Using a DBMS

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DBMS ≠ Database

- A database is a collection of your data stored in a computer
- A DBMS (DataBase Management System) is a software that manages databases

Outline

- Main Features of a DBMS
- Data Models

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Why not file systems?

Advantages of a Database System

- It answers ***queries*** fast
  - E.g., among all posts, find those written by Bob and contain word “db”
- Groups modifications into ***transactions*** such that either all or nothing happens
  - E.g., money transfer
- Recovers from crash
  - Modifications are logged
  - No corrupt data after recovery

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Queries

Q: find ID and text of all pages written by Bob and containing word “db”

Step1: structure data using ***tables***

users

id	name	karma
729	Bob	35
730	John	0

posts

Column/field

id	text	ts	authorId
33981	‘Hello DB!’	1493897351	729
33982	‘Show me code’	1493854323	812

Row/record

Queries

Q: find ID and text of all pages written by Bob and containing word “db”

Step2:

```
SELECT p.id, p.text
FROM posts AS p, users AS u
WHERE u.id = p.authorId
      AND u.name='Bob'
      AND p.text ILIKE '%db%';
```

users

id	name	karma
729	Bob	35
730	John	0

posts

id	text	ts	authorId
33981	‘Hello DB!’	1493897351	729
33982	‘Show me code’	1493904323	812

How Is a Query Answered?

```
SELECT p.id, p.text
FROM posts AS p, users AS u
WHERE u.id = p.authorId
      AND u.name='Bob'
      AND p.text ILIKE '%db%';
```

(p, u)

p.id	p.text	p.ts	p.authorId	u.id	u.name	u.karma
33981	'Hello DB!'	…	729	729	Bob	35
33981	'Hello DB!'	…	729	730	John	0
33982	'Show me code'	…	812	729	Bob	35
33982	'Show me code'	…	812	730	John	0

p

id	text	ts	authorId
33981	'Hello DB!'	…	729
33982	'Show me code'	…	812

u

id	name	karma
729	Bob	35
730	John	0

How Is a Query Answered?

```
SELECT p.id, p.text
FROM posts AS p, users AS u
WHERE u.id = p.authorId
      AND u.name='Bob'
      AND p.text ILIKE '%db%';
```

where(p, u)

p.id	p.text	p.ts	p.authorId	u.id	u.name	u.karma
33981	'Hello DB!'	…	729	729	Bob	35

(p, u)

p.id	p.text	p.ts	p.authorId	u.id	u.name	u.karma
33981	'Hello DB!'	…	729	729	Bob	35
33981	'Hello DB!'	…	729	730	John	0
33982	'Show me code'	…	812	729	Bob	35
33982	'Show me code'	…	812	730	John	0

How Is a Query Answered?

```
SELECT p.id, p.text
FROM posts AS p, users AS u
WHERE u.id = p.authorId
      AND u.name='Bob'
      AND p.text ILIKE '%db%';
```

select(where(p, u))

p.id	p.text
33981	'Hello DB!'

