THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

2. Relational Model

CSCI 2541 Database Systems & Team Projects

Wood &

Slides adapted from Prof. Bhagi Narahari; Silberschatz, Korth, and Sudarshan; and Ramakrishnan, Gerhke, and Lawrence

Admin Stuff

HW 1 due yesterday

- Test cases should give you idea of your grade

Optional RPS HW due Jan 23

Read our materials/instructions carefully

Read the syllabus for course policies

Watch Slack for ways to **#engage** and ask **#questions**

Last week…

Structure that is **independent** of the underlying file formats

Queries to flexibly read, update, and delete information

Transactions that provide guarantees about **multi-user consistency**

Relational Model Definitions

Constraints and Relationships

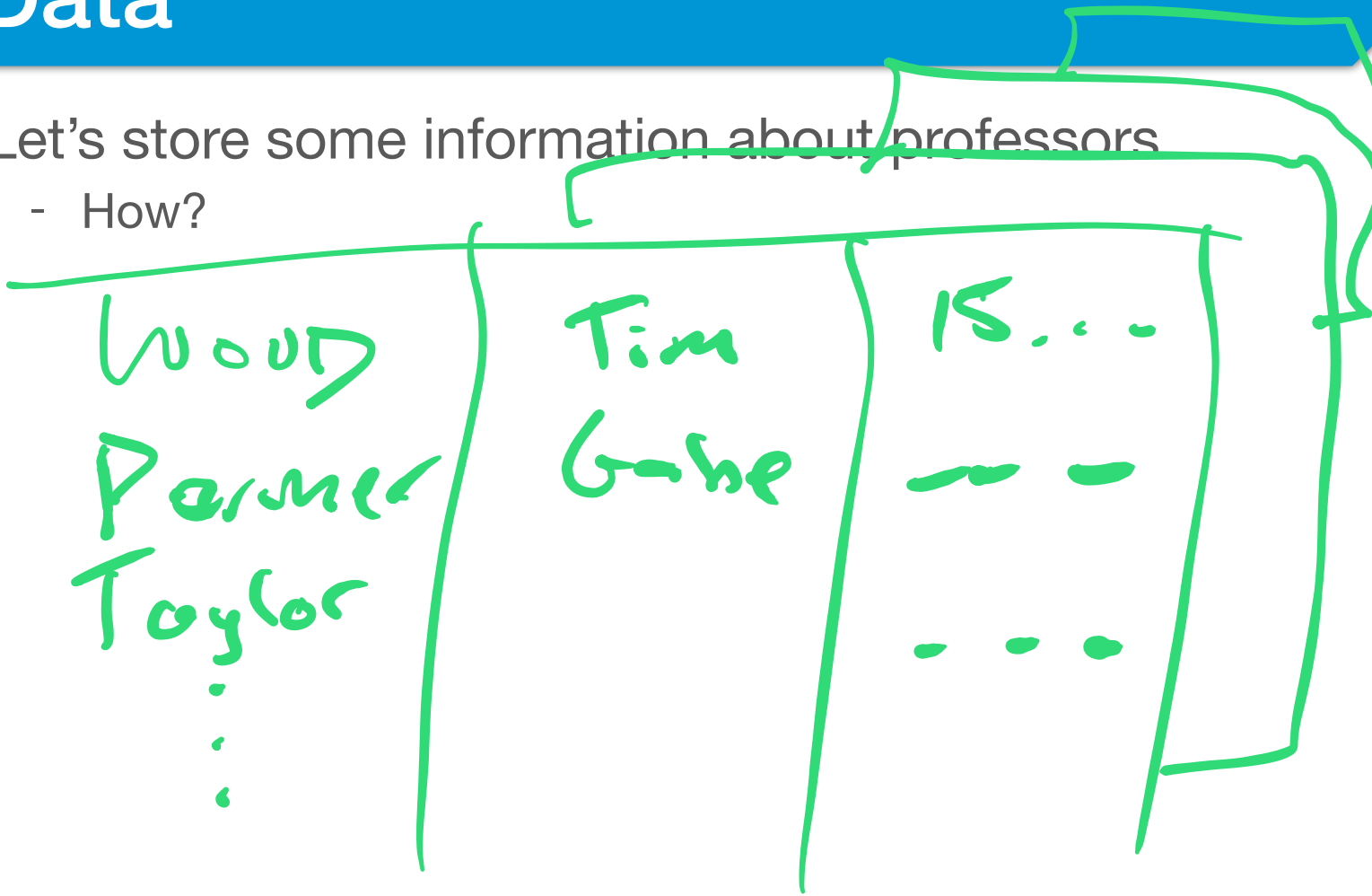
Lab!

