Introduction to Database Systems
CSE 414

Lecture 11: More Relational Algebra

Announcements

- WQ4/HW4 released
  – Both due next Tuesday
- Please make sure you get your AWS set up!
  – Will need for HW6
- Do not use seaquill for data storage
  – Machine gets wiped out periodically

Relational Algebra Operators

- Union ∪, ~~intersection ∩~~, difference -
- Selection σ
- Projection π
- Cartesian product X, join ⋈
- (Rename ρ)
- Duplicate elimination δ
- Grouping and aggregation γ
- Sorting τ

RA

Extended RA

All operators take in 1 or more relations as inputs and return another relation

Composing RA Operators

Patient

no	name	zip	disease
1	p1	98125	flu
2	p2	98125	heart
3	p3	98120	lung
4	p4	98120	heart

$\pi_{zip,disease}$(Patient)

zip	disease
98125	flu
98125	heart
98120	lung
98120	heart

$\sigma_{disease='heart'}$(Patient)

no	name	zip	disease
2	p2	98125	heart
4	p4	98120	heart

$\pi_{zip,disease}(\sigma_{disease='heart'}$(Patient))

zip	disease
98125	heart
98120	heart

Natural Join

$$R1 \bowtie R2$$

- Meaning: $R1 \bowtie R2 = \Pi_A(\sigma_\theta(R1 \times R2))$

- Where:
  - Selection σ_θ checks equality of all common attributes (i.e., attributes with same names)
  - Projection Π_A eliminates duplicate common attributes

Join Summary

- **Theta-join**: $R \bowtie_\theta S = \sigma_\theta (R \times S)$
  - Join of R and S with a join condition θ
  - Cross-product followed by selection θ
  - No projection
- **Equijoin**: $R \bowtie_\theta S = \sigma_\theta (R \times S)$
  - Join condition θ consists only of equalities
  - No projection
- **Natural join**: $R \bowtie S = \pi_A (\sigma_\theta (R \times S))$
  - Equality on **all** fields with same name in R and in S
  - Projection π_A drops all redundant attributes

Some Examples

```
Supplier(sno,sname,scity,sstate)
Part(pno,pname,psize,pcolor)
Supply(sno,pno,qty,price)
```

Name of supplier of parts with size greater than 10

$\pi_{sname}(Supplier \bowtie (Supply \bowtie (\sigma_{psize>10} (Part)))$

Name of supplier of red parts or parts with size greater than 10

$\pi_{sname}(Supplier \bowtie (Supply \bowtie (\sigma_{psize>10} (Part) \cup \sigma_{pcolor='red'} (Part))))$

$\pi_{sname}(Supplier \bowtie (Supply \bowtie (\sigma_{psize>10 \vee pcolor='red'} (Part))))$

Some Examples

```
Supplier(sno,sname,scity,sstate)
Part(pno,pname,psize,pcolor)
Supply(sno,pno,qty,price)
```

Name of supplier of parts with size greater than 10

```
Project[sname](Supplier Join[sno=sno]
              (Supply Join[pno=pno] (Select[psize>10](Part)))
```

Name of supplier of red parts or parts with size greater than 10

```
Project[sname](Supplier Join[sno=sno]
              (Supply Join[pno=pno]
              ((Select[psize>10](Part)) Union
                                        (Select[pcolor='red'](Part)))

Project[sname](Supplier Join[sno=sno] (Supply Join[pno=pno]
                             (Select[psize>10 OR pcolor='red'](Part)))
```

