CMPS 312

Data Layer

Dr. Abdelkarim Erradi

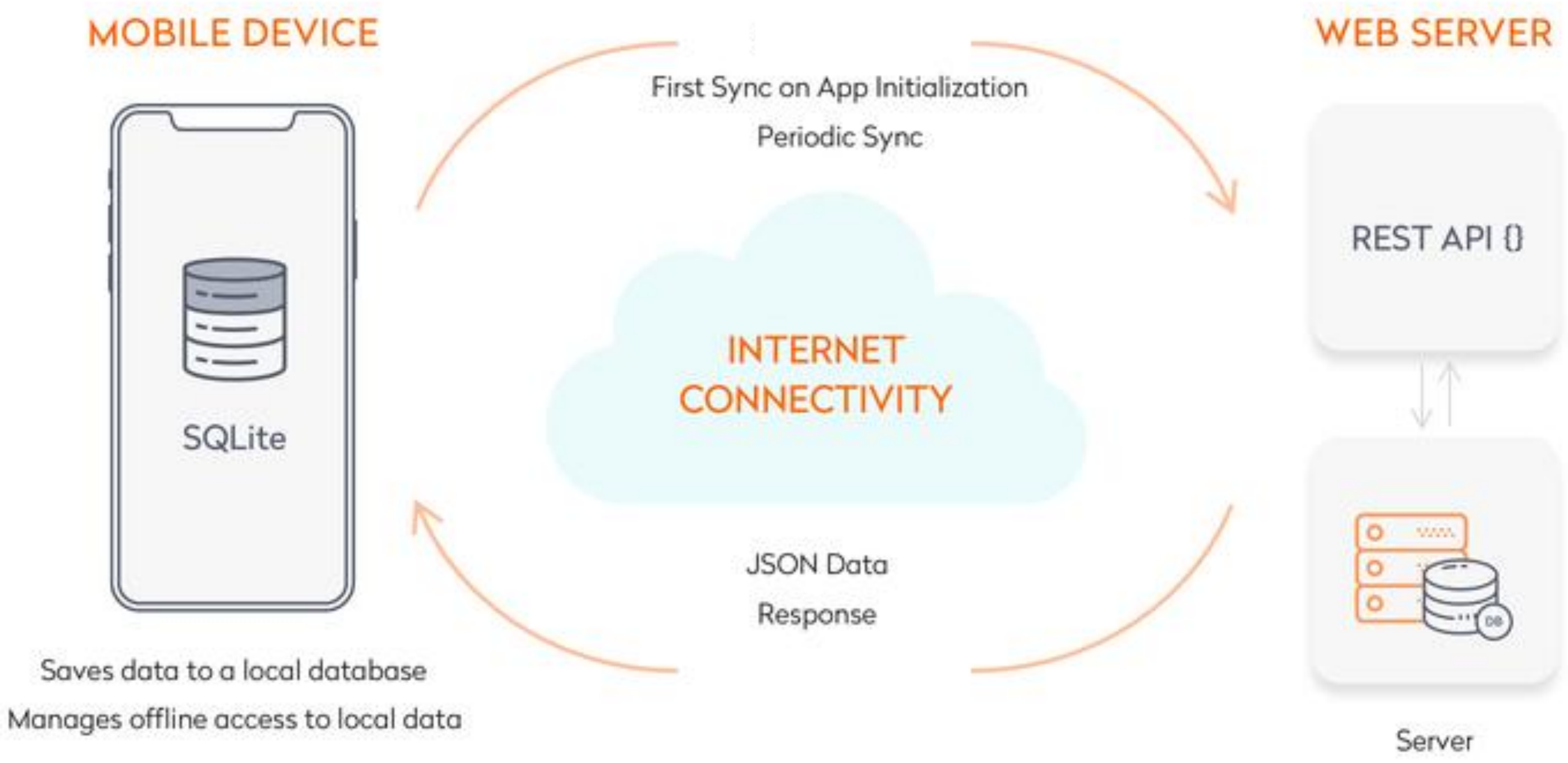
CSE@QU

Outline

1. Data persistence options for Mobile Apps
2. Floor package programming model
3. Type Converters
4. One-to-many relationships
5. Observable Queries using Streams

