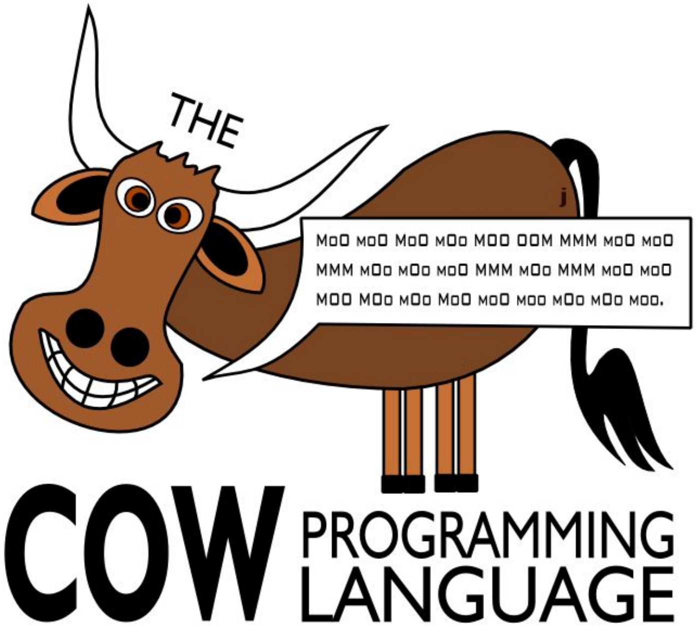
Database Application Development

The merge is offical

PS #2 now applies to both sections, stay tuned for an annoucement WRT its due date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COW PROGRAMMING LANGUAGE

Comp 521 Changes…

- There will be ***no midterm next week*** in section 001

5 –	Problem sets (lowest dropped)	~~30%~~	20%
N -	In-class exercise/worksheets	10%	10%
	Midterm	30%	30%
	Final Exam	~~30%~~	40%

- I will retrofit my problem sets so that they are compatible with Prof. Bishop's validators and autograders.
- Expect a new version of iSQL.py. But this should not keep you from starting the problem set
- We will continue with section 001's Piazza, and section 002 will be added
- I hope to convert my "exercises" into "worksheets"

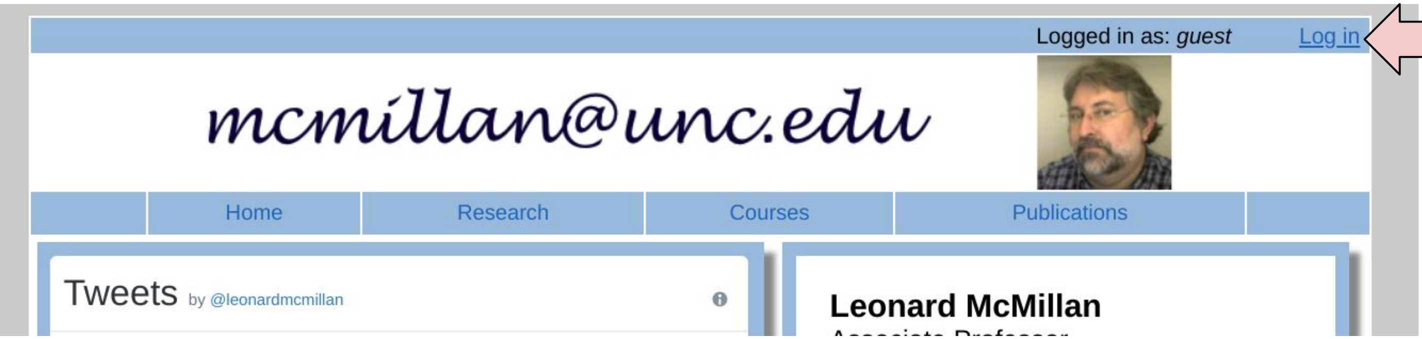
Onboarding

If you were here last Thursday, you should have

- A course website login

Let's try each.