…this week.

Data

Let's store some information about professors

- How?



Tables

A Table is a set of rows and columns…

- A column defines an attribute that can have different values
- A row represents related attributes that together represent a data element

Instructor Table

ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
32343	El Said	History	60000
33456	Gold	Physics	87000
45565	Katz	Comp. Sci.	75000
58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Course Table

course_id	*title*	*dept_name*	*credits*
BIO-101	Intro. to Biology	Biology	4
BIO-301	Genetics	Biology	4
BIO-399	Computational Biology	Biology	3
CS-101	Intro. to Computer Science	Comp. Sci.	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3
CS-319	Image Processing	Comp. Sci.	3
CS-347	Database System Concepts	Comp. Sci.	3
EE-181	Intro. to Digital Systems	Elec. Eng.	3
FIN-201	Investment Banking	Finance	3
HIS-351	World History	History	3
MU-199	Music Video Production	Music	3
PHY-101	Physical Principles	Physics	4

Tables = Relations

A **Relation** is a **set** of **tuples** and **attributes**

- Set: an unordered list of unique elements
- Tuple: a sequence of values
- Attribute: a named type with values in a domain

Why?

Instructor Relation

ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
32343	El Said	History	60000
33456	Gold	Physics	87000
45565	Katz	Comp. Sci.	75000
58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Course Relation

course_id	*title*	*dept_name*	*credits*
BIO-101	Intro. to Biology	Biology	4
BIO-301	Genetics	Biology	4
BIO-399	Computational Biology	Biology	3
CS-101	Intro. to Computer Science	Comp. Sci.	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3
CS-319	Image Processing	Comp. Sci.	3
CS-347	Database System Concepts	Comp. Sci.	3
EE-181	Intro. to Digital Systems	Elec. Eng.	3
FIN-201	Investment Banking	Finance	3
HIS-351	World History	History	3
MU-199	Music Video Production	Music	3
PHY-101	Physical Principles	Physics	4

Schema

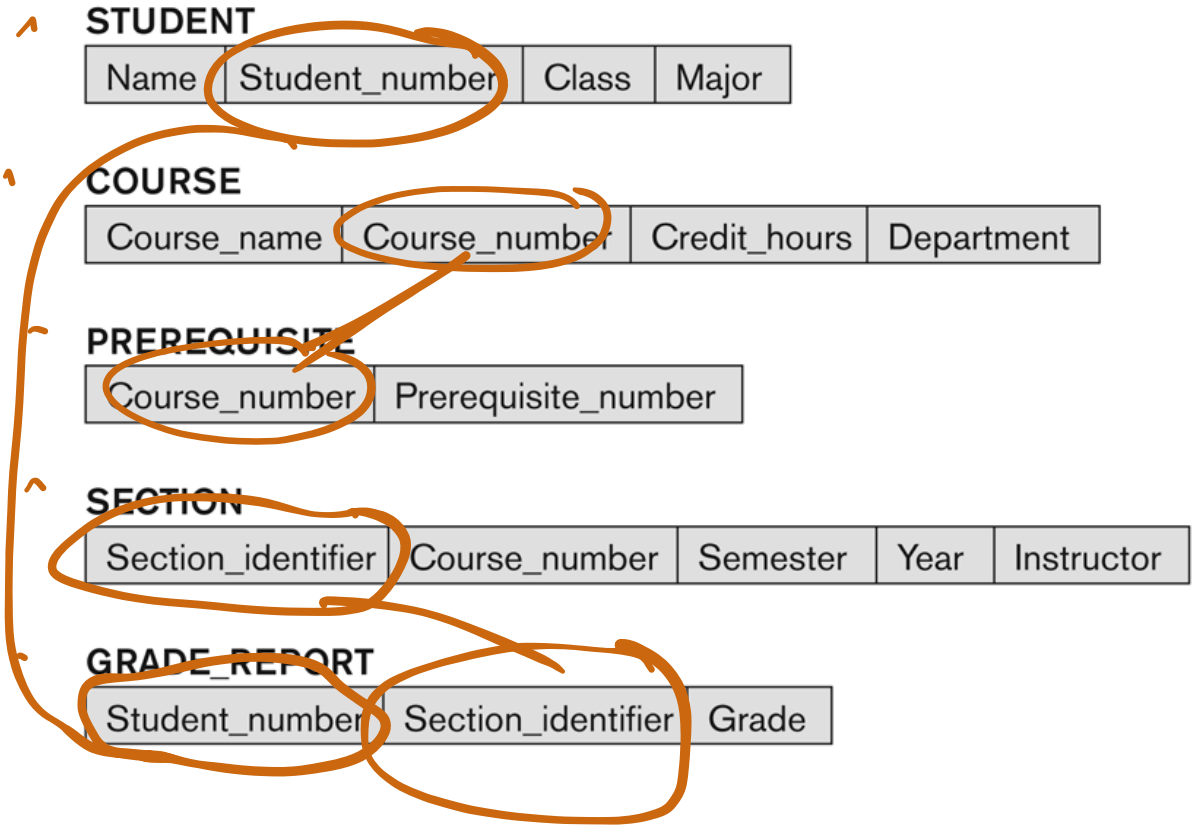
Defines the structure of one or more Relations

