Introduction to Data Management
CSE 414

11/2

Unit 4: RDBMS Internals
Logical and Physical Plans
Query Execution
Query Optimization

(3 lectures)

Introduction to Database Systems
CSE 414

Lecture 16:
Basics of Data Storage and Indexes

Query Performance

- My database application is too slow… why?
- One of the queries is very slow… why?

- To understand performance, we need to understand:
  - How is data organized on disk
  - How to estimate query costs

extracting information from the disk is by far the slowest action, which is why we focus our look into efficiency by focusing how many disk reads are required.

  - In this course we will focus on **disk-based** DBMSs

why use a disk at all? cheapest option for storing large quantities of data

drawbacks
reader physically has to move to location on disk
read speed limited by rotation speed (faster to read things sequentially, or a block at a time)

Scanning a Data File

- Disks are mechanical devices!
  - Technology from the 60s;
  - Density increases over time
- Read only at the rotation speed!
- Consequence: sequential scan faster than random
  - Good: read blocks 1,2,3,4,5,…
  - Bad: read blocks 2342, 11, 321,9, …
- Rule of thumb:
  - Random read 1-2% of file ≈ sequential scan entire file;
  - 1-2% decreases over time, because of increased density
- Solid state (SSD): still too expensive today

why use a disk at all? cheapest option for storing large quantities of data

drawbacks
reader physically has to move to location on disk (MOST expensive operation)
read speed limited by rotation speed (

faster to read things sequentially, or a block at a time
good: read blocks 1,2,3,4,5
bad : read blocks 2342, 11, 321, 9 …

to put into perspective:

Read 1 MB from memory (RAM) 250 us

Disk seek (i.e. move disk arm/reader) = 10,000 us
Read 1MB sequentially from disk (including disk seek) = 20,000 us

100 times slower!

Data Storage

Student

ID	fName	lName
10	Tom	Hanks
20	Amy	Hanks
…		

- DBMSs store data in **files**
- Most common organization is row-wise storage
- On disk, a file is split into blocks
- Each block contains a set of tuples

10	Tom	Hanks	block 1
20	Amy	Hanks	
50	…	…	block 2
200	…		
220			block 3
240			
420			
800			

In the example, we have 4 blocks with 2 tuples each

Data File Types

Student

ID	fName	lName
10	Tom	Hanks
20	Amy	Hanks
…		

The data file can be one of:

- Heap file
  - Unsorted

put tuples completely random in file

- Sequential file
  - Sorted according to some attribute(s) called *key*

order tuples based on some sort of key.

Index

- An **additional** file, that allows fast access to records in the data file given a search key
- The index contains (key, value) pairs:
  - The key = an attribute value (e.g., student ID or name)
  - The value = a pointer to the record
- Could have many indexes for one table

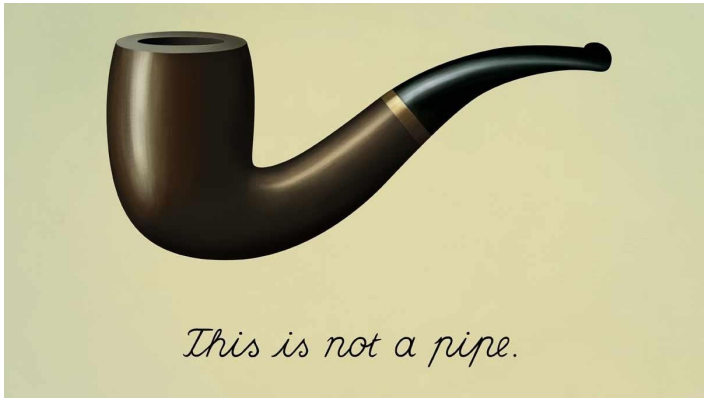
tuples; allows you to quickly access specific pieces of memory rather than scanning thru whole disk

Key = means here search key

This  Is Not A Key

Different keys:

- Primary key – uniquely identifies a tuple based on schema
- Key of the sequential file – how the data file is sorted, if at all
- Index key – how the index is organized



Example 1: Index on ID

Index the student table on the Student.ID

Student

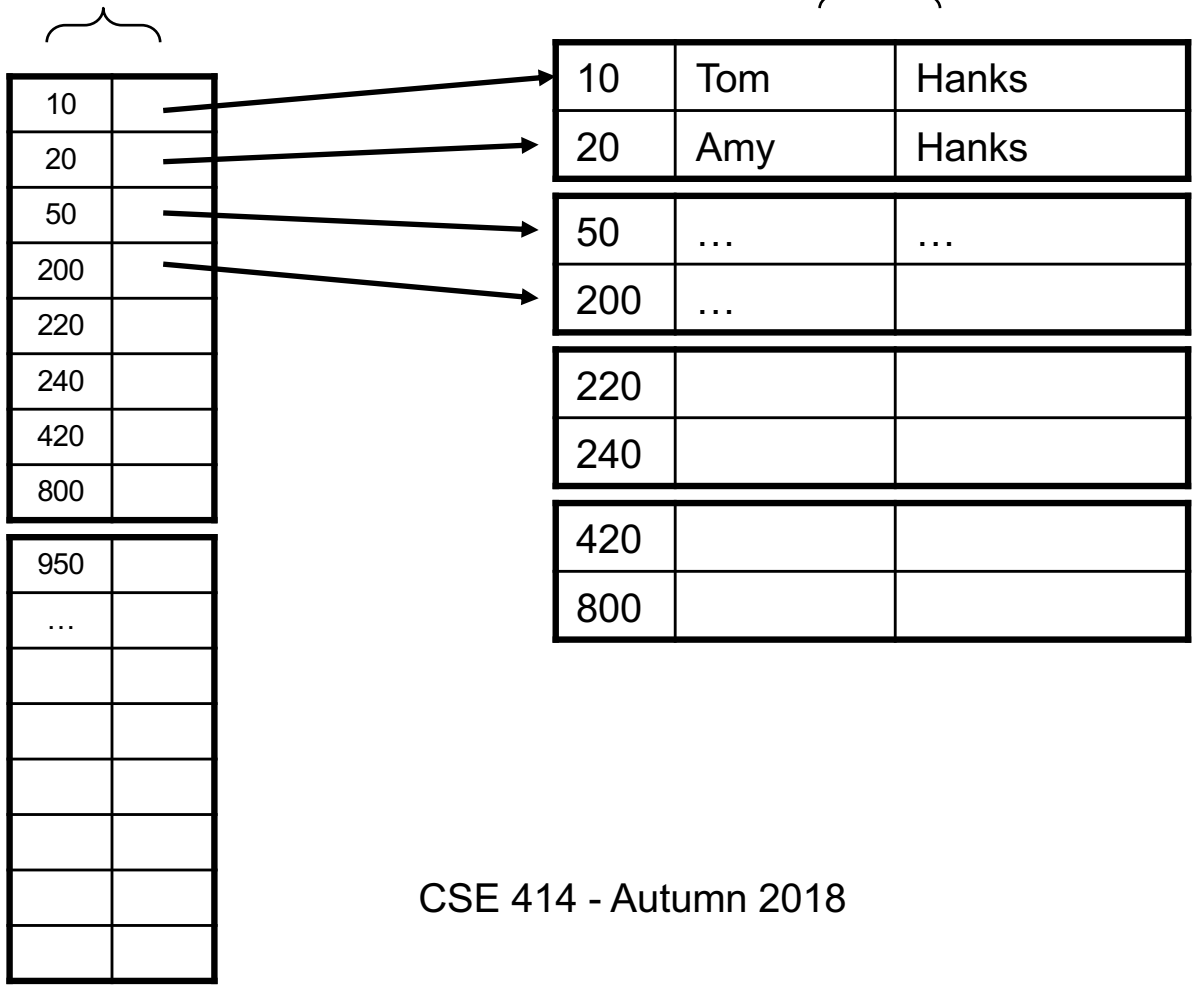
ID	fName	lName
10	Tom	Hanks
20	Amy	Hanks
…		

Index **Student_ID** on **Student.ID**

Data File **Student**

more indexs can fit in a block than full tuples; one primary advantage

can even store it in main memory as its so small (sometimes) giving fast acesses



effectiveness of index depends on how tuples are ordered on disk as well!

Unclustered index: tuples of data are not stored in file in an order based on the index; index less effective?

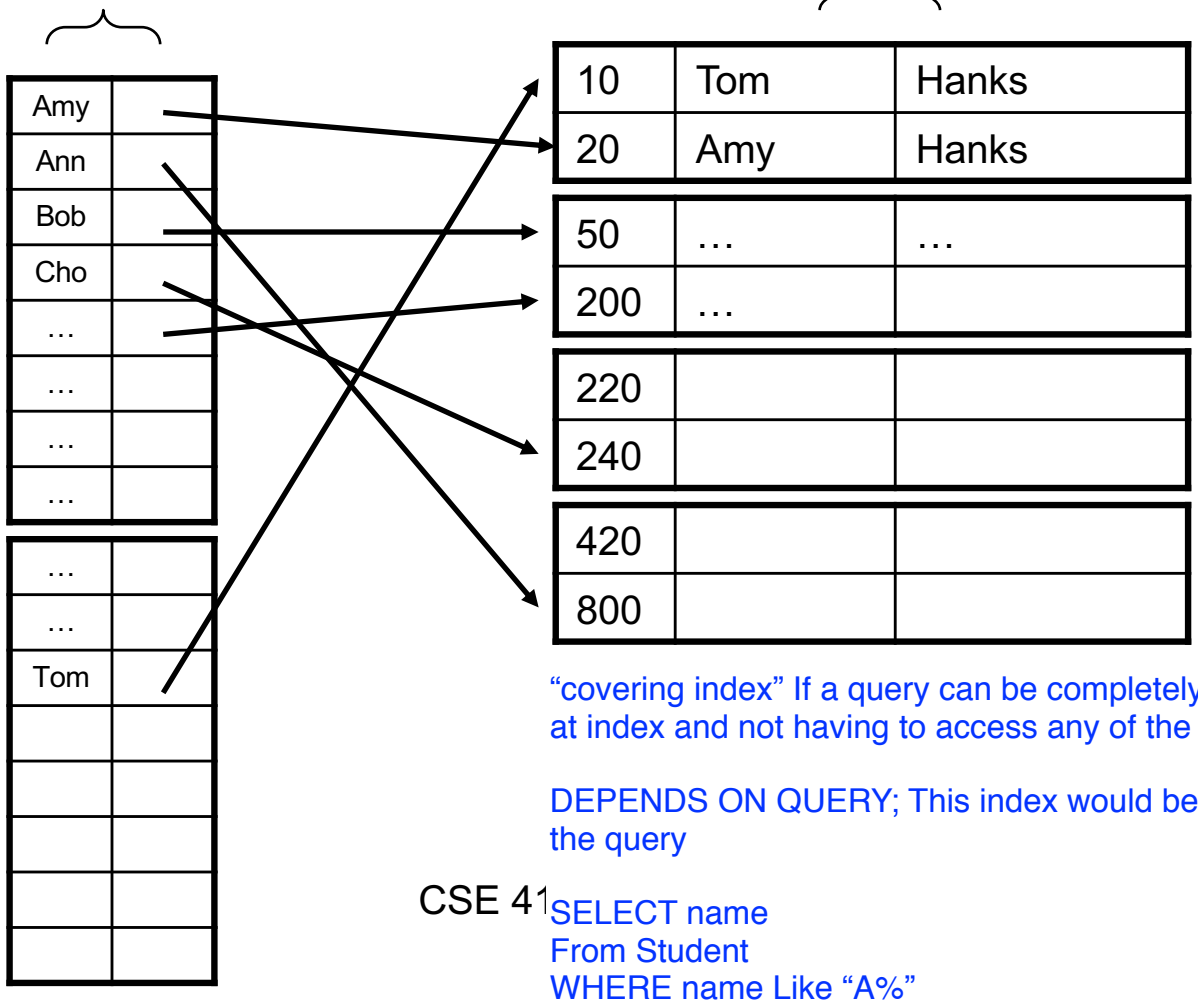
Example 2: Index on fName

Student

ID	fName	lName
10	Tom	Hanks
20	Amy	Hanks
…		

Index **Student_fName** on **Student.fName**

Data File **Student**



"covering index" If a query can be completely answered just looking at index and not having to access any of the tuples in main memory

DEPENDS ON QUERY; This index would be a covering index for the query

SELECT name
From Student
WHERE name Like "A%"

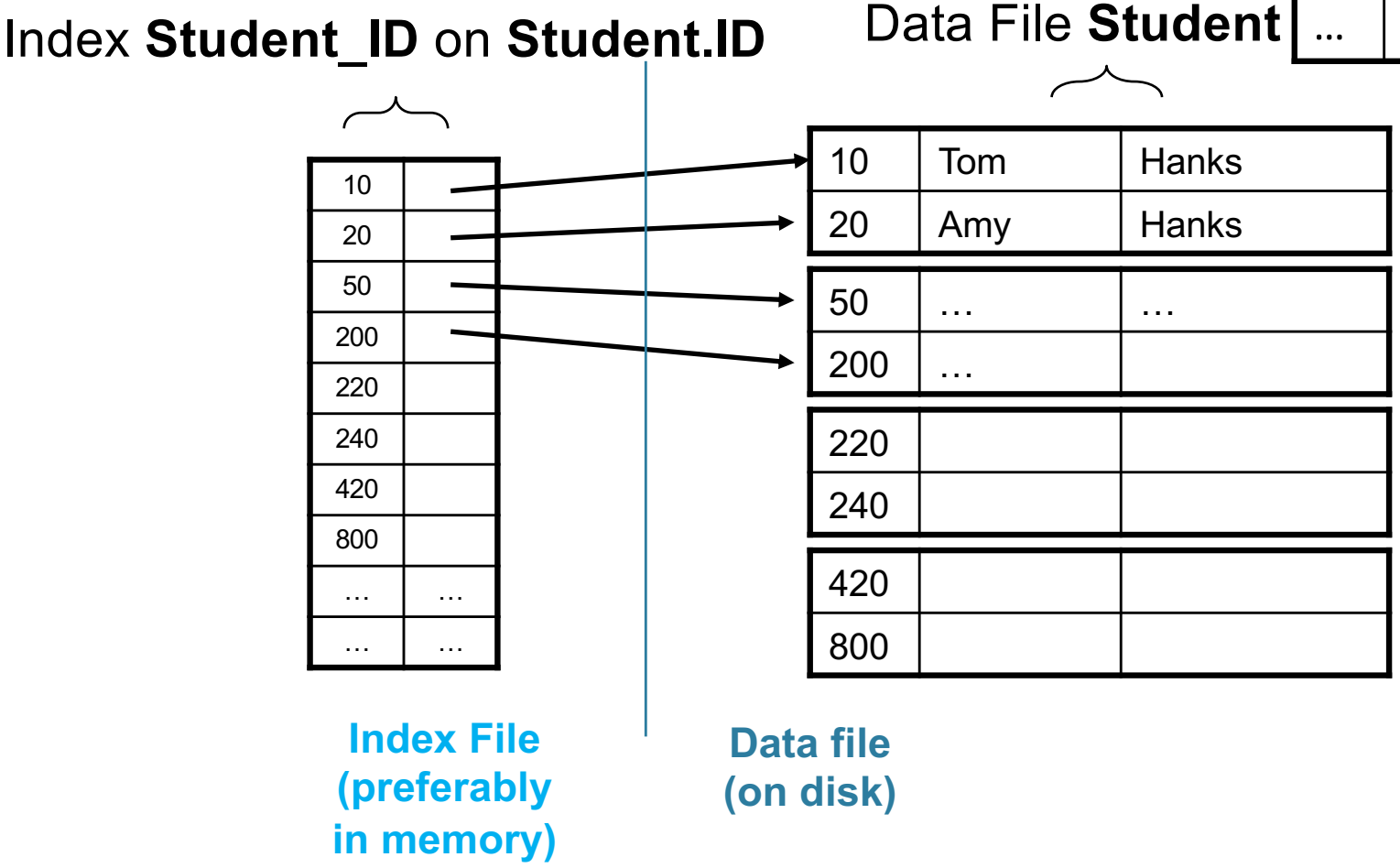
Index Organization

- Hash table
- B+ trees – most common
  - They are search trees, but they are not binary instead have higher fan-out
  - Will discuss them briefly next
- Specialized indexes: bit maps, R-trees, inverted index