Data persistence options for Mobile Apps

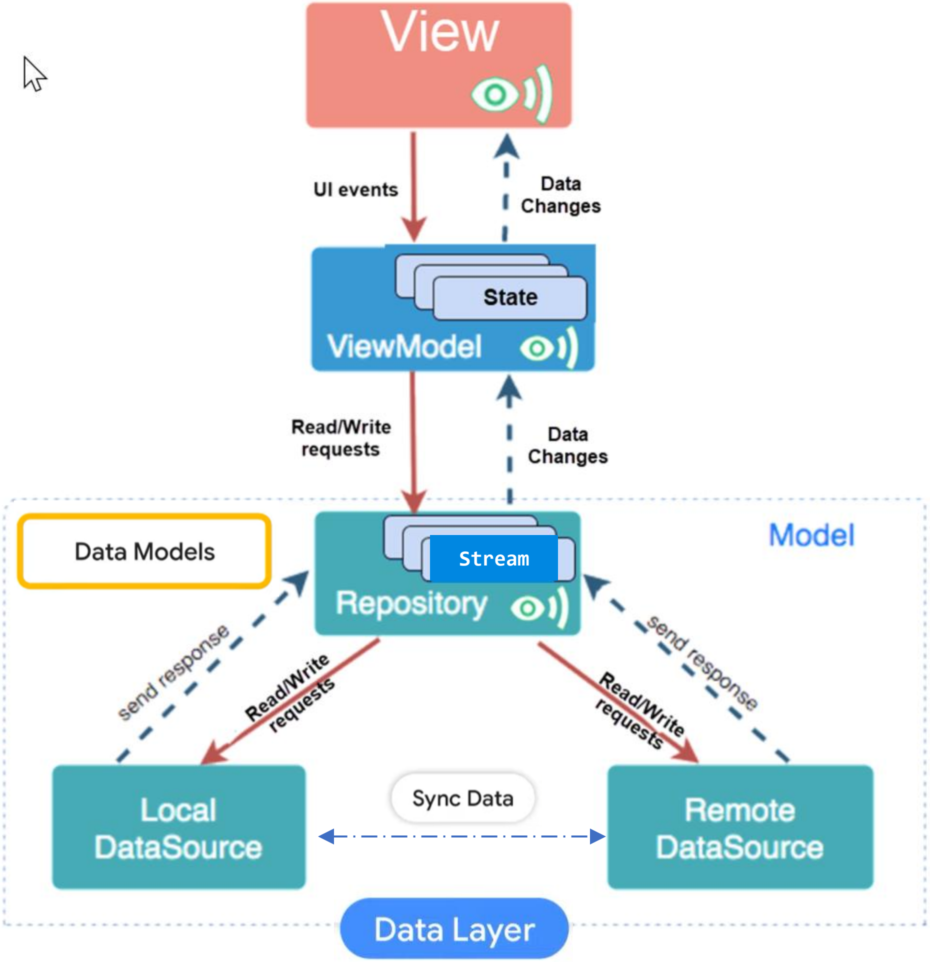
Offline app with Sync



- **Cache** relevant pieces of data on the device. App continues to work offline when a network connection is not available.
- When the network connection is back, the app's repository **syncs** the data with the server.

MVVM Data Layer

- The Data Layer manages the app data:
  - implements read/write operations
  - notifies the ViewModel of data changes
- It includes data models, data sources and repositories:
  - Data models define the entities that holds the app data (i.e., in-memory representations of the data)
  - A data source is responsible for reading and writing data to a single source such as a database or a network service.
  - The repository exposes, updates, and synchronizes data using a local datasource and/or a remote datasource + implements data-related logic