Can be represented as trees as well

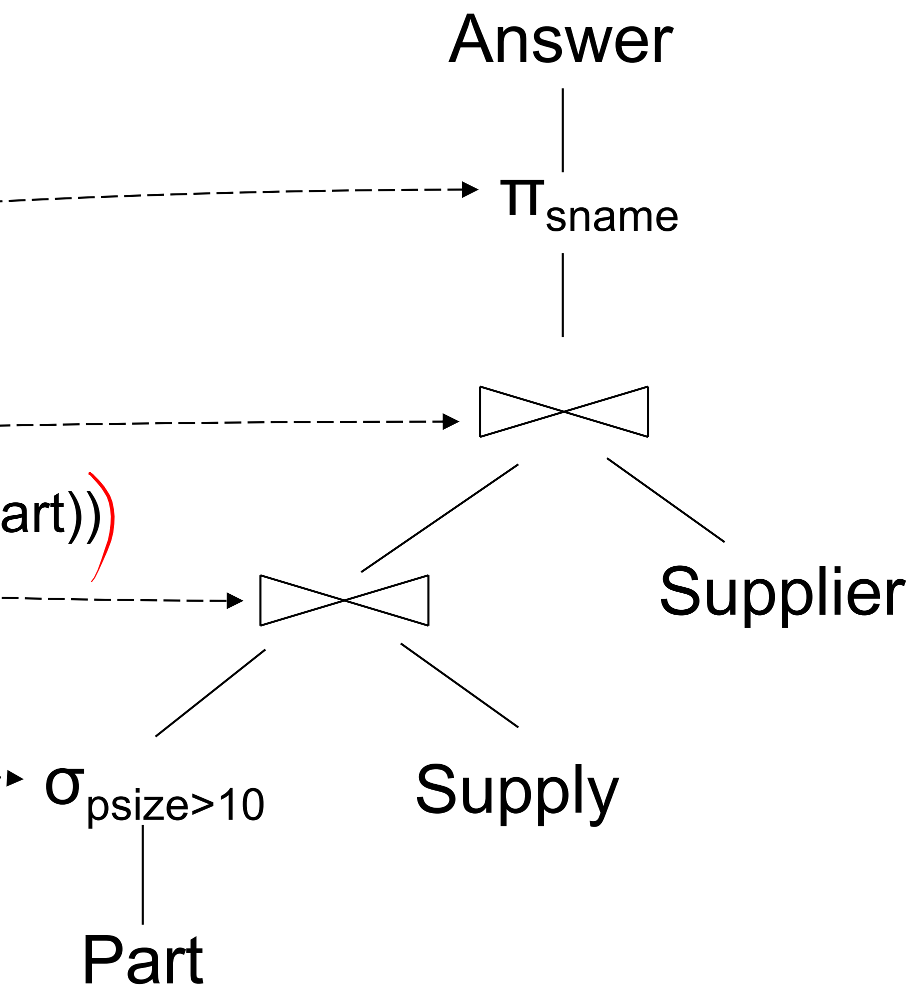
Representing RA Queries as Trees

`Supplier(sno,sname,scity,sstate)`

`Part(pno,pname,psize,pcolor)`

`Supply(sno,pno,qty,price)`

$\pi_{sname}(\text{Supplier} \bowtie (\text{Supply} \bowtie (\sigma_{psize>10}(\text{Part}))))$



Relational Algebra Operators

- Union ∪, ~~intersection ∩,~~ difference -
- Selection σ
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RA

Extended RA

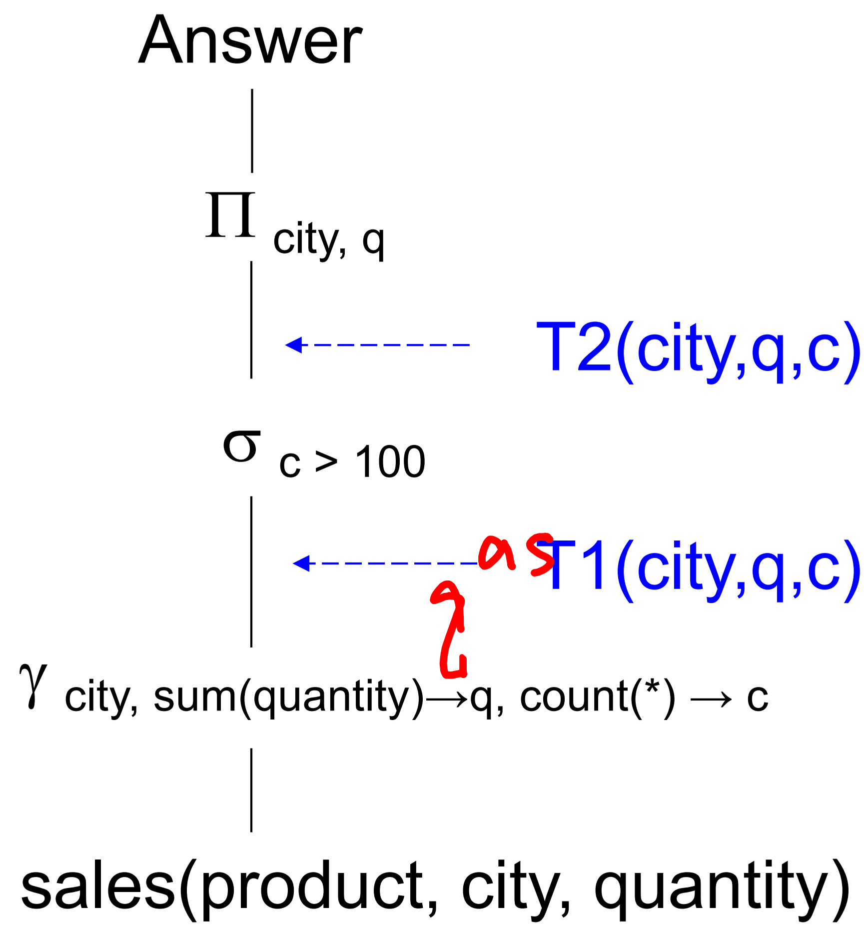
All operators take in 1 or more relations as inputs and return another relation