Hash table example

Student

ID	fName	lName
10	Tom	Hanks
20	Amy	Hanks
…		

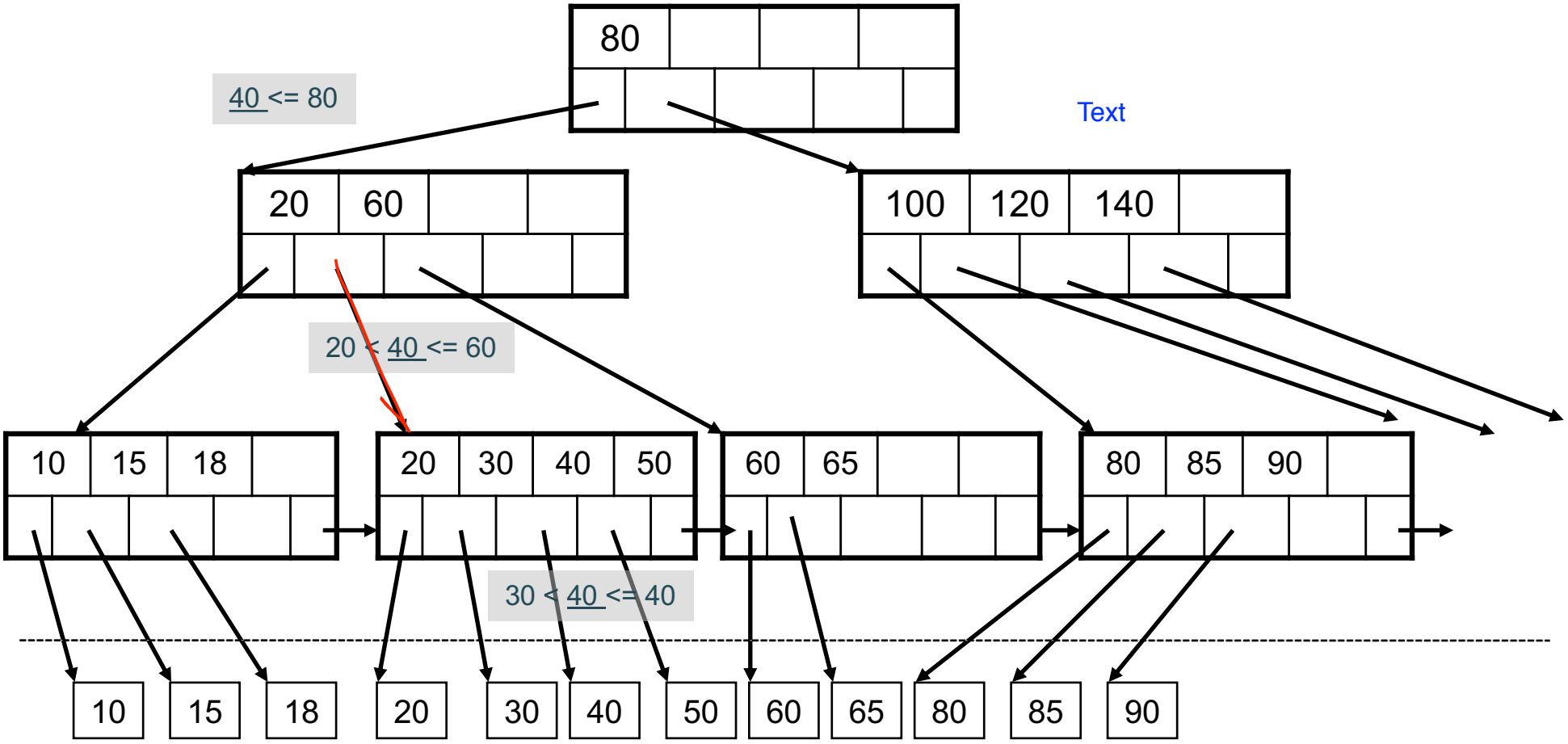


B+ Tree Index by Example

d = 2

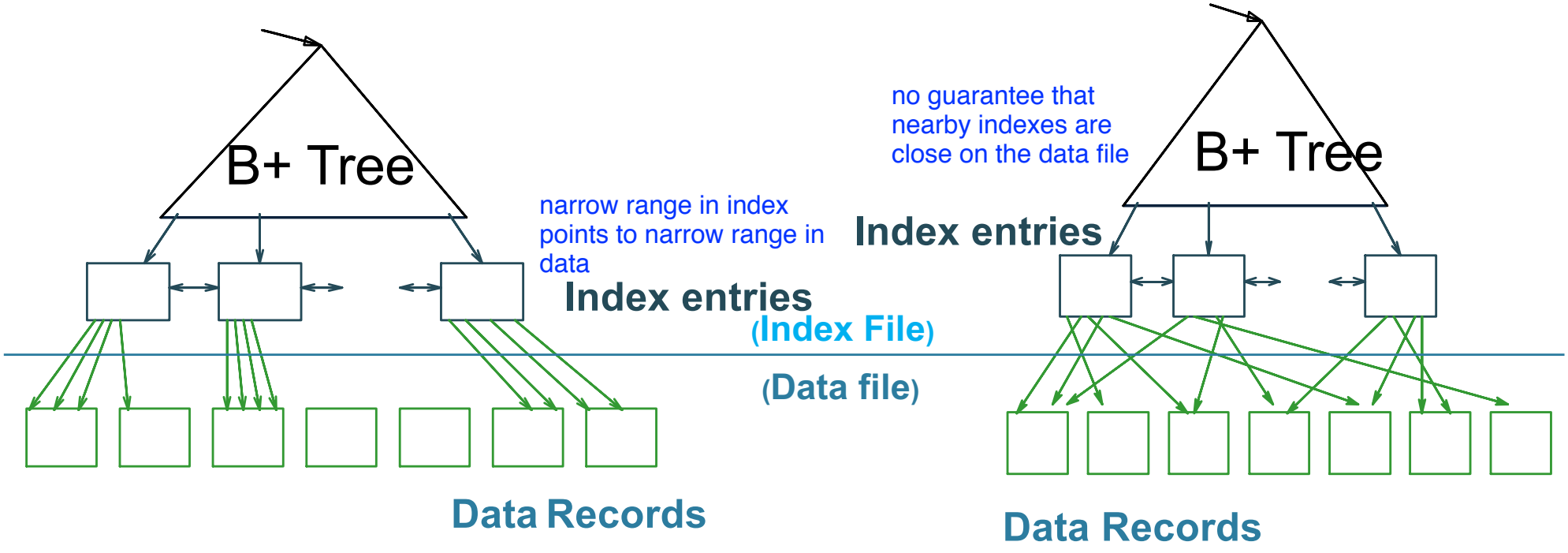
find the node that is in between the two values above it

Find the key 40



For clustered index, tuples (in data) are ordered based on the index

Clustered vs Unclustered



Every table can have **only one** clustered and **many** unclustered indexes

Why?

because the data is ordered based on the clustered index; cant order on two separate qualities

unclustered indexes dont constrain organization of data at all, so we can have as many as we want

Index Classification

- **Clustered/unclustered**
  - Clustered = records close in index are close in data
    - Option 1: Data inside data file is sorted on disk
    - Option 2: Store data directly inside the index (no separate files)
  - Unclustered = records close in index may be far in data
- **Primary/secondary**
  - Meaning 1:
    - Primary = is over attributes that include the primary key
    - Secondary = otherwise
  - Meaning 2: means the same as clustered/unclustered
- **Organization** B+ tree or Hash table

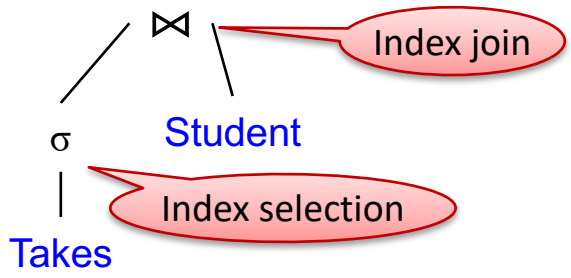
index over primary key; fastest look up by ordering data on disk by primary key

Summary So Far

- Index = a file that enables direct access to records in another data file
  - B+ tree / Hash table
  - Clustered/unclustered
- Data resides on disk
  - Organized in blocks
  - Sequential reads are efficint
  - Random access less efficient
  - Random read 1-2% of data worse than sequential

Student(ID, fname, lname)
Takes(studentID, courseID)

```
SELECT *
FROM  Student x, Takes y
WHERE x.ID=y.studentID AND y.courseID > 300
```



Example

indexes for speeding up queries!

```
for y in Takes
   if courseID > 300 then
    for x in Student
         if x.ID=y.studentID
          output *
```

Assume the database has indexes on these attributes:

- **Takes_courseID** = index on Takes.courseID
- **Student_ID** = index on Student.ID

Index selection

faster to search through indexes and filter tuples as index files exist in main memory which can be accessed much faster; Limits the number of disk accesses we have to run

Index join

```
for y' in Takes_courseID where y'.courseID > 300
  y = fetch the Takes record pointed to by y'
  for x' in Student_ID where x'.ID = y.studentID
        x = fetch the Student record pointed to by x'
        output *
```

Getting Practical: Creating Indexes in SQL

```
CREATE TABLE V(M int, N varchar(20), P int);
```

```
CREATE INDEX V1 ON V(N)
```

CREATE INDEX index name ON Relation(attribute)

```
CREATE INDEX V2 ON V(P, M)
```

With multiple attributes, order indices by first attribute, then for matching values of that order by second attribute

```
CREATE INDEX V3 ON V(M, N)
```

```
CREATE UNIQUE INDEX V4 ON V(N)
```

```
CREATE CLUSTERED INDEX V5 ON V(N)
```

Getting Practical: Creating Indexes in SQL

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CREATE TABLE V(M int, N varchar(20), P int);
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CREATE INDEX V1 ON V(N)
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```
CREATE INDEX V2 ON V(P, M)
```

What does this mean?

```
CREATE INDEX V3 ON V(M, N)
```

```
CREATE UNIQUE INDEX V4 ON V(N)
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```
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Getting Practical: Creating Indexes in SQL

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CREATE CLUSTERED INDEX V5 ON V(N)
```

yes

```
select *
from V
where P=55 and M=77
```

What does this mean?

Getting Practical: Creating Indexes in SQL

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Getting Practical: Creating Indexes in SQL

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Getting Practical: Creating Indexes in SQL

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CREATE INDEX V2 ON V(P, M)
CREATE INDEX V3 ON V(M, N)
CREATE UNIQUE INDEX V4 ON V(N)
CREATE CLUSTERED INDEX V5 ON V(N)
```

forces values in this key to be unique

forces data to be stored/sorted based on that given index

```
select *
from V
where P=55 and M=77
```

yes

What does this mean?

```
select *
from V
where P=55
```

yes

```
select *
from V
where M=77
```

no

wont speed up query

M values are spread far throughout the indices file as the file is first sorted by P, then by M. So M = 77 could occur in many places

Which Indexes?

Student

ID	fName	lName
10	Tom	Hanks
20	Amy	Hanks
…		

- How many indexes could we create?

  index files take up extra space…
  updating tuples and we also have to update index file

- Which indexes should we create?

In general this is a very hard problem

Which Indexes?

Student

ID	fName	lName
10	Tom	Hanks
20	Amy	Hanks
…		

- The *index selection problem*
  - Given a table, and a "workload" (big Java application with lots of SQL queries), decide which indexes to create (and which ones NOT to create!)
- Who does index selection:
  - The database administrator DBA

    person
  - Semi-automatically, using a database administration tool

Which Indexes?

Student

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- The *index selection problem*
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- Who does index selection:
  - The database administrator DBA

  - Semi-automatically, using a database administration tool

Index Selection: Which Search Key

- Make some attribute K a search key if the WHERE clause contains:
  - An exact match on K
  - A range predicate on K
  - A join on K

The Index Selection Problem 1

```
V(M, N, P);
```

Your workload is this

100000 queries:

```
SELECT *
FROM V
WHERE N=?
```

100 queries:

```
SELECT *
FROM V
WHERE P=?
```

The Index Selection Problem 1

V(M, N, P);

Your workload is this

100000 queries:

```
SELECT *
FROM V
WHERE N=?
```

100 queries:

```
SELECT *
FROM V
WHERE P=?
```

What indexes ?

The Index Selection Problem 1

V(M, N, P);

Your workload is this

100000 queries:

```
SELECT *
FROM V
WHERE N=?
```

100 queries:

```
SELECT *
FROM V
WHERE P=?
```

A: V(N) and V(P) (hash tables or B-trees)

make both

The Index Selection Problem 2

V(M, N, P);

Your workload is this

100000 queries:

```
SELECT *
FROM V
WHERE N>? and N<?
```

100 queries:

```
SELECT *
FROM V
WHERE P=?
```

100000 queries:

```
INSERT INTO V
VALUES (?, ?, ?)
```

What indexes ?

The Index Selection Problem 2

```
V(M, N, P);
```

Your workload is this

100000 queries:

```
SELECT *
FROM V
WHERE N>? and N<?
```

100 queries:

```
SELECT *
FROM V
WHERE P=?
```

100000 queries:

```
INSERT INTO V
VALUES (?, ?, ?)
```

need to enforced order of a B-tree; easier to find starting and end points of a range (close index values are stored near to each other)

A: definitely V(N) (must B-tree); unsure about V(P)

The Index Selection Problem 3

V(M, N, P);

Your workload is this

100000 queries:

```
SELECT *
FROM V
WHERE N=?
```

1000000 queries:

```
SELECT *
FROM V
WHERE N=? and P>?
```

100000 queries:

```
INSERT INTO V
VALUES (?, ?, ?)
```

What indexes ?

The Index Selection Problem 3

V(M, N, P);

Your workload is this

100000 queries:

```
SELECT *
FROM V
WHERE N=?
```

1000000 queries:

```
SELECT *
FROM V
WHERE N=? and P>?
```

100000 queries:

```
INSERT INTO V
VALUES (?, ?, ?)
```

By pairing N and P together, we do not have to check tuples twice. Narrowing down tuples for N, then further narrow down on P rather than narrow on N, narrow on P separately, then join

A: V(N, P)

Limit our query first to N values (as this is the more exclusive condition) and we also need to sort by P; also B+ tree
Then all the P > conditions will be next to each other

How does this index differ from:

1. Two indexes V(N) and V(P)?
2. An index V(P, N)?

The Index Selection Problem 4

V(M, N, P);

Your workload is this

1000 queries:

```
SELECT *
FROM V
WHERE N>? and N<?
```

100000 queries:

```
SELECT *
FROM V
WHERE P>? and P<?
```

What indexes ?

The Index Selection Problem 4

V(M, N, P);

Your workload is this

1000 queries:

```
SELECT *
FROM V
WHERE N>? and N<?
```

100000 queries:

```
SELECT *
FROM V
WHERE P>? and P<?
```

A: V(N) secondary, V(P) primary index

Two typical kinds of queries

```
SELECT *
FROM Movie
WHERE year = ?
```

- Point queries
- What data structure should be used for index?

```
SELECT *
FROM Movie
WHERE year >= ? AND
      year <= ?
```

- Range queries
- What data structure should be used for index?

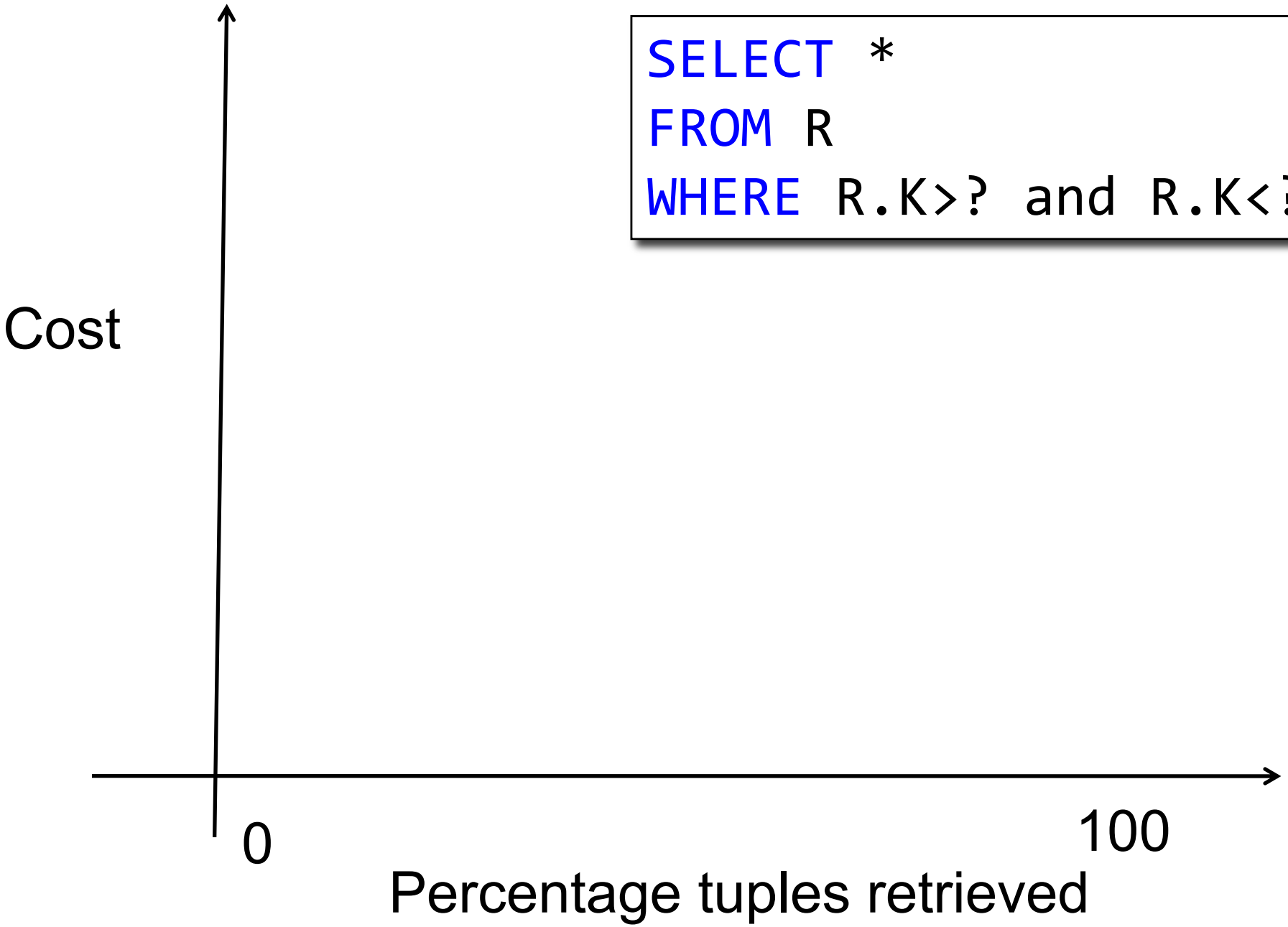
Basic Index Selection Guidelines

- Consider queries in workload in order of importance
- Consider relations accessed by query
  - No point indexing other relations i.e. attributes not accessed by query.
- Look at WHERE clause for possible search key
- Try to choose indexes that speed-up multiple queries

To Cluster or Not

- Range queries benefit mostly from clustering
- Covering indexes do *not* need to be clustered: they work equally well unclustered

```
SELECT *
FROM R
WHERE R.K>? and R.K<?
```



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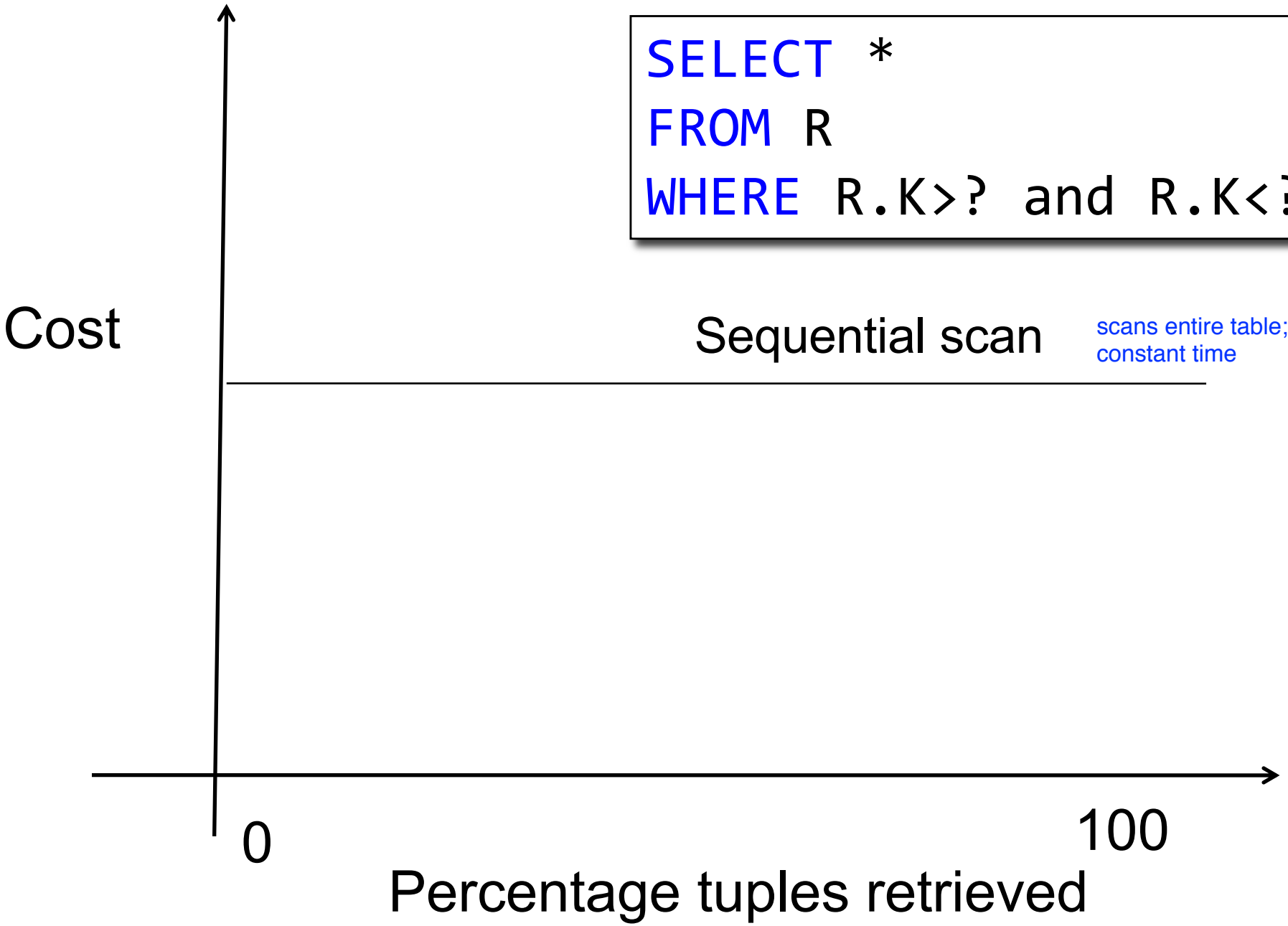