- **A1, A2, …, An** are attributes
- **R = (A1, A2, …, An)** is a relation schema

Example: **instructor = (ID, name, dept_name, salary)**

- A relation instance **r** defined over schema **R** is denoted by **r (R)**.
- The current values of a relation are specified by a table
- An element **t** of relation **r** is called a tuple and is represented by a row in a table

Example DB Schema



Relational Model Definitions

A **relation** is a table with columns and rows.

An **attribute** is a named column of a relation.

A **tuple** is a row of a relation.

A **domain** is a set of allowable values for one or more attributes.

The **degree** of a relation is the number of attributes it contains.

The **cardinality** of a relation is the number of tuples it contains.

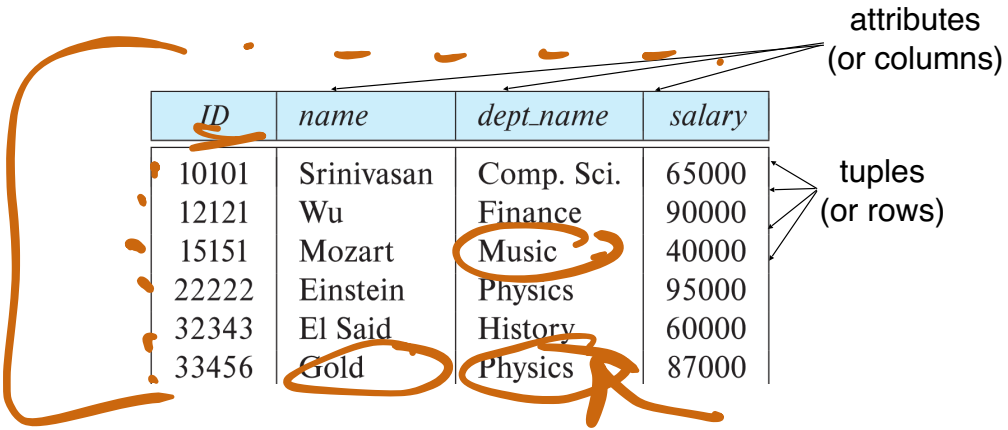
A **relational database** is a collection of normalized relations with distinct relation names.

Definitions

Degree = 4

Cardinality = 6

Help me fill these in!



ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
32343	El Said	History	60000
33456	Gold	Physics	87000

Relation Property Summary

1. Each relation name is unique
   - No two relations have the same name

2. Each cell of the relation (value of a domain) contains exactly one atomic (single) value and cannot be empty… in practice SQL allows NULL

3. Each attribute of a relation has a distinct name

4. Values of an attribute are all from the same domain

5. Each tuple is distinct. There are no duplicate tuples
   - Theoretically… in practice, SQL supports "bags" (allow duplicates)

6. Order of attributes is not important
   - Note difference from mathematical def of relations
     - Tuple (x,y) is not the same as (y,x) in mathematical definition
   - Reason: attribute names represent domain and can be reordered

7. Order of tuples is not important

Relational Model Definitions

Constraints and Relationships

Lab!

onwards…

Constraints

Relation scheme defines the types and domain of all attributes

- Can enforce constraints whenever tuples are added/modified

This can enforce many constraints to protect the integrity of your data

- Can't insert a string into an Integer type attribute
- A State field could limit domain to (AL, AK, AZ…WY)
- An SSN attribute must follow form (xxx-xx-xxxx)
- Price must be > 0.00

… but not all!

- Application or "business logic" may not be feasible
- Example: "An employee can't work more than 40 hours per week across all jobs"

Keys

Superkey of R:

- A set of attributes that is sufficient to uniquely identify each tuple in r(R)

ID	*name*	*dept_name*	*salary*
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
76766	Crick	Biology	72000
10101	Srinivasan	Comp. Sci.	65000
58583	Califieri	History	62000
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

The *professor* relation

What is a superkey for this relation?

Keys

Superkey of R:

- A set of attributes that is sufficient to uniquely identify each tuple in r(R)

What is a superkey for this relation?

course_id	*sec_id*	*semester*	*year*	*building*	*room_number*	*time_slot_id*
BIO-101	1	Summer	2017	Painter	514	B
BIO-301	1	Summer	2018	Painter	514	A
CS-101	1	Fall	2017	Packard	101	H
CS-101	1	Spring	2018	Packard	101	F
CS-190	1	Spring	2017	Taylor	3128	E
CS-190	2	Spring	2017	Taylor	3128	A
CS-315	1	Spring	2018	Watson	120	D
CS-319	1	Spring	2018	Watson	100	B
CS-319	2	Spring	2018	Taylor	3128	C
CS-347	1	Fall	2017	Taylor	3128	A
EE-181	1	Spring	2017	Taylor	3128	C
FIN-201	1	Spring	2018	Packard	101	B
HIS-351	1	Spring	2018	Painter	514	C
MU-199	1	Spring	2018	Packard	101	D
PHY-101	1	Fall	2017	Watson	100	A

The *section* relation

Candidate and Primary Keys

Superkey of R:

- A set of attributes that is sufficient to uniquely identify each tuple in r(R)

Candidate Key of R: A "minimal" superkey

- A Candidate Key is a superkey K such that removal of any attribute from K results in a set of attributes that is not a superkey (does not possess the superkey uniqueness property)
- A Candidate Key is a Superkey but opposite may not be true

Primary Key: The Candidate Key chosen to represent a relation/table

Super vs Candidate Key

Possible superkeys:

- <ID, name>,
- <ID, dept_name>,
- <ID, name, dept_name, salary>

Candidate Key must be minimal:

- <ID>
- <course_id, sec_id, semester, year>

Primary keys are listed first and underlined when showing the schema

classroom(*building*, *room_number*, *capacity*)
department(*dept_name*, *building*, *budget*)
course(*course_id*, *title*, *dept_name*, *credits*)
instructor(*ID*, *name*, *dept_name*, *salary*)

ID	*name*	*dept_name*	*salary*
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
76766	Crick	Biology	72000
10101	Srinivasan	Comp. Sci.	65000
58583	Califieri	History	62000
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

course_id	*sec_id*	*semester*	*year*	*building*	*room_number*	*time_slot_id*
BIO-101	1	Summer	2017	Painter	514	B
BIO-301	1	Summer	2018	Painter	514	A
CS-101	1	Fall	2017	Packard	101	H
CS-101	1	Spring	2018	Packard	101	F
CS-190	1	Spring	2017	Taylor	3128	E
CS-190	2	Spring	2017	Taylor	3128	A
CS-315	1	Spring	2018	Watson	120	D
CS-319	1	Spring	2018	Watson	100	B
CS-319	2	Spring	2018	Taylor	3128	C
CS-347	1	Fall	2017	Taylor	3128	A
EE-181	1	Spring	2017	Taylor	3128	C
FIN-201	1	Spring	2018	Packard	101	B
HIS-351	1	Spring	2018	Painter	514	C
MU-199	1	Spring	2018	Packard	101	D
PHY-101	1	Fall	2017	Watson	100	A

Picking a Primary Key

Every Relation must have a Primary Key

How to pick from the candidates?

- Based on business logic
- Is "Name" unique? depends on your business/ application!
- Ideally Primary Key should be something that never/rarely changes

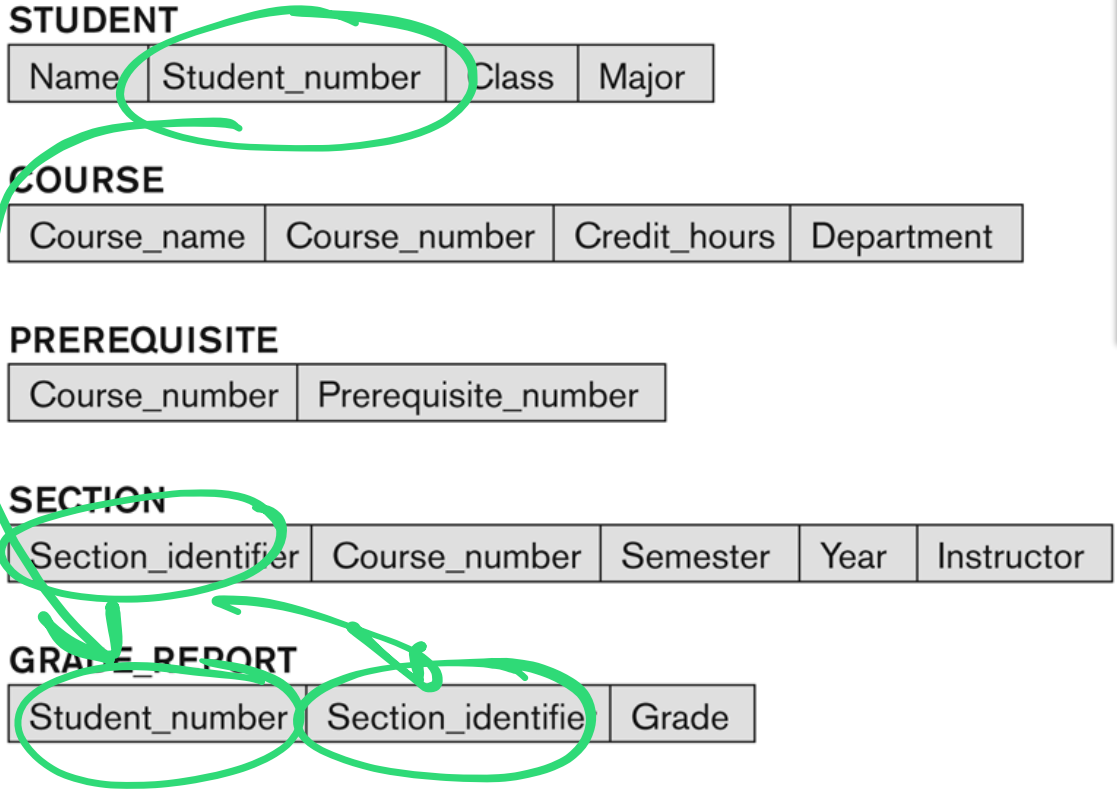
Why?

Primary Key is another type of **constraint**

- DB will enforce uniqueness of the Primary Key attributes

The magic of Databases

A database helps us **connect** multiple Relations



How are these Relations connected to each other?

Foreign Keys

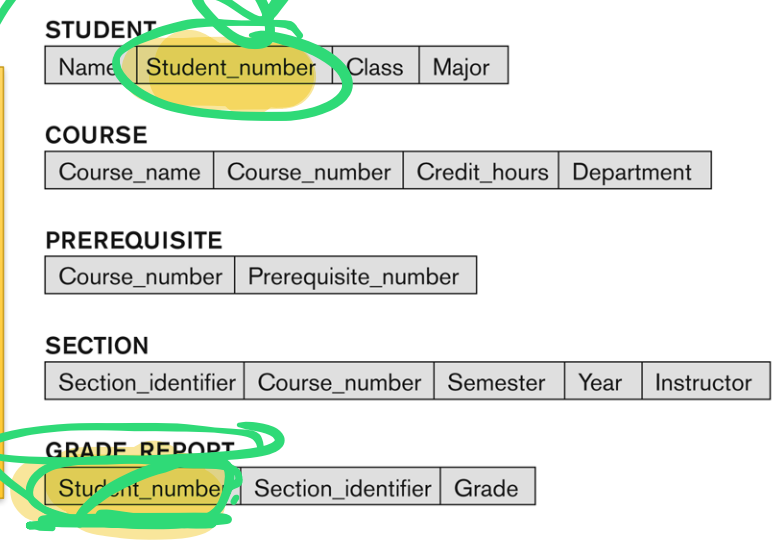
Defines a relationship connecting tuples in two relations

- The **referencing relation** and the **referenced relation**
- Defines another type of constraint - **Referential Integrity**
- **Foreign Key constraints** must connect to the Primary Key in the referenced relation

GRADE_REPORT.Student_number must match a value in **STUDENT.Student_number**

PREREQUSITE.Course_number and **Prequisite_number** must match value in **COURSE.Course_number, etc**

etc



Referential Integrity

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

- If a value of sid appears in Enrollment relation then it MUST appear in Student relation
  - "Only students can take courses"
  - Database is automatically enforcing application requirements for you… can your Array do that?

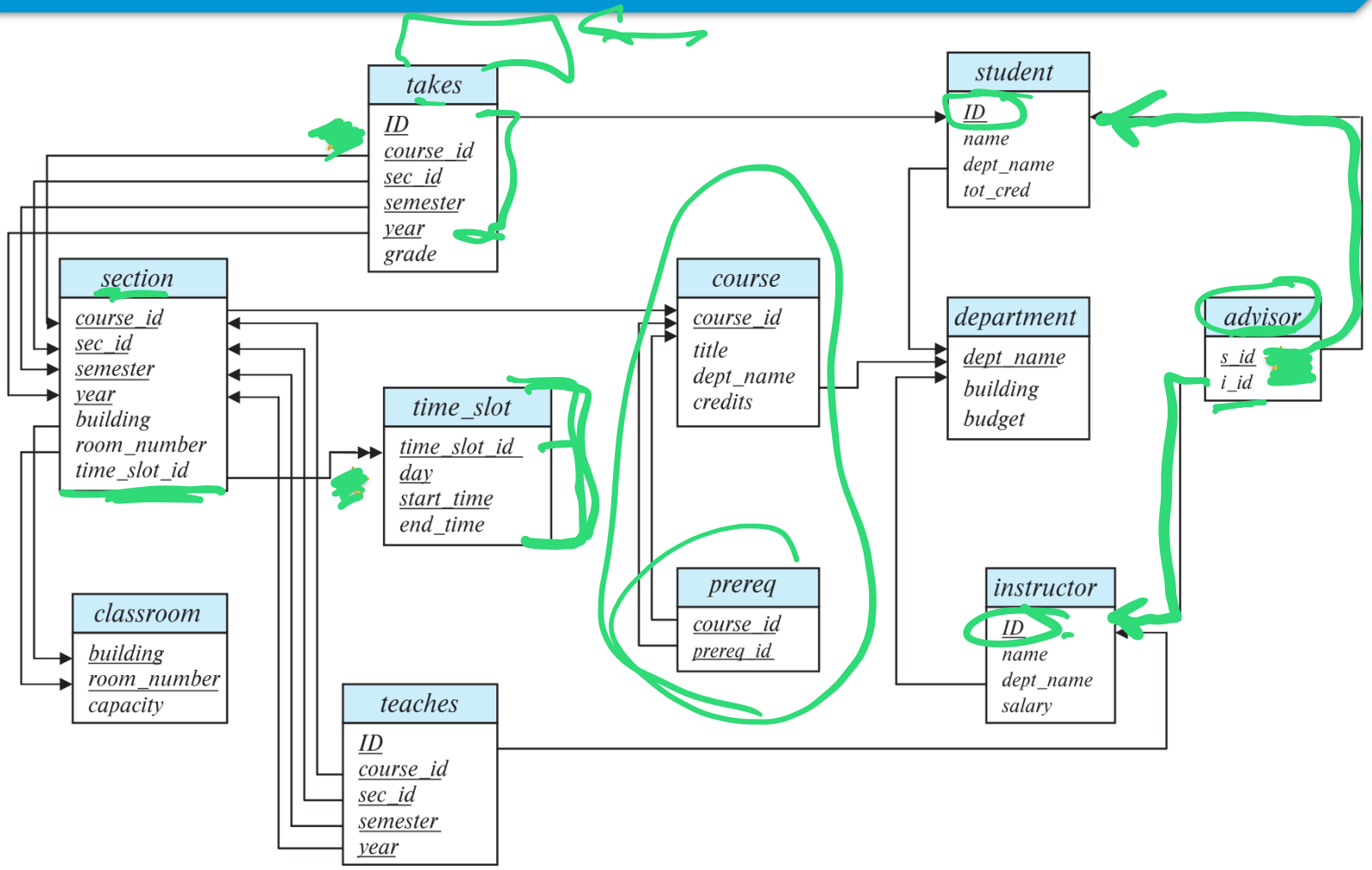
Enrollment

sid	cid	grade
53666	Jazz101	C
53666	Reggae203	B
53650	Topology112	A
53666	History105	B

Student

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

Full University Schema Diagram

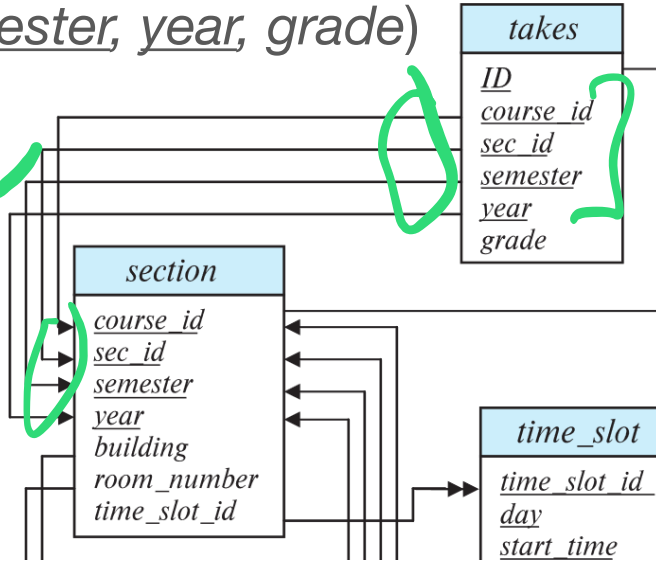


Primary Key Selection

Why do we use multiple attributes in a Primary Key?

- section(*course_id*, *sec_id*, *semester*, *year*, *building*, …)
- takes(*ID*, *course_id*, *sec_id*, *semester*, *year*, *grade*)

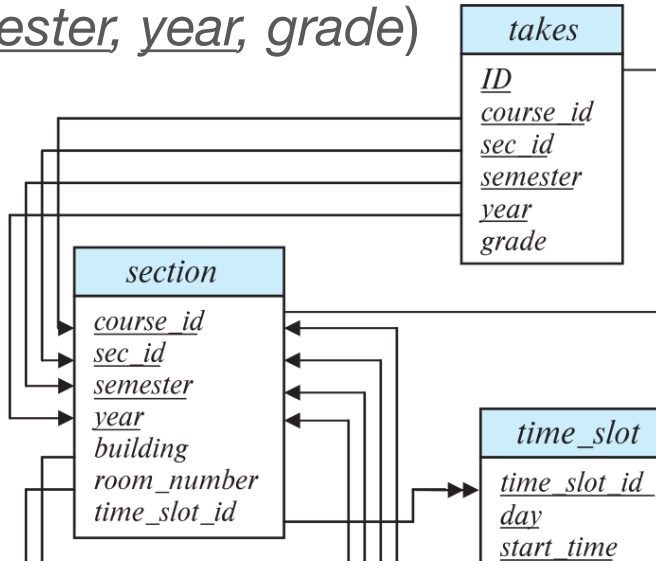
Why not just define a unique attribute like ***sec_id_number*** and use that by itself?