First goto https://csbio.unc.edu/mcmillan/


Logged in as: *guest*   Log in

mcmillan@unc.edu

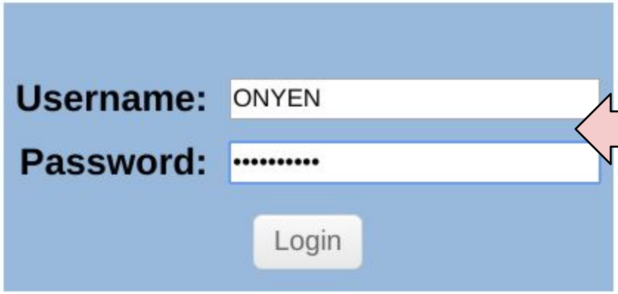
Home | Research | Courses | Publications

Tweets by @leonardmcmillan

Leonard McMillan
Associate Professor

Click Here

Course website login



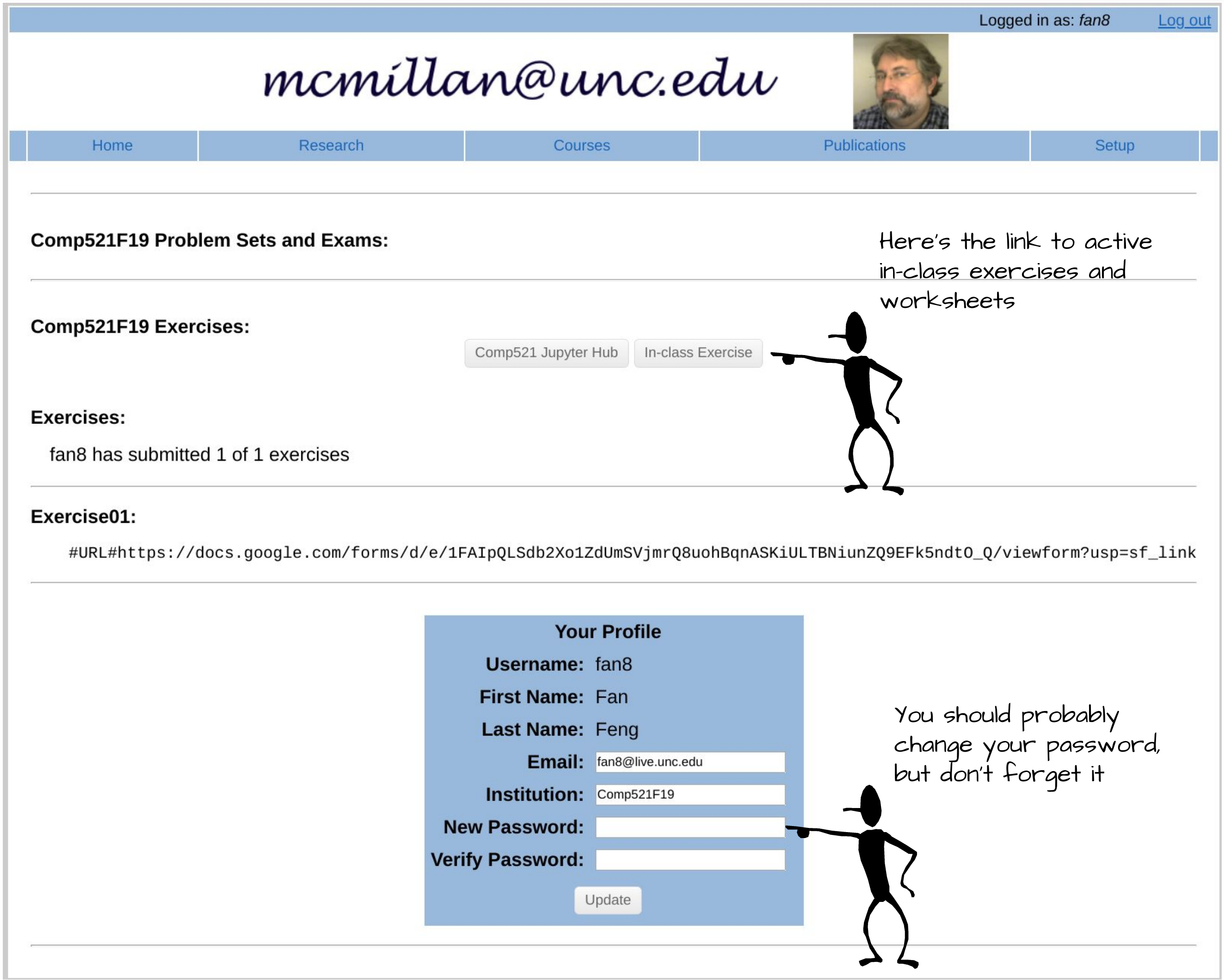
Username: ONYEN

Password: ••••••••••

Enter your ONYEN as your username, and your PID as your password

Your login should then show up as “Verified” Next press “Continue”; you should then see “Setup” as a menu option. Press it.