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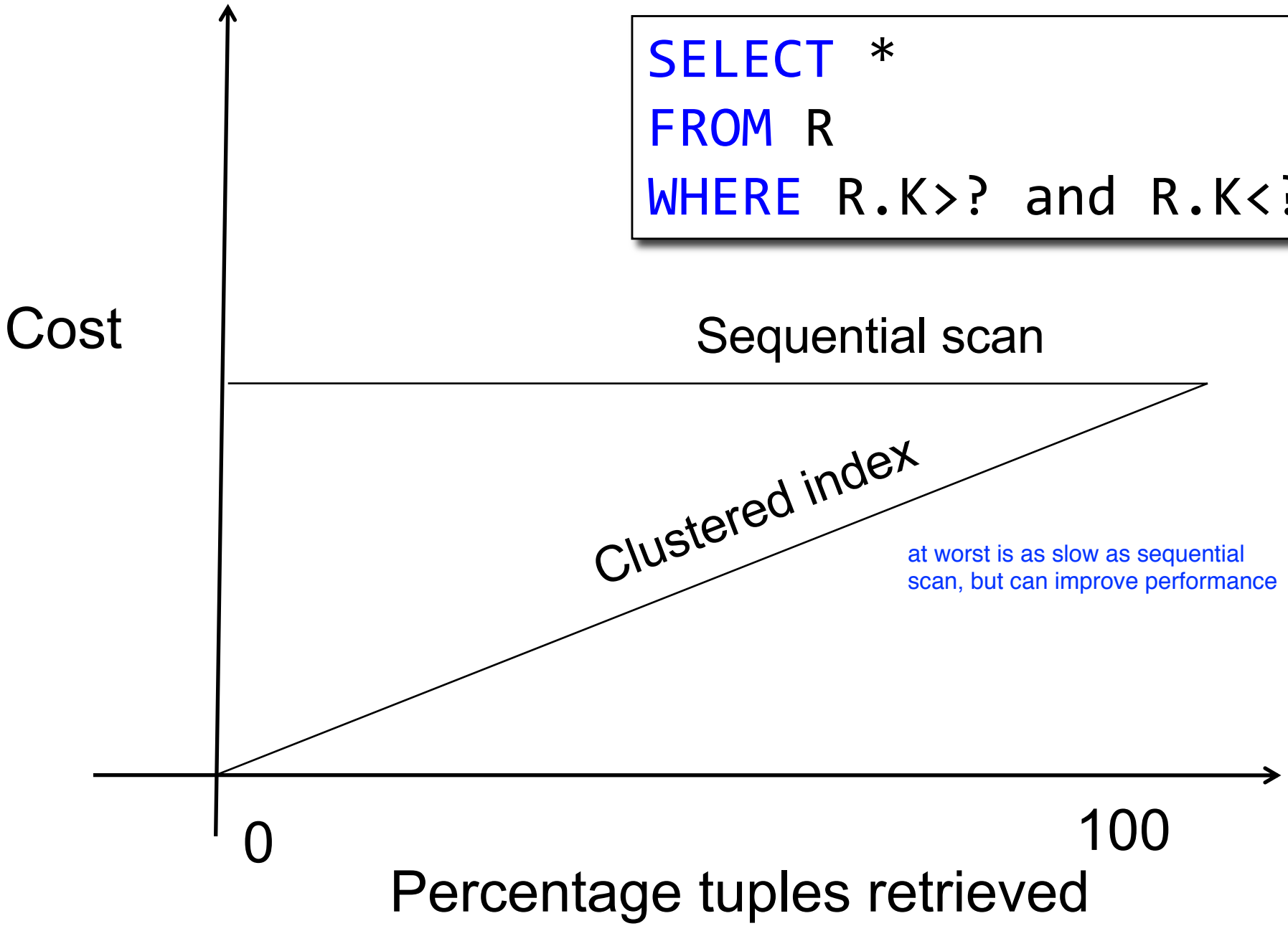
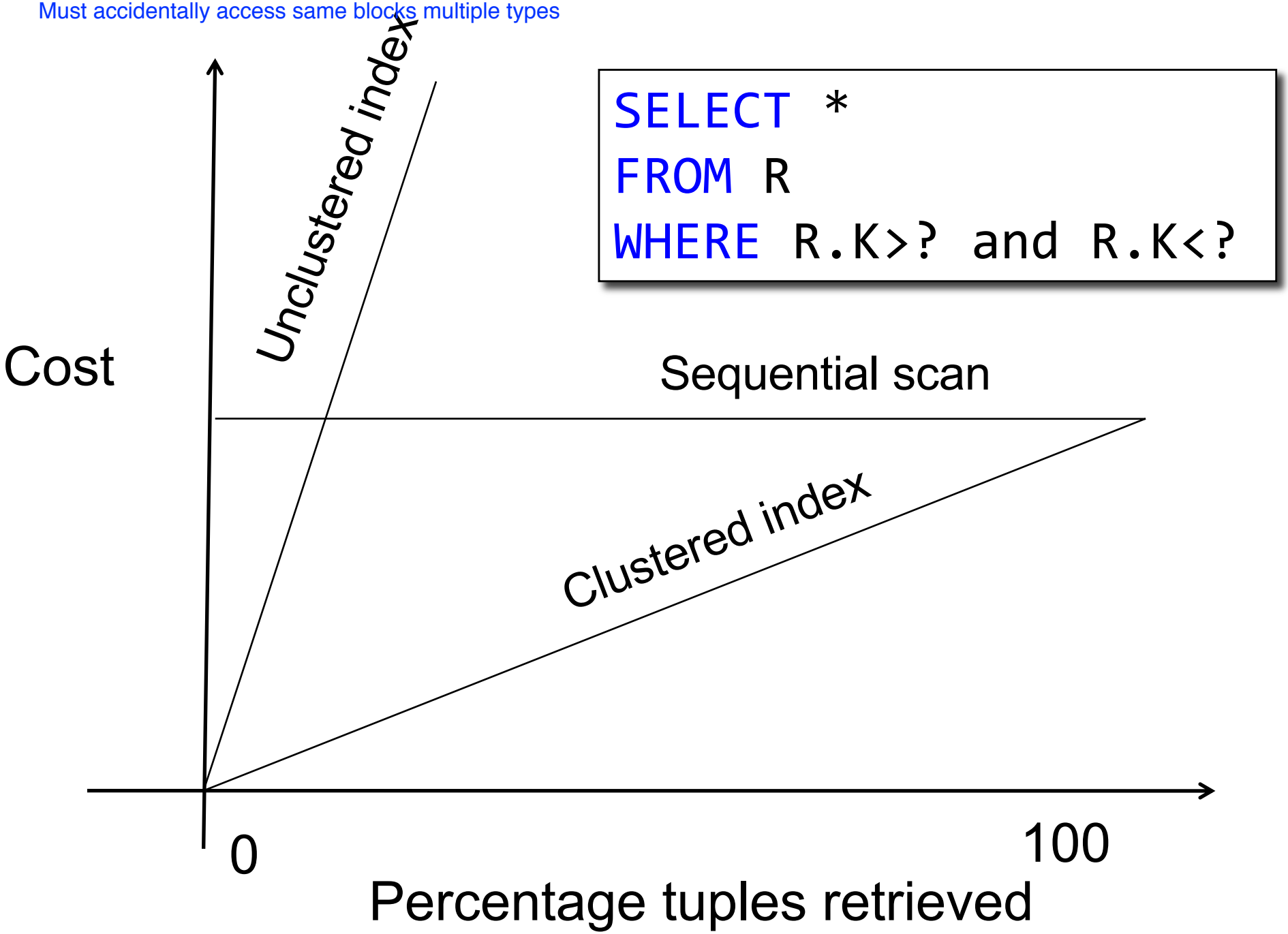


possibly worse than sequential
Must accidentally access same blocks multiple types




```
SELECT *
FROM R
WHERE R.K>? and R.K<?
```

Introduction to Database Systems
CSE 344

Lecture 17:
Basics of Query Optimization and
Query Cost Estimation

Choosing Index is Not Enough

- To estimate the cost of a query plan, we still need to consider other factors:
  - How each operator is implemented
  - The cost of each operator
  - Let's start with the basics

Cost of Reading Data From Disk

Cost Parameters

- Cost = I/O + CPU + Network BW
  - We will focus on I/O in this class
- Parameters (a.k.a. statistics):
  - **B(R)** = # of blocks (i.e., pages) for relation R
  - **T(R)** = # of tuples in relation R
  - **V(R, a)** = # of distinct values of attribute a

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When **a** is a key, **V(R,a) = T(R)**
When **a** is not a key, **V(R,a)** can be anything <= **T(R)**

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When **a** is a key, **V(R,a) = T(R)**
When **a** is not a key, **V(R,a)** can be anything <= **T(R)**

- DBMS collects statistics about base tables must infer them for intermediate results

Selectivity Factors for Conditions

- A = c /* $\sigma_{A=c}(R)$ */
  - Selectivity = 1/V(R,A)
- A < c /* $\sigma_{A<c}(R)$*/
  - Selectivity = (c - min(R, A))/(max(R,A) - min(R,A))
- c1 < A < c2 /* $\sigma_{c1<A<c2}(R)$*/
  - Selectivity = (c2 – c1)/(max(R,A) - min(R,A))

Cost of Reading Data From Disk

- Sequential scan for relation R costs **B(R)**

- Index-based selection
  - Estimate selectivity factor **f** (see previous slide)
  - Clustered index: f***B(R)**
  - Unclustered index f***T(R)**

Note: we ignore I/O cost for index pages

Index Based Selection

- Example:

B(R) = 2000
T(R) = 100,000
V(R, a) = 20

cost of $\sigma_{a=v}(R) = ?$

- Table scan:
- Index based selection:

Index Based Selection

- Example:

B(R) = 2000
T(R) = 100,000
V(R, a) = 20

cost of $\sigma_{a=v}(R) = ?$

- Table scan: B(R) = 2,000 I/Os
- Index based selection:

Index Based Selection

- Example:

B(R) = 2000
T(R) = 100,000
V(R, a) = 20

cost of $\sigma_{a=v}(R) = ?$

- Table scan: B(R) = 2,000 I/Os
- Index based selection:
  - If index is clustered:
  - If index is unclustered:

Index Based Selection

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cost of $\sigma_{a=v}(R) = ?$

- Table scan: B(R) = 2,000 I/Os
- Index based selection:
  - If index is clustered: B(R) * 1/V(R,a) = 100 I/Os
  - If index is unclustered:

Index Based Selection

- Example:

B(R) = 2000
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V(R, a) = 20

cost of $\sigma_{a=v}(R) = ?$

- Table scan: B(R) = 2,000 I/Os
- Index based selection:
  - If index is clustered: B(R) * 1/V(R,a) = 100 I/Os
  - If index is unclustered: T(R) * 1/V(R,a) = 5,000 I/Os

Index Based Selection

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B(R) = 2000
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cost of $\sigma_{a=v}(R) = ?$

- Table scan: B(R) = 2,000 I/Os
- Index based selection:
  - If index is clustered: B(R) * 1/V(R,a) = 100 I/Os
  - If index is unclustered: T(R) * 1/V(R,a) = 5,000 I/Os

Lesson: Don't build unclustered indexes when V(R,a) is small !

Cost of Executing Operators (Focus on Joins)

Outline

- **Join operator algorithms**
  - One-pass algorithms (Sec. 15.2 and 15.3)
  - Index-based algorithms (Sec 15.6)

- Note about readings:
  - In class, we discuss only algorithms for joins
  - Other operators are easier: read the book

Join Algorithms

- Hash join
- Nested loop join
- Sort-merge join

Hash Join

Hash join: $R \bowtie S$

- Scan R, build buckets in main memory
- Then scan S and join
- Cost: B(R) + B(S)
- Which relation to build the hash table on?

Hash Join

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- Then scan S and join
- Cost: B(R) + B(S)
- Which relation to build the hash table on?

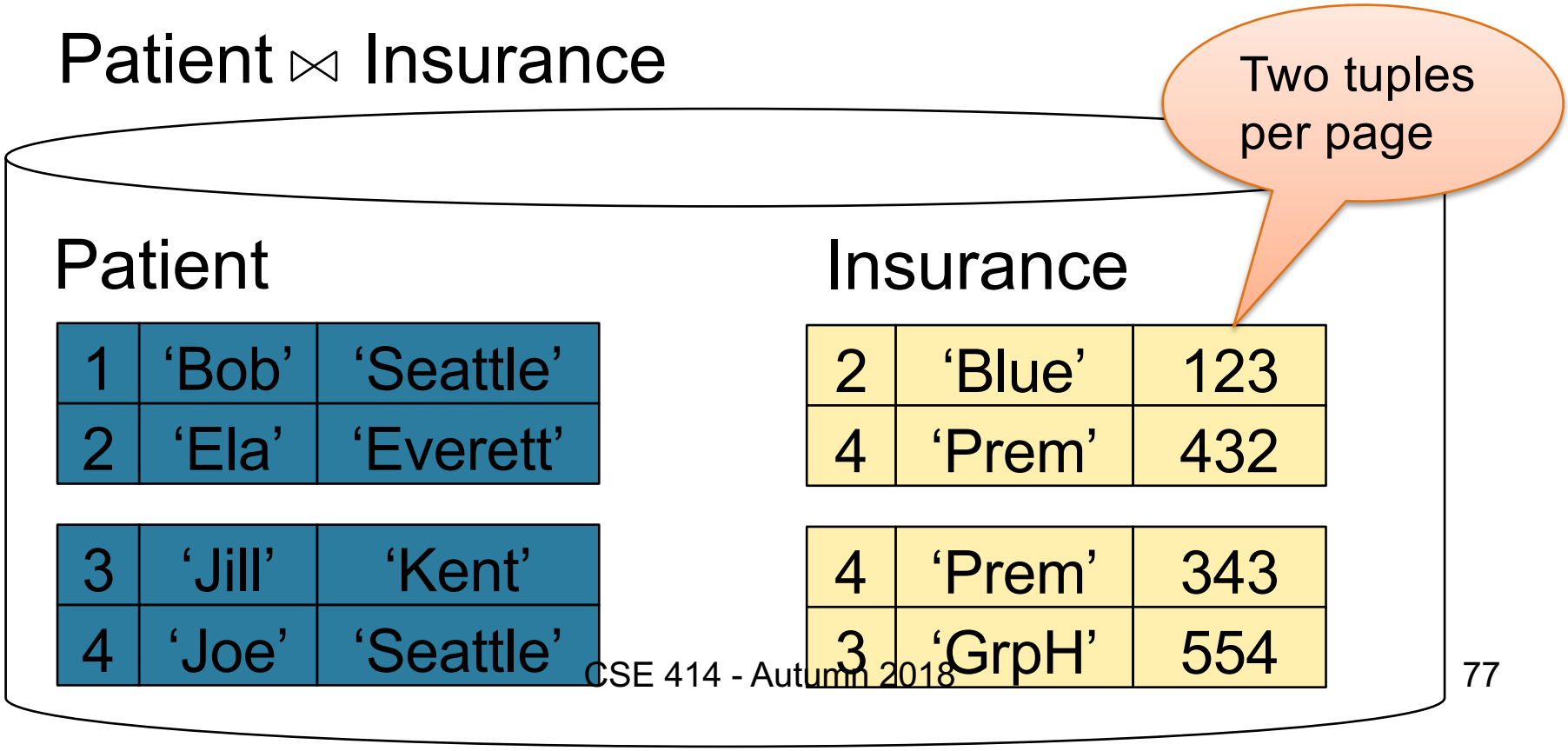
- One-pass algorithm when $B(R) \leq M$
  - M = number of memory pages available

Hash Join Example

Patient(pid, name, address)

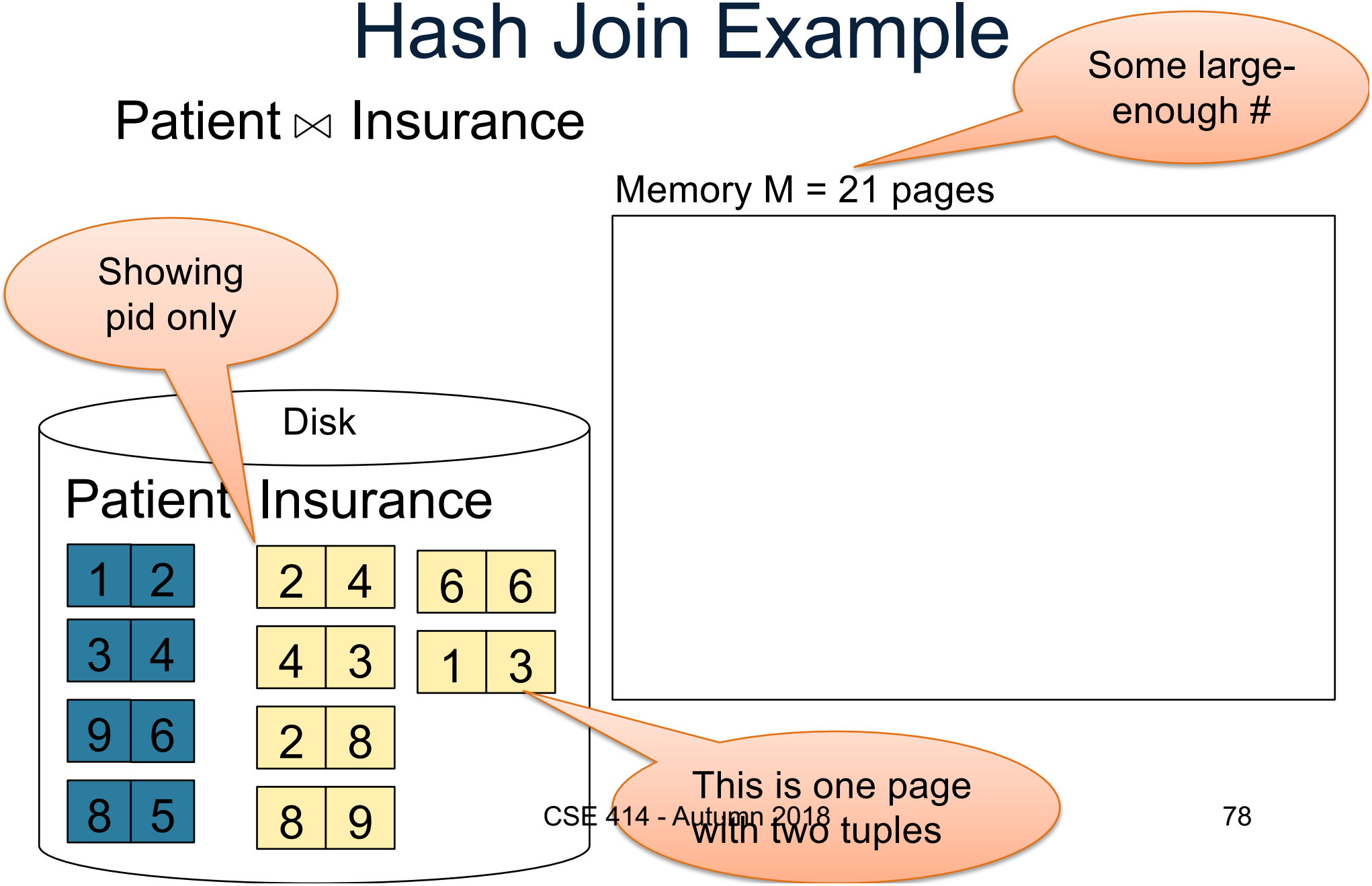
Insurance(pid, provider, policy_nb)