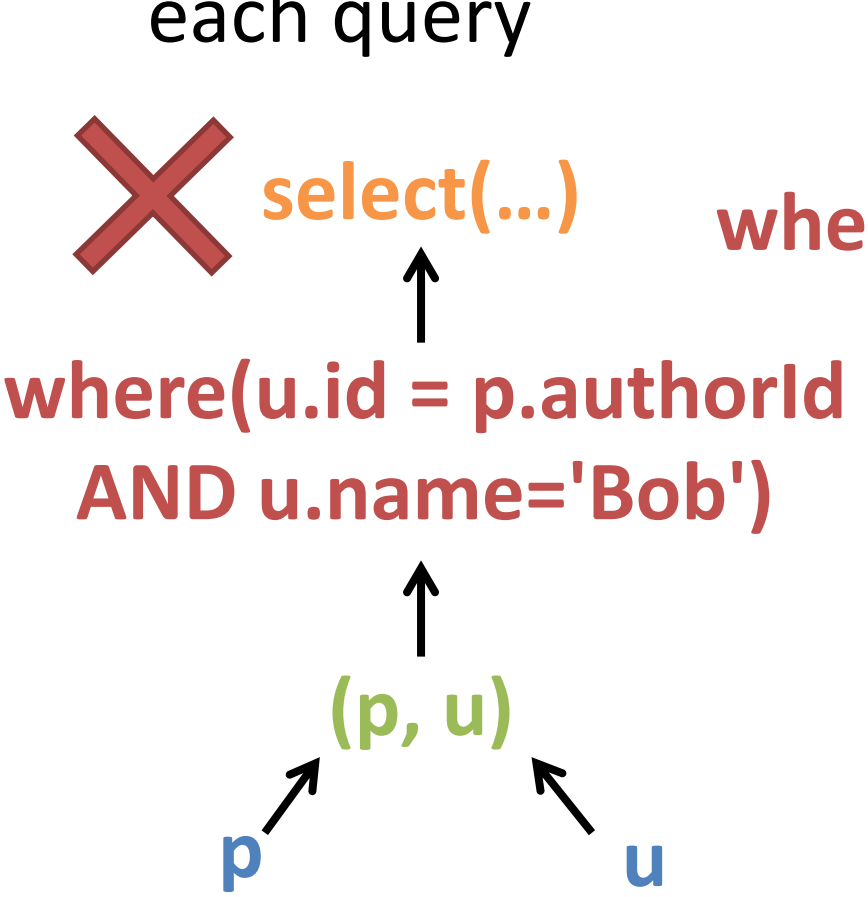
where(p, u)

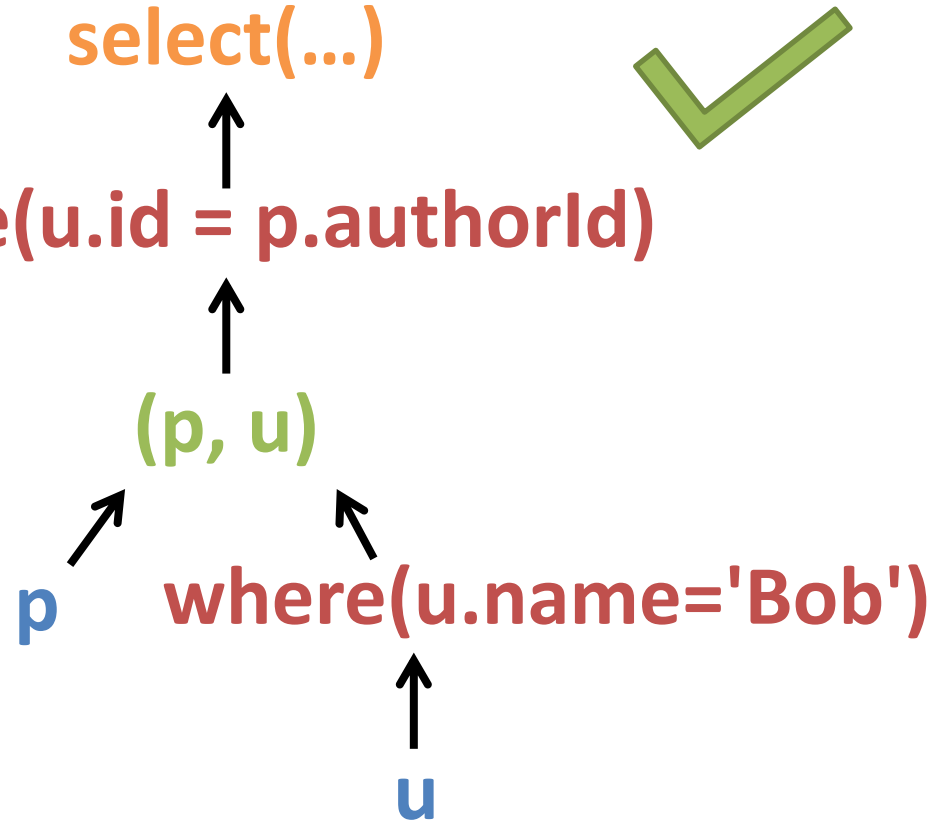
p.id	p.text	p.ts	p.authorId	u.id	u.name	u.karma
33981	'Hello DB!'	...	729	729	Bob	35

Why fast?

