CSE 444: Database Internals

Section 3:

Indexing and Operator Algorithms

Problem 1:
B+ tree insertion and deletion

- On board
- (We will do it after problem 2)

Notations

- B(R)
- T(R)
- V(R, a)
- M

Problem 2
Algorithms for Group By and Aggregate Operators

For homework 2:

Understand what is going on, do not blindly apply formula!

Try to choose outer relation carefully to reduce cost/fit data in memory

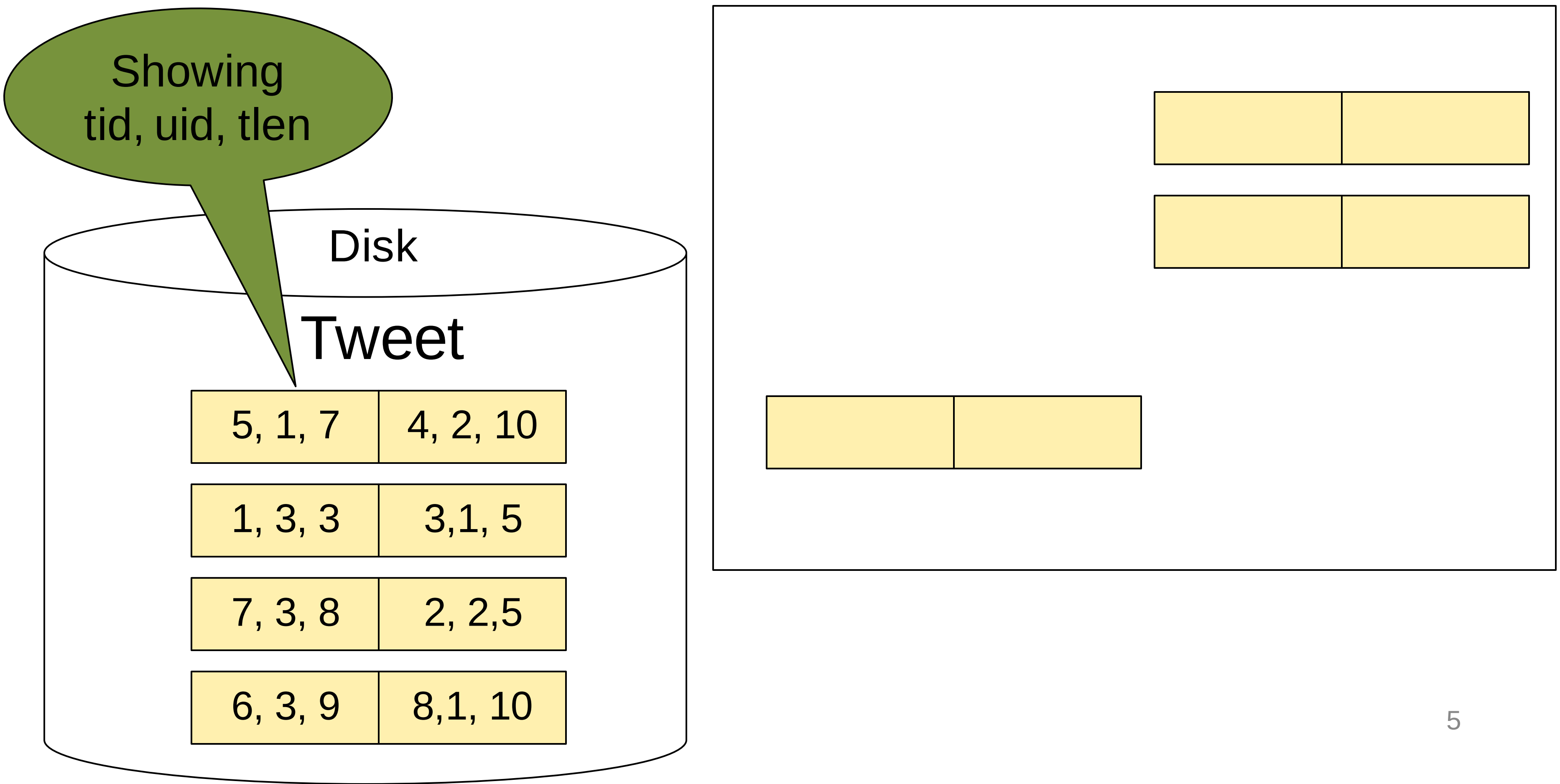
- Modified Tweet Example:

Tweet(tid, uid, tlen) tlen = tweet length

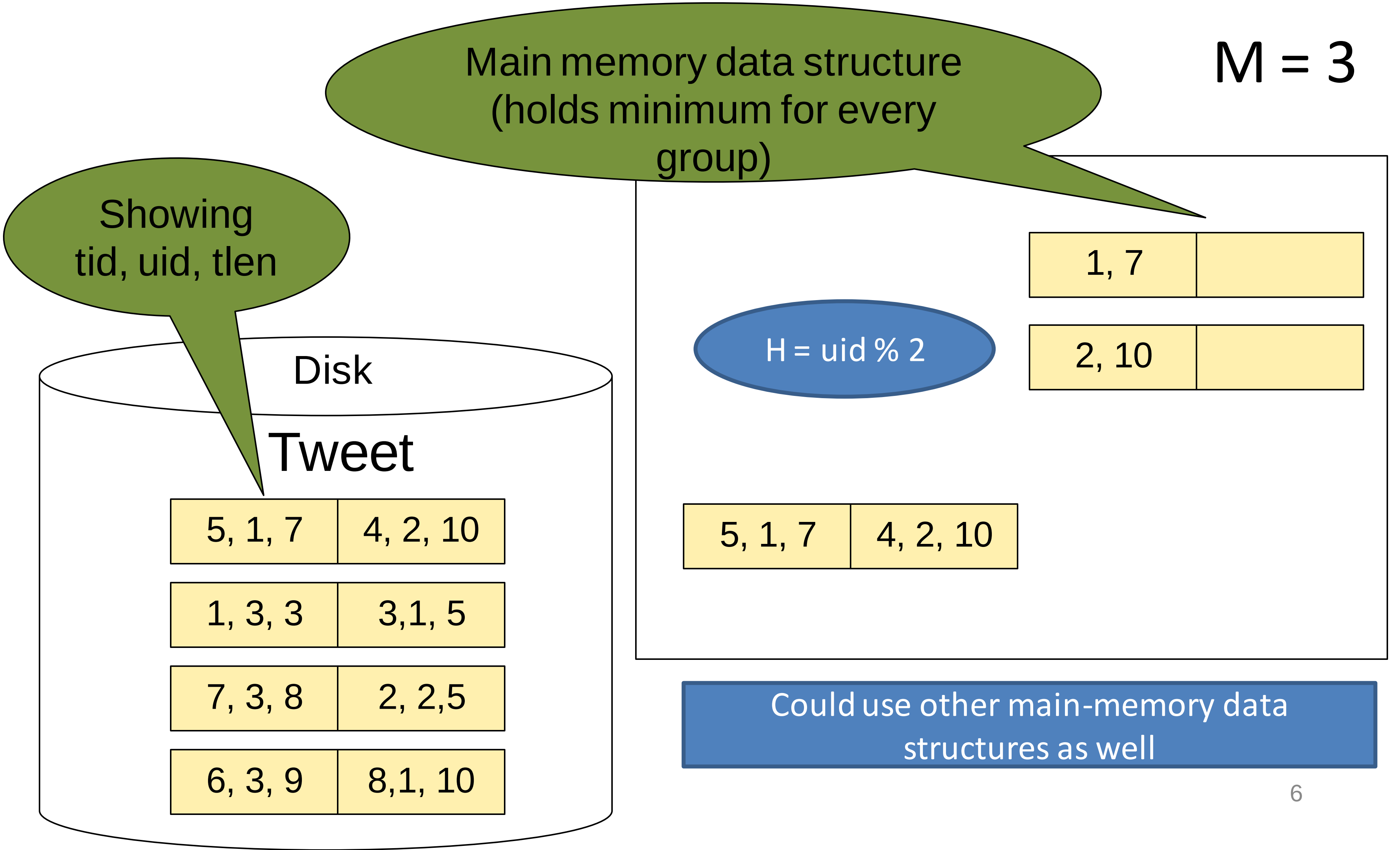
```
SELECT uid, MIN(tlen)
FROM Tweet
GROUP BY uid
```

Problem 2a:
One pass, hash-based grouping

M = 3

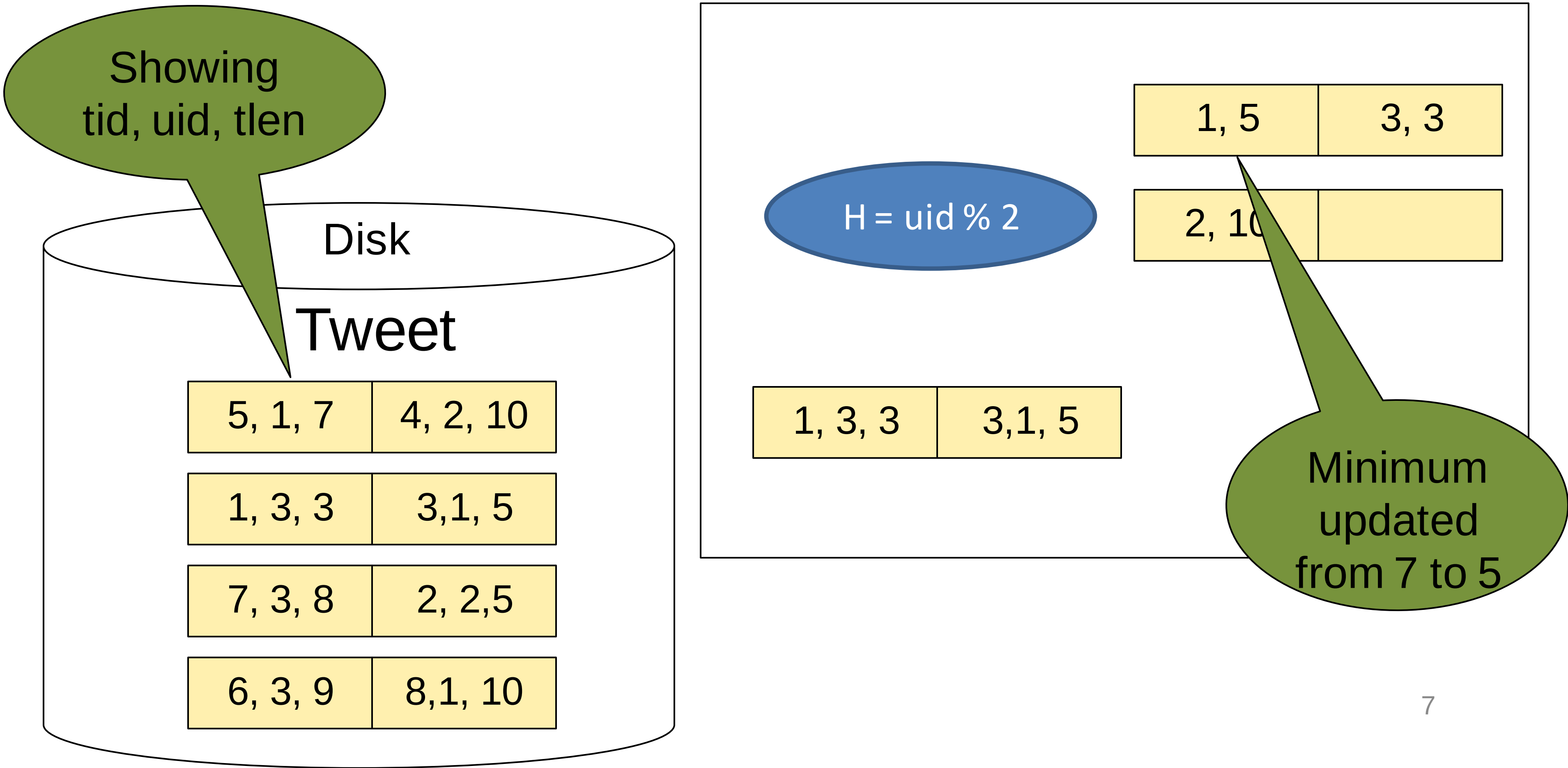


Problem 2a:
One pass, hash-based grouping



One pass, hash-based grouping

M = 3



Discussion: Problem 2a

Cost:

- Clustered?
- B(R): assuming M – 1 pages can hold all groups – tuples for groups can be shorter or larger than original tuples
- Unclustered?
- Also B(R)

Which method does the grouping:

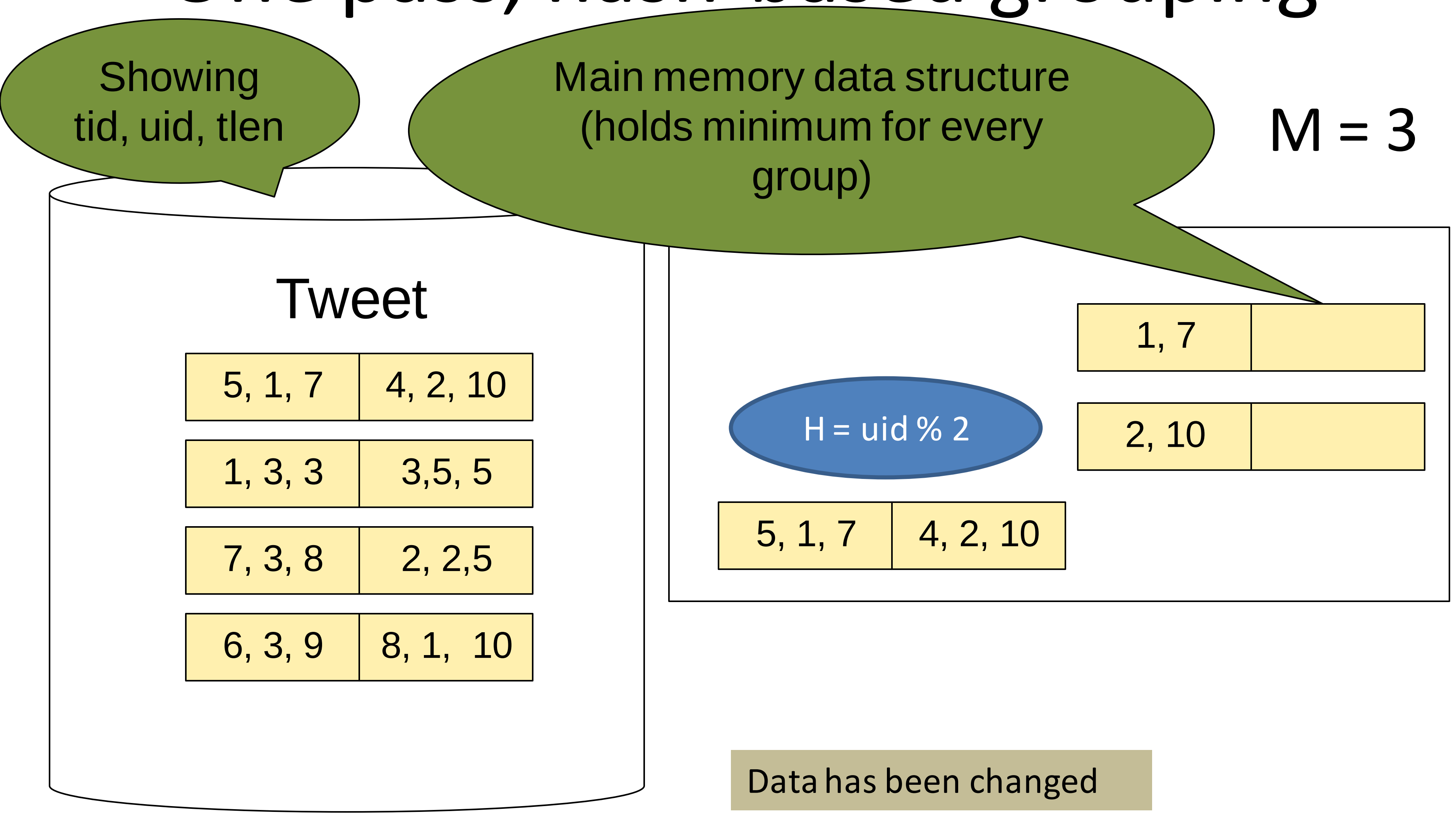
open(), next(), or close()?

- Cannot return anything until the entire data is read. Open() needs to do grouping

What to do for AVG(tlen)?

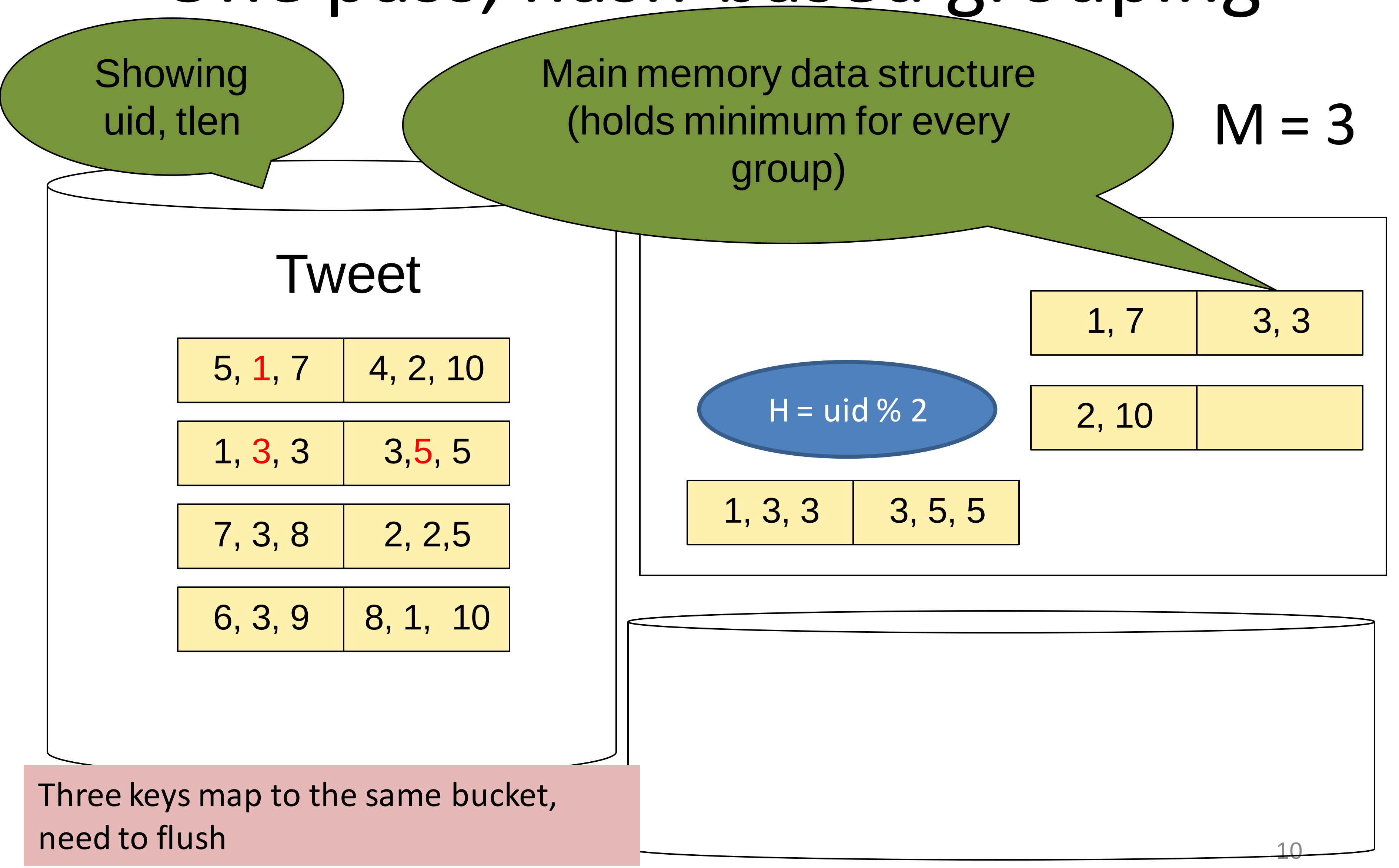
- Keep both SUM(tlen) and COUNT(*) for each group in memory

One pass, hash-based grouping



Data has been changed

One pass, hash-based grouping



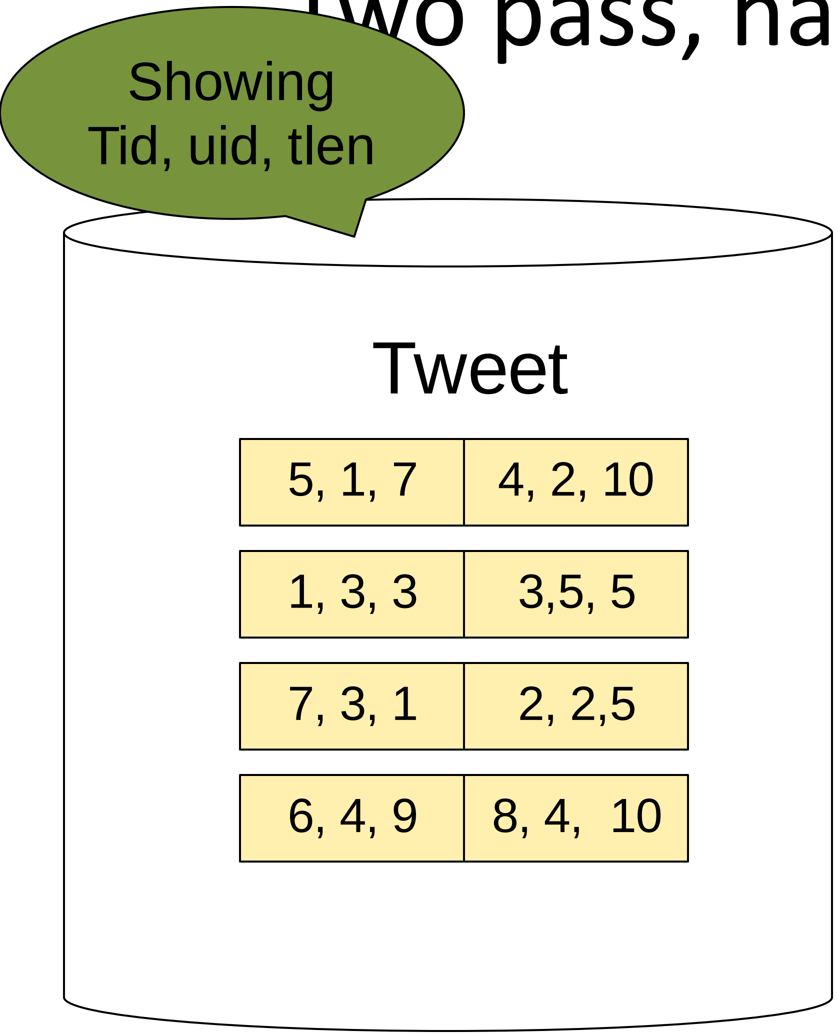
- Solution?

