Introduction to Databases
《数据库引论》

Lecture 3: Introduction to SQL
第3讲：结构化查询语言简介

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Content of the Course

- **Part 0: Overview**
  - Lect. 0/1 (Feb. 20) - Ch1: Introduction
- **Part 1 Relational Databases**
  - Lect. 2 (Feb. 27) - Ch2: Relational model (data model, relational algebra)
  - Lect. 3 (Mar. 6) - Ch3&4: SQL (Introduction and intermediate)
  - Lect. 4 (Mar. 13) - Ch5: Advanced SQL
- **Part 2 Database Design**
  - Lect. 5 (Mar. 20) - Ch6: Database design based on E-R model
  - Lect. 6 (Mar. 27) - Ch7: Relational database design (Part I)
  - Lect. 7 (Apr. 3) - Ch7: Relational database design (Part II)
- **Midterm exam: Apr. 10**
- **Part 3 Data Storage & Indexing**
  - Lect. 7 (Apr. 17) - Ch12/13: Storage systems & structures
  - Lect. 8 (Apr. 24) - Ch14: Indexing
- **Part 4 Query Processing & Optimization**
  - May 1, holiday, no classes
  - Lect. 9 (May 8) - Ch15: Query processing
  - Lect. 10 (May 15) - Ch16: Query optimization
- **Part 5 Transaction Management**
  - Lect. 11 (May 22) - Ch17: Transactions
  - Lect. 12 (May 29) - Ch18: Concurrency control
  - Lect. 13 (Jun. 5) - Ch19: Recovery system
  - Lect. 14 (Jun. 5) – Course review

Final exam: 13:00-15:00, Jun. 18

University Database

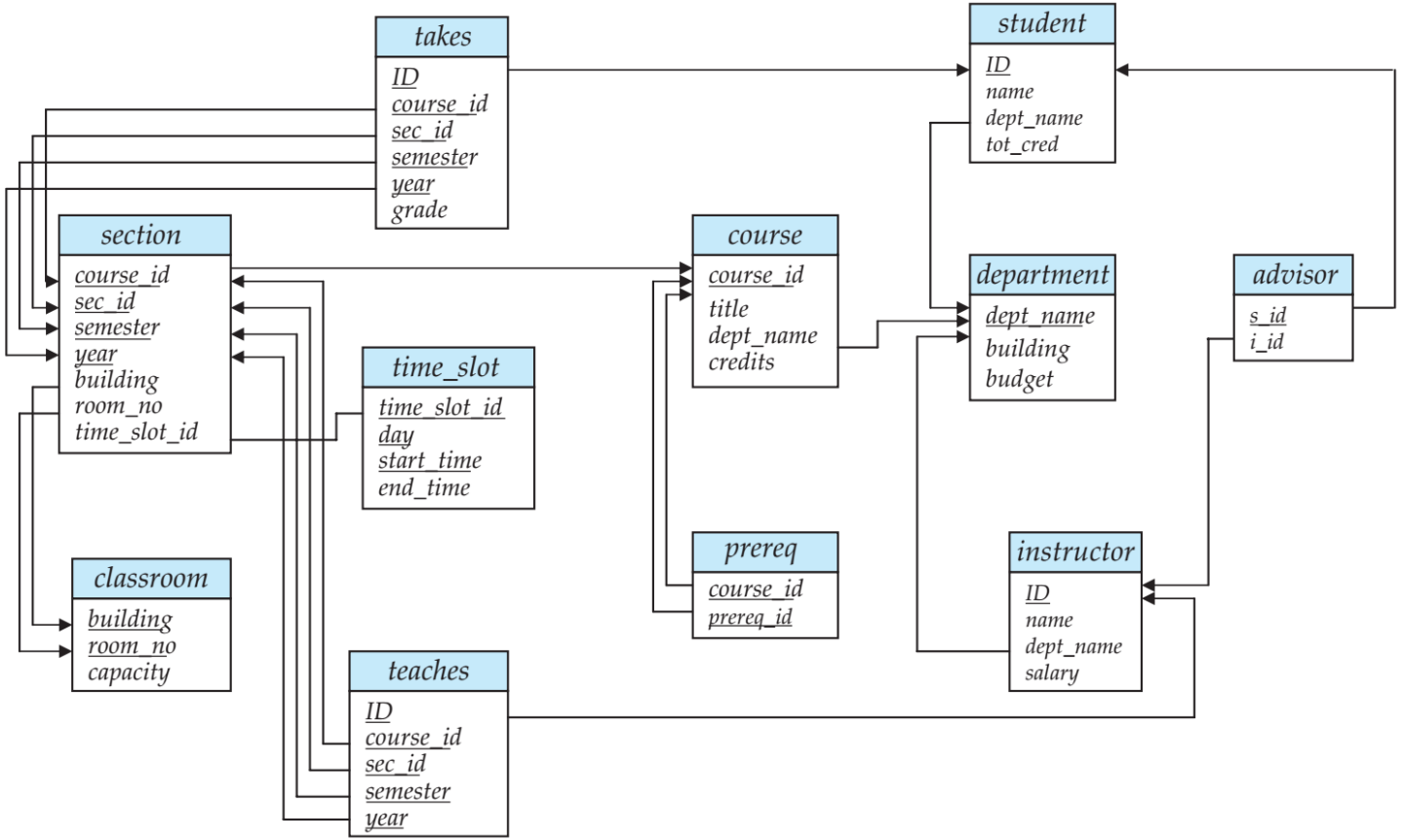
ID	*name*	*dept_name*	*salary*
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
76766	Crick	Biology	72000
10101	Srinivasan	Comp. Sci.	65000
58583	Califieri	History	62000
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music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

