

1. ■ RA

$$\pi_{sname}(\pi_{sid}((\pi_{pid}\sigma_{color='red'}Parts) \bowtie Catalog) \bowtie Suppliers)$$

■ TRC

$$\{T \mid \exists T1 \in Suppliers(\exists X \in Parts(X.color = 'red' \wedge \exists Y \in Catalog(Y.pid = X.pid \wedge Y.sid = T1.sid)) \wedge T.sname = T1.sname)\}$$

■ DRC

$$\{\langle Y \rangle \mid \langle X, Y, Z \rangle \in Suppliers \wedge \exists P, Q, R(\langle P, Q, R \rangle \in Parts \wedge R = 'red' \wedge \exists I, J, K(\langle I, J, K \rangle \in Catalog \wedge J = P \wedge I = X))\}$$

■ SQL

```
SELECT S.sname
FROM Suppliers S, Parts P, Catalog C
WHERE P.color='red' AND C.pid=P.pid AND C.sid=S.sid
```

2. ■ RA

$$\pi_{sid}(\pi_{pid}(\sigma_{color='red' \vee color='green'}Parts) \bowtie catalog)$$

■ TRC

$$\{T \mid \exists T1 \in Catalog(\exists X \in Parts((X.color = 'red' \vee X.color = 'green') \wedge X.pid = T1.pid) \wedge T.sid = T1.sid)\}$$

■ DRC

$$\{\langle X \rangle \mid \langle X, Y, Z \rangle \in Catalog \wedge \exists A, B, C(\langle A, B, C \rangle \in Parts \wedge (C = 'red' \vee C = 'green') \wedge A = Y)\}$$

■ SQL

```
SELECT C.sid
FROM Catalog C, Parts P
WHERE (P.color = 'red' OR P.color = 'green')
AND P.pid = C.pid
```

3. ■ RA

$$\begin{aligned} & \rho(R1, \pi_{sid}((\pi_{pid}\sigma_{color='red'}Parts) \bowtie Catalog)) \\ & \rho(R2, \pi_{sid}\sigma_{address='221PackerStreet'}Suppliers) \\ & R1 \cup R2 \end{aligned}$$

■ TRC

$$\{T \mid \exists T1 \in Catalog(\exists X \in Parts(X.color = 'red' \wedge X.pid = T1.pid) \wedge T.sid = T1.sid) \vee \exists T2 \in Suppliers(T2.address = '221PackerStreet' \wedge T.sid = T2.sid)\}$$

■ DRC

$$\{\langle X \rangle \mid \langle X, Y, Z \rangle \in Catalog \wedge \exists A, B, C(\langle A, B, C \rangle \in Parts \wedge C = 'red' \wedge A = Y) \vee \exists P, Q(\langle X, P, Q \rangle \in Suppliers \wedge Q = '221PackerStreet')\}$$

■ SQL

```
SELECT S.sid
FROM Suppliers S
WHERE S.address = '221 Packer street'
OR S.sid IN ( SELECT C.sid
              FROM Parts P, Catalog C
              WHERE P.color='red' AND P.pid = C.pid )
```

4. ■ RA

$$\rho(R1, \pi_{sid}((\pi_{pid}\sigma_{color='red'} Parts) \bowtie Catalog)) \\ \rho(R2, \pi_{sid}((\pi_{pid}\sigma_{color='green'} Parts) \bowtie Catalog)) \\ R1 \cap R2$$

■ TRC

$$\{T \mid \exists T1 \in Catalog(\exists X \in Parts(X.color = 'red' \wedge X.pid = T1.pid) \wedge \exists T2 \in Catalog(\exists Y \in Parts(Y.color = 'green' \wedge Y.pid = T2.pid) \wedge T2.sid = T1.sid) \wedge T.sid = T1.sid)\}$$

■ DRC

$$\{\langle X \rangle \mid \langle X, Y, Z \rangle \in Catalog \wedge \exists A, B, C(\langle A, B, C \rangle \in Parts \wedge C = 'red' \wedge A = Y) \wedge \exists P, Q, R(\langle P, Q, R \rangle \in Catalog \wedge \exists E, F, G(\langle E, F, G \rangle \in Parts \wedge G = 'green' \wedge E = Q) \wedge P = X)\}$$

■ SQL

```

SELECT C.sid
FROM   Parts P, Catalog C
WHERE  P.color = 'red' AND P.pid = C.pid
      AND EXISTS ( SELECT P2.pid
                   FROM   Parts P2, Catalog C2
                   WHERE  P2.color = 'green' AND C2.sid = C.sid
                   AND P2.pid = C2.pid )

```

5. ■ RA

$$(\pi_{sid,pid}Catalog)/(\pi_{pid}Parts)$$

■ TRC

$$\{T \mid \exists T1 \in Catalog(\forall X \in Parts(\exists T2 \in Catalog \\ (T2.pid = X.pid \wedge T2.sid = T1.sid)) \wedge T.sid = T1.sid)\}$$

■ DRC

$$\{\langle X \rangle \mid \langle X, Y, Z \rangle \in Catalog \wedge \forall \langle A, B, C \rangle \in Parts \\ (\exists \langle P, Q, R \rangle \in Catalog(Q = A \wedge P = X))\}$$

