Database Systems
(資料庫系統)

September 20, 2004

Lecture #2

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Course Administration

- Can everyone get the textbook?
- HW #1 is out on the course homepage
  - It is due one week from today.
- Next week reading:
  - R&G Chapters 4.1~4.2 & 5

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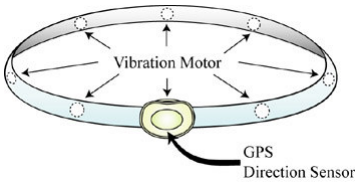
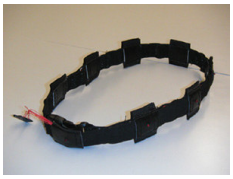
Ubicomp Project of the Week: ActiveBelt (Keio University)

- Obtain directional information with tactile (touch) display.
- Why is better than visual & audio displays?
  - Free your eyes & ears
  - Won't look lost
  - Better direction





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Chapter 2
Introduction to Database Design

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Database Design

- Step 1: Requirements Analysis
  - Discuss what data to store in the database.
  - Discuss what application (e.g., queries, updates, ..) needs from the database.
- Step 2: Conceptual Database Design
  - Come up with the design
  - The **Entity-Relation (ER) model** is the most popular data model.
  - The E/R model allows us to sketch the design of a database informally using pictures called *entity-relationship diagrams*.
- Step 3: Logical Database Design
  - Implement the design
  - The **relational data model** is the most popular data model.
  - Easy to map ER diagrams into logical schema (in the relational data model) -> CH 3.

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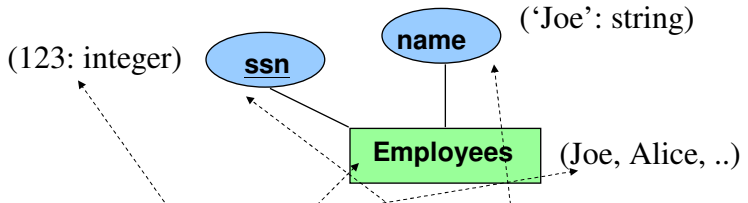
ER Model: Entity



- Proposed by Peter Chen (BS NTU EE '68) in 1976.
- **Entity**: Real-world object distinguishable from other objects (e.g., Joe).
- An entity is described by a set of **attributes**.
  - Each attribute has a **domain** of possible values.
- **Entity Set**: a collection of similar entities
- Each entity in an entity set is uniquely identified by a **key** attribute.

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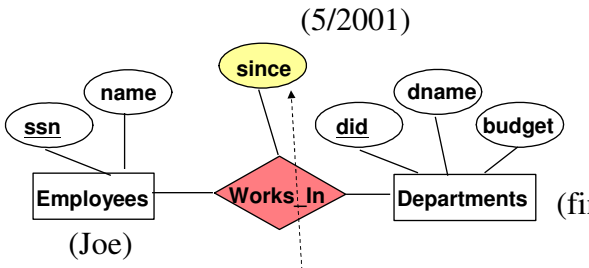
ER Model: Relationship



- **Relationship**: Association among two or more entities
  - Joe works in finance department.
- A relationship can have **description attributes**.
  - Joe has worked in finance department since 5/2001.
- **Relationship Set:** Collection of similar relationships.

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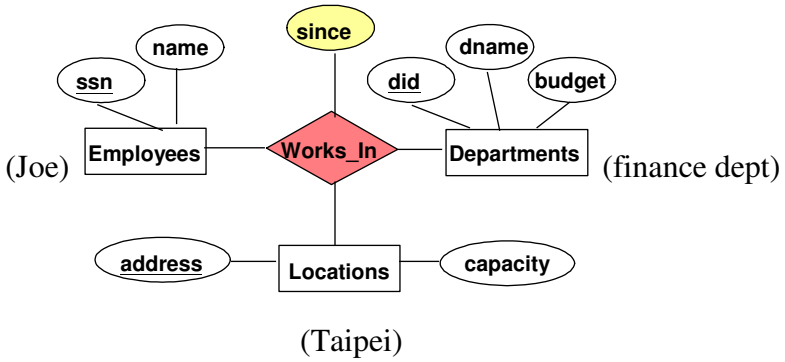
Ternary Relationship



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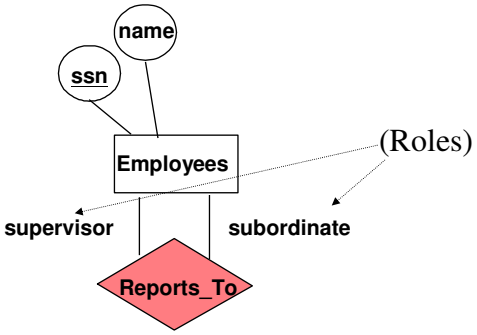
Roles in Relationship



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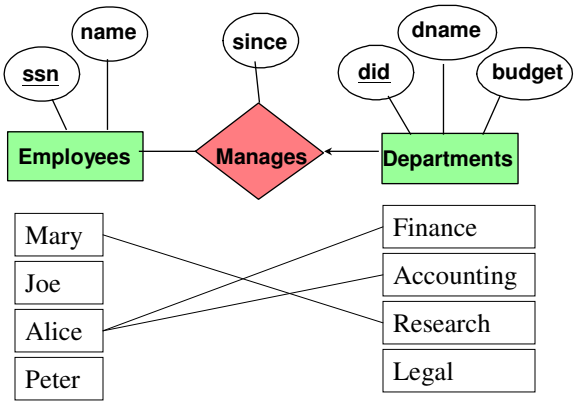
Key Constraints

- It can describe Manages relationship that each department has at most one manager.
  - One department can appear **at most once** in Manages relationship set, also called **one-to-many** relation.