Instructor table

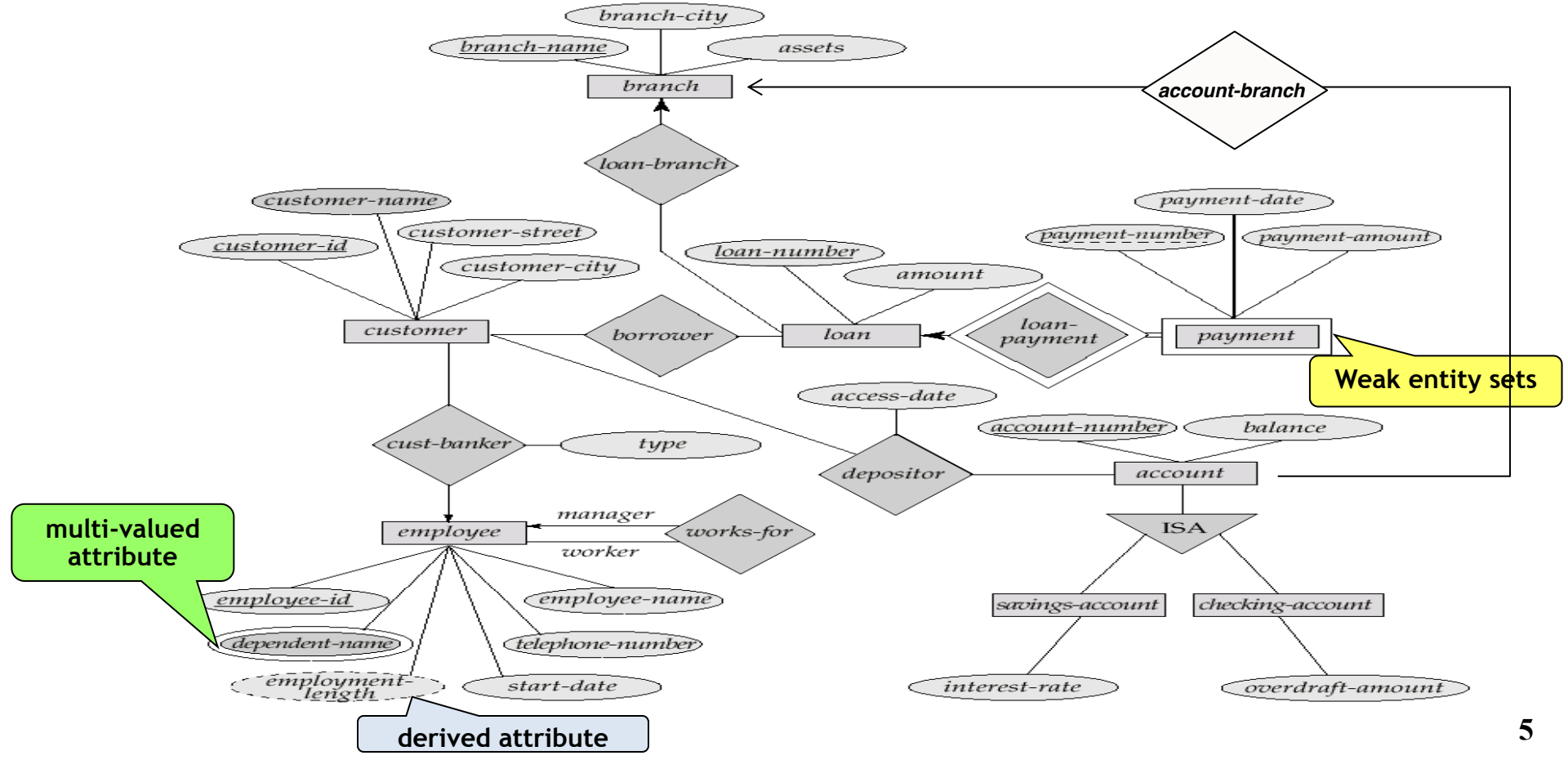
ID	*name*	*dept_name*	*tot_cred*
00128	Zhang	Comp. Sci.	102
12345	Shankar	Comp. Sci.	32
19991	Brandt	History	80
23121	Chavez	Finance	110
44553	Peltier	Physics	56
45678	Levy	Physics	46
54321	Williams	Comp. Sci.	54
55739	Sanchez	Music	38
70557	Snow	Physics	0
76543	Brown	Comp. Sci.	58
76653	Aoi	Elec. Eng.	60
98765	Bourikas	Elec. Eng.	98
98988	Tanaka	Biology	120

Student table

University Database



E-R Diagram for a Banking Enterprise



The Banking Schema

- *branch* = (*branch_name*, *branch_city*, *assets*)
- *customer* = (*customer_id*, *customer_name*, *customer_street*, *customer_city*)
- *loan* = (*loan_number*, *amount*)
- *account* = (*account_number*, *balance*)
- *employee* = (*employee_id*, *employee_name*, *telephone_number*, *start_date*)

- *dependent_name* = (*employee_id*, *dname*) (derived from a multivalued attribute)

- *account_branch* = (*account_number*, *branch_name*)
- *loan_branch* = (*loan_number*, *branch_name*)
- *borrower* = (*customer_id*, *loan_number*)
- *depositor* = (*customer_id*, *account_number*, *access_date*)
- *cust_banker* = (*customer_id*, *employee_id*, *type*)
- *works_for* = (*worker_employee_id*, *manager_employee_id*)

- *payment* =(*loan_number*,*payment_number*,*payment_date*,*payment_amount*)

- *savings_account* = (*account_number*, *interest_rate*)
- *checking_account* = (*account_number*, *overdraft_amount*)

Outline

- ☞ **Overview of SQL**
- SQL Data Definition
- Basic Structure of SQL Queries
- Additional Basic Operations
- Set Operations
- Null Values
- Aggregate Functions
- Nested Subqueries
- Modification of the Database

Overview of the SQL Query Language

- IBM SEQUEL (Structured English QUEry Language) language developed as part of System R project at the IBM San Jose Research Laboratory in the early 1970s
- Later SEQUEL was renamed to **Structured Query Language (SQL)** because it was already trademarked by an airplane company
- ANSI (美国国家标准学会) and ISO (国际标准化组织) standard SQL:
  - SQL-86
  - SQL-89
  - SQL-92
  - SQL:1999, 2003, 2006, 2008
- Commercial systems offer most, if not all, **SQL-92** features, plus varying feature sets from later standards and special proprietary features
  - Not all examples here may work on the particular system

