CMPT 354: Database System I

Lecture 10. Application Programming

Why this lecture

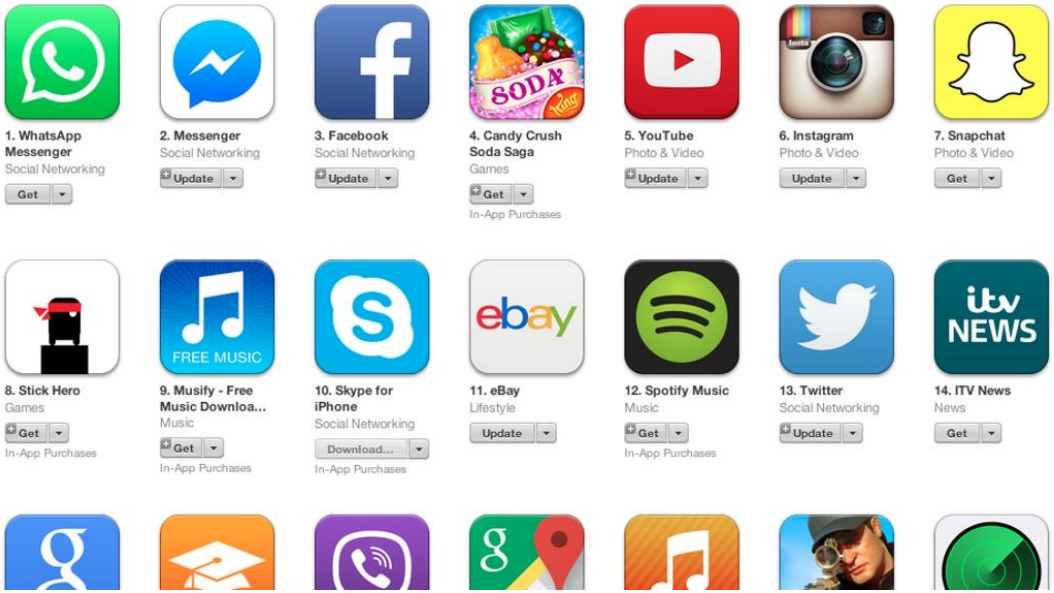
- **DB designer:** establishes schema
- **DB administrator:** tunes systems and keeps whole things running
- **Data scientist:** manipulates data to extract insights
- **Data engineer:** builds a data-processing pipeline

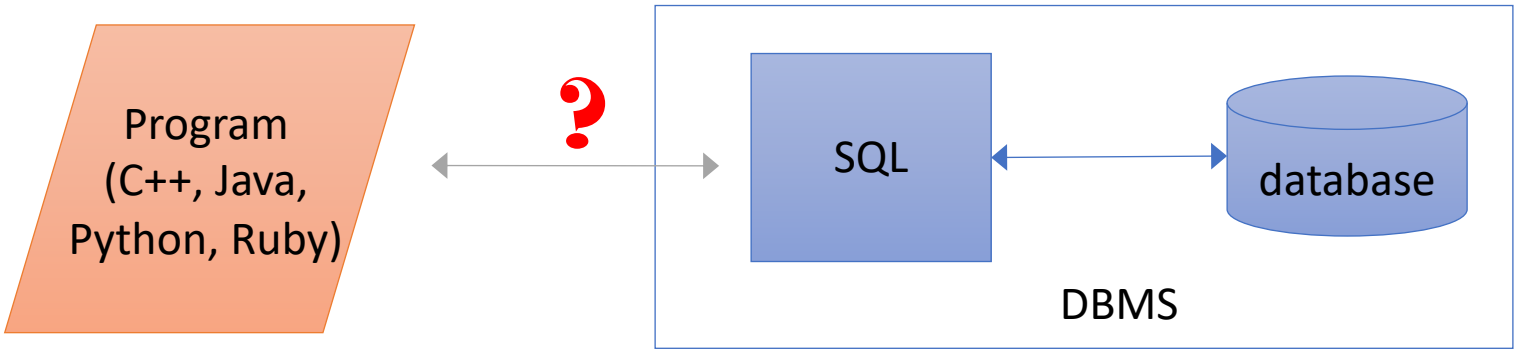
- **DB application developer:** writes programs that query and modify a database

