ICS 321 Spring 2011
Overview of Query Processing

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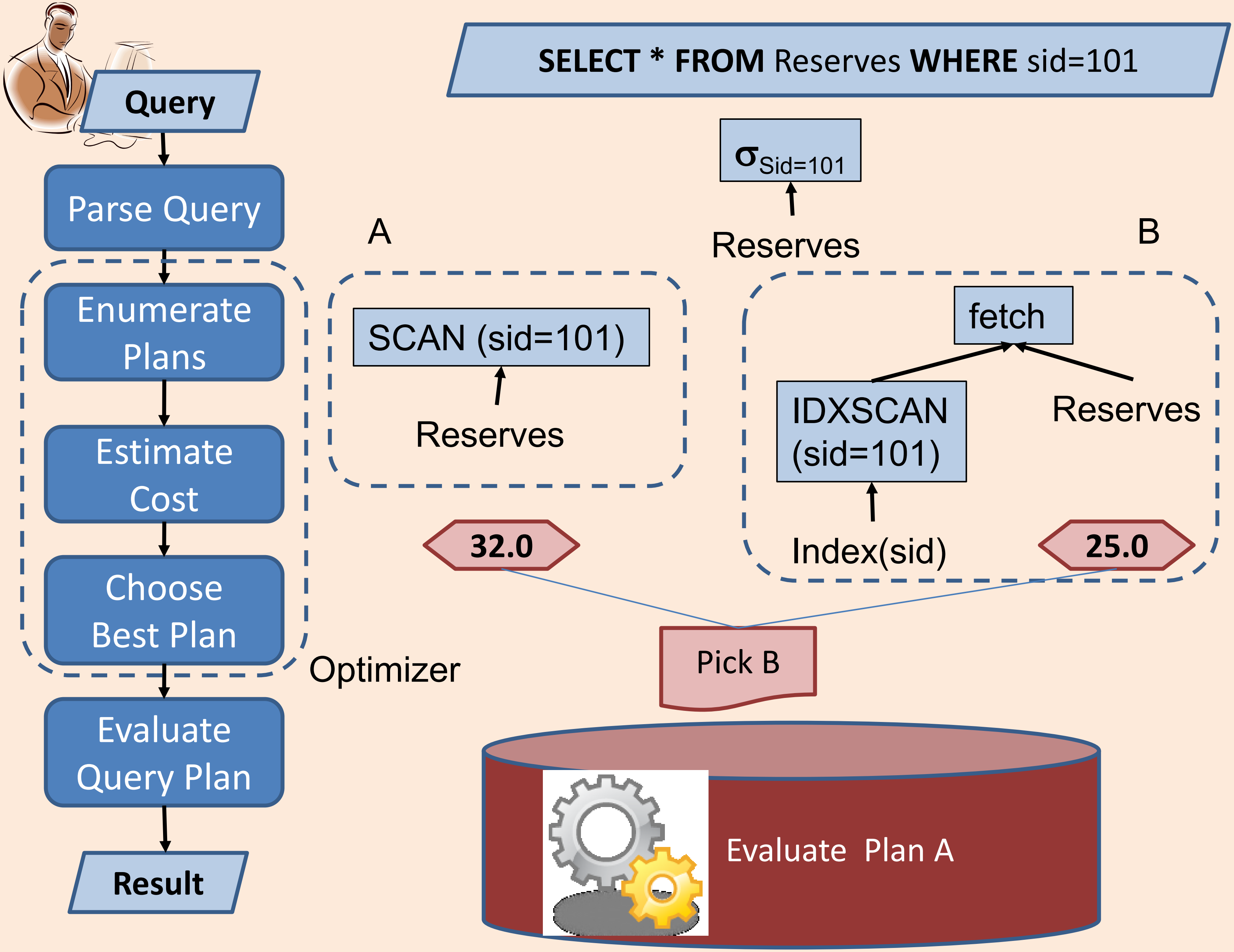

Query
Parse Query
Enumerate Plans
Estimate Cost
Choose Best Plan
Optimizer
Evaluate Query Plan
Result
SELECT * FROM Reserves WHERE sid=101
$\sigma_{Sid=101}$
Reserves
A
SCAN (sid=101)
Reserves
B
fetch
IDXSCAN (sid=101)
Reserves
Index(sid)
32.0
25.0
Pick B
Evaluate Plan A