Structured Query Language (SQL)

- SQL语言包含
  - 数据定义语言（Data definition language，DDL）
    - Relation schemas
    - Integrity constraints
    - View definition
    - Authorization
  - 数据操纵语言（Data manipulation language，DML）
    - Queries
    - Insertion, Deletion, Updates
    - Transaction processing

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Data Definition Language (DDL)

- Allows the specification of not only a set of relations but also information about each relation, including:
  - The schema for each relation
  - The domain of values associated with each attribute
  - Integrity constraints
  - The set of indices to be maintained for each relations
  - Security and authorization information for each relation
  - The physical storage structure of each relation on disk

Domain Types in SQL

- char(n)
  - Fixed length character string, with user-specified length n
- varchar(n)
  - Variable length character strings, with user-specified maximum length n
- int
  - Integer (a finite subset of the integers that is machine-dependent)
- smallint
  - Small integer (a machine-dependent subset of the integer domain type)
- numeric(p, d)
  - Fixed point number (定点数), with user-specified precision of p digits, with d digits to the right of decimal point
  - Numeric(3,1) allows 44.5 to be stored exactly, but neither 444.5 nor 0.32 can be stored exactly in a field of this type

Domain Types in SQL (Cont.)

- real, double precision
  - Floating point and double-precision floating point numbers, with machine-dependent precision
- float(n)
  - Floating point number, with user-specified precision of at least n digits
- null value
  - Allowed in all domain types. Declaring an attribute to be **not null** prohibits null values for that attribute.
- Create domain construct in SQL-92 creates user-defined domain types
  - *create domain person_name char(20) not null*

Date/Time Types in SQL (Cont.)

- date
  - Dates, containing a (4 digit) year, month and date
  - E.g., date '2020-9-30'
- time
  - Time of day, in hours, minutes and seconds.
  - E.g., time '09:25:30' time '09:25:30.75'
- Timestamp
  - date plus time of day
  - E.g., timestamp '2020-9-30 09:25:30.75'

Date/Time Types in SQL (Cont.)

- **Interval:** period of time
  - Subtracting a date/time/timestamp value from another gives an interval value, e.g., Interval '1' day
  - Interval values can be added to date/time/timestamp values
- **Extract** values of individual fields from date/time/timestamp
  - E.g., extract (year from r.starttime)
- **Cast** string types to date/time/timestamp
  - E.g., cast <string-valued-expression> as date

Basic Schema Definition

- An SQL relation is defined using the *create table* command:

  create table $r(A_1\ D_1, A_2\ D_2, \ldots, A_n\ D_n,$
  $(integrity\_constraint_1), \ldots, (integrity\_constraint_k))$

  - r is the name of the relation
  - Each A_i is an attribute name in the schema of relation r
  - D_i is the data type of values in the domain of attribute A_i

- Example:

```
create table branch
  (branch_name    char(15) not null,
   branch_city    char(30),
   assets         integer)
```

Integrity Constraints in Creating Tables

- not null
- primary key $(A_1, \ldots, A_n)$
- foreign key $(A_{k1}, A_{k2} \ldots, A_{kn})$ references s
- check (P), where P is a predicate

```
create table instructor
    (ID              varchar(5),
     name            varchar(20) not null,
     dept_name       varchar(20),
     salary          numeric(8, 2),
     primary key (ID),
     check (salary >= 0) )
```

Note: Primary key declaration on an attribute automatically ensures not null and unique in SQL-92 onwards, needs to be explicitly stated in SQL-89

Basic Insertion and Deletion of Tuples

- Newly created table is empty
- Add a new tuple to table instructor

  insert into instructor values ('10211', 'Smith', 'Computer Science', 66000)

  - Insertion fails if any integrity constraint is violated
- Delete **all** tuples from table instructor

  delete from instructor

Drop and Alter Table Constructs

- The **drop table** command deletes all information (both schema and tuples) about the dropped relation from the database
- The **alter table** command is used to add attributes to an existing relation

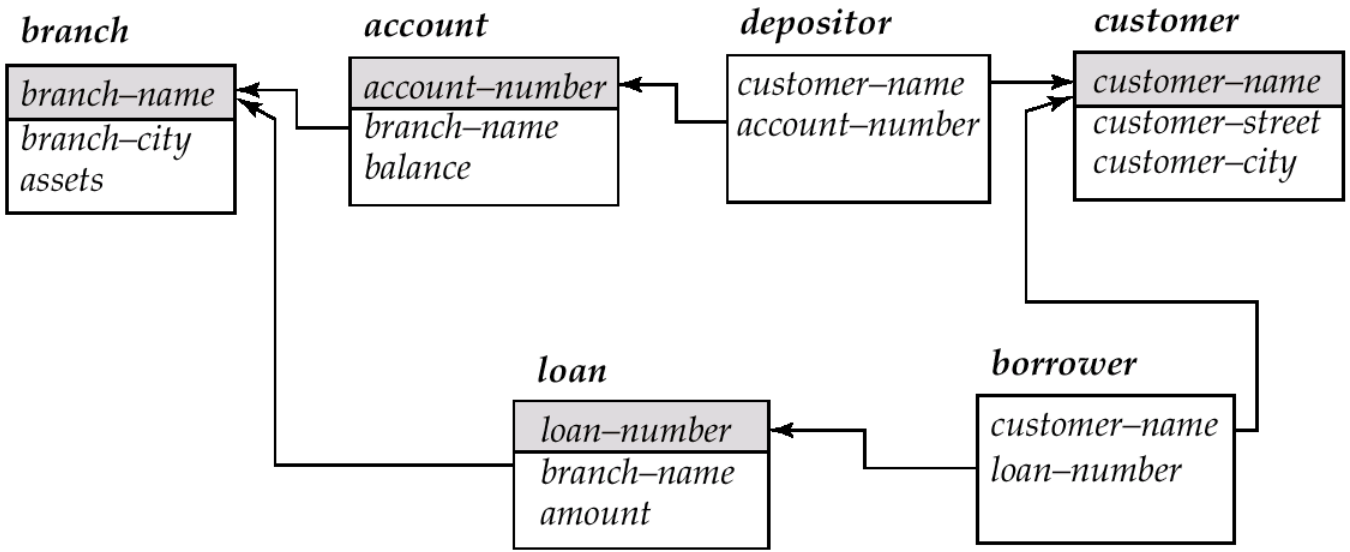
  alter table r add A D

  - All tuples in the relation are assigned null as the value for the new attribute.
- The alter table command can also be used to drop attributes of a relation