Outline

- Database Programming
- Application Architecture

Programming Environment





Many Database API options

- Fully embed into language (embedded SQL)
- Low-level library with core database calls (DB API)
- Object-relational mapping (ORM)
  - Ruby on rails, django, etc
    - define database-backed classes
    - magically maps between database rows & objects
    - magic is a double edged sword

Embedded SQL

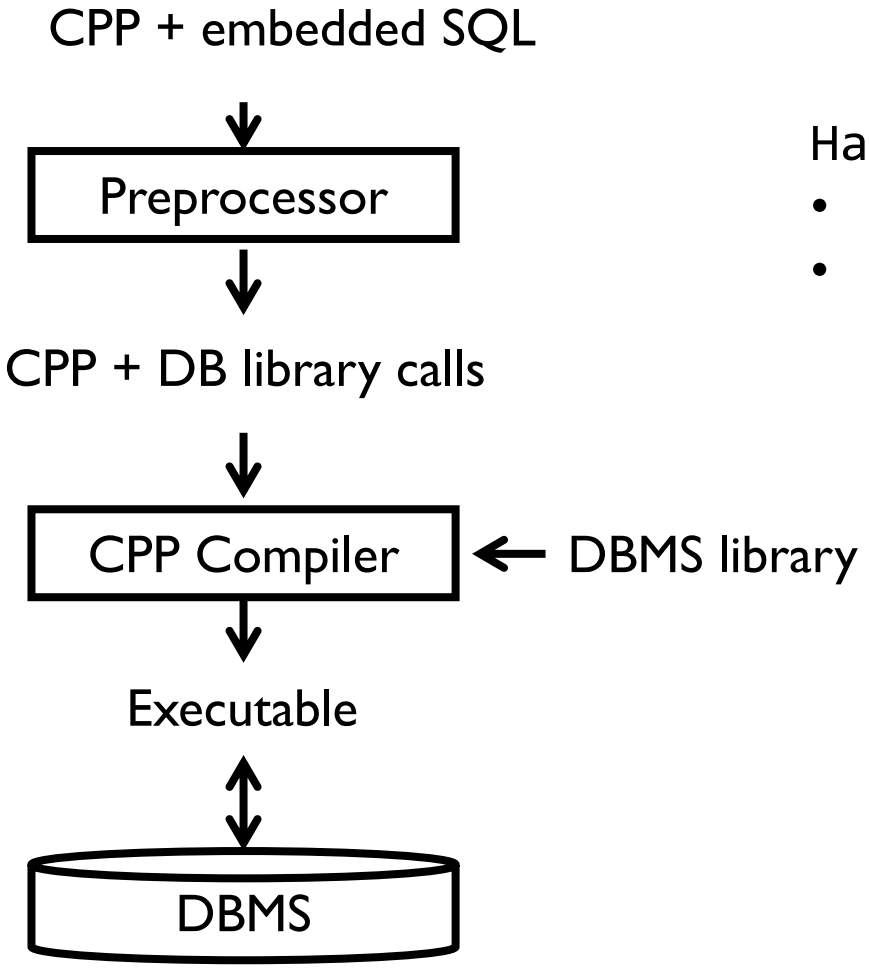
- **Extend host language (CPP) with SQL syntax**

```
4   int main() {
5       EXEC SQL INCLUDE SQLCA;
6       EXEC SQL BEGIN DECLARE SECTION;
7         int OrderID;        /* Employee ID (from user)        */
8         int CustID;         /* Retrieved customer ID          */
9         char SalesPerson[10]  /* Retrieved salesperson name    */
10        char Status[6]        /* Retrieved order status        */
11      EXEC SQL END DECLARE SECTION;
12
13      /* Prompt the user for order number */
14      printf ("Enter order number: ");
15      scanf_s("%d", &OrderID);
16
17      /* Execute the SQL query */
18      EXEC SQL SELECT CustID, SalesPerson, Status
19        FROM Orders
20        WHERE OrderID = :OrderID
21        INTO :CustID, :SalesPerson, :Status;
22
23      /* Display the results */
24      printf ("Customer number:  %d\n", CustID);
25      printf ("Salesperson: %s\n", SalesPerson);
26      printf ("Status: %s\n", Status);
27      exit();
28  }
```