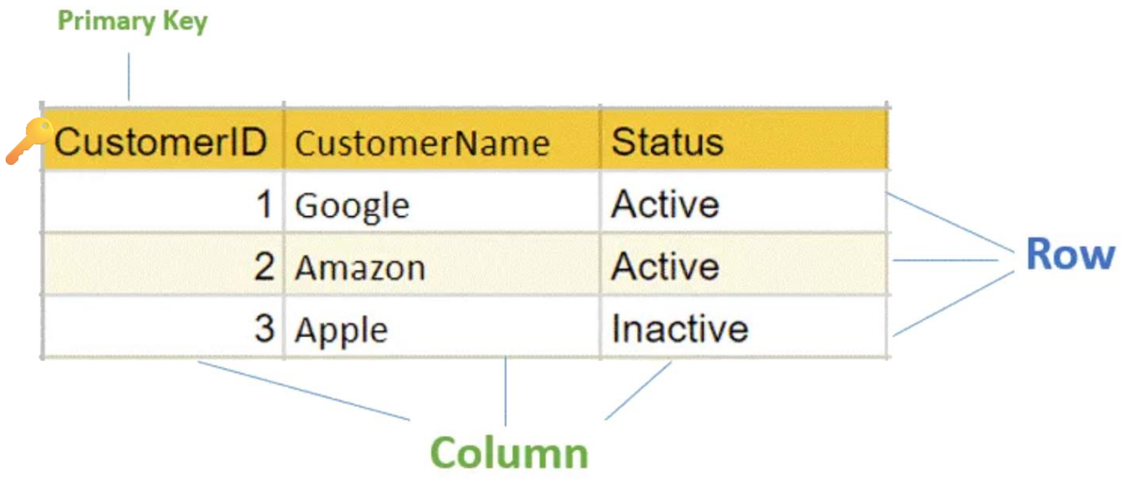


Data Storage Options on Android

- **Preferences DataStore**
  - Lightweight mechanism to store and retrieve key-value pairs
  - Typically used to store application settings (e.g., app theme, language), store user details after login
- **Files**
  - Store unstructured data such as text, photos or videos, on the device or removable storage
- SQLite **database**
  - Store structured data (e.g., posts, events) in tables
- **Cloud Data Stores**
  - e.g., Cloud Firestore

Relational Database

- Database allows **persisting structured data**
- A **relational** database organizes data into **tables**
  - A table has rows and columns
  - Tables can have relationships between them
- Tables could be queries and altered using SQL



CustomerID	CustomerName	Status
1	Google	Active
2	Amazon	Active
3	Apple	Inactive

SQL Statements

- Structured Query Language (**SQL**)
  - Language used to define, query and alter database tables
  - SQL is a language for interacting with a relational database
- **C**reating data:

```
INSERT into User (firstName, lastName)
  VALUES ("Ahmed", "Sayed")
```

- **R**eading data:

```
SELECT * FROM User WHERE id = 2
```

- **U**pdating data:

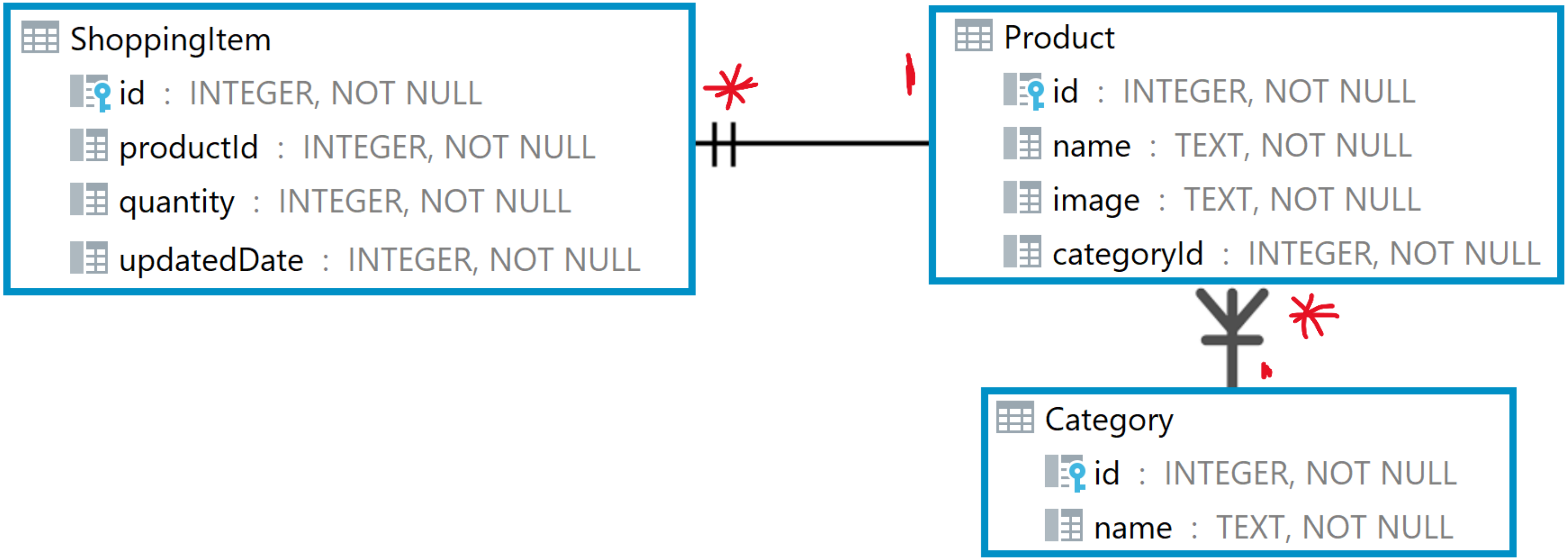
```
UPDATE User SET firstName = "Ali" where id = 2
```

