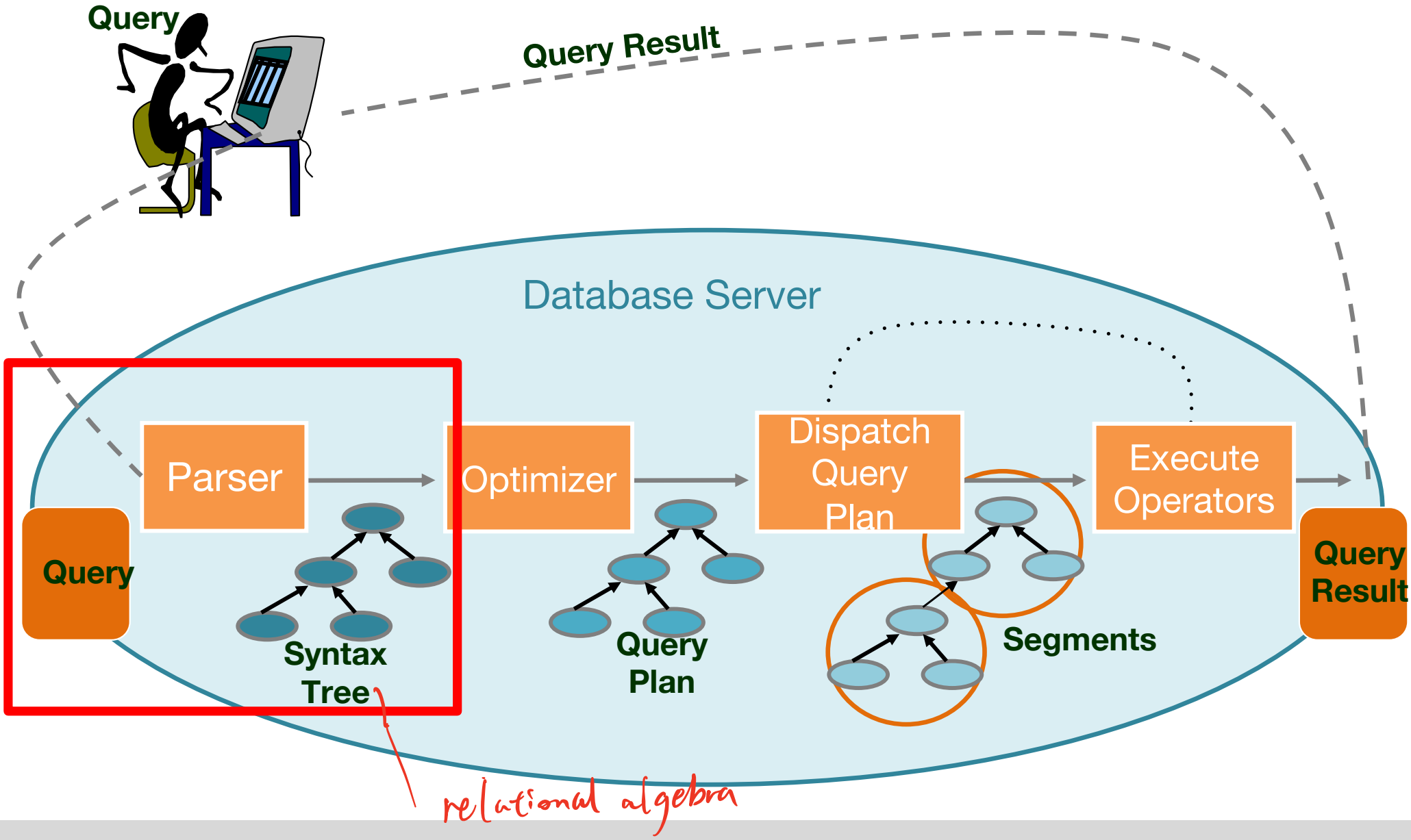
EECS 484, Database Management Systems

Evaluation of Relational Operations: Selection

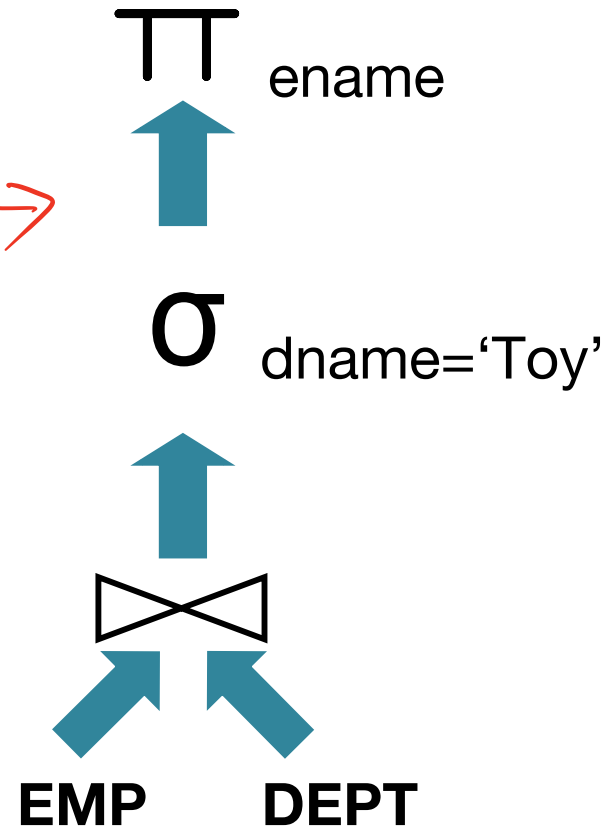
Chapter 12

Query Execution Life-Cycle



Query Parsing

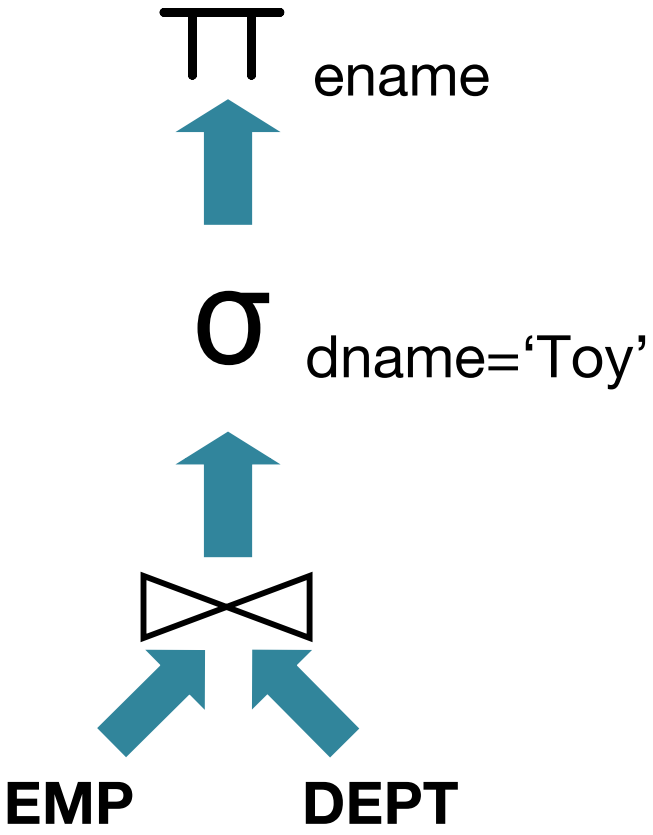