Query Optimization

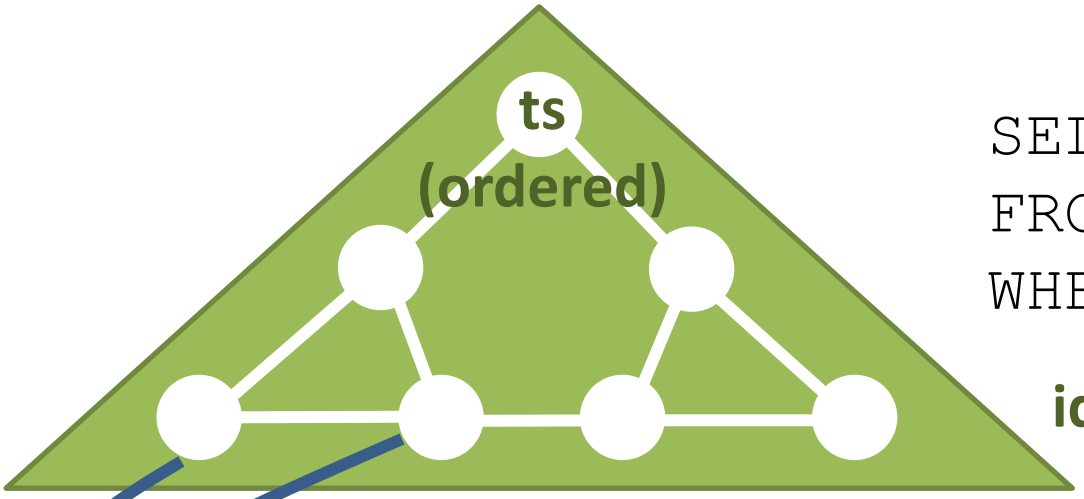
- ***Planning***: DBMS finds the best ***plan tree*** for each query





Query Optimization

- ***Indexing***: creates a search tree for column(s)




```
SELECT text
FROM posts
WHERE ts > 1493897220;
```

idx_ts

posts

id	text	ts	authorId
1	‘Good day’	1493880220	664
…	…	…	…
33981	‘Hello DB!’	1493897351	729
33982	‘Show me code’	1493904323	812

Advantages of a Database System

- It answers ***queries*** fast
  - E.g., among all posts, find those written by Bob and contain word "db"
- Groups modifications into ***transactions*** such that either all or nothing happens
  - E.g., money transfer
- Recovers from crash
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Transactions I

- Each query, by default, is placed in a ***transaction*** (***tx*** for short) automatically

```
BEGIN;
  SELECT ...; -- query
COMMIT;
```

Transactions II

- Can group multiple queries in a tx
  - ***All or nothing*** takes effect
- E.g., karma transfer

users

id	name	karma
729	Bob	35
730	John	0

```
BEGIN;
  UPDATE users
  SET karma = karma - 10
  WHERE name='Bob';

  UPDATE users
  SET karma = karma + 10
  WHERE name='John';
COMMIT;
```

ACID Guarantees

- ***Atomicity***
  - Operation are all or none in effect
- ***Consistency***
  - Data are correct after each tx commits
  - E.g., `posts.authorId` must be a valid `users.id`
- ***Isolation***
  - Concurrent txs = serial txs (in some order)
- ***Durability***
  - Changes will not be lost after a tx commits (even after crashes)

Outline

- Main Features of a DBMS
- Data Models

Why model data as ***tables***?