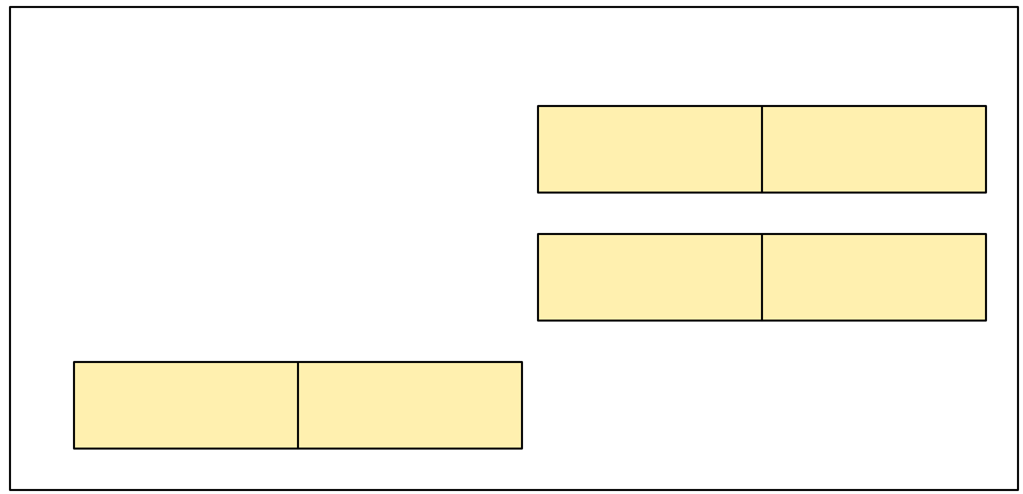
Two pass Hash-based Aggregate algorithms

- First Hash all tuples, then perform the aggregate in second pass

Problem 2b:
Two pass, hash-based grouping

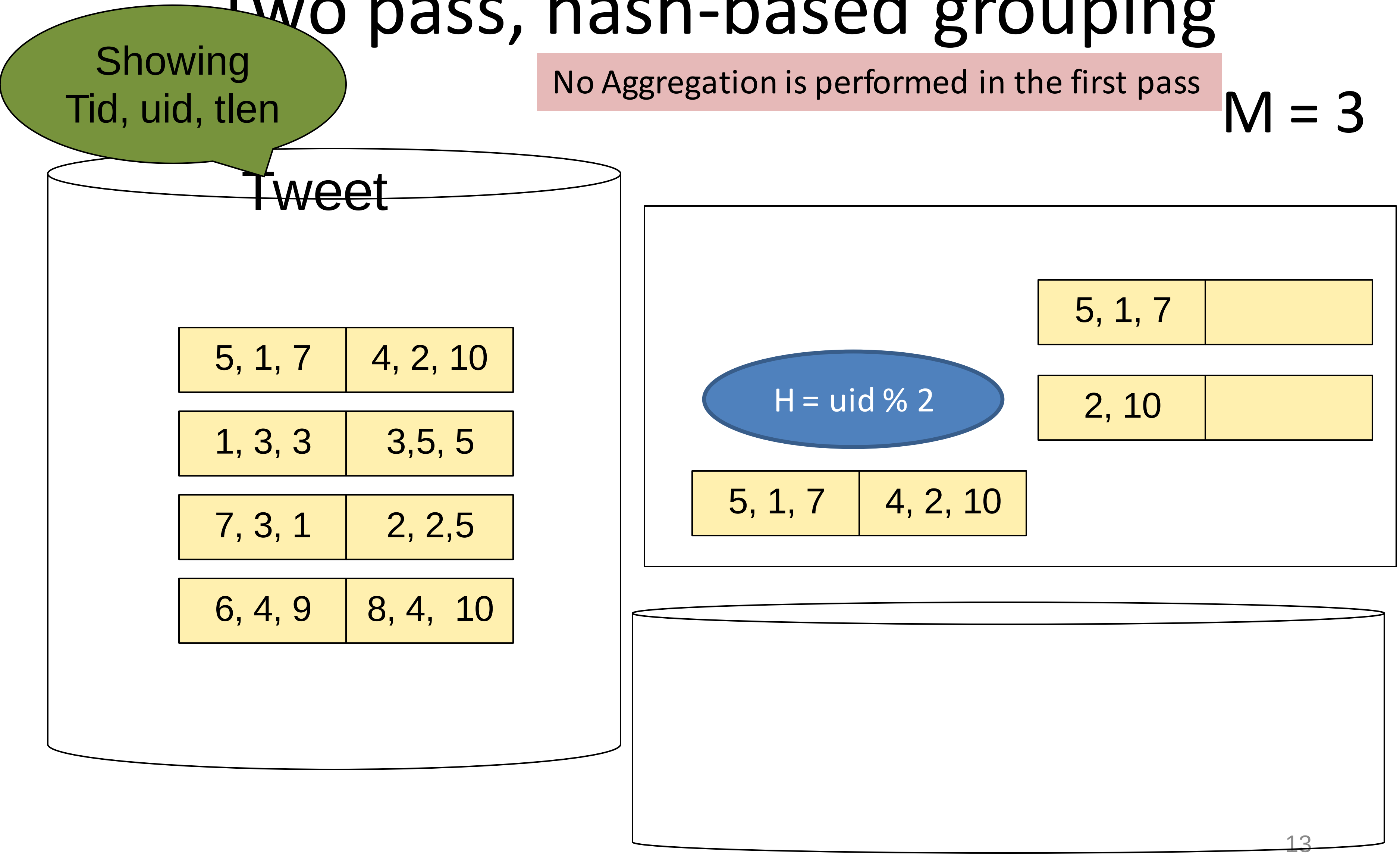
M = 3



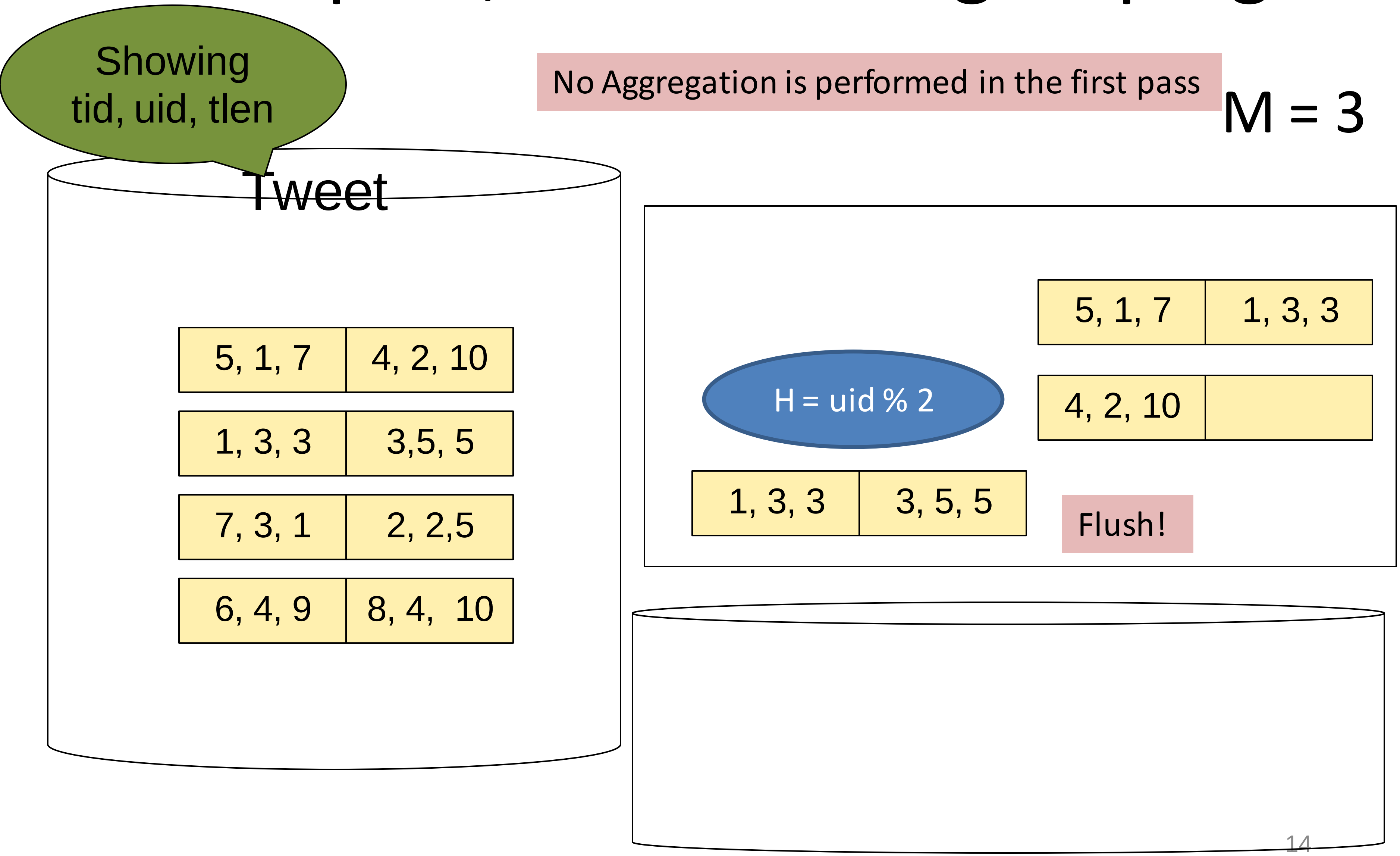


Hint: Two-pass hash-based join in yesterday's lecture!