- Consult the meta information stored in system catalogs
- Create an initial syntax tree based on relational algebra tree



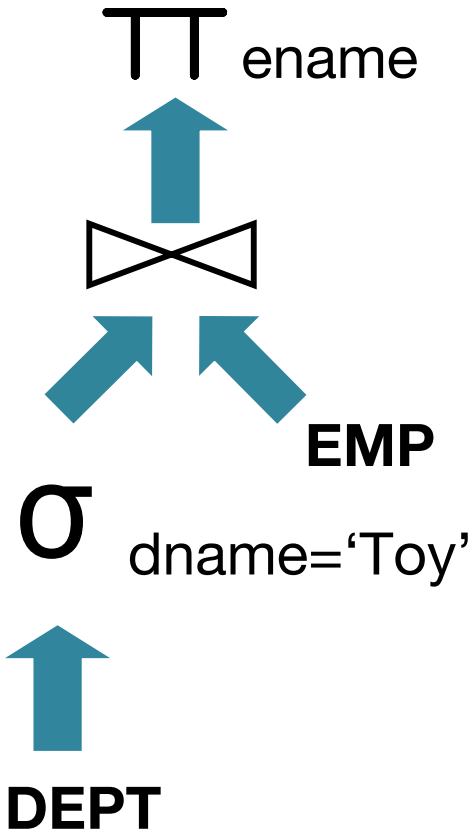

```
SELECT E.ename
FROM Emp E, Dept D
WHERE D.dname = 'Toy' AND
      D.did = E.did
```

Question??

