JavaSoft

JDBC ™: A Java SQL API

This is the specification for the JDBC™ API, which is a Java™ application programming interface to SQL databases.

Please send technical comments on this specification to:

jdbc@wombat.eng.sun.com

Because of the volume of interest in JDBC, we will not be able to respond individually to comments or questions. However, we greatly appreciate your feedback, and we will read and carefully consider all mail that we receive.

Please send product and business questions to:

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Graham Hamilton & Rick Cattell

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1 Introduction

Many vendors and customers are now looking for easy database access for Java applications. Since Java is robust, secure, easy to use, easy to understand, and automatically downloadable on a network, it is an excellent language basis for the development of database applications. It offers many advantages over C, C++, Smalltalk, BASIC, COBOL, and 4GLs for a wide variety of uses.

Many Java application developers would like to write code that is independent of the particular DBMS or database connectivity mechanism being used, and we believe that a DBMS-independent interface is also the fastest way to implement access to the wide variety of DBMSs. So, we decided it would be useful to the Java community to define a generic SQL database access framework which provides a uniform interface on top of a variety of different database connectivity modules. This allows programmers to write to a single database interface, enables DBMS-independent Java application development tools and products, and allows database connectivity vendors to provide a variety of different connectivity solutions.

Our immediate priority has been to define a common low-level API that supports basic SQL functionality. We call this API JDBC. This API in turn allows the development of higher-level database access tools and APIs.

Fortunately we didn't need to design a SQL API from scratch. We based our work on the X/Open SQL CLI (Call Level Interface) which is also the basis for Microsoft's ODBC interface. Our main task has been defining a natural Java interface to the basic abstractions and concepts defined in the X/Open CLI.

It is important that the JDBC API be accepted by database vendors, connectivity vendors, ISVs, and application writers. We believe that basing our work on the ODBC abstractions is likely to make this acceptance easier, and technically ODBC seems a good basis for our design.

ODBC is not appropriate for *direct* use from Java, since it is a C interface; calls from Java to native C code have a number of drawbacks in the security, implementation, robustness, and automatic portability of applications. Thus, we have constructed an API that can easily be implemented on top of ODBC short-term, and that can be implemented in other ways longer term.

1.1 Acknowledgments

We would like to thank the many reviewers in the database, database connectivity, and database tools communities who gave generously of their time and expertise.

We are grateful to all the reviewers who took the time to read and comment on the various drafts, but we would particularly like to thank Azad Bolour, Paul Cotton, Ed Garon, John Goodson, Mark Hapner, Tommy Hawkins, Karl Moss, and Barbara Walters for providing sustained review and helpful feedback over many drafts and revisions of the API.

The errors and omissions that remain, are however, all our own work.

2 Goals and philosophy

This section outlines the main goals and philosophy driving the API design.

2.1 A SQL level API

JDBC is intended as a "call-level" SQL interface for Java. This means the focus is on executing raw SQL statements and retrieving their results. We expect that higher-level APIs will be defined as well, and these will probably be implemented on top of this base level. Examples of higher-level APIs are direct transparent mapping of tables to Java classes, semantic tree representations of more general queries, and an embedded SQL syntax for Java.

We expect that various application builder tools will emit code that uses our API. However we also intend that the API be usable by human programmers, especially because there is no other solution available for Java right now.

2.2 SQL Conformance

Database systems support a wide range of SQL syntax and semantics, and they are not consistent with each other on more advanced functionality such as outer joins and stored procedures. Hopefully with time the portion of SQL that is truly standard will expand to include more and more functionality. In the meantime, we take the following position:

- JDBC allows any query string to be passed through to an underlying DBMS driver, so an application may use as much SQL functionality as desired at the risk of receiving an error on some DBMSs. In fact, an application query need not even be SQL, or it may be a specialized derivative of SQL, e.g. for document or image queries, designed for specific DBMSs.
- In order to pass JDBC compliance tests and to be called "JDBC COMPLIANT™" we require that a driver support at least ANSI SQL92 Entry Level. This gives applications that want wide portability a guaranteed least common denominator. We believe ANSI SQL-2 Entry Level is reasonably powerful and is reasonably widely supported today.

2.3 JDBC must be implementable on top of common database interfaces

We need to ensure that the JDBC SQL API can be implemented on top of common SQL level APIs, in particular ODBC. This requirement has colored some parts of the specification, notably the handling of OUT parameters and large blobs.

2.4 Provide a Java interface that is consistent with the rest of the Java system

There has been a very strong positive response to Java. To a large extent this seems to be because the language and the standard runtimes are perceived as being consistent, simple, and powerful.

As far as we can, we would like to provide a Java database interface that builds on and reinforces the style and virtues of the existing core Java classes.

2.5 Keep it simple

We would prefer to keep this base API as simple as possible, at least initially. In general we would prefer to provide a single mechanism for performing a particular task, and avoid providing duplicate mechanisms. We will extend the API later if any important functionality is missing.

2.6 Use strong, static typing wherever possible

We would prefer that the JDBC API be strongly typed, with as much type information as possible expressed statically. This allows for more error checking at compile time.

Because SQL is intrinsically dynamically typed, we may encounter type mismatch errors at run-time where for example a programmer expected a SELECT to return an integer result but the database returned a string “foo”. However we would still prefer to allow programmers to express their type expectations at compile time, so that we can statically check as much as possible. We will also support dynamically typed interfaces where necessary (see particularly Chapter 14).

2.7 Keep the common cases simple

We would like to make sure that the common cases are simple, and that the uncommon cases are doable.

A common case is a programmer executing a simple SQL statement (such as a SELECT, INSERT, UPDATE or DELETE) without parameters, and then (in the case of SELECT statement) processing rows of simple result types. A SQL statement with IN parameters is also common.

Somewhat less common, but still important, is the case where a programmer invokes a SQL statement using INOUT or OUT parameters. We also need to support SQL statements that read or write multi-megabyte objects, and less common cases such as multiple result sets returned by a SQL statement.

We expect that metadata access (e.g. to discover result-set types, or to enumerate the procedures in a database) is comparatively rare and is mostly used by sophisticated programmers or by builder tools. Metadata functions are therefore documented at the end of the specification, along with dynamically-typed data access; the average programmer can skip these sections.

2.8 Use multiple methods to express multiple functionality

One style of interface design is to use a very small number of procedures and offer a large number of control flags as arguments to these procedures, so that they can be used to effect a wide range of different behavior.

In general the philosophy of the Java core classes has been to use different methods to express different functionality. This tends to lead to a larger number of methods, but makes each method easier to understand. This approach has the major advantage that programmers who are learning how to use the basic interface aren’t confused by having to specify arguments related to more complex behaviors.

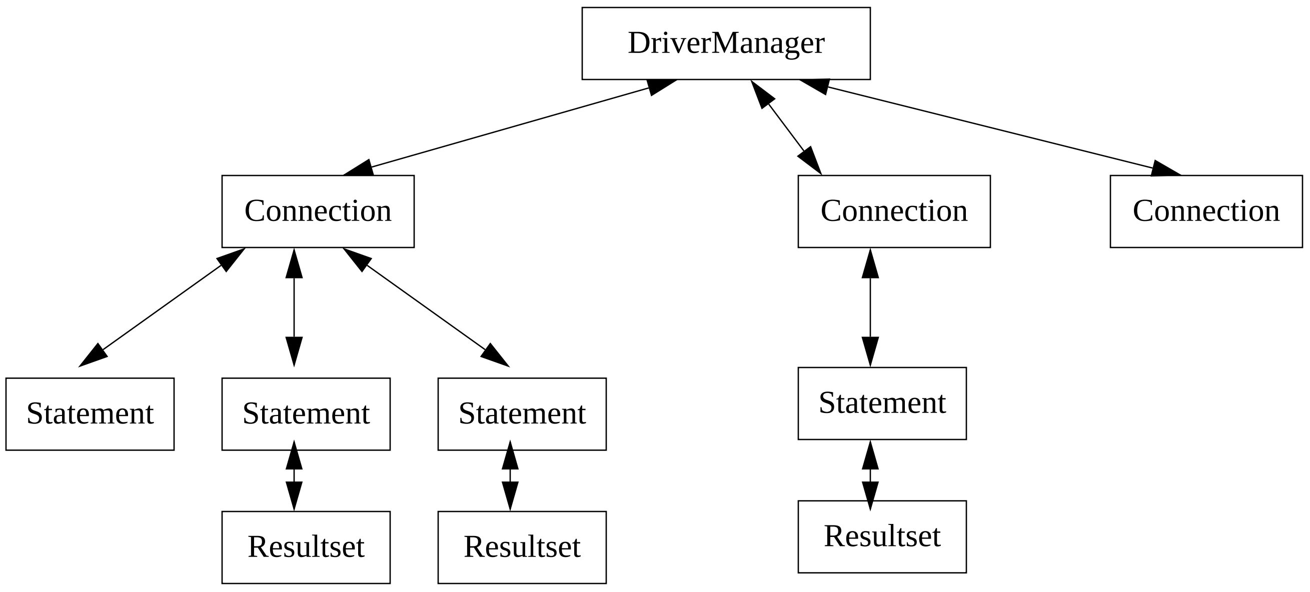
We’ve tried to adopt the same approach for the JDBC interface, and in general have preferred to use multiple methods rather than using multi-purpose methods with flag arguments.

3 Overview of the major interfaces

There are two major sets of interfaces. First there is a JDBC API for application writers. Second there is a lower level JDBC Driver API.

3.1 The JDBC API

The JDBC API is expressed as a series of abstract Java interfaces that allow an application programmer to open connections to particular databases, execute SQL statements, and process the results.

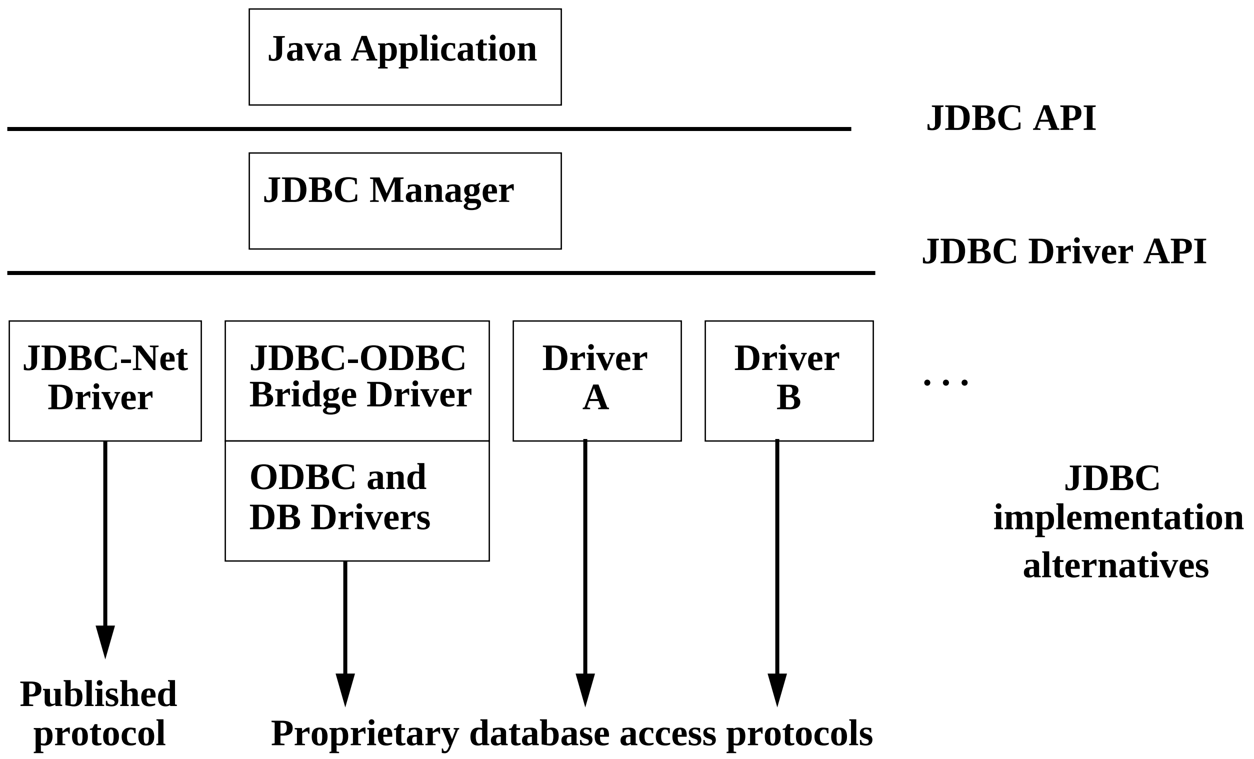


The most important interfaces are:

- java.sql.DriverManager which handles loading of drivers and provides support for creating new database connections
- java.sql.Connection which represents a connection to a particular database
- java.sql.Statement which acts as a container for executing a SQL statement on a given connection
- java.sql.ResultSet which controls access to the row results of a given Statement

The java.sql.Statement interface has two important sub-types: java.sql.PreparedStatement for executing a pre-compiled SQL statement, and java.sql.CallableStatement for executing a call to a database stored procedure.