users

id	name	karma
729	Bob	35
730	John	0

posts

id	text	ts	authorId
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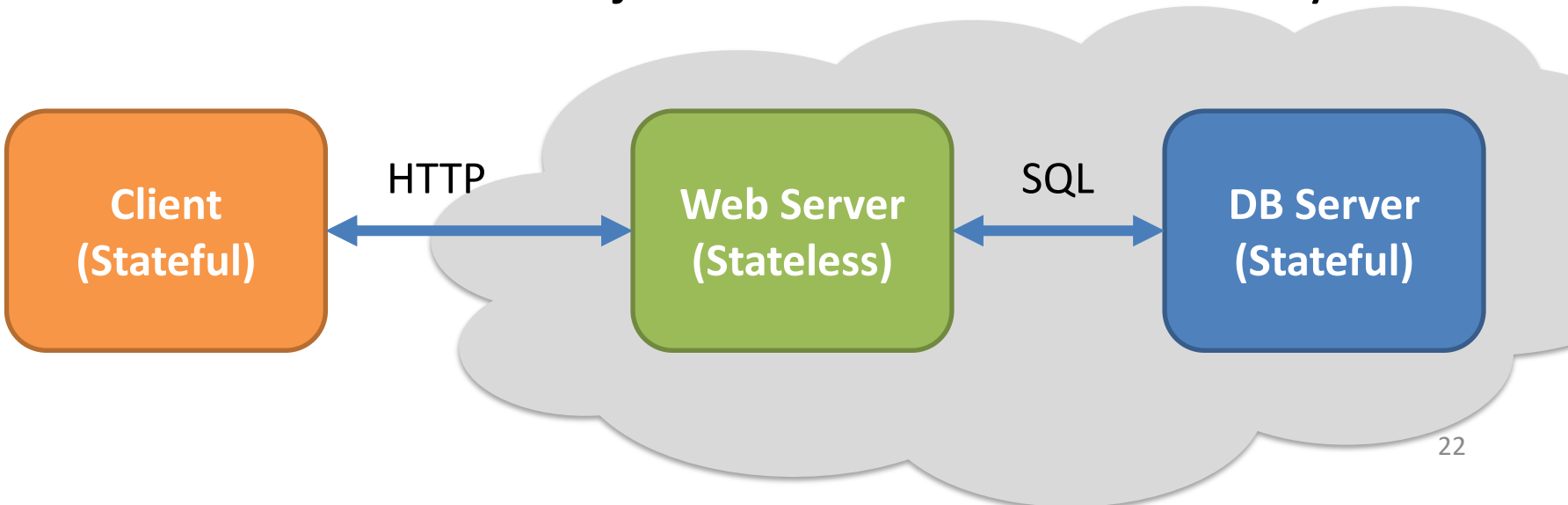
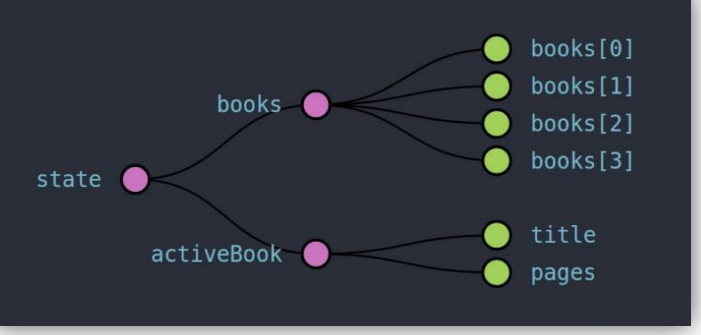
Storing Data

- Let's say, you have data/states in memory to store
- What do states look like?
  - Objects
  - References to objects
- Objects formatted by classes you defined
- Can we store these objects and references directly?



Data Models

- Definition: A ***data model*** is a framework for describing the structure of databases in a DBMS
- Common data models at client side:
  - Tree model
- Common data models at server side:
  - ***ER model*** and ***relational model***
- A DBMS supporting the relational model is called the relational DBMS



Tree Model

- At client side, data are usually stored as ***trees***

```
{ // state of client 1
  name: 'Bob',
  karma: 32,
  posts: [...],
  friends: [{
    name: 'Alice',
    karma: 10
  }, {
    name: 'John',
    karma: 17
  }, ...],
  ...
}
```

```
{ // state of client 2
  name: 'Alice',
  karma: 10,
  posts: [...],
  friends: [{
    name: 'Bob',
    karma: 32
  }, {
    name: 'John',
    karma: 17
  }, ...],
  ...
}
```

Problems at Server Side

- Space complexity: large ***redundancy***

```
{ // state of a client 1
  name: 'Bob',
  karma: 35,
  posts: [...],
  friends: [
    name: 'Alice',
    karma: 10
  }, {
    name: 'John',
    karma: 17
  }, ...],
  ...
}
```

