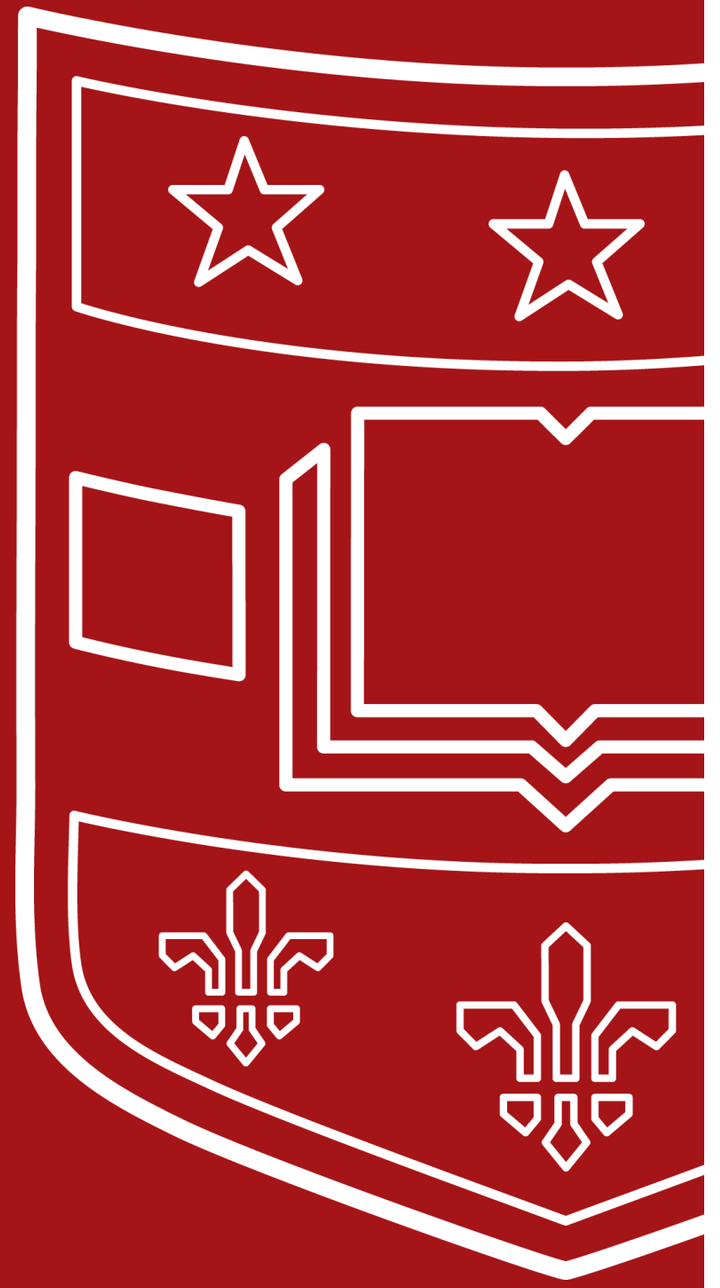
Database Management Systems

- B+ Trees



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Structure

- Internal Nodes
- Leaf Nodes
- How is this an advantage over b-trees?

Key Terms

- K is the value being searched for / inserted / deleted

- b is called the fanout
  - What dictates this?

