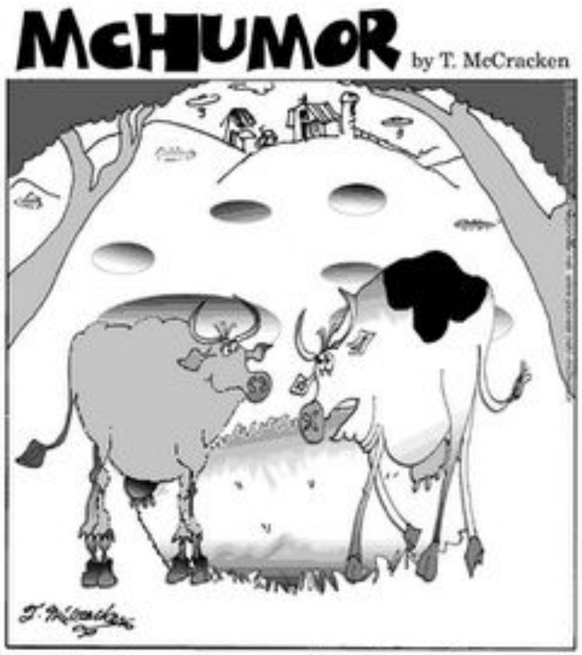
# *The Relational Model*

Exercise 2: A Redo

Problem Set #1:
Will be out Tuesday

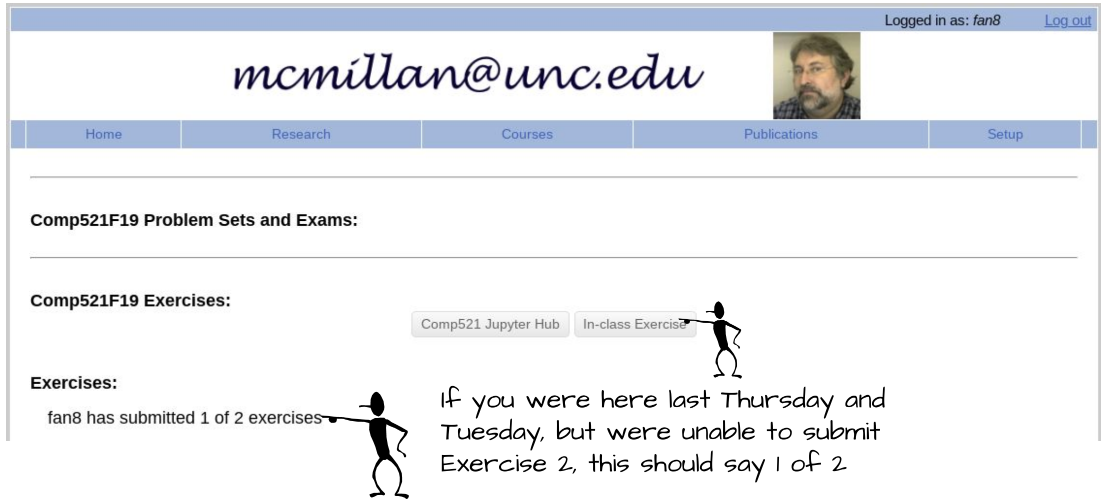


"Let's eat the grass in perfect circles.
It drives them crazy."

# One more chance for Exercise 2

- ***Login*** to the course website and check if you have only 1 of 2 exercises
- If so, click on [In-class Exercise]
- Fill in your PID and paste the following into the given form…

```
C 58
C/G 2
C/T 1
CB 197
CB/S 3
DB 131
DB-WR 1
DE 160
DE-C 1
DE/DT 2
DE/LB 7
DL 10
DT 156
DT-DE 6
DT/DE 3
Inconsistent use of '-' and '/',
and possibly ambigous orderings,
such as "DE/DT" and "DT/DE"
```




- You won't need it today, but you should make sure that you can access your Jupyter Hub
- I suggest that you test it by going through the code examples and dataset given in Lecture 3

# *Why Study the Relational Model?*

- Most widely used model by industry.
  - IBM, Informix, Microsoft, Oracle, Sybase, etc.
- It is simple, elegant, and efficient
  - Entities and relations are represented as tables
  - Tables allow for arbitrary referencing (Tables can refer to other tables)
- Recent competitor: object-oriented model
  - ObjectStore, Versant, Ontos
  - A synthesis emerging: *object-relational model*
    - Informix Universal Server, UniSQL, O2, Oracle, DB2

# *Relational Database: Definitions*

- *Relational database:* a set of *relations*
- *Relation:* made up of 2 parts:
  - *Instance* : a *table,* with rows and columns. #rows = *cardinality,* #fields = *degree / arity.*
  - *Schema* : specifies name of relation, plus a name and type for each column.
    - e.g. Students(*sid*: string, *name*: string, *login*: string, *age*: integer, *gpa*: real).
- Can think of a relation as a *set* of rows or *tuples*.

