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Structured Query Language (SQL)

- Basic SQL Query Structure
- Set Operations
- Aggregate Functions
- Nested Subqueries
- Derived Relations
- Views
- Modification of the Database
- Specialized Join Operation

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Banking Example

- SQL is a “standardized” language, but most vendors have their own version.
- Queries are typically submitted on the command-line, using a client query tool, or through an API.
- Now is the time to start issuing queries, just to get the hang of it!
- White space will be used liberally throughout the following.

Banking Example

- Recall the banking database:

branch (branch-name, branch-city, assets)

customer (customer-name, customer-street, customer-city)

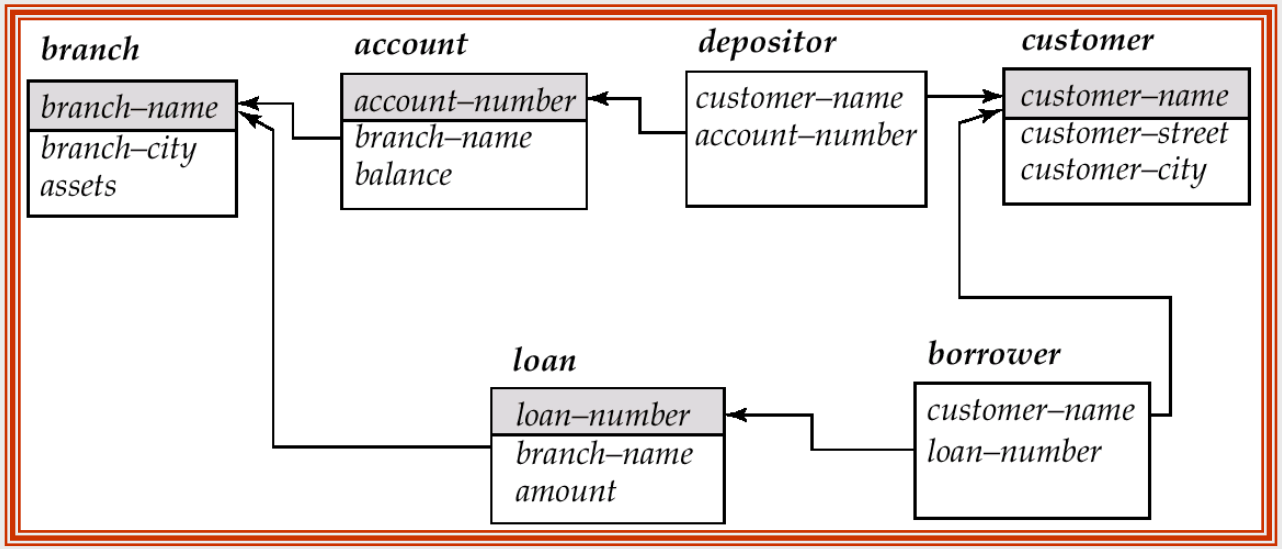
account (account-number, branch-name, balance)

loan (loan-number, branch-name, amount)

depositor (customer-name, account-number)

borrower (customer-name, loan-number)

Schema Used in Examples



Basic Structure

- Typical SQL statement/query structure:

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

- Equivalent (sort of) to:

$$\Pi_{A1, A2, \ldots, An}(\sigma_P (r_1 \times r_2 \times \ldots \times r_m))$$

The select Clause

- **select** clause - lists desired attributes (corresponds to projection).

"Find the names of those branches that have outstanding loans."

select *branch-name*
from *loan*

$$\Pi_{\text{branch-name}}(loan)$$

select *branch-name, loan-number*
from *loan*

$$\Pi_{\text{branch-name,loan-number}}(loan)$$

The select Clause (Cont.)

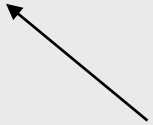
- An asterisk denotes all attributes:

  select *
  from *loan*

- **select** can contain expressions (corresponds to generalized projection).

  select *loan-number, branch-name, amount* ∗ 100
  from *loan*

- Note that the above does not modify the table.



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The select Clause (Cont.)

- The basic SQL select statement does NOT eliminate duplicates.
- Keyword **distinct** is used to eliminate duplicates.

  "Find the names of those branches that have outstanding loans (no duplication)."

  select distinct *branch-name*
  from *loan*

- Keyword **all** can be used (redundantly) when duplicates desired.

  select all *branch-name*
  from *loan*

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The where Clause

- **where** clause - specifies conditions on the result (corresponds to selection).