Course website portal



Logged in as: *fan8*

mcmillan@unc.edu

Comp521F19 Problem Sets and Exams:

Comp521F19 Exercises:

Exercises:

fan8 has submitted 1 of 1 exercises

Exercise01:

```
#URL#https://docs.google.com/forms/d/e/1FAIpQLSdb2Xo1ZdUmSVjmrQ8uohBqnASKiULTBNiunZQ9EFk5ndtO_Q/viewform?usp=sf_link
```

Your Profile

Username:	fan8
First Name:	Fan
Last Name:	Feng
Email:	fan8@live.unc.edu
Institution:	Comp521F19
New Password:	
Verify Password:	

Here's the link to active in-class exercises and worksheets

You should probably change your password, but don't forget it

Using databases within programs

- Often need to access databases from programming languages
  - as a file alternative
  - as shared data
  - as persistent state
- SQL is a direct query language; as such, it has limitations.
- Standard programming languages:
  - Complex computational processing of the data.
  - Specialized user interfaces.
  - Logistics and decision making
  - Access to multiple databases

How to tell a DB geek

SQL in Application Code

- Most often SQL commands are called from within a host language (e.g., Java or Python) program.
  - SQL statements need to reference and modify host language variables (with special variables used to return results and status).
  - Generally, an Application Programming Interface (API) is used to *connect to*, *issue queries, modify, and update* databases.

SQL in Application Code (Contd.)

Impedance mismatch:

- Differences in the data models used by SQL and programming languages
- SQL relations are (multi-) sets of tuples, with no *a priori* bound on number, length, and type.
- No such data structure exist in traditional procedural programming languages such as C++. (But Python has it!)
- SQL language interfaces often support a mechanism called a *cursor* iterator.

Desirable features of SQL APIs:

- Ease of use.
- Conformance to standards for existing programming languages, database query languages, and development environments.
- Interoperability: the ability to use a common interface to access diverse database management systems on different operating systems

Vendor specific solutions

- Oracle PL/SQL: A proprietary PL/1-like language which supports the execution of SQL queries:
- Advantages:
  - Many Oracle-specific features, high performance, tight integration.
  - Advantage, overall performance can be optimized by analyzing both the queries and the surrounding program logic.
- Disadvantages:
  - Ties the applications to a specific DBMS.
  - The application programmer must depend upon the vendor for the application development environment.
  - It may not be available for all platforms.

Vendor Independent solutions

Three basic strategies:

- Embed SQL in the host language (Embedded SQL, SQLJ)
  - SQL code appears inline with other host-language code
  - Queries are determined at compile time
- SQL call-level interfaces (Dynamic SQL)
  - Wrapper functions that pass SQL queries as strings from the host language to a separate DBMS process
  - This allows queries to be constructed "programmatically"
- SQL modules or libraries

Embedded SQL

- Approach: Embed SQL in the host language.
  - A preprocessor converts the SQL statements into special API calls.
  - Then a regular compiler is used to compile the code.
- Language constructs:
  - Connecting to a database:
    EXEC SQL CONNECT
  - Declaring variables:
    EXEC SQL BEGIN (END) DECLARE SECTION
  - Statements:
    EXEC SQL Statement;

Embedded SQL: Variables

- There is a need for the host language to share variable with the database's SQL interface:

```
EXEC SQL BEGIN DECLARE SECTION
char  c_sname[20];
long  c_sid;
short c_rating;
float c_age;
EXEC SQL END DECLARE SECTION
```

- Two special "error" variables:
  - SQLCODE (long, is negative if an error has occurred)
  - SQLSTATE (char[6], predefined codes for common errors)

Cursors

- Can declare a cursor on a relation or query statement that generates a relation.
- Can *open* a cursor, and repeatedly *fetch* tuples and *advance* the cursor as a side-effect, until all tuples have been retrieved.
- In some cases, you can also modify/delete tuple pointed to by a cursor, and changes are reflected in the database

Embedded Database Use

- Loading a table

```
EXEC SQL
INSERT INTO Sailors
  VALUES(:c_sname, :c_sid, :c_rating, :c_age);
```

- Executing a query

```
DECLARE sinfo CURSOR FOR
    SELECT S.sname, S.age
    FROM Sailors S
    WHERE S.rating > 6;

OPEN sinfo;
do {
    FETCH sinfo INTO :c_name, :c_age;
   /* do stuff */
   if (c_name == "dustin") {
         ageSum += c_age;
       dustinCount += 1;
   }
} while (SQLSTATE != NO_DATA);     /* NO_DATA == “02000” */
CLOSE sinfo;
```

Embedded SQL Disadvantages:

- Directives must be preprocessed, with subtle implications for code elsewhere
- It is a real pain to debug preprocessed programs.
- The use of a program-development environment is compromised substantially.
- The preprocessor is “compiler vendor” and “platform” specific.