# *Example Instance of Students Relation*

| sid | name | login | age | gpa |
|---|---|---|---|---|
| 53666 | Jones | jones@cs | 18 | 3.4 |
| 53688 | Smith | smith@cs | 18 | 3.2 |
| 53650 | Smith | smith@math | 19 | 3.8 |

- Cardinality = 3, degree = 5
- All rows in a relation instance *have to be distinct*– each relation is defined to be a *set* of unique tuples

# *Relational Query Languages*

- A major strength of the relational model is that it supports simple and powerful *querying* of data.
- Often *declarative* instead of *imperative*
- Queries can be written intuitively, and the DBMS is responsible for efficient evaluation.
  - Precise semantics for relational queries.
  - Allows the optimizer to extensively re-order operations, and still ensure that the answer does not change.

# *The SQL Query Language*

- Developed by IBM (system R) in the 1970s
- A portable and long-lasting standard
- Standards:
  - SQL-86
  - SQL-89 (minor revision)
  - SQL-92 (major revision)
  - SQL-1999 (major extensions, Current baseline)
  - SQL-2003, SQL-2006 (added XML support)
  - SQL-2008, (minor additions)
  - SQL-2011, (temporal support)

# Creating Relations in SQL

- SQL for creating the Students relation.
- Observe that the type (domain) of each field is specified, and enforced by the DBMS whenever tuples are added or modified.
- Another example, the Enrolled table holds information about courses that students take.

```
CREATE TABLE Students (
   sid INTEGER,
   name TEXT,
   login TEXT,
   age INTEGER,
   gpa REAL)

CREATE TABLE Enrolled (
   sid INTEGER,
   cid TEXT,
   grade TEXT)
```

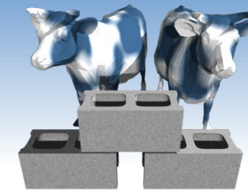
# *Destroying and Altering Relations*

```
DROP TABLE  Students
```

- Destroys the relation Students.  The schema information *and* the tuples are deleted.

```
ALTER TABLE  Students
ADD COLUMN admitYear: integer
```

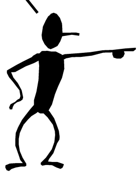
- The schema of Students is altered by adding a new field; every tuple in the current instance is extended with a *null* value in the new field.



# SQL Queries

- To find all 18 year old students, we can write:

"S" in this expression indicates a formal variable which takes on successive values from the table.



```
SELECT *
FROM Students S
WHERE S.age=18
```

| sid | name | login | age | gpa |
|---|---|---|---|---|
| 53666 | Jones | jones@cs | 18 | 3.4 |
| 53688 | Smith | smith@cs | 18 | 3.2 |

- To find just names and logins, replace the first line

```
SELECT S.name, S.login
```

- When a relation is referenced only once and attributes are unique, the use of variables is optional

# Querying Multiple Relations

- What does the following query compute?

SELECT S.name, E.cid
FROM Students S, Enrolled E
WHERE S.sid=E.sid AND E.grade="A"

Effectively "Joins" or connects two tables

Given the following instances of Enrolled and Students:

Enrolled:

| sid | cid | grade |
|---|---|---|
| 53688 | Carnatic101 | C |
| 53688 | Reggae203 | B |
| 53650 | Topology112 | A |
| 53666 | History105 | B |

Students:

| sid | name | login | age | gpa |
|---|---|---|---|---|
| 53666 | Jones | jones@cs | 18 | 3.4 |
| 53688 | Smith | smith@cs | 18 | 3.2 |
| 53650 | Smith | smith@math | 19 | 3.8 |

we get:

| S.name | E.cid |
|---|---|
| Smith | Topology112 |

# *Adding and Deleting Tuples*

- Can insert a single tuple using:

```
INSERT INTO Students (sid, name, login, age, gpa)
VALUES (53675, 'Smith', 'smith@phys', 18, 3.5)
```

- Can delete all tuples satisfying some condition (e.g., name = Smith):

```
DELETE
FROM Students S
WHERE S.name = 'Smith'
```

☞ *Powerful variants of these commands are available; more later!*

# *Integrity Constraints (ICs)*

- IC: condition that must be true for *any* instance of the database; e.g., *domain constraints.*
  - ICs are specified when schema is defined.
  - ICs are checked when relations are modified.
- A *legal* instance of a relation is one that satisfies all specified ICs.
  - DBMS should not allow illegal instances.
- If the DBMS checks ICs, stored data is more faithful to real-world meaning.
  - Avoids data entry errors, too!

```
CREATE TABLE Students (
  sid INTEGER,
  name TEXT,
  login TEXT,
  age INTEGER,
  gpa REAL)
```

# *Primary Key Constraints*

- A set of fields is a *key* for a relation if :
  1. No two tuples can have same values for all their corresponding key fields
  2. This is not true for any subset of the key
- If the key is overspecified (Rule 2 violated), it is called a *superkey*.
- If there's more than one key for a relation, one is chosen (by DBA) as the *primary key*.
- E.g., *sid* is a key for Students. (What about *name*?) The set {*sid, gpa*} is a superkey.