The following chapters provide more information on how these interfaces work. See the separate JDBC API documents for complete documentation of JDBC interfaces and classes.



3.2 The JDBC Driver Interface

The java.sql.Driver interface is fully defined in Chapter 9. For the most part the database drivers simply need to provide implementations of the abstract classes provided by the JDBC API. Specifically, each driver must provide implementations of java.sql.Connection, java.sql.Statement, java.sql.PreparedStatement, java.sql.CallableStatement, and java.sql.ResultSet.

In addition, each database driver needs to provide a class which implements the java.sql.Driver interface used by the generic java.sql.DriverManager class when it needs to locate a driver for a particular database URL.

JavaSoft is providing an implementation of JDBC on top of ODBC, shown as the JDBC-ODBC bridge in the picture. Since JDBC is patterned after ODBC, this implementation is small and efficient.

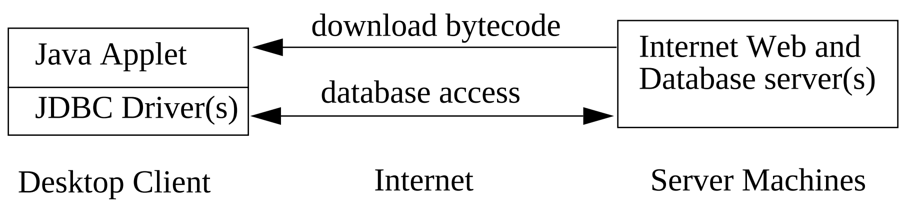
Another useful driver is one that goes directly to a DBMS-independent network protocol. It would be desirable to publish the protocol to allow multiple server implementations, e.g. on top of ODBC or on specific DBMSs (although there are already products that use a fixed protocol such as this, we are not yet trying to standardize it). Only a few optimizations are needed on the client side, e.g. for schema caching and tuple look-ahead, and the JDBC Manager itself is very small and efficient as well. The net result is a very small and fast all-Java client side implementation that speaks to any server speaking the published protocol.

4 Scenarios for use

Before looking at specifics of the JDBC API, an understanding of typical use scenarios is helpful. There are two common scenarios that must be treated differently for our purposes: *applets* and *applications*.

4.1 Applets

The most publicized use of Java to date is for implementing *applets* that are downloaded over the net as parts of web documents. Among these will be database access applets, and these applets could use JDBC to get to databases.



For example, a user might download a Java applet that displays historical price graphs for a custom portfolio of stocks. This applet might access a relational database over the Internet to obtain the historical stock prices.

The most common use of applets may be across untrusted boundaries, e.g. fetching applets from another company on the Internet. Thus, this scenario might be called the “Internet” scenario. However, applets might also be downloaded on a local network where client machine security is still an issue.

Typical applets differ from traditional database applications in a number of ways:

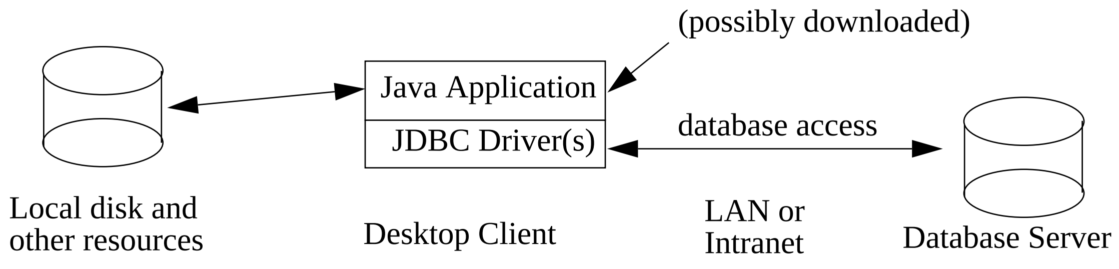
- Untrusted applets are severely constrained in the operations they are allowed to perform. In particular, they are not allowed any access to local files and they are not allowed to open network connections to arbitrary hosts.
- Applets on the Internet present new problems with respect to identifying and connecting to databases.[1]
- Performance considerations for a database connectivity implementation differ when the database may be halfway around the world. Database applets on the Internet will experience quite different network response times than database applications on a local area network.

4.2 Applications

Java can also be used to build normal applications that run like any shrink-wrapped or custom application on a client machine. We believe this use of Java will become increasingly common as better tools become available for Java and as people recognize the improved programming productivity and other advantages of Java for application development. In this case the Java

1. For example, you could not depend on your database location or driver being in a .INI file or local registry on the client’s machine, as in ODBC.

code is trusted and is allowed to read and write files, open network connections, etc., just like any other application code.



Perhaps the most common use of these Java applications will be within a company or on an "Intranet," so this might be called the Intranet scenario. For example, a company might implement all of its corporate applications in Java using GUI building tools that generate Java code for forms based on corporate data schemas. These applications would access corporate database servers on a local or wide area network. However, Java applications could also access databases through the Internet.

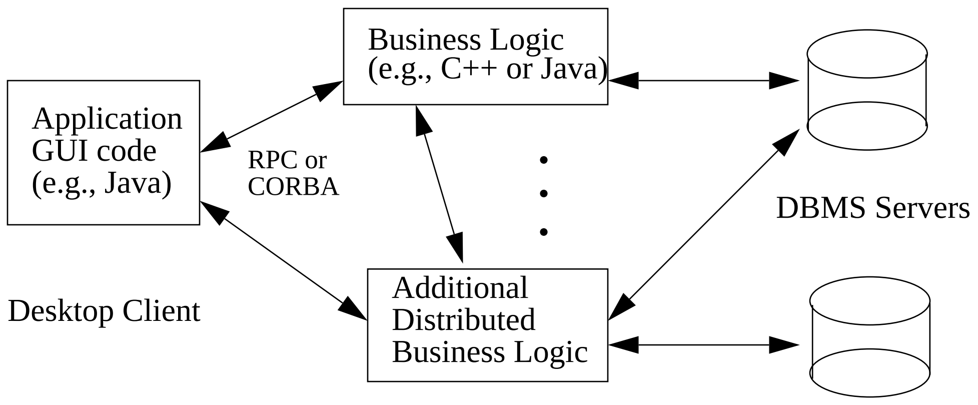
The Java application and "Intranet" cases differ from applets in a number of ways. For example, the most natural way to identify a database is typically for the user or application to specify a database name, e.g. "Customers" or "Personnel". The users will expect the system to locate the specific machine, DBMS, JDBC driver, and database.

4.3 Other scenarios

There are some other special cases of interest:

- *Trusted applets* are applets that have convinced the Java virtual machine that they can be trusted. They might be trusted because they have been signed with a particular cryptographic key, or because the user has decided to trust applets from a particular source. We will treat these applets the same as applications for security purposes, but they may behave more like applets for other purposes, e.g. locating a database on the Internet.
- *Three-tier access* to databases may be used, in contrast to direct client/server access from Java GUIs to DBMS servers. In this scenario, Java applications make calls to a "middle tier" of services on the net whose implementations in turn access databases. These calls might be made through RPC (remote procedure call) or through an ORB (object request broker), and in either case the middle tier might best be defined using an object paradigm, e.g. "customer objects" with operations for customer invoicing, address changes, and other transactions.

We expect that three-tier access will become more common because it is attractive to the MIS director to explicitly define the legal operations on their corporate data rather than allowing direct unrestricted updates to the DBMS servers. Also, the three-tier architecture can provide performance advantages in many cases.



Today, the middle tier is typically implemented in a language such as C or C++. With the introduction of optimizing compilers translating Java byte codes into efficient machine-specific code, the middle tier may practically be implemented in Java; Java has many valuable qualities (robustness, security, multi-threading) for these purposes. JDBC will be of use for this middle tier.

5 Security considerations

Based on the previous discussion, there are two main JDBC scenarios to consider for security purposes:

- In the case of Java applications, the Java code is “trusted”. We also consider trusted applets in this category for security purposes.
- In contrast, untrusted Java applets are not permitted access to local files and or network connections to arbitrary hosts.

5.1 JDBC and untrusted applets

JDBC should follow the standard applet security model. Specifically:

- JDBC should assume that normal unsigned applets are untrustworthy
- JDBC should not allow untrusted applets access to local database data
- If a downloaded JDBC Driver registers itself with the JDBC DriverManager, then JDBC should only use that driver to satisfy connection requests from code which has been loaded from the same source as the driver.
- An untrusted applet will normally only be allowed to open a database connection back to the server from which it was downloaded
- JDBC should avoid making any automatic or implicit use of local credentials when making connections to remote database servers.

If the JDBC Driver level is completely confident that opening a network connection to a database server will imply no authentication or power beyond that which would be obtainable by any random program running on any random internet host, then it may allow an applet to open such a connection. This will be fairly rare, and would require for example, that the database server doesn’t use IP addresses as a way of restricting access.

These restrictions for untrusted applets are fairly onerous. But they are consistent with the general applet security model and we can see no good way of relaxing them.

5.2 JDBC and Java applications

For a normal Java application (i.e. all Java code other than untrusted applets) JDBC should happily load drivers from the local classpath and allow the application free access to files, remote servers, etc.

However as with applets, if for some reason an untrusted sun.sql.Driver class is loaded from a remote source, then that Driver should only be used with code loaded from that same source.

5.3 Network security

The security of database requests and data transmission on the network, especially in the Internet case, is also an important consideration for the JDBC user. However, keep in mind that we are defining programming interfaces in this specification, not a network protocol. The network protocols used for database access have generally already been fixed by the DBMS vendor or connectivity vendor. JDBC users should verify that the network protocol provides adequate security for their needs before using a JDBC driver and DBMS server.

If JavaSoft proposes a standard for a published protocol for a DBMS-independent JDBC-Net driver, as described in Section 3, then security considerations will be an important factor in the selection of a protocol.

5.4 Security Responsibilities of Drivers

Because JDBC drivers may be used in a variety of different situations, it is important that driver writers follow certain simple security rules to prevent applets from making illegal database connections.

These rules are unnecessary if a driver is downloaded as an applet, because the standard security manager will prevent an applet driver from making illegal connections. However JDBC driver writers should bear in mind that if their driver is "successful" then users may start installing it on their local disks, in which case it becomes a trusted part of the Java environment, and must make sure it is not abused by visiting applets. We therefore urge all JDB driver writers to follow the basic security rules.