Extended RA: Operators on Bags

- Duplicate elimination δ
- Grouping γ
  - Takes in relation and a list of grouping operations (e.g., aggregates). Returns a new relation.
- Sorting τ
  - Takes in a relation, a list of attributes to sort on, and an order. Returns a new relation.

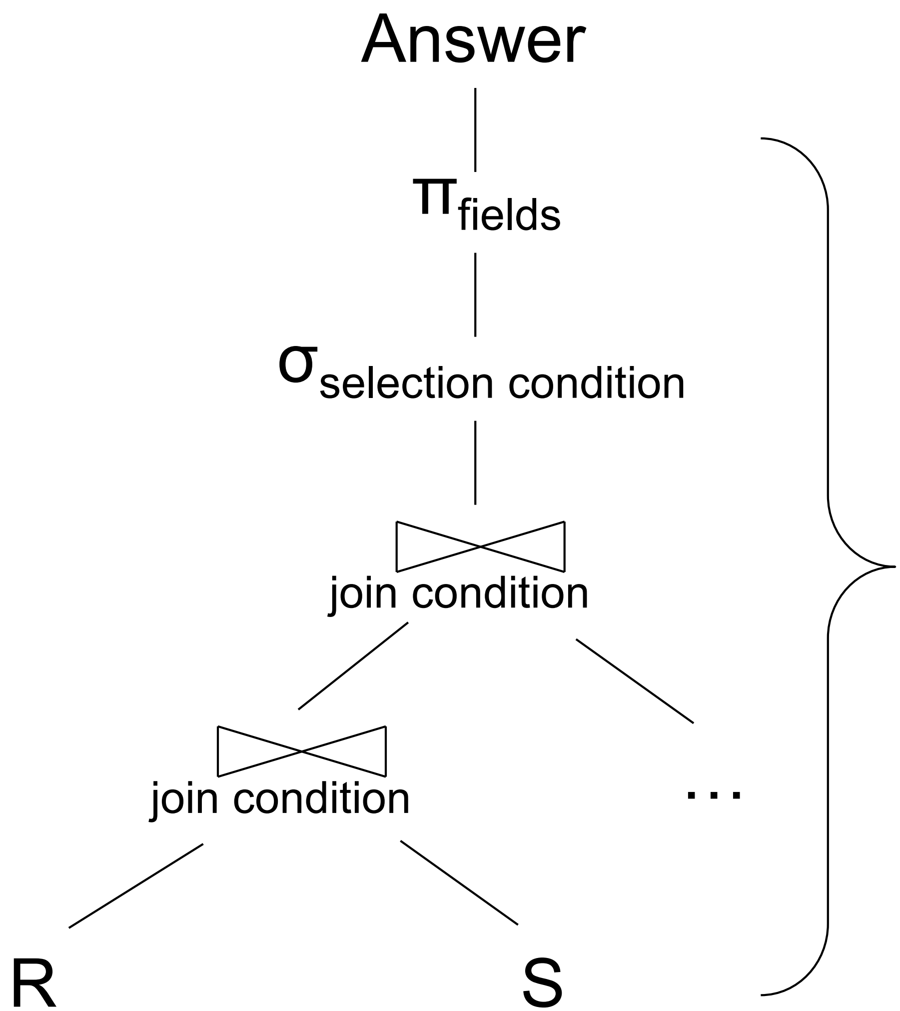
Using Extended RA Operators

```
SELECT city, sum(quantity)
FROM sales
GROUP BY city
HAVING count(*) > 100
```



