EMBEDDED SYSTEMS PROGRAMMING 2015-16

SQLite

DATA STORAGE: ANDROID

- Shared Preferences
- Filesystem: internal storage
- Filesystem: external storage
- SQLite ⟵ (Also available in iOS and WP)
- Network (Google Drive & more)

SQLITE

- **Software library that implements a lightweitght SQL database engine**
- No dependencies from external libraries
- One source file (“amalgamation”), one binary file
- Code is mature, extensively checked and portable
- License: completely open

SQLITE: LICENSE

```
The author disclaims copyright
to this source code.

In place of a legal notice,
here is a blessing:


    May you do good and not evil.

    May you find forgiveness
    for yourself and forgive others.

    May you share freely,
    never taking more than you give.
```

SQLITE: FEATURES

- SQLite implements nearly all the features mandated by the SQL-92 standard
- Foreign key support is present since version 3.6.19
- For more info on unimplemented features, look up
  - https://www.sqlite.org/omitted.html
  - https://www.sqlite.org/foreignkeys.html#fk_unsupported

IMPORTANT

- Regardless of the chosen platform, regardless of the fact that you are embracing SQLite or not, what you really need to work with an SQL database is
  - an understanding of the **fundamental concepts behind relational databases,**
  - a good knowledge of the **SQL language**

SQL EPITOME (1/6)

- An SQL database is a relational database made by one or more **tables**.
- A table is made up of **columns** and **rows**.
  Each row represents a record.
  Each column represents data associated with records
- Constraints may be specified concerning data in a table or relations between tables

SQL EPITOME (2/6)

- Defining an (empty) table `addressbook` with three columns: unique identifier, name, phone number

```
create table addressbook
(
        _id    integer primary key,
        name   text,
        phone  text
);
```

SQL EPITOME (3/6)

- Inserting a row (i.e., a record) into the table

```
insert into addressbook
values
(
    736,
    'John Doe',
    '555-1212'
);
```

SQL EPITOME (4/6)

- Updating a row (i.e., a record) inside the table

```
update table addressbook
set phone='555-1424'
where _id=736;
```

SQL EPITOME (5/6)

- Deleting a row (i.e., a record) from the table

```
delete from addressbook
where _id=736;
```

- Deleting multiple rows

```
delete from addressbook
where name like "%doe%";
```

SQL EPITOME (6/6)

- Querying, i.e. selecting a subset of rows and colums satisfying a given property

```
select name, phone
from mytable
where
    _id > 100
    and
    name like "%doe%"
order by name;
```

- The query may involve multiple tables (inner join, outer join...)

SQLITE: CORE APIS (1/4)

- `int sqlite3_open(char *filename, sqlite3 **ppDb)`
  Opens a connection to the SQLite database identified by `filename`.
  Returns a database connection entity `ppDb`.
  Like all SQLite3 APIs, returns an integer error code

- `int sqlite3_close(sqlite3 *pDB)`
  closes a database connection previously opened by a call to `sqlite3_open()`

SQLITE: CORE APIS (2/4)

- **`int sqlite3_prepare_v2(sqlite3 *pDB, char *sqlStatement, int nByte, sqlite3_stmt **ppStmt, char **pzTail)`**
  Converts the SQL statement `sqlStatement` into a prepared statement object.
  Returns a pointer `ppStmt` to the prepared object

- **`int sqlite3_finalize(sqlite3_stmt *pStmt)`**
  Destroys a prepared statement.
  Every prepared statement must be destroyed with this routine in order to avoid memory leaks

- **`int sqlite3_step(sqlite3_stmt *pStmt)`**
  Evaluates a prepared statement up to the point where the first row of the result is available

SQLITE: CORE APIS (3/4)

- `int sqlite3_column_count(sqlite3_stmt *pStmt)`
  Gives the number of columns in the result set returned by the prepared statement

- `int sqlite3_column_type(sqlite3_stmt *pStmt, int iCol)`
  Returns the datatype code for the initial data type of the result column `iCol`.
  The returned value is one of `SQLITE_INTEGER`, `SQLITE_FLOAT`, `SQLITE_TEXT`, `SQLITE_BLOB`, or `SQLITE_NULL`

- `int sqlite3_column_int(sqlite3_stmt *pStmt, int iCol)`,
  `double sqlite3_column_double(sqlite3_stmt*, int iCol)`,
  `...`
  Family of functions that return information about a single column

SQLITE: CORE APIS (4/4)

- `int sqlite3_exec(sqlite3 *pDB, const char *sqlString, int (*callback)(void*,int,char**,char**), void *, char **errmsg)`

  Convenience wrapper for `sqlite3_prepare_v2()`, `sqlite3_step()`, and `sqlite3_finalize()`.