Patient ⋈ Insurance



Hash Join Example

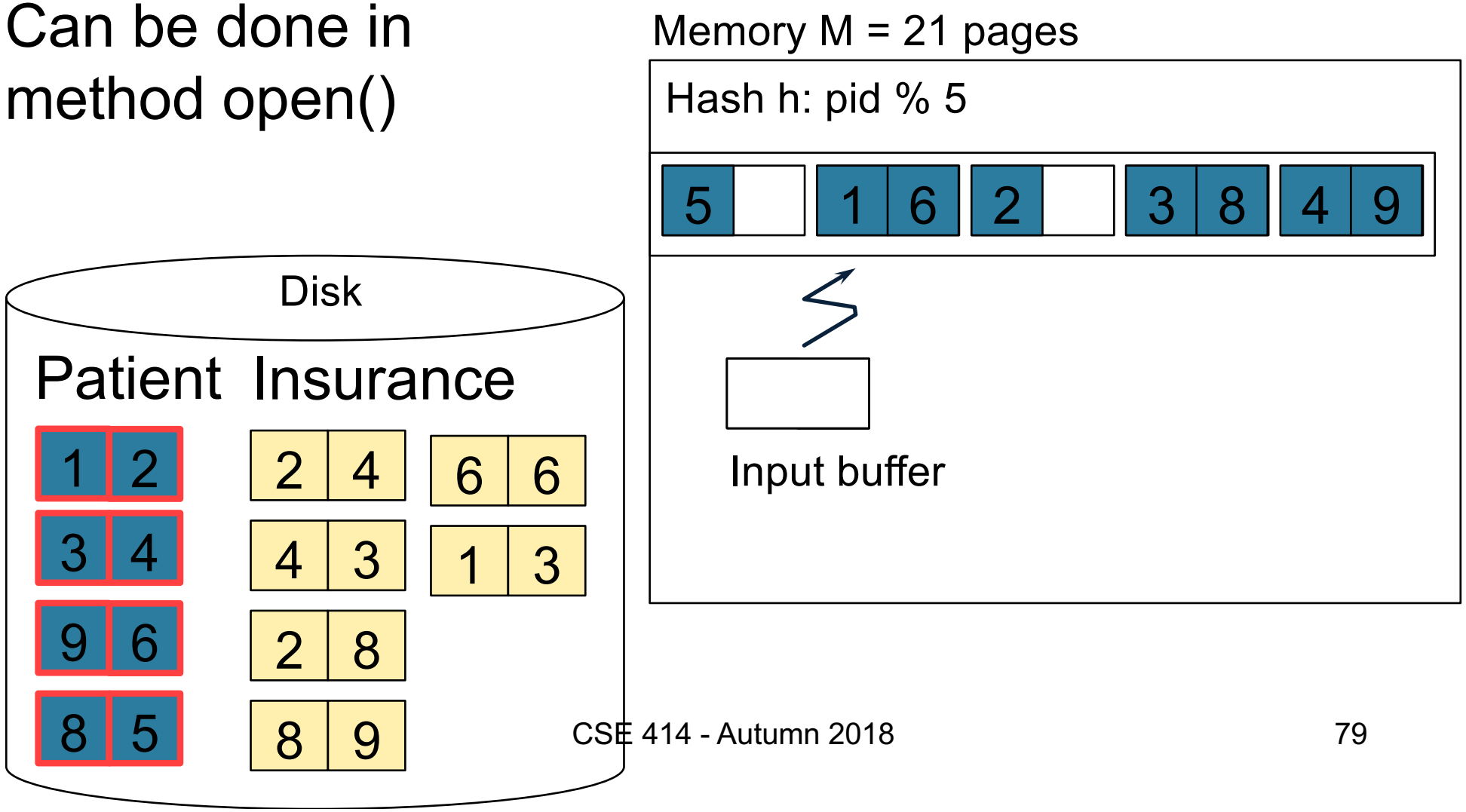
Patient ⋈ Insurance



Hash Join Example

Step 1: Scan Patient and build hash table in memory

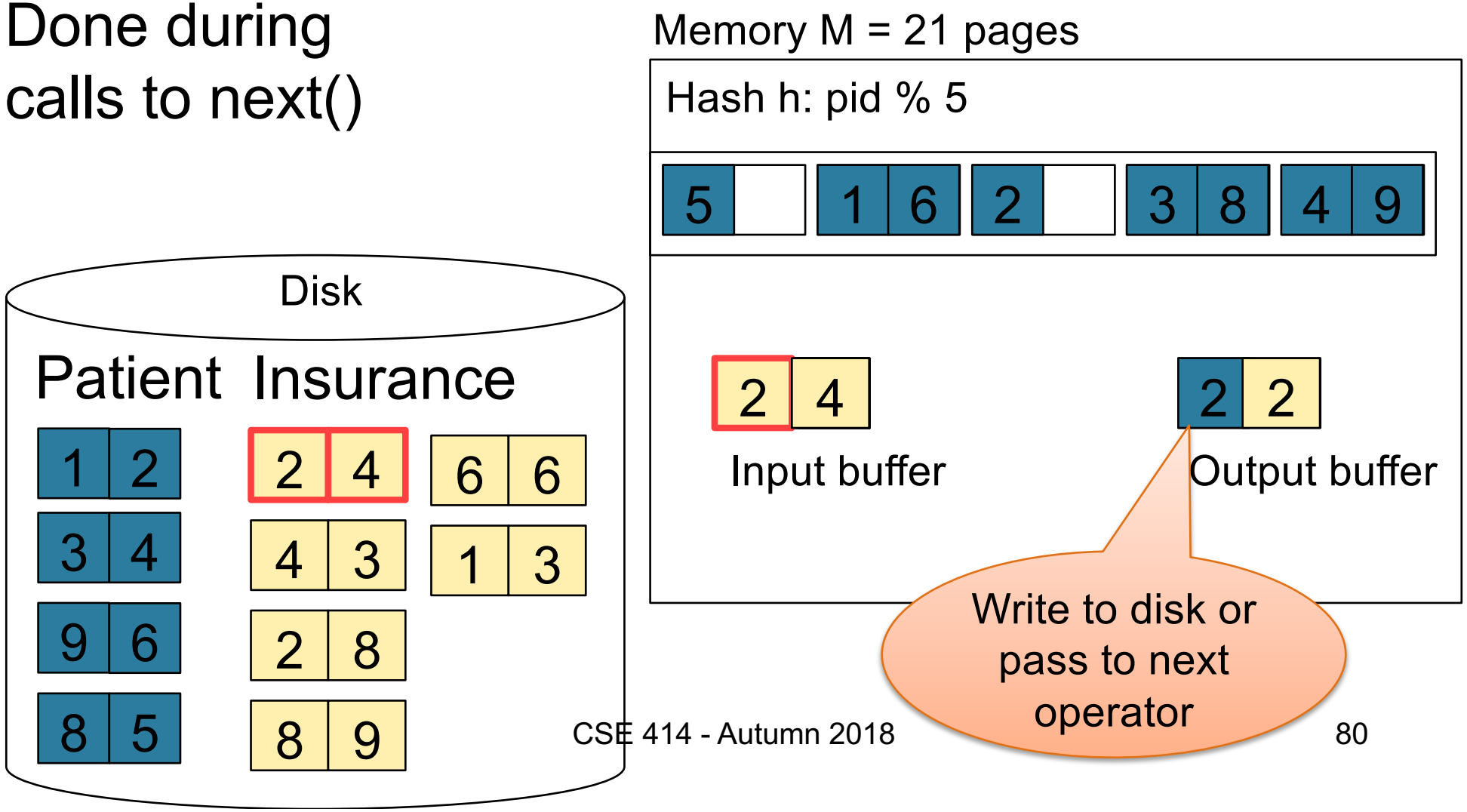
Can be done in method open()



Hash Join Example

Step 2: Scan Insurance and probe into hash table

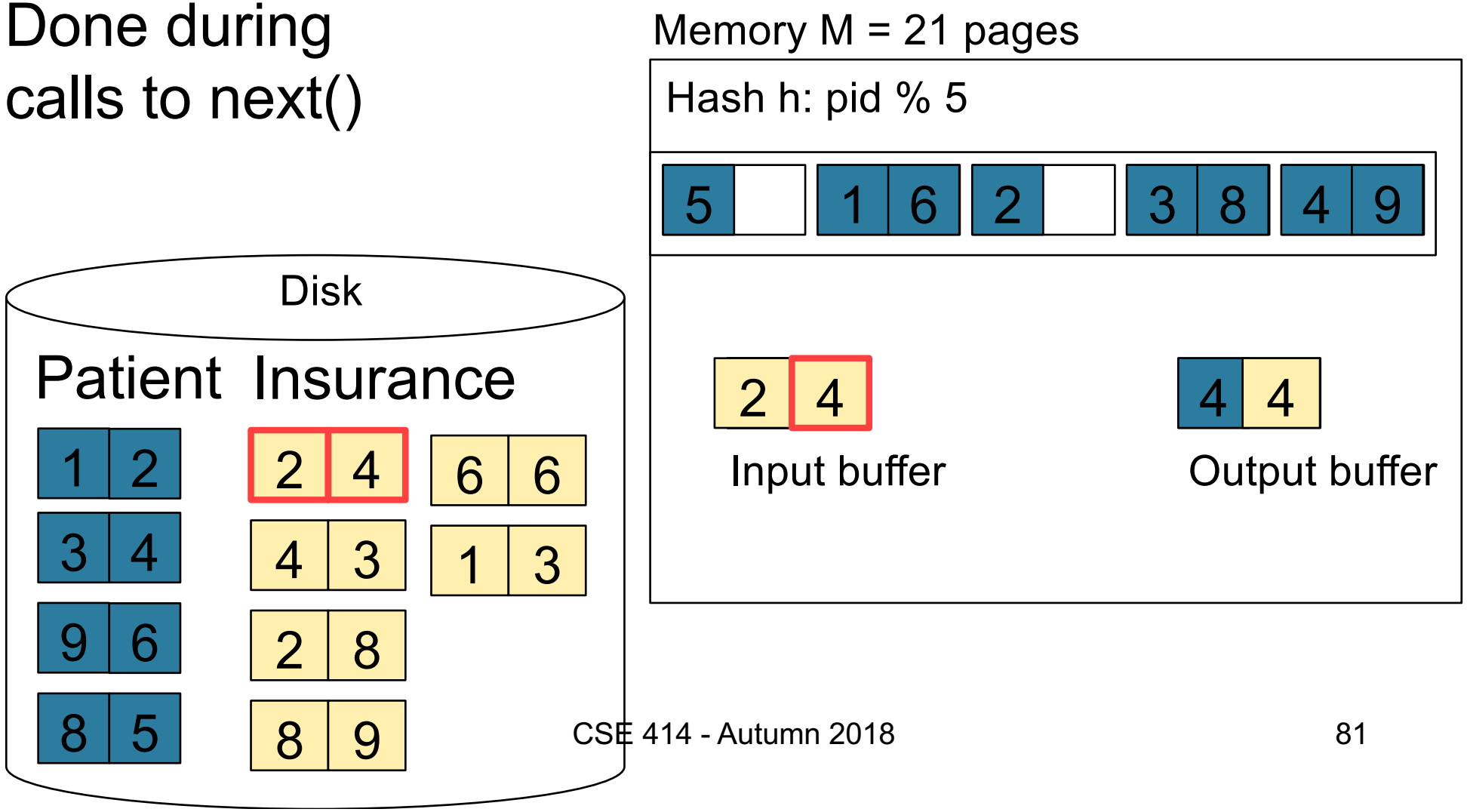
Done during calls to next()



Hash Join Example

Step 2: Scan Insurance and probe into hash table

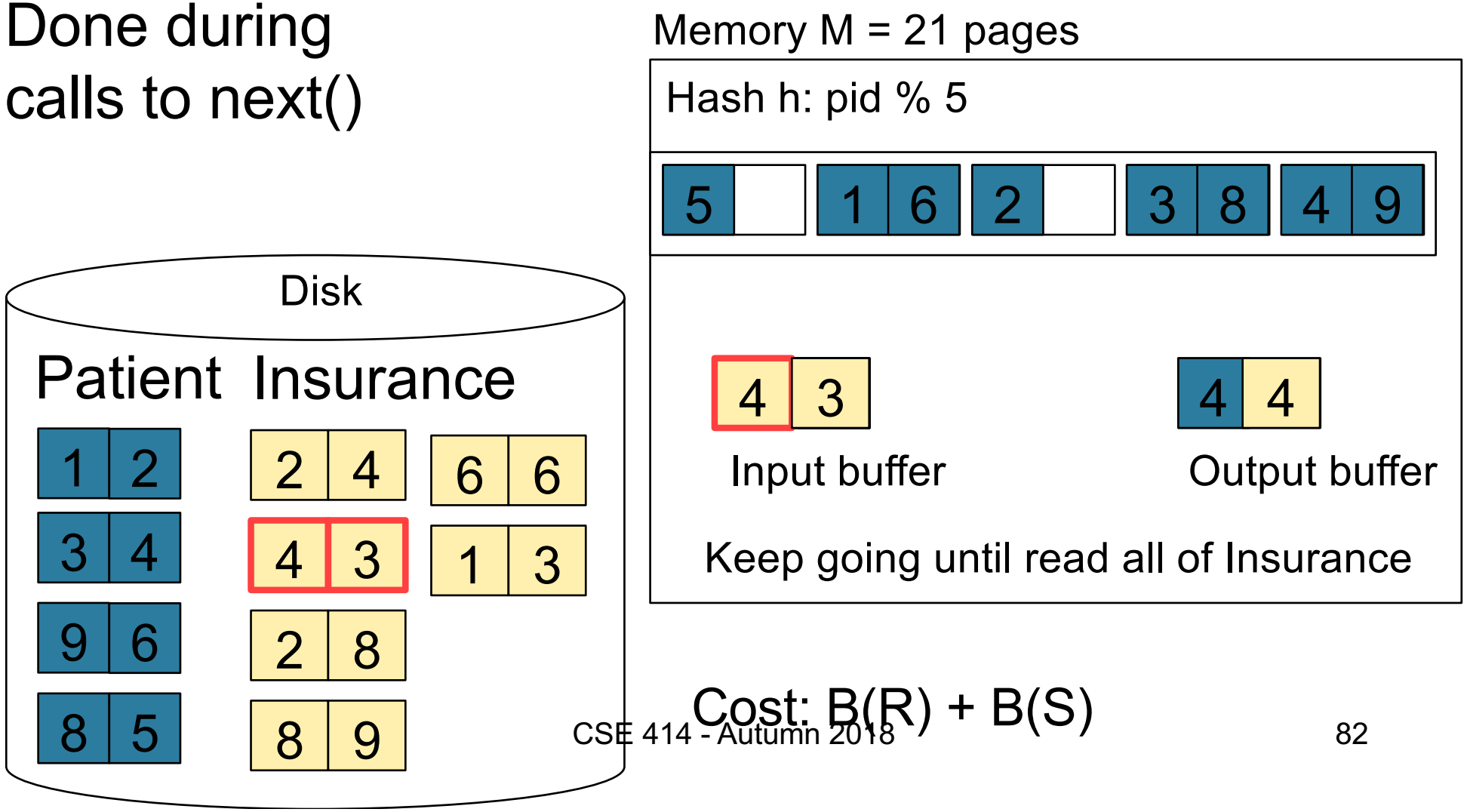
Done during
calls to next()



Hash Join Example

Step 2: Scan Insurance and probe into hash table

Done during calls to next()



Cost: B(R) + B(S)

Nested Loop Joins

- Tuple-based nested loop R ⋈ S
- R is the outer relation, S is the inner relation

```
for each tuple t1 in R do
   for each tuple t2 in S do
      if t1 and t2 join then output (t1,t2)
```

What is the Cost?

Nested Loop Joins

- Tuple-based nested loop R ⋈ S
- R is the outer relation, S is the inner relation

```
for each tuple t1 in R do
   for each tuple t2 in S do
      if t1 and t2 join then output (t1,t2)
```

What is the Cost?

