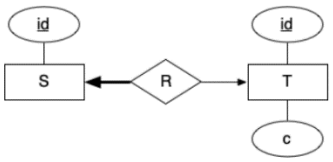
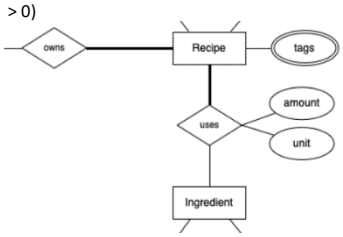
```
create table S (
   id      serial,
   t       integer,
   primary key (id),
   foreign key (t) references T(id)
);

create table T (
   id      serial,
   c       text not null,
   primary key (id)
):
```



confusing

```
create table Uses (
   recipe integer,
   ingredient integer,
   amount integer not null,
   unit text not null,
   primary key (recipe, ingredient),
   foreign key (recipe) references Recipes(id),
   foreign key (ingredient) references
Ingredients(id),
   constraint positive_amount check (amount
> 0)
```



ER-style
Person: ID, name
Employee: ID, salary
Manager: ID, bonus

O-O style
Person: ID, name
Employee: ID, name, salary
Manager: ID, name, salary, bonus

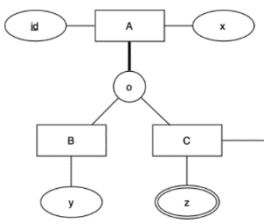
Single Table
Person: ID, name, salary, bonus
(class depends on null values)

ER-style

```
create table A (
   id      integer,
   x       text,
   primary key (id)
);
create table B (
   a       integer references A(id),
   y       text,
   primary key (a)
);
create table C (
   a       integer references A(id),
   primary key (a)
);
```

Single Table

```
create table A (
   id      integer,
   x       text,
   y       text,
   b       boolean, -- true if A is a B
   c       boolean, -- true if A is a C
   primary key (x)
);
```



ER-style

```
create table People (
   id        integer primary key,
   name      text not null,
   lives_in  text not null
);

create table Customers (
   id  integer primary key references
People(id)
);

create table Employees (
   id        integer primary key references
People(id),
   salary    integer not null check (salary > 0),
   works_in  integer not null references
Branches(id)
);
```

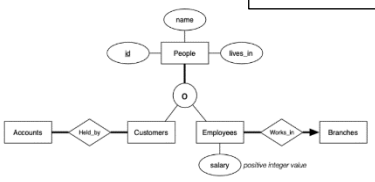
Single Table

```
create table People (
   id        integer primary key,
   name      text not null,
   lives_in  text not null,

   is_customer boolean not null,
   is_employee boolean not null,
   salary    integer,
   works_in  integer references
branches(id),

   constraint  emp_data check (
      (is_employee = false and salary is null
and works_in is null)
      -- non-employees can not have salary or
work in a branch
      or
      (is_employee = true and salary > 0 and
works_in is not null)
      -- employees must have a positive salary
and work in a branch
   ),
   constraint  total_participation check (
      is_customer = true or is_employee =
true
   )
);
```

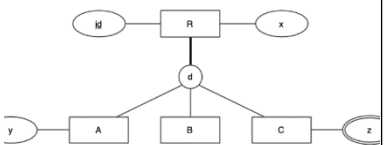
overlapping



Single Table

```
create table R (
   id integer primary key,
   is_a char(1) not null check (is_a in
('A','B','C')),
   x text,
   y text
);
```

disjoint



Superkey -> Candidate key -> Primary key

Functional Dependency example
-> (Position -> Salary)

Functional Dependencies

A	B	C
a	1	X
a	1	y

hold O: A->B
hold X: A->C, B->C, AB->C

Closure: Largest collection of dependencies that can be derived from set F (aka F+)

F = {A->B, BC->F, BD->EG, AD->C, BEG->FA}
ACEG+ = {A, B, C, E, F, G}

Minimal Cover: Smallest set of FDs which covers entire FD set

F = {A->BC, B->C, A->B, AB->C}
1) Convert FDs into canonical form
{A->B, A->C, B->C, AB->C}
2) For multi-attribute LHS, remove redundant attributes
{A->B, A->C, B->C, A~~B~~->C}
3) Eliminate redundant FDs
{A->B, ~~A->C~~, B->C}

For all FDs X->Y…
1) X->Y is trivial (is Y a subset of X?)
2) X is a superkey
3) Y is single attribute & partof candidate key
1,2: BCNF, 1,2,3: 3NF

F = {AB->C, AB->D, C->A, D->B}
AB+ = ABCD, C+ = AC, CD+ = ABCD

	3NF?	BCNF?
AB->C	2	2
AB->D	2	2
C->A	3	X
D->B	3	X

Transaction: ‘unit of work’, may change multiple databases at once.