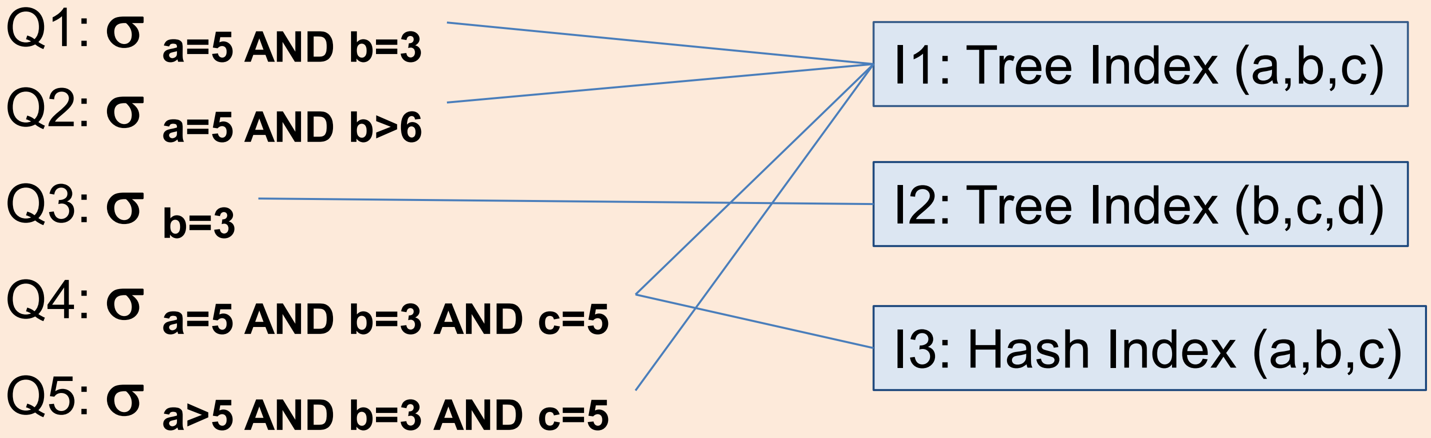
Query Processing

- **Query Execution Plan** (QEP): tree of database operators.
  - At high-level, relational algebra operators are used
  - At low-level, RA operators with particular implementation algorithm.
- **Plan enumeration**: find equivalent plans
  - Different QEPs that return the same results
  - Query rewriting : transformation of one QEP to another equivalent QEP.
- **Cost estimation:** a mapping of a QEP to a cost
  - **Cost Model:** a model of what counts in the cost estimate. Eg. Disk accesses, CPU cost …
- **Query Optimizer:**
  - Explores the space of equivalent plan for a query
  - Chooses the best plan according to a cost model

Access Paths

- An **access path** is a method of retrieving tuples. Eg. Given a query with a selection condition:
  - File or table scan
  - Index scan
- **Index matching problem:** given a selection condition, which indexes can be used for the selection, i.e., matches the selection ?
  - Selection condition normalized to conjunctive normal form (CNF), where each term is a *conjunct*
  - Eg. (day<8/9/94 **AND** rname='Paul') **OR** bid=5 **OR** sid=3
  - **CNF**: (day<8/9/94 **OR** bid=5 **OR** sid=3) AND (rname='Paul' **OR** bid=5 **OR** sid=3)

Index Matching



- A tree index matches a selection condition if the selection condition is a prefix of the index search key.
- A hash index matches a selection condition if the selection condition has a term *attribute=value* for every attribute in the index search key

One Approach to Selections

1. Find the *most selective access path,* retrieve tuples using it
2. Apply remaining terms in selection not matched by the chosen access path

- The **selectivity** of an access path is the size of the result set (in terms of tuples or pages).
  - Sometimes selectivity is also used to mean **reduction factor:** fraction of tuples in a table retrieved by the access path or selection condition.
- Eg. Consider the selection:

  day<8/9/94 **AND** bid=5 **AND** sid=3

  - Tree Index(day)
  - Hash index (bid,sid)

Query Execution Plans

- A tree of database operators: each operator is a RA operator with specific implementation
- Selection σ: Index Scan or Table Scan
- Projection π:
  - Without DISTINCT : Table Scan
  - With DISTINCT : requires sorting or index scan
- Join $\bowtie$:
  - Nested loop joins (naïve)
  - Index nested loop joins
  - Sort merge joins

Nested Loop Join

S1

sid	sname	rating	age
22	Dustin	7	45.0
31	Lubber	8	55.5
58	Rusty	10	35.0

$\bowtie$

R1

sid	bid	day
22	101	10/10/96
58	103	11/12/96

```
For each data page P_S1 of S1
   For each tuple s in P_S1
      For each data page P_R1 of R1
         For each tuple r in P_R1
            if (s.sid==r.sid)
            then output s,r
```