- **D**eleting data:

```
DELETE from User where id = 2
```

Database Schema of Shopping List App

- The Entity Relationship (ER) diagram of the Shopping List App database
  - A ShoppingItem has an associated Product
  - Product has a Category
  - Category has many products



ShoppingItem
- id : INTEGER, NOT NULL
- productId : INTEGER, NOT NULL
- quantity : INTEGER, NOT NULL
- updatedDate : INTEGER, NOT NULL

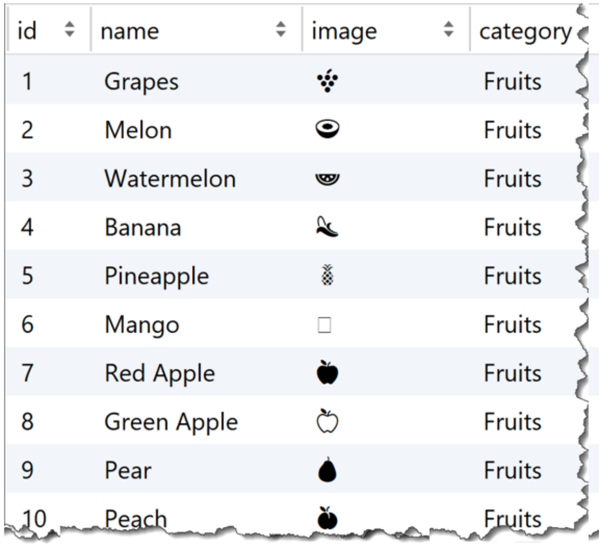
Product
- id : INTEGER, NOT NULL
- name : TEXT, NOT NULL
- image : TEXT, NOT NULL
- categoryId : INTEGER, NOT NULL

Category
- id : INTEGER, NOT NULL
- name : TEXT, NOT NULL

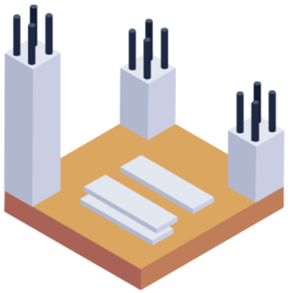
Querying Multiple Tables with Joins

- Combine rows from multiple tables by matching common columns
  - For example, return rows that combine data from the **Product** and **Category** tables by matching the **Product.categoryId** foreign key to the **Category.id** primary key

