http://www.android.com/

Data storage overview

SQLite databases

Data storage overview

- Assets (assets) and Resources (res/raw)
  - Private data installed with the application (**read-only**)
  - Use the **android.content.res.xxx** classes/methods (Resources and AssetManager) or the asset uri: "file:///android_asset/*** for access
- Shared Preferences
  - Private primitive application data in key-value pairs
- Internal storage
  - Private data on the device memory (files)
- External storage
  - Public data on the shared external storage (files). Apps can only write to files and folders that they have created or have taken ownership of
- SQLite Databases
  - Structured data in a private databases
- Network Connection
  - Data on the web; read write to server (e.g. a DB)
- When app is uninstalled or ”resetted” all private data is removed

Databases

- Organize, store, and retrieve (large amounts of) structured data
- SQL (Structured Query Language)
- S(Search)CRUD
  - Create databases (including tables etc.)
  - Allow data creation and maintenance
  - Search for data and other access
- DBMS (DataBase Management Systems)
  - **Atomicity** - modifications must follow an "all or nothing" rule
  - **Consistency** - only valid data will be written to the database
  - **Isolation** - operations cannot access data that has been modified during a transaction that has not yet completed
  - **Durability** - once the user has been notified of a transaction's success the transaction will not be lost

Operation	SQL	HTTP
Create	INSERT	POST
Read (Retrieve)	SELECT	GET
Update (Modify)	UPDATE	PUT / PATCH
Delete (Destroy)	DELETE	DELETE

SQLite

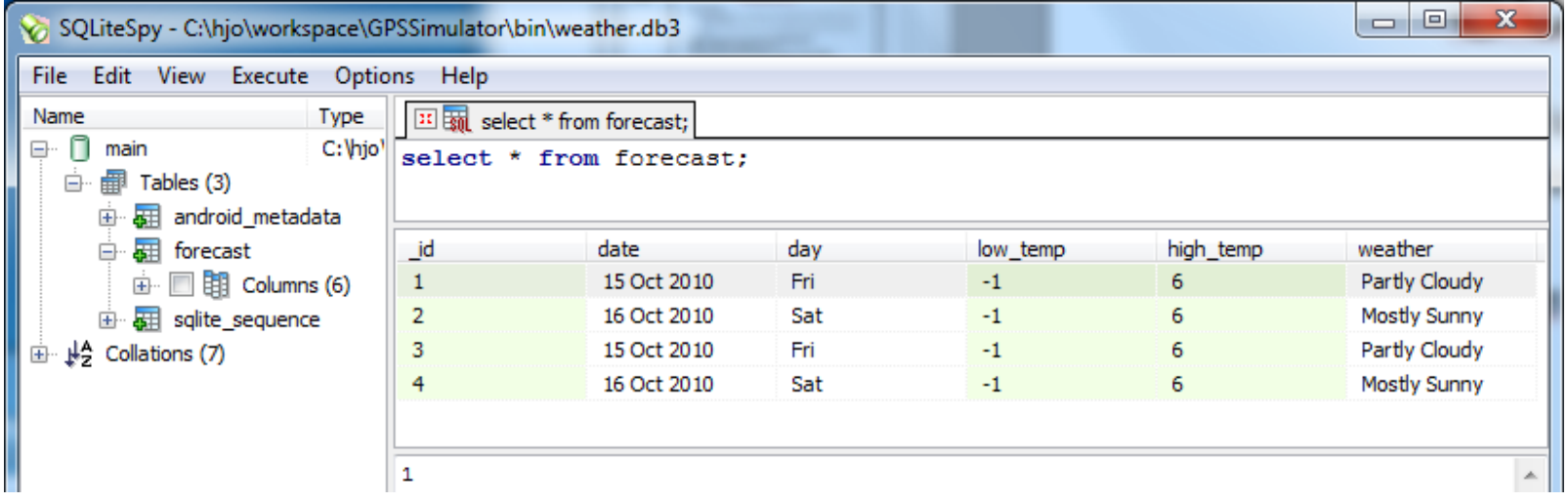
- SQLite is a software library that implements a self-contained, serverless, zero-configuration, transactional SQL database engine. Some benefits are:
  - Lightweight, reliable, standards compliant, open-source, ...
  - http://www.sqlite.org/
- A SQLite database is an integrated part of the application that created it
  - Reducing external dependencies
  - Simplifies transaction locking and synchronization
- SQLite is the most widely deployed SQL database engine in the world
  - It is almost easier to mention products that NOT use SQLite than list products that use SQLite!
  - Chrome, Firefox, all mobile OSs except Windows phone, ...
  - Embedded systems in all kinds of industry, aeroplanes, …