B+ Tree Properties

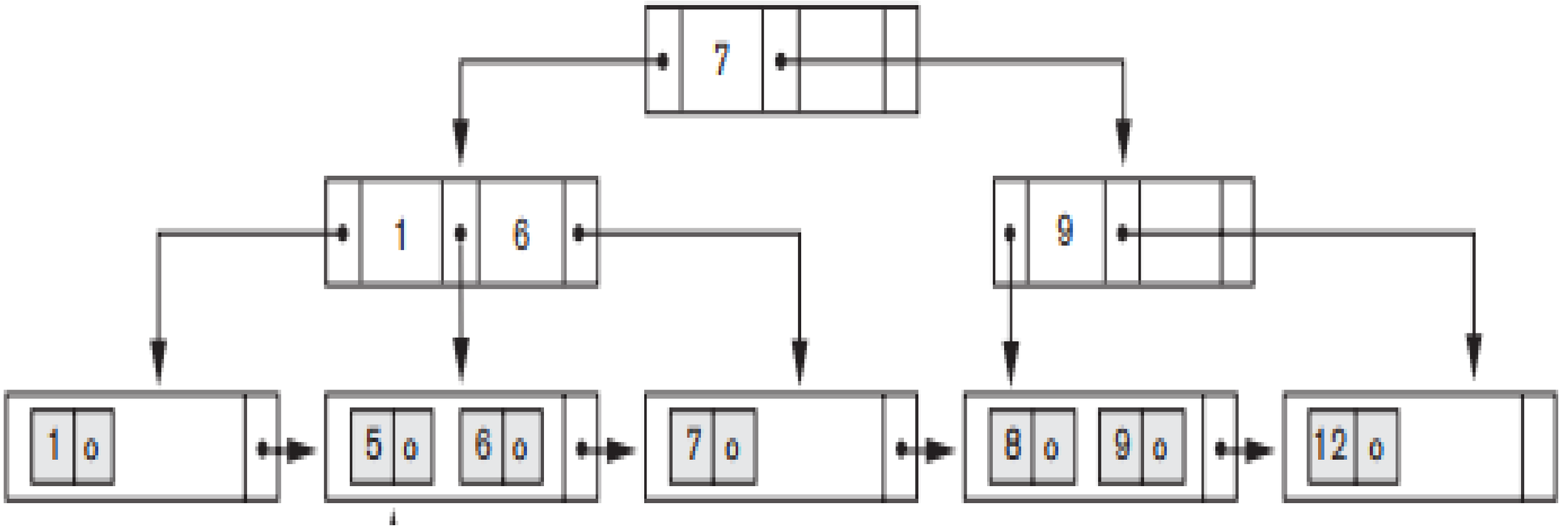
- The number of elements in a node is dictated by the degree of the tree (p):
  - Internal Nodes (children): ciel(p/2) → p
    - Exception: root
    - Minimum number of search keys?
  - Leaf nodes (keys): ciel(p/2) → p

- The degree of the inner nodes and leaf nodes does not have to be the same

Searching

Function search(k, node):
  if node is a leaf
    return node
  else
    if $k < k_0$
      return search(k, p_0)
    else if $k > k_q$
        return search(k, p_q)
      else
        Find value k_i such that $k_i < k < k_{i+1}$
        return search(k, p_{i+1})