  "Find the loan numbers for all loans over $1200 made at the Perryridge branch."

  select *loan-number*
  from *loan*
  where *branch-name* = 'Perryridge' **and** *amount* > 1200

- Logical connectives **and, or,** and **not** can be used**.**

- Comparisons can be applied to results of arithmetic expressions.

The from Clause

- **from** clause - lists required relations (corresponds to Cartesian product).

  "Find the Cartesian product borrower x loan."

  select ∗ **from** *borrower, loan*

  "Find the name, loan number and loan amount for all customers having a loan at the Perryridge branch."

  select *borrower.customer-name, borrower.loan-number, loan.amount*
  from *borrower, loan*
  where *borrower.loan-number = loan.loan-number* **and**
  loan.branch-name = 'Perryridge'

- Note the use of expanded name notation in the above.

The from Clause

- Sometimes mixed-use notation is used:

select *customer-name, borrower.loan-number, amount*
from *borrower, loan*
where *borrower.loan-number = loan.loan-number* **and**
branch-name = ‘Perryridge’

The Rename Operation

- Attribute renaming (**as**):

- In the **select** clause (for column renaming):

  "Find the name, loan number and loan amount of all customers; rename the loan-number column loan-id."

  select *customer-name, borrower.loan-number* **as** *loan-id, amount*
  from *borrower, loan*
  where *borrower.loan-number = loan.loan-number*

Tuple Variables

- In the **from** clause (for abbreviating):

  "Find the customer names, their loan numbers and loan amounts for all customers having a loan at the Perryridge branch."

  select *T.customer-name, T.loan-number, S.amount*
  from *borrower* **as** *T, loan* **as** *S*
  where *T.loan-number = S.loan-number*
  and *S.branch-name = 'Perryridge'*

Tuple Variables

- It can also be used to resolve ambiguous relation names:

  "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

- So how about strings?
- SQL supports a variety of string processing functions…surprise!!!
- Example:

"Find the names of all customers whose street includes the substring 'Main'."

select *customer-name*
from *customer*
where *customer-street* **like** '%Main%'

String Operations

- Other SQL string operations:
  - concatenation (using “||”)
  - converting from upper to lower case (and vice versa)
  - finding string length, extracting substrings, etc.

- Most COTS DBMS query processors augment SQL string processing with even more operations; the list is typically very long.

Ordering the Display of Tuples

- Sorting:

  "List in alphabetic order the names of all customers having a loan at the Perryridge branch."

  select distinct *customer-name*
  from *borrower, loan*
  where *borrower.loan-number = loan.loan-number* **and**
  branch-name = 'Perryridge'
  order by *customer-name*

- **desc** or **asc** (the default) can be specified:
  - **order by** *customer-name* **desc**

Ordering the Display of Tuples

- Sorting on multiple attributes (with both **asc** and **desc**):
- Example: add loan amount to the previous query:

select distinct *customer-name, amount*
from *borrower, loan*
where *borrower.loan-number = loan.loan-number* **and**
branch-name = ‘Perryridge’
order by *customer-name* **asc**, *amount* **desc**

Set Operations

- **union, intersect,** and **except** (∪, ∩, –, respectively):
  - *r* **union** *s*
  - *r* **intersect** *s*
  - *r* **except** *s*

  where *r* and *s* are either relations or sub-queries.

- The above operations all automatically eliminate duplicates.

Set Operations

"Find all customers who have a loan, an account, or both."

(select *customer-name* **from** *depositor*)
union
(select *customer-name* **from** *borrower)*

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

(**select** *customer-name* **from** *depositor*)
intersect
(select *customer-name* **from** *borrower)*

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

(**select** *customer-name* **from** *depositor*)
except
(select *customer-name* **from** *borrower)*

Set Operations

- **union all, intersect all** and **except all** retain duplicates:

  If 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*

Aggregate Functions

- Grouping and aggregate functions.
- Basic aggregate functions:

avg	**-** average value
min	**-** minimum value
max	**-** maximum value
sum	**-** sum of values
count	**-** number of values

- Aggregate functions operate on groups.

Aggregate Functions, Cont.

"Find the average account balance."

select avg *(balance)*
from *account*

"Find the average account balance at the Perryridge branch."

select avg *(balance)*
from *account*
where *branch-name* = 'Perryridge'

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Aggregate Functions, Cont.