Which plan is cheaper?



A



B

System Catalogs

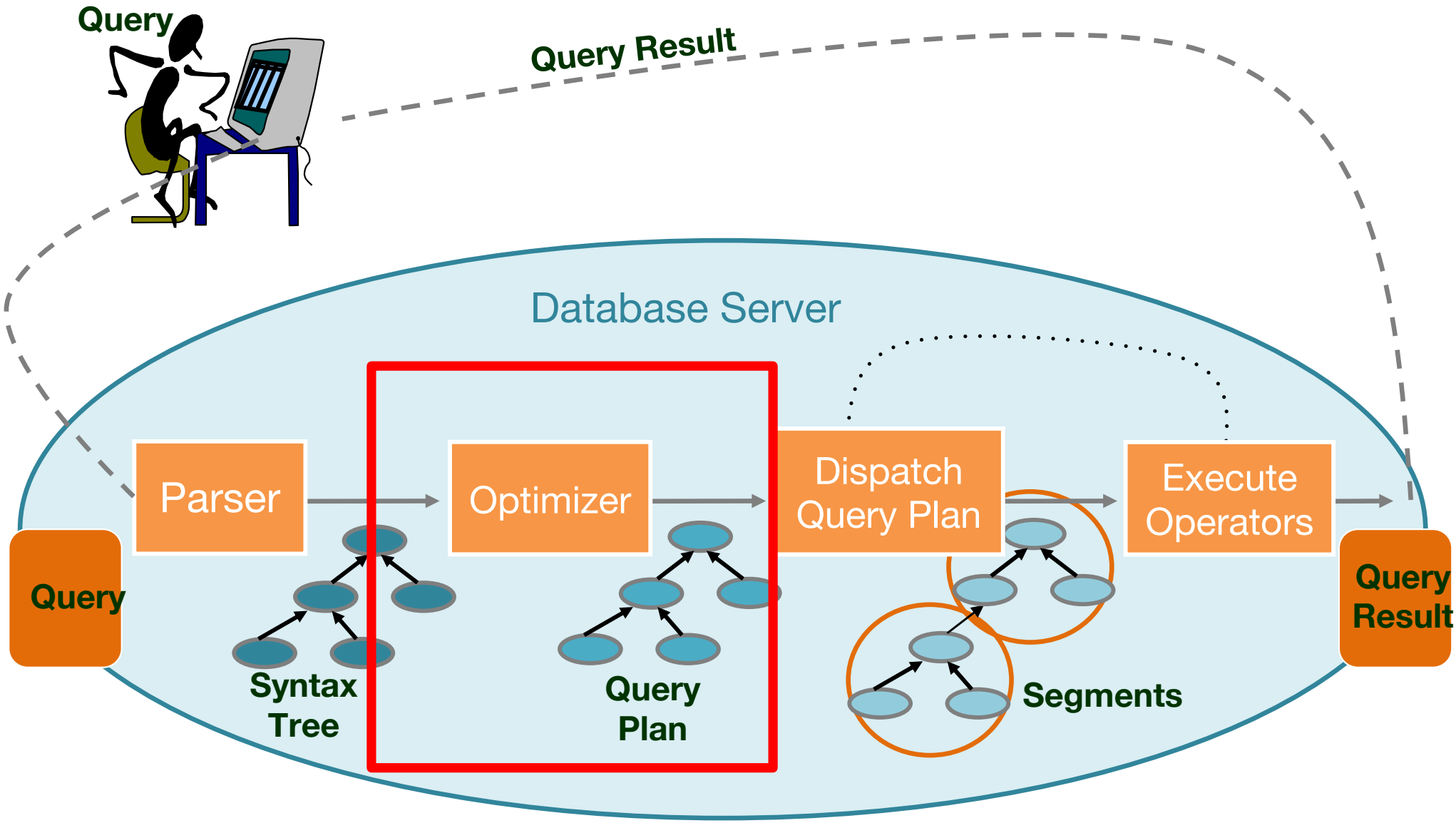
- To help optimize queries, the system keeps information on each relation (data records)
  - name, file name (table name), file structure (e.g. heap file)
  - attribute name and type, for each attribute
  - index name, for each index
  - integrity constraints
- For each index:
  - structure (e.g. B+ tree) and search key fields
- For each view:
  - view name and definition
- Plus statistics, authorization, buffer pool size, etc.