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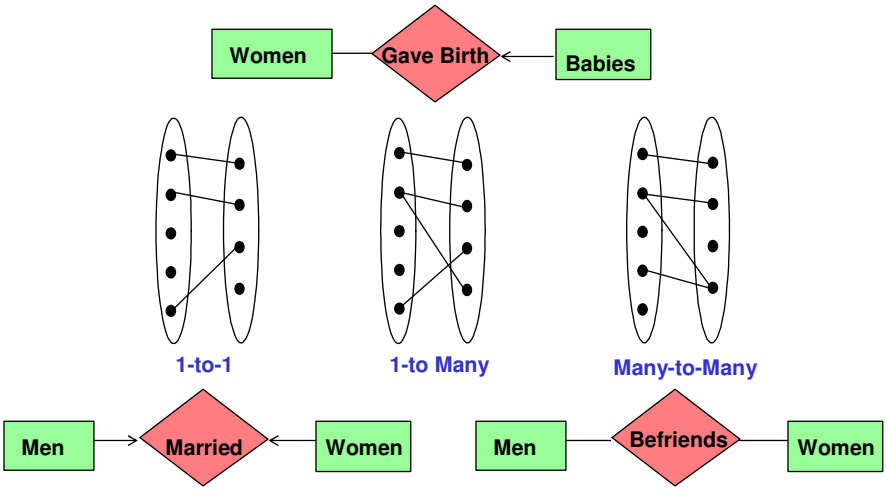
More Key Constraints



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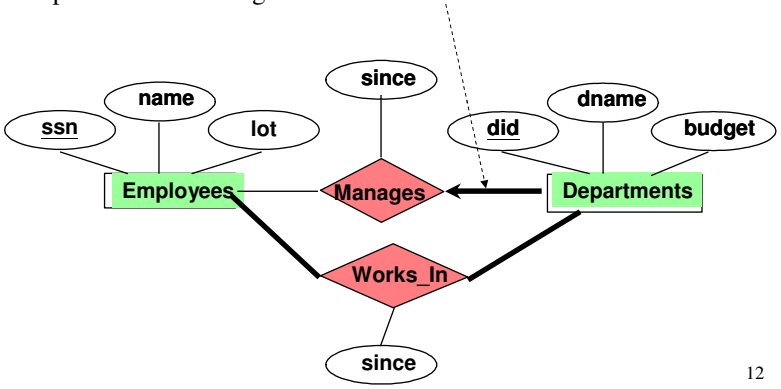
Participation Constraints

- Must every department have a manager?
  - If yes, this is a **participation constraint**: the participation of Departments in Manages is said to be **total**.



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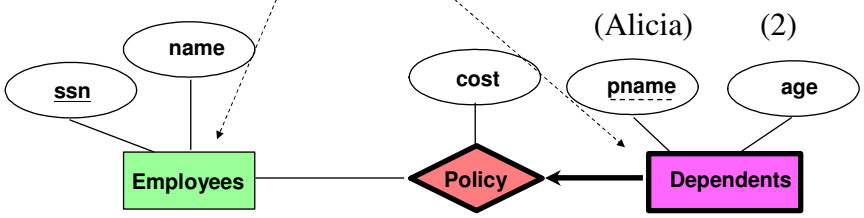
Weak Entities

- A **weak entity** can be identified uniquely only by considering the key of another **(owner) entity**.
  - Pname = partial key
  - Owner entity set and weak entity set must participate in a one-to-many relationship set (one owner, many weak entities).
  - Weak entity set must have total participation in this identifying relationship set.



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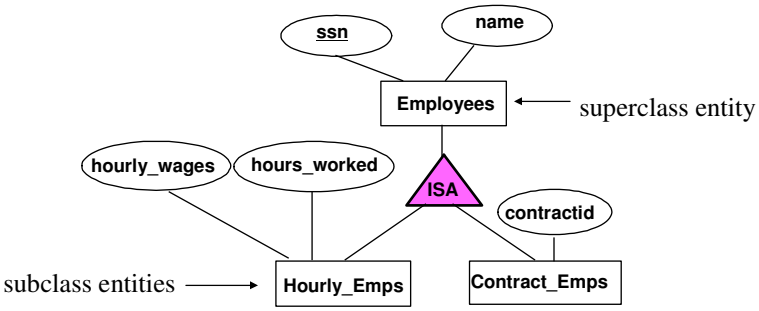
ISA (`is a') Hierarchies



- As in C++ and OO languages, attributes are inherited from superclass. If we declare A **ISA** B, every A entity is also considered to be a B entity.
- Reason for using ISA:
  - Add descriptive attributes specific (make sense) to a subclass.
  - Identify entities that participate in a relationship.