T1, T2 = temporary tables

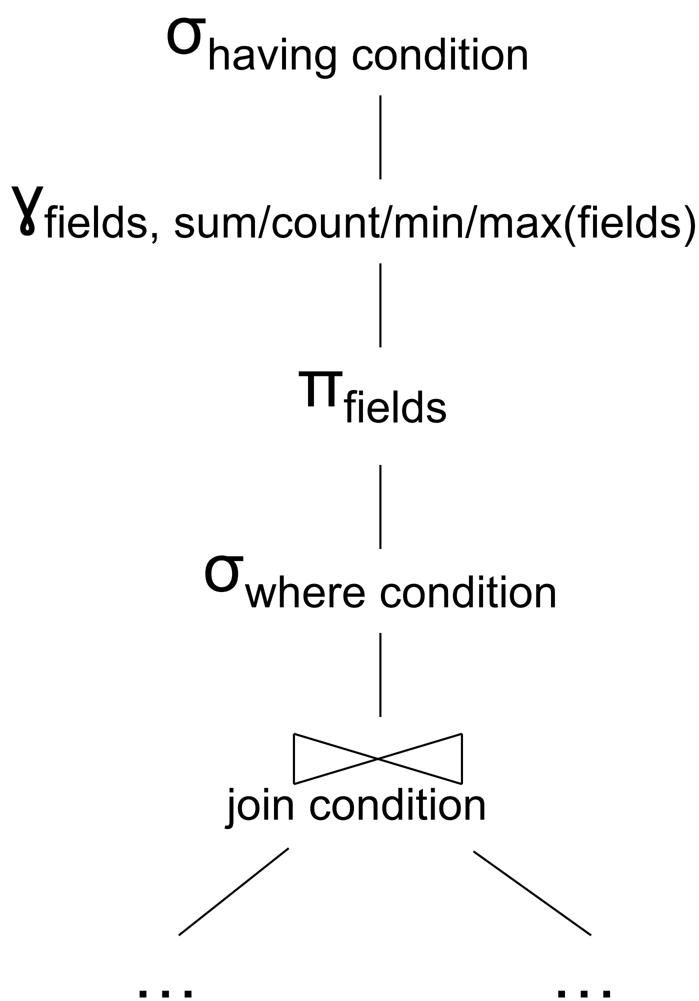
Typical Plan for a Query (1/2)




```
SELECT fields
FROM R, S, …
WHERE condition
```

SELECT-PROJECT-JOIN
Query

Typical Plan for a Query (1/2)




```
SELECT fields
FROM R, S, …
WHERE condition
GROUP BY fields
HAVING condition
```

Supplier(<u>sno</u>,sname,scity,sstate)
Part(<u>pno</u>,pname,psize,pcolor)
Supply(<u>sno,pno</u>,price)

How about Subqueries?