Declaring Variables

Embedded SQL Query

Embedded SQL



Hard to maintain

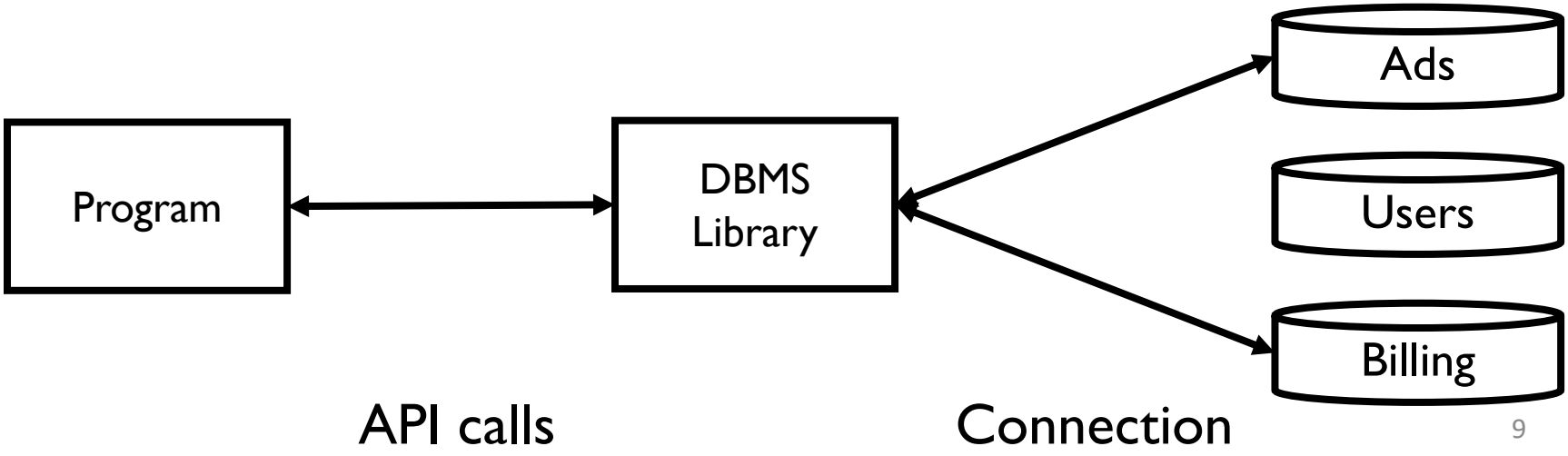
- What if SQL evolves?
- What if Compiler evolves?

Many Database API options

- Fully embed into language (embedded SQL)
- **Low-level library with core database calls (DB API)**
- Object-relational mapping (ORM)
  - Ruby on rails, django, Hibernate, sqlalchemy, etc
    - define database-backed classes
    - magically maps between database rows & objects
    - magic is a double edged sword

What does a library need to do?

- Single interface to possibly multiple DBMS engines
- Connect to a database
- Map objects between host language and DBMS
- Manage query results



ODBC and JDBC

- ODBC (Open DataBase Connectivity)

ODBC was originally developed by Microsoft and Simba Technologies

- JDBC (Java DataBase Connectivity)
  - Sun developed as set of Java interfaces
    - javax.sql.*

Connections

- Create a connection
  - Allocate resources for the connection
  - Relatively expensive to set up, libraries often cache connections for future use

```
conn = connect(sfu.db)
```

Should close connections when done! Otherwise resource leak.

Query Execution

```
foo = conn.execute("select * from student")
```

- Challenges
  - Type Mismatch
  - What is the return type of `execute()`?
  - How to pass data between DBMS and host language?