Example Catalog: Attribute Catalog

attrName	relName	type	position
attrName	Attribute_cat	string	1
relName	Attribute_cat	string	2
type	Attribute_cat	string	3
position	Attribute_cat	integer	4
sid	Students	string	1
name	Students	string	2
login	Students	string	3
age	Students	integer	4
gpa	Students	real	5
fid	Faculty	string	1
fname	Faculty	string	2
sal	Faculty	real	3

Catalogs are themselves stored as relations

Query Execution Life-Cycle



Query Evaluation Plan

EMP (ssn, ename, addr, sal, did)
DEPT (did, dname, floor, mgr)

```
SELECT E.ename
FROM Emp E, Dept D
WHERE D.dname = 'Toy' AND
      D.did = E.did
```

EMP

ssn	ename	addr	sal	did
13b	Mary	First	9,000	1
29g	Jackie	Main	3,500	2

DEPT

did	dname	floor	mgr
1	Adv	5	Depp
2	Toy	10	Brown

Query Evaluation Plan

EMP (ssn, ename, addr, sal, did)

DEPT (did, dname, floor, mgr)

```
SELECT E.ename
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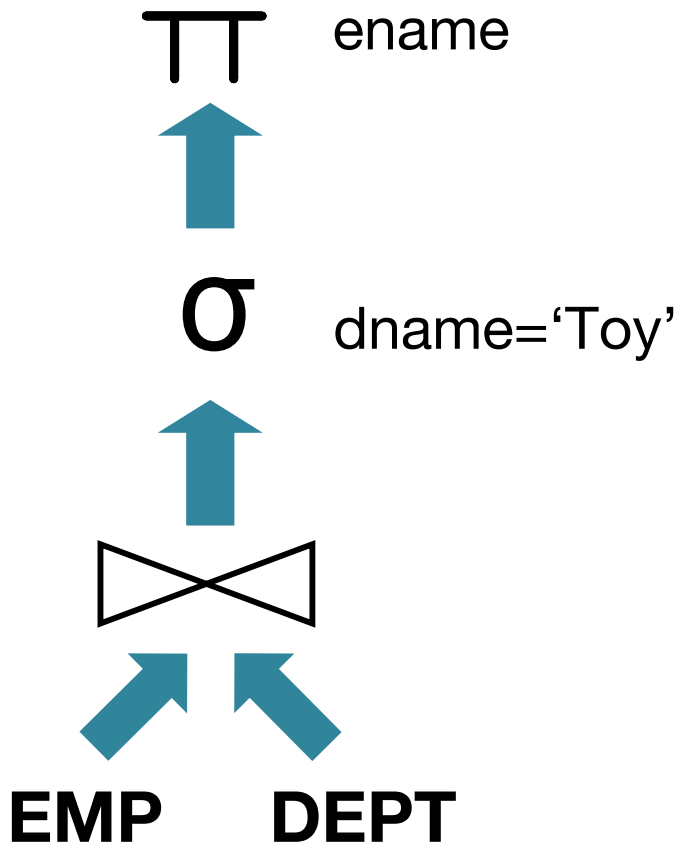


EMP

ssn	ename	addr	sal	did
13b	Ma			
29g	Jackie Smith	Main	3,500	2

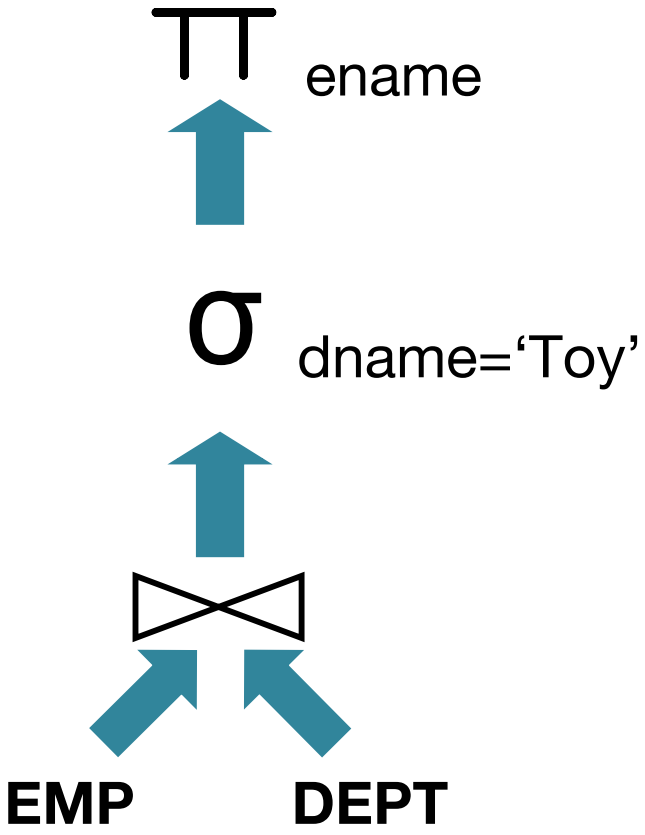
DEPT

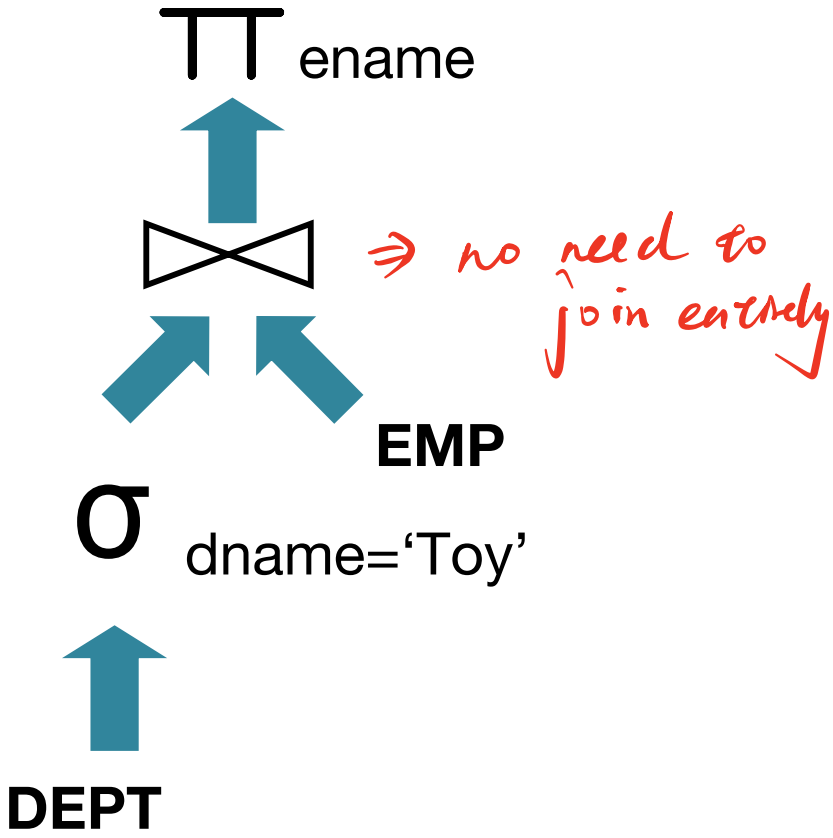
did	dname	floor	mgr
			Depp
2	Sales	10	Brown

Query Optimizer selects the evaluation plan

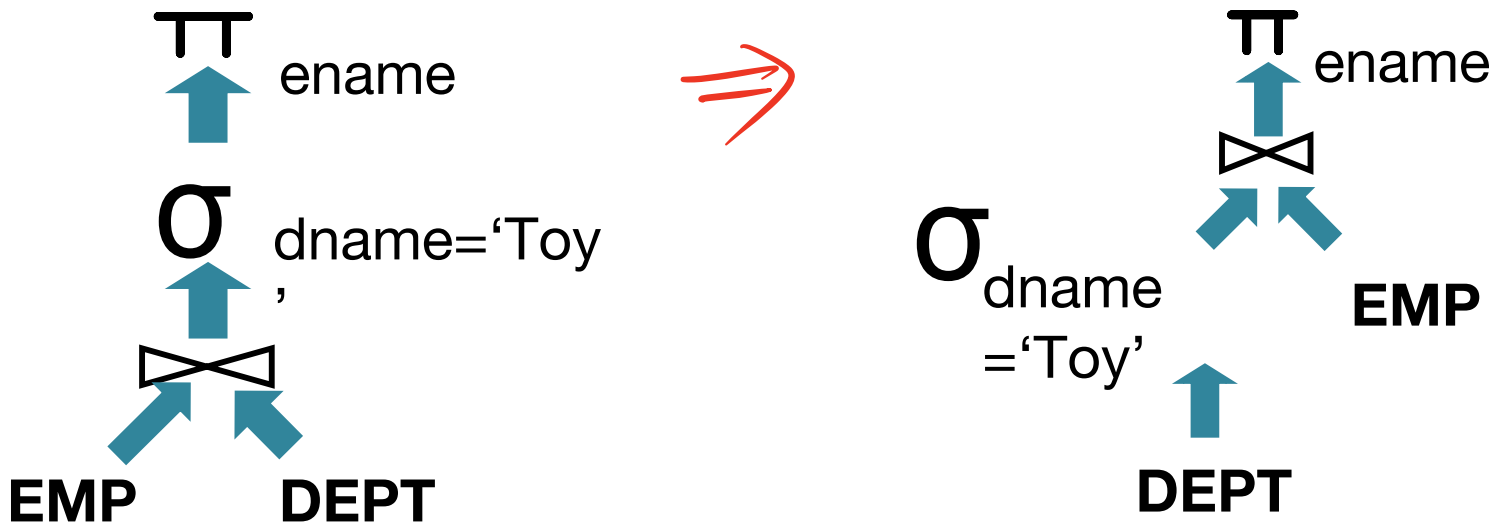
Query Optimization Example

Modify to:





Query Optimization



2. Will compare different evaluation algorithms for SELECT, JOIN, and PROJECT operator based on whether an index is available, table sizes, etc.

Query Optimization

Query optimizer selects an evaluation plan with the lease cost in two steps:

1. **Plan Enumeration**
   - Different query plans
   - Different implementations (i.e., evaluation algorithms) for each operator

Today

In 2 weeks

2. **Cost Estimation**
   - Cost of each operator
   - Overall cost of the plan

Operator Evaluation

- How to implement common operators?
  - Selection
    - Matching Indexes (previously created).
  - Join
  - Projection (optional DISTINCT)
  - Set Difference
  - Union
  - Aggregate operators (SUM, MIN, MAX, AVG)
  - GROUP BY

Selection (on one table)

- Access path defines a strategy to do a *selection* on a table, possibly utilizing an index
- Example of a selection condition
  - a predicate: gpa > 3.0 and age = 21
- Some possible access paths
  - File scan
  - Index that *matches* a selection in the query. Examples:
    - B+tree index on the <gpa, age> attributes
    - B+tree index on gpa
    - B+tree index on age
    - Hash index on age

hash index (equality index ⇒ not usable for ">")

first sort key

second sort key

⇒ more leaf pages in the tree but more efficient data access

Selection Cost

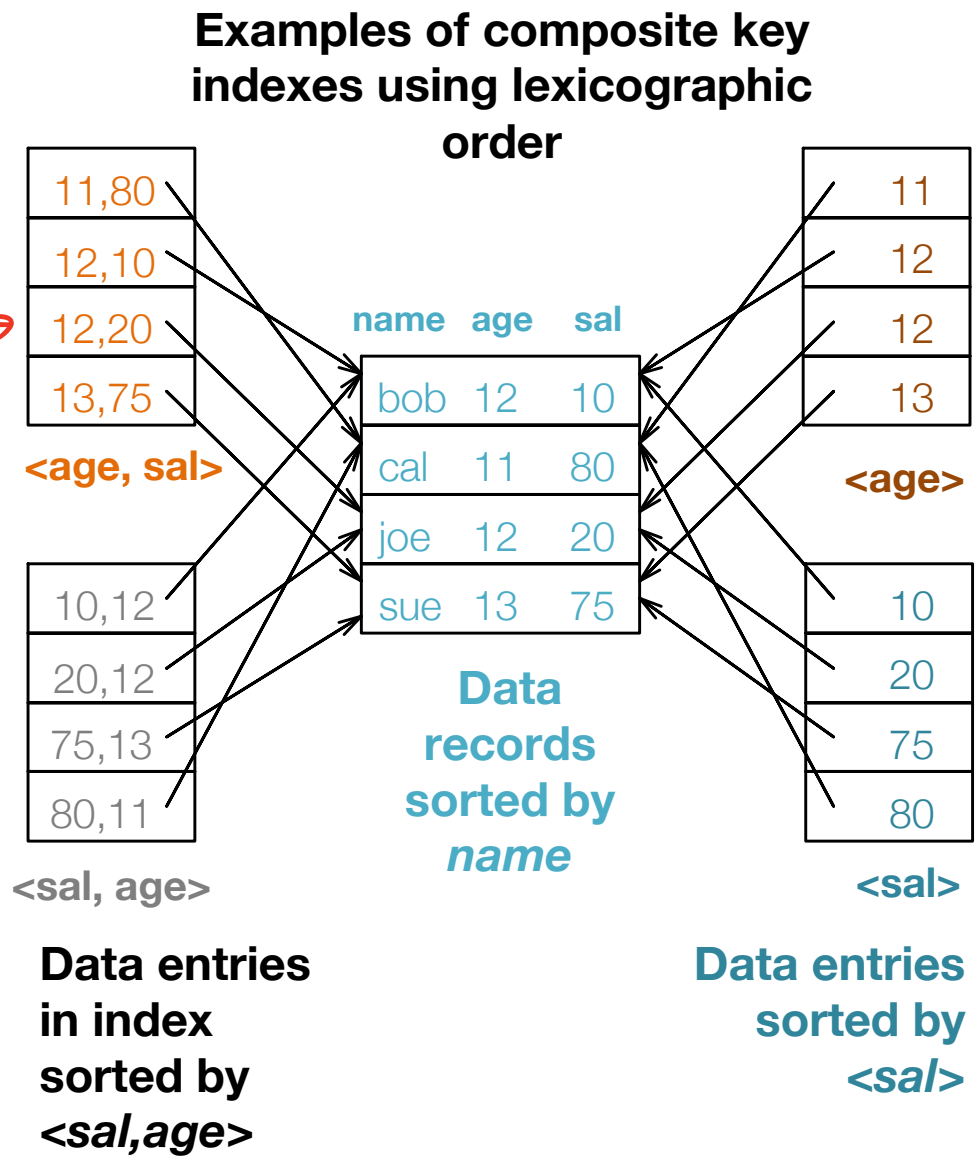
- `WHERE R.a op value`
- Options:
  - Heap file — Cost: O(N)
  - Sorted File — Cost: $O(\log_2 N) + \ldots$
  - Index
    - Hash — Cost: O(1) + …
    - B+Tree: Clustered/Unclustered — Cost: $O(\log_F N) + \ldots$

Composite Search Keys

- Index on <age>: search key is a single-attribute age
- Index on <name, age>: search key is composite (name, age) pair