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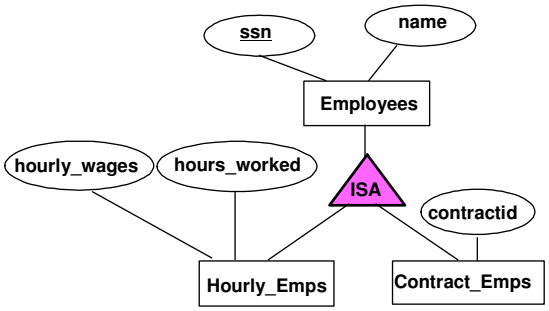
ISA (`is a') Constraints



- **Overlap constraints:** Can Joe be an Hourly_Emps as well as a Contract_Emps entity? (**Allowed/disallowed**)
- **Covering constraints**: Does every Employees entity also have to be an Hourly_Emps or a Contract_Emps entity? **(Yes/no)**

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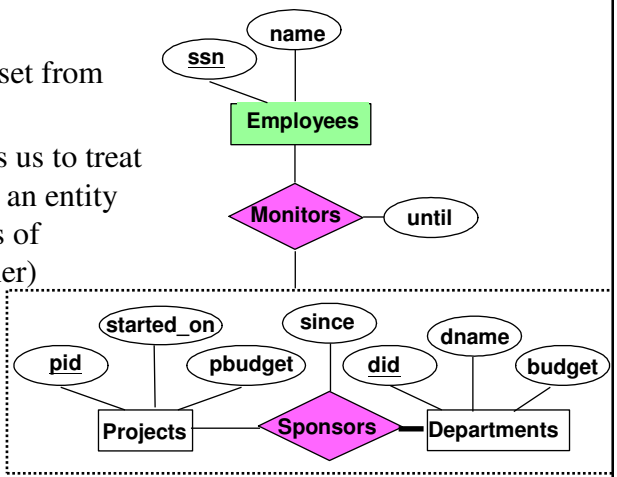
Aggregation

- Create relationship set from relationship sets.
- **Aggregation** allows us to treat a relationship set as an entity set, for the purposes of participation in (other) relationships.



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Design Techniques

1. Avoid redundancy.
2. Don't use an entity set when an attribute will do.
3. Limit the use of weak entity sets.

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Avoiding Redundancy

- Redundancy occurs when we say the same thing in two different ways.
- Redundancy wastes space and (more importantly) encourages inconsistency.
  - The two instances of the same fact may become inconsistent if we change one and forget to change the other, related version.

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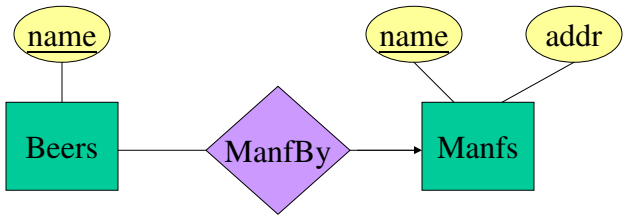
Example: Good



This design gives the address of each manufacturer exactly once.

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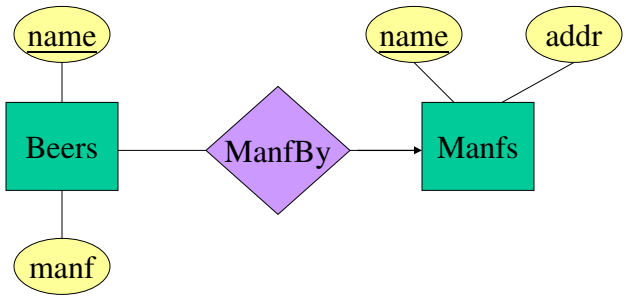
Example: Bad



This design states the manufacturer of a beer twice: as an attribute and as a related entity.

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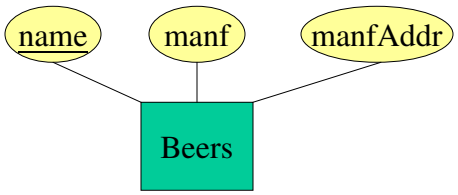
Example: Bad



This design repeats the manufacturer's address once for each beer; loses the address if there are temporarily no beers for a manufacturer.

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Entity Sets Versus Attributes

- An entity set should satisfy at least one of the following conditions:
  - It is more than the name of something; it has at least one nonkey attribute.

    or
  - It is the "many" in a many-one or many-many relationship.

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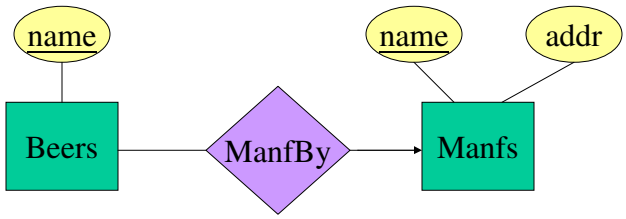
Example: Good



- *Manfs* deserves to be an entity set because of the nonkey attribute *addr*.
- *Beers* deserves to be an entity set because it is the "many" of the many-one relationship *ManfBy*.

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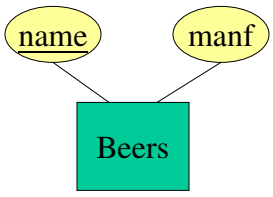
Example: Good



There is no need to make the manufacturer an entity set, because we record nothing about manufacturers besides their name.

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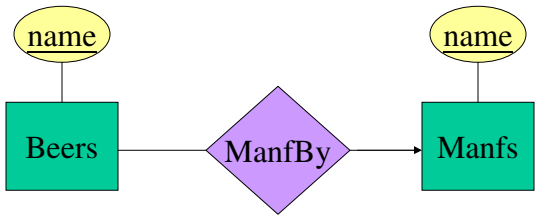
Example: Bad



Since the manufacturer is nothing but a name, and is not at the "many" end of any relationship, it should not be an entity set.

