements the network data protocol of the DBMS
  - directly connects to the data source
  - no native binaries on client required
    - applet-based DB access is possible



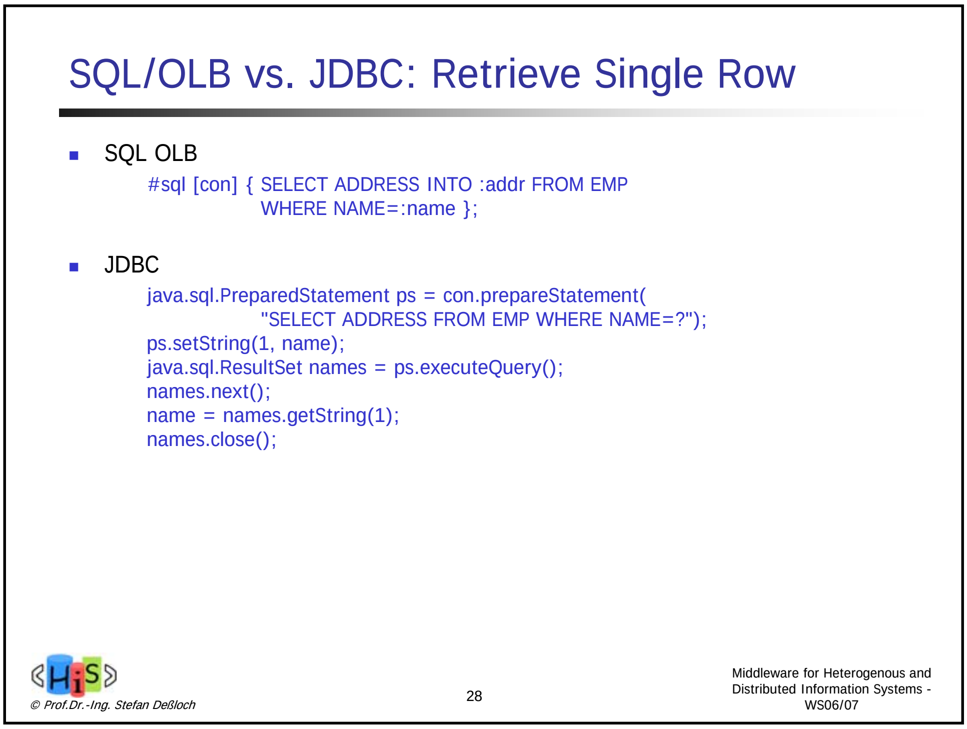
SQL Object Language Bindings (OLB)

- aka SQLJ Part 0
- Static, embedded SQL in Java
  - Development advantages over JDBC
    - more concise, easier to code
    - static type checking, error checking at precompilation time
  - Permits static authorization
- Can be used in client code and stored procedures
- SQLJ translator/customizer framework supports binary compatibility
  - SQLJ translator implemented using JDBC
    - produces statement profiles
  - vendor-specific customizers
    - can add different implementation, to be used instead of default produced by translator
    - potential performance benefits
  - resulting binary contains default and possibly multiple customized implementations
- Interoperability with JDBC
  - combined use of SQLJ with JDBC for flexibility



SQL/OLB

- Static SQL authorization option
  - Static SQL is associated with "program"
    - Plans/packages identify "programs" to DB
    - Program author's table privileges are used
    - Users are granted EXECUTE on program
  - Dynamic SQL is associated with "user"
    - No notion of "program"
    - End users must have table privileges
    - BIG PROBLEM FOR A LARGE ENTERPRISE !!!
- Static SQL syntax for Java
  - INSERT, UPDATE, DELETE, CREATE, GRANT, etc.
  - Singleton SELECT and cursor-based SELECT
  - Calls to stored procedures (including result sets)
  - COMMIT, ROLLBACK
  - Methods for CONNECT, DISCONNECT



SQL/OLB vs. JDBC: Retrieve Single Row

- SQL OLB

```
#sql [con] { SELECT ADDRESS INTO :addr FROM EMP
             WHERE NAME=:name };
```

- JDBC

```
java.sql.PreparedStatement ps = con.prepareStatement(
             "SELECT ADDRESS FROM EMP WHERE NAME=?");
ps.setString(1, name);
java.sql.ResultSet names = ps.executeQuery();
names.next();
name = names.getString(1);
names.close();
```

Result Set Iterators

- Mechanism for accessing the rows returned by a query
  - Comparable to an SQL cursor
- Iterator declaration clause results in generated iterator class
  - Iterator is a Java object
  - Iterators are strongly typed
  - Generic methods for advancing to next row
- Assignment clause assigns query result to iterator
- Two types of iterators
  - Named iterator
  - Positioned iterator