- Worst case number of disk reads

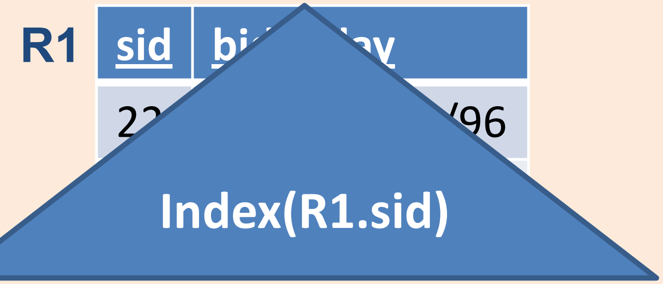
  = Npages(S1) + |S1|*Npages(R1)

Index Nested Loop Join

S1

sid	sname	rating	age
22	Dustin	7	45.0
31	Lubber	8	55.5
58	Rusty	10	35.0

$\bowtie$



For each data page P_{S1} of S1
  For each tuple s in P_{S1}
    if (s.sid ∊ Index(R1.sid))
    then fetch r & output <s,r>

- Worst case number of disk reads with tree index
  $= \text{Npages(S1)} + |S1| * (1 + \log_F \text{Npages(R1)})$
- Worst case number of disk reads with hash index
  $= \text{Npages(S1)} + |S1| * 2$

Sort Merge Join

S1

sid	sname	rating	age
22	Dustin	7	45.0
31	Lubber	8	55.5
58	Rusty	10	35.0

R1

sid	bid	day
19	100	8/8/99
22	101	10/10/96
22	99	10/12/95
58	103	11/12/96

```
1.  Sort S1 on SID
2.  Sort R1 on SID
3.  Compute join on SID using Merging algorithm
```

- If join attributes are relatively unique, the number of disk pages

  = Npages(S1) log Npages(S1)

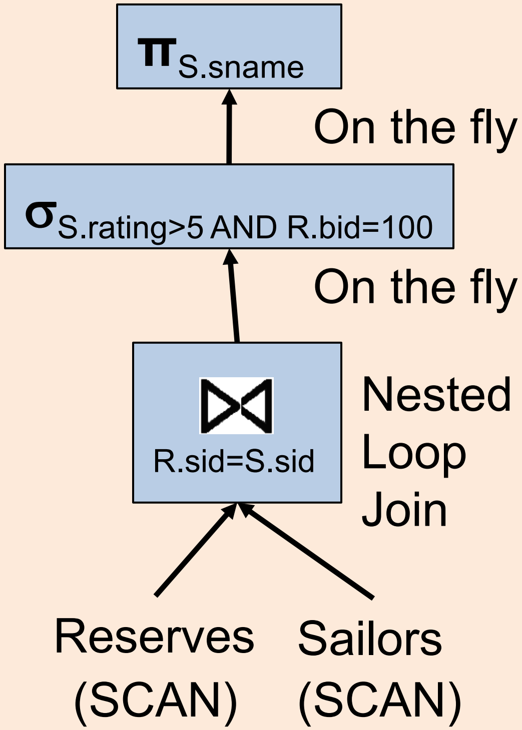
  + Npages(R1) log Npages(R1)

  + Npages(S1) + Npages(R1)
- What if the number of duplicates is large?
  – the number of disk pages approaches that of nested loop join.

Example

SELECT S.sname
FROM Reserves R, Sailors S
WHERE R.sid=S.sid **AND** R.bid=100 **AND** S.rating>5

Reserves	40 bytes/tuple	100 tuples/page	1000 pages
Sailors	50 bytes/tuple	80 tuples/page	500 pages



- Nested Loop Join cost 1K+ 100K*500
- On the fly selection and project does not incur any disk access.
- Total disk access = 500001K (worst case)