SQLite Databases 1

- For more complex data structures, a database provides a quicker and more flexible access method than flat files or shared preferences
- SQLite provides full relational database capability utilizing SQL commands
- Each application that uses SQLite has its own instance of the database, which by default is only accessible from the application itself
  - Apps signed with the same key may share the database
  - A **Content Provider** can be used to share the database information between other applications
- The database is stored in the **/data/data/<package_name>/databases** folder of an Android device

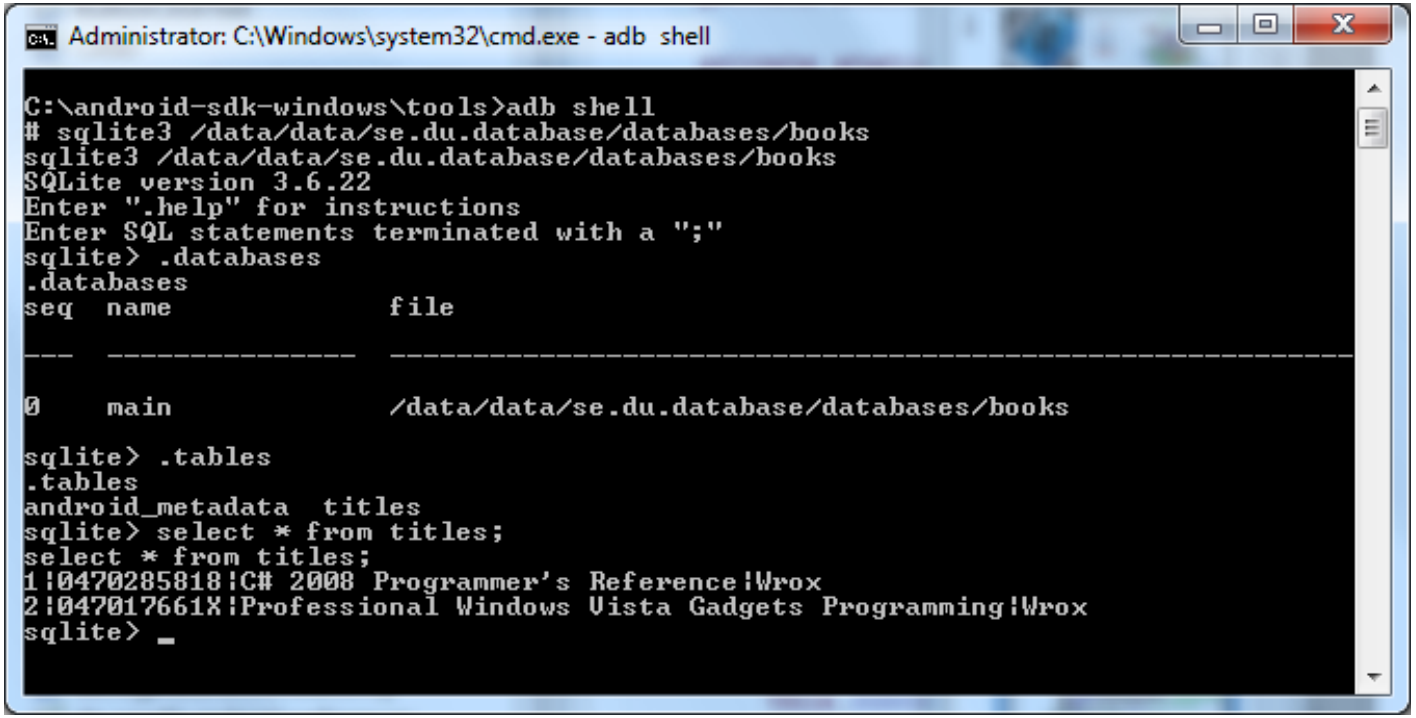
SQLite Databases 2

- Many native Android apps use SQLite DBs
  - Messaging (SMS, MMS), People (contacts), MediaStore, etc.
- Simple file based relation database
  - Not recommended to store BLOBs (Binary Large Objects) as bitmaps, media, etc. Store only the Uri to BLOBs in DB!
- adb push <local file> <phone file> or adb pull <phone file> <local file>
  - Open on desktop computer with tools as Database 4 .NET, SQLiteSpy, SQLite Database Browser, etc.



SQLite Databases 3

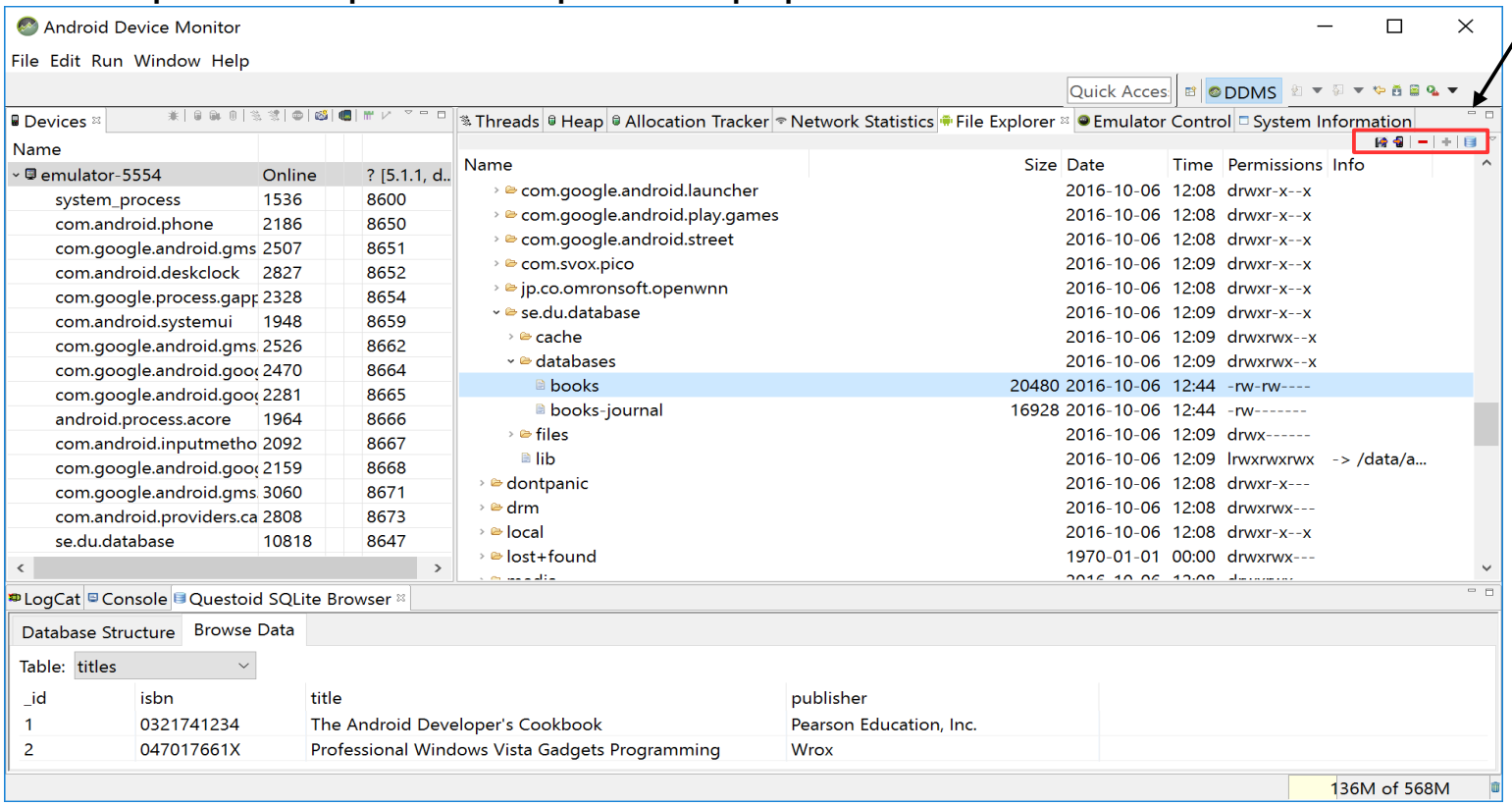
- When developing it is convenient to log in via ADB and query the database
- To get a shell in the emulator or phone: adb shell [-s (emu serial nr)] To get the serial#: adb devices
  - Open DB with: sqlite3 <path to DB>/db-name
  - Issue commands as: .databases, .tables, .help, SQL, ...