Type Mismatch

- SQL standard defines mappings between SQL and several languages

SQL types	C types	Python types
CHAR(20)	char[20]	str
INTEGER	int	int
SMALLINT	short	int
REAL	float	float

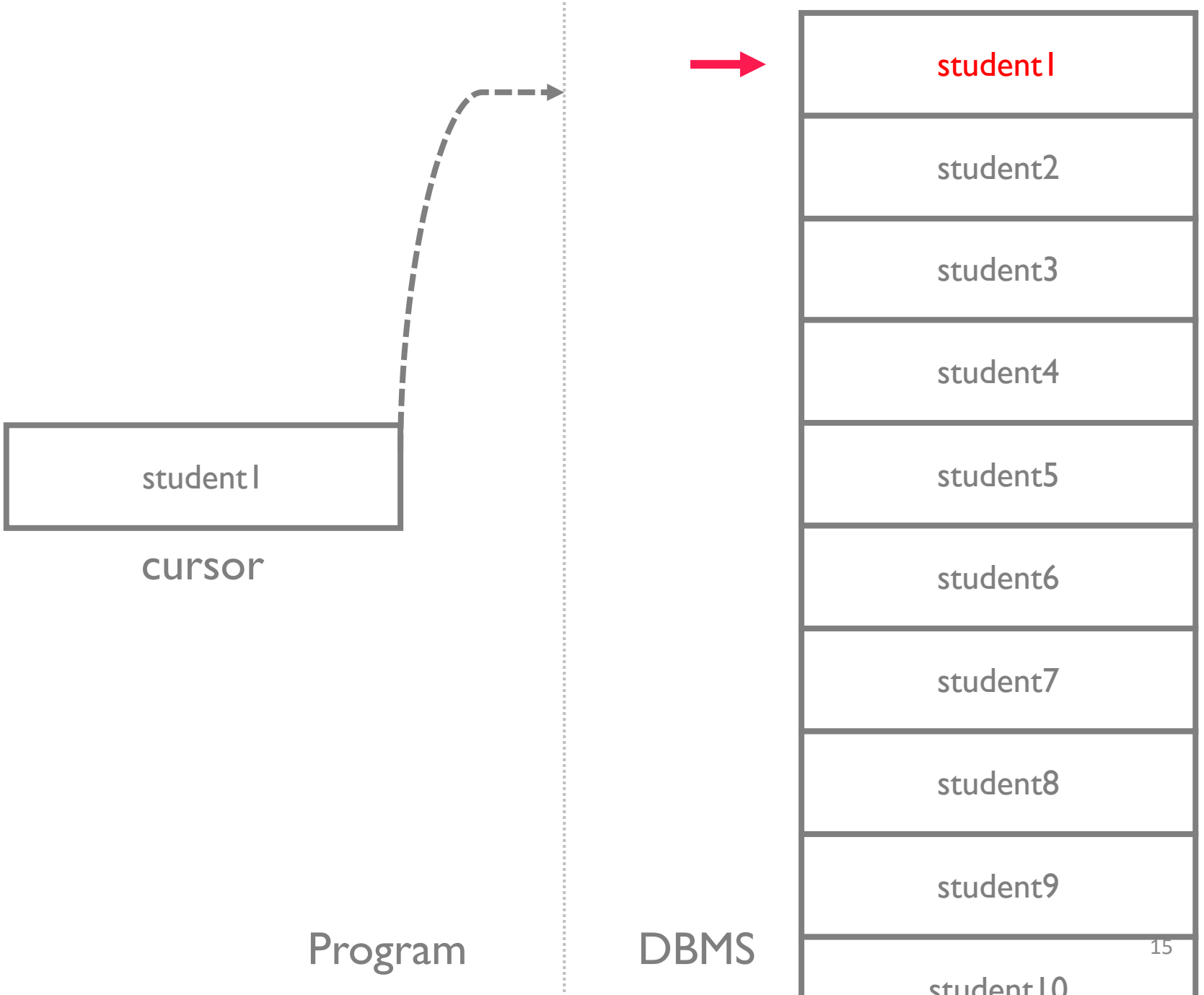
Cursor

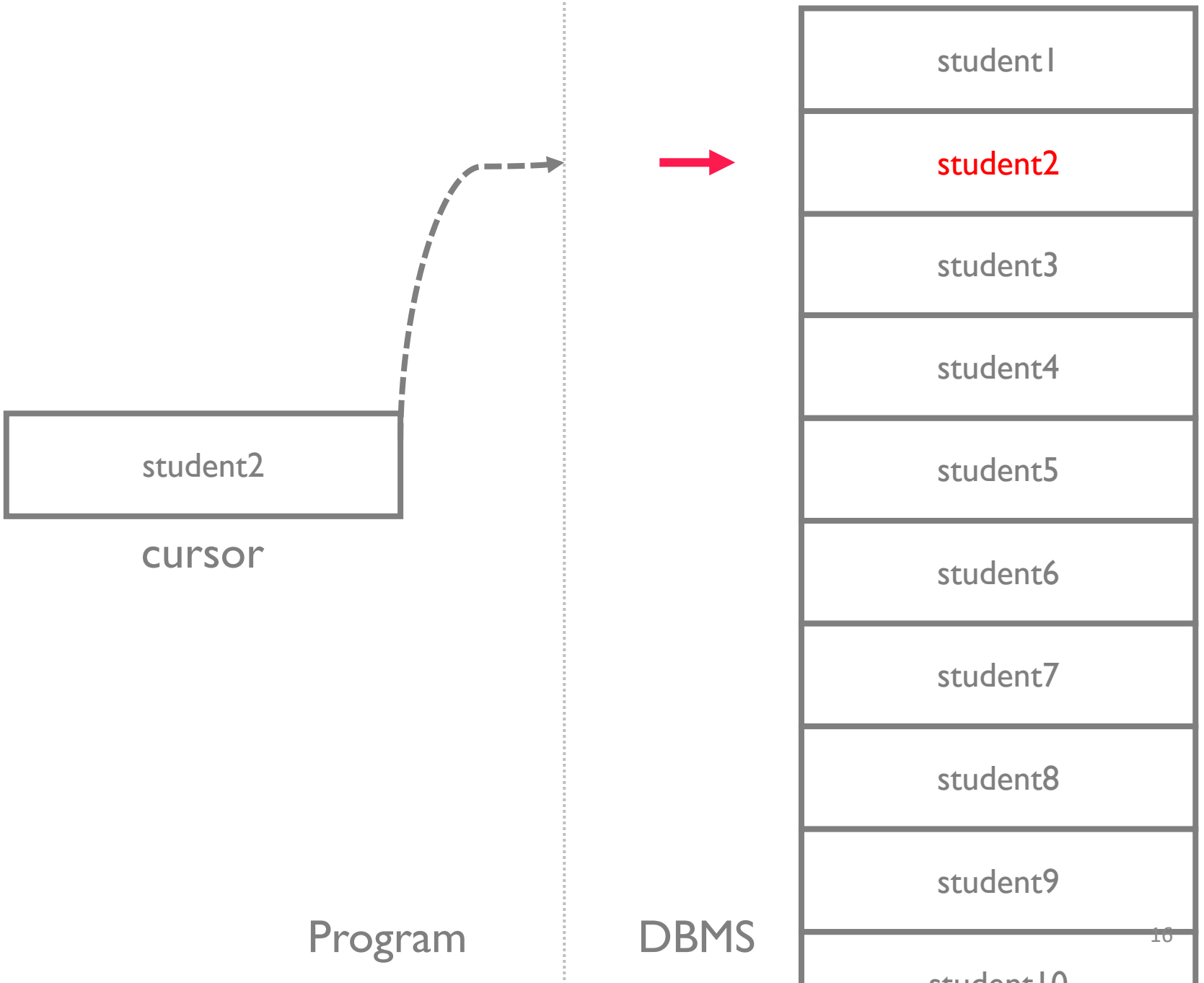
- SQL relations and results are sets of records