These rules all apply at connection open time. This is the point when the driver and the virtual machine should check that the current caller is really allowed to connect to a given database. After connection open, no additional checks are necessary.

5.4.1 Be very careful about sharing TCP connections

If a JDBC driver attempts to open a TCP connection then the open will be automatically checked by the Java security manager. The security manager will check if there is an applet on the current call stack and if so, will restrict the open to whatever set of machines that applet is allowed to call. So normally a JDBC driver can leave TCP open checks up to the Java virtual machine.

However if a JDBC driver wants to share a single TCP connection among several different database connections then it becomes the driver's responsibility to make sure that each of its callers is really allowed to talk to the target database. For example, if we open a TCP connection to the machine foobah for applet A, this does not mean that we should automatically allow applet B to share that connection. Applet B may have no right whatsoever to access machine foobah.

So before allowing someone to re-use an existing TCP connection the JDBC driver should check with the security manager that the current caller is allowed to connect to that machine. This can be done with the following code fragment:

```
SecurityManager security = System.getSecurityManager();
if (security != null) {
    security.checkConnect(hostName, portNumber);
}
```

The Security.checkConnect method will throw a java.lang.SecurityException if the connection is not permitted.

5.4.2 Check all local file access

If a JDBC driver needs to access any local data on the current machine, then it must ensure that its caller is allowed to open the target files. For example

```
SecurityManager security = System.getSecurityManager();
if (security != null) {
    security.checkRead(fileName);
}
```

The Security.checkRead method will throw a java.lang.SecurityException if the current caller is an applet which is not allowed to access the given file.

As with TCP connections, the driver need only be concerned with these security issues if file resources are shared among multiple calling threads and the driver is running as trusted code.

5.4.3 Assume the worst

Some drivers may use native methods to bridge to lower level database libraries. In these cases it may be difficult to determine what files or network connections will be opened by the lower level libraries.

In these circumstances the driver must make “worst case” security assumptions and deny all database access to downloaded applets unless the driver is completely confident that the intended access is innocuous.

For example a JDBC-ODBC bridge might check the meaning of ODBC data source names and only allow an applet to use those ODBC data source names that reference databases on machines to which the applet is allowed to open connections (see 5.4.1 above). But for some ODBC data source names the driver may be unable to determine the hostname of the target database and must therefore deny downloaded applets access to these data sources.

In order to determine if the current caller is a trusted application or applet (and can therefore be allowed arbitrary database access) the JDBC driver can check to see if the caller is allowed to write an arbitrary file:

```
SecurityManager security = System.getSecurityManager();
if (security != null) {
    security.checkWrite(“foobaz”);
}
```

6 Database connections

For the full interface descriptions see the Java interfaces in Chapter 13.

6.1 Opening a connection

When you want to access a database, you may obtain a java.sql.Connection object from the JDBC management layer's java.sql.DriverManager.getConnection method.

The DriverManager.getConnection method takes a URL string as an argument. The JDBC management layer will attempt to locate a driver that can connect to the database represented by the URL. The JDBC management layer does this by asking each driver in turn (see Section 6.2 below) if it can connect to the given URL.[1] Drivers should examine the URL to see if it specifies a subprotocol that they support (see Section 6.3 below), and if so, they should attempt to connect to the specified database. If they succeed in establishing a connection, then they should return an appropriate java.sql.Connection object.

From the java.sql.Connection object it is possible to obtain java.sql.Statement, java.sql.PreparedStatement, and java.sql.CallableStatement objects that can be used to execute SQL statements.

We also permit applications to bypass the JDBC management layer during connection open and explicitly select and use a particular driver.

6.2 Choosing between drivers

It may sometimes be the case that several JDBC drivers are capable of connecting to a given URL. For example, when connecting to a given remote database it might be possible to use either a JDBC-ODBC bridge driver, or a JDBC to generic network protocol driver, or to use a driver supplied by the database vendor.

JDBC allows users to specify a driver list by setting a Java property "jdbc.drivers". If this property is defined,then it should be a colon separated list of driver class names, such as "acme.wonder.Driver:foobaz.openNet.Driver:vendor.OurDriver".

When searching for a driver, JDBC will use the first driver it finds that can successfully connect to the given URL. It will first try to use each of the drivers specified in the sql.drivers list, in the order given. It will then proceed to try to use each loaded driver in the order in which the drivers were loaded. It will skip any drivers which are untrusted code, unless they have been loaded from the same source as the code that is trying to open the connection (see the security discussion in Section 5).

6.3 URLs

6.3.1 Goals for JDBC database naming

We need to provide a way of naming databases so that application writers can specify which database they wish to connect to.

1. At first glance this may seem inefficient, but keep in mind that this requires only a few procedure calls and string comparisons per connection since it is unlikely that dozens of drivers will concurrently be loaded.

We would like this JDBC naming mechanism to have the following properties:

1. Different drivers can use different schemes for naming databases. For example, a JDBC-ODBC bridge driver may support simple ODBC style data source names, whereas a network protocol driver may need to know additional information so it can discover which hostname and port to connect to.
2. If a user downloads an applet that wants to talk to a given database then we would like to be able to open a database connection without requiring the user to do any system administration chores. Thus for example, we want to avoid requiring an analogue of the human-administered ODBC data source tables on the client machines. This implies that it should be possible to encode any necessary connection information in the JDBC name.
3. We would like to allow a level of indirection in the JDBC name, so that the initial name may be resolved via some network naming system in order to locate the database. This will allow system administrators to avoid specifying particular hosts as part of the JDBC name. However, since there are a number of different network name services (such as NIS, DCE, etc.) we do not wish to mandate that any particular network nameserver is used.

6.3.2 URL syntax

Fortunately the World Wide Web has already standardized on a naming system that supports all of these properties. This is the Uniform Resource Locator (URL) mechanism. So we propose to use URLs for JDBC naming, and merely recommend some conventions for structuring JDBC URLs.

We recommend that JDBC URL's be structured as:

```
jdbc:<subprotocol>:<subname>
```

where a subprotocol names a particular kind of database connectivity mechanism that may be supported by one or more drivers. The contents and syntax of the subname will depend on the subprotocol.

If you are specifying a network address as part of your subname, we recommend following the standard URL naming convention of "//hostname:port/subsubname" for the subname. The subsubname can have arbitrary internal syntax.

6.3.3 Example URLs

For example, in order to access a database through a JDBC-ODBC bridge, one might use a URL like:

```
jdbc:odbc:fred
```

In this example the subprotocol is "odbc" and the subname is a local ODBC data source name "fred". A JDBC-ODBC driver can check for URLs that have subprotocol "odbc" and then use the subname in an ODBC SQLConnect.

If you are using some generic database connectivity protocol "dbnet" to talk to a database listener, you might have a URL like:

jdbc:dbnet://wombat:356/fred

In this example the URL specifies that we should use the "dbnet" protocol to connect to port 356 on host wombat and then present the subsubname "fred" to that port to locate the final database.

If you wish to use some network name service to provide a level of indirection in database names, then we recommend using the name of the naming service as the subprotocol. So for example one might have a URL like:

jdbc:dcenaming:accounts-payable

In this example, the URL specifies that we should use the local DCE naming service to resolve the database name "accounts-payable" into a more specific name that can be used to connect to the real database. In some situations, it might be appropriate to provide a pseudo driver that performed a name lookup via a network name server and then used the resulting information to locate the real driver and do the real connection open.

6.3.4 Drivers can choose a syntax and ignore other URLs.

In summary, the JDBC URL mechanism is intended to provide a framework so that different drivers can use different naming systems that are appropriate to their needs. Each driver need only understand a single URL naming syntax, and can happily reject any other URLs that it encounters.

6.3.5 Registering subprotocol names

JavaSoft will act as an informal registry for JDBC sub-protocol names. Send mail to jdbc@wombat.eng.sun.com to reserve a sub-protocol name.

6.3.6 The "odbc" subprotocol

The "odbc" subprotocol has been reserved for URLs that specify ODBC style Data Source Names. For this subprotocol we specify a URL syntax that allows arbitrary attribute values to be specified after the data source name.

The full odbc subprotocol URL syntax is:

```
jdbc:odbc:<data-source-name>[;<attribute-name>=<attribute-value>]*
```

Thus valid jdbc:odbc names include:

```
jdbc:odbc:qeor7
jdbc:odbc:wombat
jdbc:odbc:wombat;CacheSize=20;ExtensionCase=LOWER
jdbc:odbc:qeora;UID=kgh;PWD=fooey
```

6.4 Connection arguments

When opening a connection, you can pass in a java.util.Properties object. This object is a property set that maps between tag strings and value strings. Two conventional properties are "user" and "password". Particular drivers may specify and use other properties.

In order to allow applets to access databases in a generic way, we recommend that as much connection information as possible be encoded as part of the URL and that driver writers minimize their use of property sets.

6.5 Multiple connections

A single application can maintain multiple database connections to one or more databases, using one or more drivers.

6.6 Registering drivers

The JDBC management layer needs to know which database drivers are available. We provide two ways of doing this.

First, when the JDBC java.sql.DriverManager class initializes it will look for a “sql.drivers” property in the system properties. If the property exists it should consist of a colon-separated list of driver class names. Each of the named classes should implement the java.sql.Driver interface. The DriverManager class will attempt to load each named Driver class.

Second, a programmer can explicitly load a driver class using the standard Class.forName method. For example, to load the acme.db.Driver class you might do:

```
Class.forName(“acme.db.Driver”);
```

In both cases it is the responsibility of each newly loaded Driver class to register itself with the DriverManager, using the DriverManager.registerDriver method. This will allow the DriverManager to use the driver when it is attempting to make database connections.

For security reasons the JDBC management layer will keep track of which class loader provided which driver and when opening connections it will only use drivers that come from the local filesystem or from the same classloader as the code issuing the getConnection request.

7 Passing parameters and receiving results

For the full interface descriptions see the separate JDBC API documents.

See also the rejected "Holder" mechanism described in Appendix A.

7.1 Query results

The result of executing a query Statement is a set of rows that are accessible via a java.sql.ResultSet object. The ResultSet object provides a set of "get" methods that allow access to the various columns of the current row. The ResultSet.next method can be used to move between the rows of the ResultSet.

```
// We're going to execute a SQL statement that will return a
// collection of rows, with column 1 as an int, column 2 as
// a String, and column 3 as an array of bytes.
java.sql.Statement stmt = conn.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");
      byte b[] = r.getBytes("c");
      System.out.println("ROW = " + i + " " + s + " " + b[0]);
}
```

There are two alternative ways of specifying columns. You can either use column indexes (for greater efficiency) or column names (for greater convenience). Thus for example there is both a getString method that takes a column index and a getString method that takes a column name.

Reviewer input convinced us that we had to support both column indexes and column names. Some reviewers were extremely emphatic that they require highly efficient database access and therefore preferred column indexes, other reviewers insisted that they wanted the convenience of using column names. (Note that certain SQL queries can return tables without column names or with multiple identical column names. In these cases, programmers should use column numbers.)

For maximum portability, columns within a row should be read in left-to-right order, and each column should only be read once. This reflects implementation limitations in some underlying database protocols.

7.1.1 Data conversions on query results

The ResultSet.getXXX methods will attempt to convert whatever SQL type was returned by the database to whatever Java type is returned by the getXXX method.

Table 1 on page 21 lists the supported conversions from SQL types to Java types via getXXX methods. For example, it is possible to attempt to read a SQL VARCHAR value as an integer using getInt, but it is not possible to read a SQL FLOAT as a java.sql.Date.

If you attempt an illegal conversion, or if a data conversion fails (for example if you did a getInt on a SQL VARCHAR value of "foo"), then a SQLException will be raised.