SQLite Databases 4

- Or use a browse plugin as com.questoid.sqlitebrowser_1.2.0.jar
  - http://instinctcoder.com/how-to-browse-android-studio-emulator-sqlite-database/
- More advanced full access plugins are available with direct connection over USB or the network as DbAndroid
  - http://wiki.sqlitestudio.pl/index.php/DbAndroid

Storage control



Open or create a database

- Executing some SQL statements (functionbased)

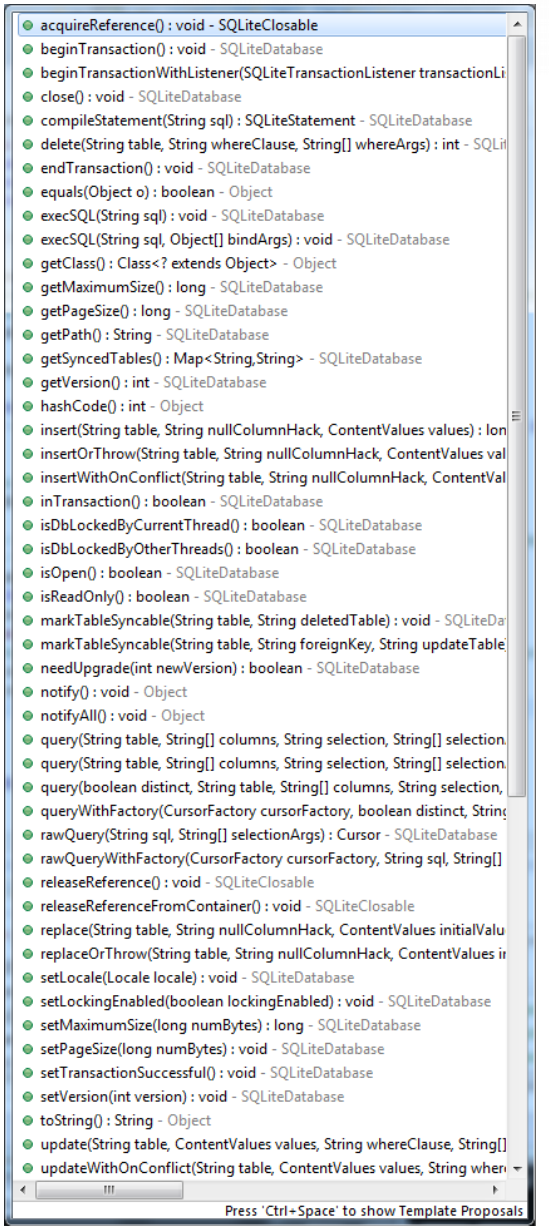
```
// Open a new private SQLiteDatabase associated with this Context's
// application package. Create the database file if it doesn't exist.
// SQLiteDatabase openOrCreateDatabase (String name, int mode,
//    SQLiteDatabase.CursorFactory factory)
SQLiteDatabase db = mContext.openOrCreateDatabase(
          "books.db",
          Context.MODE_PRIVATE,
          null);

// The language codes are two-letter lowercase ISO language codes
// (such as "en") as defined by ISO 639-1.
db.setLocale(Locale.getDefault());

// Sets the database version.
db.setVersion(1);

// Convenience methods for inserting, updating and deleteing
// rows in the database.
int num_rows_affected = db.insert(table, nullColumnHack, values);
num_rows_affected = db.update(table, values, whereClause, whereArgs);
num_rows_affected = db.delete(table, whereClause, whereArgs);

// Query the given table, returning a Cursor over the result set.
// The Cursor object is a reference to the data
Cursor cur = db.query(table, columns, selection, selectionArgs,
     groupBy, having, orderBy);
cur = db.query(distinct, table, columns, selection, selectionArgs,
     groupBy, having, orderBy, limit);
```