  - For B+-tree, name is the primary comparison attribute and age matters only when names are equal
  - For hash-index, h((name, age)) used – both name and age are needed to hash

Indexes with Composite Search Keys

- Composite Search Keys: Search on a combination of fields
  - Equality query: Every field value is equal to a constant value. e.g. wrt <sal,age> index:
    - age =12 and sal = 75
  - Range query: Some field value is not a constant
    - e.g. age = 12 and sal > 10
- Data entries in index sorted by search key to support range queries



Index Matching

- When can we use an index to evaluate a selection predicate? when match
- An index matches a predicate if the index can be used to evaluate (at least part of) the predicate

Index Matching

- Index on <a, b, c>
  - a=5 and b= 3
  - a > 5 and b < 3
  - b=3

Index matches (part of) a predicate if:

- Conjunction of terms involving only attributes (no disjunctions)
- **Hash:** only equality operation, predicate has all index attributes
- **Tree:** Attributes are a prefix of the search key, any ops

Index Matching

- Index on <a, b, c>
  - a=5 and b= 3
  - a > 5 and b < 3
  - b=3
  - a=7 and b=5 and c=4 and **d>4**
  - a=7 and c=5

Tree Idx	Hash Idx
yes	no!
yes	no!
No	No
yes	yes
yes	no!

Index matches (part of) a predicate if:

- Conjunction of terms involving only attributes (no disjunctions)
- **Hash:** only equality operation, predicate has all index attributes
- **Tree:** Attributes are a prefix of the search key, any ops

Index Selectivity