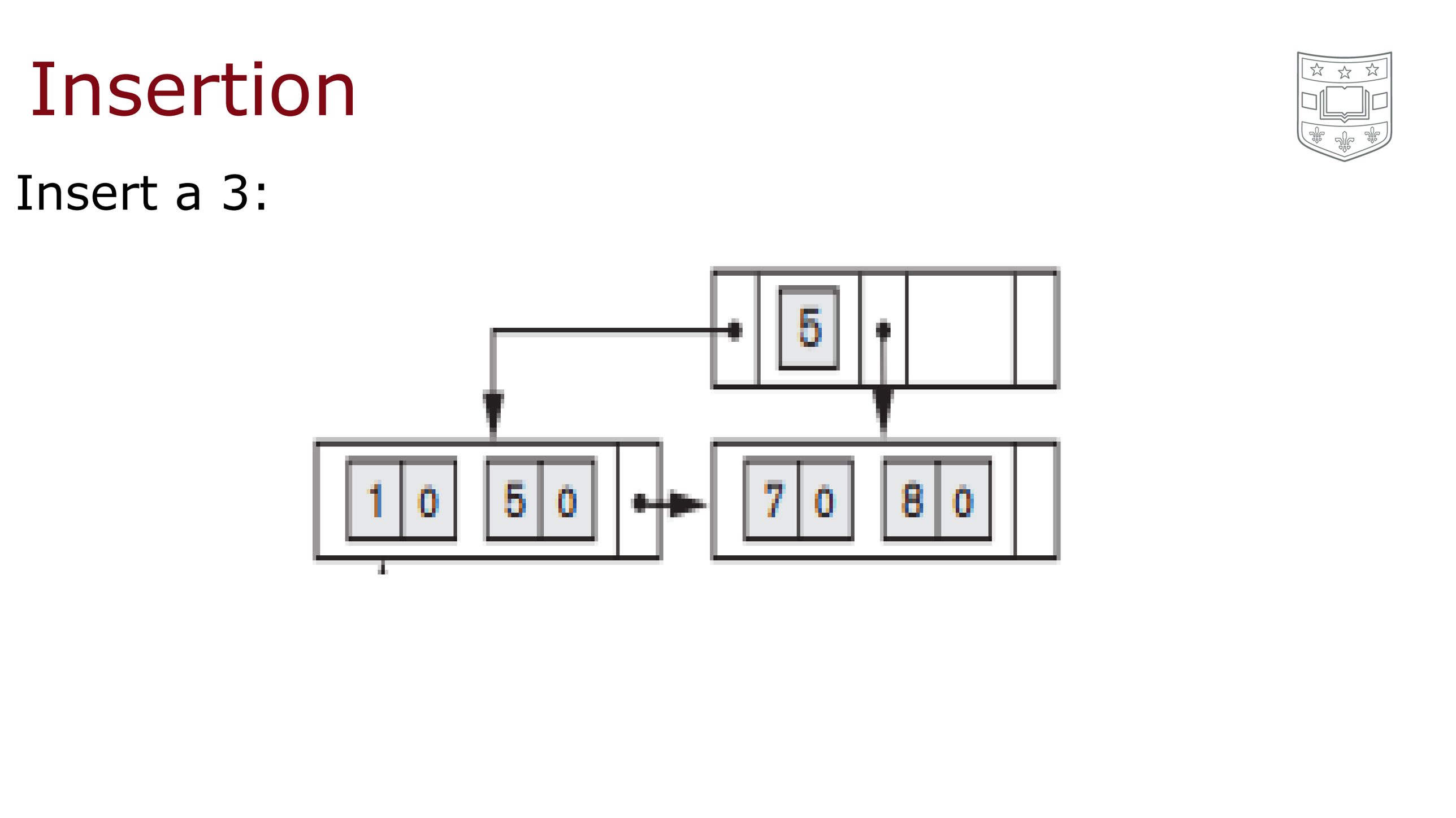
Search Example



Insertion

Search for the node where the new record should go
If the target node is not full, add the record
else:
    Make a new node that contains half the values of the old one
    Insert the largest key of the new node into the parent
    If the parent is full:
        Split the parent and add the middle key to its parent
        Repeat until a split is not needed
    If the root needs to split:
        Create a new root with one key and two pointers

