Introduction to Data Management CSE 344

Lecture 12: Cost Estimation Relational Calculus

Announcements

- HW3 due tonight
- WQ4 and HW4 out
  - Due on Thursday 2/9

Midterm!

- Monday, February 13^{th} in class
- Contents
  - Lectures and sections through February 8th
  - Homework 1 through 4
  - Webquiz 1 through 4
- Closed book. No computers, phones, watches, etc.!
- Can bring one letter-sized piece of paper with notes
  - Can write on both sides
  - You might want to save it for the final

Today's Outline

- Finish cost estimation
- Relational calculus

Review

- Estimate cost of physical query plans
  - Based on # of I/O operations
  - Estimate cost for each operator
  - Cost of entire plan = Σ operator cost

- Cost for selection operator

- Cost for join operator

Review: Cost Parameters

- Cost = I/O + CPU + Network BW
  - We will focus on I/O in this class
- Parameters:
  - **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
    - When **a** is a key, **V(R,a) = T(R)**
    - When **a** is not a key, **V(R,a)** can be anything <= **T(R)**
- Where do these values come from?
  - DBMS collects statistics about data on disk

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

- 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: B(R) * 1/V(R,a) = 100 I/Os
  - If index is unclustered:

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: 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

- Example:

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

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

(1)
- Table scan: B(R) = 2,000 I/Os
- Index based selection:

(2)
  - 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

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

Nested Loop Joins

- Tuple-based nested loop $R \bowtie S$
- 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 $R \bowtie S$
- 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)
```

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

What is the Cost?

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?

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?

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

Hash Join Example

Patient(pid, name, address)

Insurance(pid, provider, policy_nb)

Patient ⋈ Insurance

Two tuples per page

Patient

1	'Bob'	'Seattle'
2	'Ela'	'Everett'

3	'Jill'	'Kent'
4	'Joe'	'Seattle'

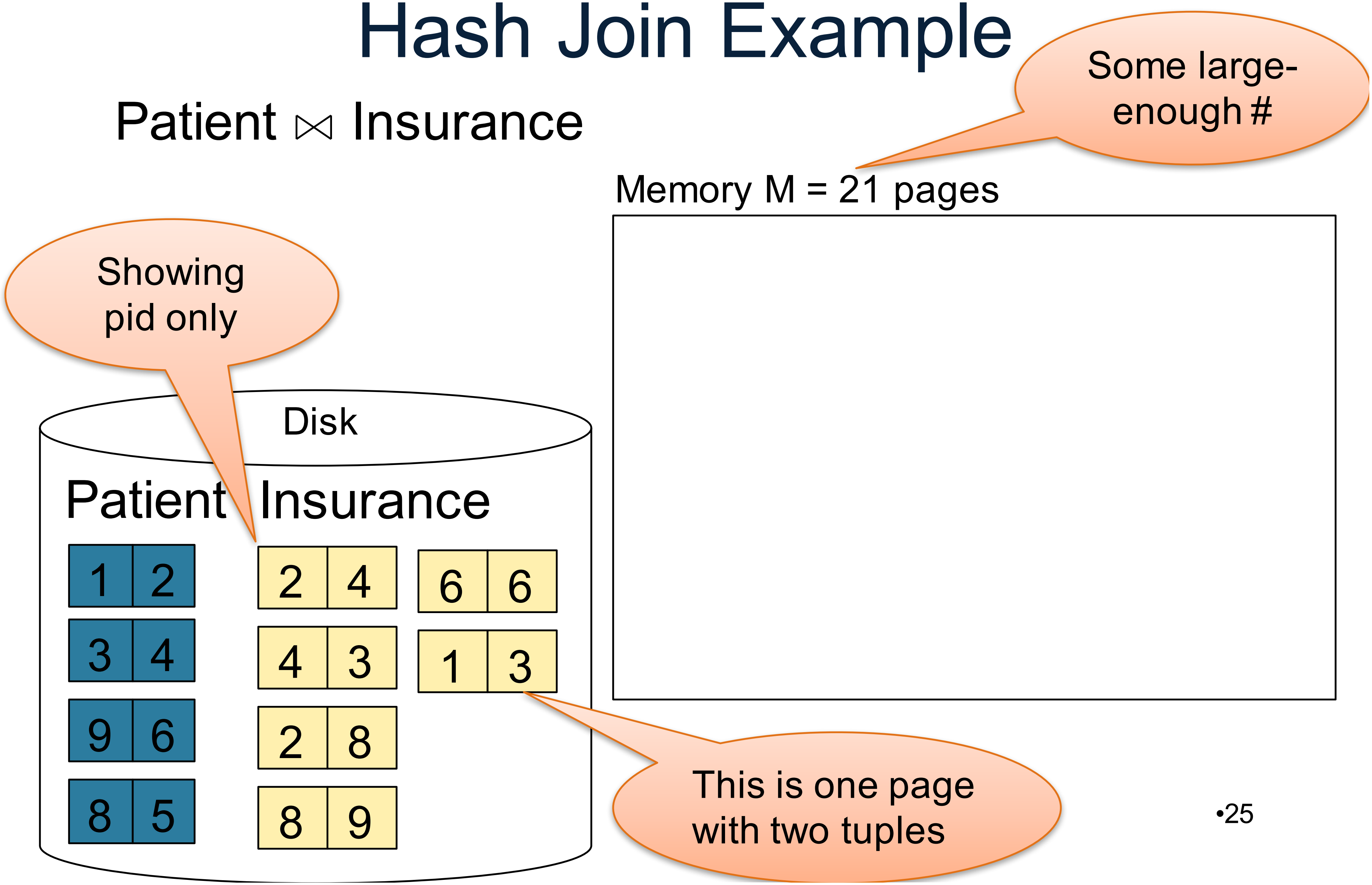
Insurance

2	'Blue'	123
4	'Prem'	432

4	'Prem'	343
3	'GrpH'	554

Hash Join Example

