

Introduction to Database Systems CSE 414

Lecture 4: SQL Joins and Aggregates

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Announcements

- WQ1 due on Tuesday
 - No late days allowed
- HW1 due on Tuesday
 - Submit using script in repo
- WQ2 and HW2 will be out tomorrow
 - Both are 1 week assignments
- Check website for up to date OHs

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Product(pname, price, category, manufacturer)
Company(cname, country)

Joins in SQL

pname	price	category	manufacturer	cname	country
MultiTouch	199.99	gadget	Canon	GizmoWorks	USA
SingleTouch	49.99	photography	Canon	Canon	Japan
Gizom	50	gadget	GizmoWorks	Hitachi	Japan
SuperGizmo	250.00	gadget	GizmoWorks		

Retrieve all Japanese products that cost < \$150

```
SELECT P.pname, P.price
FROM Product as P, Company as C
WHERE P.manufacturer=C.cname AND
      C.country='Japan' AND C.price < 150
```

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Selection predicates

Join Predicate

Product(pname, price, category, manufacturer)
Company(cname, country)

Joins in SQL

pname	price	category	manufacturer	cname	country
MultiTouch	199.99	gadget	Canon	GizmoWorks	USA
SingleTouch	49.99	photography	Canon	Canon	Japan
Gizom	50	gadget	GizmoWorks	Hitachi	Japan
SuperGizmo	250.00	gadget	GizmoWorks		

Retrieve all USA companies
that manufacture "gadget" products

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Product(pname, price, category, manufacturer)
Company(cname, country)

Joins in SQL

pname	price	category	manufacturer	cname	country
MultiTouch	199.99	gadget	Canon	GizmoWorks	USA
SingleTouch	49.99	photography	Canon	Canon	Japan
Gizom	50	gadget	GizmoWorks	Hitachi	Japan
SuperGizmo	250.00	gadget	GizmoWorks		

Retrieve all USA companies
that manufacture "gadget" products

```
SELECT DISTINCT C.cname
FROM Product as P, Company as C
WHERE C.country='USA' AND P.category = 'gadget'
      AND P.manufacturer = cname
```

Why
DISTINCT?

(Inner) joins

Product(pname, price, category, manufacturer)
Company(cname, country)
-- manufacturer is foreign key to Company

```
SELECT DISTINCT cname
FROM Product, Company
WHERE country='USA' AND category = 'gadget'
      AND manufacturer = cname
```

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(Inner) joins

```
SELECT DISTINCT cname
FROM Product, Company
WHERE country='USA' AND category = 'gadget'
AND manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

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(Inner) joins

```
SELECT DISTINCT cname
FROM Product, Company
WHERE country='USA' AND category = 'gadget'
AND manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

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(Inner) joins

```
SELECT DISTINCT cname
FROM Product, Company
WHERE country='USA' AND category = 'gadget'
AND manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

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(Inner) joins

```
SELECT DISTINCT cname
FROM Product, Company
WHERE country='USA' AND category = 'gadget'
AND manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

pname	category	manufacturer	cname	country
Gizmo	gadget	GizmoWorks	GizmoWorks	USA

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(Inner) joins

```
SELECT DISTINCT cname
FROM Product, Company
WHERE country='USA' AND category = 'gadget'
AND manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

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(Inner) joins

```
SELECT DISTINCT cname
FROM Product, Company
WHERE country='USA' AND category = 'gadget'
AND manufacturer = cname
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
Camera	Photo	Hitachi
OneClick	Photo	Hitachi

Company

cname	country
GizmoWorks	USA
Canon	Japan
Hitachi	Japan

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(Inner) joins

```
SELECT DISTINCT cname
FROM   Product, Company
WHERE  country='USA' AND category = 'gadget'
      AND manufacturer = cname
```

//

```
SELECT DISTINCT cname
FROM   Product JOIN Company ON
      country = 'USA' AND category = 'gadget'
      AND manufacturer = cname
```

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(Inner) Joins

```
SELECT  x1.a1, x2.a2, ... xm.am
FROM    R1 as x1, R2 as x2, ... Rm as xm
WHERE   Cond
```

for x1 in R1:

for x2 in R2:

...

for xm in Rm:

if Cond(x1, x2...):

output(x1.a1, x2.a2, ... xm.am)

This is called nested loop semantics since we are interpreting what a join means using a nested loop

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Another example

```
Product(pname, price, category, manufacturer)
Company(cname, country)
-- manufacturer is foreign key to Company
```

Find US companies that manufacture both 'gadgets' and 'photo' products

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Another example

```
Product(pname, price, category, manufacturer)
Company(cname, country)
-- manufacturer is foreign key to Company
```

Find US companies that manufacture both 'gadgets' and 'photo' products

```
SELECT DISTINCT z.cname
FROM Product x, Company z
WHERE z.country = 'USA'
      AND x.manufacturer = z.cname
      AND x.category = 'gadget'
      AND x.category = 'photography';
```

individual tuples
Does this work?