- What is the type of foo?

```
foo = conn1.execute("select * from student")
```

- Cursor over the Result Set
  - similar to an iterator interface
  - Note: relations are unordered!
    - Cursors have no ordering guarantees
    - Use ORDER BY to ensure an ordering


student1
cursor
Program
DBMS
student1
student2
student3
student4
student5
student6
student7
student8
student9
student10


student1
student2
student3
student4
student5
student6
student7
student8
student9
student10
student2
cursor
Program
DBMS

Cursor

- Cursor similar to an iterator
  - cursor = conn.execute(“SELECT * FROM student”)

- Cursor methods
  - fetchone()
  - fetchall()

Cursor

- Cursor similar to an iterator

```
1  conn = sqlite3.connect('sfu.db')
2  cursor = conn.execute("select * from student")
3
4  for record in cursor.fetchall():
5      print record
6
7  conn.close()
```

```
(u'Mary', 3.8)
(u'Tom', 3.6)
(u'Jack', 3.7)
```

SQL Injection!!

symbol = RHAT’ OR True --

SELECT * **FROM** stocks **WHERE** symbol = 'RHAT' OR True -- '

SELECT * **FROM** stocks **WHERE** symbol = 'RHAT'' OR True -- '

Exercise

```
1  import sqlite3
2  conn = sqlite3.connect('sfu.db')
```

```
1  def search(name, conn):
2      """
3      Input:
4          @name: student name
5          @conn: database connection
6      Output:
7          @records: all the students whose name is @name
8      """
9      # REPLACE WITH YOUR CODE
```

```
1  name = 'Mary'
2  search(name, conn)
```

```
[(u'Mary', 3.8)]
```

Outline

- Database Programming
- **Application Architecture**

Architectures

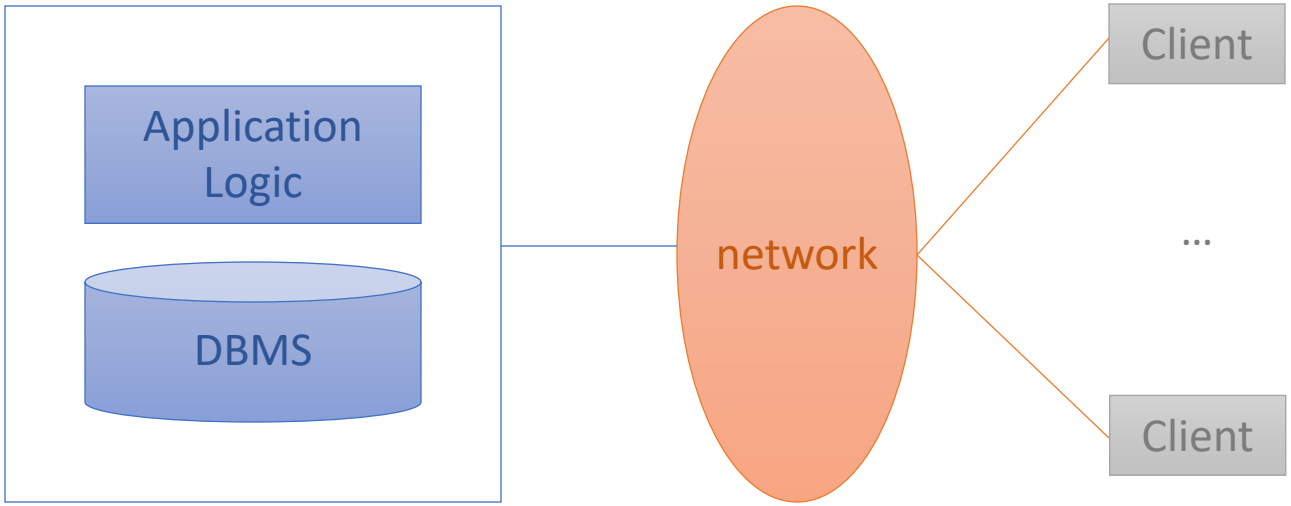
- Single tier
  - How things used to be …
- Two tier
  - Client-server architecture
- Three tier (and multi-tier)
  - Used for many web systems
  - Very scalable

