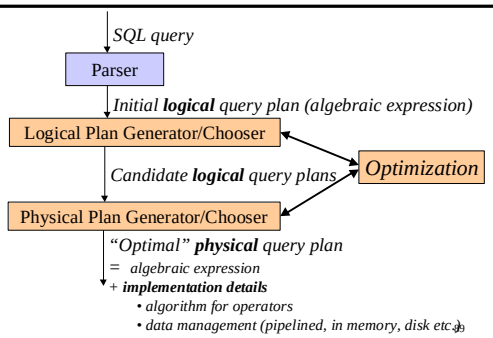
Query Processing



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Query Processor

- Basic task: turn user queries (and updates) into a sequence of operations (a *plan*) on the database
  => *from high level queries to low level commands*
- Many choices:
  - *Which of the **algebraically equivalent** forms of a query will lead to the most efficient algorithm?*
  - *For each algebraic operator which **algorithm** should we use to run the operator?*
  - *How should the operations pass data from one to the other? (eg, main memory buffers, disk buffers)*

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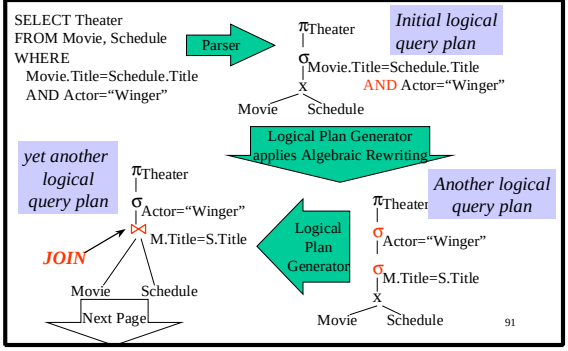
The Journey of a Query (Revisited)



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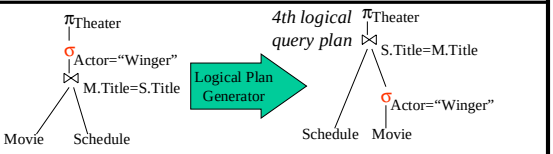
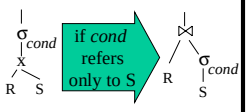
The Journey of a Query (Revisited)



- 4 logical query plans created
- ***algebraic rewritings*** were used to produce candidate logical query plans
- the last one wins
- multiple logical plans may "win" eventually (and be considered subsequently)



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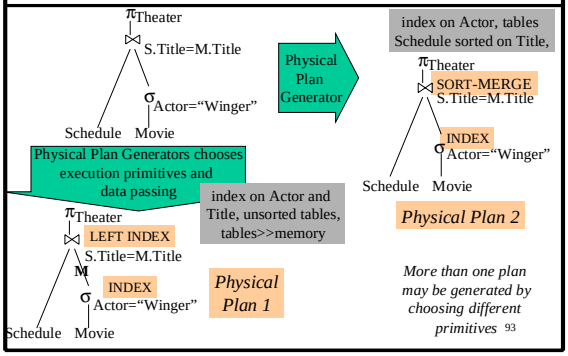
The Journey Continues at the Physical Plan Generator



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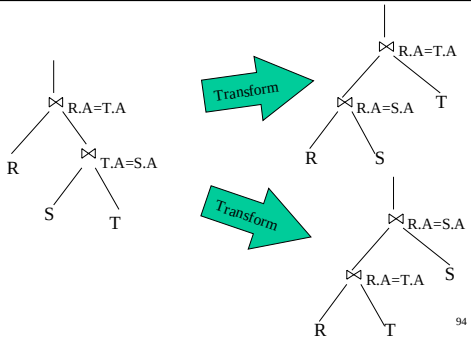
More Than One Plan May be Generated and Considered for Evaluation



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Issues in Query Processing and Optimization