READ, WRITE, BEGIN, COMMIT, ABORT
Syntax: R(X), W(Y), etc

No concurrency
T1: R(X) W(X) R(Y) W(Y)
T2: R(X) W(X) R(Y) W(Y)
With concurrency
T1: R(X) W(X) R(Y) W(Y)
T2: R(X) W(X) R(Y) W(Y)

Two concurrent transfers from same source account:

- T1 transfers $200 X→Y, T2 transfers $100 X→Y
- inital values: X=500, Y=100; final values: X=200, Y=400

T1	T2	X_{T1}	X_{T2}	X_{db}	Y_{T1}	Y_{T2}	Y_{db}
R(X)		500		500			100
X-200		300					
	R(X)		500				
W(X)		300		300			
	X-100		400				
	W(X)		400	400			
	R(Y)					100	
R(Y)					100		
Y+200					300		
W(Y)					300		300
	Y+100					200	
	W(Y)					200	200

Conflict Serializability: Make concurrent into serial schedule with swapping orders

Example: transform a concurrent schedule to serial schedule

```
T1: R(A) W(A)       R(B)       W(B)
T2:           R(A)       W(A)       R(B) W(B)
swap
T1: R(A) W(A) R(B)             W(B)
T2:           R(A) W(A)       R(B) W(B)
swap
T1: R(A) W(A) R(B)       W(B)
T2:           R(A)       W(A) R(B) W(B)
swap
T1: R(A) W(A) R(B) W(B)
T2:                      R(A) W(A) R(B) W(B)
```

View Serializability:
1) Reads same version of shared object
2) Writes same final version of shared object

T1: R(A) W(A) R(B) W(B)
T2: R(A) W(A) R(B) W(B)

T1: R(A) W(A) R(B) W(B)
T2: R(A) W(A) R(B) W(B)

A: T1 reads initial, T2 reads T1's write, T2 writes final
B: T1 reads initial, T2 reads T1's write, T2 writes final

Selection: sel[expr](rel)
-> selects the rows in some relation that satisfies expression

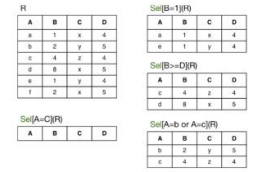
Projection: proj[a,b,c](rel)
-> filters relation by its columns a, b, c

Rename: rename[schema](rel)
-> renames the columns of rel with the columns specified in schema

Sel[B=1](R) is equivalent to

```
select *
from   R
where  B = 1;
```

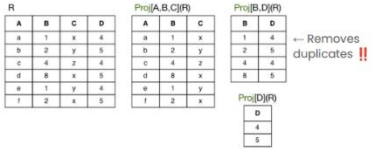
Examples of selection:



Proj[A, B, C](R) is equivalent to

```
select  distinct A,B,C
from    R;
```

Examples of projection:




```
Res = Rename[Res(b,c,d)](Project[b,c](Sel[a>5](R)) Join
S)
Tmp1 = Select[a>5](R)
Tmp2 = Project[b,c](Tmp1)
Tmp3 = Rename[Tmp3(cc,d)](S)
Tmp4 = Tmp2 Join[c=cc] Tmp3
Res  = Rename[Res(b,c,d)](Tmp4)
```

syntax

```
select c.given, c.family, t.source, t.amount
from  Transactions t join Customers c on t.actor = c.id
      join Accounts a on t.source = a.id
      join Branches b on a.held_at = b.id
where  t.tdate < '2022-05-01' and t.ttype = 'withdrawal';
```

Tmp1 = Sel[t.tdate < '2022-05-01' and t.ttype = 'withdrawal'] Transactions
Tmp2 = Customers Join[Customers.id = Tmp1.actor] Tmp1
Tmp3 = Accounts Join[Accounts.id = Tmp2.source] Tmp2
Tmp4 = Branches Join[Branches.id = Tmp3.held_at] Tmp3
Result(given, family, source, amount) = Proj[given, family, source, amount] Tmp4

Union: R ∪ S (Query1) UNION (Query2)
Intersection: R ∩ S (Query1) INTERSECT (Query2)
Difference: R - S (Query1) EXCEPT (Query2)

Divison
-> Here, get all A values where B has x and y.