  Runs the SQL statements contained in `sqlString`.

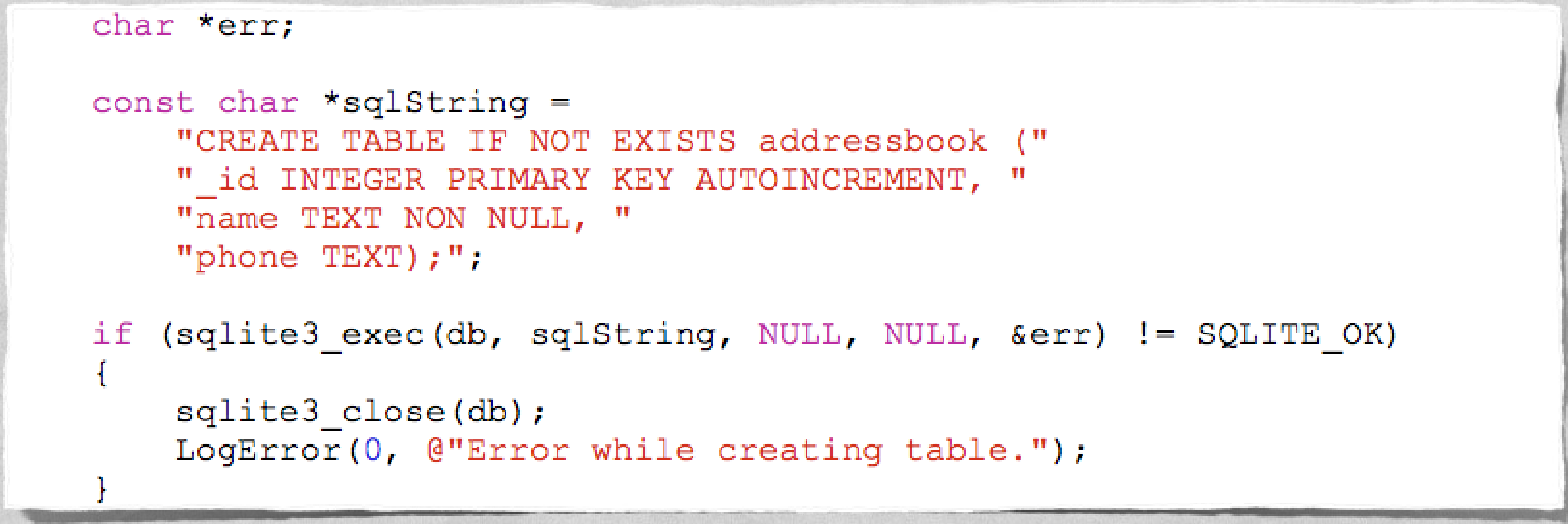
  If the callback function of the 3rd argument to `sqlite3_exec()` is not `NULL`, then it is invoked for each result row coming out of the evaluated SQL statements

SQLITE: ERROR CODES

`SQLITE_OK`	Successful result
`SQLITE_ERROR`	SQL error or missing database
`SQLITE_INTERNAL`	Internal logic error in SQLite
`SQLITE_PERM`	Access permission denied
`SQLITE_ABORT`	Callback routine requested an abort
`SQLITE_BUSY`	The database file is locked
`SQLITE_LOCKED`	A table in the database is locked
`SQLITE_NOMEM`	A `malloc()` failed
`SQLITE_READONLY`	Attempt to write a readonly database
`SQLITE_INTERRUPT`	Operation terminated by `sqlite3_interrupt()`
`SQLITE_IOERR`	Some kind of disk I/O error occurred
`SQLITE_CORRUPT`	The database disk image is malformed
`SQLITE_NOTFOUND`	Unknown opcode in `sqlite3_file_control()`
`SQLITE_FULL`	Insertion failed because database is full
`SQLITE_CANTOPEN`	Unable to open the database file
`SQLITE_PROTOCOL`	Database lock protocol error
`SQLITE_EMPTY`	Database is empty
`SQLITE_SCHEMA`	The database schema changed
`SQLITE_TOOBIG`	String or BLOB exceeds size limit
`SQLITE_CONSTRAINT`	Abort due to constraint violation
`SQLITE_MISMATCH`	Data type mismatch
`SQLITE_MISUSE`	Library used incorrectly
`SQLITE_NOLFS`	Uses OS features not supported on host
`SQLITE_AUTH`	Authorization denied
`SQLITE_FORMAT`	Auxiliary database format error
`SQLITE_RANGE`	2nd parameter to `sqlite3_bind` out of range
`SQLITE_NOTADB`	File opened that is not a database file
`SQLITE_ROW`	`sqlite3_step()` has another row ready
`SQLITE_DONE`	`sqlite3_step()` has finished executing