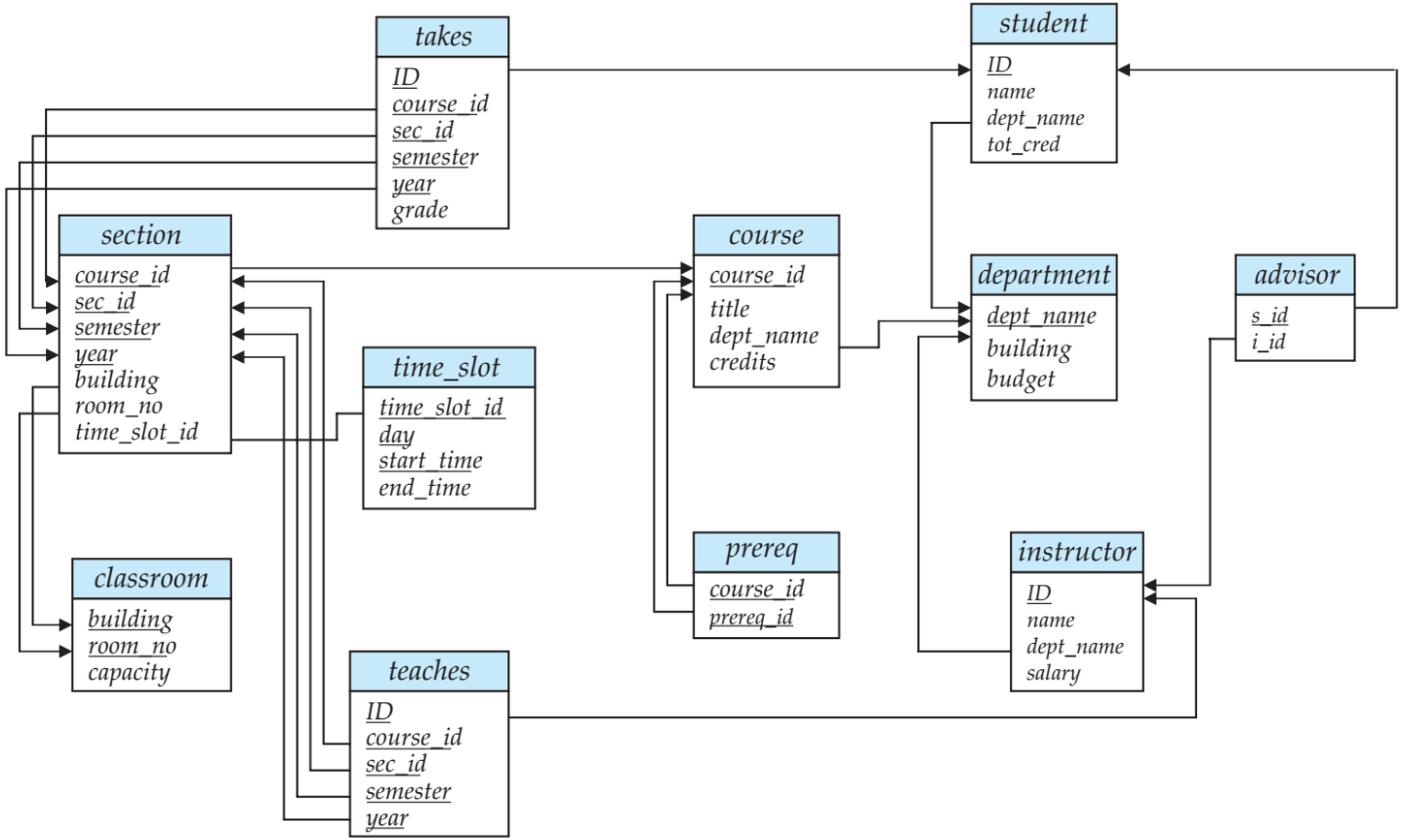
  alter table r drop A

  - Dropping of attributes not supported by many databases

Schema Used in Examples



Schema Used in Examples



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Basic Structure of SQL Queries

- SQL is based on set and relational operations with certain modifications and enhancements
- A typical SQL query has the form:

  select $A_1, A_2, \ldots, A_n$
  from $r_1, r_2, \ldots, r_m$
  where P

- This query is equivalent to the relational algebra expression:

$$\Pi_{A_1,A_2,\ldots,A_n}(\sigma_P(r_1 \times r_2 \times \cdots \times r_m))$$

- The result of an SQL query is a relation

The Select Clause

- The select clause lists the attributes desired in the result of a query
  - corresponds to the **projection** operation of the RA (relational algebra)
- E.g., find the names of all departments in the instructor relation

  select dept_name

  from instructor
- In the "pure" RA syntax, the query would be:

$$\Pi_{dept\_name}(instructor)$$

  - NOTE: SQL names are case insensitive, i.e. you can use capital or small letters

The select Clause (Cont.)

- SQL allows duplicates in relations. To eliminate duplicates, insert the keyword distinct after select
- Find the names of all departments in the instructor relation, and remove duplicates

```
select distinct dept_name
from   instructor
```

- The keyword all specifies that duplicates should not be removed by default

```
select all dept_name
from instructor
```

The select Clause (Cont.)