	TINYINT	SMALLINT	INTEGER	BIGINT	REAL	FLOAT	DOUBLE	DECIMAL	NUMERIC	BIT	CHAR	VARCHAR	LONGVARCHAR	BINARY	VARBINARY	LONGVARBINARY	DATE	TIME	TIMESTAMP
getByte	**X**	x	x	x	x	x	x	x	x	x	x	x	x						
getShort	x	**X**	x	x	x	x	x	x	x	x	x	x	x						
getInt	x	x	**X**	x	x	x	x	x	x	x	x	x	x						
getLong	x	x	x	**X**	x	x	x	x	x	x	x	x	x						
getFloat	x	x	x	x	**X**	x	x	x	x	x	x	x	x						
getDouble	x	x	x	x	x	**X**	**X**	x	x	x	x	x	x						
getBigDecimal	x	x	x	x	x	x	x	**X**	**X**	x	x	x	x						
getBoolean	x	x	x	x	x	x	x	x	x	**X**	x	x	x						
getString	x	x	x	x	x	x	x	x	x	x	**X**	**X**	x	x	x	x	x	x	x
getBytes														**X**	**X**	x			
getDate											x	x	x				**X**		x
getTime											x	x	x					**X**	x
getTimestamp											x	x	x				x		**X**
getAsciiStream											x	x	**X**	x	x	x			
getUnicodeStream											x	x	**X**	x	x	x			
getBinaryStream														x	x	**X**			
getObject	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 1: Use of ResultSet.getXXX methods to retrieve common SQL data types
An “x” means that the given getXXX method can be used to retrieve the given SQL type.
An “**X**” means that the given getXXX method is recommended for retrieving the given SQL type

7.1.2 Null result values

To determine if a given result value is SQL "NULL" you must first read the column and then use the ResultSet.wasNull method to discover if the read returned a SQL "NULL". (See also Appendix A.9).

When you read a SQL "NULL" using one of the ResultSet.getXXX methods, you will receive:

- A Java "null" value for those getXXX methods that return Java objects.
- A zero value for getByte, getShort, getInt, getLong, getFloat, and getDouble
- A false value for getBoolean.

7.1.3 Retrieving very large row values.

JDBC allows arbitrarily large LONGVARBINARY or LONGVARCHAR data to be retrieved using getBytes and getString, up to the limits imposed by the Statement.getMaxFieldSize value. However, application programmers may often find it convenient to retrieve very large data in smaller fixed size chunks.

To accommodate this, the ResultSet class can return java.io.Input streams from which data can be read in chunks. However each of these streams must be accessed immediately as they will be automatically closed on the next "get" call on the ResultSet. **This behavior reflects underlying implementation constraints on large blob access.**

Java streams return untyped bytes and can (for example) be used for both ASCII and Unicode. We define three separate methods for getting streams. GetBinaryStream returns a stream which simply provides the raw bytes from the database without any conversion. GetAsciiStream returns a stream which provides one byte ASCII characters. GetUnicodeStream returns a stream which provides 2 byte Unicode characters.

For example:

```
java.sql.Statement stmt = conn.createStatement();
ResultSet r = stmt.executeQuery("SELECT x FROM Table2");
// Now retrieve the column 1 results in 4 K chunks:
byte[] buff = new byte[4096];
while (r.next()) {
      java.io.InputStream fin = r.getAsciiStream("x");
      for (;;) {
            int size = fin.read(buff);
            if (size == -1) {
                  break;
            }
            // Send the newly filled buffer to some ASCII output stream:
            output.write(buff, 0, size);
      }
}
```

7.1.4 Optional or multiple ResultSets

Normally we expect that SQL statements will be executed using either executeQuery (which returns a single ResultSet) or executeUpdate (which can be used for any kind of database modification statement and which returns a count of the rows updated).

However under some circumstances an application may not know whether a given statement will return a ResultSet until the statement has executed. In addition, some stored procedures may return several different ResultSets and/or update counts.

To accommodate these needs we provide a mechanism so that an application can execute a statement and then process an arbitrary collection of ResultSets and update counts. This mechanism is based on a fully general "execute" method, supported by three other methods, getResultSet, getUpdateCount, and getMoreResults. These methods allow an application to explore the statement results one at a time and to determine if a given result was a ResultSet or an update count.

7.2 Passing IN parameters

To allow you to pass parameters to a SQL statement, the java.sql.PreparedStatement class provides a series of setXXX methods. These can be used before each statement execution to fill in parameter fields. Once a parameter value has been defined for a given statement, it can be used for multiple executions of that statement, until it is cleared by a call on PreparedStatement.clearParameters.

```
java.sql.PreparedStatement stmt = conn.prepareStatement(
                              “UPDATE table3 SET m = ? WHERE x = ?”);
// We pass two parameters. One varies each time around the for loop,
// the other remains constant.
stmt.setString(1, “Hi”);
for (int i = 0; i < 10; i++) {
       stmt.setInt(2, i);
       int rows = stmt.executeUpdate();
}
```

7.2.1 Data type conformance on IN parameters

The PreparedStatement.setXXX methods do not perform any general data type conversions. Instead the Java value is simply mapped to the corresponding SQL type (following the mapping specified in Table 3 on page 28) and that value is sent to the database.

It is the programmer’s responsibility to make sure that the java type of each argument maps to a SQL type that is compatible with the SQL data type expected by the database. For maximum portability programmers, should use Java types that correspond to the exact SQL types expected by the database.

If programmers require data type conversions for IN parameters, they may use the PreparedStatement.setObject method which converts a Java Object to a specified SQL type before sending the value to the database.

7.2.2 Sending SQL NULLs as IN parameters

The PreparedStatement.setNull method allows you to send a SQL NULL value to the database as an IN parameter. Note, however, that you must specify the SQL type of the parameter.

In addition, for those setXXX methods that take Java objects as arguments, if a Java null value is passed to a setXXX method, then a SQL NULL will be sent to the database.

7.2.3 Sending very large parameters

JDBC itself defines no limits on the amount of data that may be sent with a setBytes or setString call. However, when dealing with large blobs, it may be convenient for application programmers to pass in very large data in smaller chunks.

To accommodate this, we allow programmers to supply Java IO streams as parameters. When the statement is executed the JDBC driver will make repeated calls on these IO streams to read their contents and transmit these as the actual parameter data.

Separate setXXX methods are provided for streams containing uninterpreted bytes, for streams containing ASCII characters, and for streams containing Unicode characters.

When setting a stream as an input parameter, the application programmer must specify the number of bytes to be read from the stream and sent to the database.

We dislike requiring that the data transfer size be specified in advance; however, this is necessary because some databases need to know the total transfer size in advance of any data being sent.

An example of using a stream to send the contents of a file as an IN parameter:

```
java.io.File file = new java.io.File("/tmp/foo");
int fileLength = file.length();
java.io.InputStream fin = new java.io.FileInputStream(file);
java.sql.PreparedStatement stmt = conn.prepareStatement(
                  "UPDATE Table5 SET stuff = ? WHERE index = 4");
stmt.setBinaryStream(1, fin, fileLength);
// When the statement executes, the "fin" object will get called
// repeatedly to deliver up its data.
stmt.executeUpdate();
```

7.3 Receiving OUT parameters

If you are executing a stored procedure call, then you should use the CallableStatement class. CallableStatement is a subtype of PreparedStatement.

To pass in any IN parameters you can use the setXXX methods defined in PreparedStatement as described in Section 7.2 above.

However, if your stored procedure returns OUT parameters, then for each OUT parameter you must use the CallableStatememt.registerOutParameter method to register the SQL type of the OUT parameter before you execute the statement. (See Appendix A.6.) Then after the statement has executed, you must use the corresponding CallableStatement.getXXX method to retrieve the parameter value.

```
java.sql.CallableStatement stmt = conn.prepareCall(
                              "{call getTestData(?, ?)}");
stmt.registerOutParameter(1,java.sql.Types.TINYINT);
stmt.registerOutParameter(2,java.sql.types.DECIMAL, 2);
stmt.executeUpdate();
byte x = stmt.getByte(1);
BigDecimal n = stmt.getBigDecimal(2,2);
```

7.3.1 Data type conformance on OUT parameters

The CallableStatement.getXXX methods do not perform any general data type conversions. Instead the registerOutParameter call must specify the SQL type that will be returned by the database and the programmer must then subsequently call the getXXX method whose Java type corresponds to that SQL type, as specified in Table 2 on page 27.

7.3.2 Retrieving NULL values as OUT parameters

As with ResultSets, in order to determine if a given OUT parameter value is SQL "NULL" you must first read the parameter and then use the CallableStatement.wasNull method to discover if the read returned a SQL "NULL".

When you read a SQL "NULL" value using one of the CallableStatement.getXXX methods, you will receive a value of null, zero, or false, following the same rules specified in section 7.1.2 for the ResultSet.getXXX methods.

7.3.3 Retrieving very large out parameters

We do not provide any mechanism for retrieving OUT parameters as streams.

Instead we recommend that programmers retrieve very large values through ResultSets.

7.3.4 Retrieve out parameters after results

If a stored procedure returns both results and out parameters, for maximum portability, the results should be retrieved prior to retrieving the out parameters.

7.4 Data truncation

Under some circumstances data may be truncated when it is being read from or written to the database. How this is handled will depend on the circumstances, but in general data truncation on a database read will result in a warning, whereas data truncation on a database write will result in a SQLException.

7.4.1 Exceeding the Connection maxFieldSize limit

If an application uses Connection.setMaxFieldSize to impose a limit on the maximum size of a field, then attempts to read or write a field larger than this will result in the data being silently truncated to the maxFieldSize size, without any SQLException or SQLWarning.

7.4.2 Data truncation on reads

In general data truncation errors during data reads will be uncommon with JDBC as the API does not require the programmer to pass in fixed size buffers, but rather allocates appropriate data space as needed. However in some circumstances drivers may encounter internal implementation limits, so there is still a possibility for data truncation during reads.

If data truncation occurs during a read from a ResultSet then a DataTruncation object (a subtype of SQLWarning) will get added to the ResultSet's warning list and the method will return as much data as it was able to read. Similarly, if a data truncation occurs while an OUT parameter is being received from the database, then a DataTruncation object will get added to the CallableStatement's warning list and the method will return as much data as it was able to read.

7.4.3 Data truncation on writes

During writes to the database there is a possibility that the application may attempt to send more data than the driver or the database is prepared to accept. In this case the failing method should raise a DataTruncation exception as a SQLException.

8 Mapping SQL data types into Java

8.1 Constraints

We need to provide reasonable Java mappings for the common SQL data types. We also need to make sure that we have enough type information so that we can correctly store and retrieve parameters and recover results from SQL statements.

However, there is no particular reason that the Java data type needs to be exactly isomorphic to the SQL data type. For example, since Java has no fixed length arrays, we can represent both fixed length and variable length SQL arrays as variable length Java arrays. We also felt free to use Java Strings even though they don't precisely match any of the SQL CHAR types.

Table 2 shows the default Java mapping for various common SQL data types. Not all of these types will necessarily be supported by all databases. The various mappings are described more fully in the following sections.

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

Table 2: Standard mapping from SQL types to Java types.

Similarly table 3 shows the reverse mapping from Java types to SQL types.

Java Type	SQL type
String	VARCHAR or LONGVARCHAR
java.math.BigDecimal	NUMERIC
boolean	BIT
byte	TINYINT
short	SMALLINT
int	INTEGER
long	BIGINT
float	REAL
double	DOUBLE
byte[]	VARBINARY or LONGVARBINARY
java.sql.Date	DATE
java.sql.Time	TIME
java.sql.Timestamp	TIMESTAMP

Table 3: Standard mapping from Java types to SQL types.