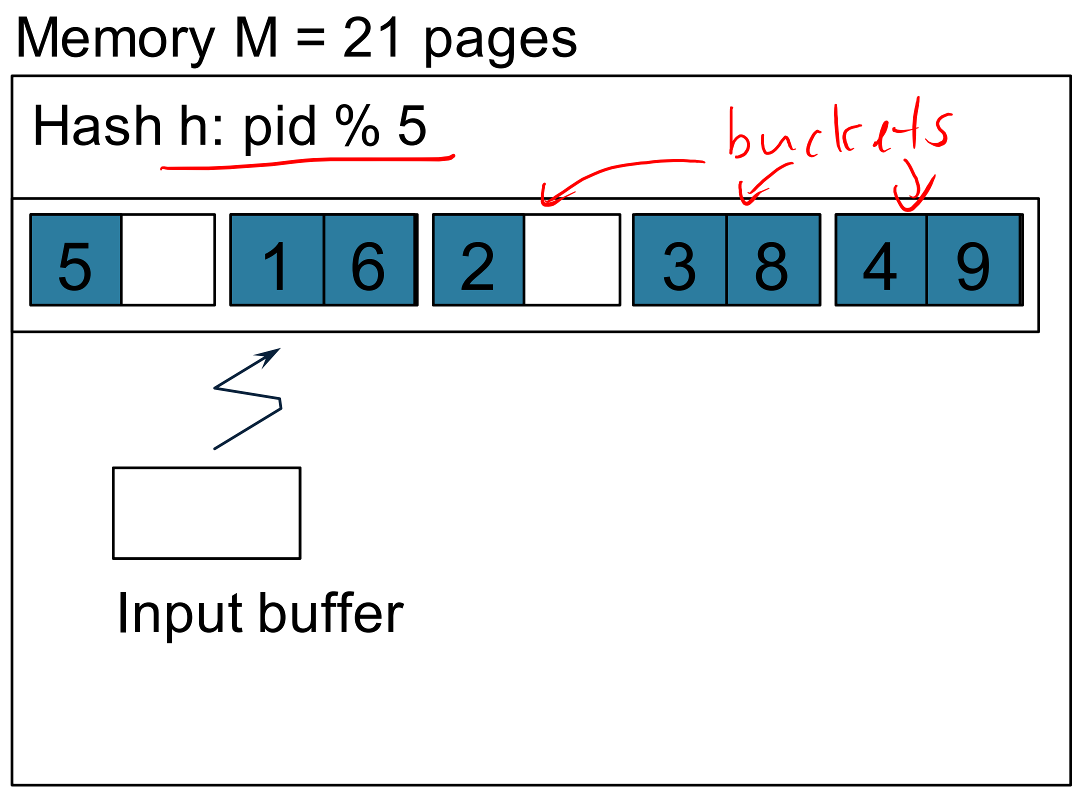
Patient $\bowtie$ Insurance

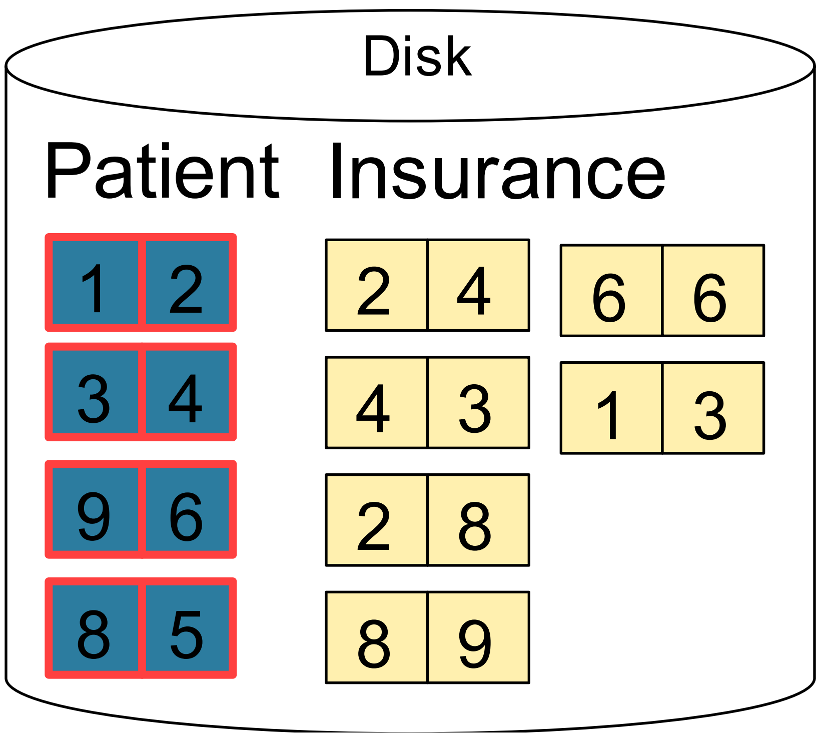


Hash Join Example

Step 1: Scan Patient and build hash table in memory

Can be done in method open()

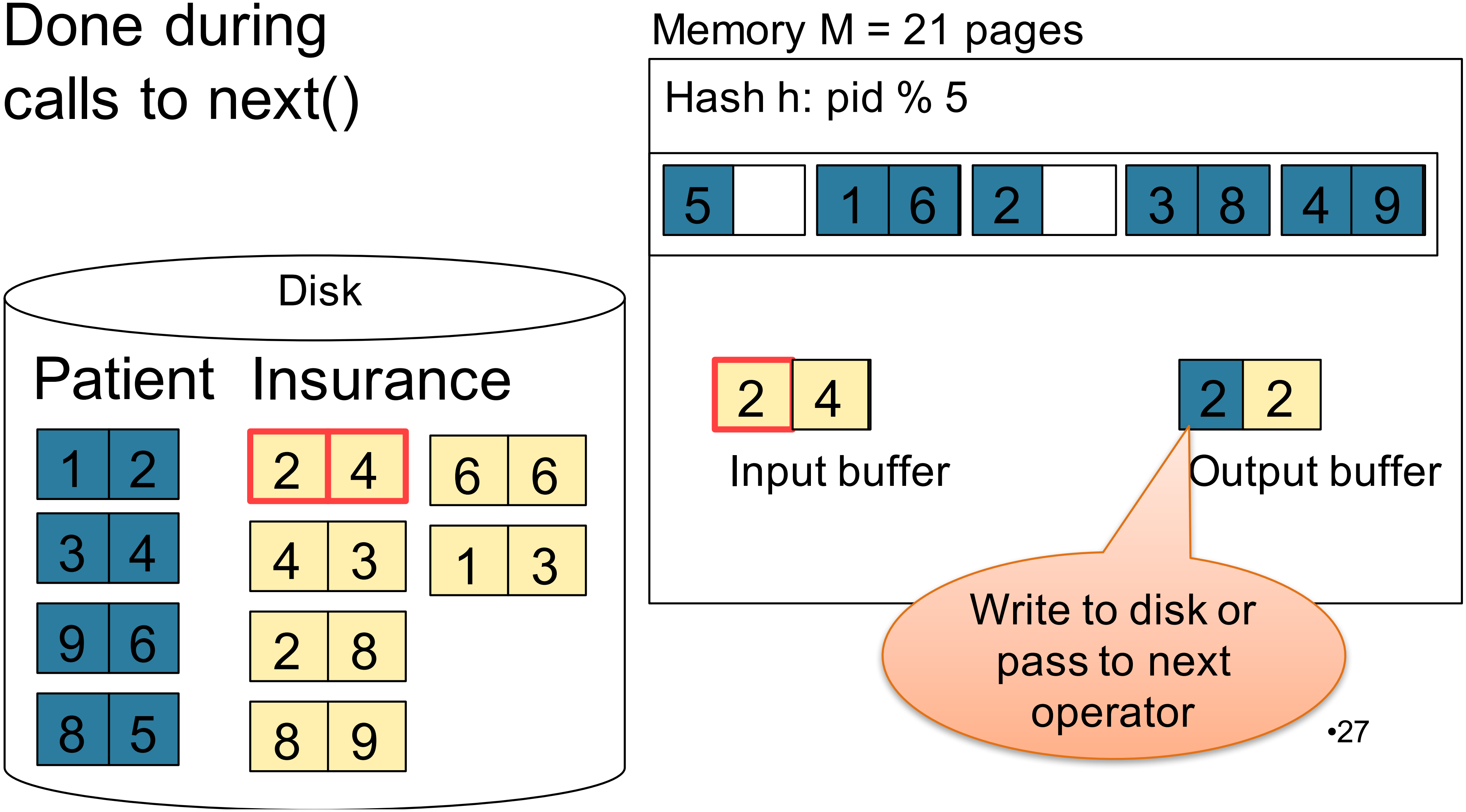




Hash Join Example

Step 2: Scan Insurance and probe into hash table

Done during calls to next()

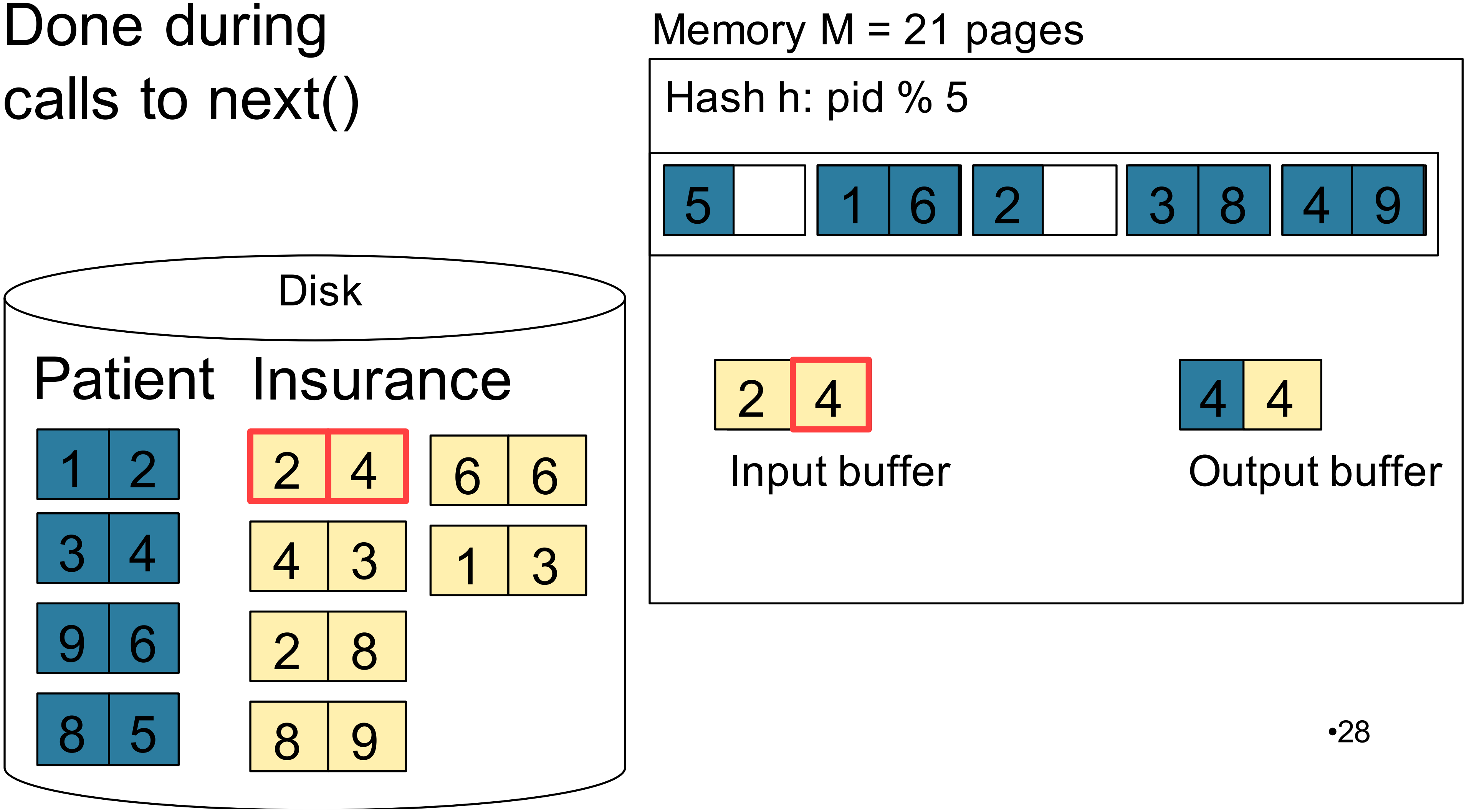


Hash Join Example