- To retrieve Emp records with age=30 AND sal=4000, an index on <age, sal> would be better than an index on age or an index on sal
  - <age, sal> is more selective than just <age> or just <sal>
  - It identifies fewer spurious records that will later be rejected
- If condition is: age=80 AND 3000 < sal <20,000:
  - <age> index much better than <sal> index!
- Ideally, the more selective index preferred

apply more selective index first

Example: Index Matching

- Predicate could match more than 1 index
- Hash index on <a, b> and B+tree index on <a, c>
- Predicate: a=7 and b=5 and c=4. Which index?
  1. Option 0: Neither. Simply use file scan
  2. Option 1: More selective one. Then, scan among the selected records
  3. Option2: Use both!
     - Algorithm: Intersect rid sets
       - Sort rids, retrieve rids in both sets

Example Choices

- Hash index on <a> and Hash index on <b>
  - a=7 or b>5
  - Neither! File scan required for b>5

Which index?

force to do full scan for b pure ⇒ can check a=7 during scan ⇒ no need hash look up for a

no hash index on b

- Hash index on <a> and B+tree on <b>
  - a=7 or b>5
  - Option 1: Neither
  - Option 2: Use both! Fetch rids and union
    - Note: Option 1 could be better sometimes. (When?)

Which index?

hash on a=7 ∪ tree on b>5.

B+ tree maybe unclustered ⇒ worse than full scan.

Question??

- Hash index on <a> and B+tree on <b>
  - (a=7 **or** c>5) **and** b > 5

no index ⇒ file scan ⇒ so ◯ has to full scan

Which index choices should we consider?

A. None (file scan) and Tree
B. None and Hash