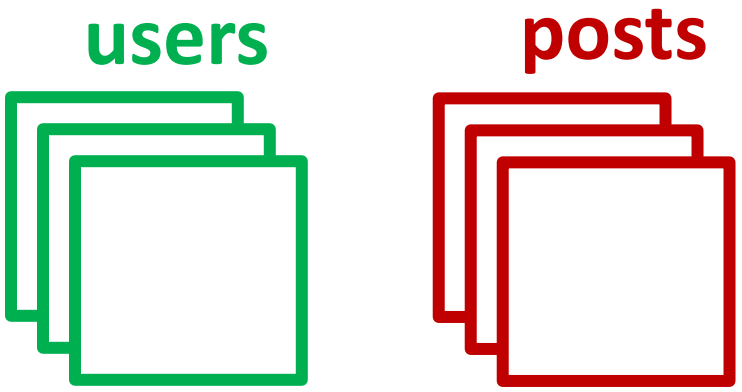
```
{ // state of a client 2
  name: 'Alice',
  karma: 10,
  posts: [...],
  friends: [{
    name: 'Bob',
    karma: 35
  }, {
    name: 'John',
    karma: 17
  }, ...],
  ...
}
```

Speed: slow update

Data Modeling at Server Side

1. Identify ***entity groups/classes***
   - Each class represents an "atomic" part of the data
2. Store entities of the same class in a ***table***
   - A rows/record denotes an entity
   - A column/field denote an attribute (e.g., "name")
3. Define ***primary keys*** for each table
   - Special column(s) that uniquely identifies an entity
   - E.g., "ID"

Identifying Entity Classes




```
{ // state of a client 1
  name: 'Bob',
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  posts: [...],
  friends: [{
    name: 'Alice',
    karma: 10
  }, {
    name: 'John'
    karma: 17
  }, ...],
  ...
}
```
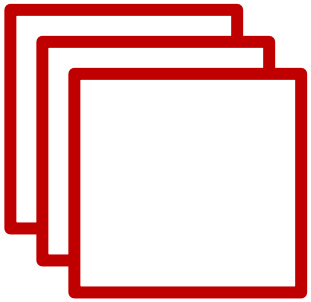

```
{ // state of a client 2
  name: 'Alice',
  karma: 10,
  posts: [...],
  friends: [{
    name: 'Bob',
    karma: 32
  }, {
    name: 'John'
    karma: 17
  }, ...],
  ...
}
```

One Table per Entity Class

id	name	karma
729	Bob	35
730	John	0



id	text
33981	‘Hello DB!’
33982	‘Show me code’

- No redundancy
- No repeated update

Wait, relationship is missing!

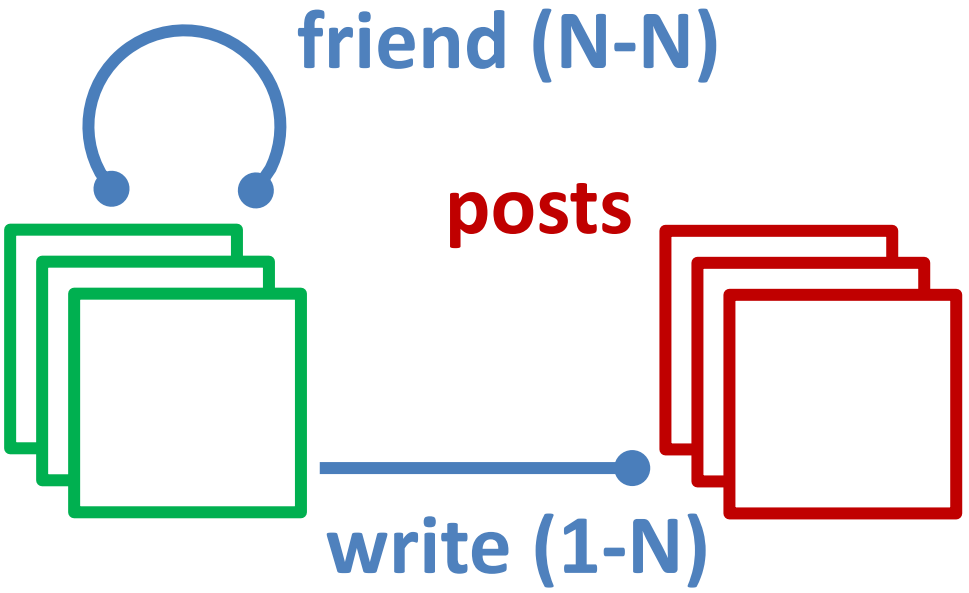
Step1 (ER Model)

```
{ // state of a client 1
  name: 'Bob',
  karma: 32,
  posts: [...],
  friends: [{
    name: 'Alice',
    karma: 10
  }, {
    name: 'John'
    karma: 17
  }, ...],
  ...
}
```

friend

write

- Identify relationships between entities



Step 2 (Relational Model)

- Relationships as ***foreign keys***

friend (N-N)

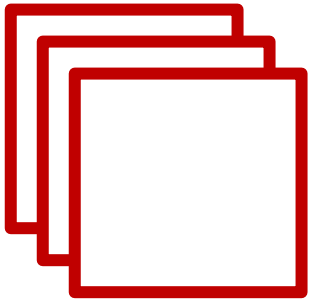
users

id	name	karma
729	Bob	35
730	John	0

friend

uId1	uId2	since
729	730	14928063
729	882	14827432

write (1-N)



foreign keys

posts

write

id	text	authorId	ts
33981	Hello DB!'	729	1493897351
33982	Show me code'	729	1493854323

Recap on Terminology

- Columns = fields = attributes
- Rows = records = tuples
- Tables = ***relations***

- Relational database: a collection of tables
  ≠ Relational DBMS
- ***Schema***: column definitions of tables in a database
  - Basically, the "look" of a database
  - Schema of a relation/table is fields and field types

Why ER Model?

- Allows thinking your data in OOP way
- ***Entity***
  - An object (or instance of a class)
  - With attributes
- ***Entity group/class***
  - A class
  - Must define the ID attribute for each entity
- ***Relationship*** between entities
  - References (“has-a” relationship)
  - Could be 1-1, 1-N, or N-N

Why Relational Model?

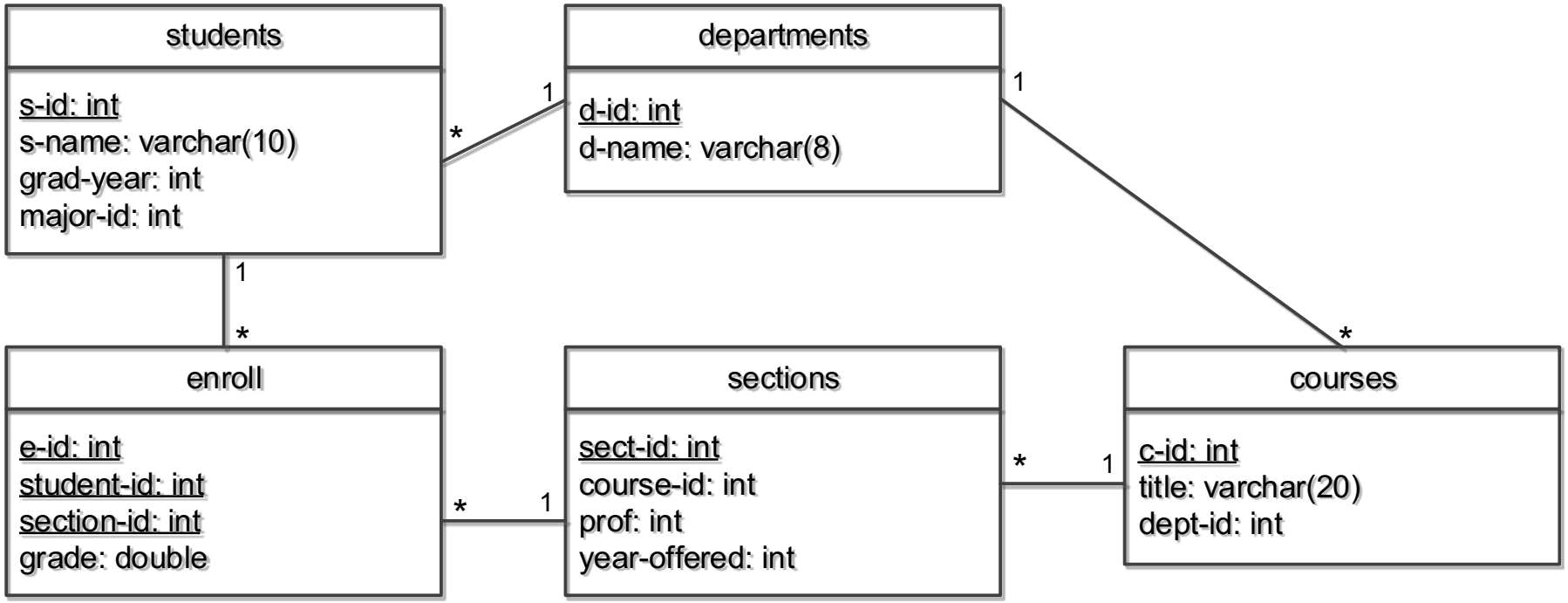
- Simplifies data management and query processing
- ***Table/relations*** for all kinds of entity classes
- ***Primary/foreign keys*** for all kinds of relationships between entities
- Relational schema is logical
  - ***Not*** how your data stored physically
  - Vs. physical schema