Step 2: Scan Insurance and probe into hash table

Done during

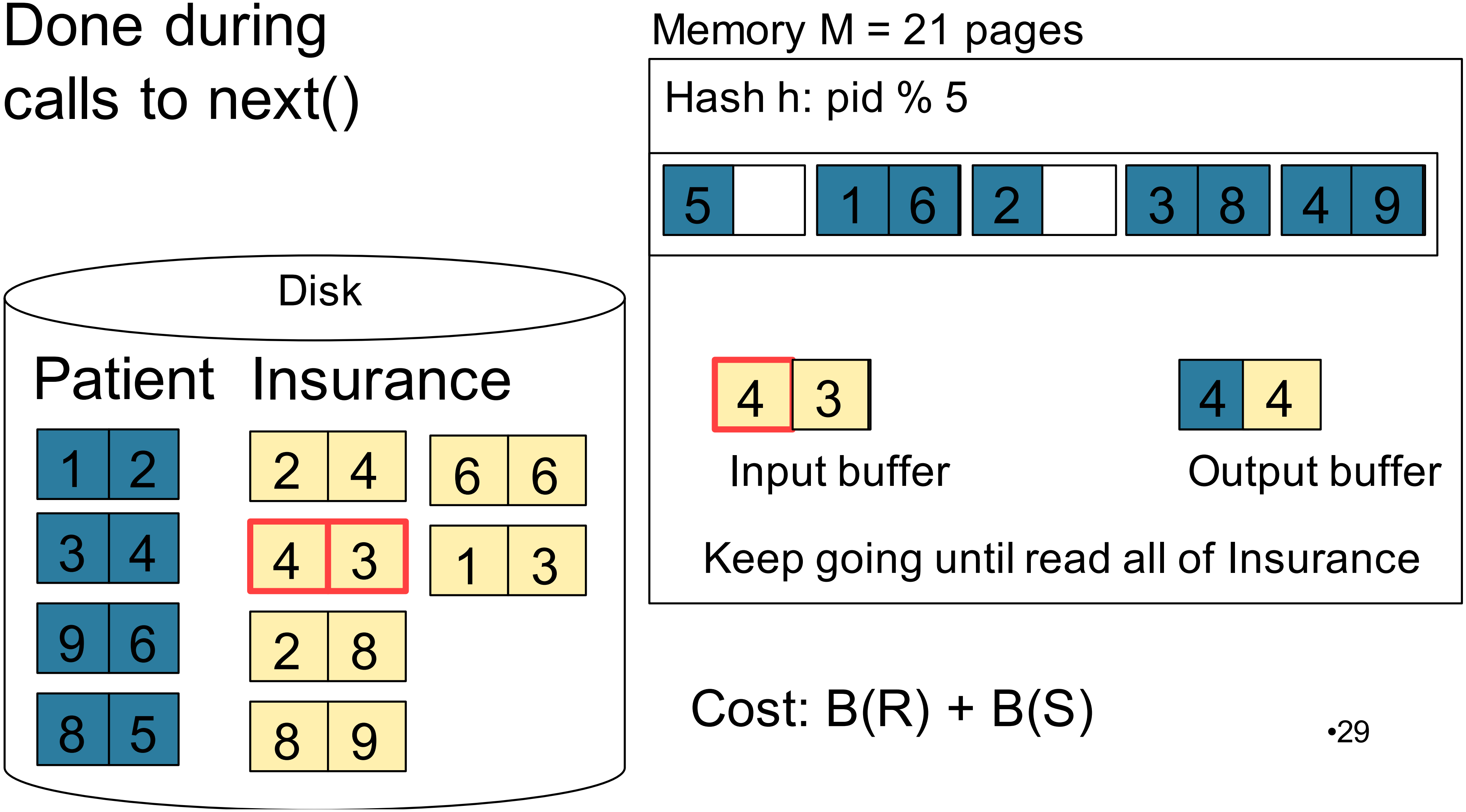
calls to next()



Hash Join Example

Step 2: Scan Insurance and probe into hash table

Done during calls to next()



Cost: B(R) + B(S)

Sort-Merge Join

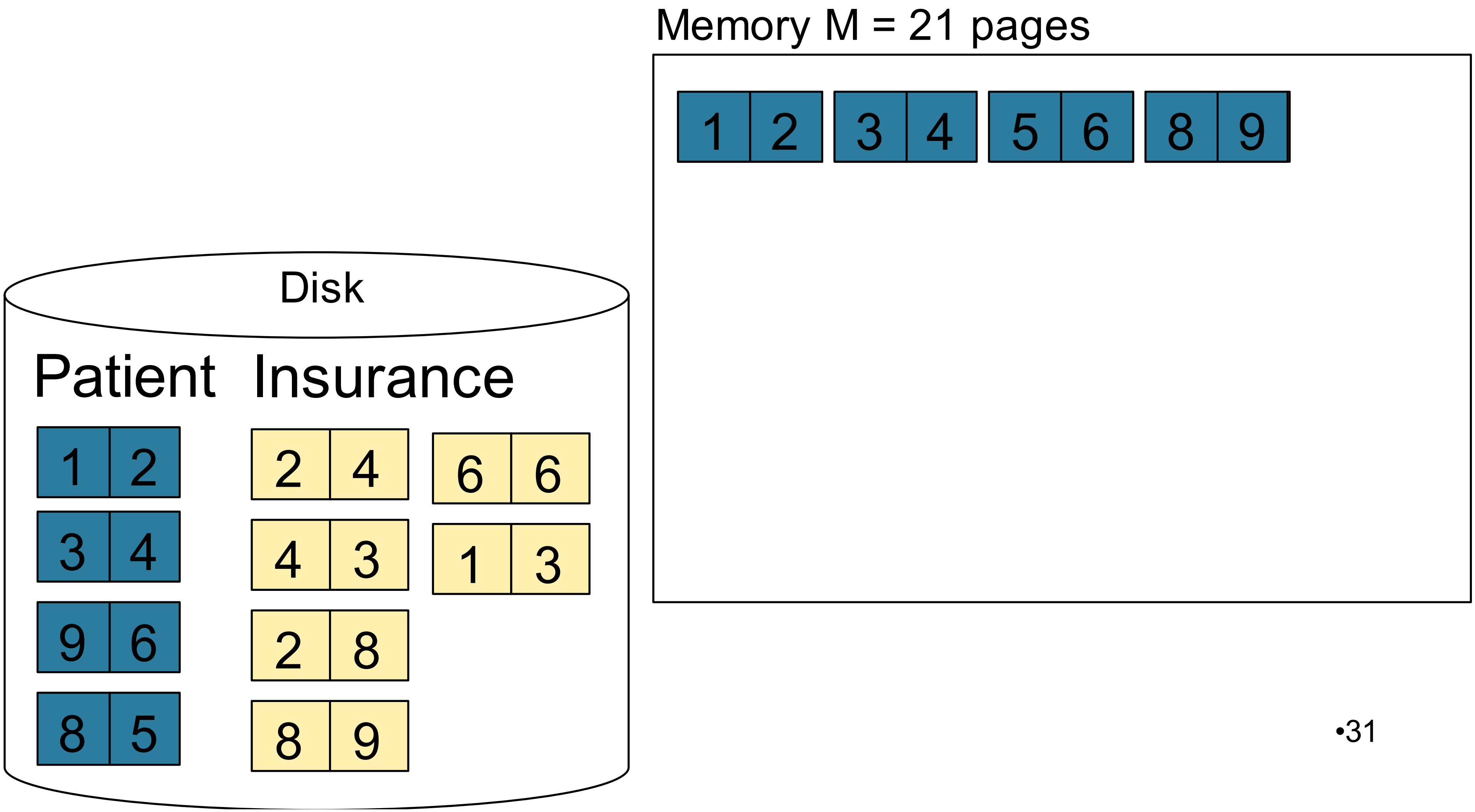
Sort-merge join: $R \bowtie S$

- 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

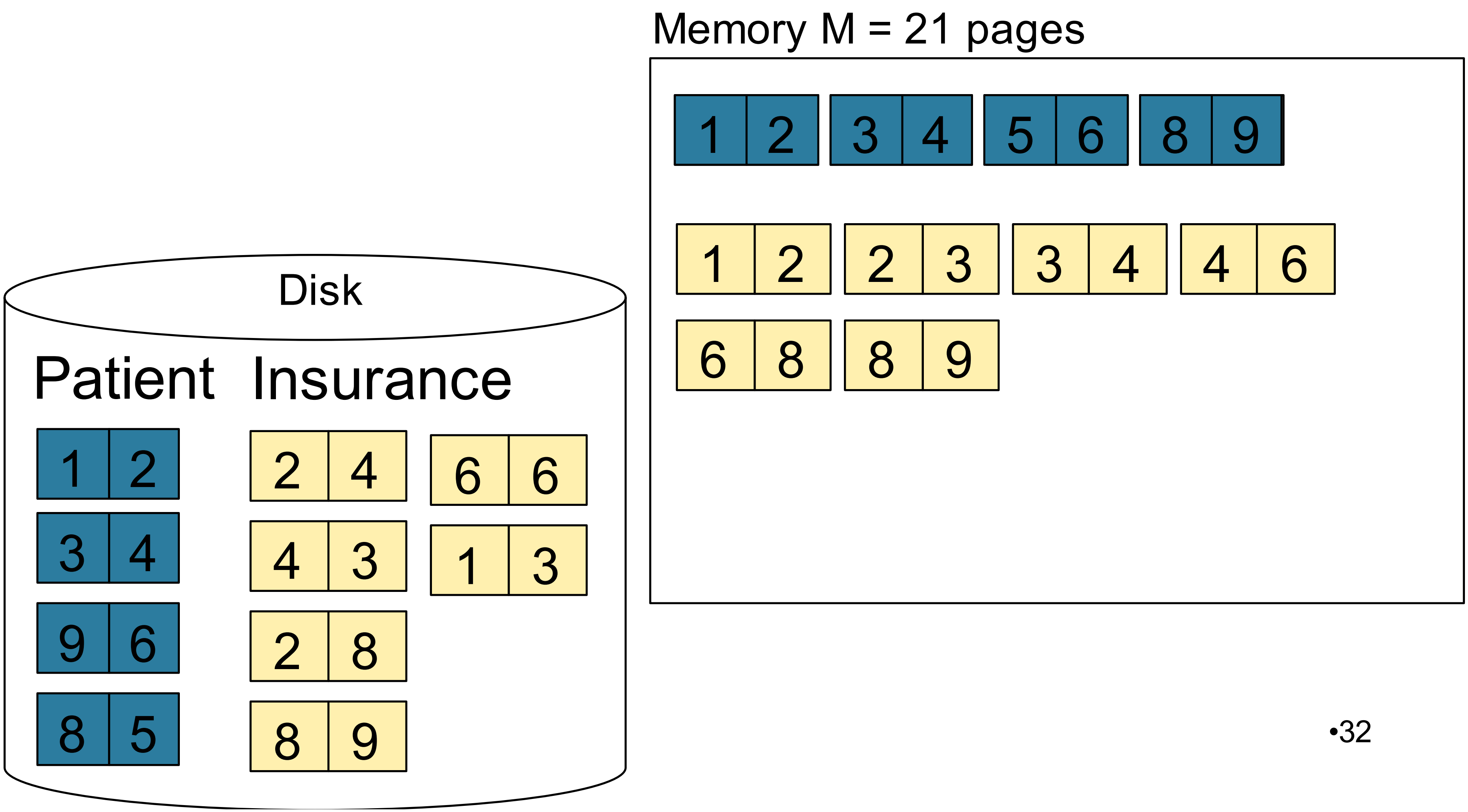
Sort-Merge Join Example