CORE SQLITE: EXAMPLES (1/3)

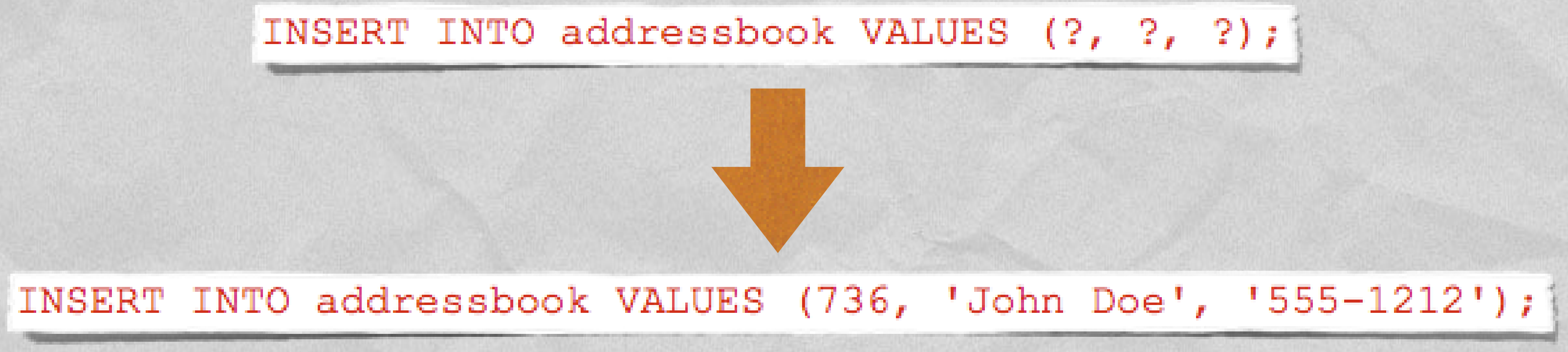
- Creating a table



```
char *err;

const char *sqlString =
    "CREATE TABLE IF NOT EXISTS addressbook ("
    "_id INTEGER PRIMARY KEY AUTOINCREMENT, "
    "name TEXT NON NULL, "
    "phone TEXT);";

if (sqlite3_exec(db, sqlString, NULL, NULL, &err) != SQLITE_OK)
{
    sqlite3_close(db);
    LogError(0, @"Error while creating table.");
}
```

BIND VARIABLES

- SQLite can accept a string where parameters are identified by templates (like a question mark "?") and replace the templates with the real names of the parameters