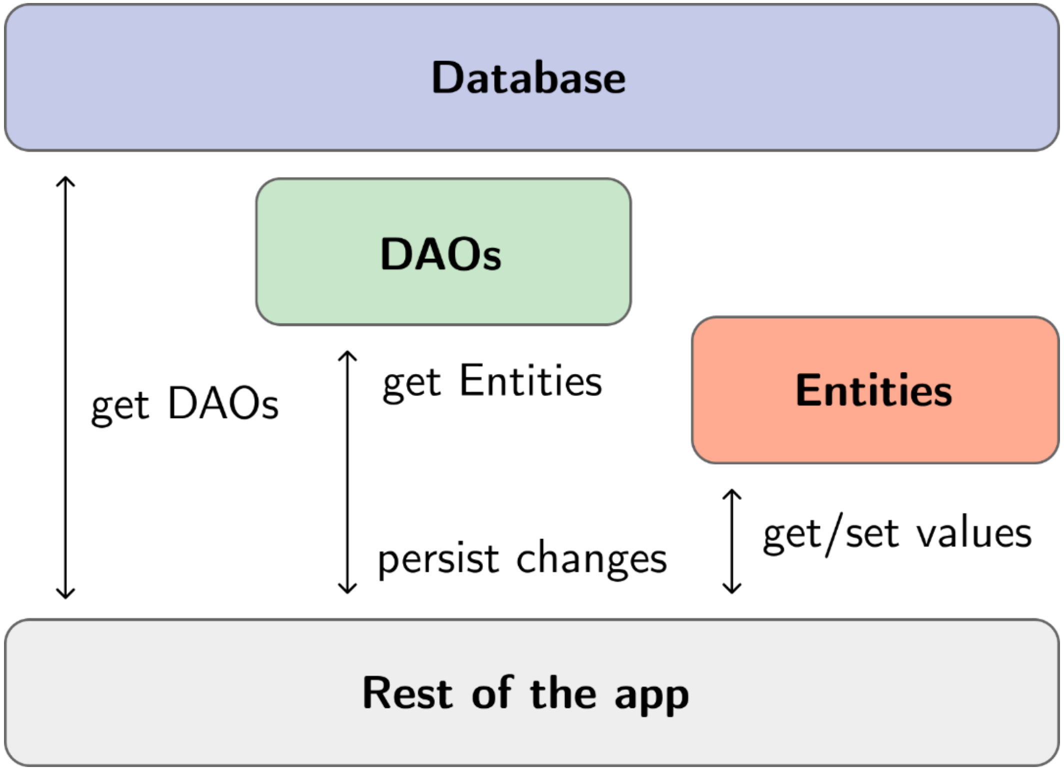
```
select p.id, p.name, p.image, c.name category
    from Product p join Category c on p.categoryId = c.id
    where p.categoryId = '1'
```



id	name	image	category
1	Grapes	🍇	Fruits
2	Melon	🍈	Fruits
3	Watermelon	🍉	Fruits
4	Banana	🍌	Fruits
5	Pineapple	🍍	Fruits
6	Mango	□	Fruits
7	Red Apple	🍎	Fruits
8	Green Apple	🍏	Fruits
9	Pear	🍐	Fruits
10	Peach	🍑	Fruits



Floor package programming model



Database

DAOs

Entities

get DAOs

get Entities

persist changes

get/set values

Rest of the app

< Back

Floor Library

- The **Floor** persistence library provides an abstraction layer over SQLite to ease data management
  - Define the database, its tables and data operations using **annotations**
    - Floor automatically translates these annotations into SQLite instructions/queries to be executed by the DB engine
    - Enables automatic mapping between in-memory objects and database rows while still offering full control of the database with the use of SQL
- **Dependencies and documentation:**
  - https://pinchbv.github.io/floor/