Single Tier Architecture

- Historically, data intensive applications ran on a single tier which contained
  - The DBMS,
  - Application logic and business rules, and
  - User interface

Two-Tier Architecture

- Client/ server architecture
  - The server implements the business logic and data management
- Separate presentation from the rest of the application



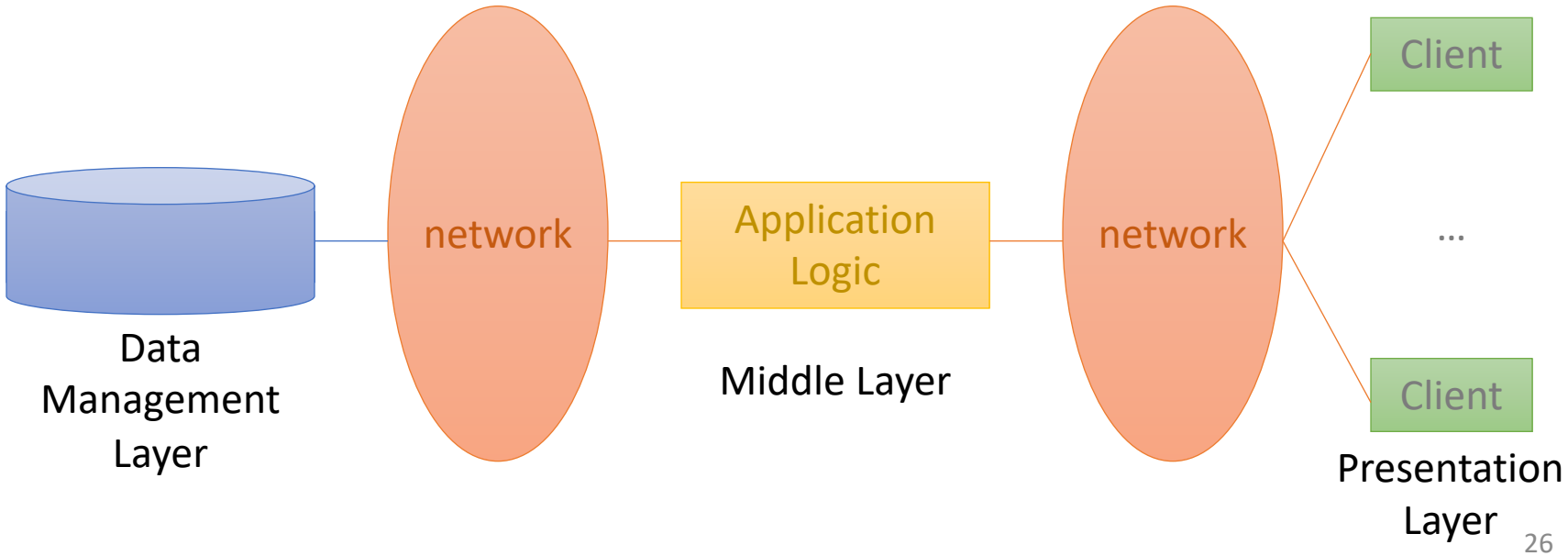
Presentation Layer

- Responsible for handling the user's interaction with the middle tier

- One application may have multiple versions that correspond to different interfaces
  - Web browsers, mobile phones, …
  - Style sheets can assist in controlling versions

Three-Tier Architecture

- Separate presentation from the rest of the application
- Separate the application logic from the data management



Business logic Layer

- The middle layer is responsible for running the business logic of the application which controls
  - What data is required before an action is performed
  - The control flow of multi-stage actions
  - Access to the database layer

- Multi-stage actions performed by the middle tier may require database access
  - But will not usually make permanent changes until the end of the process
    - e.g. adding items to a shopping basket in an Internet shopping site