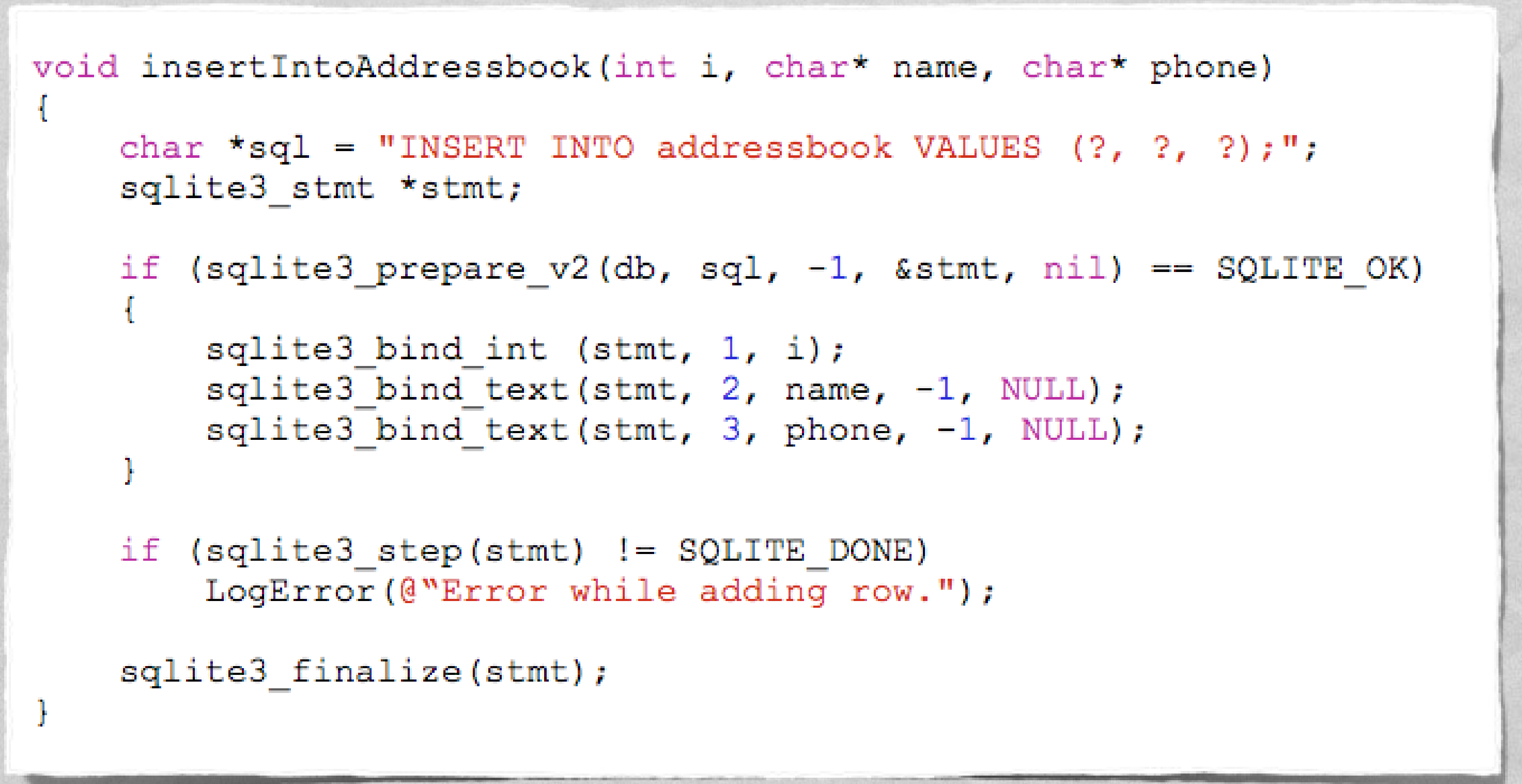
```
INSERT INTO addressbook VALUES (?, ?, ?);
```

```
INSERT INTO addressbook VALUES (736, 'John Doe', '555-1212');
```

- Use the [`sqlite_bind_XXX()`]() family of functions

CORE SQLITE: EXAMPLES (2/3)

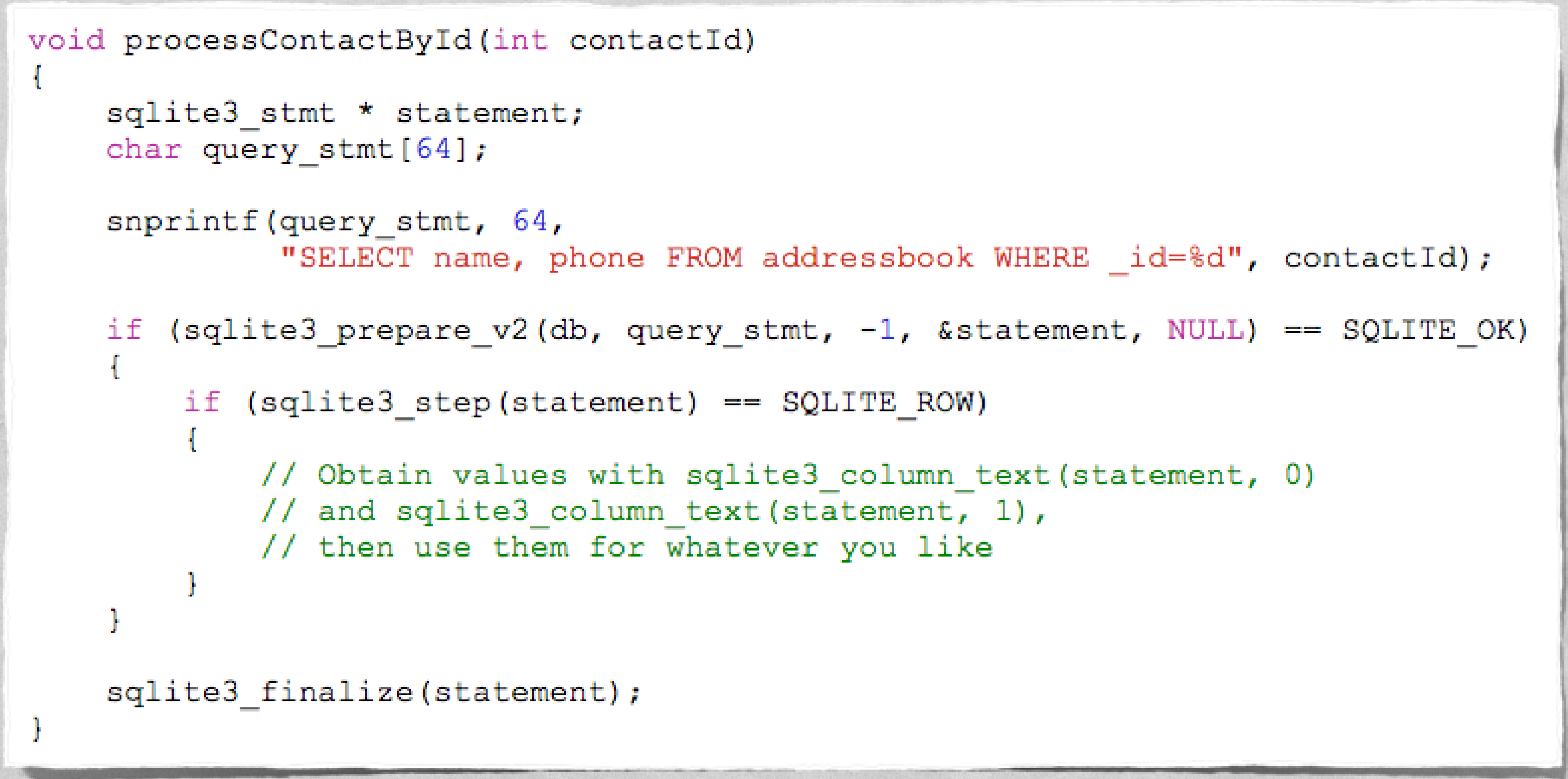
- Adding a row to a table



```
void insertIntoAddressbook(int i, char* name, char* phone)
{
    char *sql = "INSERT INTO addressbook VALUES (?, ?, ?);";
    sqlite3_stmt *stmt;

    if (sqlite3_prepare_v2(db, sql, -1, &stmt, nil) == SQLITE_OK)
    {
        sqlite3_bind_int (stmt, 1, i);
        sqlite3_bind_text(stmt, 2, name, -1, NULL);
        sqlite3_bind_text(stmt, 3, phone, -1, NULL);
    }

    if (sqlite3_step(stmt) != SQLITE_DONE)
        LogError(@"Error while adding row.");

    sqlite3_finalize(stmt);
}
```

CORE SQLITE: EXAMPLES (3/3)

- Performing a query



```c
void processContactById(int contactId)
{
    sqlite3_stmt * statement;
    char query_stmt[64];

    snprintf(query_stmt, 64,
             "SELECT name, phone FROM addressbook WHERE _id=%d", contactId);

    if (sqlite3_prepare_v2(db, query_stmt, -1, &statement, NULL) == SQLITE_OK)
    {
        if (sqlite3_step(statement) == SQLITE_ROW)
        {
            // Obtain values with sqlite3_column_text(statement, 0)
            // and sqlite3_column_text(statement, 1),
            // then use them for whatever you like
        }
    }

    sqlite3_finalize(statement);
}
```

SQLITE: ANDROID

- Android supports SQLite well
- The SQLite version depends on the Android release and on the choices of the device vendor.
  Android 2.2 and 2.3 usually ship with SQLite 3.6.22.
  Android 4.0+ usually ships with SQLite 3.7.x
- Java Package: **`android.database.sqlite`**
- Tool: **`sqlite3`**

ANDROID.DATABASE.SQLITE

- Provides SQLite DB management classes
- Most important classes:
  - `SQLiteDatabase`
  - `SQLiteOpenHelper`
  - `SQLiteStatement`
  - `SQLiteQueryBuilder`, `SQLiteCursor`

SQLITEDATABASE (1/2)

Offers methods to perform common DB management tasks on the database associated with a class instance

- **`SQLiteDatabase openDatabase(String path, SQLiteDatabase.CursorFactory factory, int flags)`**
  Opens a database according to `flags`
- **`void close()`**
  Closes a database

SQLITEDATABASE (2/2)

- **`void execSQL(String sql)`**
  Executes a single SQL statement that is neither a SELECT nor any other SQL statement that returns data

- There are also convenience methods named **`insert`**, **`delete`**, **`replace`**, **`update`**, ... to ease the execution of the corresponding SQL commands

- **`Cursor rawQuery(String sql, String[] selectionArgs)`**
  Runs the provided SQL statement returning data, and returns a `Cursor` over the result set

CURSOR

Provides random access to the result set returned by a DB query

- `int GetCount()`
  Returns the number of rows in the cursor

- `boolean moveToFirst()`, `moveToLast()`, `moveToNext()`, `moveToPrevious()`, `moveToPosition(int position)`
  Moves the cursor to the specified row

- `int getType(int columnIndex)` (Android 3.0+)
  Returns the data type of the given column's value

- `getString(int columnIndex)`, `getInt(int columnIndex)`, `getFloat(int columnIndex)`, ...
  Returns the value for the given column in the current row

SQLITEOPENHELPER (1/2)

- Helper class that wraps an `SQLiteDatabase`, providing support for DB creation and management
- Two methods:
  - **`onCreate`**,
  - **`onUpgrade`**,

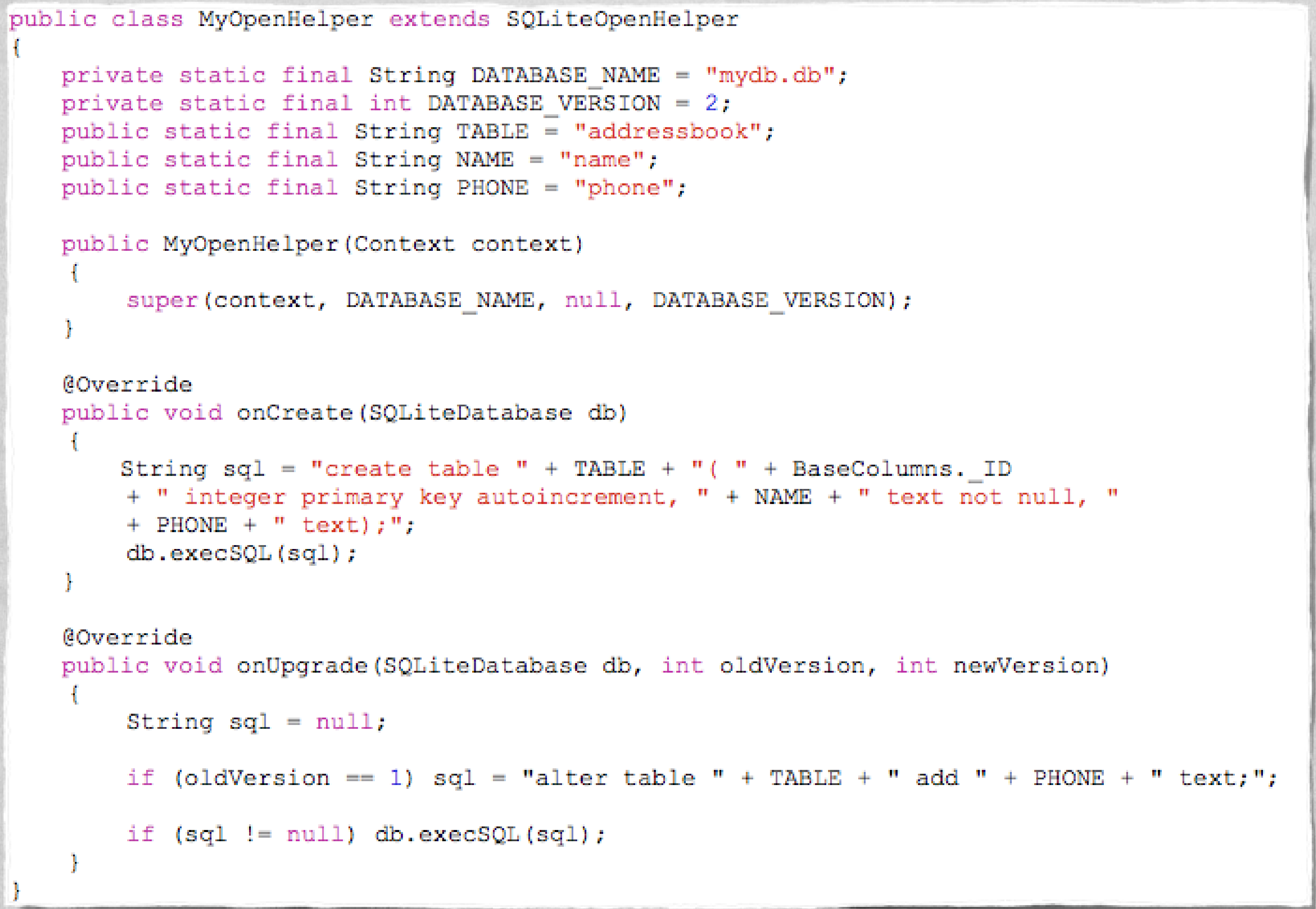
which are `abstract` because their implementation is tailored to the specific database