"Find the number of tuples in the depositor relation."

select count (*)
from *depositor*

Or any single or combination of columns:

select count (customer-name)
from *depositor*

select count (account-number)
from *depositor*

select count (customer-name, account-number)
from *depositor*

Aggregate Functions, Cont.

"Find the number of depositors in the bank."

select count (distinct *customer-name)*
from *depositor*

Aggregate Functions – Group By

- Aggregate functions applied to groups:

  "Find the number of accounts for each branch."

  select *branch-name,* **count** *(account-number)*
  from *account*
  group by *branch-name*

  "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*

- Why does the second have *distinct* but not the first?

Aggregate Functions – Group By

- Grouping can be on multiple attributes:

  "For each depositor, determine how many accounts that depositor has at each branch."

  select *customer-name, branch-name,* **count** (*depositor.account-number)*
  from *depositor, account*
  where *depositor.account-number = account.account-number*
  group by *customer-name, branch-name*

- Notes:
  - Should *distinct* have been included?
  - Attributes in the **select** clause outside of the aggregate functions must appear in **group by** list (e.g., delete *branch-name* from the group-by clause).
  - Group-by *might* require a sort.

Aggregate Functions – Group By

- Grouping on multiple attributes, and multiple aggregate functions.

  "For each depositor, determine how many accounts that depositor has at each branch, plus the average, min and max balance for any account at that branch."

```
select customer-name,
       branch-name,
       count (depositor.account-number)
       avg (account.balance)
       min (account.balance)
       max (account.balance)
from depositor, account
where depositor.account-number = account.account-number
group by customer-name, branch-name
```

Aggregate Functions – Having Clause

- Groups can be selected or eliminated using the *having* clause.

"Find those branches in Orlando with an average balance over 1200."

```
select branch-name
        from account, branch
        where account.branch-name = branch.branch-name
                and branch-city = 'Orlando'
        group by branch-name
        having avg (balance) > 1200
```

- Predicates in the **having** clause are applied after the formation of groups, but those in the **where** clause are applied before forming groups.

Null Values

- It is possible for tuples to have a *null* value for some attributes.
- *null* signifies an unknown value or that a value does not exist.
- The rules for null values are consistent with relational algebra (repeated on the following pages), except for the following addition…
- The predicate **is null** can be used to check for null values.

"Find all loan numbers in the loan relation with null values for amount."

select *loan-number*
from *loan*
where *amount* **is null**

Null Values and Three Valued Logic

- Rule #1 - Any comparison with *null* (initiallly) returns *unknown:*
  - *5 < null or null <> null or null = null*

```
select loan-number
from loan
where amount > 50
```

```
select borrower-name, branch-name
from borrower, loan
where borrower.loan-number = loan.loan-number
```

- Rule #2 - The result of any arithmetic expression involving *null* is *null*
  - *5 + null* evaluates to *null*

```
select loan-number
from loan
where amount*100 > 50000
```

Null Values and Three Valued Logic

- Rule #3 - A “three-valued logic” is applied to complex expressions:
  - 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*

select *loan-number*
from *loan*
where *amount*100 > 5000* **and** *branch-name* = *“Perryridge”*

- Rule #4 - Final result of a **where** clause predicate is treated as *false* if it evaluates to *unknown.*

select *loan-number*
from *loan*
where *amount*100 > 5000* **and** *branch-name* = *“Perryridge”*

Null Values, Cont.

- Rule #5 - Aggregate functions, except **count**, simply ignore nulls.
- Total all loan amounts:

select sum (*amount)*
from *loan*

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

Null Values and Expression Evaluation, Cont.

- This all seems like a pain…couldn't it be simplified?
- Why doesn't a comparison with *null* simply result in *false*?

If *false* was used instead of *unknown*, then:

not (A < 5)

would not be equivalent to:

A >= 5

Why would this be a problem?

Nested Subqueries

- SQL provides a mechanism for nesting queries.
- A sub-query is a **select** statement that is nested in another SQL query.
- Nesting is usually in a **where** clause, but may be in a **from** clause.

Nested Subqueries

- Sub-query in a **where** clause typically performs a set test.

in	<comp> some	exists	unique
not in	<comp> all	not exists	not unique

where <comp> can be $<, \leq, >, =, \neq$

Example Query

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

select distinct *customer-name*
from *borrower*
where *customer-name* **in (select** *customer-name*
from depositor)

Example Query

"Find all customers who have a loan but do not have an account."

select distinct *customer-name*
from *borrower*
where *customer-name* **not in (select** *customer-name*
from *depositor)*

Example Query

"Find the names of 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)*

=> Note that the above query can be "simplified."