Data Management Layer

- The data management tier contains one, or more databases
  - Which may be running on different DBMSs
- Data needs to be exchanged between the middle tier and the database servers
  - This task is not required if a single data source is used but,
  - May be required if multiple data sources are to be integrated
  - *XML* is a language which can be used as a data exchange format between database servers and the middle tier

Example: Airline reservations

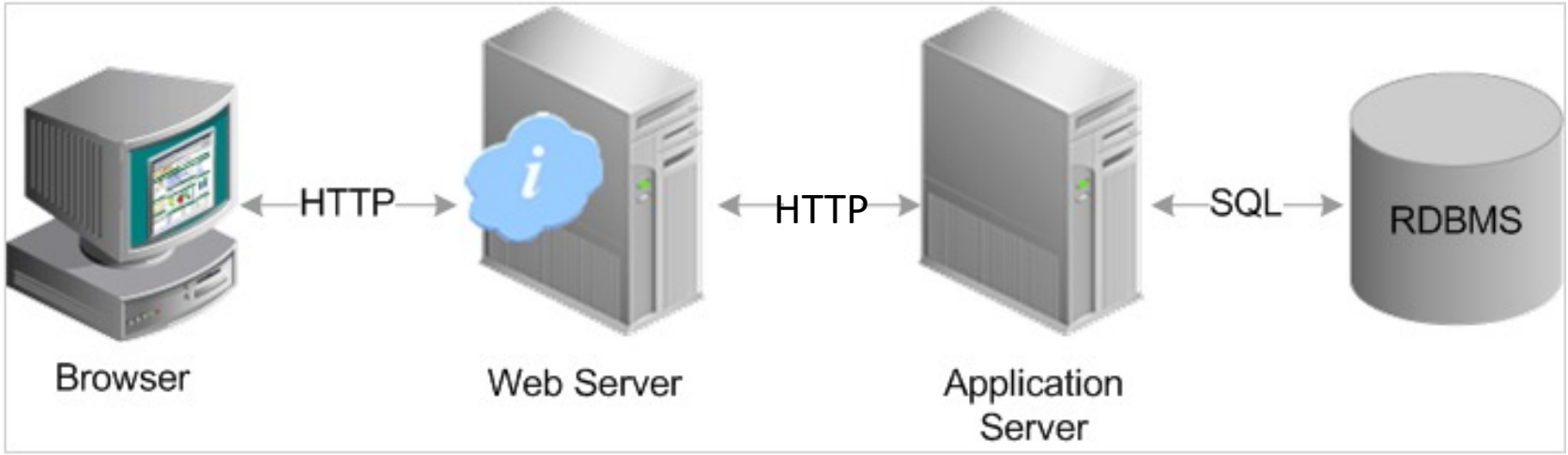
- Consider the three tiers in a system for airline reservations
- Database System
  - Airline info, available seats, customer info, etc.
- Application Server
  - Logic to make reservations, cancel reservations, add new airlines, etc.
- Client Program
  - Log in different users, display forms and human-readable output

Example: Course Enrollment

- Student enrollment system tiers
- Database System
  - Student information, course information, instructor information, course availability, pre-requisites, etc.
- Application Server
  - Logic to add a course, drop a course, create a new course, etc.
- Client Program
  - Log in different users (students, staff, faculty), display forms and human-readable output

3 Tier Architecture and the Web

- In the domain of web applications three tier architecture usually refers to
  - Web server
  - Application server
  - Database server



Summary

- Database Programming
  - Embedded SQL
  - DB API

- Application Architecture
  - Three Tier Architecture

Acknowledge

- Some lecture slides were copied from or inspired by the following course materials
  - “W4111: Introduction to databases” by Eugene Wu at Columbia University
  - “CSE344: Introduction to Data Management” by Dan Suciu at University of Washington
  - “CMPT354: Database System I” by John Edgar at Simon Fraser University
  - “CS186: Introduction to Database Systems” by Joe Hellerstein at UC Berkeley
  - “CS145: Introduction to Databases” by Peter Bailis at Stanford
  - “CS 348: Introduction to Database Management” by Grant Weddell at University of Waterloo