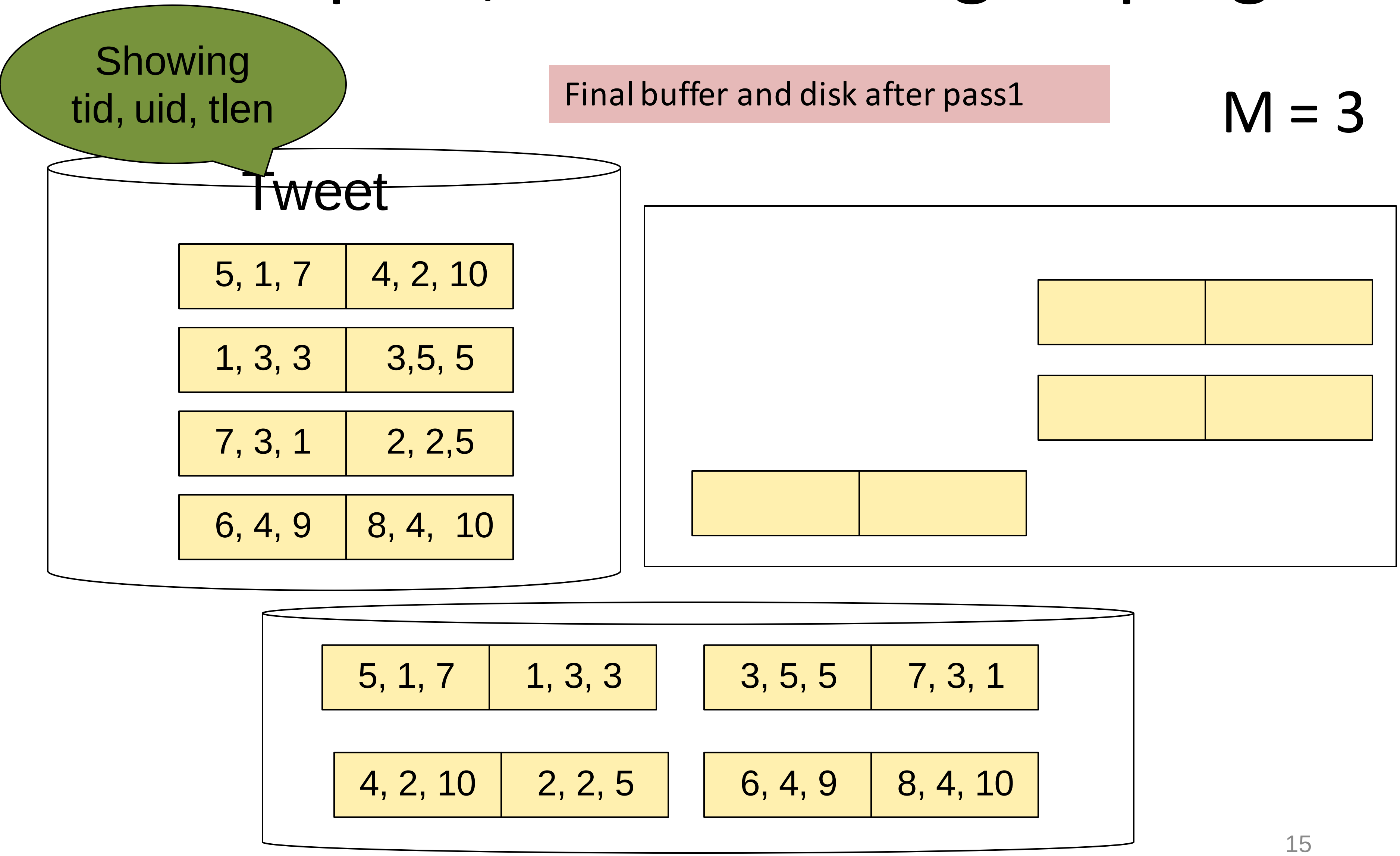
Problem 2b:
Two pass, hash-based grouping



Two pass, hash-based grouping

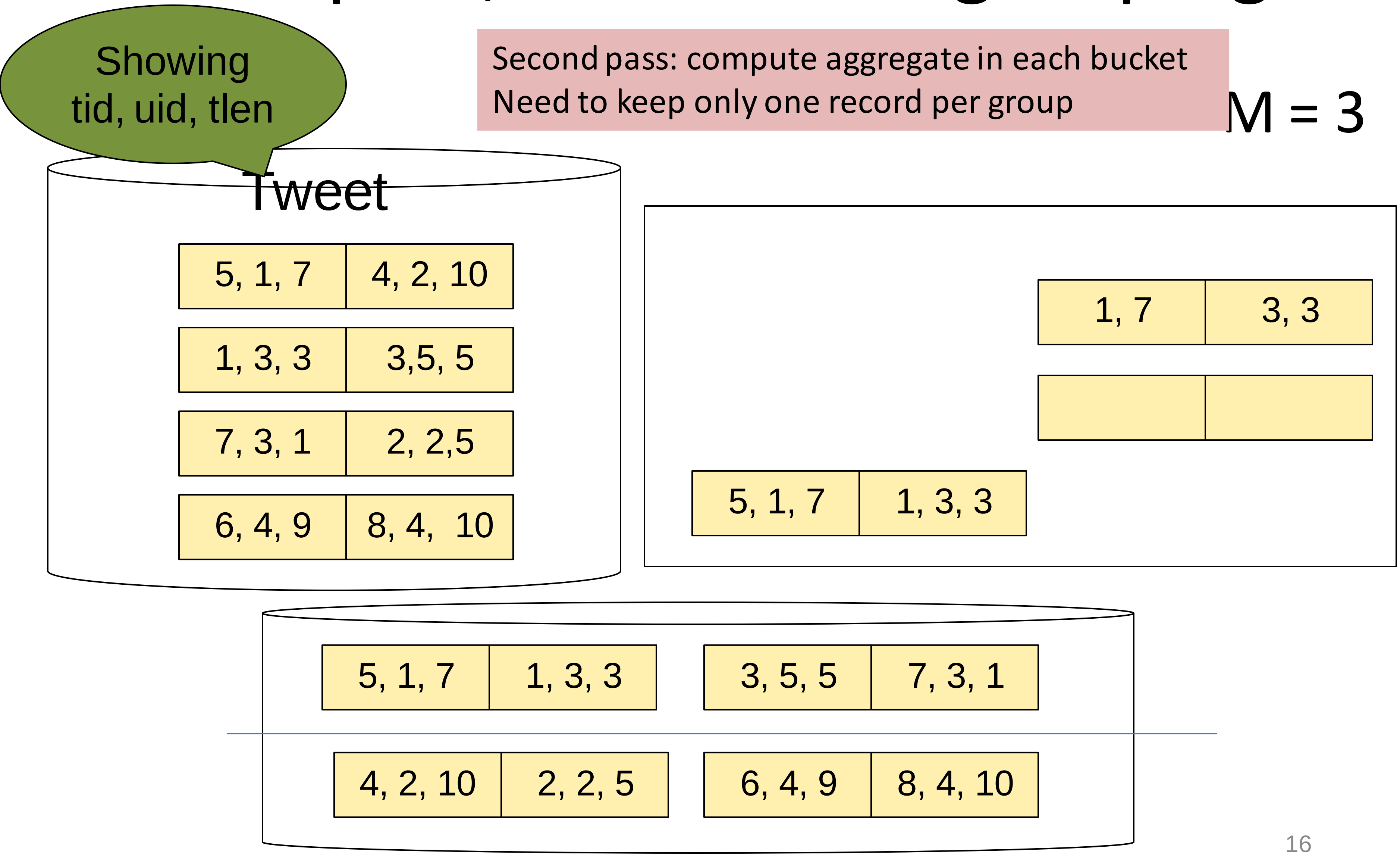


Two pass, hash-based grouping

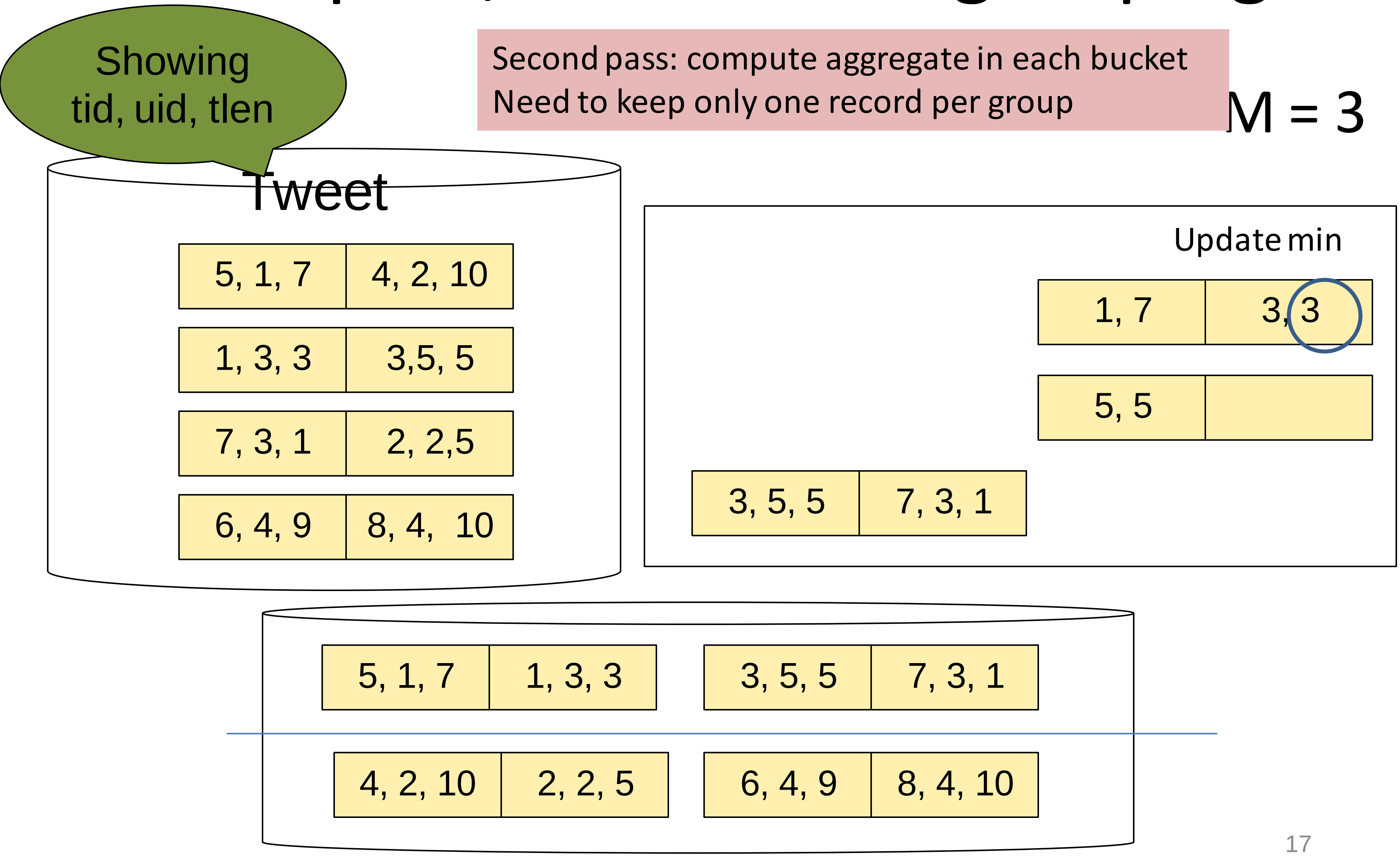


Two pass, hash-based grouping

Second pass: compute aggregate in each bucket
Need to keep only one record per group



Two pass, hash-based grouping



Discussion: Problem 2b

Cost?