Exercise: Student DB

- Storing course-enrollment info in a school
  - Each department has many students and offers different courses
  - Each courses can have multiple sections (e.g., 2018 spring, 2019 fall, etc.)
  - Each students can enroll in different sections

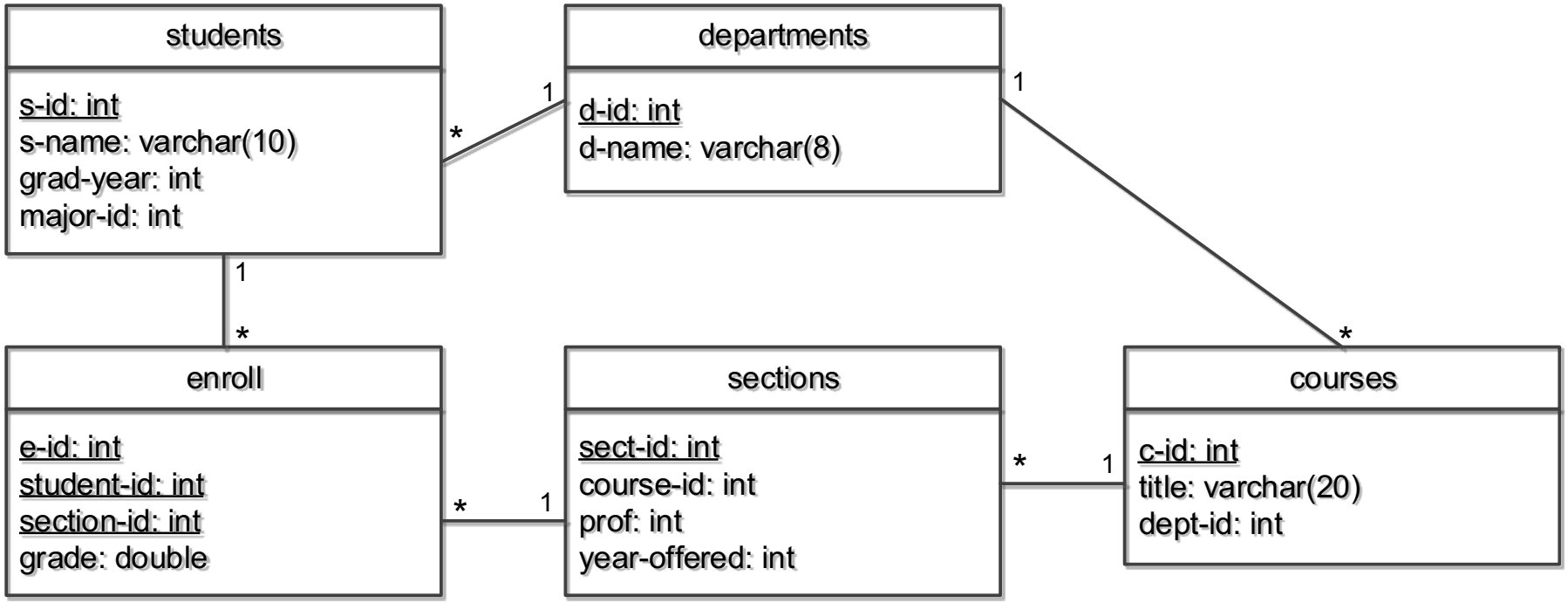
- Can you model data and draw a relational schema?