SQL Querys → function

- query(String table, String[] columns, String selection, String[] selectionArgs, String groupBy, String having, String orderBy)
- SELECT _id, word, definition FROM table_words
- Translates into

```
db.query("table_word",
   new String[] {"_id",
      "word", "definition"},
   null, null, null, null, null
);
```

Example DB, execSQL()

- DatabaseTest example app - A database with book titles
  - A modified DatabaseActivity and DBAdapter class which in turn contains a static DatabaseHelper class which extends the SQLiteOpenHelper class
  - http://www.devx.com/wireless/Article/40842/1954

_id	isbn	title	publisher

- **execSQL()** can execute a single SQL statement that is **NOT** a SELECT or any other SQL statement that does not return any data
- For complex queries returning a cursor - use SQLiteQueryBuilder.query()

```
// Execute a single SQL statement that is NOT a SELECT or any other SQL statement that returns data.
db.execSQL("DROP TABLE IF EXISTS books");

String word = "alpha", definition = "aplpha is...";
String ins = "INSERT INTO table_word (word, definition) VALUES('" + word + "','" + definition + "')";
db.execSQL(ins);
String upd = "UPDATE table_word set word = '" + word + "', definition = '" + definition + "' WHERE _id = " + row;
db.execSQL(upd);

// This is a convience class that helps build SQL queries to be sent to SQLiteDatabase objects.
SQLiteQueryBuilder qBuilder = new SQLiteQueryBuilder();
qBuilder.setTables("example et JOIN secondtable st ON et.id = st.example_id");
qBuilder.appendWhere(" et.someRow = ? ");
Cursor cursor = qBuilder.query(sqlitedatabase, projection, selection, selectionArgs, null, null, sortOrder);
startManagingCursor(cursor);
```

Create a table and delete a row

- The **Activity.startManagingCursor(cursor)** on previous slide allows the activity to take care of managing the given Cursor's lifecycle based on the activity's lifecycle - it requires that the row key id is named "_id".
- startManagingCursor(cursor) is deprecated since API 11. Use the new CursorLoader class with LoaderManager instead! It will manage the cursor in a similar way.

```
private static final String DATABASE_CREATE =
    "create table titles (_id integer primary key autoincrement, "
    + "isbn text not null, title text not null, "
    + "publisher text not null);";

public void CreateDB(SQLiteDatabase db) {
      try {
            db.execSQL(DATABASE_CREATE);
      }
      catch(SQLiteException ex) {
            Log.e("Create table exception", ex.getMessage());
      }
}

// deletes a particular row in a db - delete(table, whereClause, whereArgs);
public int deleteRow(SQLiteDatabase db, long rowId) {
      int ret = -1;
      try{
            ret = db.delete("titles", "_id" + "=" + rowId, null);
      }
      catch(SQLiteException ex) {
            Log.e("deleteRow exception caught", ex.getMessage());
      }
// delete() returns the number of rows affected if a whereClause is passed in, 0 otherwise.
      return ret;
}
```

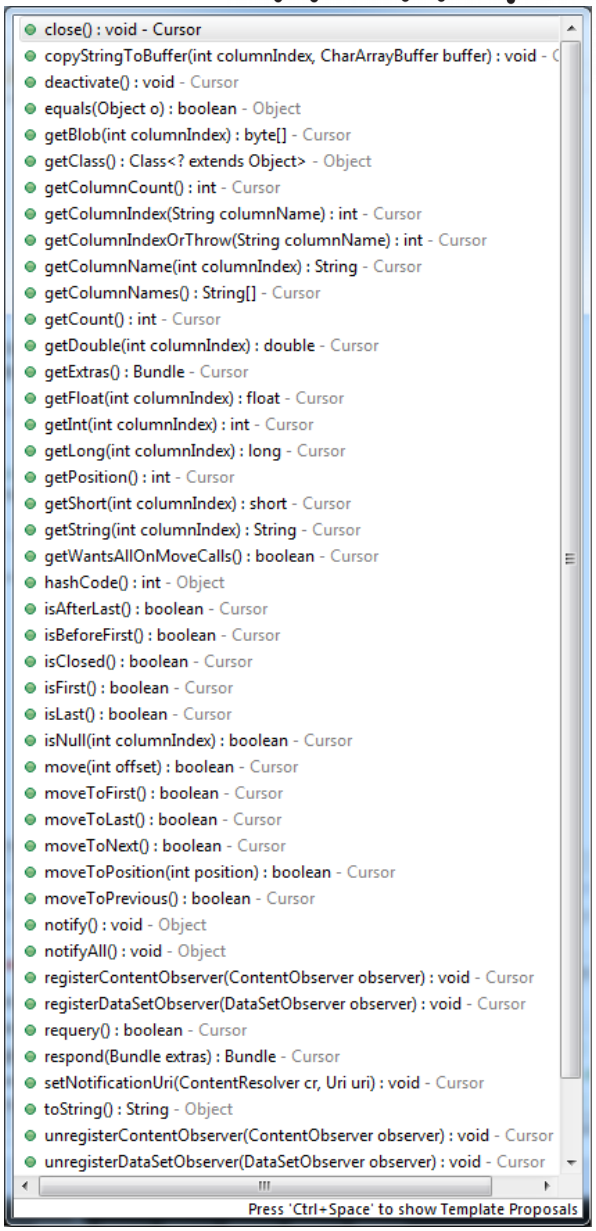
Insert and update

- Use **ContentValues** to provide column names and column values

```
// insert a book title into the database, returns row id, -1 if error - insert(table, nullColumnHack, values);
public long insertTitle(SQLiteDatabase db, String isbn, String title, String publisher) {
      long ret = -1;
      ContentValues initialValues = new ContentValues();
      initialValues.put("isbn", isbn);
      initialValues.put("title", title);
      initialValues.put("publisher", publisher);
      try{
            ret = db.insert("titles", null, initialValues);
      }
      catch(SQLiteException ex) {
            Log.e("insertTitle exception caught", ex.getMessage());
      }
      return ret; // insert() returns the row id or -1
}
// updates a book title - update(table, values, whereClause, whereArgs);
public int updateTitle(SQLiteDatabase db, long rowId, String isbn, String title, String publisher) {
      int ret = -1;
      ContentValues args = new ContentValues();
      args.put("isbn", isbn);
      args.put("title", title);
      args.put("publisher", publisher);
      try{
            ret = db.update("titles", args, "_id" + "=" + rowId, null);
      }
      catch(SQLiteException ex) {
            Log.e("updateTitle exception caught", ex.getMessage());
      }
      return ret; // update() returns the number of rows updated
}
```

Query and Cursor 1

- Query results are accessed using a Cursor, allowing random access to the query result
- Common used Cursor methods
  - **Move**ToFirst()/...ToNext()/...ToPrevious() /...ToPosition(), ... **get**Count()/...ColumnName()/...ColumnNames() /...Position(), ...
- For longer cursor tasks – manage the cursor as part of the application lifecycle
  - onPause() - deactivate cursor (deprecated API 16)
  - onResume() - requery cursor (deprecated API 11)
  - OnDestroy() - close cursor
- CursorLoader class and LoaderManager
  - An asyncronous framework which offloads the UI thread and simplifies your cursor management
  - Manage the Loader in the Activity/Fragment lifecycle methods and special loader callback methods



Query and Cursor 2

```
public void iterateAllTitles()
{
      mDBA.open();
      Cursor c = mDBA.getAllTitles();
      Toast.makeText(this, "iterateAllTitles()", Toast.LENGTH_SHORT).show();

      if(c.moveToFirst()){
          do{
              DisplayTitle(c);
          }while (c.moveToNext());
      }
     mTV.setText(mstTextView);
     mDBA.close();
}

// retrieves a cursor to all the titles
// (rows in the database)
public Cursor getAllTitles()
{
      Cursor c = null;
      try{
// public Cursor query (String table, String[] columns, String selection,
// String[] selectionArgs, String groupBy, String having, String orderBy)
         c = mDB.query("titles", new String[] {
                  "_id", "isbn", "title", "publisher"},
                null, null, null, null, null);
      }
      catch(SQLiteException ex) {
            Log.d("getAllTitles exception caught", ex.getMessage());
      }
      return c;
}
```

```
// display the columns (0, 1, 2, 3)
// from where the row cursor is at
public void DisplayTitle(Cursor c)
{
   String row = "id: " + c.getString(0) + "\n" +
      "ISBN: " + c.getString(1) + "\n" +
      "TITLE: " + c.getString(2) + "\n" +
      "PUBLISHER:  " + c.getString(3) + "\n";

   mstTextView += row + "\n";
}
```