Example Query

"Find the names of 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
              customer-name in
                    (select customer-name
                     from depositor, account
                     where depositor.account-number =
                           account.account-number and
                           branch-name = "Perryridge")
```

Set Comparison – the "Some" Clause

"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')
```

Set Comparison – the "All" Clause

"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')
```

Note that the some and all clauses correspond to existential and universal quantification, respectively.

Definition of the "Some" Clause

- F <comp> **some** *r* $\Leftrightarrow$ $\exists$ *t* $\in$ *r* *s.t.* (F <comp> *t*)

(5< **some** | 0 / 5 / 6 |) = true

(5< **some** | 0 / 5 |) = false

(5 = **some** | 0 / 5 |) = true

(5 $\neq$ **some** | 0 / 5 |) = true (since 0 $\neq$ 5)

(= **some**) $\equiv$ **in**

However, ($\neq$ **some**) $\not\equiv$ **not in**

Definition of the "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**

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Test for Empty Relations

- The **exists** operator can be used to test if a relation is empty.
- Operator **exists** returns **true** if its argument is nonempty.
  - **exists** r $\Leftrightarrow$ $r \neq \emptyset$
  - **not exists** r $\Leftrightarrow$ $r = \emptyset$
- On a personal note, why not call it **empty**?

Example Query

"Find all customers who have an account at all branches located in Brooklyn."

```
select distinct S.customer-name
        from customer as S
        where not exists (
                (select branch-name
                 from branch
                 where branch-city = 'Brooklyn')
                        except
                (select R.branch-name
                 from depositor as T, account as R
                 where T.account-number = R.account-number and
                        S.customer-name = T.customer-name))
```

- Because of the use of the tuple variable S in the nested query, the above is sometimes referred to as a *correlated* query.
- The above demonstrates that nesting can be almost arbitrarily composed and deep.
- According to the book, the above cannot be written using = **all** or its variants…hmmm…

Test for Absence of Duplicate Tuples

- The **unique** operator tests whether a sub-query contains duplicate tuples.

  "Find all customers who have at most one account at the Perryridge branch."

```
select T.customer-name
      from customer as T
      where unique (
            select D.customer-name
            from account as A, depositor as D
            where T.customer-name = D.customer-name and
                  A.account-number = D.account-number and
                  A.branch-name = 'Perryridge')
```

- What if the inner query selected the account number?
  - count(…) <= 1

Example Query

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

```
select distinct T.customer-name
from customer 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')
```

Nesting in the From-Clause

"Find the average account balance of those branches where the average account balance is greater than $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 that previously we saw an equivalent query that used a *having* clause.

Views

- Purpose of a view:
  - Hide certain data from the view of certain users
  - Provide pre-canned, named queries
  - Simplify complex queries

- Syntax of a view:

  create view *v* **as** <query expression>

  where:
  - *v* - view name
  - <query expression> - view definition (SQL)

Example Views

- A view consisting of branches and their customers:

create view *all-customer* **as**
(**select** *branch-name, customer-name*
from *depositor as D, account as A*
where *D.account-number = A.account-number)*
union
(**select** *branch-name, customer-name*
from *borrower as B, loan as L*
where *B.loan-number = L.loan-number)*

"Find all customers of the Perryridge branch."

select *customer-name*
from *all-customer*
where *branch-name* = 'Perryridge'

Modification of the Database – Insertion

- Basic insert*:*

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

- Ordering values:

  insert into *account (branch-name, balance, account-number)*
  values (‘Perryridge’, 1200, ‘A-9732’)

- Inserting a null value:

  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, a $200 savings account. Let the loan number serve as the account number for the new 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 branch-name = 'Perryridge'
              and loan.account-number = borrower.account-number
```

- The above would typically be a transaction.