■ SQL

```

SELECT C.sid
FROM   Catalog C
WHERE  NOT EXISTS (SELECT P.pid
                  FROM   Parts P
                  WHERE  NOT EXISTS (SELECT C1.sid
                                     FROM   Catalog C1
                                     WHERE  C1.sid = C.sid
                                     AND C1.pid = P.pid))

```

6. ■ RA

$$(\pi_{sid,pid}Catalog)/(\pi_{pid\sigma_{color \neq 'red'}}Parts)$$

■ TRC

$$\{T \mid \exists T1 \in Catalog(\forall X \in Parts(X.color \neq 'red' \\ \vee \exists T2 \in Catalog(T2.pid = X.pid \wedge T2.sid = T1.sid)) \\ \wedge T.sid = T1.sid)\}$$

■ DRC

$$\{\langle X \rangle \mid \langle X, Y, Z \rangle \in Catalog \wedge \forall \langle A, B, C \rangle \in Parts \\ (C \neq 'red' \vee \exists \langle P, Q, R \rangle \in Catalog(Q = A \wedge P = X))\}$$

■ SQL

```

SELECT C.sid
FROM   Catalog C
WHERE  NOT EXISTS (SELECT P.pid
                   FROM   Parts P
                   WHERE  P.color = 'red'
                   AND (NOT EXISTS (SELECT C1.sid
                                   FROM   Catalog C1
                                   WHERE  C1.sid = C.sid AND
                                       C1.pid = P.pid)))
    
```

7. ■ RA

$$(\pi_{sid, pid} Catalog) / (\pi_{pid} \sigma_{color='red' \vee color='green'} Parts)$$

■ TRC

$$\{T \mid \exists T1 \in Catalog (\forall X \in Parts ((X.color \neq 'red' \wedge X.color \neq 'green') \vee \exists T2 \in Catalog (T2.pid = X.pid \wedge T2.sid = T1.sid)) \wedge T.sid = T1.sid)\}$$

■ DRC

$$\{\langle X \rangle \mid \langle X, Y, Z \rangle \in Catalog \wedge \forall \langle A, B, C \rangle \in Parts ((C \neq 'red' \wedge C \neq 'green') \vee \exists \langle P, Q, R \rangle \in Catalog (Q = A \wedge P = X))\}$$

■ SQL

```

SELECT C.sid
FROM   Catalog C
WHERE  NOT EXISTS (SELECT P.pid
                   FROM   Parts P
                   WHERE  (P.color = 'red' OR P.color = 'green')
                   AND (NOT EXISTS (SELECT C1.sid
                                   FROM   Catalog C1
                                   WHERE  C1.sid = C.sid AND
                                       C1.pid = P.pid)))
    
```

8. ■ RA

$$\rho(R1, ((\pi_{sid, pid} Catalog) / (\pi_{pid} \sigma_{color='red'} Parts)))$$

$$\rho(R2, ((\pi_{sid, pid} Catalog) / (\pi_{pid} \sigma_{color='green'} Parts)))$$

$$R1 \cup R2$$

- TRC

$$\{T \mid \exists T1 \in Catalog((\forall X \in Parts \\ (X.color \neq 'red' \vee \exists Y \in Catalog(Y.pid = X.pid \wedge Y.sid = T1.sid)) \\ \vee \forall Z \in Parts(Z.color \neq 'green' \vee \exists P \in Catalog \\ (P.pid = Z.pid \wedge P.sid = T1.sid))) \wedge T.sid = T1.sid)\}$$

- DRC

$$\{\langle X \rangle \mid \langle X, Y, Z \rangle \in Catalog \wedge (\forall \langle A, B, C \rangle \in Parts \\ (C \neq 'red' \vee \exists \langle P, Q, R \rangle \in Catalog(Q = A \wedge P = X)) \\ \vee \forall \langle U, V, W \rangle \in Parts(W \neq 'green' \vee \langle M, N, L \rangle \in Catalog \\ (N = U \wedge M = X)))\}$$

- SQL

```
SELECT C.sid
FROM   Catalog C
WHERE  (NOT EXISTS (SELECT P.pid
                   FROM   Parts P
                   WHERE  P.color = 'red' AND
                   (NOT EXISTS (SELECT C1.sid
                               FROM   Catalog C1
                               WHERE  C1.sid = C.sid AND
                                       C1.pid = P.pid))))
OR ( NOT EXISTS (SELECT P1.pid
                FROM   Parts P1
                WHERE  P1.color = 'green' AND
                (NOT EXISTS (SELECT C2.sid
                            FROM   Catalog C2
                            WHERE  C2.sid = C.sid AND
                                    C2.pid = P1.pid))))
```

9. ■ RA

$$\rho(R1, Catalog) \\ \rho(R2, Catalog) \\ \pi_{R1.sid, R2.sid}(\sigma_{R1.pid=R2.pid \wedge R1.sid \neq R2.sid \wedge R1.cost > R2.cost}(R1 \times R2))$$