- An asterisk in the select clause denotes "all attributes"

```
select *
from instructor
```

- The select clause can contain arithmetic expressions involving the operation, +, −, * , and /, and operating on constants or attributes of tuples
- Example:

```
select ID, dept_name, salary * 1.1
from instructor
```

The where Clause

- The where clause specifies conditions that the result must satisfy
  - correspond to the selection predicate of the RA (relational algebra)
  - E.g., to find all loan numbers for loans made at the Perryridge branch with loan amount greater than $1200.

```
select loan_number
from   loan
where branch_name = 'Perryridge' and amount > 1200
```

  - Comparison results can be combined using the logical connectives **and**, **or**, and **not**
  - Comparison can be applied to results of arithmetic expressions

The where Clause (Cont.)

- SQL includes a between comparison operator
  - E.g. find the loan numbers of those loans with loan amount between $90,000 and $100,000

```
select loan_number
from   loan
where amount between 90000 and 100000
```

The from Clause

- The **from clause** lists the relations involved in the query
  - corresponds to the Cartesian product operation of the RA
- E.g., find the Cartesian product $borrower \times loan$

```
select *
from borrower, loan
```

- E.g., find the name, loan number and loan amount of all customers having a loan at the Perryridge branch

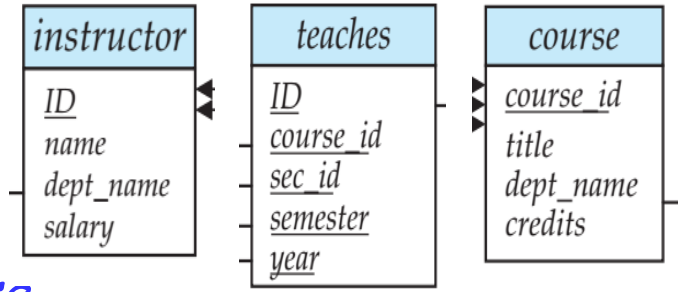
```
select customer_name, borrower.loan_number, amount
from borrower, loan
where borrower.loan_number = loan.loan_number and
      branch_name='Perryridge'
```

The Natural Join

select $A_1, A_2, \ldots, A_n$
from r_1 ***natural join*** r_2 ***natural join*** ...***natural join*** r_m
where *P;*

select *name, course_id*
from *instructor* ***natural join*** *teaches;*

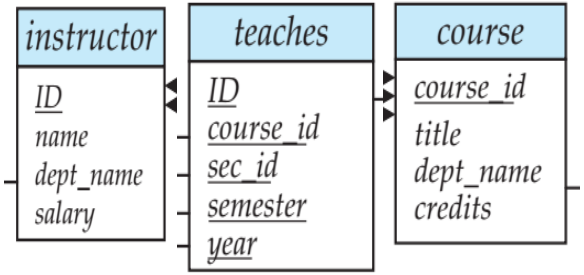
select *name, title*
from *instructor* ***natural join*** *teaches, course*
where *teaches.course_id = course.course_id;*



Notice that we do not repeat those attributes that appear in the schemas of both relations; rather they appear only once. Notice also the order in which the attributes are listed: first the attributes common to the schemas of both relations, second those attributes unique to the schema of the first relation, and finally, those attributes unique to the schema of the second relation.

join … using(…)

- natural join of instructor and teaches
  - (ID, name, dept_name, salary, course_id, sec_id, semester, year)
- course
  - (course_id, title, dept_name, credits)



结果不等

```
select name, title
from instructor natural join teaches, course
where teaches.course_id= course.course_id;

select name, title
from instructor natural join teaches natural join course;

select name, title
from (instructor natural join teaches) join course using (course_id);
```

结果相等

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The Rename Operation

- The SQL allows renaming relations and attributes using the as clause:
  old_name ***as*** *new_name*

- Find the name, loan_number and loan_amount of all customers; rename the column name loan_number as loan_id:

```
select customer_name, borrower.loan_number as loan_id, amount
from   borrower, loan
where borrower.loan_number = loan.loan_number
```

Tuple Variables

- Tuple variables are defined in the from clause via the use of the as clause
- Find the customer names and their loan numbers for all customers having a loan at some branch

```
select  customer_name, T.loan_number, S.amount
from    borrower as T, loan as S
where   T.loan_number = S.loan_number
```

- Find the names of all branches that have greater assets than some branch located in Brooklyn.

```
select  distinct T.branch_name
from    branch as T, branch as S
where T.assets > S.assets and S.branch_city = 'Brooklyn'
```

String Operations

- SQL includes a string-matching operator for comparisons on character strings.
  - percent (%): The % character matches any substring
  - underscore (_): The _ character matches any character
- like/not like: Find the names of all customers whose street includes (or not) the substring "Main"

```
select customer_name
from   customer
where customer_street like '%Main%'
```

- Match the name "Main%"要匹配的字符中有百分号的情况，需要转义

```
like 'Main\%';  escape  '\'
```

- "*" denote "all attributes" : *select instructor.**
- SQL supports a variety of string operations such as
  - Concatenation（串联） (using "||")
  - converting from upper to lower case (and vice versa)
  - finding string length, extracting substrings, etc.

Order the Display of Tuples

- List in alphabetic order the names of all customers having a loan in Perryridge branch

```
select  distinct customer_name
from    borrower, loan
where borrower.loan_number = loan.loan_number and
        branch_name = 'Perryridge'
order by customer_name
```

- We may specify desc for descending order or asc for ascending order, for each attribute; **ascending order is the default.**

```
select *
from   loan
order by amount desc, loan-number asc
```

Where Clause Predicates

- SQL includes a between\not between comparison operator
  - Example: find the names of all instructors with salary between $90,000 and $100,000

```
select name
from instructor
where salary between 90000 and 100000
```

- Tuple comparison

```
select name, course_id
from   instructor, teaches
where (instructor.ID, dept_name) = (teaches.ID, 'Biology');
```

等价

```
select name, course_id
from   instructor, teaches
where instructor.ID=teaches.ID and dept_name='Biology'
```