Floor architecture diagram

Working with Floor

1. Model DB Tables as regular **Entity Classes**

2. Create Data Access Objects (DAOs)

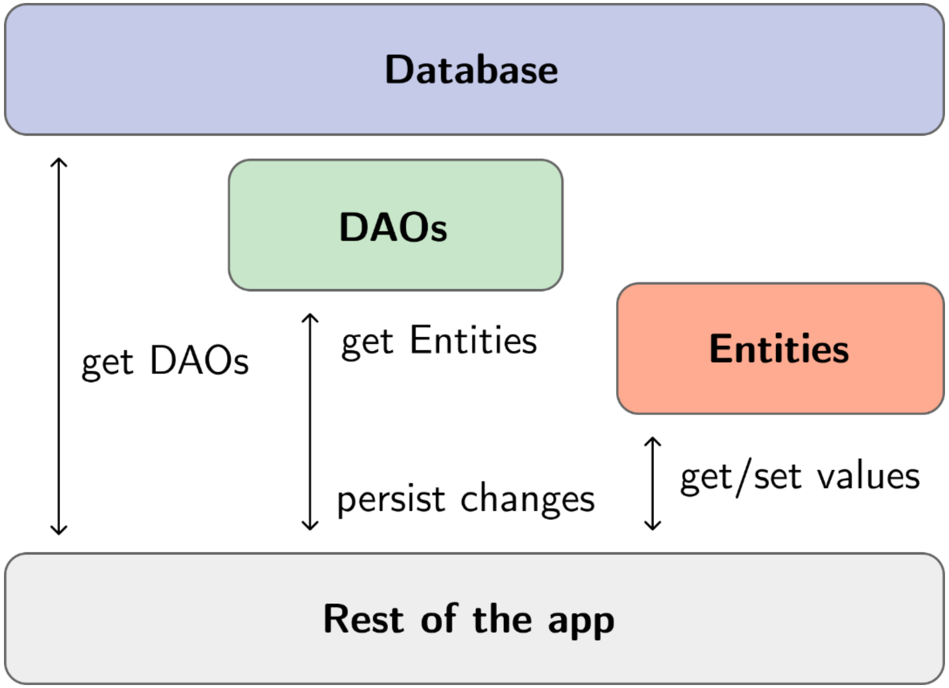
   - **DAO abstract class** methods are annotated with queries for Select, Insert, Update and Delete

   - DOA implementation is auto-generated by the complier

   - DOA is used to interact with the database

3. **FloorDatabase** → holds a connection to the SQLite DB and all the operations are executed through it

3 major components in Floor



Floor main components

- **Entity** → each entity class is mapped to a DB table
  - Dart class annotated with **@entity** to map it to a DB table
  - Must specify one of the entity properties as a **primary key**
  - Table name = Entity name & Column names = Property names (but can be changed by annotations)

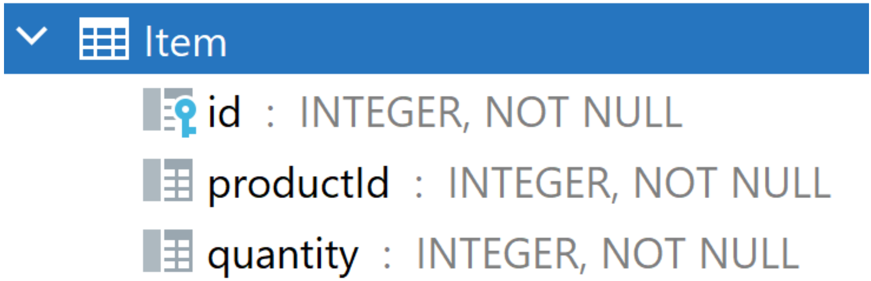
- Data Access Object (**DAO**) → has methods to read/write entities
  - Contains CRUD methods defining operations to be done on data
  - Interface or abstract class marked as **@dao**
  - One or many DAOs per database

- **Database** → where data is persisted
  - Abstract class that extends **FloorDatabase** and annotated with @Database

Entity

- Entity represents a database table, and each entity instance corresponds to a row in that table
  - Class properties are mapped to table columns
  - Each entity object has a Primary Key that **uniquely identifies** the entity object in memory and in the DB
  - The primary key values can be assigned by the database by specifying **`autoGenerate = true`**

```
@entity
class Item {
    @PrimaryKey(autoGenerate = true)
    long id;
    long productid;
    int quantity;
}
```



Item
id : INTEGER, NOT NULL
productId : INTEGER, NOT NULL
quantity : INTEGER, NOT NULL

Customizing Entity Annotations

OPTIONAL

- By default, the name of the entity class is the same as the associated table and the name of table columns are the same as the class properties
  - In most cases, the defaults are sufficient but can be customized
  - Use @entity (tableName = “…”) to set the name of the table
  - The columns can be customized using **@ColumnInfo**(name = “column_name”) annotation
- If an entity has properties that you don't want to persist, you can annotate them using **@ignore**