- *Generate Plans*
  - systematically transform expressions
  - employ execution primitives for computing relational algebra operations
- *Estimate Cost of Generated Plans*
  - Statistics
- *"Smart" Search of the Space of Possible Plans*
  - always do the "good" transformations (relational algebra optimization)
  - prune the space (e.g., System R)
- Often the above steps are mixed

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Bag Semantics of Operators

- SQL semantics for collections of tuples:
  - often ***bags*** (aka ***multisets***) instead of sets.
  - ***Union(R,S)***: a tuple t occurs in the result as many times as the **sum** of occurrences in each of R and S
  - ***Intersection of R and S***: ... the **minimum** number of occurrences in R and S
  - ***Difference of R and S***: ... occurrences in R **minus** occurrences in S
  - ***δ(R)*** converts the **bag** *R* into a **set**
    - SQL's **R UNION S** by default ***δ(R∪S)***
- **Example:** *R={A,B,B}* and *S={C,A,B,C}.*

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Extended Algebra Operators

- **selection σ_C(R)**: condition C over arithmetic-, string-, and comparison-operators
  ~WHERE in SQL, but C depends only on individual tuples
- **projection π_A(R)**: attribute list A may include
  - x→y (*rename x to y in the output schema*)
  - a+b→x (*output schema contains x column with sum of a and b*)
  - c||d→y (*concatenate c and d as y*)
  - again: look at one tuple at a time
- alternatively: s**pecial purpose operators**:
  - **MULT $_{A,B\to C}$(R)**:
    - for each tuple of R, multiply attribute A with attribute B and put the result in a new attribute named C.
  - **PLUS $_{A,B\to C}$(R), CONCAT $_{A,B\to C}$(R), . . .**

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Product and Joins

- **product (R×S)**:
  - *r* is *n* times in *R*, *s* is *m* times in *S*, then (*r*,*s*) is ***n*m*** times in the product
  - (qualify attributes if necessary: R.a vs S.a)
- **natural join R⋈S = $\pi_A \sigma_C$(R×S)** where
  - *C equates all common attributes*
  - *A* has all attributes from R and S (but only one copy per equated attribute)
  - (definition of join ~ simple rewriting rule)
- **theta join**
  - arbitrary condition involving attributes

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Grouping and Aggregation

- **Grouping & Aggregation** in SQL:

```
SELECT selection-list FROM from-list WHERE...
GROUP BY groupby-list
HAVING group-qualification
```

- **Example**: *given* **movie(title, year, actor)**, *find for each actor having more than two movies, the first year of appearance*

```
SELECT actor, MIN(year) as firstYear FROM movie
GROUP BY actor
HAVING COUNT(title) > 2
```

- Every attribute in the *selection-list* must appear in the *groupby-list* ***(Why?)***
- $grp_{actor,\ MIN(year)=>firstYear,\ COUNT(title)=>aux}$ *(movie)*

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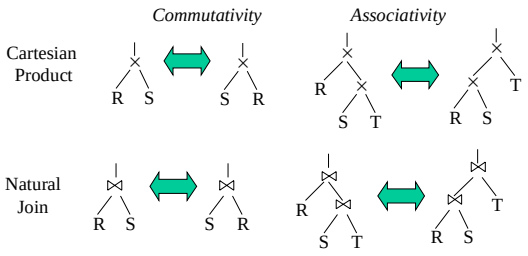
Algebraic Rewritings: Commutativity and Associativity



- *Do the above hold for both sets and bags?*
- *Do commutativity and associativity hold for arbitrary Theta Joins?*

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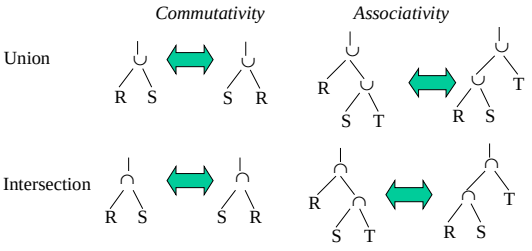
Algebraic Rewritings: Commutativity and Associativity



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