SQLITEOPENHELPER (1/2)

- `abstract void onCreate(SQLiteDatabase db)`
  Called when the database is created for the first time.
  The implementation should use this method to create tables and relations between tables

- `abstract void onUpgrade(SQLiteDatabase db, int oldVersion, int newVersion)`
  Called when the database schema needs to be upgraded (e.g., because a new version of the application has been installed).
  The implementation should use this method to drop/add tables, or do anything else it needs to upgrade to the new schema version

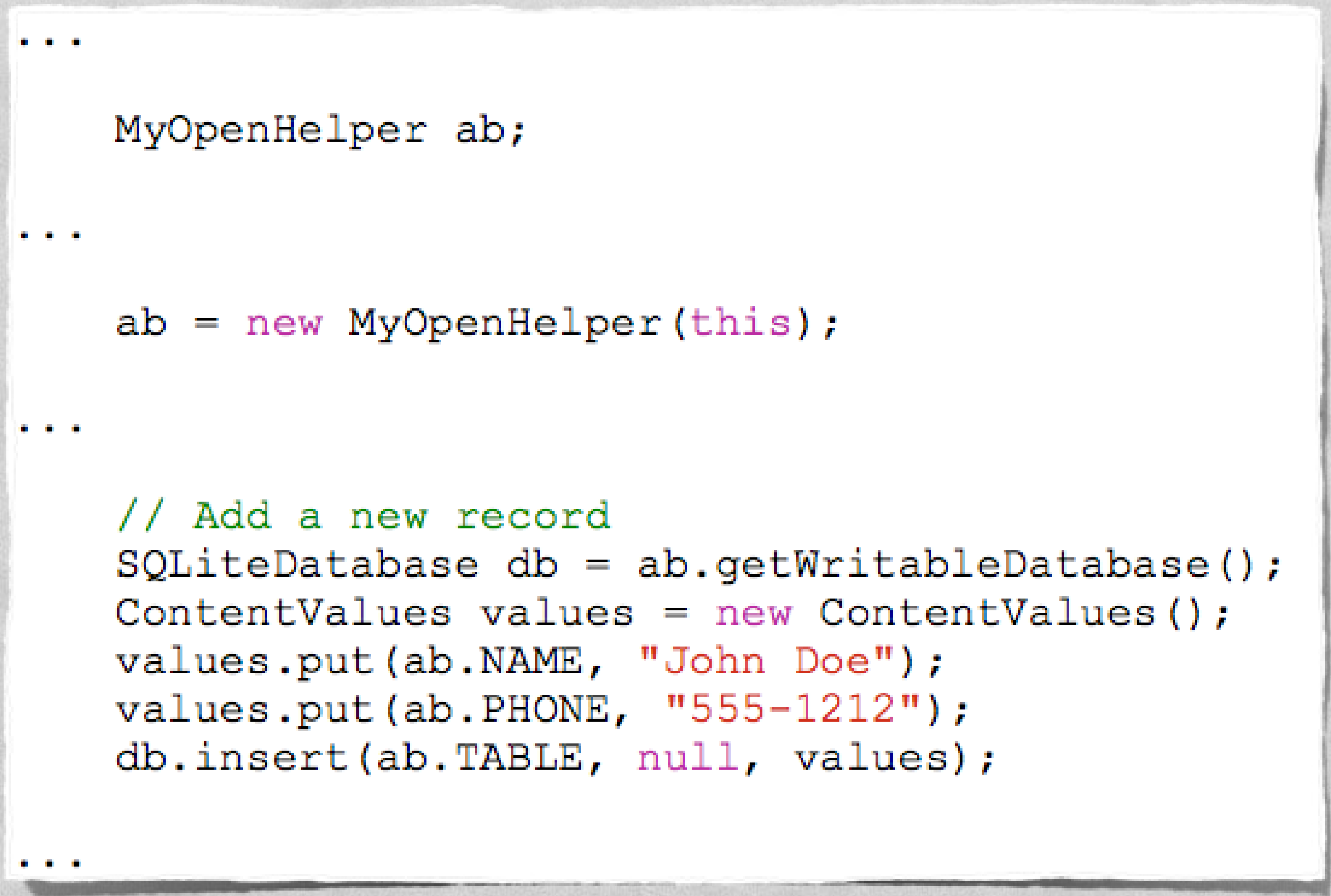
EXAMPLE (1/2)



```java
public class MyOpenHelper extends SQLiteOpenHelper
{
    private static final String DATABASE_NAME = "mydb.db";
    private static final int DATABASE_VERSION = 2;
    public static final String TABLE = "addressbook";
    public static final String NAME = "name";
    public static final String PHONE = "phone";

    public MyOpenHelper(Context context)
     {
         super(context, DATABASE_NAME, null, DATABASE_VERSION);
    }

    @Override
    public void onCreate(SQLiteDatabase db)
     {
        String sql = "create table " + TABLE + "( " + BaseColumns._ID
         + " integer primary key autoincrement, " + NAME + " text not null, "
         + PHONE + " text);";
         db.execSQL(sql);
    }

    @Override
    public void onUpgrade(SQLiteDatabase db, int oldVersion, int newVersion)
     {
         String sql = null;

         if (oldVersion == 1) sql = "alter table " + TABLE + " add " + PHONE + " text;";