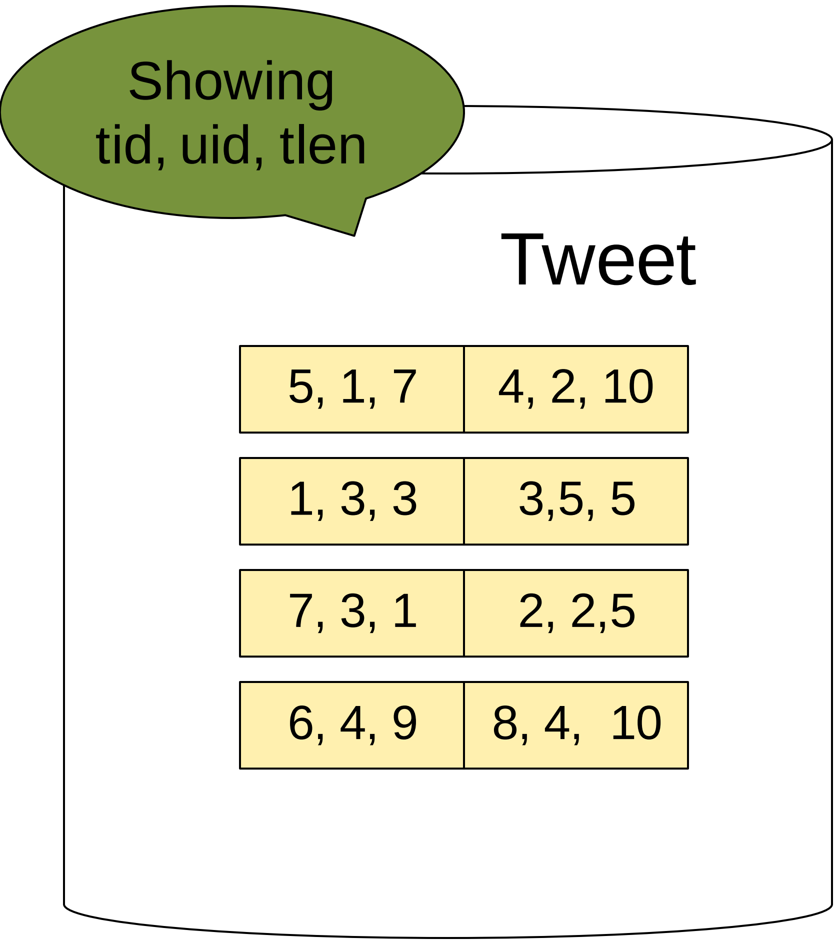
- 3B(R)

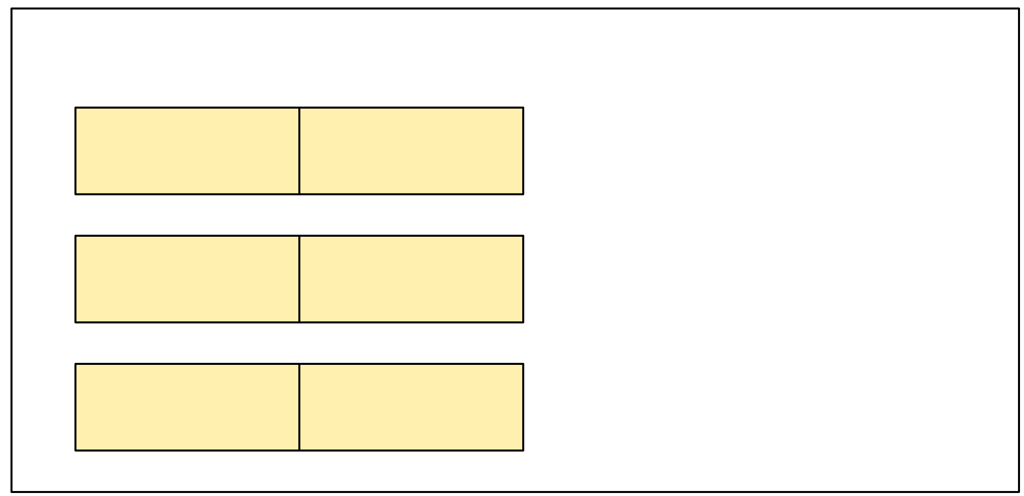
Assumptions?

- Need to hold all distinct values in the same bucket in M-1
- Assuming uniformity, B(R) <= M^2 is safe to assume
- But note that can handle much bigger relations R if the groups are large and #groups is small.

Problem 2c:
Two pass, sort-merge-based grouping

M = 3

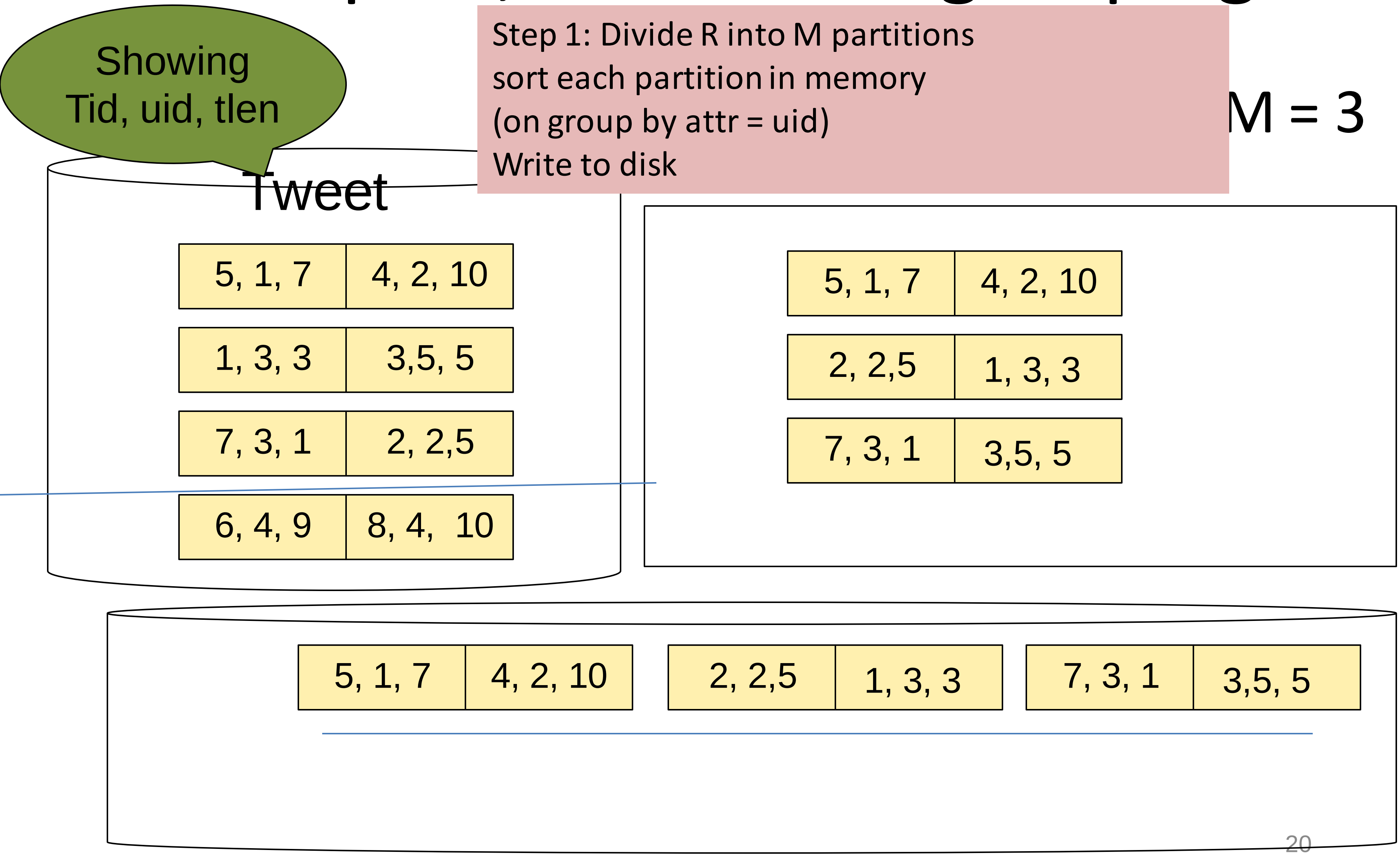




Hint: Two-pass sort-merged join in yesterday's lecture!