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Don't Overuse Weak Entity Sets

- Beginning database designers often doubt that anything could be a key by itself.
  - They make all entity sets weak, supported by all other entity sets to which they are linked.
- In reality, we usually create unique ID's for entity sets.
  - Examples include social-security numbers, automobile VIN's etc.

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When Do We Need Weak Entity Sets?

- The usual reason is that there is no global authority capable of creating unique ID′s.
- Example: it is unlikely that there could be an agreement to assign unique player numbers across all football teams in the world.

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Summary

- ER model is popular for conceptual design
  - Sketch the design of a database informally using pictures
- Basic constructs in ER model: *entities*, *relationships*, and *attributes* (of entities and relationships).
- Some additional constructs:
  - *weak entities*, *ISA hierarchies*, and *aggregation*.
- Several kinds of integrity constraints:
  - *key constraints*, *participation constraints*, and *overlap/covering constraints* for ISA hierarchies.
- Design Techniques in ER model

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Relational Model

Chapter 3

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Relational Model

- It is the most widely used model.
  - Vendors: Oracle, Microsoft, IBM (DB2), Sybase, …
- It is simple and elegant.
  - A relational database is a collection of **relations.**
  - Each relation is represented as a **table** of rows and columns.
- Why do people like it?
  - Simple tabular data representation, easy to understand.
  - Ease of expressing complex query (using SQL) on the data
  - Efficient query evaluation (using query optimization)

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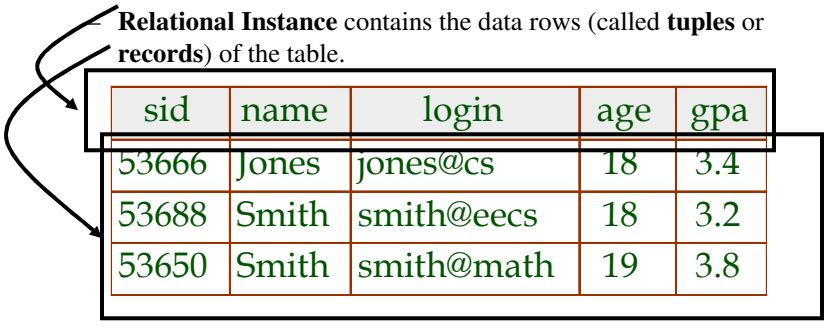
Example of a Relation

- This is a "Students relation".
- A relation has two parts:
  - **Relational Schema** defines column heads of the table.
  - **Relational Instance** contains the data rows (called **tuples** or **records**) of the table.



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

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Relational Schema (1)

- A relational schema specifies:
  - name of the relation: Students
  - names of **fields**: (sid, name, login, age, and gpa)
  - **domain** of each field: it is type of possible **values** (some of built-in types in SQL are integer, real, string, and date.)
- A field can also be called an **attribute** or a **column**.

Students

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

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Relational Schema (2)

- We can refer to the field by
  - Field name (more common): the order of fields does not matter.
  - Position of the field (less common): the order of fields matters.
- A relational schema can be written using the following notation:
  - relation-name (field-name-1: domain-name-1, field-name-2: domain-name-2, …, field-name-n: domain-name-n)
  - Example:

  Students(sid: string, name: string, login: string, age: integer, gpa: real)

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Relational Instance

- A relation instance contains a set of **tuples**
  - A relation instance is referred to as a **relation**.
  - A tuple can also be called a **record** or a **row**.
  - A relation instance is a set, and it has **no duplicate tuples**.
  - Order of tuples is **not** important.

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

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Degree and Cardinality

- **Degree** is the number of fields in schema (=5 in the table below)
- **Cardinality** is the number of tuples in relation (=3 in the table below)

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

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Domain Constraints

- Values in the tuple fields must satisfy the specified domain in the schema.
  - Similar to type matching in compilation
- Example of domain constraint violation:
  - Schema: Students(sid: string, name: string, login: string, age: integer, gpa: real)
  - A tuple: <sid: '50000', name: 38, login: 'dave@cs', age: 18.5, gpa: 3.3>
- There are other types of integrity constraints:
  - **Key constraints, foreign key constraints**, and **general constraints**.

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Outline on SQL Basics

- History
- Basic commands
- Integrity constraints

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SQL History

- It is a query language for relational databases.
- Developed by IBM (system R) in the 1970s
- Need for a standard since it is used by many database vendors.
- Two standard organizations
  - ANSI (American National Standard Institutes)
  - ISO (International Organization for Standardization)
- Standards:
  - SQL-86, SQL-89, SQL-92, SQL-99 (current standard)

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SQL Basic Commands

- **create table**: create a table
- **drop table**: delete a table
- **alter table**: alter a field in a table
- **insert**: add a tuple
- **delete**: delete a tuple
- **update**: change field values in a tuple

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SQL: **create table**

create table Students (sid **char(20)**, name **char(20)**, login **char(10)**, age **integer**, gpa **real**)