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Another example

```
Product(pname, price, category, manufacturer)
Company(cname, country)
-- manufacturer is foreign key to Company
```

Find US companies that manufacture both 'gadgets' and 'photo' products

```
SELECT DISTINCT z.cname
FROM Product x, Company z
WHERE z.country = 'USA'
      AND x.manufacturer = z.cname
      AND (x.category = 'gadget'
           OR x.category = 'photography');
```

What about this?

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Another example

```
Product(pname, price, category, manufacturer)
Company(cname, country)
-- manufacturer is foreign key to Company
```

Find US companies that manufacture both 'gadgets' and 'photo' products

```
SELECT DISTINCT z.cname
FROM Product x, Product y, Company z
WHERE z.country = 'USA'
      AND x.manufacturer = z.cname
      AND y.manufacturer = z.cname
      AND x.category = 'gadget'
      AND y.category = 'photography';
```

Need to include Product twice!

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Self-Joins and Tuple Variables

Find US companies that manufacture both 'gadgets' and 'photo' products

- Joining Product with Company is insufficient: need to join Product, with Product, and with Company
- When a relation occurs twice in the FROM clause we call it a self-join; in that case we must use tuple variables (aka table aliases) (why?)

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Self-joins

```
SELECT DISTINCT z.cname
FROM Product x, Product y, Company z
WHERE z.country = 'USA'
AND x.category = 'gadget'
AND y.category = 'photo'
AND x.manufacturer = z.cname
AND y.manufacturer = z.cname;
```

Product

pname	category	manufacturer
Gizmo	gadget	GizmoWorks
SingleTouch	photo	Hitachi
MultiTouch	Photo	GizmoWorks

Company

cname	country
GizmoWorks	USA
Hitachi	Japan

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Self-joins

```
SELECT DISTINCT z.cname
FROM Product x, Product y, Company z
WHERE z.country = 'USA'
AND x.category = 'gadget'
AND y.category = 'photo'
AND x.manufacturer = z.cname
AND y.manufacturer = z.cname;
```

Product

x	pname	category	manufacturer
	Gizmo	gadget	GizmoWorks
	SingleTouch	photo	Hitachi
	MultiTouch	Photo	GizmoWorks

Company

cname	country
GizmoWorks	USA
Hitachi	Japan

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Self-joins

```
SELECT DISTINCT z.cname
FROM Product x, Product y, Company z
WHERE z.country = 'USA'
AND x.category = 'gadget'
AND y.category = 'photo'
AND x.manufacturer = z.cname
AND y.manufacturer = z.cname;
```

Product

x	y	pname	category	manufacturer
		Gizmo	gadget	GizmoWorks
		SingleTouch	photo	Hitachi
		MultiTouch	Photo	GizmoWorks

Company

cname	country
GizmoWorks	USA
Hitachi	Japan

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Self-joins

```
SELECT DISTINCT z.cname
FROM Product x, Product y, Company z
WHERE z.country = 'USA'
AND x.category = 'gadget'
AND y.category = 'photo'
AND x.manufacturer = z.cname
AND y.manufacturer = z.cname;
```

Product

x	y	pname	category	manufacturer
		Gizmo	gadget	GizmoWorks
		SingleTouch	photo	Hitachi
		MultiTouch	Photo	GizmoWorks

Company

cname	country
GizmoWorks	USA
Hitachi	Japan

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Self-joins

```
SELECT DISTINCT z.cname
FROM Product x, Product y, Company z
WHERE z.country = 'USA'
AND x.category = 'gadget'
AND y.category = 'photo'
AND x.manufacturer = z.cname
AND y.manufacturer = z.cname;
```

Product

x	y	pname	category	manufacturer
		Gizmo	gadget	GizmoWorks
		SingleTouch	photo	Hitachi
		MultiTouch	Photo	GizmoWorks

Company

cname	country
GizmoWorks	USA
Hitachi	Japan

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Self-joins

```
SELECT DISTINCT z.cname
FROM Product x, Product y, Company z
WHERE z.country = 'USA'
AND x.category = 'gadget'
AND y.category = 'photo'
AND x.manufacturer = z.cname
AND y.manufacturer = z.cname;
```