         if (sql != null) db.execSQL(sql);
     }
}
```

EXAMPLE (2/2)

- Somewhere in an activity
  an instance of `MyOpenHelper` is allocated and used



```
...

    MyOpenHelper ab;

...

    ab = new MyOpenHelper(this);

...

    // Add a new record
    SQLiteDatabase db = ab.getWritableDatabase();
    ContentValues values = new ContentValues();
    values.put(ab.NAME, "John Doe");
    values.put(ab.PHONE, "555-1212");
    db.insert(ab.TABLE, null, values);

...
```

SQLITESTATEMENT

- Encapsulates a pre-compiled statement that is intended for reuse
- The statement must be compiled with the `SQLiteDatabase` method `compileStatement(String)`
- The statement works only with the database it has been compiled for

SQLITEQUERYBUILDER, SQLITECURSOR

- **SQLiteQueryBuilder** class
  Helps build SQL queries for `SQLiteDatabase` objects. The key method of this class is

```
String buildQuery(String[] projectionIn, String selection,
                  String groupBy, String having, String sortOrder,
                  String limit)
```

- **SQLiteCursor** class
  Encapsulate results from a query. The SQL statement for the query and the name of the `SQLiteDatabase` are passed as parameters to the constructor

SQLITE3

- Command-line program.
  Can be invoked from an adb remote shell
- Gives you the ability to execute SQLite statements on a database and includes some useful extra commands
- Note: database files for package `<x>` are stored under `/data/data/<x>/databases/`
- Not installed on several devices