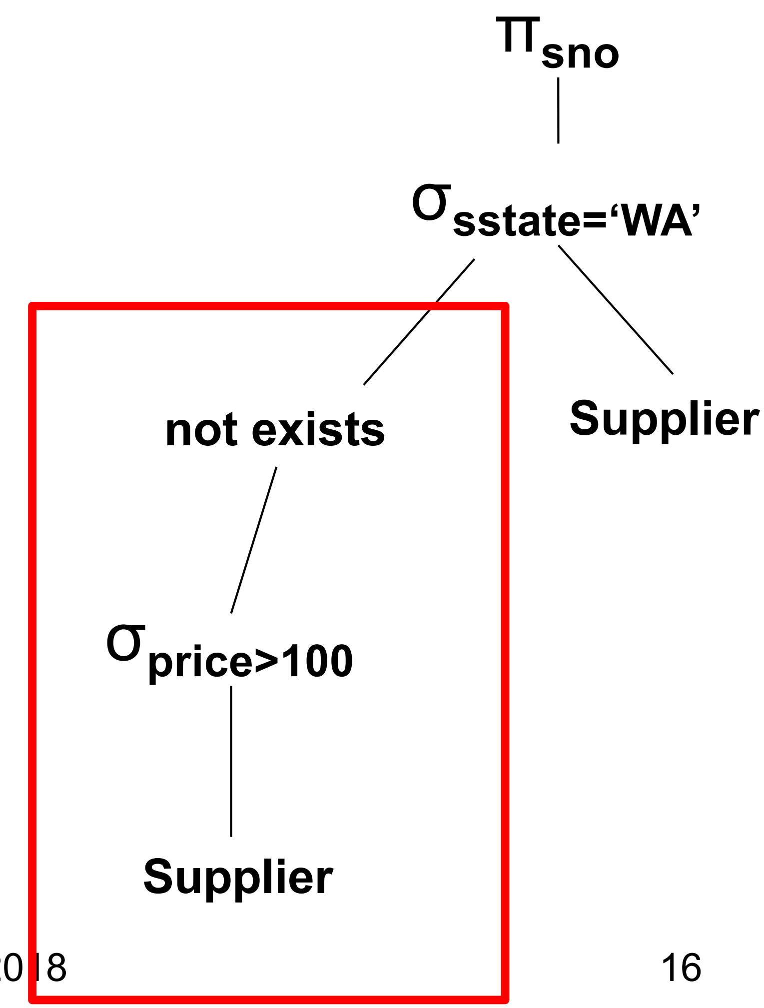
```
SELECT  Q.sno
FROM Supplier AS Q
WHERE  Q.sstate = 'WA'
  and not exists
  (SELECT *
   FROM Supply AS P
   WHERE P.sno = Q.sno
         and P.price > 100)
```

```
Supplier(sno,sname,scity,sstate)
Part(pno,pname,psize,pcolor)
Supply(sno,pno,price)
```

How about Subqueries?

Option 1: create nested plans

```
SELECT  Q.sno
FROM Supplier AS Q
WHERE  Q.sstate = 'WA'
  and not exists
  (SELECT *
   FROM Supply AS P
   WHERE P.sno = Q.sno
         and P.price > 100)
```



Supplier(sno,sname,scity,sstate)
Part(pno,pname,psize,pcolor)
Supply(sno,pno,price)

How about Subqueries?

```
SELECT  Q.sno
FROM Supplier AS Q
WHERE  Q.sstate = 'WA'
  and not exists
  (SELECT *
   FROM Supply AS P
   WHERE P.sno = Q.sno
         and P.price > 100)
```

Correlation !

```
Supplier(sno,sname,scity,sstate)
Part(pno,pname,psize,pcolor)
Supply(sno,pno,price)
```

How about Subqueries?

```
SELECT  Q.sno
FROM Supplier AS Q
WHERE  Q.sstate = ‘WA’
  and not exists
  (SELECT *
   FROM Supply AS P
   WHERE P.sno = Q.sno
         and P.price > 100)
```

De-Correlation

```
SELECT  Q.sno
FROM Supplier AS Q
WHERE  Q.sstate = ‘WA’
  and Q.sno not in
  (SELECT P.sno
   FROM Supply AS P
   WHERE P.price > 100)
```

Supplier(sno,sname,scity,sstate)
Part(pno,pname,psize,pcolor)
Supply(sno,pno,price)

How about Subqueries?

Un-nesting

```
(SELECT  Q.sno
 FROM Supplier AS Q
 WHERE  Q.sstate = 'WA')
    EXCEPT
 (SELECT P.sno
   FROM Supply AS P
   WHERE P.price > 100)
```

```
SELECT  Q.sno
FROM Supplier AS Q
WHERE  Q.sstate = 'WA'
  and Q.sno not in
  (SELECT P.sno
   FROM Supply AS P
   WHERE P.price > 100)
```