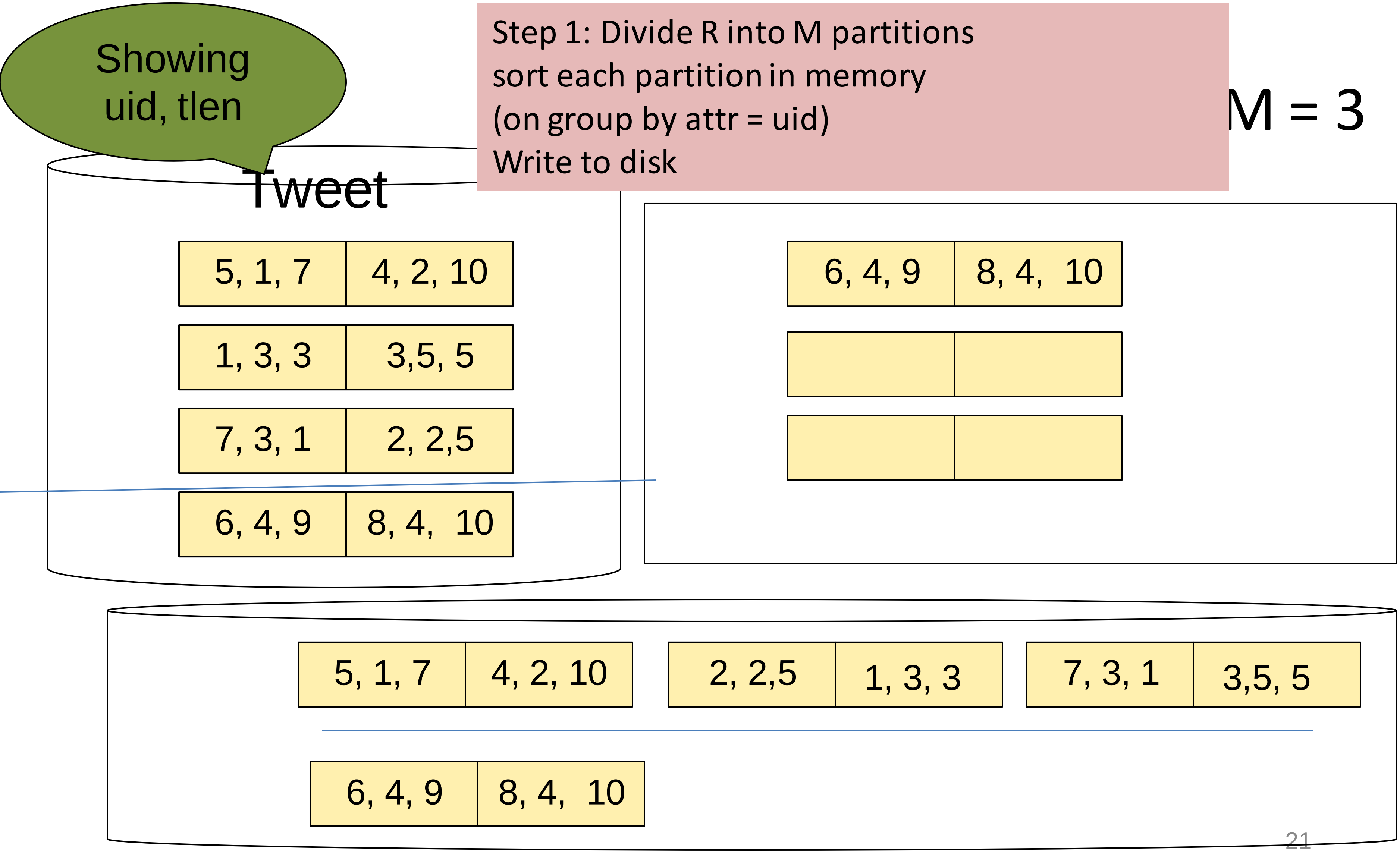
Two pass, sort-based grouping

Step 1: Divide R into M partitions
sort each partition in memory
(on group by attr = uid)
Write to disk



Two pass, sort-merged-based grouping

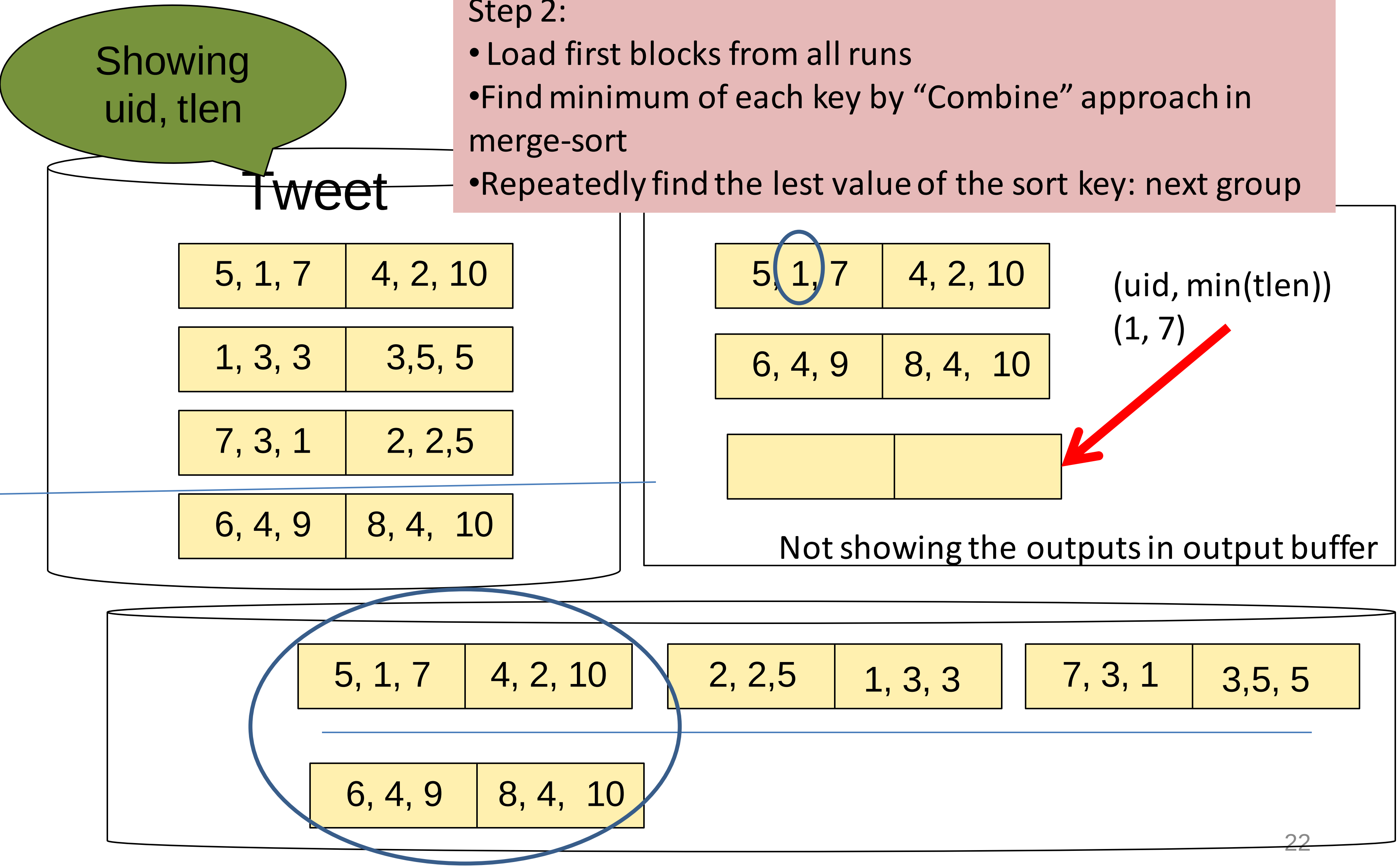
Step 1: Divide R into M partitions
sort each partition in memory
(on group by attr = uid)
Write to disk



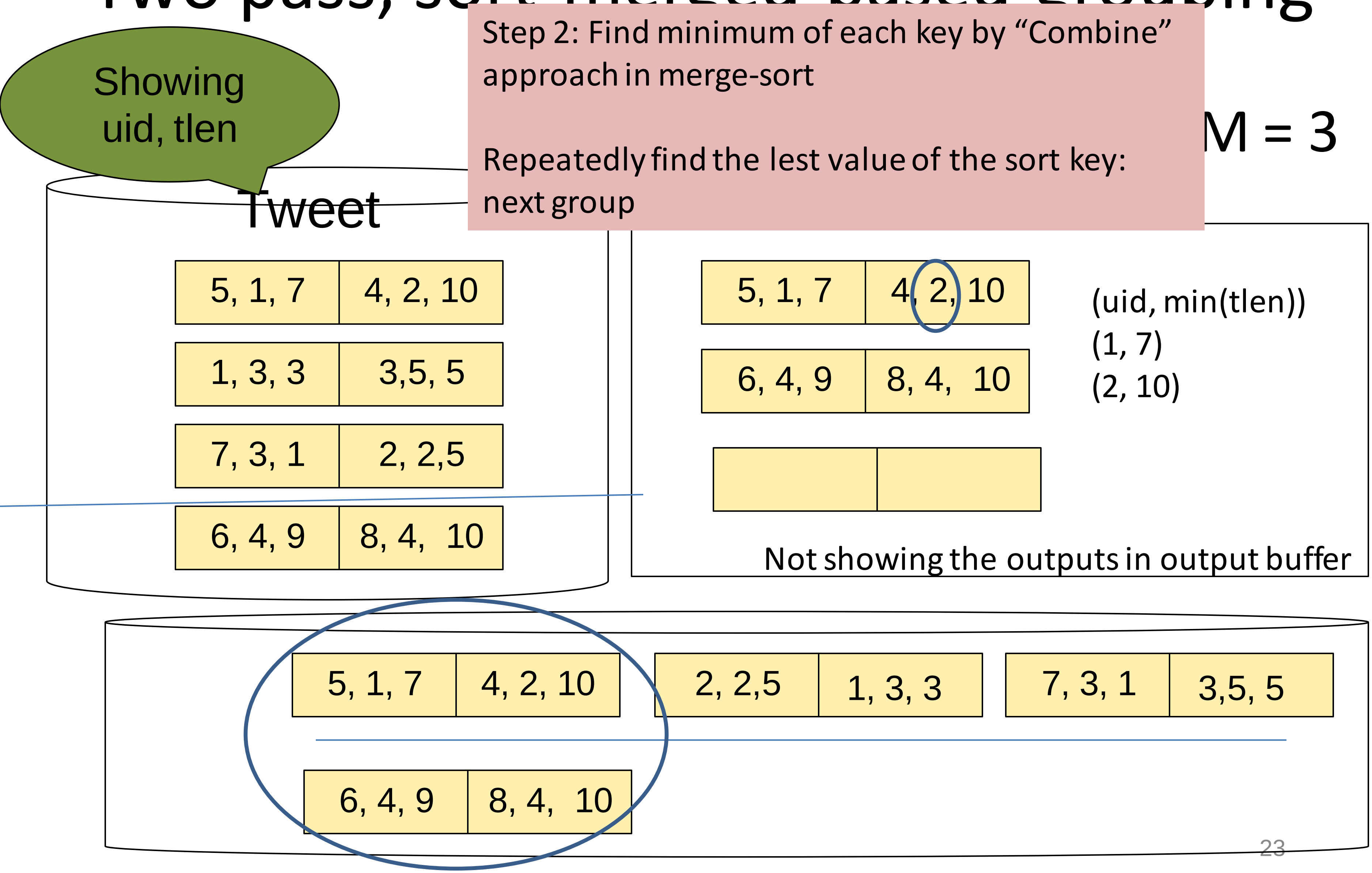
Two pass, sort-merged-based grouping

Step 2:

- Load first blocks from all runs
- Find minimum of each key by “Combine” approach in merge-sort
- Repeatedly find the lest value of the sort key: next group