- Cost: B(R) + T(R) B(S)
- Multiple-pass since S is read many times

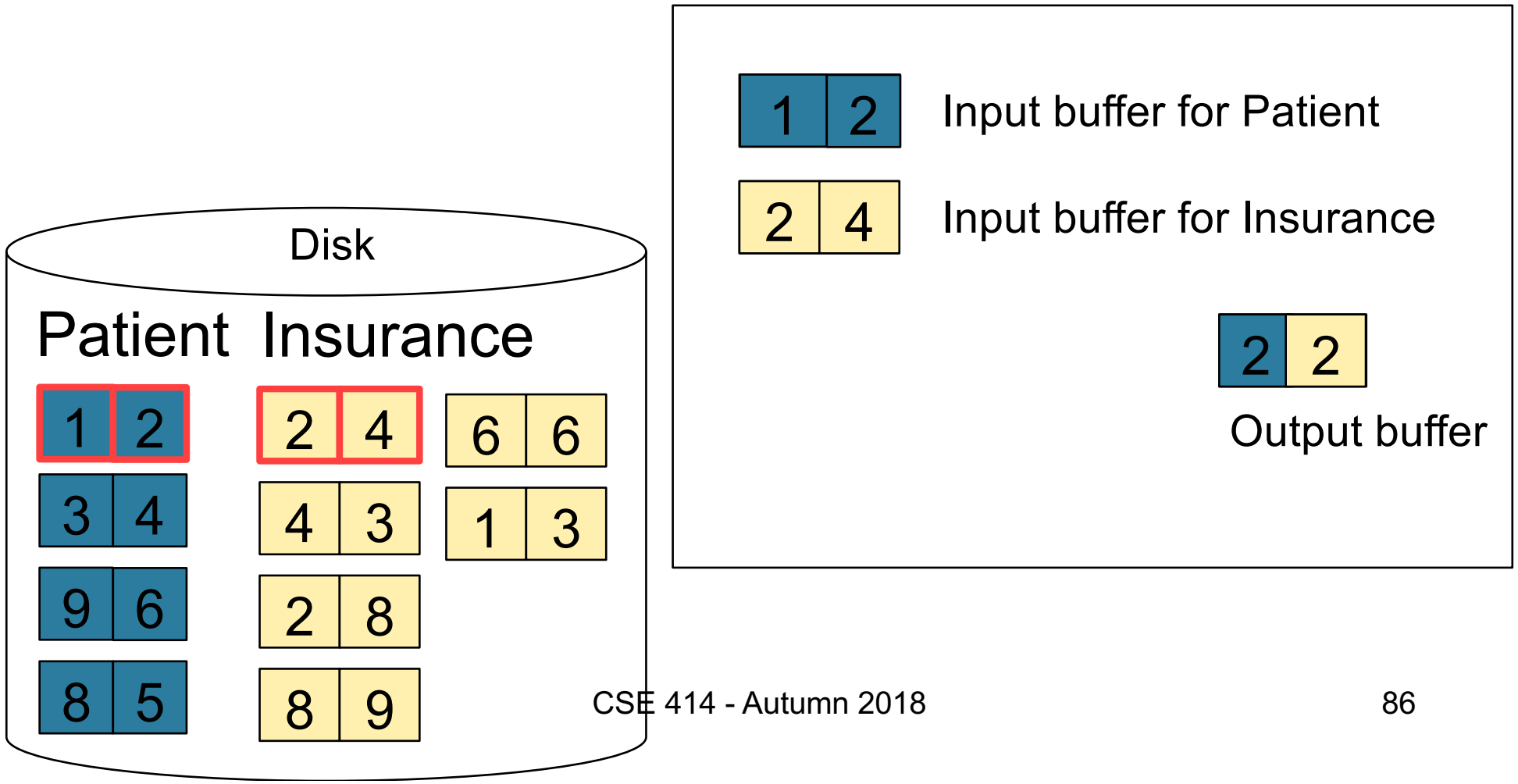
Page-at-a-time Refinement

```
for each page of tuples r in R do
   for each page of tuples s in S do
         for all pairs of tuples t1 in r, t2 in s
               if t1 and t2 join then output (t1,t2)
```

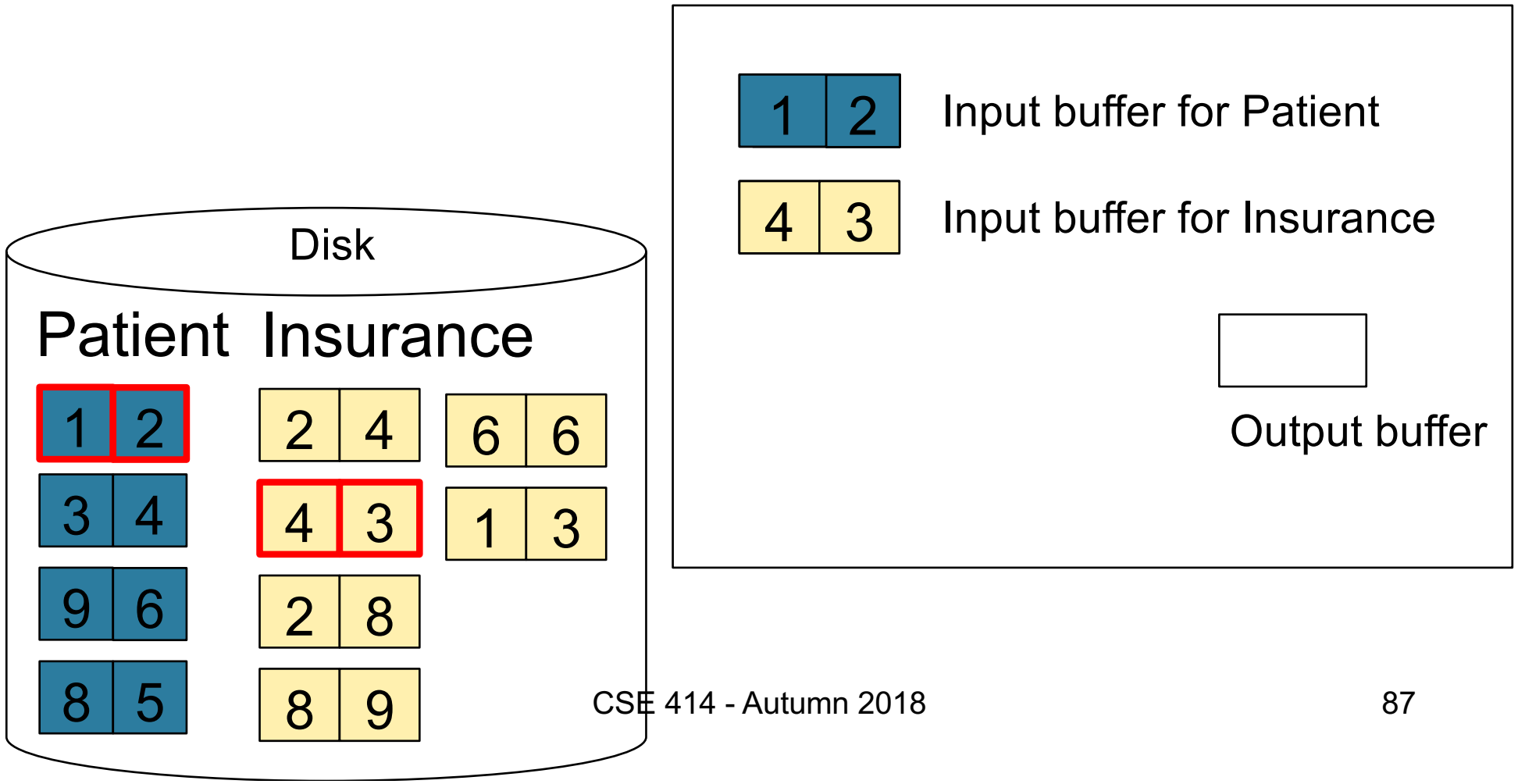
- Cost: B(R) + B(R)B(S)

What is the Cost?

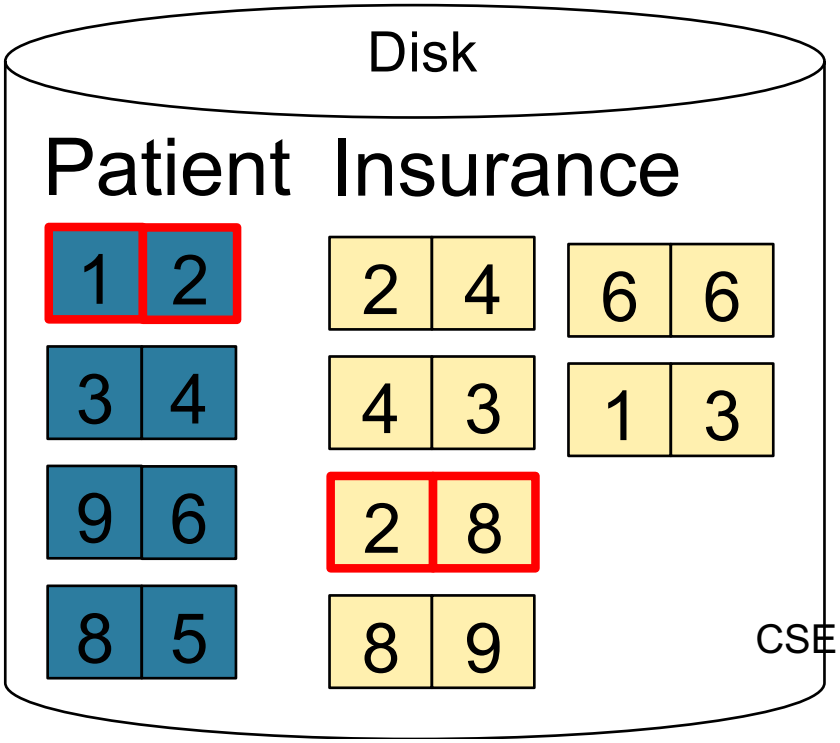
Page-at-a-time Refinement

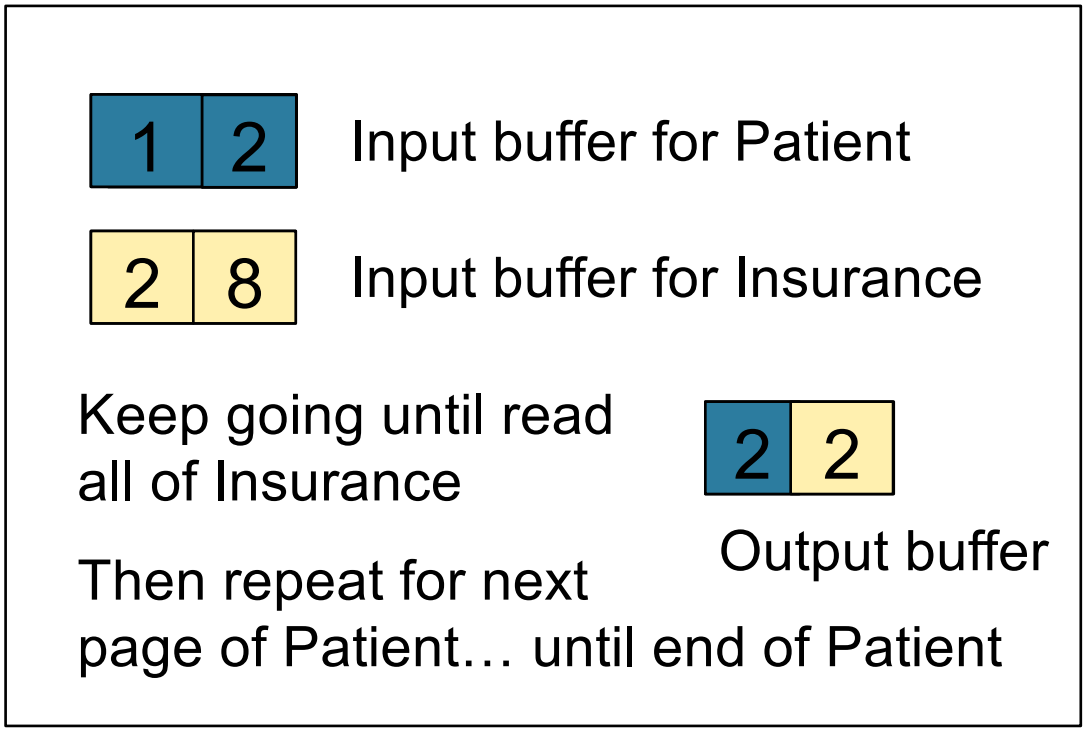


Page-at-a-time Refinement



Page-at-a-time Refinement





Cost: B(R) + B(R)B(S)

Block-Nested-Loop Refinement

```
for each group of M-1 pages r in R do
   for each page of tuples s in S do
         for all pairs of tuples t1 in r, t2 in s
               if t1 and t2 join then output (t1,t2)
```

- Cost: B(R) + B(R)B(S)/(M-1)

What is the Cost?

Sort-Merge Join

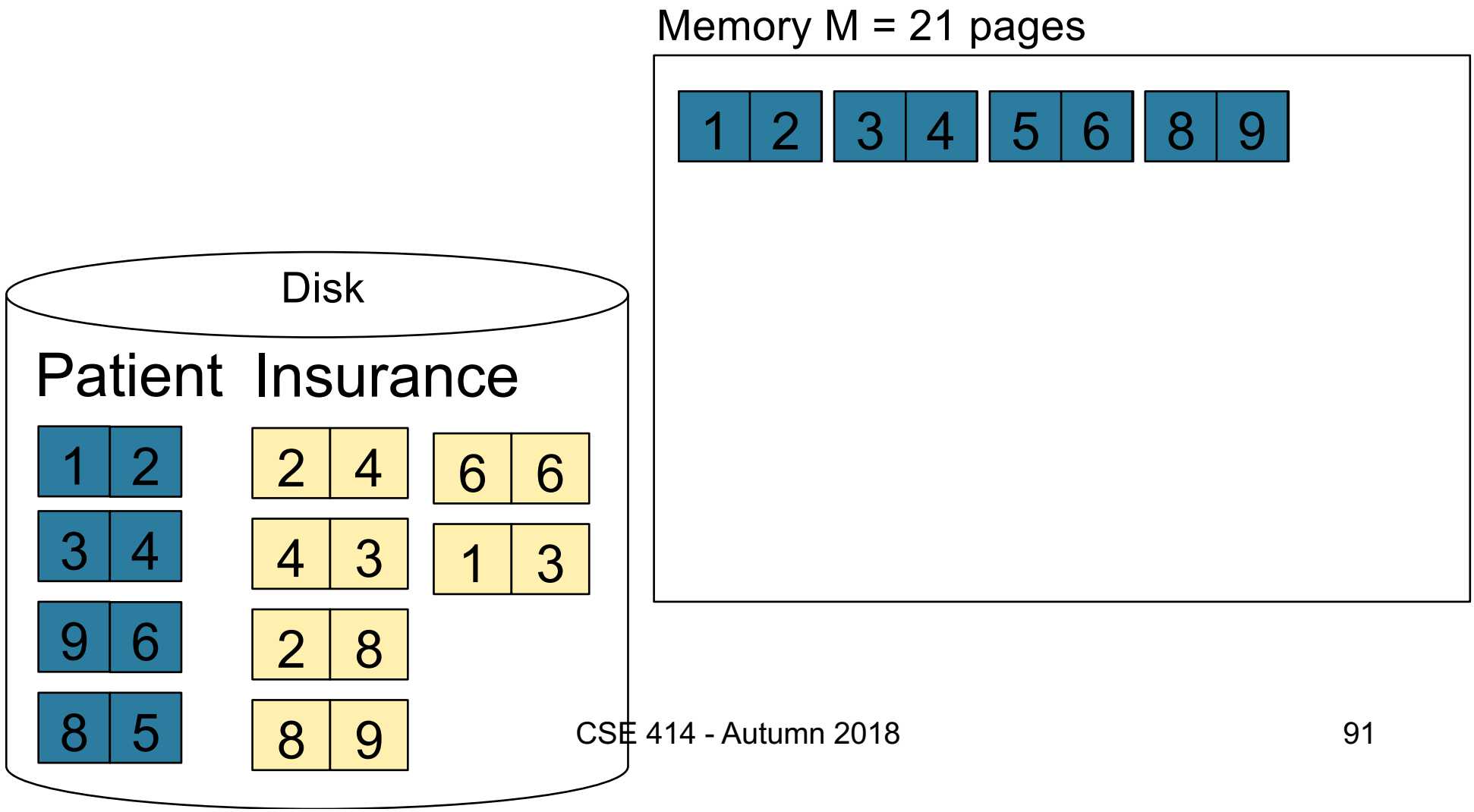
Sort-merge join: $R \bowtie S$

- Scan R and sort in main memory
- Scan S and sort in main memory
- Merge R and S

- Cost: B(R) + B(S)
- One pass algorithm when B(S) + B(R) <= M
- Typically, this is NOT a one pass algorithm

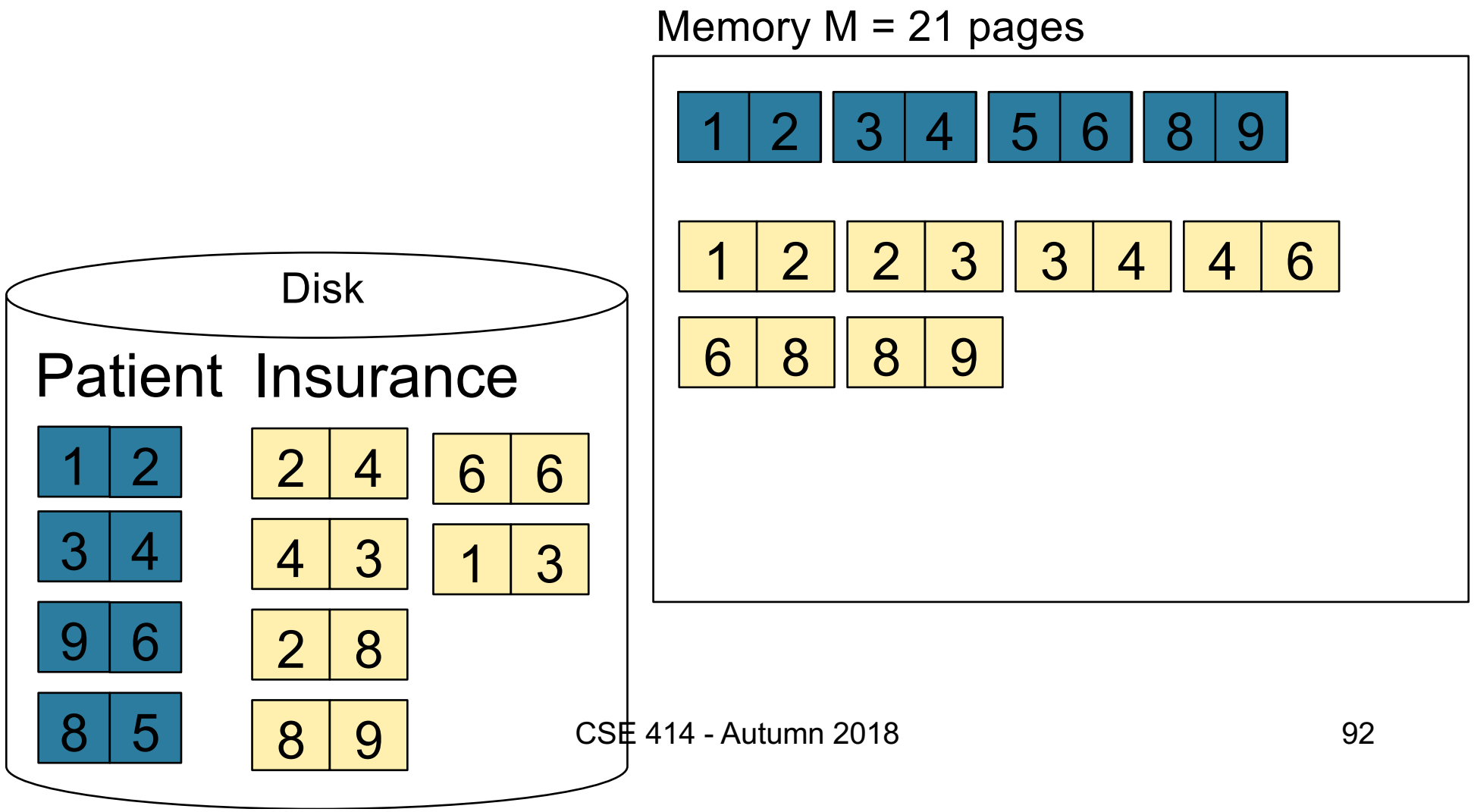
Sort-Merge Join Example

Step 1: Scan Patient and sort in memory



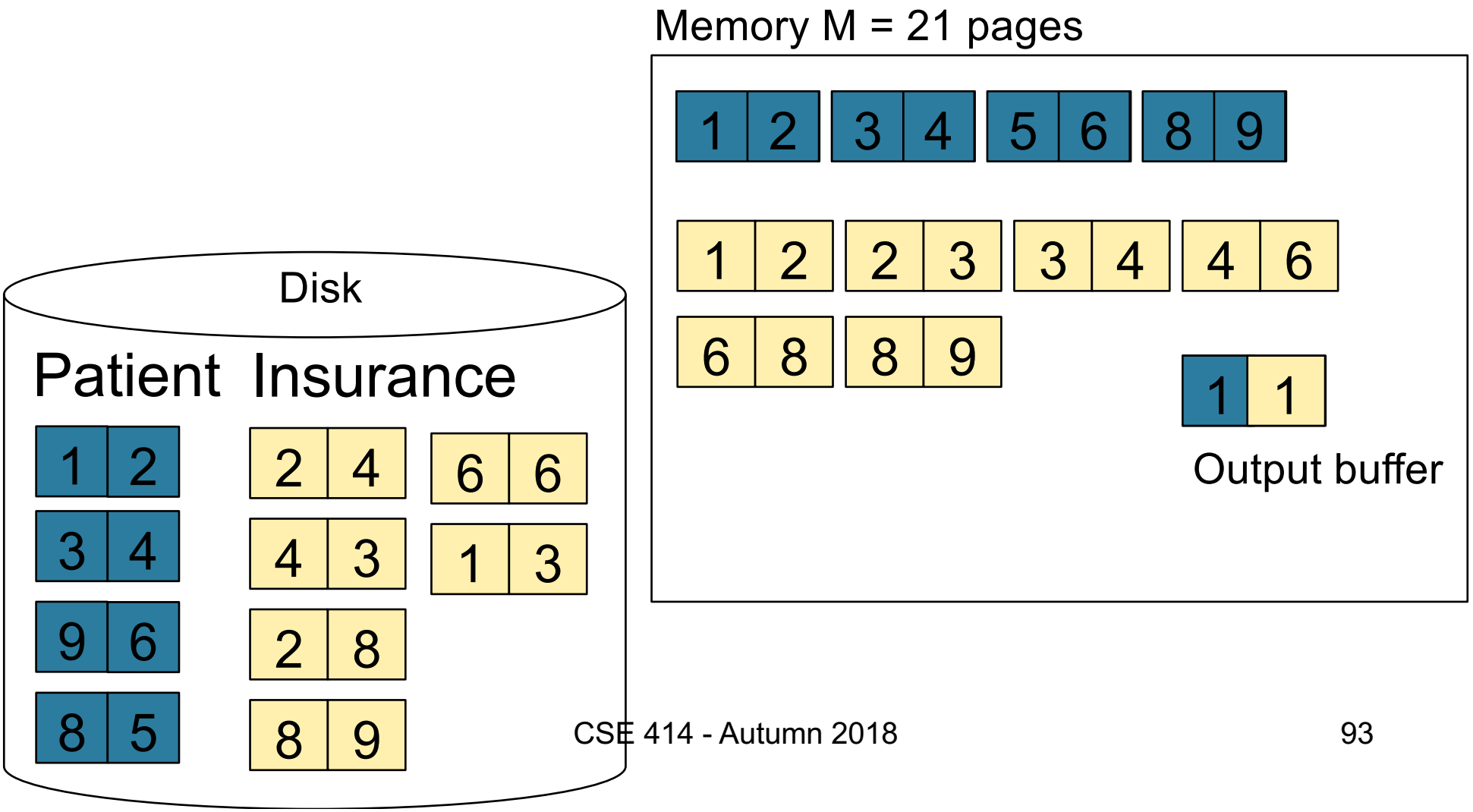
Sort-Merge Join Example

Step 2: Scan Insurance and sort in memory



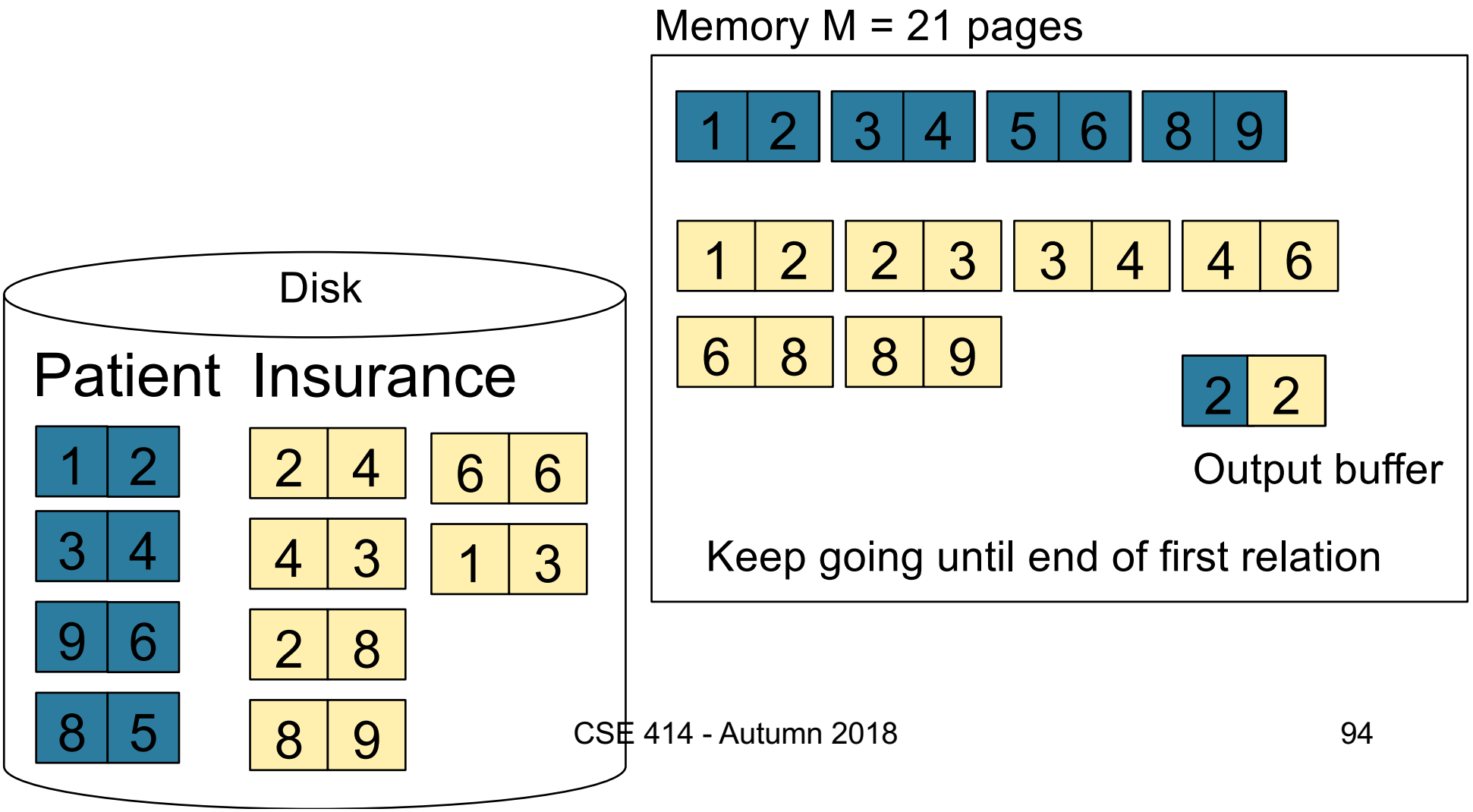
Sort-Merge Join Example

Step 3: Merge Patient and Insurance



Sort-Merge Join Example

Step 3: Merge Patient and Insurance



Index Nested Loop Join

$R \bowtie S$

- Assume S has an index on the join attribute
- Iterate over R, for each tuple fetch corresponding tuple(s) from S

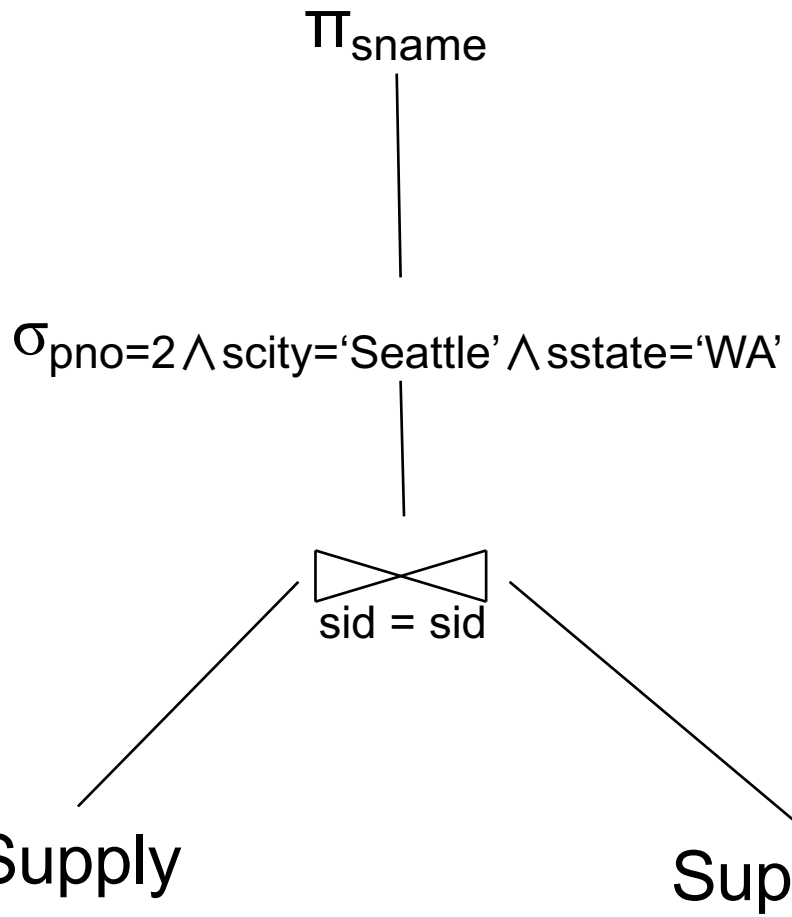
- Cost:
  - If index on S is clustered:
    B(R) + T(R) * (B(S) * 1/V(S,a))
  - If index on S is unclustered:
    B(R) + T(R) * (T(S) * 1/V(S,a))

Cost of Query Plans

Supplier(sid, sname, scity, sstate)

Supply(sid, pno, quantity)

Logical Query Plan 1




```
SELECT sname
FROM Supplier x, Supply y
WHERE x.sid = y.sid
    and y.pno = 2
    and x.scity = 'Seattle'
    and x.sstate = 'WA'
```

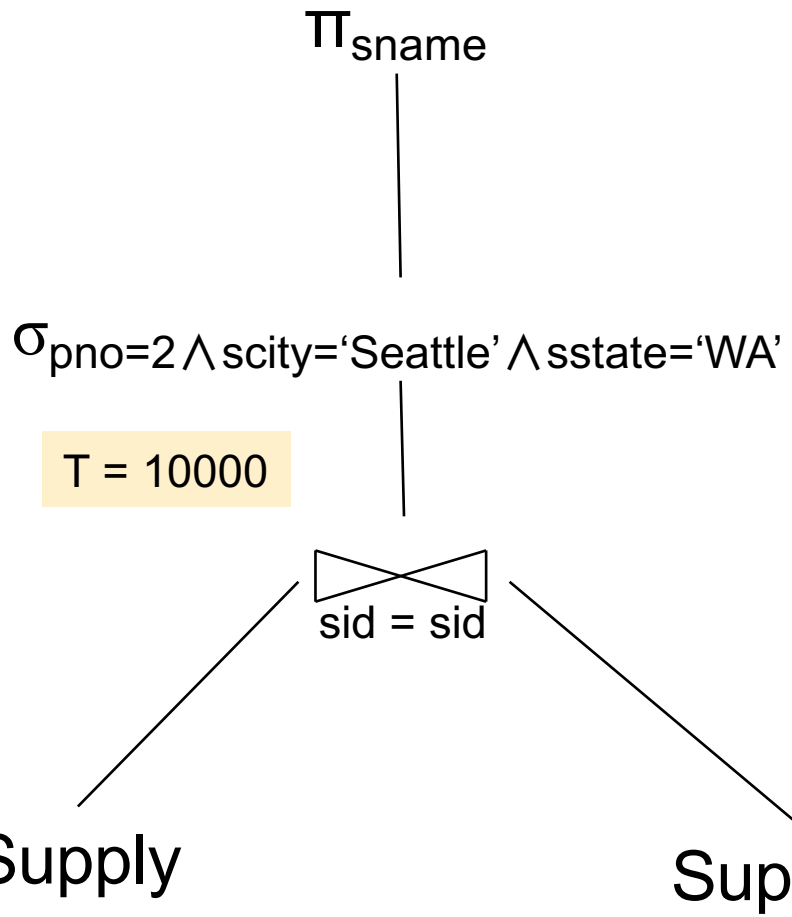
T(Supply) = 10000
B(Supply) = 100
V(Supply, pno) = 2500

T(Supplier) = 1000
B(Supplier) = 100
V(Supplier, scity) = 20
V(Supplier, state) = 10

M=11

Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)

Logical Query Plan 1

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Supplier(sid, sname, scity, sstate)
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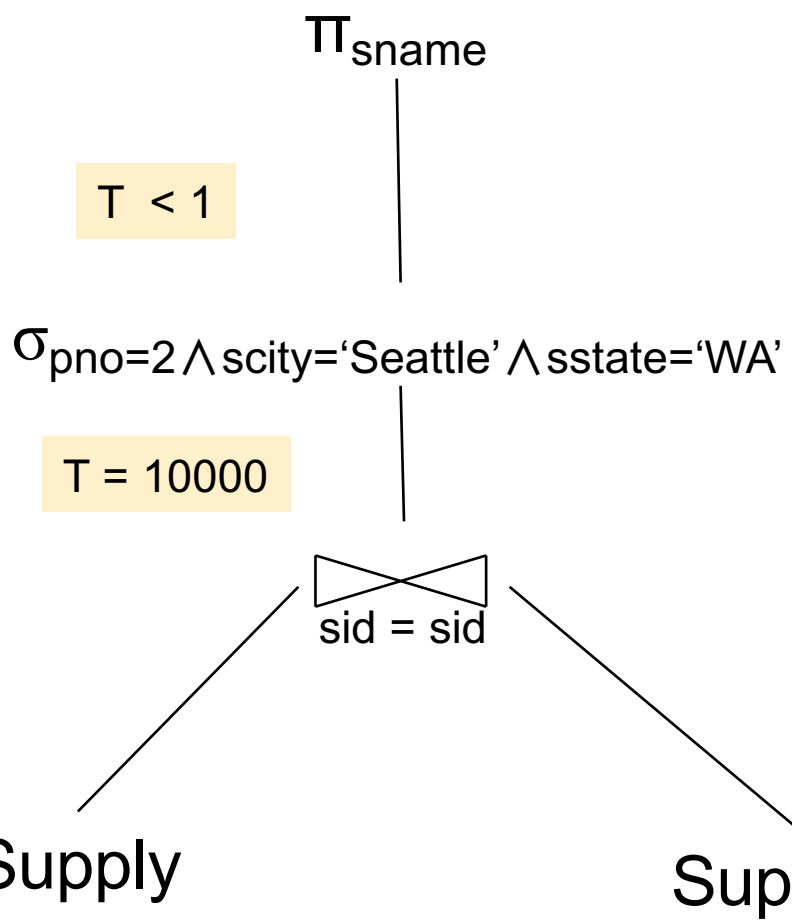
Logical Query Plan 1

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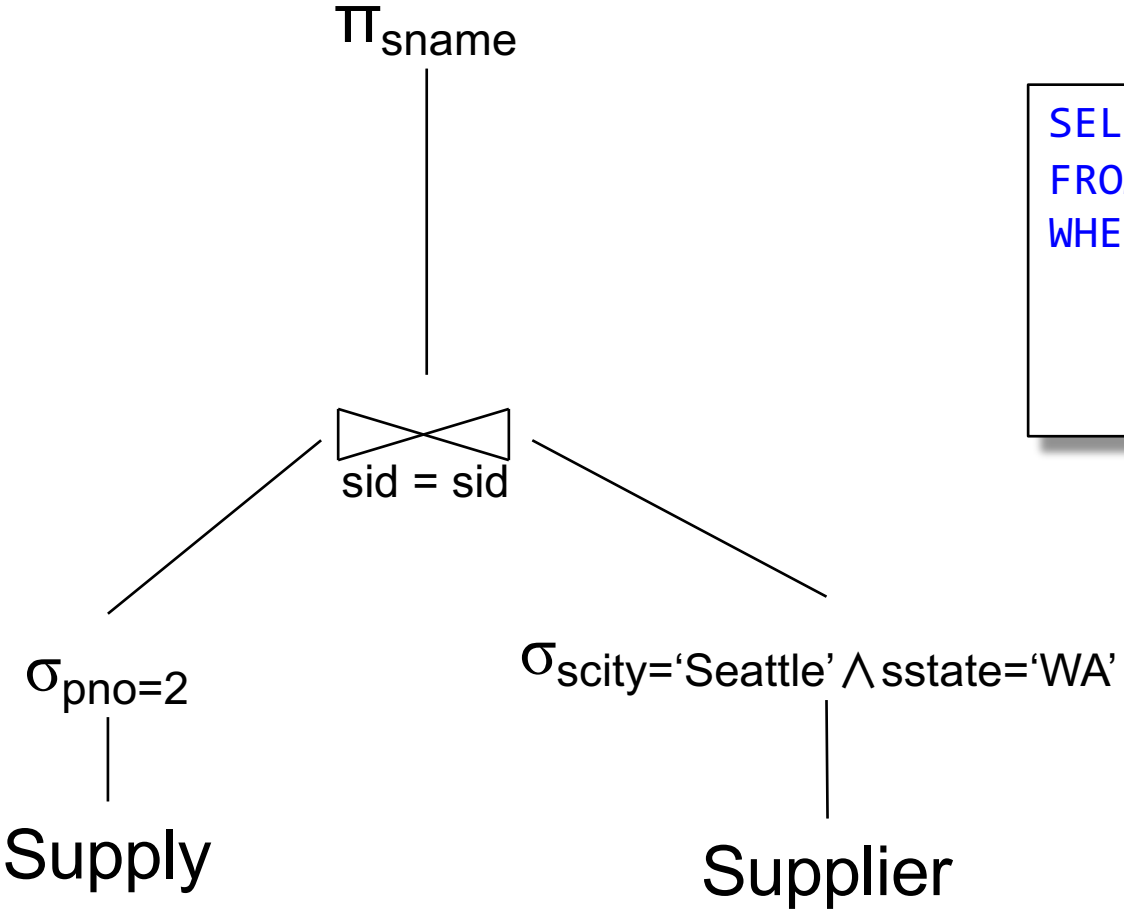
M=11

Supplier(sid, sname, scity, sstate)

Supply(sid, pno, quantity)