R

A	B
4	x
4	y
4	z
5	x
5	y
5	z

S

A	B
4	x
4	y
4	z
5	x
5	z

T

B
x
y

R / T

A
4
5

S / T

A
4

There is a conflict between 2 transactions if 1 & 2 apply
1) Performs operations on same data item
2) At least one is write (e.g. R&W, W&W, W&R)

Conflict Serializable:
If we can swap non-conflicting operations so that result is serial schedule: ‘Conflict Serializable’

View Serializable: If some schedule S and some serial schedule S’
1. Same transaction reads same initial value of X
2. Same transaction reads same changed version of X
3. Same transaction writes to final value of X

e.g.
T1: W(Y) W(X)
T2: R(Y) W(X)
T3: W(X)

Conflict:
X: T1->T2, T2->T3, T1->T3
Y: T2->T1
Cycle In T1 and T2, not conflict serializable

View:
Considering T2;T1;T3
T1: W(Y), W(X)
T2: R(Y) W(X)
T3: W(X)

X) Final write: T3
Y) First read: T2, Final write: T1
Both satisfy above, therefore is ‘view serializable’

```
having ( -- advanced(?) having
   sum(s.length) = (
      select max(total_length)
      from (
         select sum(s1.length) as total_length
         from groups g1
         group by a1.id
```

```
case -- case usage
when instrument ilike '%guitar%' then
'guitar'
when instrument in ('keyboard', 'piano') then
'piano'
else instrument
end
```

```
select
p.id, -- string concat
(p.street_no || ' ' || st.name || ' ' ||
st.stype) as street_name,
su.name
from properties p
```

```
select
   r.name, -- case example
   count(case when h.gender = 'S' then 1
end) as s_count,
   count(case when h.gender = 'G' then 1
end) as g_count,
```

```
select
   department,
string_agg(employee_name, ', ' order by
employee_name) as employee_list
from
   employees
group by
   department;
```

string_agg(expression, delimiter [order by expression])

```
select distinct -- distinct select
   b.location,
   c.lives_in
from customers c
```

```
select distinct -- distinct select
   b.location,
   c.lives_in
from customers c
```

```
create or replace function q4()
returns setof SongCounts
as $$
declare
result SongCounts;
begin
for group_id, group_name in
~
loop
result."group" := group_name;
for album_id in
~
loop
~
end loop;
result.nshort := nshort;
result.nlong := nlong;
return next result;
```

```
create or replace function q4()
returns setof SongCounts
as $$
declare
result SongCounts;
begin
for group_id, group_name in
~
loop
result."group" := group_name;
for album_id in
~
loop
~
end loop;
result.nshort := nshort;
result.nlong := nlong;
return next result;
```

```
select unit_no, street_no, street, ptype
into unit_num, street_num, street_id,
property_type
from properties
where id = propID;
```

```
for horse_id, horse_name in
   select id, name
   from horses
   where name ~* part_name
   order by name
loop
   result.horse := horse_name;
   prize_sum := 0;
   races_ran := 0;
   select race_count
   into races_ran
   from (
      select h.name, count(*) as race_count
      from horses h
      join blah
      where h.id = horse_id
      group by h.name
   );
   for prize in (for loop in for loop)
      select r.prize
      from horses h
      join blah
      where h.id = horse_id and ru.finished = 1
   loop
      prize_sum := prize_sum + prize;
   end loop;
   average := prize_sum / races_ran;
   result.average = average;
   return next result;
end loop;
```

```
create or replace view
farthest(person,event,location,ordering)
as (helper view)
select person, event, location, ordering
from  trail t
where ordering = (select max(ordering) from
trail where person=t.person and
event=t.event);

create or replace function q3(_eventID
integer)
   returns setof text
as $$
declare
   _last integer;
   _tuple record;
   _nquitters integer := 0;
begin
   perform id from Events where id =
_eventID;
   if not found then
      return next 'No such event';
      return;
   end if;
   select max(c.ordering) into _last
   from CheckPoints c
   join Events e on c.route_id = e.route_id
   where e.id = _eventID;

   for _tuple in
      select person,location
      from farthest
      where event = _eventID and ordering <
_last
   loop
      return next _tuple.person || ' gave up at
' || _tuple.location;
      _nquitters := _nquitters + 1;
   end loop;

   if _nquitters = 0 then
      return next 'Nobody gave up';
   end if;
end;
$$ language plpgsql;
```

return; exits function without returning further values

```
nullif(val1,val2)
-> returns null if val1 is equal to val2
insert into employees (id, name,
department, salary) values (101, 'Alice
Johnson', 'HR', 60000);
update employees set salary = 65000 where
id = 101;
delete from employees where id = 101;
```

```
Meaning of 'new' and 'old' in triggers
create trigger q9_2
after update of name on groups
-> if 'of name' exists, only triggered when
'name' column is updated.
```