Dynamic SQL

- SQL query strings are not always known at compile time (e.g., spreadsheet, graphical DBMS frontend): Allow construction of SQL statements on-the-fly

- Example:

```
char c_sqlstring[]=
   {“DELETE FROM Sailors WHERE rating>5”};
EXEC SQL PREPARE readytogo FROM :c_sqlstring;
EXEC SQL EXECUTE readytogo;
```

SQL Package and Libraries

- In the package approach, invocations to SQL are made via libraries of procedures , rather than via preprocessing

- Special standardized interface: procedures/objects

- Pass SQL strings from language, presents result sets in a language-friendly way

- Supposedly DBMS-neutral
  - a "driver" traps the calls and translates them into DBMS-specific code
  - database can be across a network

Example module based

- Python’s built-in SQLite package
  - Add-ons for
    - MySQL (MySQL for Python),
    - Oracle (Oracle+Python, cx_Oracle)
    - Postgres (PostgreSQL)
    - etc.
- Sun’s *JDBC:* Java API
- Part of the java.sql package

Verdict on SQL Modules

- Advantages over embedded SQL:
  - Cleaner separation of SQL from the host programming language.
  - Debugging is much more straightforward, since no preprocessor is involved.

- Disadvantages:
  - The module libraries tend to be specific to the programming language and DBMS. Thus, portability is somewhat compromised.

SQL in Python

- Python is a high-level interpreted language with dynamic types
- High-level means that is provide a rich set of data structures built-in to the language with strong abstractions from the details of their implementation
- Tuples are a built-in datatype which makes it particularly compatible with relational databases
- A SQLite API is built into Python.

Python and SQL Data Types

Python type	SQLite type
None	NULL
int	INTEGER
long	INTEGER
float	REAL
str (UTF8-encoded)	TEXT
unicode	TEXT
buffer	BLOB

SQLite type conversions to Python

SQLite type	Python type
NULL	None
INTEGER	int or long, depending on size
REAL	float
TEXT	depends on text_factory, unicode by default
BLOB	buffer

Embedding SQL in Python

List the name, jersey number, and position of 2019 Kansas City Chief players with jersey numbers less than 20.

```
import sqlite3

db = sqlite3.connect("NFL.db")
cursor = db.cursor()

cursor.execute("""SELECT P.name, R.jersey, R.position
                  FROM Player P, PlayedFor R, Team T
                  WHERE P.pid=R.pid AND R.tid=T.tid
                    AND T.mascot='chiefs' AND R.year=2019 AND R.jersey<>'--'
                  ORDER BY R.jersey""")

print("          Name        Jersey Position")
for row in sorted(cursor, key=lambda tup: int(tup[1])):
    if (int(row[1]) < 20):
        print("%20s %5s  %6s" % row)

db.close()
```

More Involved Example

- What is then name, jersey number, age, and number of seasons played for each active quarterback (i.e. playing on a 2019 roster)?

```
import sqlite3
import datetime

db = sqlite3.connect("NFL.db")
cursor = db.cursor()

cursor.execute("""SELECT P.name, R.jersey, P.dob, MIN(R.year), T.mascot
                  FROM Player P, PlayedFor R, Team T
                  WHERE P.pid=R.pid AND R.tid=T.tid AND dob<>'--'
                    AND P.pid in (SELECT pid FROM PlayedFor
                                  WHERE year=2019 AND position='QB')
                  GROUP BY P.pid
                  ORDER BY P.dob""")

print("          Name        Jersey  Age   Seasons    Team")
for row in cursor:
    ymd = [int(v) for v in row[2].split('-')]
    age = int((datetime.date.today() - datetime.date(ymd[0],ymd[1],ymd[2])).days/365.25)
    seasons = datetime.date.today().year - int(row[3])
    print("%20s %5s %6d %6d %18s" % (row[0],row[1],age,seasons,row[4]))
db.close()
```

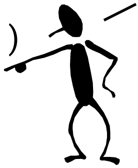
Where Python and SQL meet

- UGLY inter-language semantics
  - Within SQL we can reference a relation’s attributes by its field name
  - From the cursor interface we only see a tuple in which attributes are indexed by position
  - Can be a maintenance nightmare
- Solution “Row-factories”
  - Allows you to remap each relation to a local Python data structure
    (Object, dictionary, array, etc.)
  - Built-in “dictionary-based” row factory