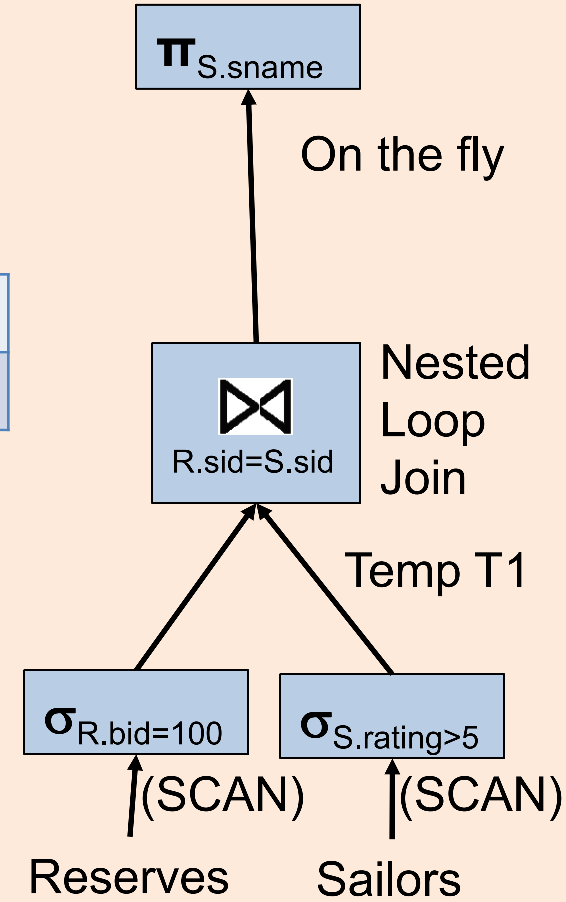
Example: Predicate Pushdown

SELECT S.sname
FROM Reserves R, Sailors S
WHERE R.sid=S.sid **AND** R.bid=100 **AND** S.rating>5

10% (R.bid=100)
50% (S.rating>5)

Reserves	40 bytes/tuple	100 tuples/page	1000 pages
Sailors	50 bytes/tuple	80 tuples/page	500 pages

- Nested Loop Join requires materializing the inner table as T1.
- With 50% selectivity, T1 has 250 pages
- With 10% selectivity, outer "table" in join has 10K tuples
- Disk accesses for scans = 1000 + 500
- Writing T1 = 250
- NLJoin = 10K * 250
- Total disk access = 2500.175 K (worst case)



What happens if we make the left leg the inner table of the join ?

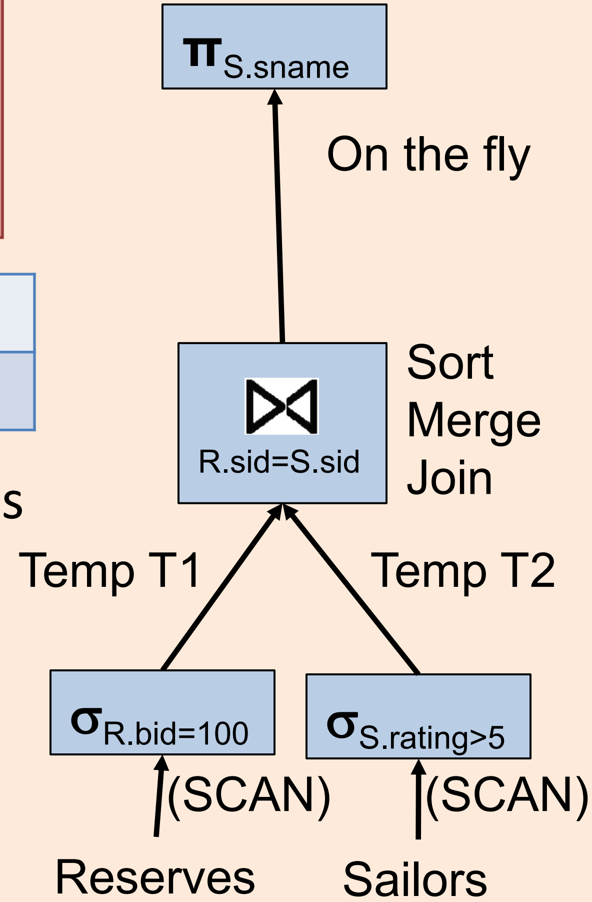
Example: Sort Merge Join

SELECT S.sname
FROM Reserves R, Sailors S
WHERE R.sid=S.sid **AND** R.bid=100 **AND** S.rating>5

10% **50%**

Reserves	40 bytes/tuple	100 tuples/page	1000 pages
Sailors	50 bytes/tuple	80 tuples/page	500 pages

- Sort Merge Join requires materializing both legs for sorting.
- With 10% selectivity, T1 has 100 pages
- With 50% selectivity, T2 has 250 pages
- Disk accesses for scans = 1000 + 500
- Writing T1 & T2 = 100 + 250
- Sort Merge Join = 100 log 100 + 250 log 250 + 100+250 (assume 10 way merge sort)
- Total disk access = 52.8 K



What happens if we make the left leg the inner table of the join ?