Triggers

```
#!/usr/bin/python3
import sys
import psycopg2
conn = None
usage = f"Usage: {sys.argv[0]} lmao"
name = sys.argv[1]
conn = None

if len(sys.argv) != 2:
   print(usage)
   sys.exit(1)

main_query = """
select blah
from blah b
join what w on something
order by b.lol
"""

try:
   conn = psycopg2.connect("dbname=bank")
   cur = conn.cursor()
   cur.execute(main_query, [name])
               main_result = cur.fetchall()
   except Exception as err:
   print("DB error: ", err)
finally:
   if conn is not None:
      conn.close()
```

```
Triggers – what to do:
1. Split between 'before' and 'after' triggers
2. Split again by analysing the requirements

Before triggers: Raise exceptions (usually)
After triggers: Update values

create trigger TotalSalary2
after update on Employee
for each row execute procedure
totalSalary2();

create function totalSalary2() returns trigger
as $$
begin
   update Department
   set    totSal = totSal + new.salary
   where  Department.id = new.dept;

   update Department
   set    totSal = totSal - old.salary
   where  Department.id = old.dept;
   return new;
end;
$$ language plpgsql;
```

Triggers

	Insert	Update	Delete
NEW	NewRow	NewRow	X
OLD	X	OldRow	OldRow

```
  if TG_OP = 'INSERT' then
    fno := new.flight_no
  else
    fno := old.flight_no
  end if;

  if TG_OP = 'DELETE' then
    return old; -> for 'before delete'
  else
    if flight.nbooked = flight.nseats then
      raise exception 'Booking error';
    end if;        -> raise exception for befores
    return new;-> for 'before insert & update'
end if;
```

P.S. returns not needed for after triggers

```
Flights(fid, from, to, distance, departs,
arrives, price)
Aircraft(aid, aname, range)
Certified(employee, aircraft)
Employees(eid, ename, salary)

fid, aid, eid are primary keys.
from,to -> distance violates BCNF, we need
new table
```

Non-BCNF schema to BCNF schema

```
new schema:
Flights(fid,from,to,departs,arrives,price)
Routes(from,to,distance)
Aircraft(aid,aname,range)
Certified(employee,aircraft)
Employees(eid,ename,salary)
```

```
create aggregate myCount(anyelement) (
   stype    = int,    -- the accumulator type
   initcond = 0,      -- initial accumulator value
   sfunc    = oneMore -- increment function
);

create function
   oneMore(sum int, x anyelement) returns
int
as $$
begin
   return sum + 1;
end;
$$ language plpgsql;
```

```
create aggregate prod(numeric) (
   stype    = numeric,
   initcond = 1,
   sfunc    = mult
);

create function
   mult(soFar numeric, next numeric) returns
numeric
as $$
begin
   return soFar * next;
end;
$$ language plpgsql;
```

```
create aggregate concat(text) (
   stype    = text,
   initcond = '',
   sfunc    = join
);

create function
   join(s1 text, s2 text) returns text
as $$
begin
   if (s1 = '') then
      return s2;
   else
      return s1||','||s2;
   end if;
end;
$$ language plpgsql;
```

Aggregate

```
- First parameter: value so far
- Second parameter: new value
   - that's why we don't need to use 2nd
parameter in count aggregate
```

```
create or replace function
   Q5(pattern text)
returns table(
   rug text,
   size_and_stoper text,
   total_knots numeric(8,0)
) as $$
select
   name as rug,
   size || 'sf ' || coalesce(rug_stop::text, '') as
size_and_stoper,
   (coalesce(knot_per_foot, 50) *
coalesce(knot_per_foot, 50) *
size)::numeric(8,0) as total_knots
from
   rugs
where
   name ~ pattern;
$$ language sql;
```

SQL functions

```
create or replace function
   Q6(pattern text)
returns table(
   province text,
   first integer,
   nrugs integer,
   rating numeric(3,1)
) as $$
select
   l.province,
   min(r.year_crafted) as first,
   count(r.id)::integer as nrugs,
   avg(r.rating)::numeric(3,1) as rating
from locations l
join factories f on l.id = f.located_in
join crafted_by cb on f.id = cb.factory
join rugs r on cb.rug = r.id
where l.province ~* pattern
group by l.province;
```