SimpleCursorAdapter

- An easy adapter to map columns from a cursor to TextViews or ImageViews defined in an XML file – Note: Runs on the UI thread!
- You can specify which columns you want, which views you want to display the columns, and the XML file that defines the appearance of these views
- **You should use a Loader instead (Loader examples in next presentation)**
  - https://developer.android.com/guide/components/loaders.html

SimpleCursorAdapter example

```
// full example: http://www.vogella.com/articles/AndroidListView/article.html#cursor
public class MyListActivity extends ListActivity {
   @Override
   public void onCreate(Bundle savedInstanceState) {
      super.onCreate(savedInstanceState);
      Cursor mCursor = getContacts(); // returns a cursor to the queried contacts DB in the phone
      startManagingCursor(mCursor); // deprecated since API 11
      int flags = 0;
      // Now create a new list adapter bound to the cursor.
      // ListAdapter is designed for binding to a Cursor.
      ListAdapter adapter = new SimpleCursorAdapter(this, // Context.
            android.R.layout.two_line_list_item, // Specify the row template to use (here, two
                                                 // columns bound to the two retrieved cursor rows).
            mCursor, // Pass in the cursor to bind to.
            // Array of cursor columns to bind to.
            new String[] { ContactsContract.Contacts._ID, ContactsContract.Contacts.DISPLAY_NAME },
            // Parallel array of which template objects to bind to those columns.
            new int[] { android.R.id.text1, android.R.id.text2 }, flags);
      // Bind to our new adapter.
      setListAdapter(adapter);
   }
```

Transactions

- Handle multiple operations that should happen all together, or not at all
- setTransactionSuccessful() plus endTransaction() commits the changes
- endTransaction() without setTransactionSuccessful() causes a roll back on all changes

```
// Begins a transaction in EXCLUSIVE mode.
db.beginTransaction();

try {
      // insert/delete/update records
      // Marks the current transaction as successful.
      db.setTransactionSuccessful();
}
catch(SQLiteException ex) {
      Log.d("Transaction exception", ex.getMessage());
}
finally {
      // End a transaction.
      db.endTransaction();
}
```

SQLiteOpenHelper

- Create a subclass implementing **onCreate**(SQLiteDatabase), **onUpgrade**(SQLiteDatabase, int, int) and optionally **onOpen**(SQLiteDatabase), and this class takes care of opening the database if it exists, creating it if it does not, and upgrading it as necessary.
- Transactions are used to make sure the database is always in a sensible state.
- This class makes it easy for ContentProvider implementations to delay opening and upgrading the database until first use, to avoid blocking application startup with long-running database upgrades.

```
private static class DatabaseHelper extends SQLiteOpenHelper {
    DatabaseHelper(Context context, String name, CursorFactory factory, int version) {
        super(context, name, factory, version);
    }
    @Override
    public void onCreate(SQLiteDatabase db) {
      try {
            db.execSQL(DATABASE_CREATE);
      }
      catch(SQLiteException ex) {
            Log.d("Create table exception", ex.getMessage());
      }
    }
    @Override
    public void onUpgrade(SQLiteDatabase db, int oldVersion, int newVersion) {
        Log.w(Consts.TAG, "Upgrading database from version " + oldVersion
                + " to " + newVersion + ", which will destroy all old data");
        db.execSQL("DROP TABLE IF EXISTS " + Consts.DATABASE_TABLE);
        onCreate(db);
    }
}
```

(Android) Databases, design considerations

- Use (extend from) SQLiteOpenHelper to manage database creation and version management
- Write an “adapter class”, with (strongly typed) methods, hiding the database manipulation, and constants representing keys
  - Example DbAdapter.java in the books Database test example app
- Model rows as class instances
- SQLite does not enforce foreign key constraints – use triggers instead (via execSQL), trigger == attached stored pocedure
  - http://www.sqlteam.com/article/an-introduction-to-triggers-part-i
- Don’t store large files (media etc.) in the database
- Data type integrity and referential integrity is not maintained in SQLite
- Full Unicode support (UTF-16) is optional, UTF-8 is used by default
- http://www.codeproject.com/Articles/119293/Using-SQLite-Database-with-Android