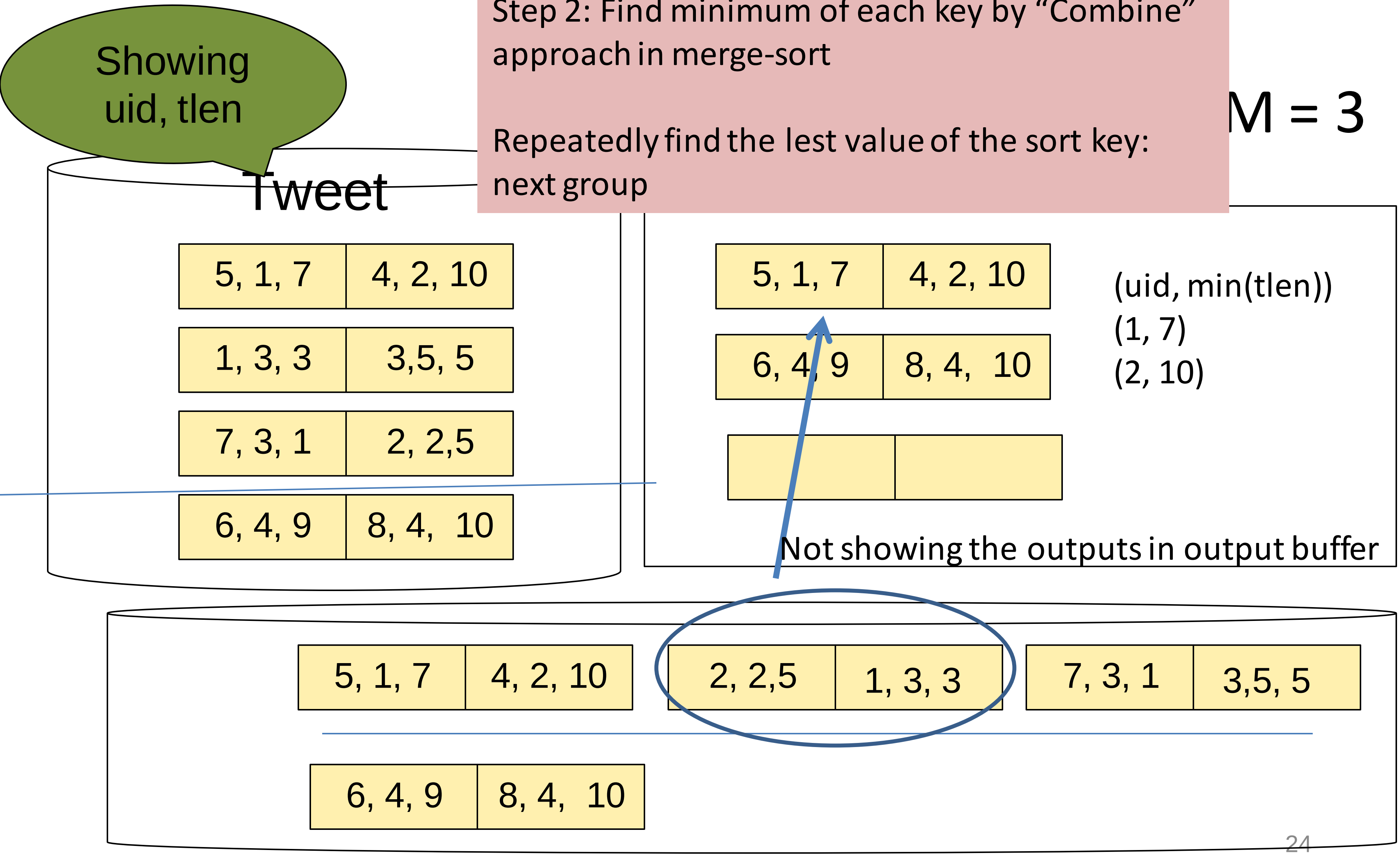
Two pass, sort-merged-based grouping



Two pass, sort-merged-based grouping

Step 2: Find minimum of each key by "Combine" approach in merge-sort

Repeatedly find the lest value of the sort key: next group



Two pass, sort-merged-based grouping

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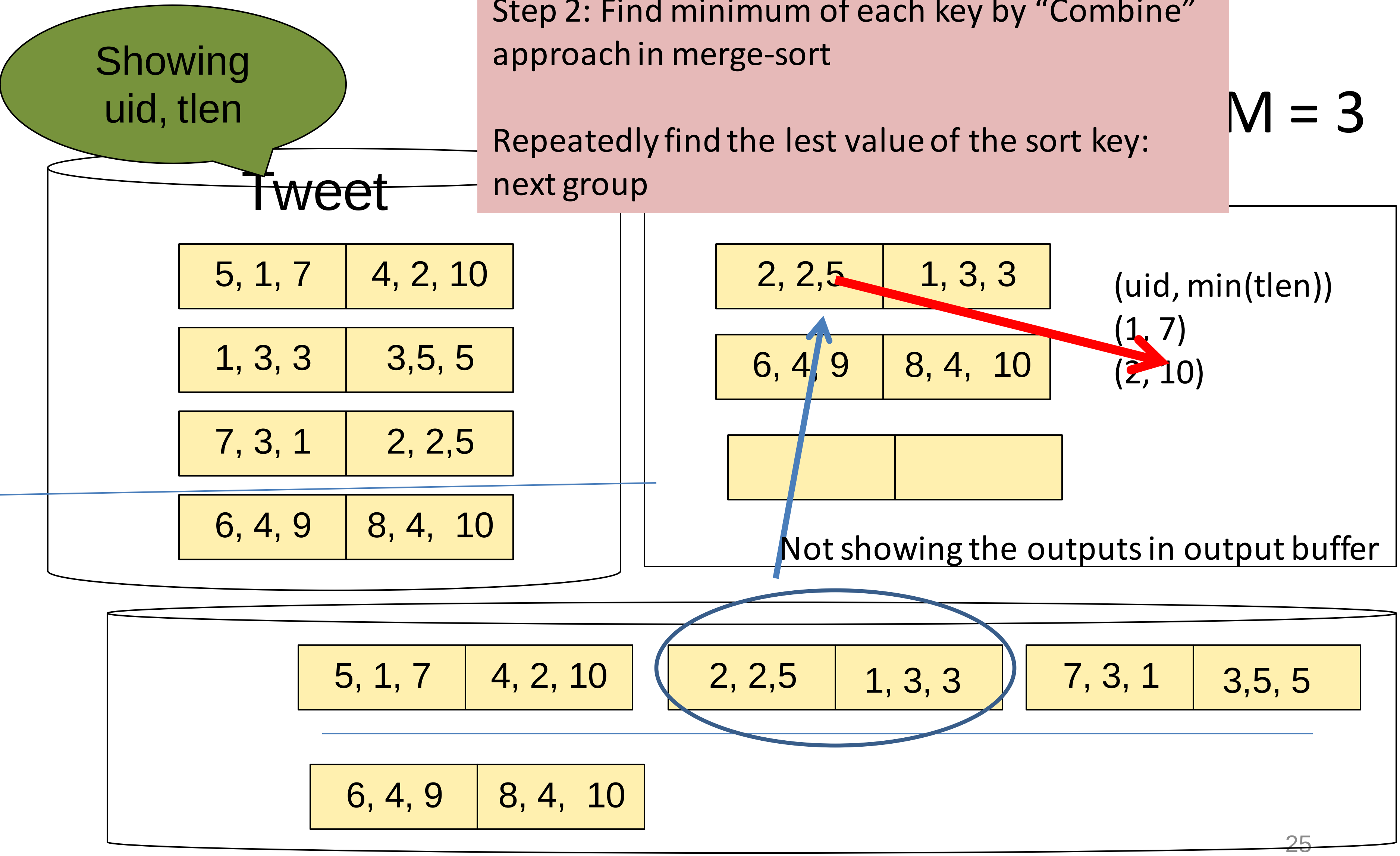

Two pass, sort-merged-based grouping

Step 2: Find minimum of each key by "Combine" approach in merge-sort

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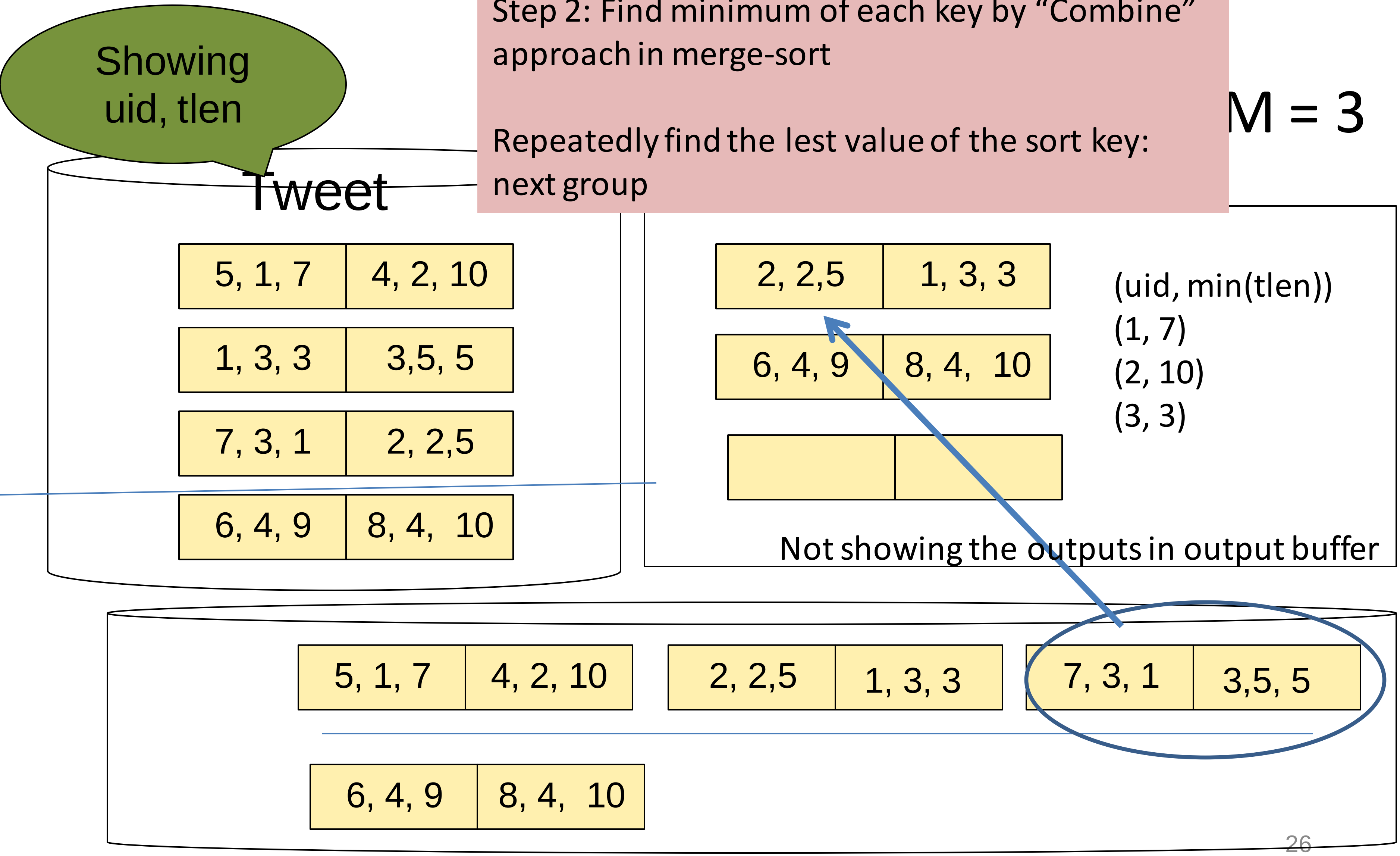