Modification of the Database – Insertion

- Most DBMSs provide a command-line, bulk-load command:

```
LOAD DATA LOCAL INFILE '<file-path>' INTO TABLE part
        FIELDS TERMINATED BY ‘<file-separator>' LINES TERMINATED BY ‘<line-separator>';
```

- Example:

```
LOAD DATA LOCAL INFILE‘C:\\Users\\pbernhar\\department.csv’ INTO TABLE department
        FIELDS TERMINATED BY ‘,’ ;
```

Modification of the Database – Deletion

"Delete all tuples in the depositor table."

delete from *depositor*

"Delete all depostor records for Smith."

delete from *depositor*
where *customer-name* = 'Smith'

Modification of the Database – Deletion

"Delete all accounts at every branch located in Needham city."

```
delete from depositor
where account-number in
        (select account-number
          from branch as B, account
          where branch-city = 'Needham' and B.branch-name = A.branch-name)

delete from account
where branch-name in (select branch-name
                      from branch
                      where branch-city = 'Needham')
```

Example Query

"Delete the record of all accounts with balances below the average at the bank."

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

Modification of the Database – Updates

"Set the balance of all accounts at the Perryridge branch to 0."

update *account*
  set *balance = 0*
  where *branch-name = "Perryridge"*

"Set the balance of account A-325 to 0, and also change the branch name to "Mianus."

update *account*
  set *balance = 0, branch-name = "Mianus"*
  where *account-number* = "A-325"

Modification of the Database – Updates

"Increase all accounts with balances over $10,000 by 6%, all other accounts by 5%."

Option #1:

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

update *account*
set *balance* = *balance* ∗ 1.05
where *balance* <= 10000

Modification of the Database – Updates

"Increase all accounts with balances over $10,000 by 6%, all other accounts by 5%."

Option #2:

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

Transactions

- Some of the previous multi-query operations should be made transactions.
- A *transaction* is a sequence of SQL statements executed as a single unit.
- Example - Transferring money from one account to another:
  - deducting the money from one account
  - crediting the money to another account
- If one step succeeds and the other fails, the database is left in an inconsistent state.
- Therefore, either both steps should succeed, or both should fail (note: failing is better than corrupting).

Transaction - Syntax

- Transactions are started either implicitly or explicitly.
- Transactions are terminated by:
  - *commit* - makes all updates of the transaction permanent
  - *rollback* - undoes all updates performed by the transaction
- Commits and rollbacks can also be either implicit or explicit.
- Implicit transactions with implicit commits (no special syntax):
  - DDL statements
  - Individual SQL statements that execute successfully
- Implicit rollbacks:
  - System failure

Transactions, Cont.

- Automatic commit can be turned off, allowing multi-statement transactions.
- Transactions are identified by some variant of:

```
begin transaction          // shuts off auto-commit
  …
end transaction            // commits the transaction
```

- Within the transaction, partial work can be:
  - made permanent by using the **commit work** statement.
  - undone by using the **rollback work** statement.
- Transactions are, or rather, should be the *rule* for programmers, rather than the exception.

Joined Relations

- Join operations take two relations and return another as a result.
- Specialized join operations are typically used as subquery expressions.
- Join condition – defines which tuples in the two relations match, and what attributes are present in the result of the join.
  - **natural**
  - **using** (A_1, A_2, ..., A_n) // equi-join
  - **on** <predicate> // theta-join
- Join type – defines how non-matching tuples (based on the join condition) in each relation are treated.
  - **inner join**
  - **left outer join**
  - **right outer join**
  - **full outer join**

Joined Relations – Datasets for Examples

- Relation *loan*

loan-number	*branch-name*	*amount*
L-170	Downtown	3000
L-230	Redwood	4000
L-260	Perryridge	1700

- Relation *borrower*

customer-name	*loan-number*
Jones	L-170
Smith	L-230
Hayes	L-155

- Note that borrower information is missing for L-260 and loan information missing for L-155.

Joined Relations – Examples

loan **inner join** *borrower*
on *loan.loan-number = borrower.loan-number*

loan-number	*branch-name*	*amount*	*customer-name*	*loan-number*
L-170	Downtown	3000	Jones	L-170
L-230	Redwood	4000	Smith	L-230

loan **left outer join** *borrower*
on *loan.loan-number = borrower.loan-number*

loan-number	*branch-name*	*amount*	*customer-name*	*loan-number*
L-170	Downtown	3000	Jones	L-170
L-230	Redwood	4000	Smith	L-230
L-260	Perryridge	1700	*null*	*null*

Joined Relations – Examples

loan **natural inner join** *borrower*

loan-number	*branch-name*	*amount*	*customer-name*
L-170	Downtown	3000	Jones
L-230	Redwood	4000	Smith

loan **natural right outer join** *borrower*

loan-number	*branch-name*	*amount*	*customer-name*
L-170	Downtown	3000	Jones
L-230	Redwood	4000	Smith
L-155	null	null	Hayes