The mapping for String will normally be VARCHAR but will turn into LONGVARCHAR if the given value exceeds the drivers limit on VARCHAR values. Similarly for byte[] and VARBINARY and LONGVARBINARY.

8.2 Dynamic data access

This chapter focuses on access to results or parameters whose types are known at compile time. However, some applications, for example generic browsers or query tools, are not compiled with knowledge of the database schema they will access, so JDBC also provides support for fully dynamically typed data access. See Section 14.2.

8.3 CHAR, VARCHAR, and LONGVARCHAR

There is no need for Java programmers to distinguish among the three different flavours of SQL strings CHAR, VARCHAR, and LONGVARCHAR. These can all be expressed identically in Java. It is possible to read and write the SQL correctly without needing to know the exact data type that was expected.

These types could be mapped to either String or char[]. After considerable discussion we decided to use String, as this seemed the more appropriate type for normal use. Note that the Java String class provides a method for converting a String to a char[] and a constructor for turning a char[] into a String.

For fixed length SQL strings of type CHAR(n), the JDBC drivers will perform appropriate padding with spaces. Thus when a CHAR(n) field is retrieved from the database the resulting String will always be of length “n” and may include some padding spaces at the end. When a

String is sent to a CHAR(n) field, the driver and/or the database will add any necessary padding spaces to the end of the String to bring it up to length "n".

The ResultSet.getString method allocates and returns a new String. This is suitable for retrieving normal data, but the LONGVARCHAR SQL type can be used to store multi-megabyte strings. We therefore needed to provide a way for Java programmers to retrieve a LONGVARCHAR value in chunks. We handle this by allowing programmers to retrieve a LONGVARCHAR as a Java input stream from which they can subsequently read data in whatever chunks they prefer. Java streams can be used for either Unicode or Ascii data, so the programmer may chose to use either getAsciiStream or getUnicodeStream.

8.4 DECIMAL and NUMERIC

The SQL DECIMAL and NUMERIC data types are used to express fixed point numbers where absolute precision is required. They are often used for currency values.

These two types can be expressed identically in Java. The most convenient mapping uses the java.math.BigDecimal extended precision number type provided in JDK1.1

We also allow access to DECIMAL and NUMERIC as simple Strings and arrays of chars. Thus Java programmers can use getString to receive a NUMERIC or DECIMAL result.

8.5 BINARY, VARBINARY, and LONGVARBINARY

There is no need for Java programmers to distinguish among the three different flavours of SQL byte arrays BINARY, VARBINARY, and LONGVARBINARY. These can all be expressed identically as byte arrays in Java. (It is possible to read and write the SQL correctly without needing to know the exact BINARY data type that was expected.)

As with the LONGVARCHAR SQL type, the LONGVARBINARY SQL type can sometimes be used to return multi-megabyte data values. We therefore allow a LONGVARBINARY value to be retrieved as a Java input stream, from which programmers can subsequently read data in whatever chunks they prefer.

8.6 BIT

The SQL BIT type can be mapped directly to the Java boolean type.

8.7 TINYINT, SMALLINT, INTEGER, and BIGINT

The SQL TINYINT, SMALLINT, INTEGER, and BIGINT types represent 8 bit, 16 bit, 32 bit, and 64 bit values. These therefore can be mapped to Java's byte, short, int, and long data types.

8.8 REAL, FLOAT, and DOUBLE

SQL defines three floating point data types, REAL, FLOAT, and DOUBLE.

We map REAL to Java float, and FLOAT and DOUBLE to Java double.

REAL is required to support 7 digits of mantissa precision. FLOAT and DOUBLE are required to support 15 digits of mantissa precision.

8.9 DATE, TIME, and TIMESTAMP

SQL defines three time related data types. DATE consists of day, month, and year. TIME consists of hours, minutes and seconds. TIMESTAMP combines DATE and TIME and also adds in a nanosecond field.

There is a standard Java class java.util.Date that provides date and time information. However, this class doesn't perfectly match any of the three SQL types, as it includes both DATE and TIME information, but lacks the nanosecond granularity required for TIMESTAMP.

We therefore define three subclasses of java.util.Date. These are:

- java.sql.Date for SQL DATE information
- java.sql.Time for SQL TIME information
- java.sql.Timestamp for SQL TIMESTAMP information

In the case of java.sql.Date the hour, minute, second, and milli-second fields of the java.util.Date base class are set to zero.

In the case of java.sql.Time the year, month, and day fields of the java.util.Date base class are set to 1970, January, and 1, respectively. This is the "zero" date in the Java epoch.

The java.sql.Timestamp class extends java.util.Date by adding a nanosecond field.

9 Asynchrony, Threading, and Transactions

9.1 Asynchronous requests

Some database APIs, such as ODBC, provide mechanisms for allowing SQL statements to execute asynchronously. This allows an application to start up a database operation in the background, and then handle other work (such as managing a user interface) while waiting for the operation to complete.

Since Java is a multi-threaded environment, there seems no real need to provide support for asynchronous statement execution. Java programmers can easily create a separate thread if they wish to execute statements asynchronously with respect to their main thread.

9.2 Multi-threading

We require that all operations on all the java.sql objects be multi-thread safe and able to cope correctly with having several threads simultaneously calling the same object.

Some drivers may allow more concurrent execution than others. Developers can assume fully concurrent execution; if the driver requires some form of synchronization, it will provide it. The only difference visible to the developer will be that applications will run with reduced concurrency.

For example, two Statements on the same Connection can be executed concurrently and their ResultSets can be processed concurrently (from the perspective of the developer). Some drivers will provide this full concurrency. Others may execute one statement and wait until it completes before sending the next.

One specific use of multi-threading is to cancel a long running statement. This is done by using one thread to execute the statement and another to cancel it with its Statement.cancel() method.

In practice we expect that most of the JDBC objects will only be accessed in a single threaded way. However some multi-thread support is necessary, and our attempts in previous drafts to specify some classes as MT safe and some as MT unsafe appeared to be adding more confusion than light.

9.3 Transactions.

New JDBC connections are initially in “auto-commit” mode. This means that each statement is executed as a separate transaction at the database.

In order to execute several statements within a single transaction, you must first disable auto-commit by calling Connection.setAutoCommit(false).

When auto-commit is disabled, the connection always has an implicit transaction associated with it. You can execute a Connection.commit to complete the transaction or a Connection.rollback to abort it. The commit or rollback will also start a new implicit transaction.

The exact semantics of transactions and their isolation levels depend on the underlying database. There are methods on java.sql.DatabaseMetaData to learn the current defaults, and on java.sql.Connection to move a newly opened connection to a different isolation level.

In the first version of the interface we will provide no support for committing transactions across different connections.

10 Cursors

JDBC provides simple cursor support. An application can use ResultSet.getCursorName() to obtain a cursor associated with the current ResultSet. It can then use this cursor name in positioned update or positioned delete statements.

The cursor will remain valid until the ResultSet or its parent Statement is closed.

Note that not all DBMSs support positioned update and delete. The DatabaseMetaData.supportsPositionedDelete and supportsPositionedUpdate methods can be used to discover whether a particular connection supports these operations. When they are supported, the DBMS/driver must insure that rows selected are properly locked so that positioned updates do not result in update anomalies or other concurrency problems.

Currently we do not propose to provide support for either scrollable cursors or ODBC style bookmarks as part of JDBC.

11 SQL Extensions

Certain SQL features beyond SQL-2 Entry Level are widely supported and are desirable to include as part of our JDBC compliance definition so that applications can depend on the portability of these features. However, SQL-2 Transitional Level, the next higher level of SQL compliance defined by ANSI, is not widely supported. Where Transitional Level semantics *are* supported, the syntax is often different across DBMSs.

We therefore define two kinds of extensions to SQL-2 Entry Level that must be supported by a JDBC-Compliant™ driver:

- Selective Transitional Level syntax and semantics must be supported. We currently demand just one such feature: the DROP TABLE command is required for JDBC compliance.
- Selective Transitional Level semantics must be supported through an escape syntax that a driver can easily scan for and translate into DBMS-specific syntax. We discuss these escapes in the remainder of Section 11. Note that these escapes need only be supported where the underyling database supports the corresponding Transitional Level semantics.

An ODBC driver that supports ODBC Core SQL as defined by Microsoft complies with JDBC SQL as defined in this section.

11.1 SQL Escape Syntax

JDBC supports the same DBMS-independent escape syntax as ODBC for stored procedures, scalar functions, dates, times, and outer joins. A driver maps this escape syntax into DBMS-specific syntax, allowing portability of application programs that require these features. The DBMS-independent syntax is based on an escape clause demarcated by curly braces and a keyword:

```
{keyword ... parameters ...}
```

This ODBC-compatible escape syntax is in general *not* the same as has been adopted by ANSI in SQL-2 Transitional Level for the same functionality. In cases where all of the desired DBMSs support the standard SQL-2 syntax, the user is encouraged to use that syntax instead of these escapes. When enough DBMSs support the more advanced SQL-2 syntax and semantics these escapes should no longer be necessary.

11.2 Stored Procedures

The syntax for invoking a stored procedure in JDBC is:

```
{call procedure_name[(argument1, argument2, ...)]}
```

or, where a procedure returns a result parameter:

```
{?= call procedure_name[(argument1, argument2, ...)]}
```

Input arguments may be either literals or parameters. To determine if stored procedures are supported, call DatabaseMetaData.supportsStoredProcedure.

11.3 Time and Date Literals

DBMSs differ in the syntax they use for date, time, and timestamp literals. JDBC supports ISO standard format for the syntax of these literals, using an escape clause that the driver must translate to the DBMS representation.

For example, a date is specified in a JDBC SQL statement with the syntax

```
{d ‘yyyy-mm-dd’}
```

where yyyy-mm-dd provides the year, month, and date, e.g. 1996-02-28. The driver will replace this escape clause with the equivalent DBMS-specific representation, e.g. ‘Feb 28, 1996’ for Oracle.

There are analogous escape clauses for TIME and TIMESTAMP:

```
{t ‘hh:mm:ss’}

{ts ‘yyyy-mm-dd hh:mm:ss.f...’}
```

The fractional seconds (.f...) portion of the TIMESTAMP can be omitted.

11.4 Scalar Functions

JDBC supports numeric, string, time, date, system, and conversion functions on scalar values. These functions are indicated by the keyword “fn” followed by the name of the desired function and its arguments. For example, two strings can be concatenated using the concat function

```
{fn concat(“Hot”, “Java”)}
```

The name of the current user can be obtained through the syntax

```
{fn user()}
```

See the X/Open CLI or ODBC specifications for specifications of the semantics of the scalar functions. The functions supported are listed here for reference. Some drivers may not support all of these functions; to find out which functions are supported, use the folowing DatabaseMetadata methods: getNumericFunctions() returns a comma separated list of the names of the numeric functions supported, getStringFunctions() does the same for the string functions, and so on.

The numeric functions are ABS(number), ACOS(float), ASIN(float), ATAN(float), ATAN2(float1, float2), CEILING(number), COS(float), COT(float), DEGREES(number), EXP(float), FLOOR(number), LOG(float), LOG10(float), MOD(integer1, integer2), PI(), POWER(number, power), RADIANS(number), RAND(integer), ROUND(number, places), SIGN(number), SIN(float), SQRT(float), TAN(float), and TRUNCATE(number, places).

The string functions are ASCII(string), CHAR(code), CONCAT(string1, string2), DIFFERENCE(string1, string2), INSERT(string1, start, length, string2), LCASE(string), LEFT(string, count), LENGTH(string), LOCATE(string1, string2, start), LTRIM(string), REPEAT(string, count), REPLACE(string1, string2, string3), RIGHT(string, count), RTRIM(string), SOUNDEX(string), SPACE(count), SUBSTRING(string, start, length), and UCASE(string).