Logical Query Plan 2

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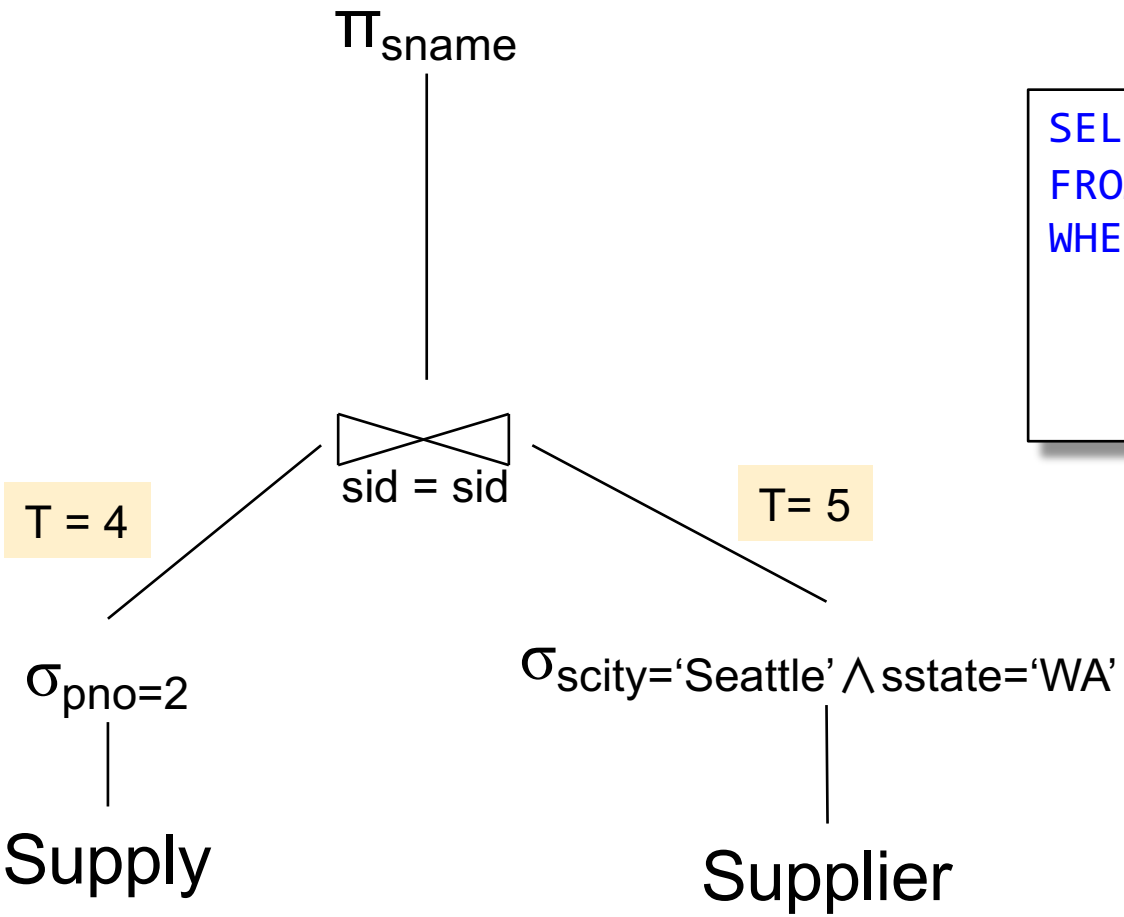
Supplier(sid, sname, scity, sstate)

Supply(sid, pno, quantity)

Logical Query Plan 2

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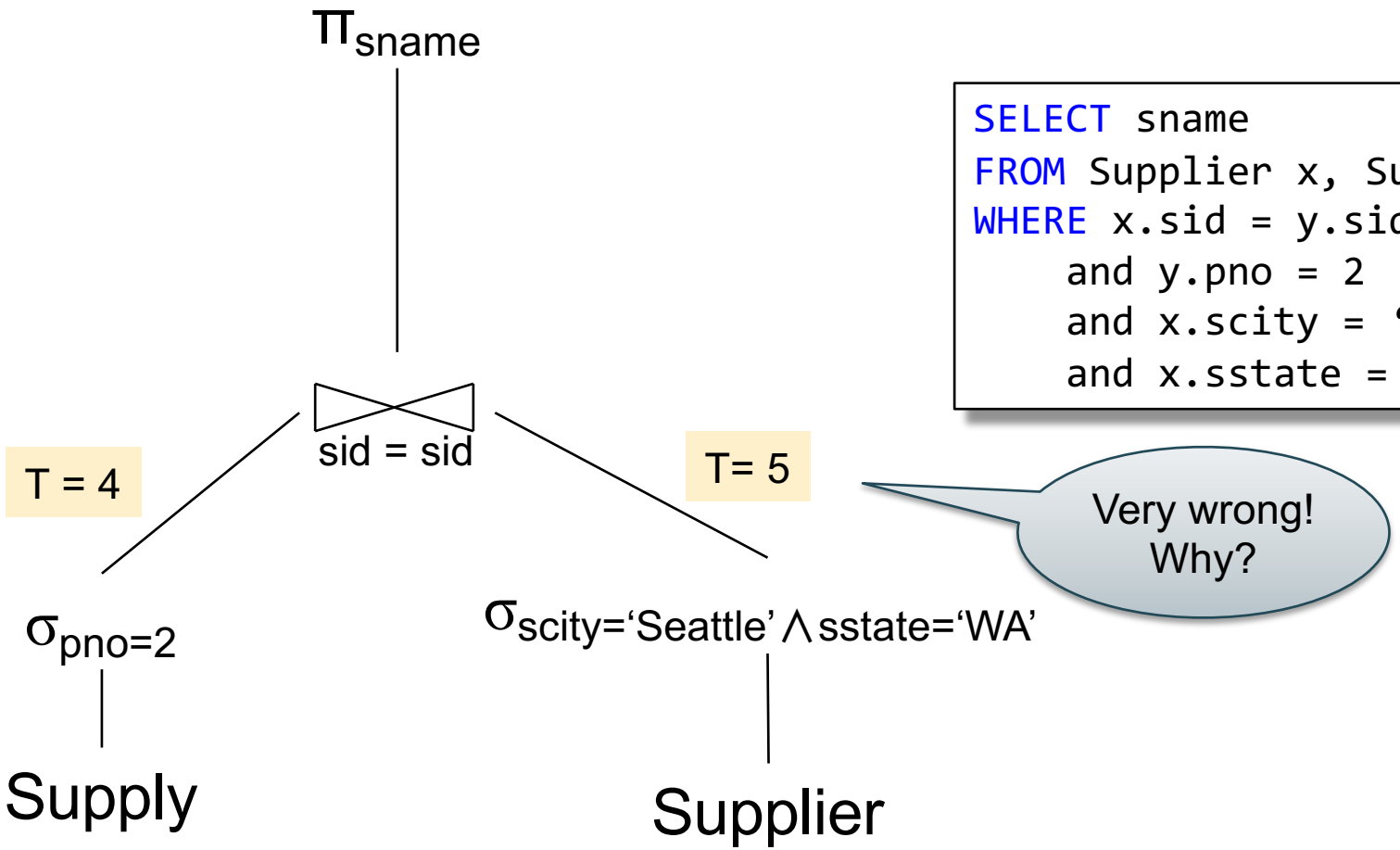


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```

Very wrong!
Why?

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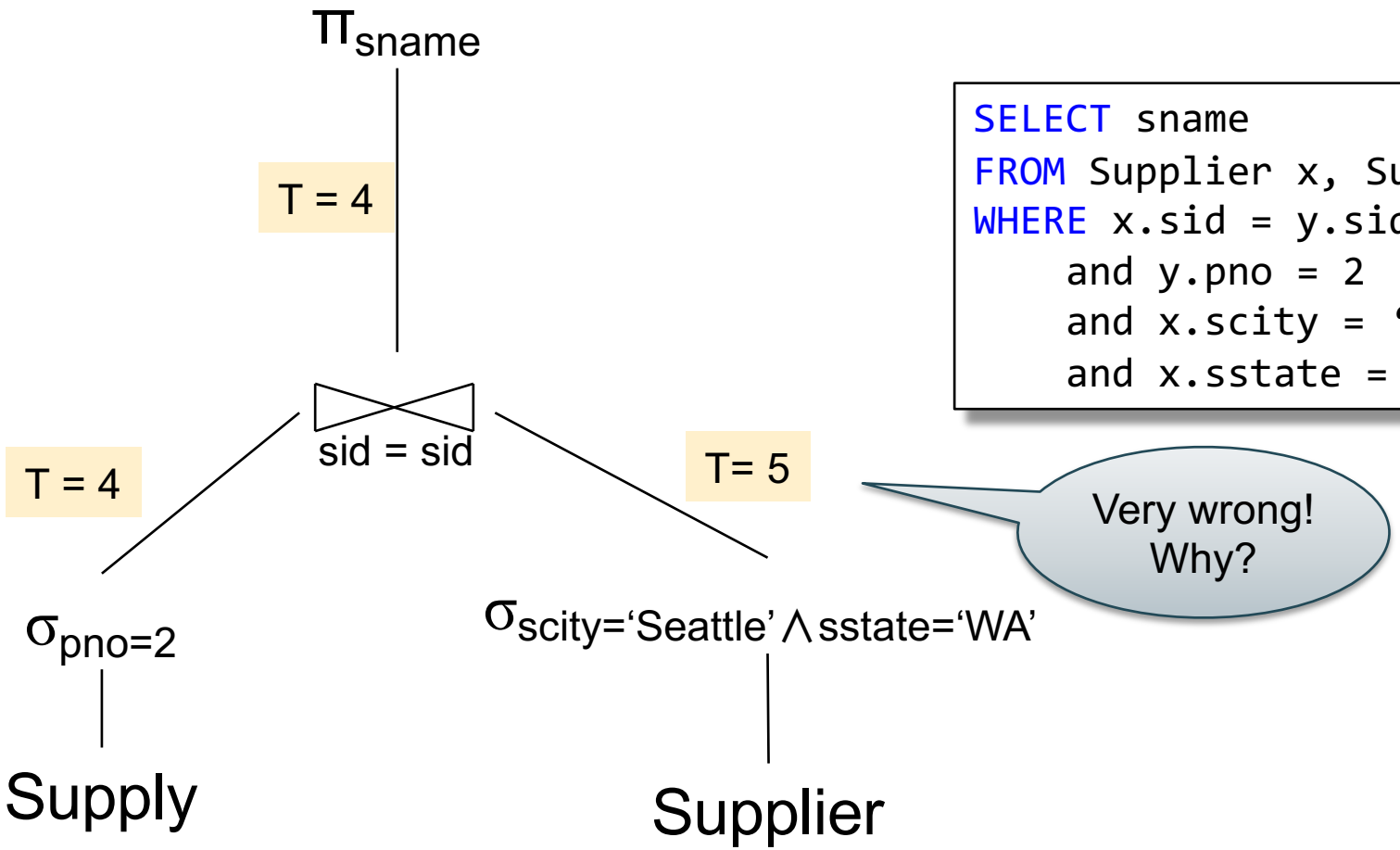
Logical Query Plan 2

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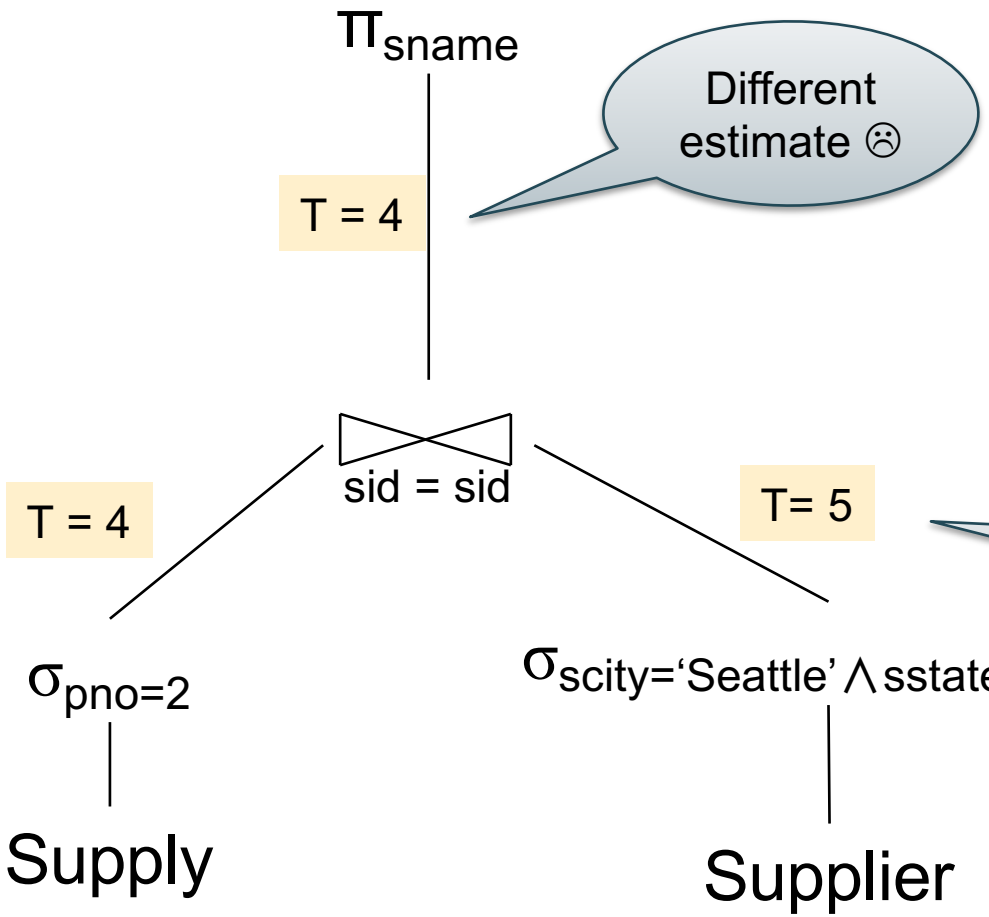
Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)

Logical Query Plan 2

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T(Supplier) = 1000
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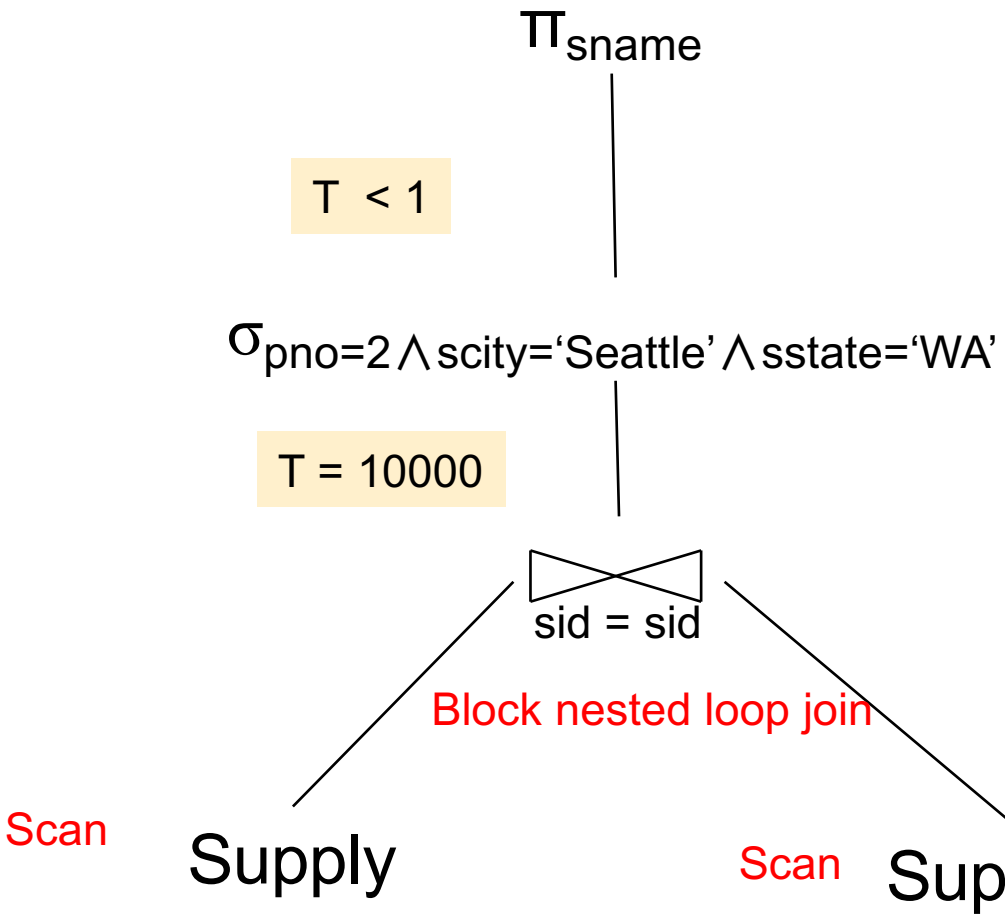
V(Supplier, state) = 10

M=11

Supplier(sid, sname, scity, sstate)

Supply(sid, pno, quantity)

Physical Plan 1



Total cost:

T(Supply) = 10000
B(Supply) = 100
V(Supply, pno) = 2500

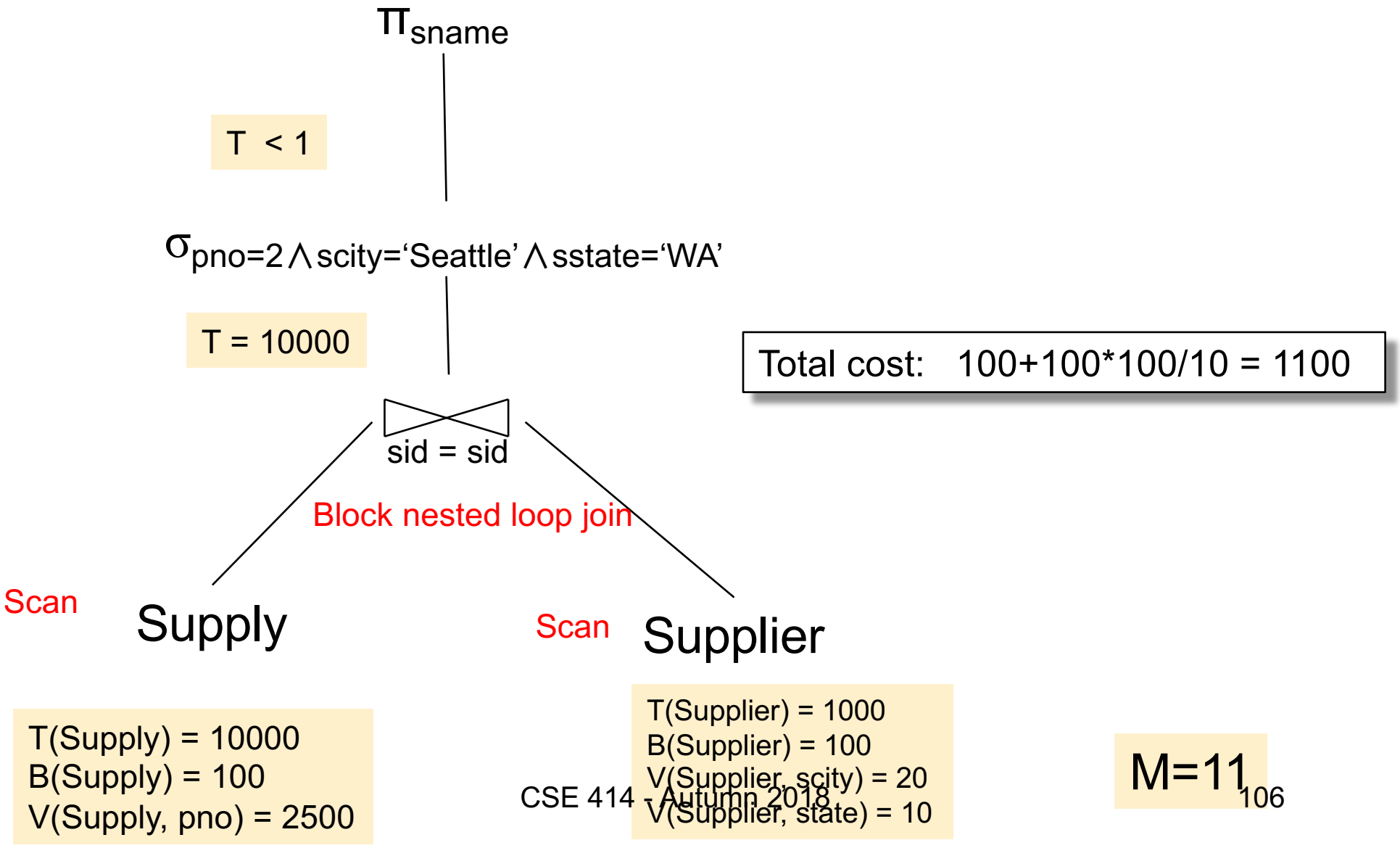
T(Supplier) = 1000
B(Supplier) = 100
V(Supplier, scity) = 20
V(Supplier, state) = 10