- TRC

$$\{T \mid \exists T1 \in Catalog(\exists T2 \in Catalog \\ (T2.pid = T1.pid \wedge T2.sid \neq T1.sid \\ \wedge T2.cost < T1.cost \wedge T.sid2 = T2.sid) \\ \wedge T.sid1 = T1.sid)\}$$

- DRC

$$\{\langle X, P \rangle \mid \langle X, Y, Z \rangle \in Catalog \wedge \exists P, Q, R \\ (\langle P, Q, R \rangle \in Catalog \wedge Q = Y \wedge P \neq X \wedge R < Z)\}$$

- SQL

```
SELECT C1.sid, C2.sid
FROM   Catalog C1, Catalog C2
WHERE  C1.pid = C2.pid AND C1.sid ≠ C2.sid
AND    C1.cost > C2.cost
```

10. ■ RA

$$\rho(R1, Catalog) \\ \rho(R2, Catalog) \\ \pi_{R1.pid} \sigma_{R1.pid=R2.pid \wedge R1.sid \neq R2.sid} (R1 \times R2)$$

- TRC

$$\{T \mid \exists T1 \in Catalog (\exists T2 \in Catalog \\ (T2.pid = T1.pid \wedge T2.sid \neq T1.sid) \\ \wedge T.pid = T1.pid)\}$$

- DRC

$$\{\langle X \rangle \mid \langle X, Y, Z \rangle \in Catalog \wedge \exists A, B, C \\ (\langle A, B, C \rangle \in Catalog \wedge B = Y \wedge A \neq X)\}$$

- SQL

```
SELECT C.pid
FROM   Catalog C
WHERE  EXISTS (SELECT C1.sid
              FROM   Catalog C1
              WHERE  C1.pid = C.pid AND C1.sid ≠ C1.sid)
```

11. ■ RA

$$\rho(R1, \pi_{sid} \sigma_{sname='YosemiteSham'} Suppliers) \\ \rho(R2, R1 \bowtie Catalog) \\ \rho(R3, R2) \\ \rho(R4(1 \rightarrow sid, 2 \rightarrow pid, 3 \rightarrow cost), \sigma_{R3.cost < R2.cost} (R3 \times R2)) \\ \pi_{pid} (R2 - \pi_{sid, pid, cost} R4)$$

- TRC

$$\{T \mid \exists T1 \in Catalog(\exists X \in Suppliers$$

$$(X.sname = 'YosemiteSham' \wedge X.sid = T1.sid) \wedge \neg(\exists S \in Suppliers$$

$$(S.sname = 'YosemiteSham' \wedge \exists Z \in Catalog$$

$$(Z.sid = S.sid \wedge Z.cost > T1.cost))) \wedge T.pid = T1.pid\}$$

- DRC

$$\{\langle Y \rangle \mid \langle X, Y, Z \rangle \in Catalog \wedge \exists A, B, C$$

$$(\langle A, B, C \rangle \in Suppliers \wedge C = 'YosemiteSham' \wedge A = X)$$

$$\wedge \neg(\exists P, Q, R(\langle P, Q, R \rangle \in Suppliers \wedge R = 'YosemiteSham'$$

$$\wedge \exists I, J, K(\langle I, J, K \rangle \in Catalog(I = P \wedge K > Z)))\}$$

- SQL

```
SELECT C.pid
FROM   Catalog C, Suppliers S
WHERE  S.sname = 'Yosemite Sham' AND C.sid = S.sid
      AND C.cost ≥ ALL (Select C2.cost
                        FROM   Catalog C2, Suppliers S2
                        WHERE  S2.sname = 'Yosemite Sham'
                        AND C2.sid = S2.sid)
```

Exercise 4.4 Consider the Supplier-Parts-Catalog schema from the previous question. State what the following queries compute:

1. $\pi_{sname}(\pi_{sid}(\sigma_{color='red'} Parts) \bowtie (\sigma_{cost < 100} Catalog) \bowtie Suppliers)$
2. $\pi_{sname}(\pi_{sid}((\sigma_{color='red'} Parts) \bowtie (\sigma_{cost < 100} Catalog) \bowtie Suppliers))$
3. $(\pi_{sname}((\sigma_{color='red'} Parts) \bowtie (\sigma_{cost < 100} Catalog) \bowtie Suppliers)) \cap$
 $(\pi_{sname}((\sigma_{color='green'} Parts) \bowtie (\sigma_{cost < 100} Catalog) \bowtie Suppliers))$
4. $(\pi_{sid}((\sigma_{color='red'} Parts) \bowtie (\sigma_{cost < 100} Catalog) \bowtie Suppliers)) \cap$
 $(\pi_{sid}((\sigma_{color='green'} Parts) \bowtie (\sigma_{cost < 100} Catalog) \bowtie Suppliers))$
5. $\pi_{sname}((\pi_{sid, sname}((\sigma_{color='red'} Parts) \bowtie (\sigma_{cost < 100} Catalog) \bowtie Suppliers)) \cap$
 $(\pi_{sid, sname}((\sigma_{color='green'} Parts) \bowtie (\sigma_{cost < 100} Catalog) \bowtie Suppliers)))$

Answer 4.4 The statements can be interpreted as: