

# 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

# Advantages of a Database System

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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

Column/field

posts

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



u



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

id	name	karma
729	Bob	35
730	John	0

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```
SELECT p.id, p.text
FROM posts AS p, users AS u
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    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
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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)

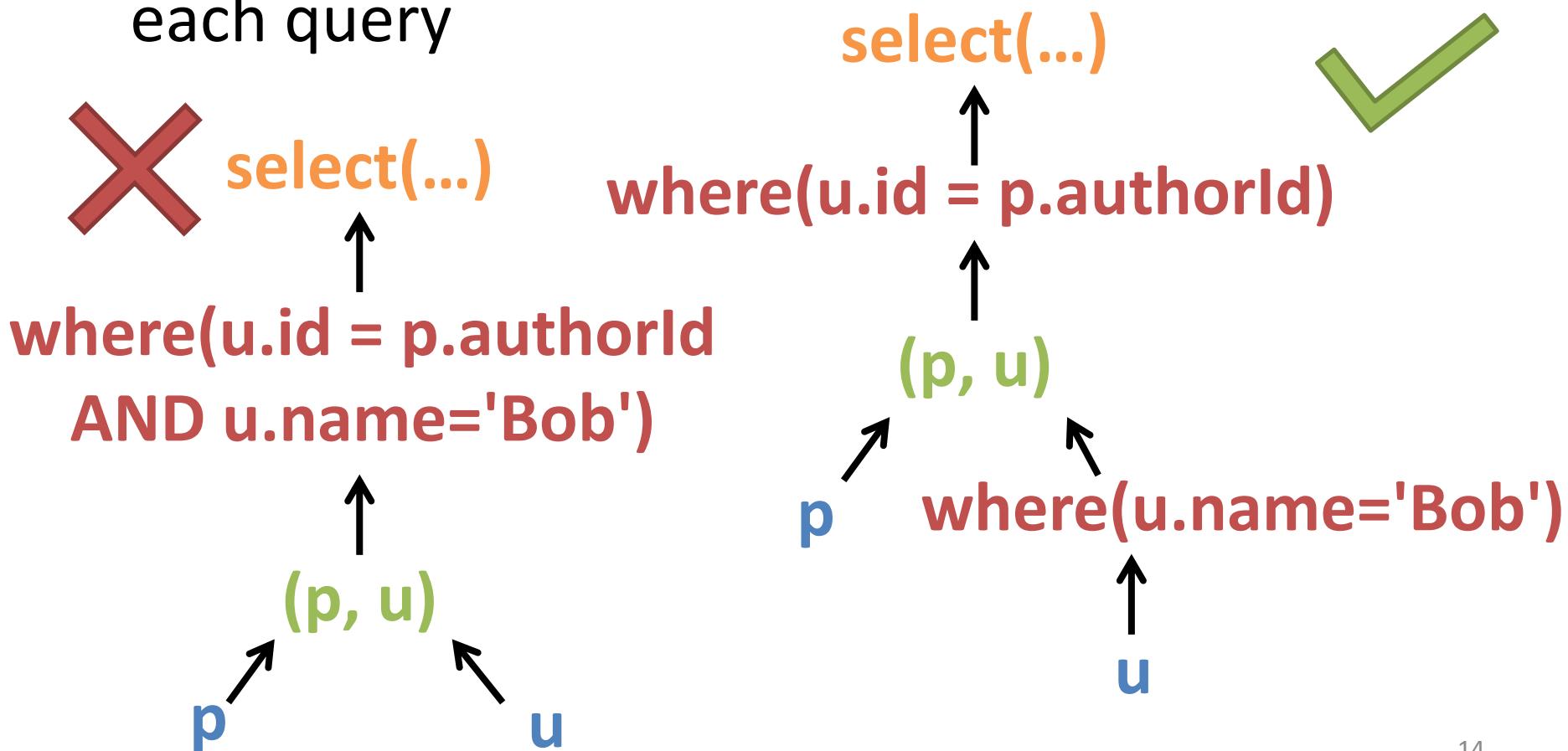


p.id	p.text	p.ts	p.authorId	u.id	u.name	u.karma
33981	'Hello DB!'	...	729	729	Bob	35

# Why fast?

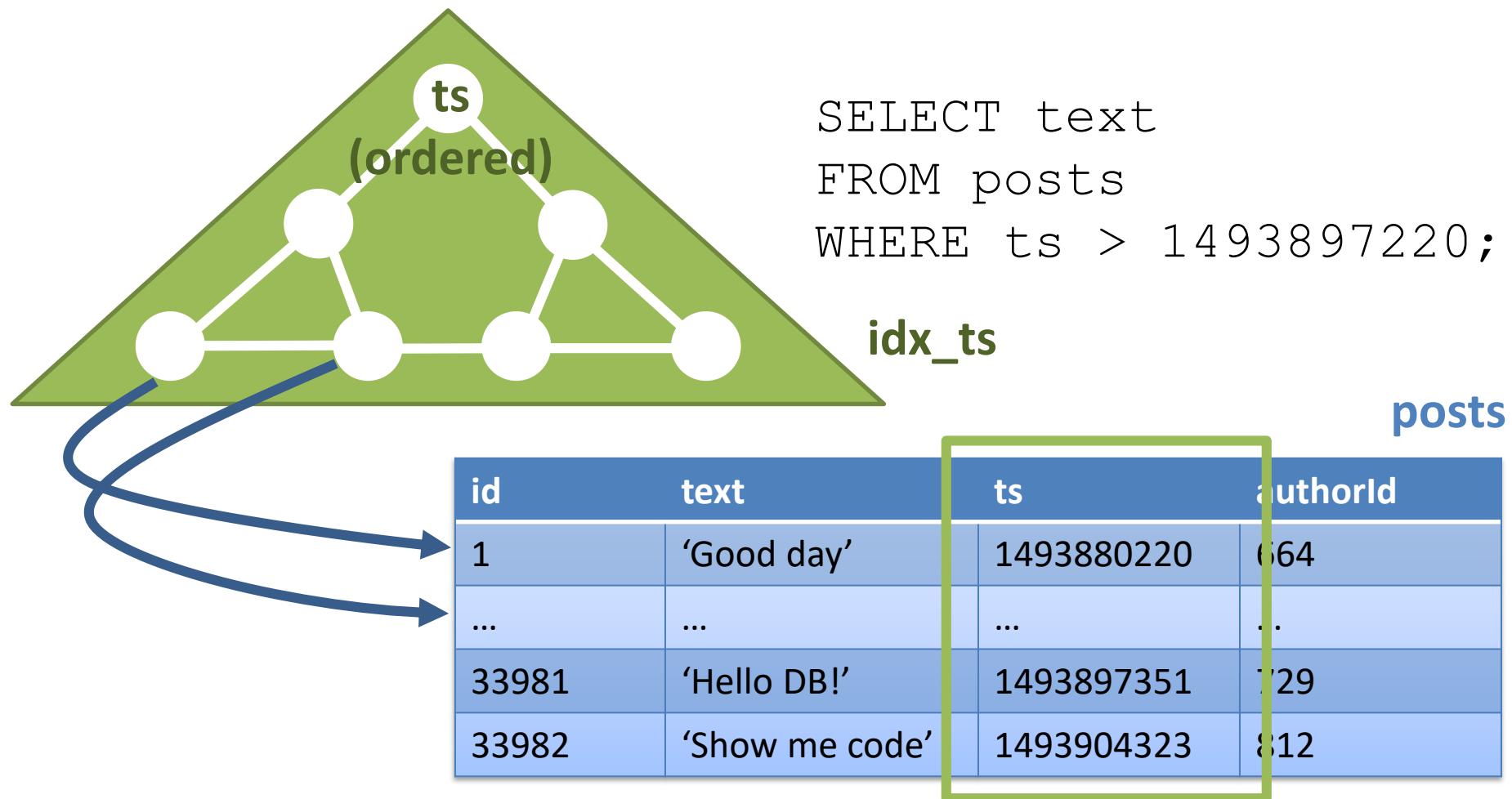
# Query Optimization

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



# Query Optimization

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



# Advantages of a Database System

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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

<b>id</b>	<b>name</b>	<b>karma</b>
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

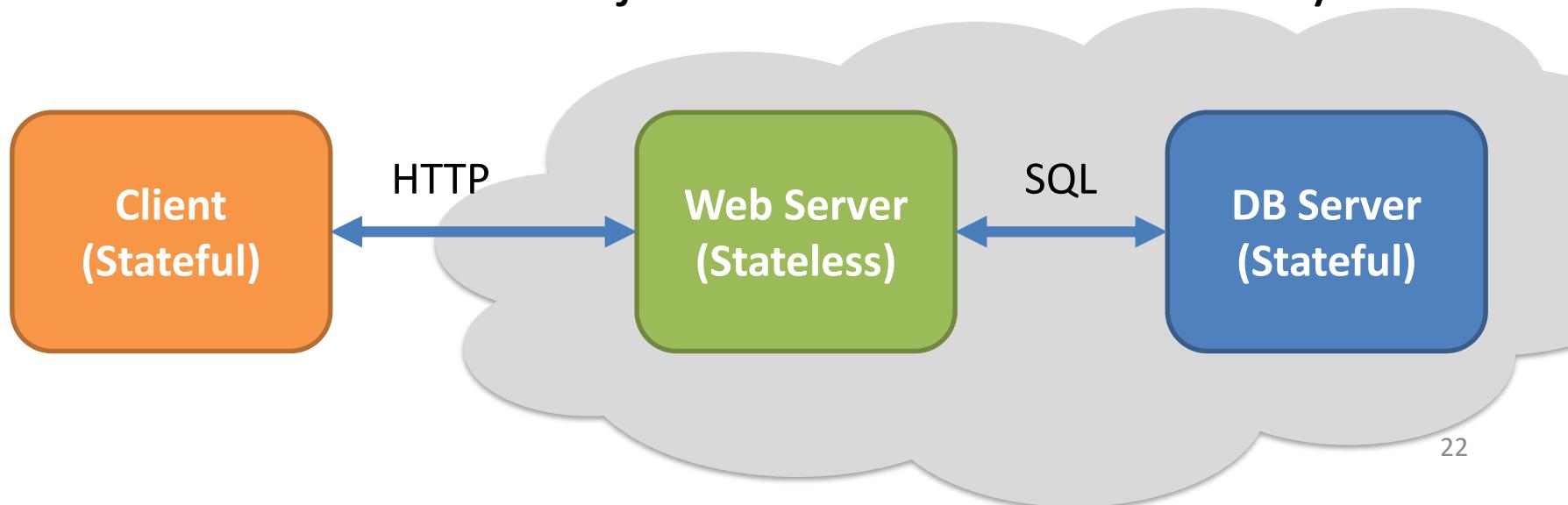
<b>id</b>	<b>name</b>	<b>karma</b>
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posts

<b>id</b>	<b>text</b>	<b>ts</b>	<b>authorId</b>
33981	'Hello DB!'	1493897351	729
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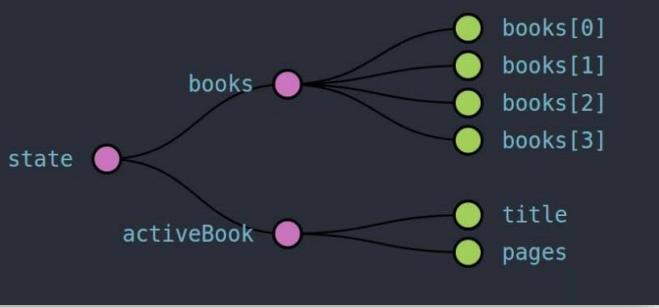
# Storing Data

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

}

# Problems at Server Side

- Space complexity: large *redundancy*

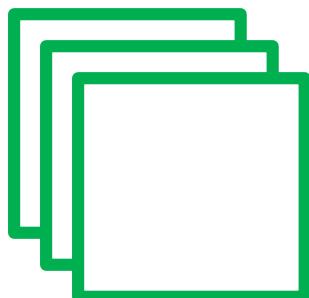
```
{ // state of a client 1           { // state of a client 2
  name: 'Bob',                   name: 'Alice',
  karma: 35,                     karma: 10,
  posts: [...],                 posts: [...],
  friends: [                     friends: [
    {                           {                           ...
      name: 'Alice',             name: 'Bob',
      karma: 10                 karma: 35
    }, {                         },
      name: 'John',             name: 'John',
      karma: 17                 karma: 17
    }, ...],                   ...],
    ...
  }
}
```

**Speed: slow update**

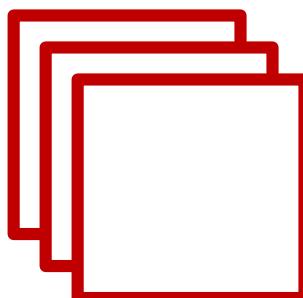
# Data Modeling at Server Side

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”

users



posts

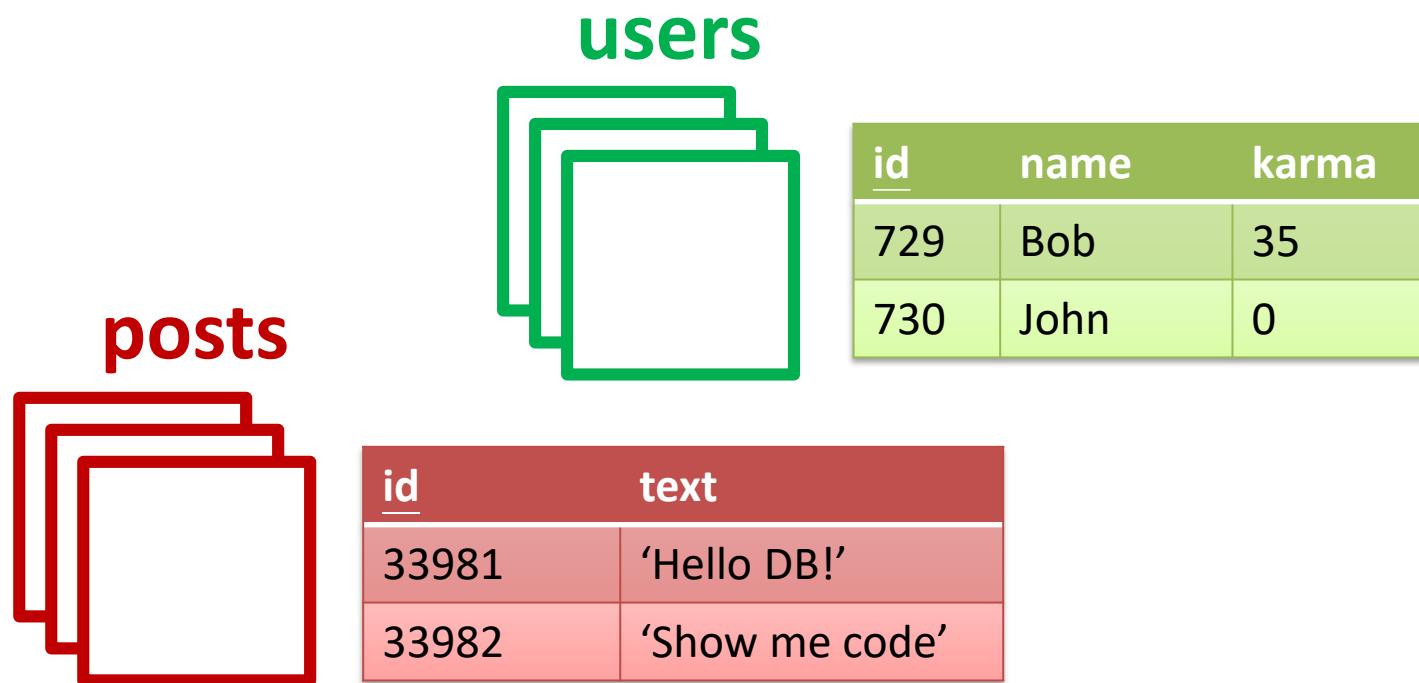


```
{ // state of a client 1
  name: 'Bob',
  karma: 32,
  posts: [ ... ],
  friends: [ {
    name: 'Alice',
    karma: 10
  },
  {
    name: 'John',
    karma: 17
  },
  ...
],
  ...
}
```

# Identifying Entity Classes

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

# One Table per Entity Class



- No redundancy
- No repeated update

Wait, relationship is missing!

```

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

```

**friend**

**write**

## Step1 (ER Model)

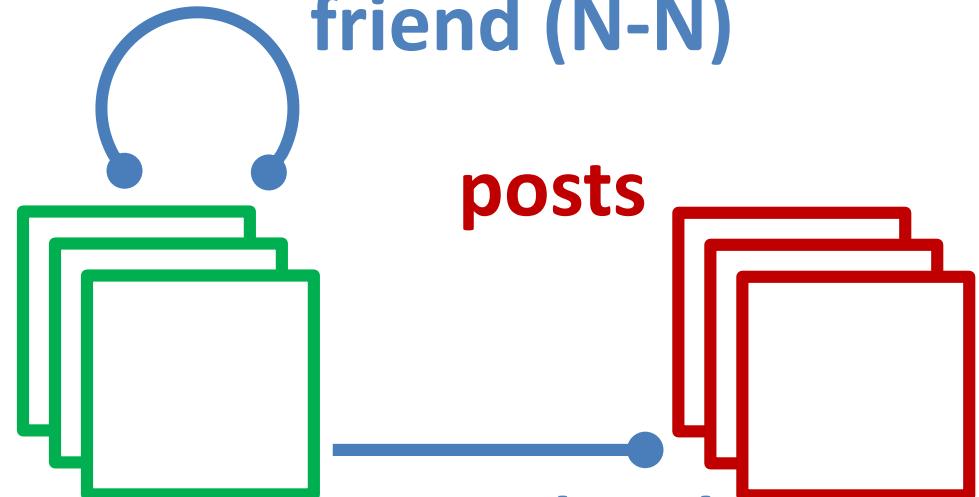
- Identify relationships between entities

**users**

**friend (N-N)**

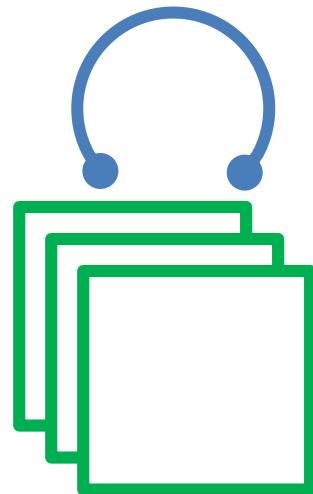
**posts**

**write (1-N)**



## Step 2 (Relational Model)

friend (N-N)



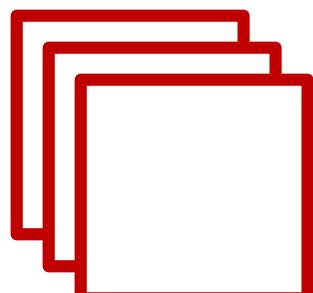
users

<u>id</u>	name	karma
729	Bob	35
730	John	0

friend

<u>uld1</u>	<u>uld2</u>	since
729	730	14928063
729	882	14827432

write (1-N)



posts

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

- Relationships as *foreign keys*

foreign keys

write

# 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

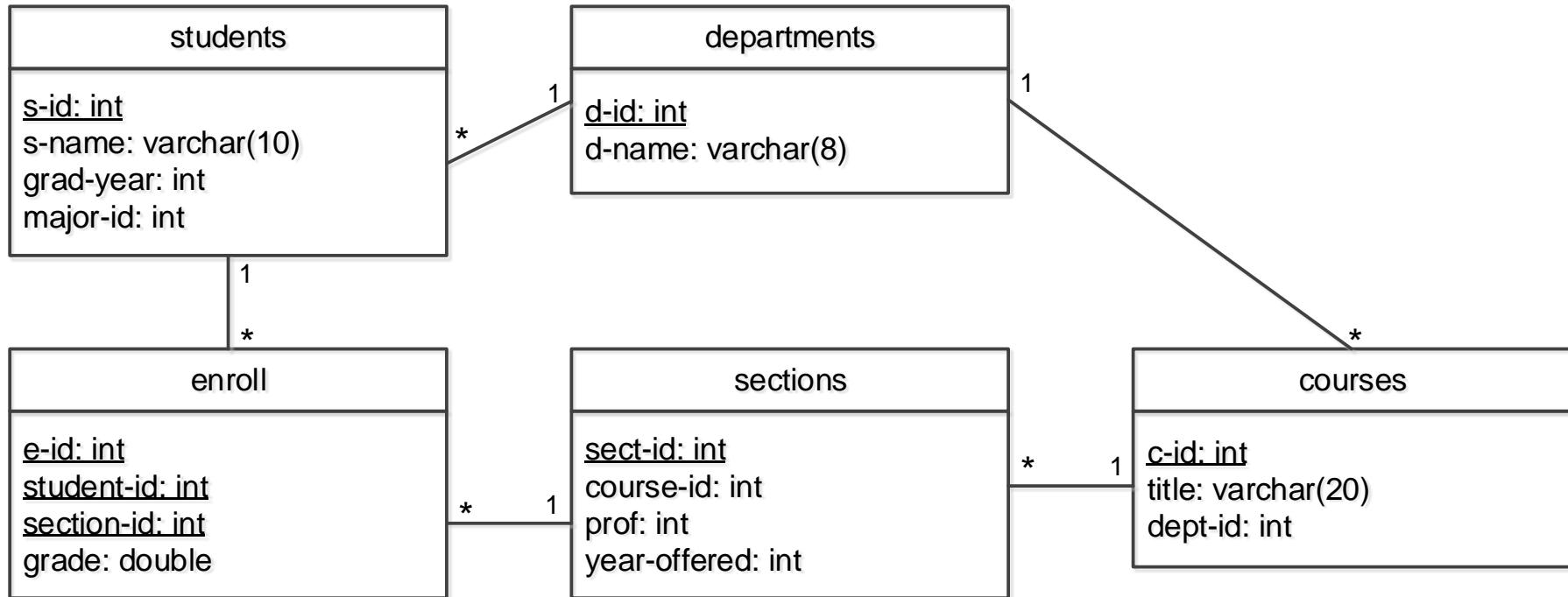
# Why Relational Model?

- 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

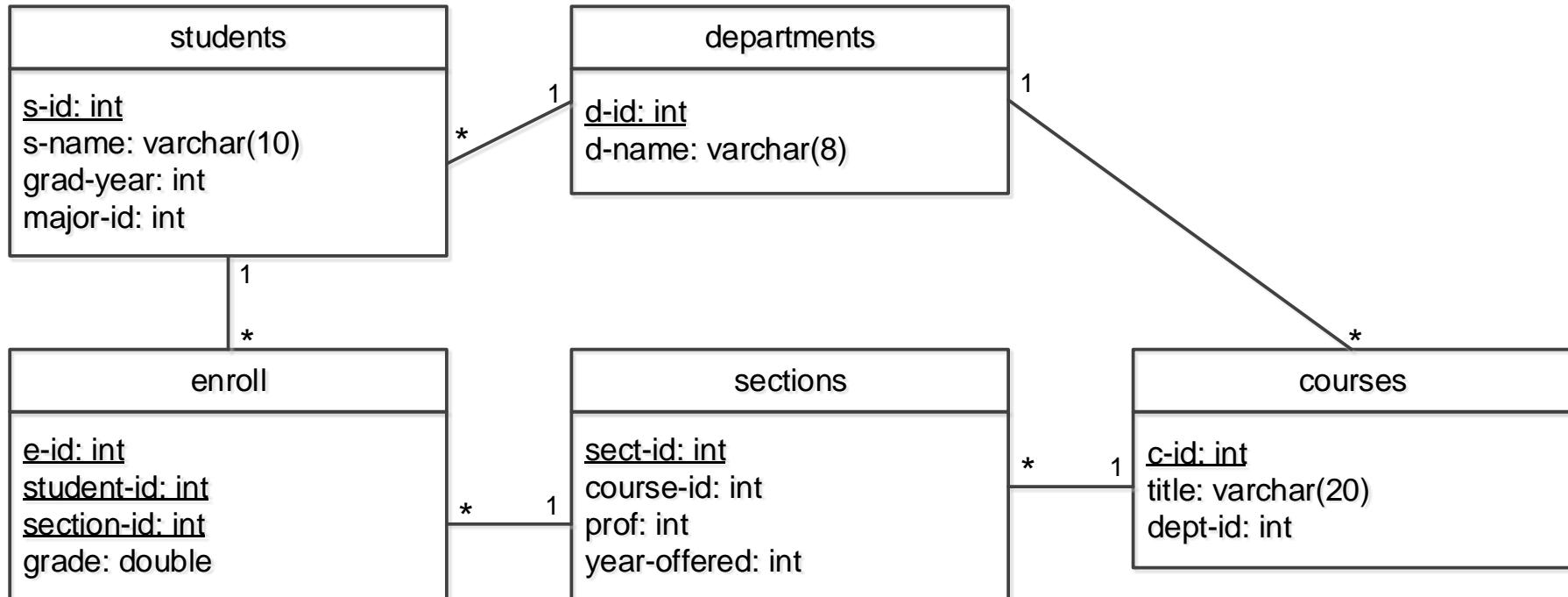
- Storing course-enrollment info in a school
  - Each department has many students and offers different courses
  - Each courses can have multiple sections (e.g., 2018 spring, 2019 fall, etc.)
  - Each students can enroll in different sections
- Can you model data and draw a relational schema?

# Exercise: Student DB



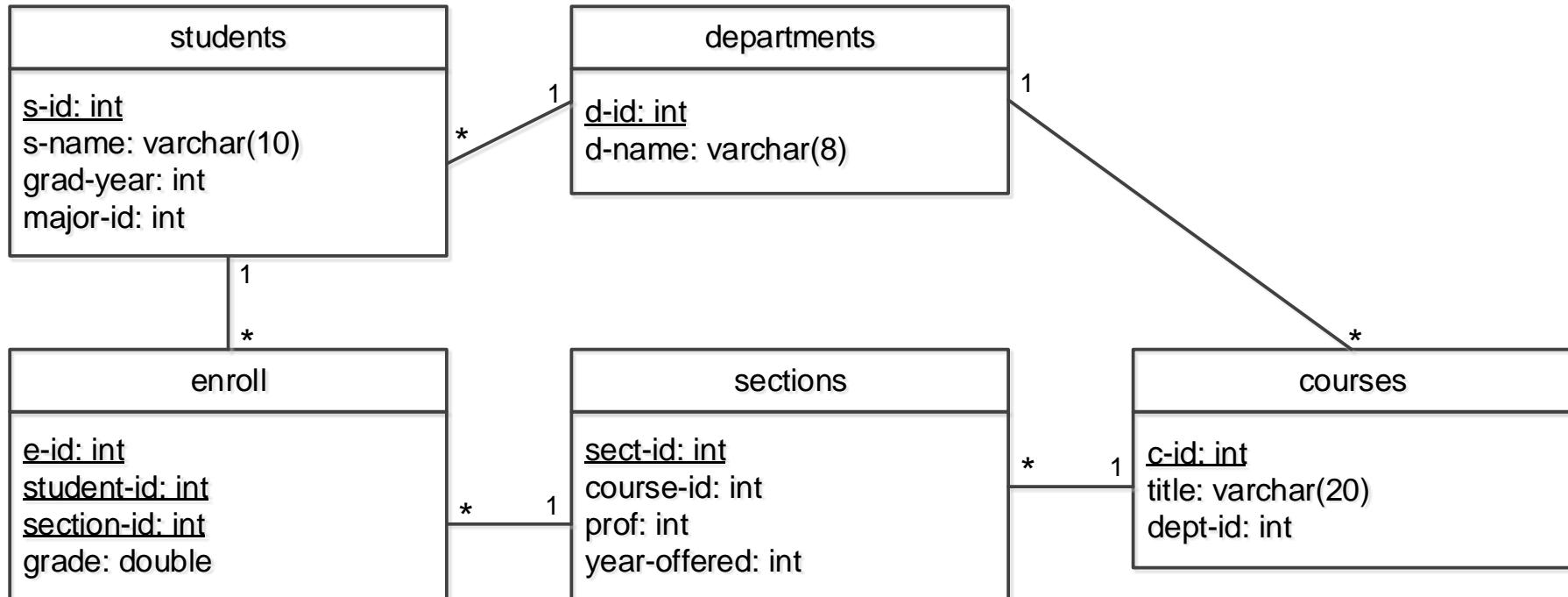
- Relation (table)
  - Realization of 1) an entity group via table; or 2) a relationship
  - **Fields/attributes** as columns
  - **Records/tuples** as rows

# 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 Wed!