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Set Operations

- The set operations union, intersect, and except operate on relations and correspond to the relational algebra operations ∪, ∩, −
- Each of the above operations automatically eliminates duplicates
- To retain all duplicates use the corresponding multiset versions union all, intersect all and except all
  - Suppose a tuple occurs m times in r and n times in s, then, it occurs:
    - $m + n$ times in r union all s
    - $\min(m, n)$ times in r intersect all s
    - $\max(0, m - n)$ times in r except all s

Set Operations

- Find all customers who have a loan, an account, or both:

```
(select customer_name from depositor)
union [all]
(select customer_name from borrower)
```

- Find all customers who have both a loan and an account.

```
(select customer_name from depositor)
intersect [all]
(select customer_name from borrower)
```

- Find all customers who have an account but no loan.

```
(select customer_name from depositor)
except [all]
(select customer_name from borrower)
```

Duplicates

- In relations with duplicates, SQL can define how many copies of tuples appear in the result
- Multiset versions of some of the relational algebra operators, given multiset relations r_1 and r_2:
  - $\sigma_\theta(r_1)$: If there are c_1 copies of tuple t_1 in r_1, and t_1 satisfies selections σ_θ, then there are c_1 copies of t_1 in $\sigma_\theta(r_1)$
  - $\Pi_A(r_1)$: For each copy of tuple t_1 in r_1, there is a copy of tuple $\Pi_A(t_1)$ in $\Pi_A(r_1)$ where $\Pi_A(t_1)$ denotes the projection of the single tuple t_1
  - $r_1 \times r_2$: If there are c_1 copies of tuple t_1 in r_1 and c_2 copies of tuple t_2 in r_2, there are $c_1 \times c_2$ copies of the tuple $t_1 t_2$ in $r_1 \times r_2$

Duplicates (Cont.)

- E.g., suppose multiset relations $r_1(A, B)$ and $r_2(C)$ are as follows:

  $r_1 = \{(1, a), (2, a)\}$ $r_2 = \{(2), (3), (3)\}$

- Then $\Pi_B(r_1)$ would be $\{(a), (a)\}$, while $\Pi_B(r_1) \times r_2$ would be $\{(a, 2), (a, 2), (a, 3), (a, 3), (a, 3), (a, 3)\}$

- SQL duplicate semantics:

  select A_1, A_2, …, A_n
  from r_1, r_2, …, r_m
  where P

is equivalent to the multiset version of the expression:

$$\boldsymbol{\Pi_{A_1, A_2, \ldots, A_n}(\sigma_P(r_1 \times r_2 \times \cdots \times r_m))}$$

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Null Values

- It is possible for tuples to have a null value, signifies an unknown value or that a value does not exist
- The predicate *is null* can be used to check for null values

```
select loan_number
from   loan
where amount is null
```

- The result of any arithmetic expression involving null is null
  - E.g. 5 + null returns null
- Aggregate functions simply ignore null values

Null Values and Three Valued Logic

- Any comparison with null returns unknown
  - E.g. 5 < null or null <> null or null = null
- Three-valued logic (三值逻辑) using the truth value unknown:
  - OR: (unknown or true) = true, (unknown or false) = unknown
    (unknown or unknown) = unknown
  - AND: (true and unknown) = unknown, (false and unknown) = false,
    (unknown and unknown) = unknown
  - NOT: (not unknown) = unknown
  - "P is unknown" evaluates to true if predicate P evaluates to unknown
- Result of where clause predicate is treated as false if it evaluates to unknown

Null Values and Aggregates

- Calculate the sum of all loan amounts

```
select sum (amount)
from   loan
```

  - Above statement ignores null amounts
  - Result is null if there is no non-null amount

- All aggregate operations except **count(*)** ignore tuples with null values on the aggregated attributes

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Aggregate Functions

- These functions operate on a set of values of a column of a relation, and return a value
  - **avg**: average value
  - **min**: minimum value
  - **max**: maximum value
  - **sum**: sum of values
  - **count**: number of values

Aggregate Functions (Cont.)

- Find the average account balance at the Perryridge branch

```
select avg (balance)
from account
where branch_name = 'Perryridge'
```

- Find the number of tuples in the customer relation

```
select count (*)
from customer
```

- Find the number of depositors in the bank

```
select count (distinct customer_name)
from depositor
```

Aggregate Functions – Group By

- Find the number of depositors for each branch

```
select branch_name, count (distinct customer_name)
from depositor, account
where depositor.account_number = account.account_number
group by branch_name
```

- **Note:** Attributes in select clause **outside of aggregate functions must appear in group by list**

```
/*erroneous query*/
select dept_name, ID, avg(salary)
from instructor
group by dept_name
```

Aggregate Functions – Having Clause

- At times, it is useful to state a condition that applies to groups rather than to tuples.
- E.g., find the names of all branches where the average account balance is more than $1,200.

```
select branch_name, avg (balance)
from account
group by branch_name
having avg (balance) > 1200
```

- Note
  - predicates in the having clause are applied after the information of groups whereas
  - predicates in the where clause are applied before forming groups

Aggregate Functions – Having Clause

- E.g., find the average balance for each customer who lives in Harrison and has at least three accounts

```
select depositor.customer_name, avg (balance)
from depositor, account, customer
where depositor.account_number=account.account_number
      and depositer.customer_name=customer.customer_name
      and customer_city='Harrison'
group by depositor.customer_name
having count(distinct depositor.account_number) >=3
```

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Nested Subqueries（嵌套子查询）

- SQL provides a mechanism for the nesting of subqueries
- A subquery is a select-from-where expression that is nested within another query in the from clause

- A common use of subqueries is to perform
  - tests for set membership
  - make set comparisons
  - determine set cardinality (基数)

Set Membership

- Find all customers who have both an account and a loan at the bank

```
select distinct customer_name
from borrower
where customer_name in (select customer_name
                        from depositor)
```

- Find all customers who have a loan but do not have an account at the bank

```
select distinct customer_name
from borrower
where customer_name not in (select customer_name
                            from depositor)
```

select distinct *name*
from *instructor*
where *name* **not in** ('Mozart', 'Einstein');

Set Membership (Cont.)