Step 1: Scan Patient and sort in memory



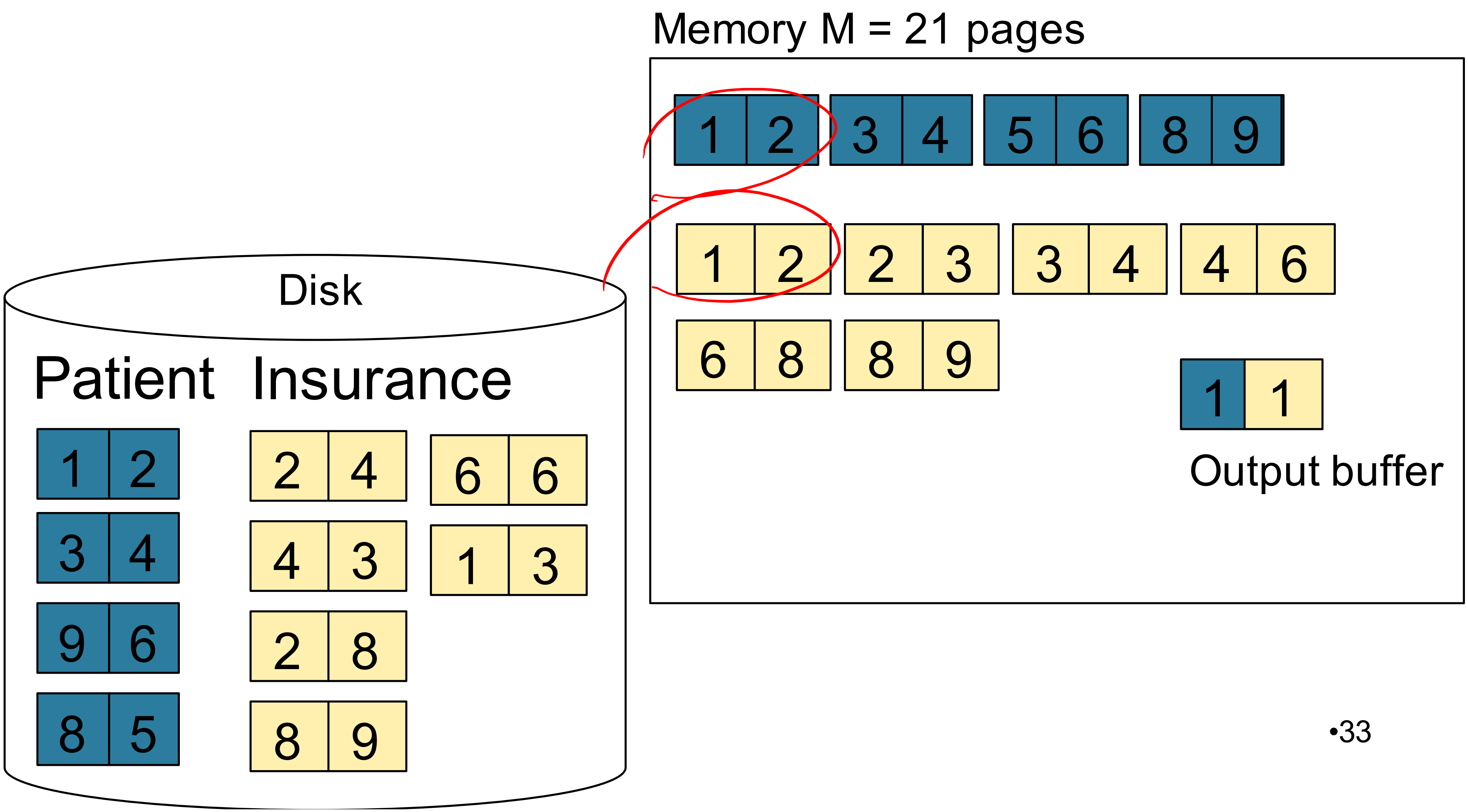
Sort-Merge Join Example

Step 2: Scan Insurance and sort in memory



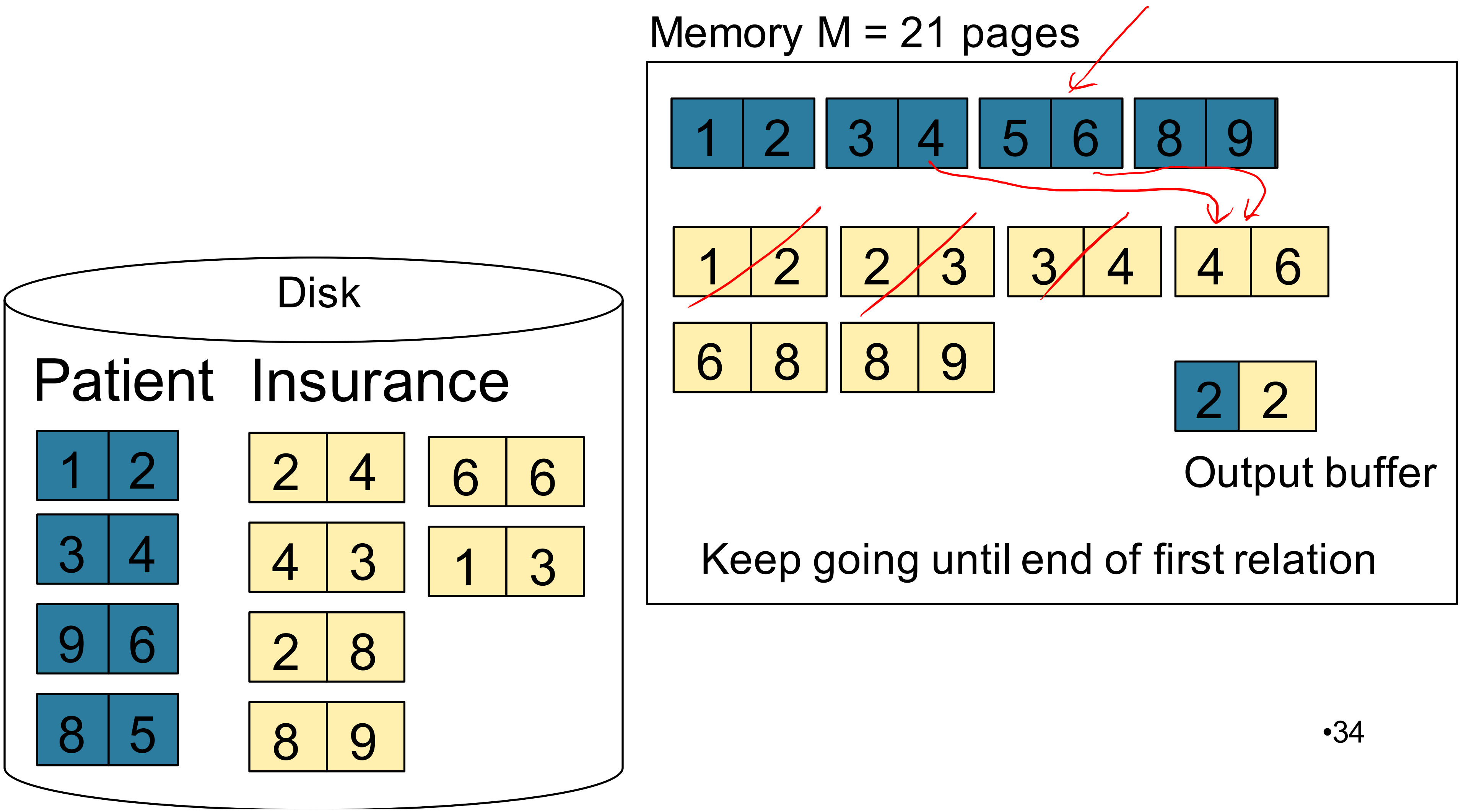
Sort-Merge Join Example

Step 3: Merge Patient and Insurance



Sort-Merge Join Example

Step 3: Merge Patient and Insurance



Cost of Query Plans

T(Supplier) = 1000
T(Supply) = 10,000

B(Supplier) = 100
B(Supply) = 100

V(Supplier,scity) = 20