Primary Key Selection

Why do we use multiple attributes in a Primary Key?

- section(*course_id*, *sec_id*, *semester*, *year*, *building*, …)
- takes(*ID*, *course_id*, *sec_id*, *semester*, *year*, *grade*)



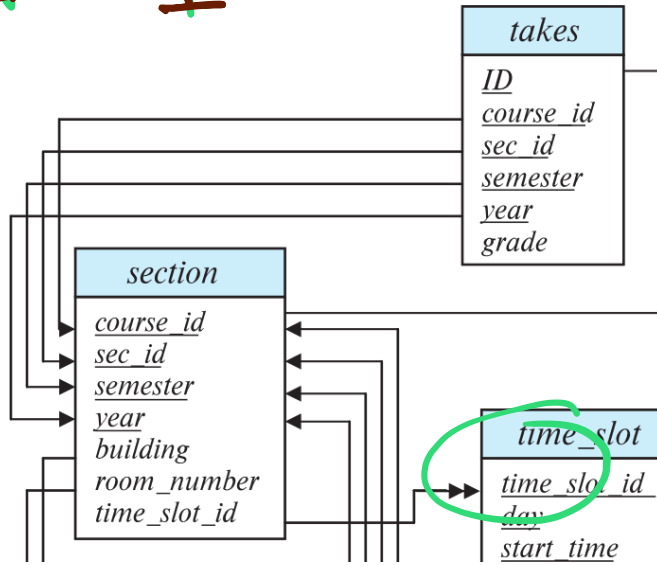
- Using a single field looks simpler, but it prevents the benefit of the DB enforcing uniqueness
- Using sec_id_number as foreign key requires us to look up info from multiple tables which may be less efficient

Primary Key Selection

Consider this:

- takes(*ID*, *course_id*, *sec_id*, *semester*, *year*, *grade*)

Does this match the "business logic" we actually want for our university? (Hint: what uniqueness will this enforce?)

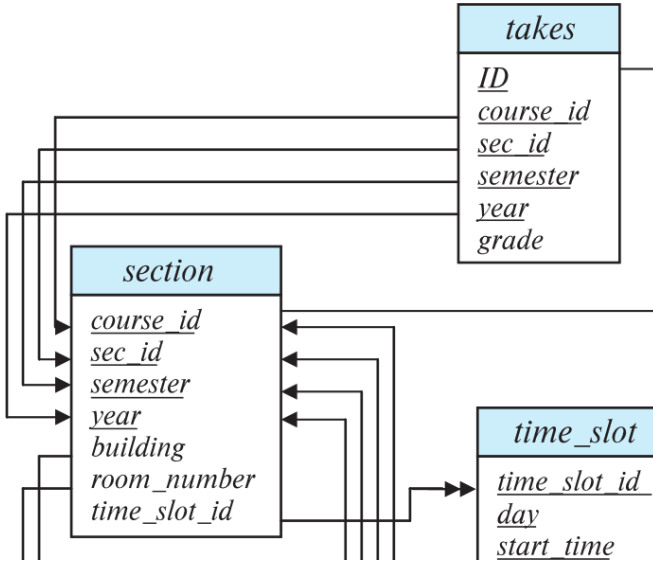


Primary Key Selection

Consider this:

- takes(*ID*, *course_id*, *sec_id*, *semester*, *year*, *grade*)

This Primary Key allows a student to be registered for multiple sections of the same course at once!



But if we remove *sec_id*, then we will not have a complete Foreign Key!

- We must match all fields in the other relation's PK to qualify as a Foreign Key
- In practice, many SQL DBs don't support Referential Integrity without a complete Foreign Key

Relational Model Definitions

Constraints and Relationships

Lab!

onwards…