Two pass, sort-merged-based grouping

Step 2: Find minimum of each key by "Combine" approach in merge-sort

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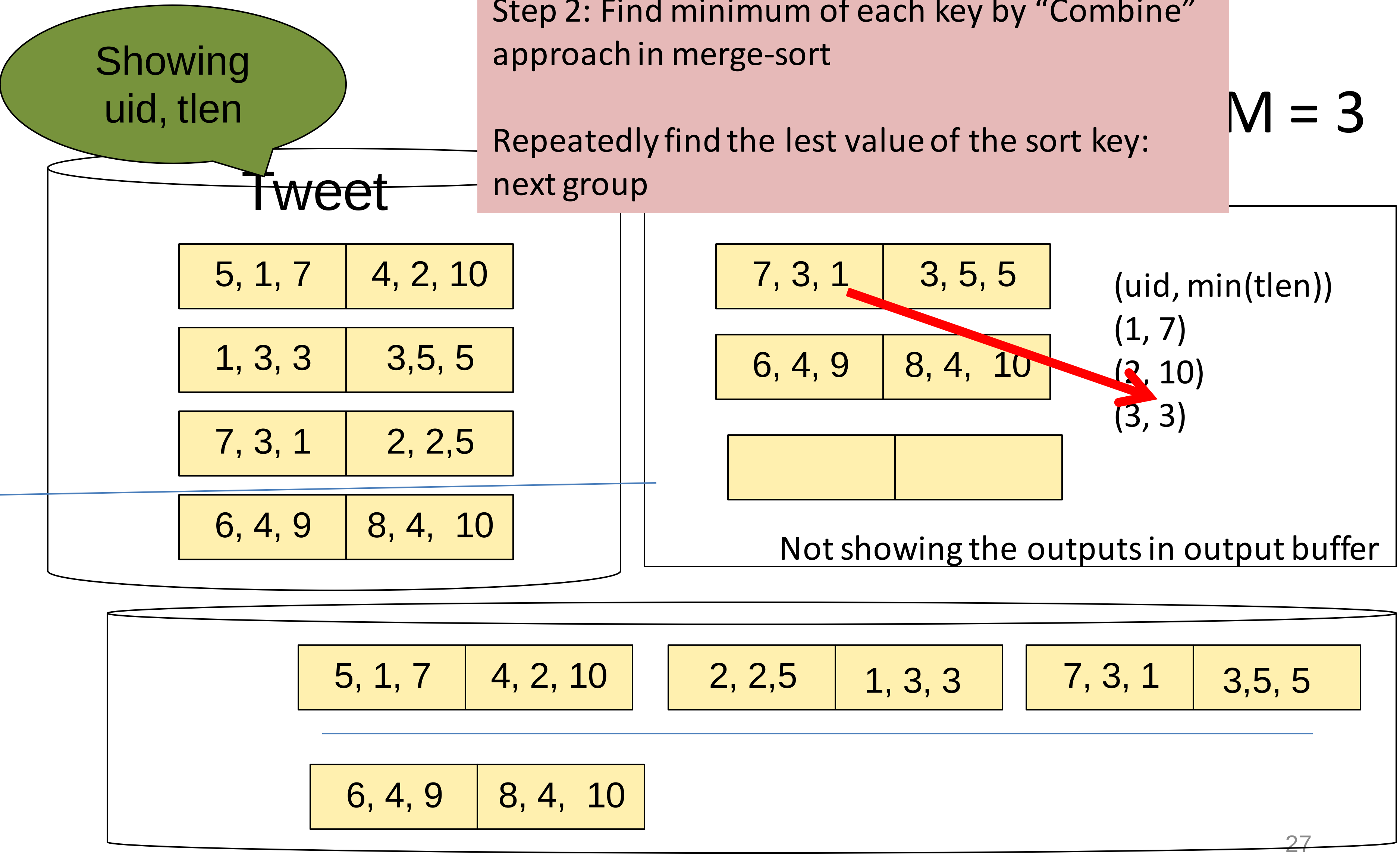
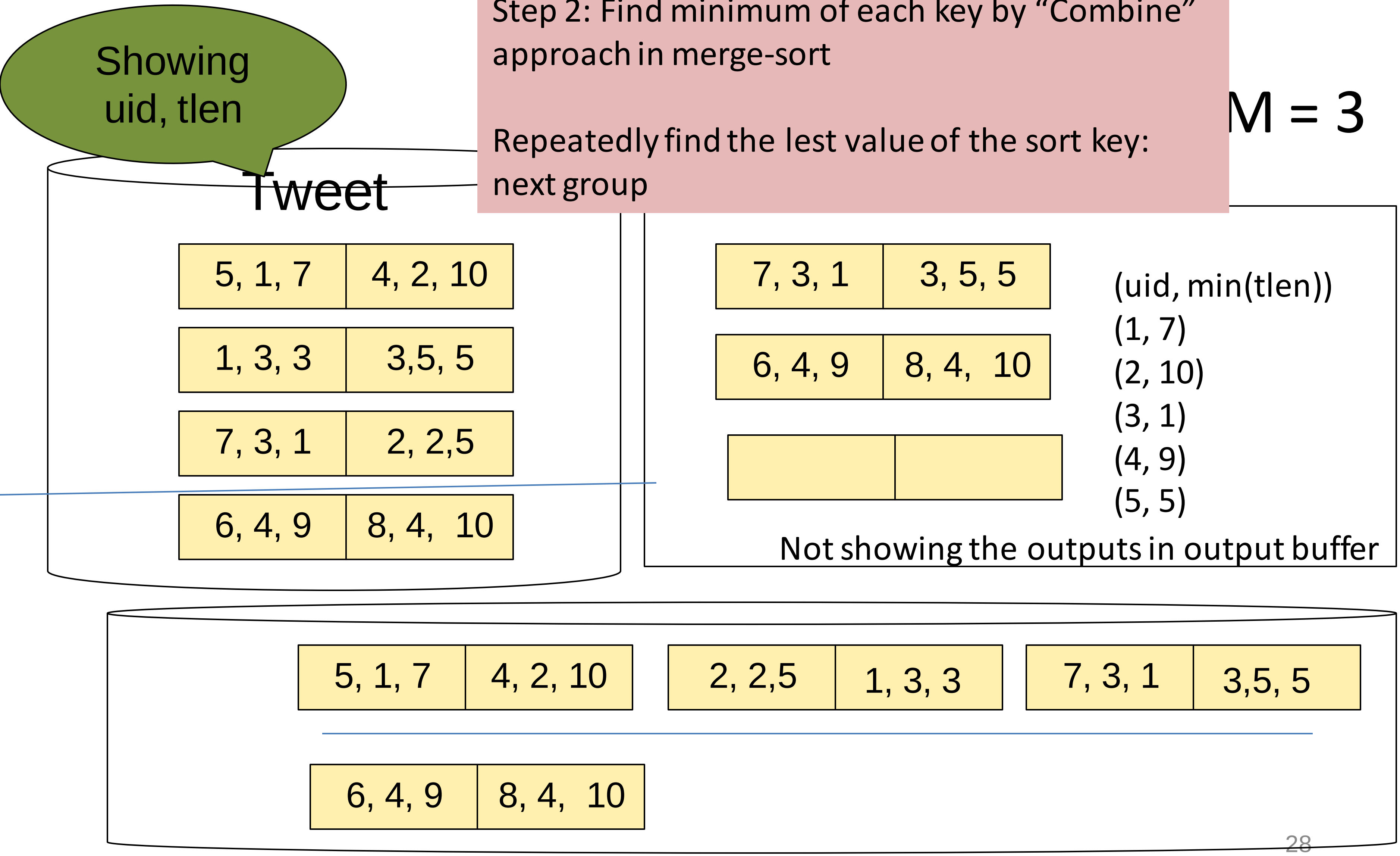


Two pass, sort-merged-based grouping

Step 2: Find minimum of each key by "Combine" approach in merge-sort

Repeatedly find the lest value of the sort key: next group



Discussion: Problem 2c

Cost?

- 3B(R)

Assumptions?

- Need to hold one block from each run in M pages
- $B(R) <= M^2$

Merge-sort based single pass algorithm?

- Not good here: same IO cost, more CPU cost

One pass vs. Two pass

- One pass:
  - smaller disk I/O cost
    - e.g. B(R) for one-pass hash-based aggregation
  - Handles smaller relations
    - e.g. B(R) <= M

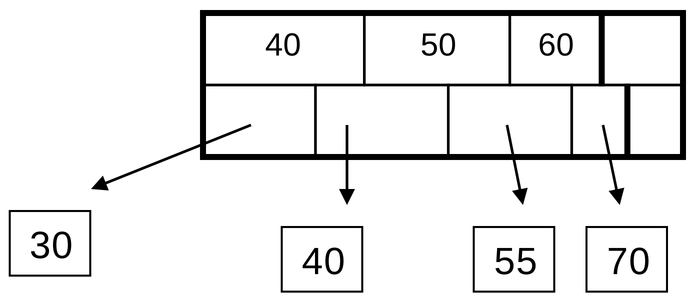
- Two/Multi pass:
  - Larger disk I/O cost
    - e.g. 3B(R) for two-pass hash-based aggregation
  - Can handle larger relations
    - e.g. $B(R) <= M^2$

Review

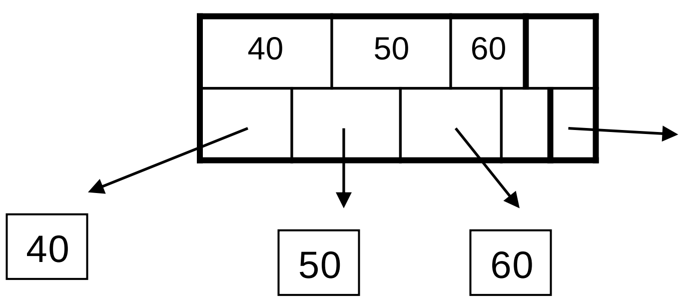
- Two-pass Hash-based Join
  - Cost: 3B(R) + 3B(S)
  - Assumption: Min(B(R), B(S)) <= M^2
- Two-pass Sort-merge-based Join
  - Implementation 1:
    - Cost: 5B(R) + 5B(S)
      - For R, S: sort runs/sublists (2 I/O, read + write)
      - Merge sublists to have entire R, S sorted individually (2 I/O, read + write)
      - Join by combining R and S (only read, write not counted - 1 I/O)
    - Assumption: B(R) <= M^2 , B(S)) <= M^2
  - Implementation 2:
    - Cost: 3B(R) + 3B(S)
    - Assumption: B(R) + B(S) <= M^2

Problem 1
Insertions and Deletion in a B+ tree

- On whiteboard, see the scanned example
- Note: the <, <= assumptions in this class:



Internal node:
- Left pointer from key = k: to keys < k
- Right pointer: to keys >= k



Leaf node:
- Left pointer from key = k: to the block containing data with value k in that attribute
- Last remaining pointer on right: To the next leaf on right

Problem 1
Insertions and Deletion in a B+ tree

- Note: when a leaf is split, the middle (d+1-th) key is copied to the new leaf on right (and also inserted in parent)
  - Since we assumed the right pointer from key = k points to keys >= k

- Note: when an internal node is split, we do not need to copy the middle (d+1-th) key to the right, only insert it in parent
  - Use the left pointer of the new right internal node.
  - See the scanned example