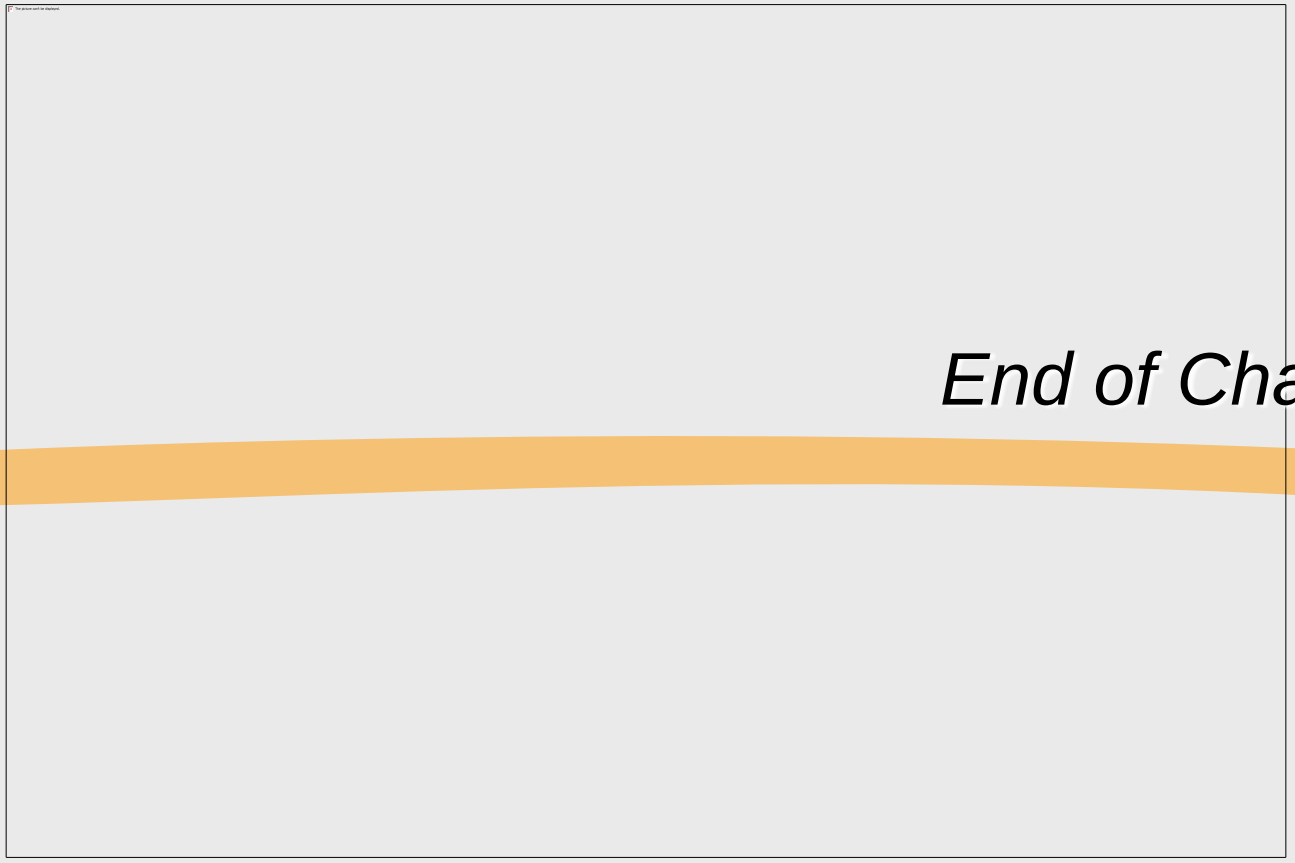
Joined Relations – Examples

loan **full outer join** *borrower* **using** *(loan-number)*

loan-number	*branch-name*	*amount*	*customer-name*
L-170	Downtown	3000	Jones
L-230	Redwood	4000	Smith
L-260	Perryridge	1700	*null*
L-155	null	null	Hayes

"Find all customers who have either an account or a loan (but not both) at the bank."

select *customer-name*
from (*depositor* **natural full outer join** *borrower*)
where *account-number* **is** *null* **or** *loan-number* **is** *null*



End of Chapter