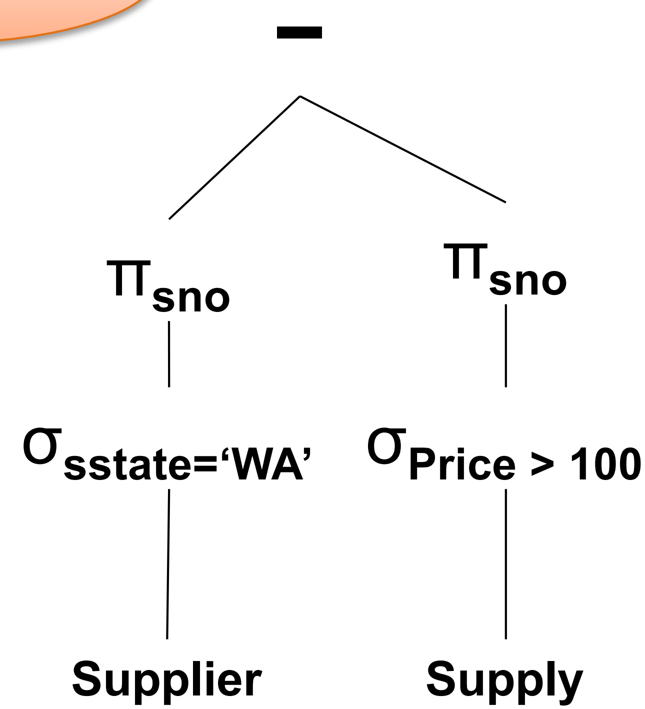
EXCEPT = set difference

```
Supplier(sno,sname,scity,sstate)
Part(pno,pname,psize,pcolor)
Supply(sno,pno,price)
```

How about Subqueries?

```
(SELECT  Q.sno
 FROM Supplier AS Q
 WHERE  Q.sstate = 'WA')
    EXCEPT
 (SELECT P.sno
   FROM Supply AS P
   WHERE P.price > 100)
```

Finally…



Summary of RA and SQL

- SQL = a declarative language where we say *what* data we want to retrieve
- RA = an algebra where we say *how* we want to retrieve the data
- **Theorem**: SQL and RA can express exactly the same class of queries

RDBMS translate SQL → RA, then optimize RA

Summary of RA and SQL

- SQL (and RA) cannot express ALL queries that we could write in, say, Java
- Example:
  – Parent(p,c): find all descendants of ‘Alice’
  – No RA query can compute this!
  – This is called a *recursive query*
  – *Use Datalog!*

Datalog v.s. RA (and SQL)

- Datalog without recursion, but with negation and aggregates expresses the same queries as RA: next slides

R(A,B,C)
S(A,B,C)
T(G,H)

RA to Datalog by Examples

Union:
R(A,B,C) $\cup$ S(A,B,C)

U(x,y,z) :- R(x,y,z).
U(x,y,z) :- S(x,y,z).

R(A,B,C)
S(A,B,C)
T(G,H)

RA to Datalog by Examples

Intersection:

R(A,B,C) ∩ S(A,B,C)

I(x,y,z) :- R(x,y,z), S(x,y,z).

R(A,B,C)
S(D,E,F)
T(G,H)

RA to Datalog by Examples

Selection: $\sigma_{A>100 \text{ and } B=\text{'foo'}}(R)$

L(x,y,z) :- R(x,y,z), x > 100, y='foo'.

Selection: $\sigma_{A>100 \textbf{ or } B=\text{'foo'}}(R)$

L(x,y,z) :- R(x,y,z), x > 100.

L(x,y,z) :- R(x,y,z), y='foo'.

R(A,B,C)
S(D,E,F)
T(G,H)

RA to Datalog by Examples

Equi-join: $R \bowtie_{R.A=S.D \text{ and } R.B=S.E} S$

!= natural join

J(x,y,z,q) :- R(x,y,z), S(x,y,q).

R(A,B,C)
S(D,E,F)
T(G,H)

RA to Datalog by Examples

Projection: $\Pi_A(R)$

P(x) :- R(x,y,z).

R(A,B,C)
S(D,E,F)
T(G,H)

RA to Datalog by Examples

To express difference, we add negation

R – S

D(x,y,z) :- R(x,y,z), NOT S(x,y,z).

R(A,B,C)
S(D,E,F)
T(G,H)

Examples

Translate: $\Pi_A(\sigma_{B=3}(R))$

A(a) :- R(a,3,_).

Underscore used to denote an "anonymous variable”
Each such variable is unique

R(A,B,C)
S(D,E,F)
T(G,H)

Examples

Translate: $\Pi_A(\sigma_{B=3}(R) \bowtie_{R.A=S.D} \sigma_{E=5}(S))$

A(a) :- R(a,3,_), S(a,5,_).

These are different "_"s