The time and date functions are CURDATE(), CURTIME(), DAYNAME(date), DAYOFMONTH(date), DAYHOFWEEK(date), DAYOFYEAR(date), HOUR(time), MINUTE(time), MONTH(time), MONTHNAME(date), NOW(), QUARTER(date), SECOND(time), TIMESTAMPADD(interval, count, timestamp), TIMESTAMPDIFF(interval, timestamp1, timpestamp2), WEEK(date), and YEAR(date).

The system functions are DATABASE(), IFNULL(expression, value), and USER().

There is also a CONVERT(value, SQLtype) expression, where type may be BIGINT, BINARY, BIT, CHAR, DATE, DECIMAL, DOUBLE, FLOAT, INTEGER, LONGVARBINARY, LONGVARCHAR, REAL, SMALLINT, TIME, TIMESTAMP, TINYINT, VARBINARY, and VARCHAR.

Again, these functions are supported by DBMSs with slightly different syntax, and the driver's job is either to map these into the appropriate syntax or to implement the function directly in the driver.

11.5 LIKE Escape Characters

The characters "%" and "_" have special meaning in SQL LIKE clauses (to match zero or more characters, or exactly one character, respectively). In order to interpret them literally, they can be preceded with a special escape character in strings, e.g. "\". In order to specify the escape character used to quote these characters, include the following syntax on the end of the query:

```
{escape 'escape-character'}
```

For example, the query

```
SELECT NAME FROM IDENTIFIERS WHERE ID LIKE '\_%' {escape '\'}
```

finds identifier names that begin with an underbar.

11.6 Outer Joins

The syntax for an outer join is

```
{oj outer-join}
```

where outer-join is of the form

```
table LEFT OUTER JOIN {table | outer-join} ON search-condition
```

See the SQL grammar for an explanation of outer joins. Three boolean DatabaseMetaData methods are provided to determine the kinds of outer joins supported by a driver.

12 Variants and Extensions

As far as possible we would like a standard JDBC API that works in a uniform way with different databases. However it is unavoidable that different databases support different SQL features and provide different semantics for some operations.

12.1 Permitted variants

The methods in java.sql.Connection, java.sql.Statement, java.sql.PreparedStatement, java.sql.CallableStatement, and java.sql.Resultset should all be supported for all JDBC drivers. For databases which don't support OUT parameters with stored procedures, the various registerOutParameter and getXXX methods of CallableStatement may raise SQLException.

The actual SQL that may be used varies somewhat between databases. For example, different databases provide different support for outer joins. The java.sql.DatabaseMetaData interface provides a number of methods that can be used to determine exactly which SQL features are supported by a particular database. Similarly, the syntax for a number of SQL features may vary between databases and can also be discovered from java.sql.DatabaseMetaData. However, in order to pass JDBC conformance tests a driver must support at least ANSI SQL-2 Entry Level syntax and semantics plus support for the SQL extensions listed in Section 11.

Finally, some fundamental properties, such as transaction isolation levels, vary between databases. The default properties of the current database and the range of properties it supports can also be obtained from DatabaseMetaData.

12.2 Vendor-specific extensions

JDBC provides a uniform API that is intended to work across all databases. However, database vendors may wish to expose additional functionality that is supported by their databases.

Database vendors may add additional functionality by adding new subtypes of existing JDBC types that provide additional methods. Thus the Foobah corporation might define a new Java type foobah.sql.FooBahStatement that inherits from the standard java.sql.Statement type but adds some new functionality.

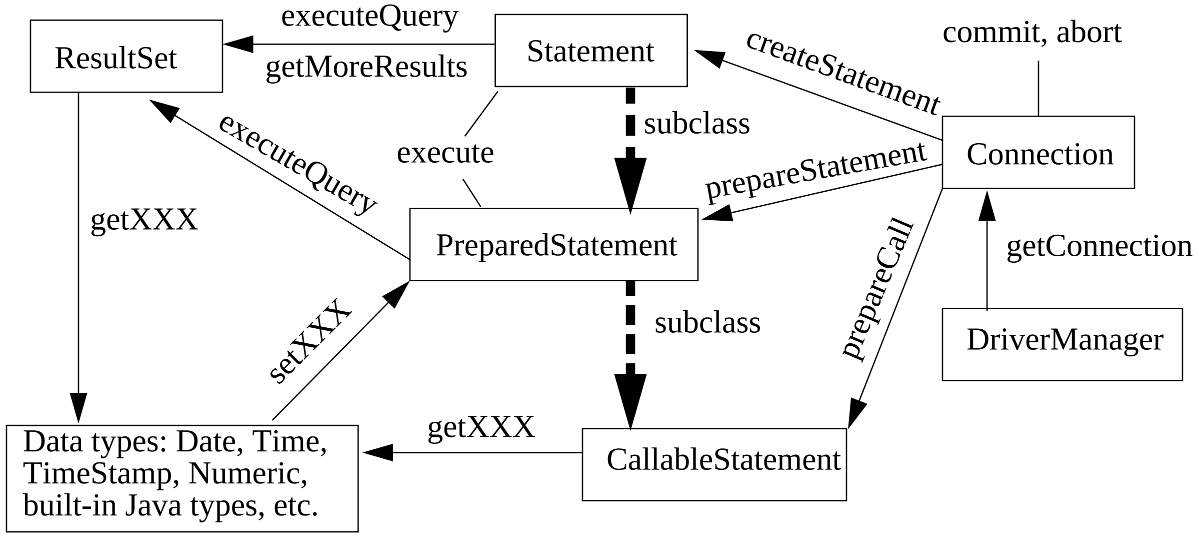
13 JDBC Interface Definitions

See the separate JDBC API documentation which contains the Java definitions of the core java.sql interfaces and classes listed below.

java.sql.CallableStatement
java.sql.Connection
java.sql.DataTruncation
java.sql.Date
java.sql.Driver
java.sql.DriverManager
java.sql.DriverPropertyInfo
java.sql.PreparedStatement
java.sql.ResultSet
java.sql.SQLException
java.sql.SQLWarning
java.sql.Statement
java.sql.Time
java.sql.Timestamp
java.sql.Types

The JDBC API documentation also includes definitions of the JDBC metadata interfaces - java.sql.DatabaseMetaData and java.sql.ResultSetMetaData. See also the short example programs in Appendix B.

The more important relationships between the interfaces are as follows (with arrows showing functions and lines showing other methods):



14 Dynamic Database Access

We expect most JDBC programmers will be programming with knowledge of their target database's schema. They can therefore use the strongly typed JDBC interfaces described in Section 7 for data access. However there is also another extremely important class of database access where an application (or an application builder) dynamically discovers the database schema information and uses that information to perform appropriate dynamic data access. This section describes the JDBC support for dynamic access.

14.1 Metadata information

JDBC provides access to a number of different kinds of metadata, describing row results, statement parameters, database properties, etc., etc. We originally attempted to provide this information via extra methods on the core JDBC classes such as java.sql.Connection and java.sql.ResultSet. However, because of the complexity of the metadata methods and because they are likely to be used by only a small subset of JDBC programmers, we decided to split the metadata methods off into two separate Java interfaces.

In general, for each piece of metadata information we have attempted to provide a separate JDBC method that takes appropriate arguments and provides an appropriate Java result type. However, when a method such as Connection.getProcedures() returns a collection of values, we have chosen to use a java.sql.ResultSet to contain the results. The application programmer can then use normal ResultSet methods to iterate over the results.

We considered defining a set of enumeration types for retrieving collections of metadata results, but this seemed to add additional weight to the interface with little real value. JDBC programmers will already be familiar with using ResultSets, so using them for metadata results should not be too onerous.

A number of metadata methods take String search patterns as arguments. These search patterns are the same as for ODBC, where a '_' iimplies a match of any single character and a '%' implies a match of zero or more characters. For catalog and schema values, a Java empty string matches an 'unnamed' value; and a Java null String causes that search criteria to be ignored.

The java.sql.ResultSetMetaData type provides a number of methods for discovering the types and properties of the columns of a particular java.sql.ResultSet object.

The java.sql.DatabaseMetaData interface provides methods for retrieving various metadata associated with a database. This includes enumerating the stored procedures in the database, the tables in the database, the schemas in the database, the valid table types, the valid catalogs, finding information on the columns in tables, access rights on columns, access rights on tables, minimal row identification, and so on.

14.2 Dynamically typed data access

In Section 8 we described the normal mapping between SQL types and Java types. For example, a SQL INTEGER is normally mapped to a Java int. This supports a simple interface for reading and writing SQL values as simple Java types.

However, in order to support generic data access, we also provide methods that allow data to be retrieved as generic Java objects. Thus there is a ResultSet.getObject method, a Prepared-

Statement.setObject method, and a CallableStatement.getObject method. Note that for each of the two getObject methods you will need to narrow the resulting java.lang.Object object to a specific data type before you can retrieve a value.

Since the Java built-in types such as boolean and int are not subtypes of Object, we need to use a slightly different mapping from SQL types to Java object types for the getObject/setObject methods. This mapping is shown in Table 4.

SQL type	Java Object Type
CHAR	String
VARCHAR	String
LONGVARCHAR	String
NUMERIC	java.math.BigDecimal
DECIMAL	java.math.BigDecimal
BIT	Boolean
TINYINT	Integer
SMALLINT	Integer
INTEGER	Integer
BIGINT	Long
REAL	Float
FLOAT	Double
DOUBLE	Double
BINARY	byte[]
VARBINARY	byte[]
LONGVARBINARY	byte[]
DATE	java.sql.Date
TIME	java.sql.Time
TIMESTAMP	java.sql.Timestamp

Table 4: Mapping from SQL types to Java Object types.

The corresponding default mapping from Java Object types to SQL types is show in Table 5.

Java Object Type	SQL type
String	VARCHAR or LONGVARCHAR
java.math.BigDecimal	NUMERIC
Boolean	BIT
Integer	INTEGER
Long	BIGINT
Float	REAL
Double	DOUBLE
byte[]	VARBINARY or LONGVARBINARY
java.sql.Date	DATE
java.sql.Time	TIME
java.sql.Timestamp	TIMESTAMP

Table 5: Mapping from Java Object types to SQL types.
Note that the mapping for String will normally be VARCHAR but will turn into LONGVARCHAR if the given value exceeds the drivers limit on VARCHAR values. The situation is similar for byte[] and VARBINARY and LONGVARBINARY.

Note that it is not possible to send or receive Java input streams using the getObject or setObject methods. You must explicitly use PreparedStatement.setXXXStream or ResultSet.getXXXStream to transfer a value as a stream.

14.2.1 ResultSet.getObject

ResultSet.getObject returns a Java object whose type correspond to the SQL type of the ResultSet column, using the mapping specified in Table 4.

So for example, if you have a ResultSet where the “a” column has SQL type CHAR, and the “b” column has SQL type SMALLINT, here are the types returned by some getObject calls:

```
ResultSet rs = stmt.executeQuery(“SELECT a, b FROM foo”);
while (rs.next()) {
      Object x = rs.getObject(“a”);             // gets a String
      Object y = rs.getObject(“b”);             // gets an Integer
}
```

14.2.2 PreparedStatement.setObject

For PreparedStatement.setObject you can optionally specify a target SQL type. In this case the argument Java Object will first be mapped to its default SQL type (as specified in Table 5), then converted to the specified SQL type (see Table 6), and then sent to the database.

Alternatively you can omit the target SQL type, in which case the given Java Object will simply get mapped to its default SQL type (using Table 5) and then be sent to the database .

14.2.3 CallableStatement.getObject

Before calling CallableStatement.getObject you must first have specified the parameter's SQL type using CallableStatement.registerOutParameter. When you call CallableStatement.getObject the Driver will return a Java Object type corresponding to that SQL type, using the mapping specified Table 4.