- Use built-in types: integer, real, char(#)
  - Similar to type definition in programming language
  - You can define your own types (describe in CH5)

sid	name	login	age	gpa

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SQL: **delete table**

drop table Students

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SQL: **alter table**

- Add a new field in a table

alter table Students **add** dept char[20]

sid	name	login	age	gpa	dept

- Delete a field in a table

alter table Students **drop** gpa

sid	name	login	age	dept

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SQL: **insert**

insert into Students (sid, name, login, age, gpa)
values ('53688', 'Smith', 'smith@cs', 18, 3.2)

or you can omit the fields

insert into Students
values ('53688', 'Smith', 'smith@cs', 18, 3.2)

sid	name	login	age	gpa
53688	Smith	Smith@cs	18	3.2

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SQL: **delete**

delete from Students **as** S **where** S.name = 'Smith'

or you can omit **as** and the tuple variable S

delete from Students **where** name = 'Smith'

sid	name	login	age	gpa
53666	Jones	Jones@cs	18	3.3
~~53688~~	~~Smith~~	~~Smith@cs~~	~~18~~	~~3.2~~
~~53650~~	~~Smith~~	~~Smith@math~~	~~19~~	~~3.7~~

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SQL: **update**

update Students S
  set S.age = S.age + 1, S.gpa = S.gpa – 1
  where S.sid = 53688

sid	name	login	age	gpa
53666	Jones	Jones@cs	18	3.3
53688	Smith	Smith@cs	~~18~~ 19	~~3.2~~ 2.2
53650	Smith	Smith@math	19	3.7

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Integrity Constraints (IC)

- **IC:** condition that must be true for **any** instance of the database; e.g., domain constraints.
  - ICs are specified when schema is defined, (create table)
  - ICs are checked when relations are modified (add, remove, and update).
- A **legal** instance of a relation is one that satisfies all specified ICs.
  - DBMS should not allow illegal instances.
- DBMS checks ICs to prevent data entry errors, or command errors.

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Types of Integrity Constraints

- Domain constraint
- Key constraint
- Foreign key constraint (referential integrity)
- Other constraints

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Key Constraint

- A **key** is a set of **minimal fields** that can **uniquely** identify a tuple in a relation.
  1. No two distinct tuples can have same values in all key fields, and
  2. It is minimal, (no subset of the key is another key).
  - Part 2 false? A **superkey**.
  - If #key >1, one of the keys is chosen (by DBA) to be the **primary key**.
- Why is this a constraint?
  - When a table is modified (e.g., by adding a new tuple), DBMS checks to make sure that the specified keys remain valid keys (e.g., the new tuple has a unique key value).

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Examples of Keys

- Valid keys: {sid}, {name, age} and {login}
- Invalid keys: {name} and {age}
- Valid Superkeys: {sid, gpa}, {sid, age}, and {sid, name, login, age, gpa)

sid	name	login	age	gpa
50000	Dave	Dave@cs	19	3.2
53666	Jones	Jones@cs	18	3.3
53688	Smith	Smith@cs	18	3.2
53650	Smith	Smith@math	19	3.7
53831	Madayan	Madayan@music	11	1.8

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Primary and Candidate Keys

- A relation can have many possible keys, called **candidate keys**. But only one is chosen as the **primary key**.
  - DBMS may create an index on primary key to optimize tuple lookup (using primary key).
- Specify keys in SQL:

create table Students
(sid **char(20)**, name **char(20)**, login **char(10)**, age **integer**, gpa **real,**
unique (name, age),
constraint StudentsKey **primary key** (sid))

constraint name

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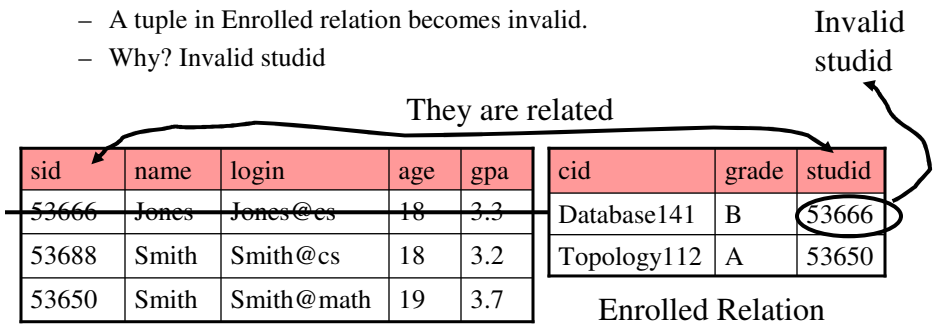
Foreign Key Constraint

- Suppose some fields in one relation refer to some fields in another relation: studid in Enrolled -> sid in Students.
- Example: delete a tuple from Students
  - A tuple in Enrolled relation becomes invalid.
  - Why? Invalid studid



sid	name	login	age	gpa
~~53666~~	~~Jones~~	~~Jones@cs~~	~~18~~	~~3.3~~
53688	Smith	Smith@cs	18	3.2
53650	Smith	Smith@math	19	3.7

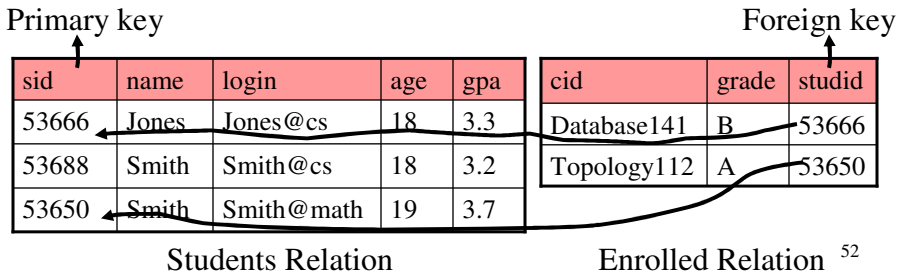
Students Relation

cid	grade	studid
Database141	B	53666
Topology112	A	53650

Enrolled Relation

Foreign Key

- Studid is called a **foreign key**.
- A foreign key is like a "**pointer**" in C, referencing a unique tuple/field in the referenced relation.
  - A foreign key constraint makes sure that there is **no dangling pointer**.



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Students Relation

cid	grade	studid
Database141	B	53666
Topology112	A	53650

Enrolled Relation

More on Foreign Key

- The foreign key must refer to primary key in the referenced relation
  - Why? Foreign key is used to create links between tuples in two relations. Like a memory pointer, it must be able to uniquely identify the tuple in the referenced relation.
- The foreign key needs not be a candidate key.
  - Why? It is only used to uniquely identify a tuple in the referenced relation.
- If all foreign key constraints are enforced, **referential integrity** is achieved, i.e., no dangling pointers.
- Can you name a data model w/o referential integrity?
  - Bad links in HTML!

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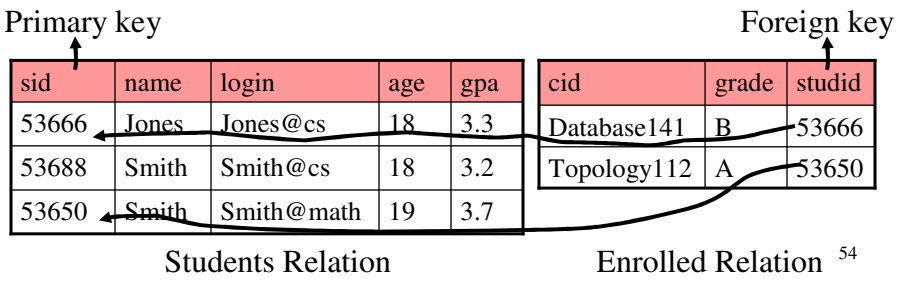
Specify Foreign Keys in SQL

- Constraint: only students listed in the Students relation should be allowed to enroll for courses.

```
create table Enrolled
  (studid char(20),  cid char(20),  grade char(20),
    primary key  (studid, cid),
    foreign key (studid) references Students)
```



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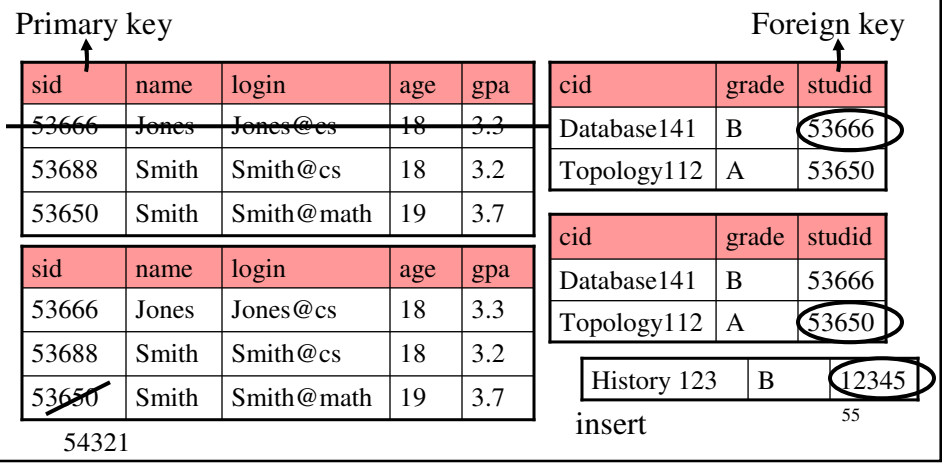
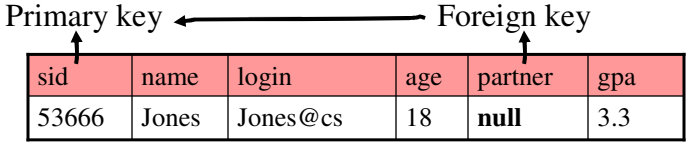
Foreign Key Constraint Violations

- They can happen in **delete**, **insert** and **update** commands.



Self-Referral Foreign Key

- A foreign key can refer to the same relation.
- Example: each student could have a partner.
  - If a student hasn't found a partner, the value can be set to **null**.
  - It is ok to have null value in foreign key field.
  - It is NOT ok to have null value in primary key field.



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General Constraints

- An example of a general constraint: say students ages must be over 16 years old.

create table Students (sid char(20), name char(20), login char(10), age integer, gpa real, unique (name, age), constraint StudentsKey primary key (sid), **check (age > 16**))

- Two types of general constraints:
  - Table constraint: associate with a single table (above example)
  - Assertions: associate with multiple tables (if 1/3 of courses taken by a student has a grade = F in the Enrolled relation, the status of the student in the Students relation must be set to "In Trouble".)

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Enforcing Referential Integrity

- 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?
  - Option 1: Also delete all Enrolled tuples that refer to it.
  - Option 2: Disallow deletion of a Students tuple that is referred to.
  - Option 3: Set studid in Enrolled tuples that refer to it to a *default sid*.
  - Option 4: (In SQL, also: Set studid in Enrolled tuples that refer to it to a special value *null*, denoting *`unknown'* or *`inapplicable'*.)
- Similar if primary key of Students tuple is updated.

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Referential Integrity in SQL

- Option 1: Default is NO ACTION (delete/update is rejected)
- Option 2: CASCADE (also delete all tuples that refer to deleted tuple)
- Options ¾: SET NULL / SET DEFAULT (sets foreign key value of referencing tuple)

```
CREATE TABLE Enrolled
  (studid CHAR(20) default
    "00000",
   cid CHAR(20),
   grade CHAR(2),
   PRIMARY KEY (sid,cid),
   FOREIGN KEY (sid)
    REFERENCES Students
   ON DELETE CASCADE
   ON UPDATE SET DEFAULT )
```

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Translate ER Model to Relational Model

- An entity set to a table
- A relationship set without constraints to a table
- A relationship set with only key constraints to a table
- A relationship set with participation constraints to a table
- A weak entity set to a table
- ISA hierarchies to a table

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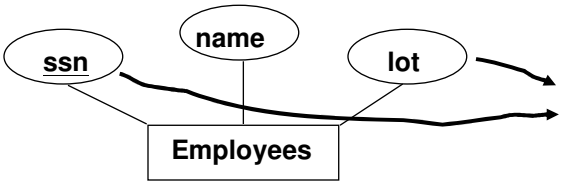
Entity Sets to Tables

key attribute attributes




```
CREATE TABLE Employees
    (ssn CHAR(11),
    name CHAR(20),
    lot  INTEGER,
    PRIMARY KEY  (ssn))
```

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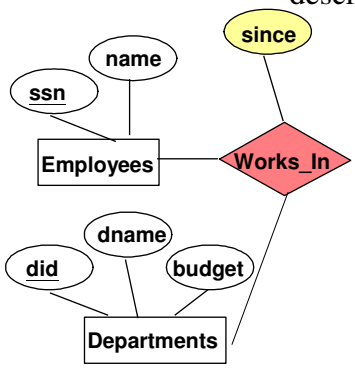
Relationship Sets (without Constraints) to Tables

descriptive attribute




```
CREATE TABLE Works_In(
  ssn  CHAR(11),
  did  INTEGER,
  since  DATE,
  PRIMARY KEY (ssn, did),
  FOREIGN KEY (ssn)
      REFERENCES Employees,
  FOREIGN KEY (did)
      REFERENCES Departments)
```

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Relationship Sets to Tables

- Fields (attributes) of a table must include:
  - Keys for each participating entity set (as **foreign keys**).
    - This set of attributes forms a **superkey** for the relation.
  - All descriptive attributes.

```
CREATE TABLE Works_In(
  ssn  CHAR(11),
  did  INTEGER,
  since  DATE,
  PRIMARY KEY (ssn, did),
  FOREIGN KEY (ssn)
     REFERENCES Employees,
  FOREIGN KEY (did)
     REFERENCES Departments)
```

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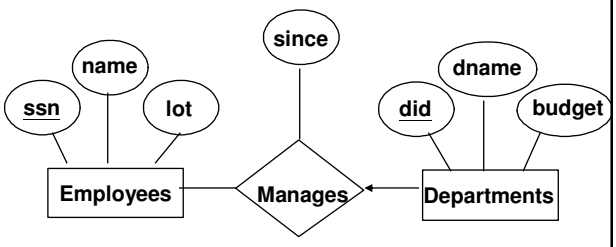
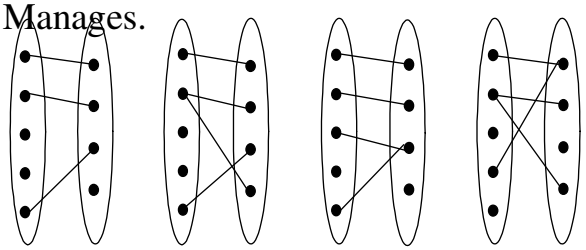
Review: Key Constraints

- Each dept has at most one manager, according to the *key constraint* on Manages.





Translation to relational model?

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Relationship Sets (with key Constraints) to Tables

- Map a relationship set to a table:
  - Note that did is the key now! Why?
  - Since each department has a unique manager, we could instead combine Manages and Departments.
- Second approach:
  - Map Manages into the Departments table.

```
CREATE TABLE Manages(
  ssn CHAR(11),
  did INTEGER,
  since DATE,
  PRIMARY KEY (did),
  FOREIGN KEY (ssn) REFERENCES Employees,
  FOREIGN KEY (did) REFERENCES Departments)
```

```
CREATE TABLE Dept_Mgr(
  did INTEGER,
  dname CHAR(20),
  budget REAL,
  ssn CHAR(11), // can be null -> at most one
  since DATE,
  PRIMARY KEY (did),
  FOREIGN KEY (ssn) REFERENCES Employees)
```

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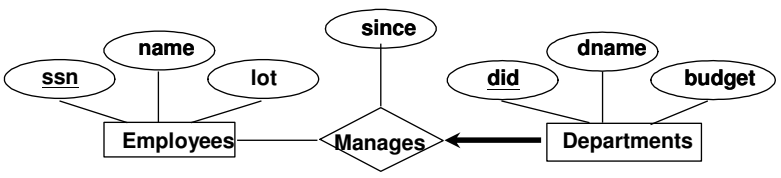
Review: Participation Constraints

- Does every department have a manager?
  - If so, this is a *participation constraint*: the participation of Departments in Manages is said to be *total* (vs. *partial*).
    - Every *did* value in Departments table must appear in a row of the Manages table (with a non-null *ssn* value!)



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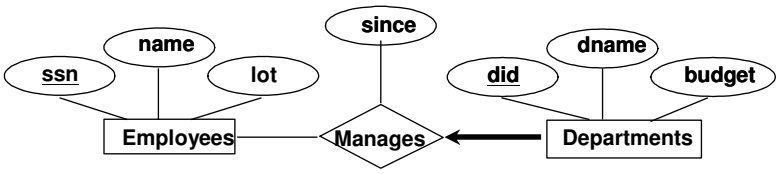
Participation Constraints in SQL

```
CREATE TABLE  Dept_Mgr(
  did  INTEGER;
  dname  CHAR(20),
  budget  REAL,
  ssn  CHAR(11) NOT NULL,  // must have one!
  since  DATE,
  PRIMARY KEY  (did),
  FOREIGN KEY  (ssn) REFERENCES Employees)
```



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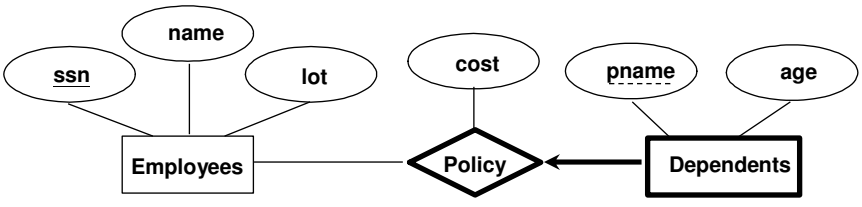
Review: Weak Entities

- A *weak entity* can be identified uniquely only by considering the primary key of another (*owner*) entity.
  - One-to-many relationship set (1 owner, many weak entities).
  - Total participation in this *identifying* relationship set.



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Translating Weak Entity Sets

- Weak entity set and identifying relationship set are translated into a single table.
  - When the owner entity is deleted, all owned weak entities must also be deleted.

```
CREATE TABLE  Dependent_Policy (
  pname  CHAR(20),
  age  INTEGER,
  cost  REAL,
  ssn  CHAR(11) NOT NULL,
  PRIMARY KEY  (pname, ssn),
  FOREIGN KEY  (ssn) REFERENCES Employees,
    ON DELETE CASCADE)
```

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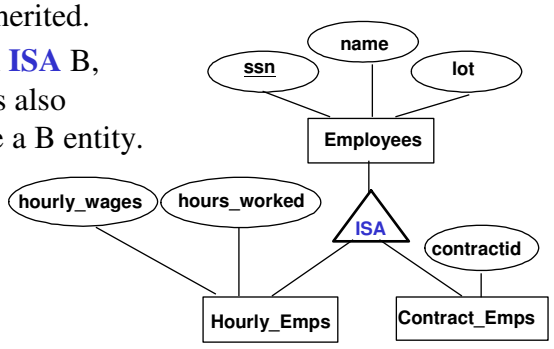
Review: ISA Hierarchies

- As in C++, or other PLs, attributes are inherited.
- If we declare A **ISA** B, every A entity is also considered to be a B entity.



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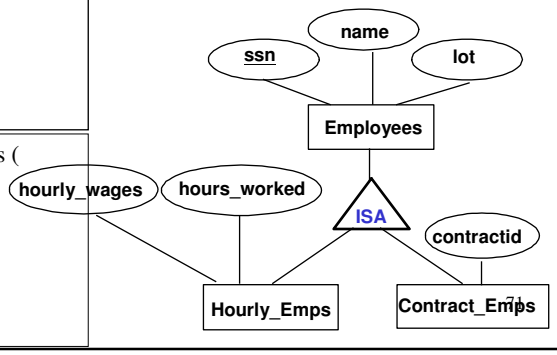
Translating ISA Hierarchies to Tables

- ***General approach:***
  - 3 tables: Employees, Hourly_Emps and Contract_Emps.
  - Hourly_Emps: Every employee is recorded in Employees. For hourly emps, extra info recorded in Hourly_Emps (hourly_wages, hours_worked, ssn).
  - Must delete Hourly_Emps tuple if referenced Employees tuple is deleted).

```
CREATE TABLE employees (
  ssn  CHAR(11),
  name  CHAR(20),
  lot  INTEGER,
 PRIMARY KEY  (ssn))
```

```
CREATE TABLE hourly_emps (
  hourly_wages  INTEGER,
  hours_worked  INTEGER,
  ssn  CHAR(11),
  PRIMARY KEY (ssn)
  FOREIGN KEY  (ssn)
REFERNECES employees)
```



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Views

- A *view* is just a relation, but we only store its *definition*, rather than its tuples/rows in database.

```
CREATE VIEW StudentsInHistory105(name, sid)
        AS SELECT  S.name, S.sid
        FROM  Students S, Enrolled E
        WHERE  S.sid = E.studid and E.cid='History105'
```

- 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.

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Views and Security

- Views can be used to present necessary information (or a summary), while hiding details in underlying relation(s).
- Example: a student can use the view StudentsInHistory105 to find out his/her classmates.
- But a student cannot find out the gpa of his/her classmates.

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Summary

- Relational model is about tabular representation of data.
  - Simple and intuitive, currently the most widely used.
- Integrity constraints
  - Domain constraints, key constraints, foreign key constraints, general constraints
- Basic SQL commands
  - Create, update, and delete tables
  - Insert and delete tuples
- Rules to translate ER to relational model
- Define views for security

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