- Find all customers who have both an account and a loan at the Perryridge branch

```
select distinct customer_name
from borrower, loan
where borrower.loan_number=loan.loan_number and
    branch_name="Perryridge" and
    (branch_name, customer_name) in
        (select branch_name, customer_name
         from depositor, account
         where depositor.account_number =account.account_number)
```

Set Comparison

- Find all branches that have greater assets than some branch located in Brooklyn

```
select distinct  T.branch_name
from  branch as T, branch as S
where T.assets > S.assets and S.branch_city = 'Brooklyn'
```

- Same query using **>some** clause

```
select branch_name
from  branch
where assets > some
          (select assets
           from branch
           where branch_city = 'Brooklyn')
```

Definition of Some Clause

- $F < comp >$ some $r \Leftrightarrow \exists\, t \in r$ such that $(F < comp > t)$, where <comp> can be: $<, \leq, >, \geq, =, \neq$

(5< some | 0 / 5 / 6) = true (read: 5 < some tuple in the relation)

(5< some | 0 / 5) = false

(5 = some | 0 / 5) = true

(5 ≠ some | 0 / 5) = true (since 0 ≠ 5)

(= some) ≡ in
However,
(≠ some) ≢ not in

Definition of all Clause

- $F < comp > all\ r \Leftrightarrow \forall t \in r\ (F < comp > t)$

(5< all | 0 / 5 / 6 |) = false

(5< all | 6 / 10 |) = true

(5 = all | 4 / 5 |) = false

(5 ≠ all | 4 / 6 |) = true (since 5 ≠ 4 and 5 ≠ 6)

(≠ all) ≡ not in
However, (= all) ≡/in

Example

- Find the names of all branches that have greater assets than all branches located in Brooklyn.

```
select branch_name
from branch
where assets > all
        (select assets
         from branch
         where branch_city = 'Brooklyn')
```

平均工资最高的系

```
select dept_name
from instructor
group by dept_name
having avg (salary) >= all (select avg (salary)
                            from instructor
                            group by dept_name);
```

Test for Empty Relations

- The exists construct returns the value TRUE if the argument subquery is nonempty
  - **exists** $r \Leftrightarrow r \neq \emptyset$
  - **not exists** $r \Leftrightarrow r = \emptyset$

- E.g., find all customers who have both an account & a loan at the bank

```
select customer_name
from borrower
where exists (
    select *
    from depositor
    where depositor.customer_name = borrower.customer_name)
```

Test for Empty Relations

- Find all customers who have both an account and a loan at the bank

✓
```
select customer_name
from borrower
where exists (
    select *
    from depositor
    where depositor.customer_name = borrower.customer_name)
```

✓
```
select distinct customer_name
    from borrower
    where customer_name in (select customer_name
                            from depositor)
```

✓
```
select distinct customer_name
    from borrower, loan
    where borrower.loan_number = loan.loan_number and (branch_name, customer_name) in
        (select branch_name, customer_name
         from depositor, account
         where depositor.account_number = account.account_number)
```

Test for Empty Relations (Cont.)

- Find all customers who have accounts at all branches located in Brooklyn

```
select distinct S.customer_name
from depositor as S
where not exists (
    (select branch_name      /* all branches in Brooklyn  X */
     from branch
     where branch_city = 'Brooklyn')
       except
       (select R.branch_name   /* finds all the branches at which customer
            S.customer_name has an account  Y */
        from depositor as T, account as R
        where T.account_number = R.account_number and
                        S.customer_name = T.customer_name))
```

- Note: *not exists* $(X - Y) \Leftrightarrow X - Y = \emptyset \Leftrightarrow X \subseteq Y$

Test for Empty Relations (Cont.)

- Write "relation A contains relation B" as "not exists (B except A)."

- E.g., find all students who have taken all courses offered by the Biology department

```
select distinct S.ID, S.name
from student as S
where not exists ((select course_id
                   from course
                   where dept_name = 'Biology')
                   except
                   (select T.course_id
                    from takes as T
                    where S.ID=T.ID))
```

Test for Absence of Duplicate Tuples

- The **unique** construct tests whether a subquery has any duplicate tuples in its result
- E.g., find all customers who have at most one account at the Perryridge branch

```
select T.customer_name
from depositor as T
where unique (
    select R.customer_name
    from account, depositor as R
    where T.customer_name = R.customer_name and
          R.account_number = account.account_number and
          account.branch_name = 'Perryridge')
```

Examples

找出所有在2009年最多开设一次的课程

等价

```
select T.course_id
from course as T
where unique (select R.course_id
              from section as R
              where T.course_id= R.course_id and
                    R.year = 2009);
```

```
select T.course_id
from course as T
where 1 <= (select count(R.course_id)
            from section as R
            where T.course_id= R.course_id and
                  R.year = 2009);
```

>=

Examples

- Find all customers who have at least two accounts at the Perryridge branch.

```
select distinct T.customer_name
from depositor T
where not unique(
        select R.customer_name
        from account, depositor as R
        where T.customer-name = R.customer_name and
              R.account-number = account.account_number and
              account.branch_name = 'Perryridge')
```

```
select T.course_id
from course as T
where not unique (select R.course_id
                  from section as R
                  where T.course_id= R.course_id and
                        R.year = 2009);
```

找出所有在2009年至少开设两次的课程

Views

- In some cases, it is not desirable for all users to see the entire logical model (that is, all the actual relations stored in the database.)
- Consider a person who needs to know a customer's name, loan number and branch name, but has no need to see the loan amount. This person should see a relation described by

  *(**select** customer_name, borrower.loan_number, branch_name*
  __from__ borrower, loan
  __where__ borrower.loan_number = loan.loan_number)
- A **view** provides a mechanism to hide certain data from the view of certain users. Any relation that is not of the conceptual model but is made visible to a user as a "**virtual relation**" is called a view.

View Definition

- A view is defined using the create view statement which has the form

  create view v as < query expression >

  where <query expression> is any legal SQL expression. The view name is represented by *v*.