DAO @Query

- **@Query** used to annotate query methods
- Floor ensures **compile time verification** of SQL queries

```
@dao
abstract class UserDao {
    @Query("select * from User limit 1")
    Future<User> getFirstUser();
    @Query("select * from User")
    Stream<List<User>> getUsers();
    @Query("select firstName from User")
    Future<List<String>> getFirstNames();
    @Query("select * from User where firstName = :fn")
    Future<List<User>> getUsersByFn(String fn);
    @Query("delete from User where lastName = :ln")
    Future<int> deleteUsers(String ln);
}
```

DAO @insert, @update, @delete

- Used to annotate insert, update and delete methods
- DAO methods are async functions to ensure that DB operations are not done on the main UI isolate

```
@dao
abstract class UserDao {
    @insert
    Future<int> add(User user);
    @insert
    Future< List<int>> addList(List<User> users);

    @delete
    Future<void> delete(user: User);
    @delete
    Future<void> deleteList(List<User> users);

    @update
    Future<void> update(user: User);
    @update
    Future<void> updateList(List<User> users);
}
```

Floor database class

- Abstract class that extends **`FloorDatabase`** and Annotated with **`@Database`**
- Serves as the **main access point** to get DAOs to interact with DB

```
@Database(version: 1, entities: [Item, User])
abstract class ShoppingDB extends FloorDatabase() {
     UserDao get userDao;
}
```

- Then run this code to generate the database and DAO implementations

```
dart run build_runner build --delete-conflicting-outputs
```

AsyncNotifierProvider

AsyncNotifierProvider combines async operations with mutable state, allowing **custom methods to refresh, update, or mutate async data**.

💡 When to Use

✅ **CRUD operations** with async data (calls DAO to read/write to DB)

✅ **Refreshable** remote data

🌍 Real-World Scenarios

- Shopping cart (add/remove with server sync)
- User profile with update capabilities
- Todo list synced with backend

🆚 vs FutureProvider

Feature	FutureProvider	AsyncNotifierProvider
Custom Methods	❌ No	✅ Yes
Mutations	❌ No	✅ Yes
When to Use	Read-only	Need mutations

💻 **Example: Shopping Cart with Server Sync**

```
class ShoppingCartNotifier extends AsyncNotifier<List<CartItem>> {
  @override
  Future<List<CartItem>> build() async {
    // Load cart from server
    return await CartRepository().fetchCart();
  }

  Future<void> addItem(Product product) async {
    // Optimistic update
    final currentCart = state.valueOrNull ?? [];
    state = AsyncValue.data([...currentCart, CartItem.fromProduct(product)]);

    // Sync with server
    try {
      await CartRepository().addToCart(product.id);
    } catch (e) {
      // Revert on error
      state = AsyncValue.data(currentCart);
      rethrow;
    }
  }

  Future<void> removeItem(String itemId) async {
    final currentCart = state.valueOrNull ?? [];
    state = AsyncValue.data(currentCart.where((item) => item.id != itemId).toList());

    try {
      await CartRepository().removeFromCart(itemId);
    } catch (e) {
      state = AsyncValue.data(currentCart);
      rethrow;
    }
  }

  Future<void> refresh() async {
    state = const AsyncValue.loading();
    state = await AsyncValue.guard(() => CartRepository().fetchCart());
  }
}

final shoppingCartProvider = AsyncNotifierProvider<ShoppingCartNotifier, List<CartItem>>(
  () => ShoppingCartNotifier(),
);
```

Type Converters
One-to-many relationships

< Back

TypeConverter

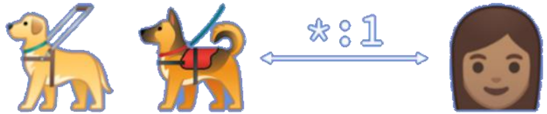
- SQLite only support basic data types, no support for data types such as Date, DateTime, enum, etc. Need to add a **TypeConverter** for such data types
- Convert an entity property datatype to a type that can be written to the associated table column and vice versa

```
class DateTimeConverter extends TypeConverter<DateTime, int> {
  @override
  DateTime decode(int databaseValue) {
    return DateTime.fromMillisecondsSinceEpoch(databaseValue);
  }

  @override
  int encode(DateTime value) {
    return value.millisecondsSinceEpoch;
  }
}
```

```
@TypeConverters([DateTimeConverter])
abstract class ShoppingDB extends FloorDatabase() { … }
```