Example: Index Nested Loop Join

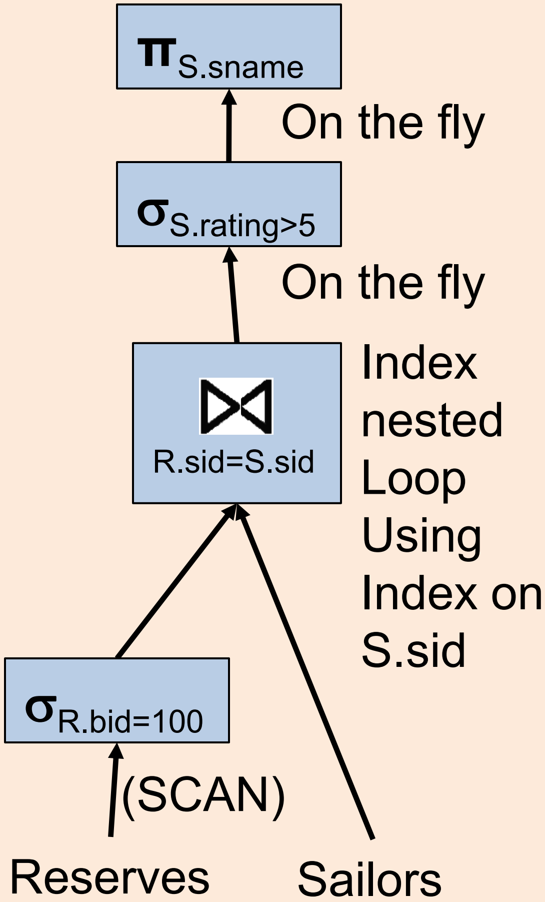
SELECT S.sname
FROM Reserves R, Sailors S
WHERE R.sid=S.sid **AND** R.bid=100 **AND** S.rating>5

10%

50%

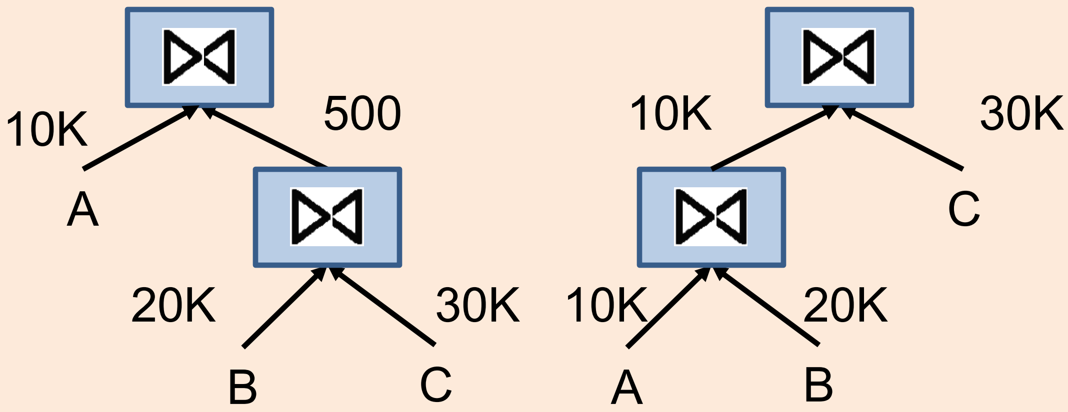
Reserves	40 bytes/tuple	100 tuples/page	1000 pages
Sailors	50 bytes/tuple	80 tuples/page	500 pages

- With 10% selectivity, selection on R has 10K tuples
- Disk accesses for scan = 1000
- Index Nested Loop Join = 10K*(1 + $\log_{10}$ 500) = 37K
- Total disk access = 38 K



What happens if we make the left leg the inner table of the join ?

Join Ordering



Relations	Tuples	Pages
A	10K	1000
B	20K	2000
C	30K	3000
A join B	10K	1000
B join C	1K	100

- Independent of what join algorithm is chosen, the order in which joins are perform affects the performance.
- Rule of thumb: do the most “selective” join first
- In practice, left deep trees (eg. the right one above) are preferred --- why ?

Statistics & Cost Estimation

- Page size
- Data Statistics:
  - Record size -> number of records per data page
  - Cardinality of relations (including temporary tables)
  - Selectivity of selection operator on different columns of a relation
- (Tree) Index Statistics
  - number of leaf pages, index entries
  - Height
- Statistics collection is user triggered
  - DB2: RUNSTATS ON TABLE mytable AND INDEXES ALL