Example database 1

- It's good practice to create a DB adapter class to encapsulate all the complexities of accessing the database so it's transparent to the calling code

```
// From: http://www.devx.com/wireless/Article/40842
private static final String DATABASE_CREATE = "create table titles (_id integer primary key autoincrement, "
    + "isbn text not null, title text not null, publisher text not null);";
private final Context mContext;
private DatabaseHelper mDBHelper;
private SQLiteDatabase mDB;
// SQLiteDatabase has methods to create, delete, execute SQL commands and perform other common database management tasks
public DBAdapter(Context ctx)
{
    this.mContext = ctx;
    mDBHelper = new DatabaseHelper(mContext, DATABASE_NAME, null, DATABASE_VERSION);
}
// Within the DBAdapter class, we extend the DataBaseHelper with the SQLiteOpenHelper class –
// an Android helper class for database creation and versioning management.
// In particular, we override the onCreate() and onUpgrade() methods.
private static class DatabaseHelper extends SQLiteOpenHelper
{
    DatabaseHelper(Context context, String name, CursorFactory factory, int version) {
        super(context, name, factory, version);
    }
    @Override
    public void onCreate(SQLiteDatabase db) {
        db.execSQL(DATABASE_CREATE); //in this string we have our SQL create table statement
    }
    @Override
    public void onUpgrade(SQLiteDatabase db, int oldVersion, int newVersion) {
        Log.w(TAG, "Upgrading database from version " + oldVersion
                + " to " + newVersion + ", which will destroy all old data");
        db.execSQL("DROP TABLE IF EXISTS " + DATABASE_TABLE);
        onCreate(db);
    }
}
```

Example database 2

- Some usage examples from DatabaseActivity and DBAdepter

```
public class DatabaseActivity extends Activity {
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        mDBA = new DBAdapter(this);
     }
...
mDBA.open();
mDBA.insertTitle("0470285818", "C# 2008 Programmer's Reference", "Wrox");

--------------------------------------------------------------------------------
public class DBAdapter {
private DatabaseHelper mDBHelper;
// SQLiteDatabase has methods to create, delete, execute SQL commands and perform other common database management tasks
private SQLiteDatabase mDB;

//---opens the database---
public DBAdapter open() throws SQLiteException {
     return mDB = mDBHelper.getWritableDatabase();
}
//---insert a title into the database, returns row id, -1 if error---
public long insertTitle(String isbn, String title, String publisher) {
    ContentValues initialValues = new ContentValues();
    initialValues.put(KEY_ISBN, isbn);
    initialValues.put(KEY_TITLE, title);
    initialValues.put(KEY_PUBLISHER, publisher);
    return mDB.insert(DATABASE_TABLE, null, initialValues);
}
```

Example database 3

- Some more usage examples from the DatabaseActivity using the DBAdepter class

```
public class DatabaseActivity extends Activity {
...
//---get a cursor for a title and put it in a string---
Cursor c = mDBA.getTitle(id);
// display the columns (0, 1, 2, 3) from where the row cursor is at
String row = "id: " + c.getString(0) + "\n" + "ISBN: " + c.getString(1) + "\n" +
     "TITLE: " + c.getString(2) + "\n" + "PUBLISHER:  " + c.getString(3) + "\n";
mDBA.deleteTitle(id);

-------------------------------------------------------------------------------------
public class DBAdapter {
//---retrieves a cursor for a particular title---
//public Cursor query (boolean distinct, String table, String[] columns, String selection,
//String[] selectionArgs, String groupBy, String having, String orderBy, String limit)
public Cursor getTitle(long rowId)
{
     return mDB.query(true, DATABASE_TABLE, new String[] {
               KEY_ROWID, KEY_ISBN, KEY_TITLE, KEY_PUBLISHER },
               KEY_ROWID + "=" + rowId, null, null, null, null, null);
     }
}
//---deletes a particular title---
public boolean deleteTitle(long rowId) {
     return = mDB.delete(DATABASE_TABLE, KEY_ROWID + "=" + rowId, null) > 0;
}
```