V(Supplier,state) = 10
V(Supply,pno) = 2,500

M = 11

Physical Query Plan 1

(On the fly) π_{sname}

(On the fly) $\sigma_{scity='Seattle' \text{ and } sstate='WA' \text{ and } pno=2}$

(Nested loop) ⋈ sid = sid

Supplier (File scan)

Supply (File scan)

Selection and project on-the-fly
→ No additional cost.

Total cost of plan is thus cost of join:
= B(Supplier)+B(Supplier)*B(Supply)
= 100 + 100 * 100
= 10,100 I/Os

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

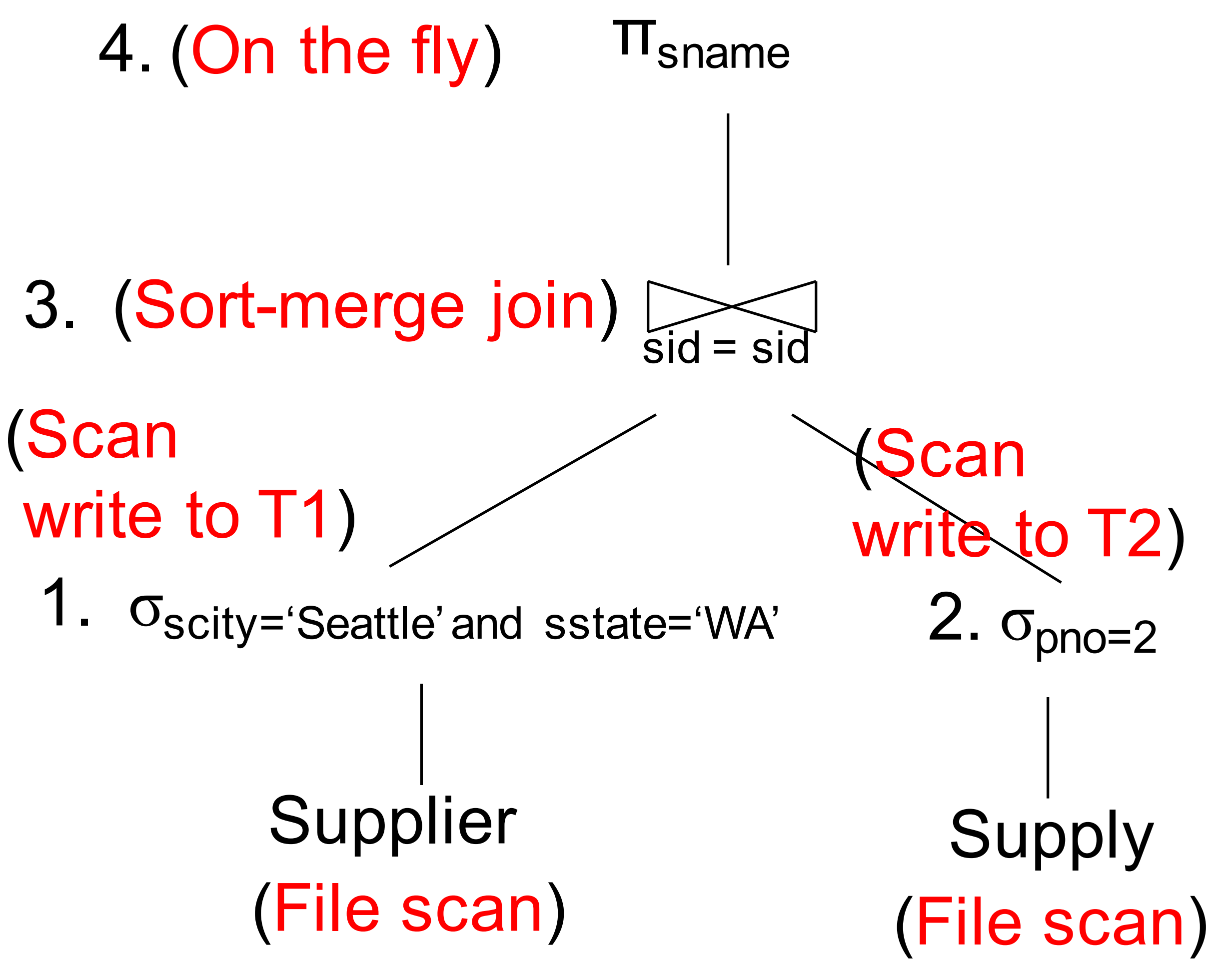
T(Supplier) = 1000
T(Supply) = 10,000

B(Supplier) = 100
B(Supply) = 100

V(Supplier,scity) = 20
V(Supplier,state) = 10
V(Supply,pno) = 2,500

M = 11

Physical Query Plan 2



Total cost
= 100 + 100 * 1/20 * 1/10
(step 1)
+ 100 + 100 * 1/2500
(step 2)
+ 2
(step 3)
+ 0
(step 4)
Total cost ≈ **204 I/Os**

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