	TINYINT	SMALLINT	INTEGER	BIGINT	REAL	FLOAT	DOUBLE	DECIMAL	NUMERIC	BIT	CHAR	VARCHAR	LONGVARCHAR	BINARY	VARBINARY	LONGVARBINARY	DATE	TIME	TIMESTAMP
String	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
java.math.BigDecimal	x	x	x	x	x	x	x	x	x	x	x	x	x						
Boolean	x	x	x	x	x	x	x	x	x	x	x	x	x						
Integer	x	x	x	x	x	x	x	x	x	x	x	x	x						
Long	x	x	x	x	x	x	x	x	x	x	x	x	x						
Float	x	x	x	x	x	x	x	x	x	x	x	x	x						
Double	x	x	x	x	x	x	x	x	x	x	x	x	x						
byte[]														x	x	x			
java.sql.Date											x	x	x				x		x
java.sql.Time											x	x	x					x	
java.sql.Timestamp											x	x	x				x	x	x

Table 6: Conversions performed by setObject between Java object types and target SQL types.
An "x" means that the given Java object type may be converted to the given SQL type.
Note that some conversions may fail at runtime if the value presented is invalid.

Appendix A: Rejected design choices

A.1 Use Holder types rather than get/set methods.

In earlier drafts of JDBC we used a mechanism of “Holder” types to pass parameters and to obtain results. This mechanism was an attempt to provide a close analogue to the use of pointers to variables in ODBC. However as we tried to write test examples we found the need to create and bind Holder types fairly irksome, particularly when processing simple row results.

We therefore came up with the alternative design using the getXXX and setXXX methods that is described in Sections 7.2 and 7.1. After comparing various example programs we decided that the getXXX/setXXX mechanism seemed to be simpler for programmers to use. It also removed the need to define a dozen or so Holder types as part of the JDBC API. So we decided to use the getXXX/setXXX mechanism and not to use Holders.

A.1.1 Using Holder types to pass parameters

As part of the java.sql API, we define a set of Holder types to hold parameters to SQL statements. There is an abstract base class Holder, and then specific subtypes for different Java types that may be used with SQL. For example, there is a StringHolder to hold a String parameter and a ByteHolder to hold a byte parameter.

To allow parameters to be passed to SQL statements, the java.sql.Statement class allows you to associate Holder objects with particular parameters. When the statement is executed any IN or INOUT parameter values will be read from the corresponding Holder objects, and when the statement completes, then any OUT or INOUT parameters will get written back to the corresponding Holder objects.

An example of IN parameters using Holders:

```
java.sql.Statement stmt = conn.createStatement();
// We pass two parameters. One varies each time around
// the for loop, the other remains constant.
IntHolder ih = new IntHolder();
stmt.bindParameter(1, ih);
StringHolder sh = new StringHolder();
stmt.bindParameter(2, sh);
sh.value =“Hi”
for (int i = 0; i < 10; i++) {
      ih.value = i;
      stmt.executeUpdate(“UPDATE Table2 set a = ? WHERE b = ?”);
}
```

An example of OUT parameters using Holders:

```
java.sql.Statement stmt = conn.createStatement();
IntHolder ih = new IntHolder();
stmt.bindParameter(1, ih);
StringHolder sh = new StringHolder();
stmt.bindParameter(2, sh);
for (int i = 0; i < 10; i++) {
      stmt.executeUpdate("{CALL testProcedure(?, ?)}");
      byte x = ih.value;
      String s = sh.value;
}
```

A.1.2 Getting row results using Holder objects

Before executing a statement, we can allow the application programmers to bind Holder objects to particular columns. After the statement has executed, the application program can iterate over the ResultSet using ResultSet.next() to move to successive rows. As the application moves to each row, the Holder objects will be populated with the values in that row. This is similar to the SQLBindColumn mechanism used in ODBC.

Here's a simple example:

```
// We're going to execute a SQL statement that will return a
// collection of rows, with column 1 as an int, column 2 as
// a String, and column 3 as an array of bytes.
java.sql.Statement stmt = conn.createStatement();
IntHolder ih = new IntHolder();
stmt.bindHolder(1, ih);
StringHolder sh = new StringHolder();
stmt.bindHolder(2, sh);
BytesHolder bh = new BytesHolder();
stmt.bindHolder(3, bh);
ResultSet r = stmt.executeQuery("SELECT a, b, c FROM Table7");
while (r.next()) {
      // print the values for the current row.
      int i = ih.value;
      String s = sh.value;
      byte b[] = bh.value;
      System.out.println("ROW = " + i + " " + s + " " + b[0]);
}
```

A.2 Design Alternative: Don't use types such as fooHolder, instead use foo[]

At some point in the future we would probably like to add support for some form of column-wise binding, so that a bunch of rows can be read at once. When we were using the Holder design, we considered the following design alternative that would allow for column-wise binding.

Holder objects are capable of holding single instances of various Java types. However an array of a single element could instead be used as a holder. This approach has several disadvantages, but one major advantage.

The first disadvantage is that people may be confused if they read "foo f[] = new foo[1];". The corresponding holder declaration "fooHolder f = new fooHolder();" gives a better clue as to what f is and why we are allocating it.

The second disadvantage is that we would have to replace the single method Statement.bindColumn with a distinct method for each array type. This is because all our Holder types inherit from java.sql.Holder and can therefore be passed as arguments to a generic method that takes a java.sql.Holder argument. (On the other hand at least we avoid defining the dozen or so holder classes.)

The last disadvantage is that using foo[] only gives us the raw Java type information. By defining a specific set of holder types for use with SQL, we can define extra fields and/or semantics, e.g. for the CurrencyHolder type.

The corresponding major advantage is that if we use foo[1] as the container for a parameter then it is very natural to allow foo[x] as a way of binding multiple rows of a table in column-wise binding. This would let us add support for column-wise binding without having to remodel the interface.

If we use arrays instead of Holders, them the bindColumn mechanism makes it easier to scale up to column-wise binding.

A.3 Support for retrieving multiple rows at once

Currently we provide methods for retrieving individual columns within individual rows, a field at a time. We anticipate that drivers will normally prefetch rows in larger chunks so as to reduce the number of interactions with the target database. However, it might also be useful to allow programmers to retrieve data in larger chunks through the JDBC API.

The easiest mechanism to support in Java would probably be to support some form of column-wise binding where a programmer can specify a set of arrays to hold (say) the next 20 values in each of the columns, and then read all 20 rows at once.

However we do not propose to provide such a mechanism in the first version of JDBC. We do recommend that drivers should normally prefetch rows in suitable chunks.

A.4 Columns numbers in ResultSet.get methods

In an earlier version of the JDBC spec, the various “get” methods took no arguments, but merely returned the next column value in left-to-right order. We (re)introduced a column number argument because we were unsatisfied with the readability of the resulting example code. We frequently found ourselves having to count through the various “get” calls in order to match them up with the columns specified in the SELECT statement.

A.5 Method overloading for set methods

In an earlier version of the design we used method overloading so that rather than having methods with different names such as setByte, setBoolean, etc., all these methods were simply called setParameter, and were distinguished only by their different argument types. While this is a legal thing to do in Java, several reviewers commented that it was confusing and was likely to lead to error, particularly in cases where the mapping between SQL types and Java types is ambiguous. On reflection we agreed with them.

A.6 That wretched registerOutParameter method

We dislike the need for a registerOutParameter method. During the development of JDBC we made a determined attempt to avoid it and instead proposed that the drivers should use database metadata to determine the OUT parameter types. However reviewer input convinced us that for performance reasons it was more appropriate to require the use of registerOutParameter to specify OUT parameter types.

A.7 Support for large OUT parameters.

We don't currently support very large OUT parameters. If we were to provide a mechanism for very large OUT parameters, it would probably consist of allowing programmers to register java.io.OutputStreams into which the JDBC runtimes could send the OUT parameter's data when the statement executes. However, this seems to be harder to explain than it is worth, given that there is a already a mechanism for handling large results as part of ResultSet.

A.8 Support for GetObject versus getXXX

Because of the overlap between the various get/set methods and the generic getObject/setObject methods we looked at discarding our get/set methods and simply using getObject/setObject. However for the simple common cases where a programmer know the SQL types, the resulting casts and extracts are extremely tedious:

int i = ((Integer)r.getObject(1, java.sql.Types.INTEGER)).intValue()

We therefore decided to bend our minimalist principles a little in this case and retain the various get/set methods as the preferred interface for the majority of applications programmers, while also adding the getObject/setObject methods for tool builders and sophisticated applications

A.9 isNull versus wasNull

We had some difficulty in determining a good way of handling SQL NULLs. However by JDBC 0.50 we had designed a ResultSet.isNull method that seemed fairly pleasant to use. The isNull method could be called on any column to check for NULL before (or after) reading the column.

```
if (!ResultSet(isNull(3)) {
       count += ResultSet.getInt(3);
}
```

Unfortunately, harsh reality intervened and it emerged that "isNull" could not be implemented reliably on all databases. Some databases have no separate means for determining if a column is null other than reading the column and they would only permit a given column to be read once. We looked at reading the column value and "remembering" it for later use, but this caused problems when data conversions were required.

After examining a number of different solutions we reluctantly decided to replace the isNull method with the wasNull method. The wasNull method merely reports whether the last value read from the given ResultSet (or CallableStatement) was SQL NULL.

A.10 Use of Java type names v SQL type names.

In an earlier version of the spec we used getXXX and setXXX method for retrieving results and accessing parameters, where the XXX was a SQL type name. In revision 0.70 of JDBC we changed to use getXXX and setXXX methods where the XXX was a Java type name.

Thus for example, getChar was replaced by getString and setSmallInt by setShort.

The new methods have essentially the same semantics as the methods that they replace. However the use of Java type names makes the meaning of each of the methods clearer to Java programmers.

Appendix B: Example JDBC Programs

B.1 Using SELECT

```
import java.net.URL;
import java.sql.*;

class Select {

     public static void main(String argv[]) {
        try {
            // Create a URL specifying an ODBC data source name.
            String url = “jdbc:odbc:wombat”;

            // Connect to the database at that URL.
            Connection con = DriverManager.getConnection(url, “kgh”, ““);

            // Execute a SELECT statement
            Statement stmt = con.createStatement();
            ResultSet rs = stmt.executeQuery(“SELECT a, b, c, d, key FROM Table1”);

            // Step through the result rows.
            System.out.println(“Got results:”);
            while (rs.next()) {
                // get the values from the current row:
                int a = rs.getInt(1);
                BigDecimal b = rs.getBigDecimal(2);
                char c[] = rs.getString(3).tocharArray();
                boolean d = rs.getBoolean(4);
                String key = rs.getString(5);

                // Now print out the results:
                System.out.print(“  key=” + key);
                System.out.print(“  a=” + a);
                System.out.print(“  b=” + b);
                System.out.print(“  c=”);
                for (int i = 0; i < c.length; i++) {
                    System.out.print(c[i]);
                }
                System.out.print(“  d=” + d);
                System.out.print(“\n”);
            }

            stmt.close();
            con.close();
        } catch (java.lang.Exception ex) {
            ex.printStackTrace();
        }
     }
}
```