Product			Company		Z
x	pname	category	manufacturer	cname	
	Gizmo	gadget	GizmoWorks	GizmoWorks	USA
y	SingleTouch	photo	Hitachi	Hitachi	Japan
	MultiTouch	Photo	GizmoWorks		

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Self-joins

```
SELECT DISTINCT z.cname
FROM Product x, Product y, Company z
WHERE z.country = 'USA'
AND x.category = 'gadget'
AND y.category = 'photo'
AND x.manufacturer = z.cname
AND y.manufacturer = z.cname;
```

Product			Company		Z
x	pname	category	manufacturer	cname	
	Gizmo	gadget	GizmoWorks	GizmoWorks	USA
y	SingleTouch	photo	Hitachi	Hitachi	Japan
	MultiTouch	Photo	GizmoWorks		

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Self-joins

```
SELECT DISTINCT z.cname
FROM Product x, Product y, Company z
WHERE z.country = 'USA'
AND x.category = 'gadget'
AND y.category = 'photo'
AND x.manufacturer = z.cname
AND y.manufacturer = z.cname;
```

Product			Company		Z
x	pname	category	manufacturer	cname	
	Gizmo	gadget	GizmoWorks	GizmoWorks	USA
	SingleTouch	photo	Hitachi	Hitachi	Japan
y	MultiTouch	Photo	GizmoWorks		

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Self-joins

```
SELECT DISTINCT z.cname
FROM Product x, Product y, Company z
WHERE z.country = 'USA'
AND x.category = 'gadget'
AND y.category = 'photo'
AND x.manufacturer = z.cname
AND y.manufacturer = z.cname;
```

Product			Company		Z
x	pname	category	manufacturer	cname	
	Gizmo	gadget	GizmoWorks	GizmoWorks	USA
	SingleTouch	photo	Hitachi	Hitachi	Japan
y	MultiTouch	Photo	GizmoWorks		

x.pname	x.category	x.manufacturer	y.pname	y.category	y.manufacturer	z.cname	z.country
Gizmo	gadget	GizmoWorks	MultiTouch	Photo	GizmoWorks	GizmoWorks	USA

Self-joins

```
SELECT DISTINCT z.cname
FROM Product x, Product y, Company z
WHERE z.country = 'USA'
AND x.category = 'gadget'
AND y.category = 'photo'
AND x.manufacturer = z.cname
AND y.manufacturer = z.cname;
```

Product			Company		Z
x	pname	category	manufacturer	cname	
	Gizmo	gadget	GizmoWorks	GizmoWorks	USA
	SingleTouch	photo	Hitachi	Hitachi	Japan
y	MultiTouch	Photo	GizmoWorks		

x.pname	x.category	x.manufacturer	y.pname	y.category	y.manufacturer	z.cname	z.country
Gizmo	gadget	GizmoWorks	MultiTouch	Photo	GizmoWorks	GizmoWorks	USA

Joins in SQL

- The join we have just seen is sometimes called an **inner join**
 - Each row in the result **must come from both tables in the join**
- Sometimes we want to include rows from only one of the two table: **outer join**

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Employee(id, name)
Sales(employeeID, productID)

Inner Join

Employee		Sales	
id	name	employeeID	productID
1	Joe	1	344
2	Jack	1	355
3	Jill	2	544

Retrieve employees and their sales

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Employee(id, name)
Sales(employeeID, productID)

Inner Join

Employee		Sales	
id	name	employeeID	productID
1	Joe	1	344
2	Jack	1	355
3	Jill	2	544

Retrieve employees and their sales

```
SELECT *
FROM Employee E, Sales S
WHERE E.id = S.employeeID
```

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Employee(id, name)
Sales(employeeID, productID)

Inner Join

Employee		Sales	
id	name	employeeID	productID
1	Joe	1	344
2	Jack	1	355
3	Jill	2	544

Retrieve employees and their sales

```
SELECT *
FROM Employee E, Sales S
WHERE E.id = S.employeeID
```

id	name	employeeID	productID
1	Joe	1	344
1	Joe	1	355
2	Jack	2	544

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Employee(id, name)
Sales(employeeID, productID)

Inner Join

Employee		Sales	
id	name	employeeID	productID
1	Joe	1	344
2	Jack	1	355
3	Jill	2	544