C. None, Hash, Tree, and Both
D. None, Tree, and Both
E. None, Hash, and Both

Question??

- Hash index on <a> and B+tree on <b>
  - (a=7 **or** c>5) **and** b > 5

Which index choices should we consider?

A. None (file scan) and Tree
B. None and Hash
C. None, Hash, Tree, and Both
D. None, Tree, and Both
E. None, Hash, and Both

Why is Hash not appropriate?

Among None and Tree, what factors will determine the choice? In other words, when Is the optimizer likely to prefer the tree-based Index and when it is likely to simply use a file Scan?

When to Use a B+tree Index?

- Consider a relation with 1M tuples
- 100 tuples on a page
- 500 (key, rid) pairs on a page
- Fill factor in index: 0.67
- Plan a selection query for which the index matches

data pages = 1M/100 = 10K pages (data records)

leaf idx pgs (leaf page) = 1M / (500 * 0.67) ~ 3K pages

	1% SELECTIVITY	10% SELECTIVITY
CLUSTERED	~ 30 + 100	~ 300 + 1000
NON-CLUSTERED	~ 30 + 10,000	~ 300 + 100,000
NC + SORT RIDS by page ID.	~ 30 + (~10,000)	~ 300 + (~10,000)

⇨ Choice of Index access plan, consider:
1. Index Selectivity 2. Clustering
⇨ Similar consideration for hash-based indices

Summary

- DBMS use catalogs, which are relations themselves.
- Query Optimizer selects the evaluation plan after evaluating the cost of *many* plans. It evaluates the potential algorithms and chooses the best one per operator.
- Single vs. composite search keys
- Each relation may have multiple indexes
  - Selectivity
  - Clustering

Optional Exercises

12.1 (1-4), 12.3, 12.5