Named Iterators - Example

- Generated iterator class has accessor methods for each result column

```
#sql iterator Honors ( String name, float grade );
Honors honor;
...
#sql [recs] honor =
      { SELECT SCORE AS "grade", STUDENT AS "name"
        FROM GRADE_REPORTS
        WHERE SCORE >= :limit AND ATTENDED >= :days
        ORDER BY SCORE DESCENDING };
while (honor.next())
  {
    System.out.println( honor.name() + " has grade "
          + honor.grade() );
  }
```

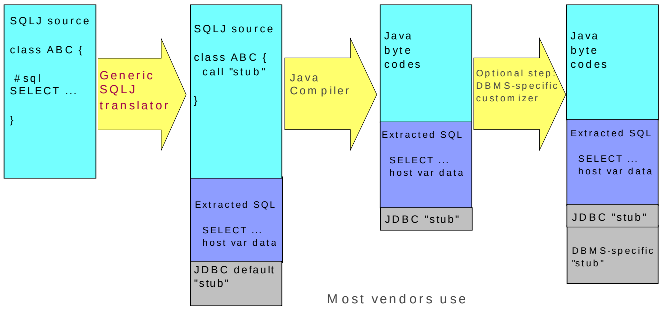
Positioned Iterator

- Use FETCH statement to retrieve result columns into host variables based on position

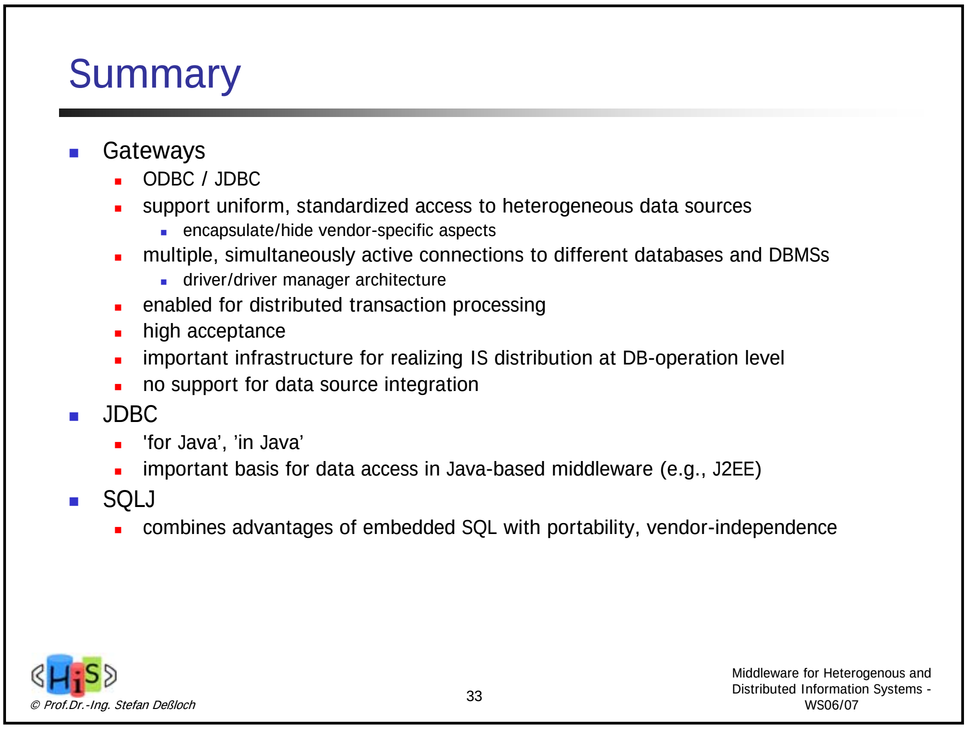
```
#sql iterator Honors ( String, float );
Honors honor;
String name;
float grade;
#sql [recs] honor =
    { SELECT STUDENT, SCORE  FROM GRADE_REPORTS
      WHERE SCORE >= :limit AND ATTENDED >= :days
      ORDER BY SCORE DESCENDING };
while (true) {
   #sql {FETCH :honor  INTO :name, :grade };
   if (honor.endFetch()) break;
  System.out.println( name + " has grade " + grade );
}
```

SQLJ - Binary Portability

- Java as a platform-independent language
- Use of generic SQLJ-precompiler/translator (avoids DBMS-specific precompiler technology)
- Generated code uses “standard” JDBC by default
- Compiled SQLJ application (Java byte code) is portable
- Customizer technology allows DBMS-specific optimizations after the compilation



Most vendors use default JDBC "stub"



Summary

- Gateways
  - ODBC / JDBC
  - support uniform, standardized access to heterogeneous data sources
    - encapsulate/hide vendor-specific aspects
  - multiple, simultaneously active connections to different databases and DBMSs
    - driver/driver manager architecture
  - enabled for distributed transaction processing
  - high acceptance
  - important infrastructure for realizing IS distribution at DB-operation level
  - no support for data source integration
- JDBC
  - 'for Java', 'in Java'
  - important basis for data access in Java-based middleware (e.g., J2EE)
- SQLJ
  - combines advantages of embedded SQL with portability, vendor-independence