Exercise: Student DB



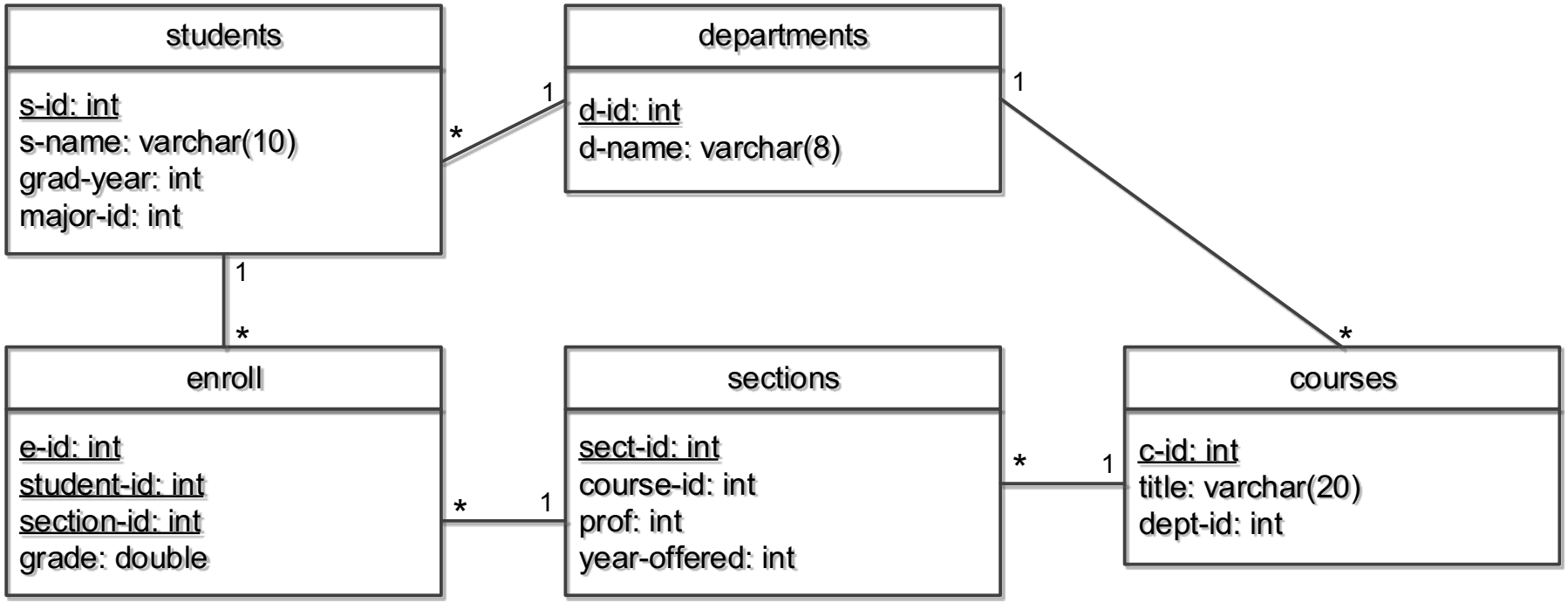
- Relation (table)
  - Realization of 1) an entity group via table; or 2) a relationship
  - ***Fields/attributes*** as columns
  - ***Records/tuples*** as rows

Exercise: Student DB



- ***Primary Key***
  - Realization of ID via a group of fields

Exercise: Student DB



- ***Foreign key***
  - Realization of relationship
  - A record can point to the primary key of the other record
  - Only 1-1 and 1-many
  - Intermediate relation is needed for many-many

Assigned Reading

- A nice SQL Tutorial

- ***We will have a quiz on SQL next Thu!***