M=11

Supplier(sid, sname, scity, sstate)

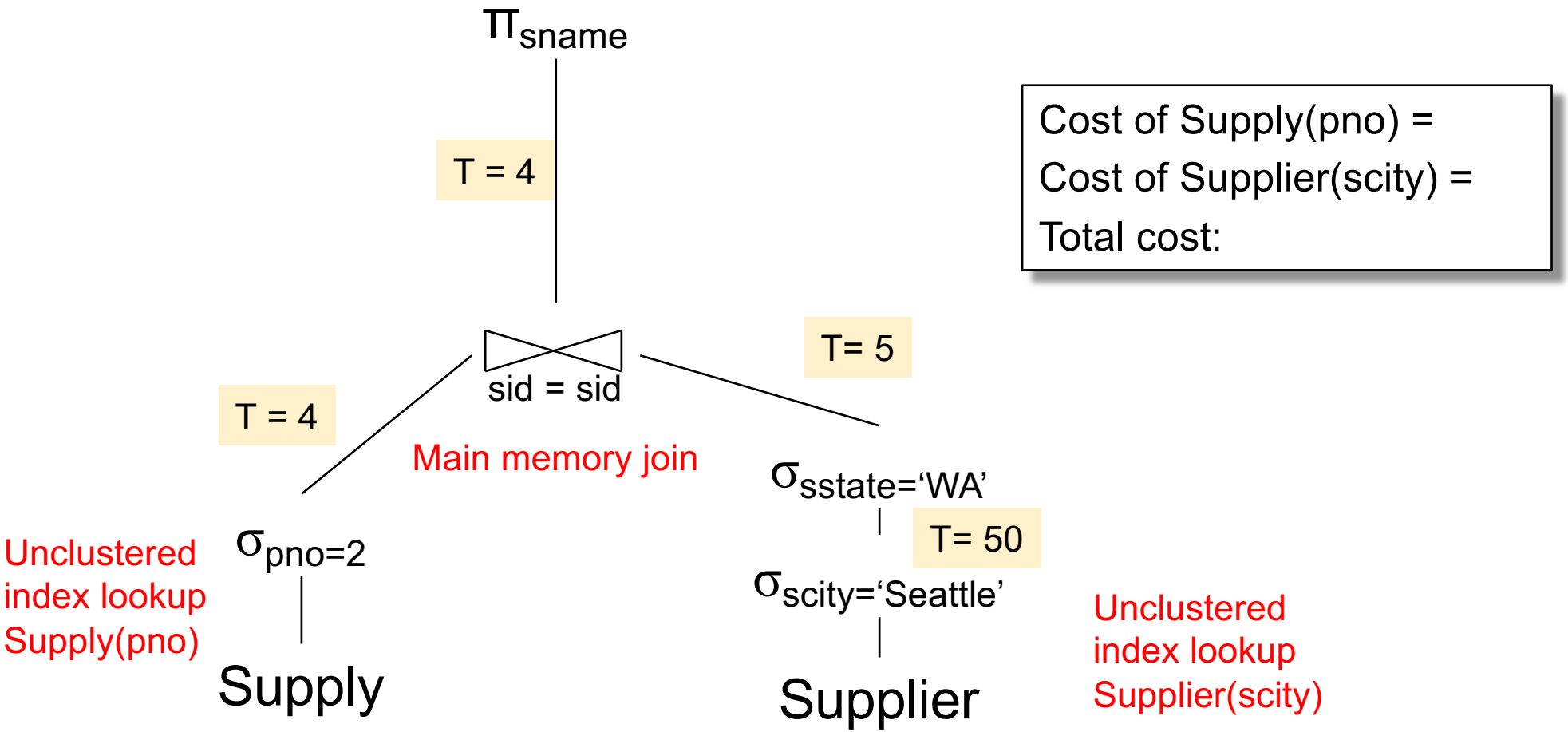
Supply(sid, pno, quantity)

Physical Plan 1



Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)

Physical Plan 2



Cost of Supply(pno) =
Cost of Supplier(scity) =
Total cost:

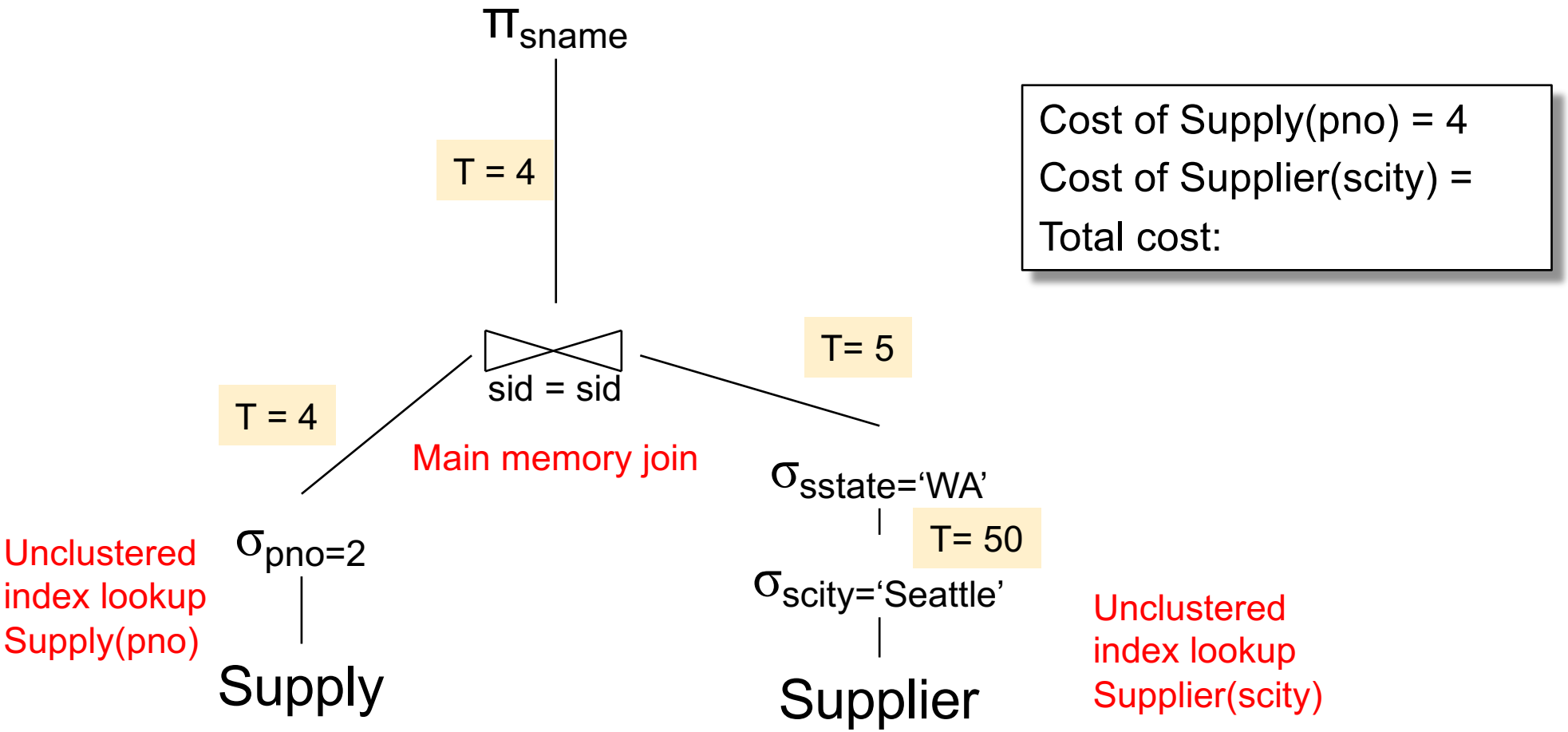
T(Supply) = 10000
B(Supply) = 100
V(Supply, pno) = 2500

T(Supplier) = 1000
B(Supplier) = 100
V(Supplier, scity) = 20
V(Supplier, state) = 10

M=11

Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)

Physical Plan 2



Cost of Supply(pno) = 4
Cost of Supplier(scity) =
Total cost:

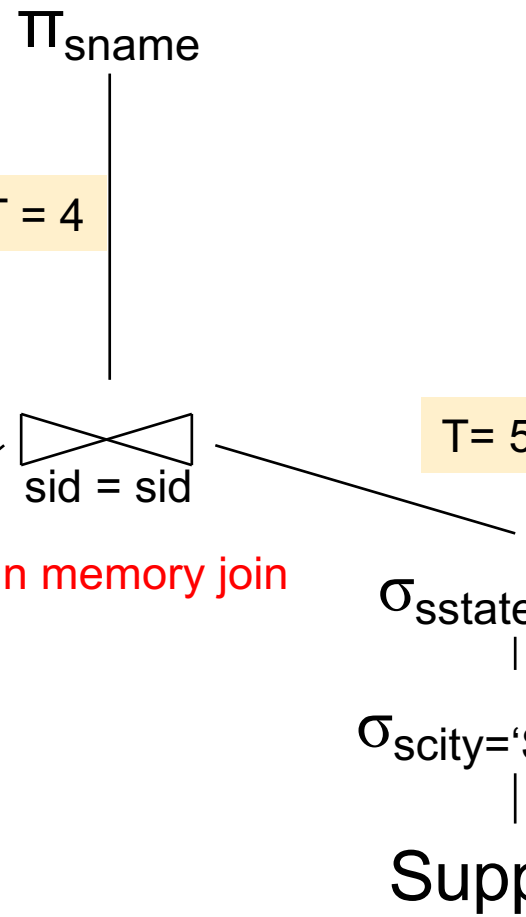
T(Supply) = 10000
B(Supply) = 100
V(Supply, pno) = 2500

T(Supplier) = 1000
B(Supplier) = 100
V(Supplier, scity) = 20
V(Supplier, state) = 10

M=11

Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)

Physical Plan 2



Cost of Supply(pno) = 4
Cost of Supplier(scity) = 50
Total cost: 54

Unclustered index lookup Supply(pno)

Unclustered index lookup Supplier(scity)

T(Supply) = 10000
B(Supply) = 100
V(Supply, pno) = 2500

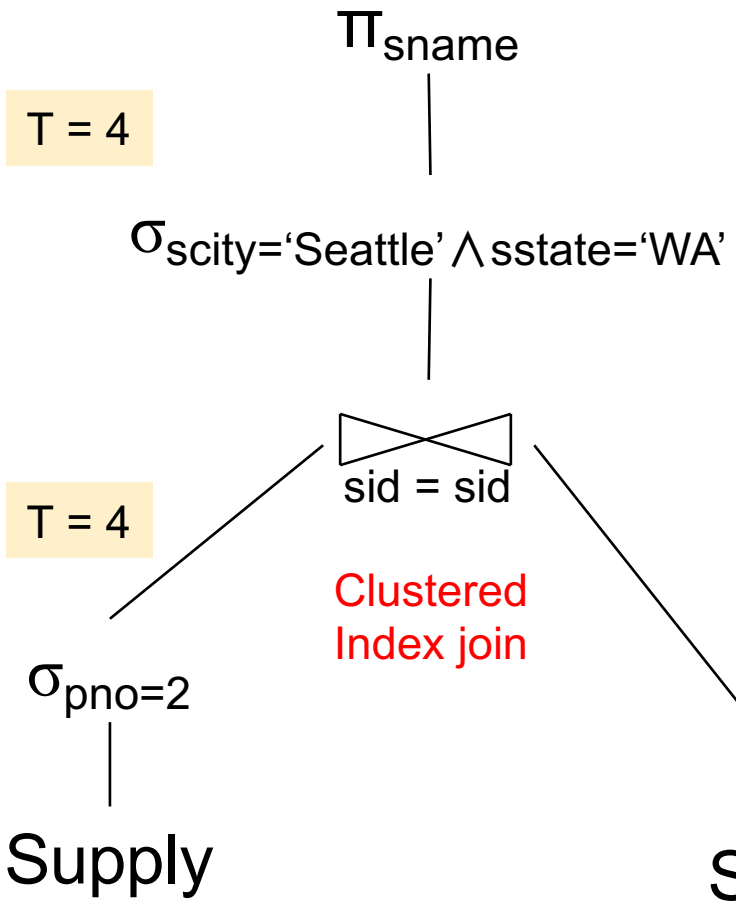
T(Supplier) = 1000
B(Supplier) = 100
V(Supplier, scity) = 20
V(Supplier, state) = 10

M=11

Supplier(sid, sname, scity, sstate)

Supply(sid, pno, quantity)

Physical Plan 3



Cost of Supply(pno) =

Cost of Index join =

Total cost:

T(Supply) = 10000
B(Supply) = 100
V(Supply, pno) = 2500

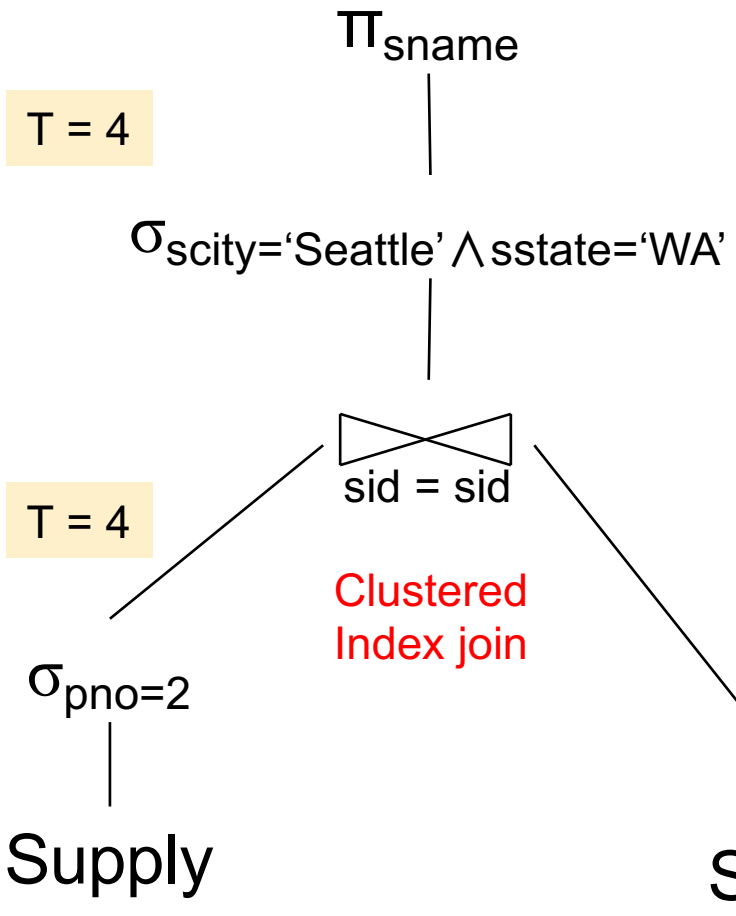
T(Supplier) = 1000
B(Supplier) = 100
V(Supplier, scity) = 20
V(Supplier, state) = 10

M=11

Supplier(sid, sname, scity, sstate)

Supply(sid, pno, quantity)

Physical Plan 3



Cost of Supply(pno) = 4

Cost of Index join =

Total cost:

T(Supply) = 10000
B(Supply) = 100
V(Supply, pno) = 2500

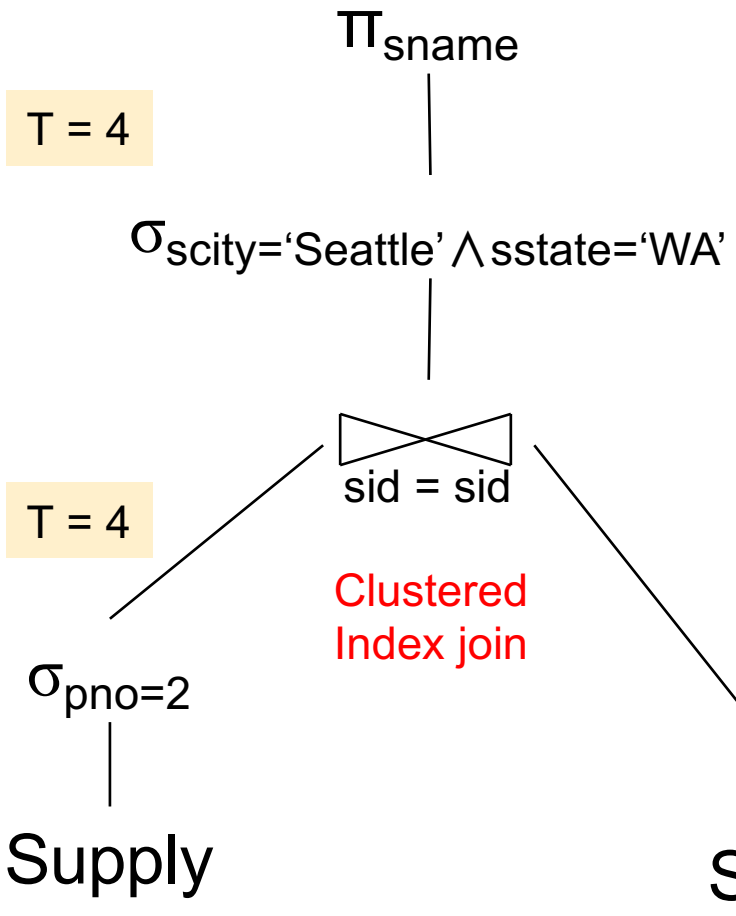
T(Supplier) = 1000
B(Supplier) = 100
V(Supplier, scity) = 20
V(Supplier, state) = 10

M=11

Supplier(sid, sname, scity, sstate)

Supply(sid, pno, quantity)

Physical Plan 3



Cost of Supply(pno) = 4
Cost of Index join = 4
Total cost: 8

T(Supply) = 10000
B(Supply) = 100
V(Supply, pno) = 2500

T(Supplier) = 1000
B(Supplier) = 100
V(Supplier, scity) = 20
V(Supplier, state) = 10

M=11

Query Optimizer Summary

- Input: A logical query plan
- Output: A good physical query plan
- Basic query optimization algorithm
  - Enumerate alternative plans (logical and physical)
  - Compute estimated cost of each plan
  - Choose plan with lowest cost

- This is called cost-based optimization