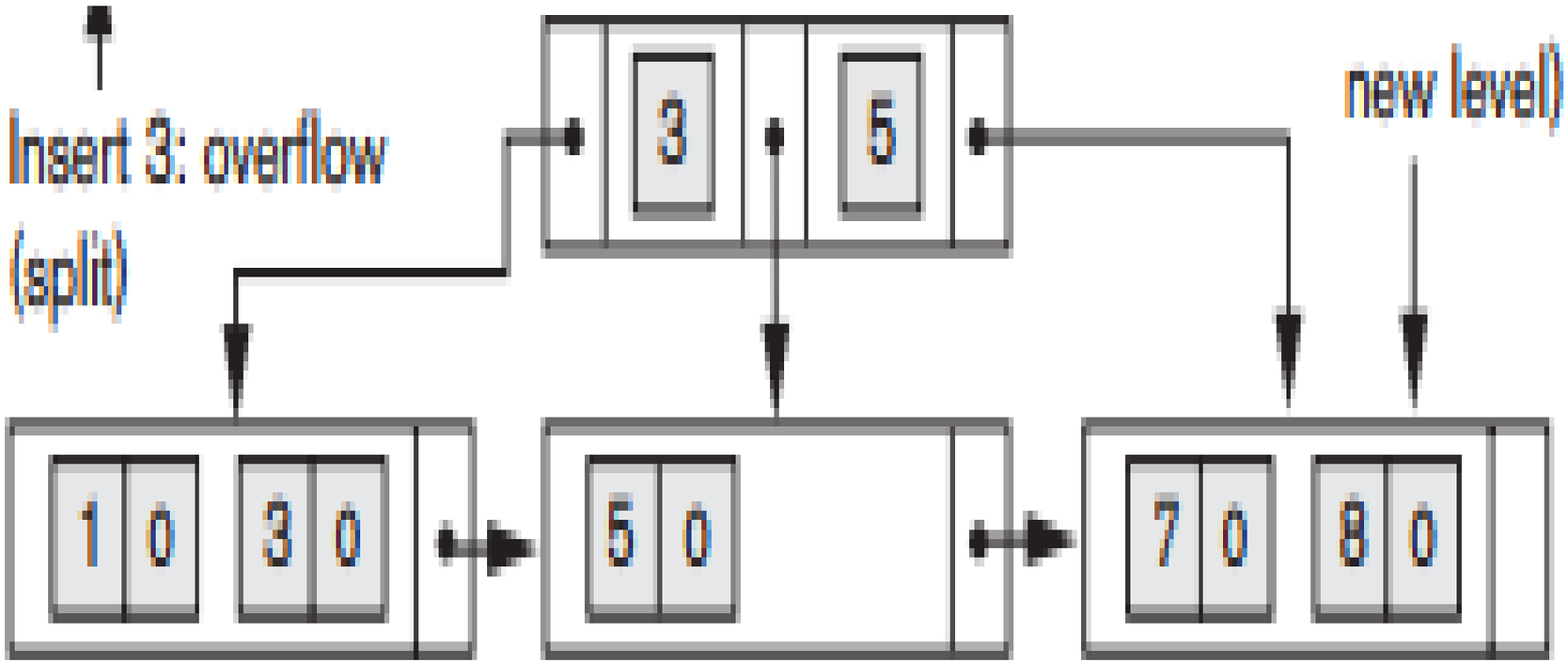
Insertion



Insert a 3:

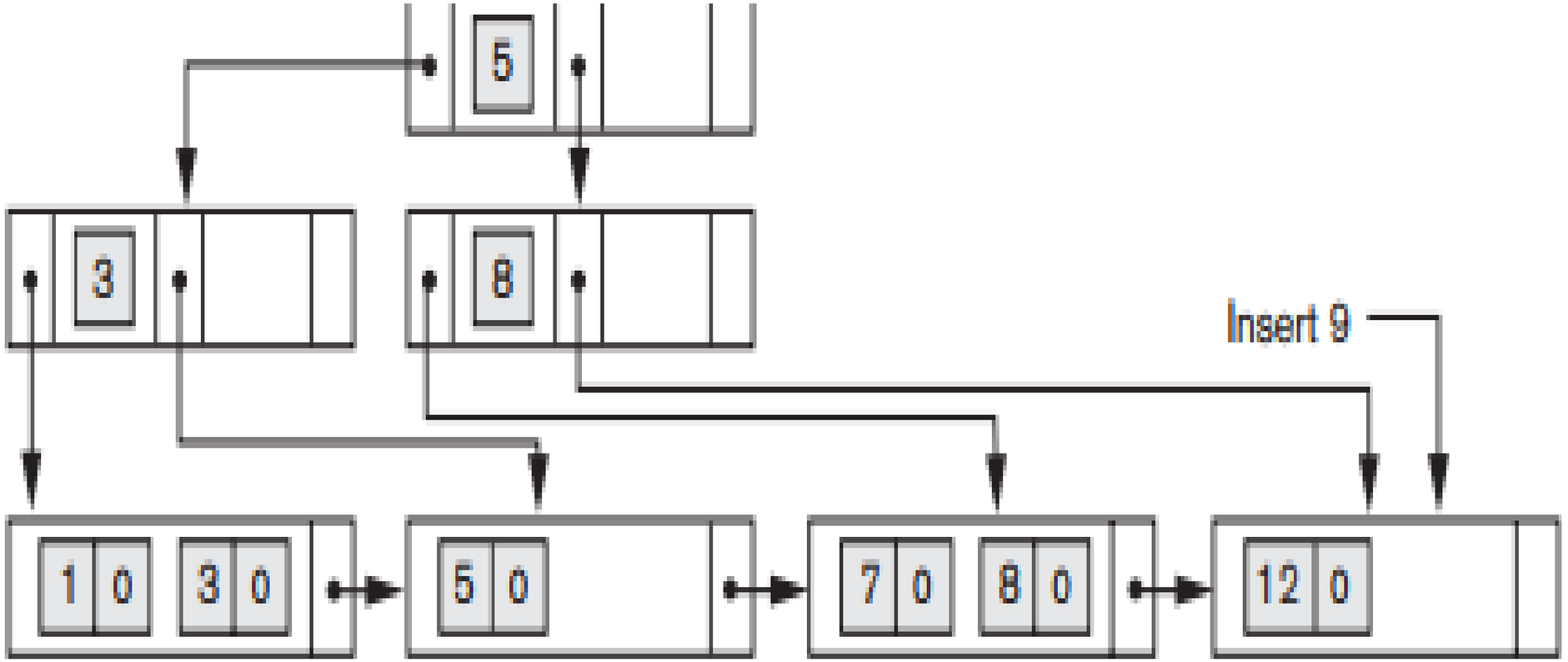
Insertion

Insert a 12:



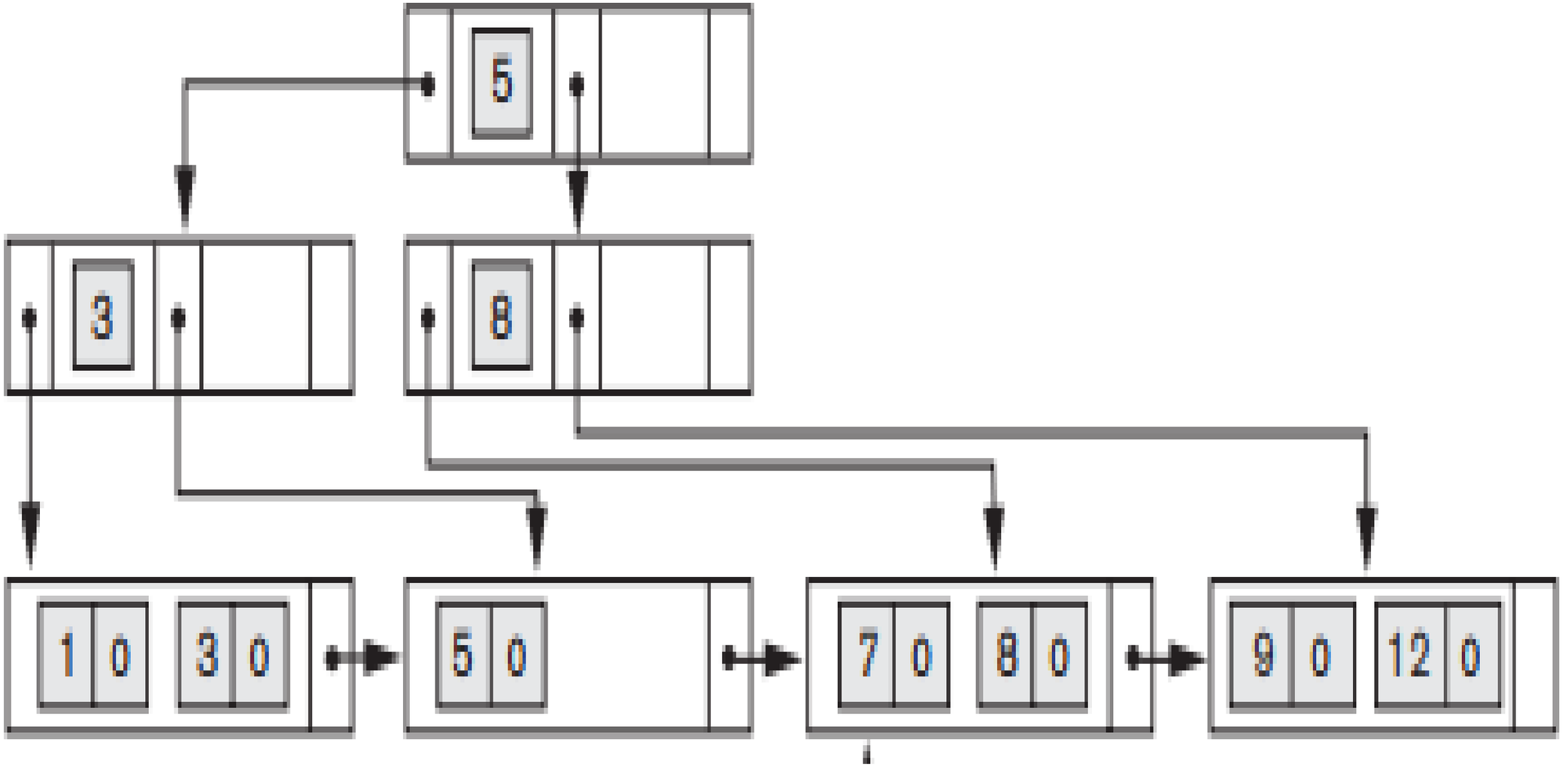
Insertion

Insert a 9:



Insertion

Insert a 6:



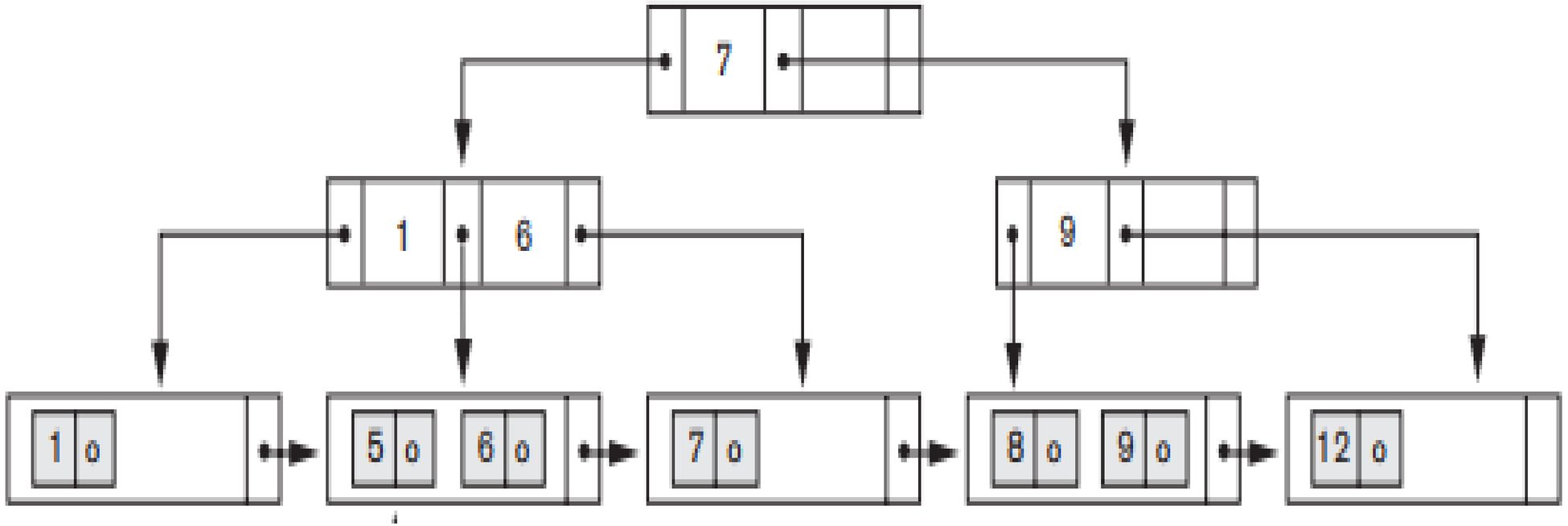
Deletion

Search for the node where the new record should go
If the node is more than half full, remove entry and done
Else:
  If sibling (with same parent) is more than half full, take an entry from it, update parent
  Otherwise
    - Merge node with sibling
    - Delete entry from parent of removed node
    - May cause parents to merge

  – Merging internal nodes:
    - Grab value from sibling and “push through”
    - Update pointers

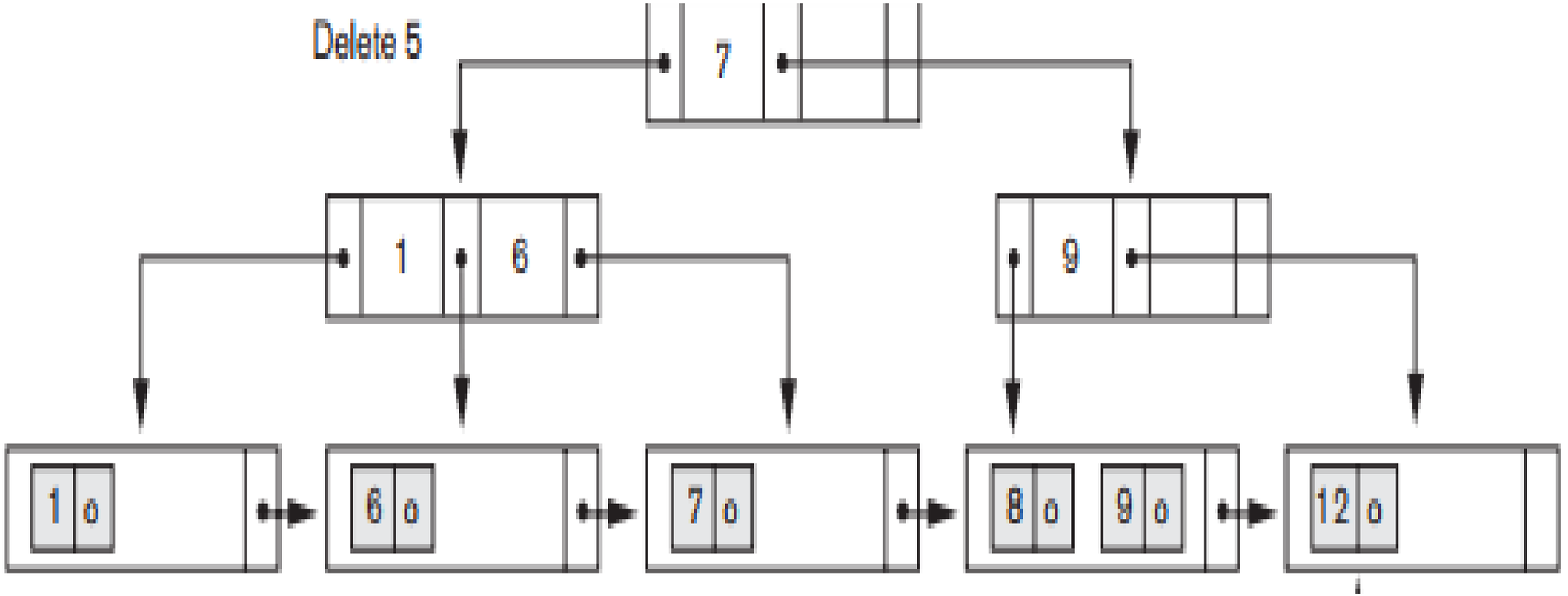
Deletion

Delete 5:



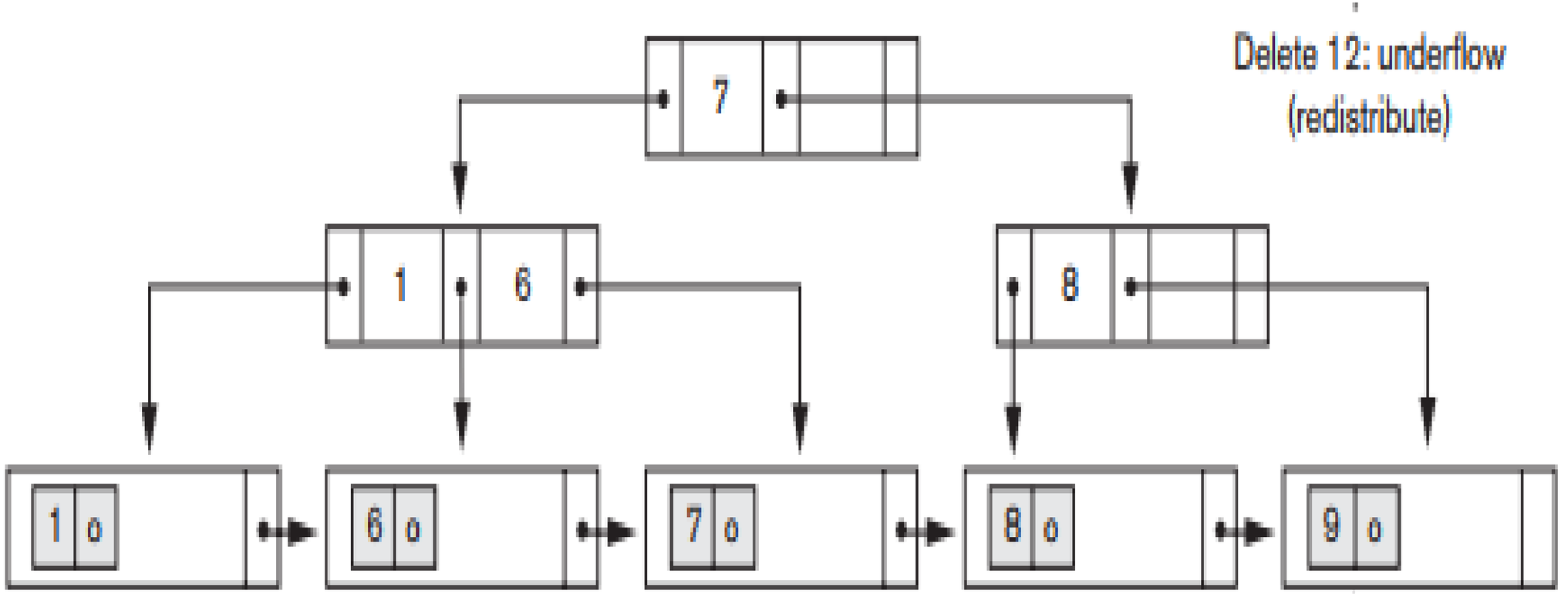
Deletion

Delete 12:



Deletion

Delete 9:



Exercise

Using a btree with $p_{inner} = 3$ and $p_{leaf} = 2$, sketch the result of the insertion of the following values:

9, 4, 12, 7, 2, 6, 1, 3, 10

Repeat the above example with a btree with $p_{inner} = 4$ and $p_{leaf} = 3$

Exercise

Using the btree (p_{inner} = 3 and p_{leaf} = 2)from the previous exercise, show the result of deleting the following values:

7, 3, 4, 10, 2

Repeat the above example with your p_{inner} = 4 and p_{leaf} = 3 tree

Indexing in SQL

- What columns should we be indexing?
  - Should we just index all columns?

- What part of the query process is affected by the index?

SQL Example

- CREATE INDEX name_idx on Student (lname);

- Can include multiple columns as part of an index
  - How does this affect the index structure?

Exercise

- Revisit your course tracking database. Decide what columns would be worthy of an index, and create them.