Retrieve employees and their sales

```
SELECT *
FROM Employee E, Sales S
WHERE E.id = S.employeeID
```

id	name	employeeID	productID
1	Joe	1	344
1	Joe	1	355
2	Jack	2	544

Jill is missing

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Employee(id, name)
Sales(employeeID, productID)

Inner Join

Employee		Sales	
id	name	employeeID	productID
1	Joe	1	344
2	Jack	1	355
3	Jill	2	544

Retrieve employees and their sales

```
SELECT *
FROM Employee E
INNER JOIN
Sales S
ON E.id = S.employeeID
```

Alternative syntax

id	name	employeeID	productID
1	Joe	1	344
1	Joe	1	355
2	Jack	2	544

Jill is missing

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Employee(id, name)
Sales(employeeID, productID)

Outer Join

Employee		Sales	
id	name	employeeID	productID
1	Joe	1	344
2	Jack	1	355
3	Jill	2	544

Retrieve employees and their sales

```
SELECT *
FROM Employee E
LEFT OUTER JOIN
Sales S
ON E.id = S.employeeID
```

id	name	employeeID	productID
1	Joe	1	344
1	Joe	1	355
2	Jack	2	544
3	Jill	NULL	NULL

Jill is present

Outer joins

Product(name, category)
Purchase(prodName, store)

-- prodName is foreign key

```
SELECT Product.name, Purchase.store
FROM Product LEFT OUTER JOIN Purchase ON
Product.name = Purchase.prodName
```

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```
SELECT Product.name, Purchase.store
FROM Product JOIN Purchase ON
Product.name = Purchase.prodName
```

Product		Purchase	
Name	Category	ProdName	Store
Gizmo	gadget	Gizmo	Wiz
Camera	Photo	Camera	Ritz
OneClick	Photo	Camera	Wiz

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```
SELECT Product.name, Purchase.store
FROM Product JOIN Purchase ON
Product.name = Purchase.prodName
```

Product		Purchase	
Name	Category	ProdName	Store
Gizmo	gadget	Gizmo	Wiz
Camera	Photo	Camera	Ritz
OneClick	Photo	Camera	Wiz

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```
SELECT Product.name, Purchase.store
FROM Product JOIN Purchase ON
Product.name = Purchase.prodName
```

Product		Purchase	
Name	Category	ProdName	Store
Gizmo	gadget	Gizmo	Wiz
Camera	Photo	Camera	Ritz
OneClick	Photo	Camera	Wiz

Name	Store
Gizmo	Wiz

Output

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```
SELECT Product.name, Purchase.store
FROM Product JOIN Purchase ON
Product.name = Purchase.prodName
```

Product		Purchase	
Name	Category	ProdName	Store
Gizmo	gadget	Gizmo	Wiz
Camera	Photo	Camera	Ritz
OneClick	Photo	Camera	Wiz

Name	Store
Gizmo	Wiz

Output

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```
SELECT Product.name, Purchase.store
FROM Product JOIN Purchase ON
Product.name = Purchase.prodName
```

Product		Purchase	
Name	Category	ProdName	Store
Gizmo	gadget	Gizmo	Wiz
Camera	Photo	Camera	Ritz
OneClick	Photo	Camera	Wiz

Name	Store
Gizmo	Wiz

Output

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```
SELECT Product.name, Purchase.store
FROM Product JOIN Purchase ON
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz

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```
SELECT Product.name, Purchase.store
FROM Product JOIN Purchase ON
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz

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```
SELECT Product.name, Purchase.store
FROM Product JOIN Purchase ON
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

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```
SELECT Product.name, Purchase.store
FROM Product JOIN Purchase ON
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

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```
SELECT Product.name, Purchase.store
FROM Product LEFT OUTER JOIN Purchase ON
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

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```
SELECT Product.name, Purchase.store
FROM Product LEFT OUTER JOIN Purchase ON
Product.name = Purchase.prodName
```

Product

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Output

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
OneClick	NULL

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```
SELECT Product.name, Purchase.store
FROM Product FULL OUTER JOIN Purchase ON
Product.name = Purchase.prodName
```

Name	Category
Gizmo	gadget
Camera	Photo
OneClick	Photo

ProdName	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
Phone	Foo

Name	Store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
OneClick	NULL
NULL	Foo

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Outer Joins

```
tableA (LEFT/RIGHT/FULL) OUTER JOIN tableB ON p
```

- Left outer join:
 - Include tuples from tableA even if no match
- Right outer join:
 - Include tuples from tableB even if no match
- Full outer join:
 - Include tuples from both even if no match
- In all cases:
 - Patch tuples without matches using NULL

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