# *Primary and Candidate Keys in SQL*

- Possibly many *candidate keys*, one of which is chosen as the *primary key*. Alternative, non primary keys can be specified using UNIQUE.
- "For a given student and course, there is a single grade." vs. "Students can take only one course, and receive a single grade for that course; further, no two students in a course receive the same grade."
- Used carelessly, an IC can prevent the storage of database instances that arise in practice!

```
CREATE TABLE Enrolled (
    sid INTEGER,
    cid  TEXT,
    grade TEXT,
    PRIMARY KEY (sid,cid) )
```

```
CREATE TABLE Enrolled (
    sid INTEGER,
    cid  TEXT,
    grade TEXT,
    PRIMARY KEY (sid),
    UNIQUE (cid, grade) )
```

# *Foreign Keys, Referential Integrity*

- *Foreign key* : Set of fields in one relation that is used to "reference" a tuple in another relation. (Must correspond to primary key of the second relation.) Like a "logical pointer".
- E.g. *sid* is a foreign key referring to Students:
  - Enrolled(*sid*: string, *cid*: string, *grade*: string)
  - If all foreign key constraints are enforced, *referential integrity* is achieved, i.e., no dangling references.
  - Can you name a data model w/o referential integrity?

Links in HTML!

# *Foreign Keys in SQL*

- Only students listed in the Students relation should be allowed to enroll for courses.

```
CREATE TABLE Enrolled (
    sid INTEGER,  cid TEXT,  grade TEXT,
    PRIMARY KEY  (sid,cid),
    FOREIGN KEY (sid) REFERENCES Students )
```

Enrolled

| sid | cid | grade |
|---|---|---|
| 53688 | Carnatic101 | C |
| 53688 | Reggae203 | B |
| 53650 | Topology112 | A |
| 53666 | History105 | B |

Students

| sid | name | login | age | gpa |
|---|---|---|---|---|
| 53666 | Jones | jones@cs | 18 | 3.4 |
| 53688 | Smith | smith@cs | 18 | 3.2 |
| 53650 | Smith | smith@math | 19 | 3.8 |

# *Enforcing Referential Integrity*

- Consider Students and Enrolled; *sid* in Enrolled is a foreign key that references Students.
- What should be done if an Enrolled tuple with a non-existent student id is inserted? (*Reject it!*)
- What should be done if a Students tuple is deleted?
  1. Also delete all Enrolled tuples that refer to it.
  2. Disallow deletion of a Students tuple that is referred to.
  3. Set sid in Enrolled tuples that refer to it to a *default sid*.
  4. (In SQL, also: Set sid in Enrolled tuples that refer to it to a special value *null*, denoting *unknown* or *does not apply*.)
- Similar if primary key of Students tuple is updated.

# Referential Integrity in SQL

- SQL/92 and SQL:1999 support all 4 options on deletes and updates.
  - Default is NO ACTION (no consequences on *delete or update*)
  - CASCADE (also delete all tuples that refer to deleted tuple)
  - SET NULL / SET DEFAULT (sets foreign key value of referencing tuple)

```
CREATE TABLE Enrolled (
    sid INTEGER,
    cid TEXT,
    grade TEXT,
    PRIMARY KEY (sid, cid),
    FOREIGN KEY (sid)
      REFERENCES Students
      ON DELETE CASCADE
      ON UPDATE SET DEFAULT )
```

# *Where do ICs Come From?*

- ICs are based upon the semantics of the real-world enterprise that is being described in the database relations.
- We can check a database instance to see if an IC is violated, but we can NEVER infer that an IC is true by looking at an instance.
  - An IC is a statement about *all possible* instances!
  - From example, we know *name* is not a key, but the assertion that *sid* is a key is given to us.
- Key and foreign key ICs are the most common; more general ICs supported too.

# Views

- A *view* is just a relation, but it is derived from other relations. Thus, we store a *definition*, rather than a set of tuples.

```
CREATE VIEW YoungActiveStudents(name, grade)
    AS SELECT S.login, E.grade
    FROM Students S, Enrolled E
    WHERE S.sid = E.sid and S.age<21
```

- Views can be dropped using the DROP VIEW command.
  - How to handle DROP TABLE if there's a view on the table?
  - DROP TABLE command has options to let the user specify this.

# *Views to support ISA relations*

- The common elements of an ISA hierarchy can be supported using views.
- For example, consider this implementation of Alternate 2 from slide 29

```
CREATE VIEW Employee(ssn, name, jobtitle)
   AS SELECT  H.ssn, H.name, H.jobtitle
        FROM  Hourly_Emps H
      UNION
        SELECT  C.ssn, C.name, C.jobtitle
        FROM  Contract_Emps C
```

# *Views and Security*

- Views can be used to present necessary information (or a summary), while hiding details in underlying relation(s).
- Ex. A list of grades made by YoungStudents, sorted by email addresses.

| login | grade |
|---|---|
| smith@cs | C |
| smith@cs | B |
| jones@cs | B |

# Relational Model: Summary

- A tabular representation of data.
- Simple and intuitive, currently the most widely used.
- Integrity constraints can be specified by the DBA, based on application semantics. DBMS checks for violations.
  - Two important ICs: primary and foreign keys
  - In addition, we *always* have domain constraints.
- Powerful and natural query languages exist.