B.2 Using UPDATE

```
// Update a couple of rows in a database.

import java.net.URL;
import java.sql.*;

class Update {

    public static void main(String argv[]) {
        try {
            // Create a URL specifying an ODBC data source name.
            String url = “jdbc:odbc:wombat”;

            // Connect to the database at that URL.
            Connection con = DriverManager.getConnection(url, “kgh”, ““);

            // Create a prepared statement to update the “a” field of a
            // row in the “Table1” table.
            // The prepared statement takes two parameters.
            PreparedStatement stmt = con.prepareStatement(
                        “UPDATE Table1 SET a = ? WHERE key = ?”);

            // First use the prepared statement to update
            // the “count” row to 34.
            stmt.setInt(1, 34);
            stmt.setString(2, “count”);
            stmt.executeUpdate();
            System.out.println(“Updated \”count\” row OK.”);

            // Now use the same prepared statement to update the
            // “mirror” field.
            // We rebind parameter 2, but reuse the other parameter.
            stmt.setString(2, “mirror”);
            stmt.executeUpdate();
            System.out.println(“Updated \”mirror\” row OK.”);

            stmt.close();
            con.close();

        } catch (java.lang.Exception ex) {
            ex.printStackTrace();
        }
    }
}
```

Appendix C: Implementation notes

C.1 ResultSet lookups by method name

Here is some specimen code that implements the ResultSet.findColumn and (for example) ResultSet.getString using ResultSetMetaData.

```
private java.util.Hashtable s2c;     // Maps strings to column indexes
private ResultSetMetaData md;        // Our metadata object.

public synchronized int findColumn(String columnName)
                                           throws SQLException {
       // Make a mapping cache if we don't already have one.
       if (md == null) {
           md = getMetaData();
           s2c = new java.util.Hashtable();
       }
       // Look for the mapping in our cache.
       Integer x = (Integer)s2c.get(columnName);
       if (x != null) {
           return (x.intValue());
       }
       // OK, we'll have to use metadata.
       for (int i = 1; i < md.getColumnCount(); i++) {
           if (md.getColumnName(i).equalsIgnoreCase(columnName)) {
             // Success!  Add an entry to the cache.
             s2c.put(columnName, new Integer(i));
             return (i);
           }
       }
       throw new SQLException("Column name not found", "S0022");
}

// now the individual get-by-column-name methods are easy:

public String getString(String columnName) throws SQLException {
       return (getString(findColumn(columnName)));
}
```

C.2 Object finalization

Applets are advised to call “close” on the various JDBC objects such as Statement, ResultSet, Connection, when they are done with them. However, some applets will forget and some applets may get killed before they can close these objects.

If JDBC drivers have state associated with JDBC objects that needs to get explicitly cleared up, then they should take care to provide “finalize” methods. The garbage collector will call these finalize methods when the objects are found to be garbage, and this will give the driver a chance to close (or otherwise clean up) the objects. Note, however, that there is no guarantee that the garbage collector will ever run, so you can’t rely on the finalizers being called.

Appendix D: Change History

Changes between 0.50 and 0.60:

- Revised the description of transactions to remove references to the obsolete beginTransaction method (9.3).
- Fixed various minor spelling errors, miscapitalizations, and inconsistencies in method names, particularly in the DatabaseMetaData interface.
- Added methods to SQLWarning for managing chains.
- Specified that metadata methods should throw exceptions rather than returning null ResultSets if you try to retrieve catalog information that isn't available. (See comment at the head of DatabaseMetaData.java).
- Moved various historical notes from the main text to Appendix A.
- Added Statement.executeUpdate and modified Statement.execute. Broadly speaking, the execute method is intended for dynamic programming whereas executeQuery and executeUpdate are intended for simple statement execution.
- Rewrote Section 5.3 to clarify security requirements for JDBC driver implementors.
- Added DriverManager.println for logging to the JDBC log stream.
- Removed DriverManager.loadDriver and modified Section 6.6 to advise that you use Class.forName to load drivers (this reflects Java classloader implementation issues.)
- Clarifications in Section 11 but no interface changes.
- Removed ParameterMetadata. The contents were a subset of the information returned by DatabaseMetaData.getProcedureColumns and the latter interface is much more complete.
- Renamed Environment to DriverManager. This name better reflects the final functionality of this class.
- Stated that JDBC will do space padding for CHAR(n) fields (Section 8.3).
- Added section 7.4 to describe data truncation rules.
- Removed ResultSet.getRowNumber. This is easy for application to do themselves.
- Changed constant values for transaction isolation levels to be the same as ODBC.
- Removed ResultSet.getRowCount. Several reviewers had expressed concern that this was prohibitively expensive to implement.
- Removed ResultSet.getColumnCount. This method is unnecessary as there is already a ResultSetMetaData.getColumnCount method and programmers requiring to know the number of columns are also likely to require other column metadata.
- By popular demand added additional ResultSet methods to retrieve values by column name.
- Made ResultSet an abstract class (rather than an interface) so we could provide default implementations of the methods that take column names. (Note: we are nervous about the implications of this and are still reviewing this decision.)
- Added Statement.setCursorName
- Added Java "doc comment" stylized comments to many of the API descriptions.

Changes between 0.60 and 0.70

- Added separate ResultSet warning chain (and access methods) in addition to the Statement warning chain.
- Clarified the behaviour of getAscciStream and getUnicodeStream on ResultSets.
- Clarified the behaviour of setAsciiStream and setUnicodeStream on PreparedStatements.
- Stated explicitly that LONGVARCHAR and LONGVARBINARY are not supported for stored procedure OUT parameters (see 7.3.3 and 14.2).
- Removed getLongVarChar and getLongVarBinary from CallableStatement.
- Changed ResultSet back to an interface (rather than an abstract class). We now provide an specimen implementation of ResultSet.findColumn as reference material in Appendix C.
- Replaced ResultSet.isNull with ResultSet.wasNull. We prefer the isNull style, but early JDBC implementors discovered that it was impossible to implement isNull reliably on some databases for some data types. Unfortunately on these databases it is necessary to first attempt a read and then to check if the read returned null.
- Similarly replaced CallableStatement.isNull with CallableStatement.wasNull.
- Added Driver.jdbcCompliant to report if driver is fully JDBC COMPLIANT (tm).
- Added specification of jdbc:odbc sub-protocol URL syntax (6.3.6).
- Added LIKE escape characters (11.4).
- Added Driver.acceptURL and DriverManager.getDriver
- Stated that auto-close only applied to PreparedStatements, CallableStatements, and ResultSets and doesn't affect simple Statements (9.3).
- Added Driver.getPropertyInfo method and DriverPropertyInfo class to allow generic GUI applications to discover what connection properties a driver expects.
- Removed the SQLWarning type NullData. The wasNull method can be used to check if null data has been read.
- Clarified that ResultSet warnings are cleared on each call to "next".
- Clarified that Statement warnings are cleared each time a statement is (re)executed.
- Replaced all methods of the format getXXX or setXXX with analogous methods whose names are based on the Java type returned rather than the SQL type. Thus, for example, getTinyInt becomes getByte. See Section 7 and also Appendix A.10. This is a fairly substantial change which we made because of reviewer input that showed widespread confusion over the use of SQL types in the method names, and a widely stated preference for Java type names.
- Added additional getObject/setObject methods and extra explanatory text (14.2).
- Added sections to clarify when data conversions are and are not performed (7.1.1, 7.2.1, and 7.3.1).
- Added extra tables to clarify Java to SQL type mappings (Tables 3 and 5).

Changes between 0.70 and 0.95

- Changed the default mapping for SQL FLOAT to be Java double or Double (Tables 1, 2, 4).
- Changed the default mapping for Java float and Float to be SQL REAL (Tables 3, 5).
- Clarified that network protocol security is not a JDBC issue (Section 5).
- Renamed SQL Escape section, explaining extensions and clarifying relationship to SQL levels defined by ANSI and Microsoft's ODBC.
- Added sentence clarifying positioned updates (Section 10).
- Removed old Section 7.1 "Parameters and results in ODBC" and various other comparisons with ODBC. While this was useful for early reviewers, it's not terribly useful in the finished spec.
- Clarified that all JDBC compliant drivers must support CallableStatement but need not support the methods relating to OUT parameters (3.2, 12.1).
- Replaced disableAutoClose with setAutoClose
- Added Connection.getAutoClose and Connection.getAutoCommit
- Added Table 6 to document conversions in PreparedStatement.setObject.
- Removed the versions of ResultSet.getObject and CallableStatement.getObject that took a target SQL type. (We still retain the simpler getObject methods.) These methods were hard to implement and hard to explain and there appeared to be no real demand for them.
- Added advice on finalizers in Appendix C.2.

Changes between 0.95 and 1.00

- Clarified that when retrieving ResultSet column values by column name then the first matching column will be returned in cases where there are several columns with the same name.
- Clarified that if you pass a Java null to one of the PreparedSattement.setXXX methods then this will cause a SQL NULL to be sent to the database.
- Added an extra column SQL_DATA_TYPE to the DatabaseMetaData.getColumns results.
- Removed the transaction isolation level TRANSCTION_VERSIONING
- Noted that if a stored procedure returns both ResultSets and OUT parameters then the ResultSets must be read and processed before the OUT parameters are read (7.3).
- Noted that for maximum portability the columns of a ResultSet should be retrieved in left-to-right order (7.1).
- Reworded some of the introduction that was written before we first released the spec.

Changes between 1.00 and 1.01 - all of the changes are clarificationsand errata; no actual changes to the specification have been made. Most of the clarifications only affect the API documentation.

- Removed getBinary for CHAR types from ResultSet conversion table. These were simply in error.

- Noted that the precision used for setXXX and setObject is a maximum precision value chosen by the driver.
- The description of the various SQL identifier case sensitivity and case storage modes were clarified and the JDBC driver requirements were adjusted.
- Added a note that JDBC java.io.stream.available() may return 0 whether or note data is available. JDBC drivers may not be able to provide an accurate count of available data.
- Statement.getMoreResults termination conditions were not documented correctly. This was corrected.
- Noted that Statement.executeUpdate implicitly closes the statement's current result set.
- The Driver comments were changed to note that a static section should create an instance and register it. This was a documentation error.
- Fixed parameters for getCrossReference. They were documented in error.
- Noted that a SQLException should be thrown if the driver does not support a DatabaseMetaData method.
- Noted that executeQuery never returns a null ResultSet ref
- Clarified the semantics of auto commit for the case of statements that return results.
- Removed ColumnName from the getTablePrivileges ResultSet; this was added in error.
- Noted that CallableStatement ResultSets and update counts should be processed prior to getting output parameter values.

The following changes have been made to JDBC 1.10. All of these changes are minor clarifications or additions. Unfortunately, although the removal of auto close and the java.sql.Numeric name change are minor they are not backward compatible. In particular, the name change requires that drivers must be updated to work with JDBC 1.1.

- Revised isolation level description
- Revised getTablePrivileges description to note that a privilege applies to one or more columns of the table.
- Revised preserve across commit/rollback metadata to specify positive case while allowing negative case result in partial preservation.
- Added NO ACTION and SET DEFAULT values for getImportedKeys, getExportedKeys and getCrossReference ON DELETE and ON UPDATE
- Added DEFERRABILITY attribute to getImportedKeys, getExportedKeys and getCrossReference
- Removed the auto close facility
- Rename java.sql.Numeric to java.lang.Bignum
- Note that for maximum portability values less than 256 should not be used for setMaxFieldSize
- Changed initialization of SQLState to null from "" to agree with initialization of reason.
- Clarify definition of Date, Time and Timestamp
- Added private constructor to DriverManager and Types to prevent instantiation.
- Added millis constructor for Date, Time and Timestamp

- Clarified default values for the SQLException, SQLWarning, DriverPropertyInfo and DataTruncation constructors.

The following changes were made to JDBC 1.2:

- The java.lang.Bignum class was replaced by the java.math.BigDecimal class. All Bignum parameters were changed to BigDecimal; all operation names that included the term Bignum were changed to use BigDecimal.
- The driver property name was incorrect. The correct name is ‘jdbc.drivers’; it was incorrectly noted as ‘sql.drivers’.