- Once a view is defined, the view name can be used to refer to the virtual relation that the view generates

- When a view is created, the query expression is stored in the database; the expression is substituted into queries using the view

Example

- A view consisting of branches and their customers

```
create view all_customer as
    (select branch_name, customer_name
     from depositor, account
     where depositor.account_number =
account.account_number)
     union
    (select branch_name, customer_name
     from borrower, loan
     where borrower.loan_number = loan.loan_number)
```

- Find all customers of the Perryridge branch

```
select customer_name
from all_customer
where branch_name = 'Perryridge'
```

Derived Relations

- **Derived Relations**
  - E.g. Find the average account balance of those branches where the average account balance is greater than $1200.

```
select branch_name, avg (balance)
from account
group by branch_name
having avg (balance) > 1200
```

```
select branch_name, avg_balance
from (select branch_name, avg (balance)
      from account
      group by branch_name)
      as result (branch_name, avg_balance)
where avg_balance > 1200
```

  - **Note:** we do not need to use the having clause, since we compute the temporary (view) relation result in the from clause, and the attributes of result can be used directly in the where clause

Derived Relations (Cont.)

- E.g. Find the maximum total balance across all branches

```
select max(tot_balance)
from (select branch_name, sum (balance)
        from account
        group by branch_name)
        as branch_total (branch_name, tot_balance)
```

With Clause

- With clause allows views to be defined locally to a query, rather than globally. Analogous to procedures in a programming language

- E.g. Find all accounts with the maximum balance.

```
with max_balance(value) as
        select max(balance)
        from account

select account_number
    from account, max_balance
    where account.balance = max_balance.value
```

Complex Query using with Clause

- E.g. Find all branches where the total account deposit is greater than the average of the total account deposits at all branches

```
with branch_total (branch_name, value) as
select branch_name, sum (balance)
from account
group by branch_name

with branch_total_avg (value) as
select avg (value)
from branch_total

select branch_name
from branch_total, branch_total_avg
where branch_total.value >= branch_total_avg.value
```

Scalar Subquery

- Scalar subquery(标量子查询) is used where **a single value** is expected
- E.g. List all departments along with the number of instructors in each department

```
select dept_name,
    (select count(*)
     from instructor
     where department.dept_name = instructor.dept_name)
     as num_instructors
from department;
```

- Note: Runtime error if subquery returns more than one tuple

Outline

- Overview of SQL
- SQL Data Definition
- Basic Structure of SQL Queries
- Additional Basic Operations
- Set Operations
- Null Values
- Aggregate Functions
- Nested Subqueries

☞ **Modification of the Database**

Modification of the Database – Deletion

- E.g. Delete all accounts at every branch located in Needham city

```
delete from account
where branch_name in (select branch_name
                      from branch
                      where branch_city = 'Needham')
```

```
delete from depositor
where account_number in
        (select account_number
         from branch, account
         where branch_city = 'Needham'
         and branch.branch_name = account.branch_name)
```

Example

- **E.g.** Delete the records of all accounts with balances below the average at the bank

```
delete from account
where balance < (select avg(balance)
                 from account)
```

- **Note:** as we delete tuples from account, the average balance changes

- **Solution used in SQL:**
  - First, compute avg balance and find all tuples to delete
  - Next, delete all tuples found above (without recomputing avg or retesting the tuples)

Modification of the Database – Insertion

- Add a new tuple to account

  insert into *account*
  values *('A-9732', 'Perryridge',1200)*

  or equivalently

  insert into *account (branch_name, balance, account_number)*
  values *('Perryridge', 1200, 'A-9732')*

- Add a new tuple to account with balance setting to null

  insert into *account*
  values *('A-777','Perryridge', null)*

Modification of the Database – Insertion

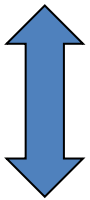
- Provide as a gift for all loan customers of the Perryridge branch, i.e., a $200 saving account. Let the loan number serve as the account number for the new saving account

```
insert into account
    select loan_number, branch_name, 200
    from loan
    where branch_name = 'Perryridge'
insert into depositor
    select customer_name, loan_number
    from loan, borrower
    where loan.loan_number = borrower.loan_number
        and branch_name = 'Perryridge'
```

- **Note:** The **select from where** statement is fully evaluated before any of its results are inserted into the relation. Otherwise, queries like *insert into table1 select * from table2* would cause problems

Modification of the Database – Updates

- Increase all accounts with balances over $10,000 by 6%, and all other accounts receive an increase of 5%.
  - Write two update statements:



```
update account
set balance = balance * 1.06
where balance > 10000

update account
set balance = balance * 1.05
where balance ≤ 10000
```

- The order is important
- Can be done better using the case statement (next slide)

Case Statement for Conditional Updates

- Same query as before: Increase all accounts with balances over $10,000 by 6%, all other accounts receive 5%.

```
update account
   set balance =  case
   when balance <= 10000 then balance *1.05
     else  balance * 1.06
   end
```

```
case
      when pred1 then result1
      when pred2 then result2
      ...
      when predn then resultn
      else result0
end
```

Review Terms

- DDL:Data definition language
- DML:Data manipulation language
- Database schema
- Database instance
- Relation schema
- Relation instance
- Primary key
- Foreign key
  - Referencing relation
  - Referenced relation
- Query language
- SQL query structure
  - **select** clause
  - **from** clause
  - **where** clause
- Natural join operation
- **as** clause
- **order by** clause
- Tuple variable
- Set operations
  - **Union**
  - **Intersect**
  - **except**
- **Null** values
  - Truth value "unknown"
- Aggregate functions
  - **avg, min, max, sum, count**
  - **group by**
  - **having**
- Nested subqueries
- Set comparisons
  - **{<, ≤, >, ≥}{some, all}**
  - **exists**
  - **unique**
- **with** clause
- Scalar subquery
- Database modification
  - **Deletion**
  - **Insertion**
  - **Updating**

Homework

- Further Reading
  - Chapter 3
- Exercises
  - 3.8, 3.9
  - 3.15, 3.16, 3.17, 3.21
- Submission
  - Deadline: 12:00pm, March 12, 2025

End of Lecture 3