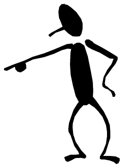
With a Row-Factory

Increase the rating of all sailors who have made more than two reservations by one unless their rating is already 10.

```
import sqlite3

db = sqlite3.connect("sailors.db")
db.row_factory = sqlite3.Row
cursor = db.cursor()

cursor.execute("""SELECT s.sid, COUNT(r.bid) as reservations
                  FROM Sailors s, Reserves r
                  WHERE s.sid=r.sid AND s.rating < 10
                  GROUP BY s.sid""")

for row in cursor.fetchall():
    if (row['reservations'] > 2):
       cursor.execute("""UPDATE Sailors
                         SET rating = rating + 1
                         WHERE sid=%d""" % row['sid'])

db.commit()
db.close()
```



Must come before dependent cursor



Must "commit" to make INSERTs, DELETEs, and/or UPDATEs persistent

Other SQLite in Python Features

- Alternatives to iterating over cursor
  - Fetch the next tuple:

    ```
    tvar = cursor.fetchone()
    ```

  - Fetch N tuples into a list:

    ```
    lvar = cursor.fetchmany(N)
    ```

  - Fetch all tuples into a list:

    ```
    lvar = cursor.fetchall()
    ```

- Alternative execution statement
  - Repeat the same command over an iterator

    ```
    cursor.executemany(“SQL Statement”, args)
    ```

  - Execute a list of ‘;’ separted commands

    ```
    cursor.executescript(“SQL Statements;”)
    ```

Variable Substitution

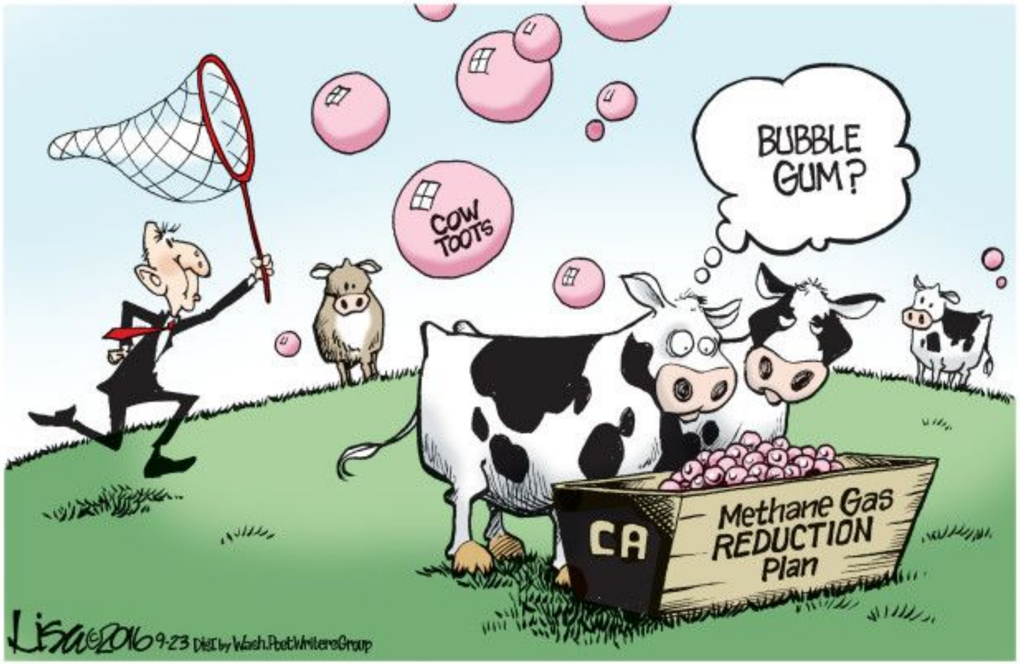
- Usually your SQL operations will need to use values from Python variables. You shouldn't assemble your query using Python's string formatters because doing so is insecure; it makes your program vulnerable to SQL *injection attacks*.
- Instead, use the DB-API's parameter substitution. Put '?' as a placeholder wherever you want to use a value, and then provide a tuple of values as the second argument to the cursor's <u>execute()</u> method.

With a Row-Factory

```
import sqlite3

db = sqlite3.connect("sailors.db")
db.row_factory = sqlite3.Row
cursor = db.cursor()

cursor.execute("""SELECT s.sid, COUNT(r.bid) as reservations
                  FROM Sailors s, Reserves r
                  WHERE s.sid=r.sid
                  GROUP BY s.sid
                  HAVING s.rating < 10""")

for row in cursor.fetchall():
    if (row['reservations'] > 2):
        cursor.execute("""UPDATE Sailors
                          SET rating = rating + ?
                          WHERE sid=?"””, (value,row['sid']))
db.commit()
db.close()
```

Next Time

- A first look at query performance
- Building and using indices


COW TOOTS
BUBBLE GUM?
CA
Methane Gas REDUCTION Plan
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