One-to-many relationships



- Define one-to-many relationship between entities by defining a **foreign key** through the column references and performing joins in queries
  - Foreign key allows **integrity checks** (e.g., can insert pet only for a valid owner) & **cascading** deletes

```
@entity
class Owner {
  @PrimaryKey(autoGenerate: false)
  final int id;
  final String name;
  Owner({required this.id, required this.name});
}
@Entity(
  foreignKeys: [
    ForeignKey(
      childColumns: ['ownerId'], // Column in this entity
      parentColumns: ['id'],     // Column in the parent entity
      entity: Owner,
      onDelete: ForeignKeyAction.cascade,
    ),
  ],
  indices: [
    Index(value: ['ownerId']),
  ],
)
class Pet {
  @PrimaryKey(autoGenerate: false)
  final int id; // Primary key
  final String name;
  final int ownerId; // Foreign key linking to the Owner table
  Pet({required this.id, required this.name, required this.ownerId});
}
```

The **foreignKeys** parameter in the @Entity annotation specifies the parent table (Owner), the linking columns

When an owner is deleted then auto-delete associated pets

An **index** is created on the ownerId column to improve query performance

Database Views

🦮 🐕‍🦺 ⟷ *:1 👩🏽

- A database view is a virtual table created by defining a SQL query: a cleaner and reusable way to structure complex queries
  - This eliminates the need to write complex SQL queries repeatedly

```
@DatabaseView(
  'SELECT Pet.name AS petName, Owner.name AS ownerName FROM Pet INNER JOIN Owner ON Pet.ownerId = Owner.id',
   viewName: 'PetWithOwnerView',
)
class PetOwner {
  final String petName;
  final String ownerName;
  PetOwner({required this.petName, required this.ownerName});
}
```

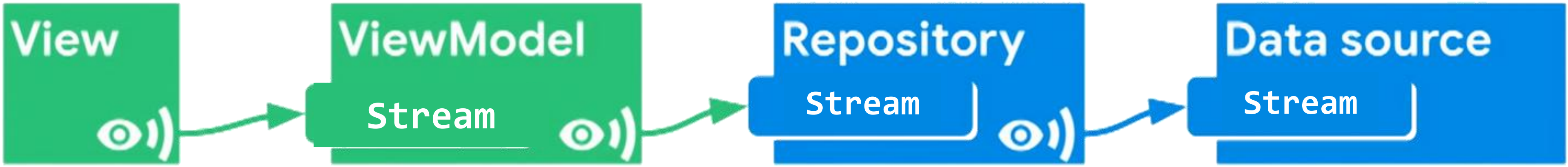
- DAO for querying the View

```
@dao
abstract class PetDao {
  @Query('SELECT * FROM PetWithOwnerView')
  Future<List<PetOwner>> getPetsWithOwners();
}
```

- Add the class returned by the view to the @Database annotation as a view

```
@Database(version: 1, entities: [Owner, Pet], views: [PetOwner])
abstract class PetDatabase extends FloorDatabase { ... }
```

Observable Queries using Stream



< Back

Observable Queries

- Observable queries allow automatic notifications when data changes
  - Notifies the app with of any data updates
- We can accomplish this by simply **wrapping** the return type of the DAO methods with **Stream**
  - **active** observers (i.e., UI) get notified when data change

```
// App will be notified of any changes of the Item table data
// Whenever Floor detects Item table data change, the new list of
Items will be provided to the app
@Query("Select * from Item")
Stream<List<Item>> observeItems();
```

Summary

Major Components

- **@entity** - Defines table structure
- **@dao** - An abstract class with functions to read/write from the database
- **@Database** - Serves as the **main access point** to get DAOs to interact with DB

Resources

- Save data in a local database using Floor
  - https://pinchbv.github.io/floor/
- Persist data with SQLite
  - https://docs.flutter.dev/cookbook/persistence/sqlite