# 15-415/615
# Database Applications
# Fall 2015

# HW3: B+ Tree (Recitation)

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# Overview

- You are given a basic B+ tree implementation
- **Task**: extend the B+ tree implementation for new operations
- **Goal**: get familiar with B+ tree and recursive code that manipulates the tree & pages

# Roadmap

- ➡ B+ tree overview
- This B+ tree package
- To be implemented
- Makefile (for your convenience)
- Example insertion algorithm

# Why B+ tree?

- Efficient indexing for block I/O devices
- Block I/O devices (e.g. HDD)
  - Access latency is large (in milliseconds)
- B+ tree
  - Large fan out and balanced
  - Shallow – find a key with only a few disk reads
  - B+ tree vs. B tree:
    Store all values on leaves to for more compact index
- For more details, see the lecture slides

# Basic B+ Tree Implementation

- Creates an “inverted index” in the form of a B+ tree
  - key: *word*, value: *document name*
- Supports: insert, scan, search, print
- No duplicate keys are allowed
- No support for deletion
- The tree is stored on disk

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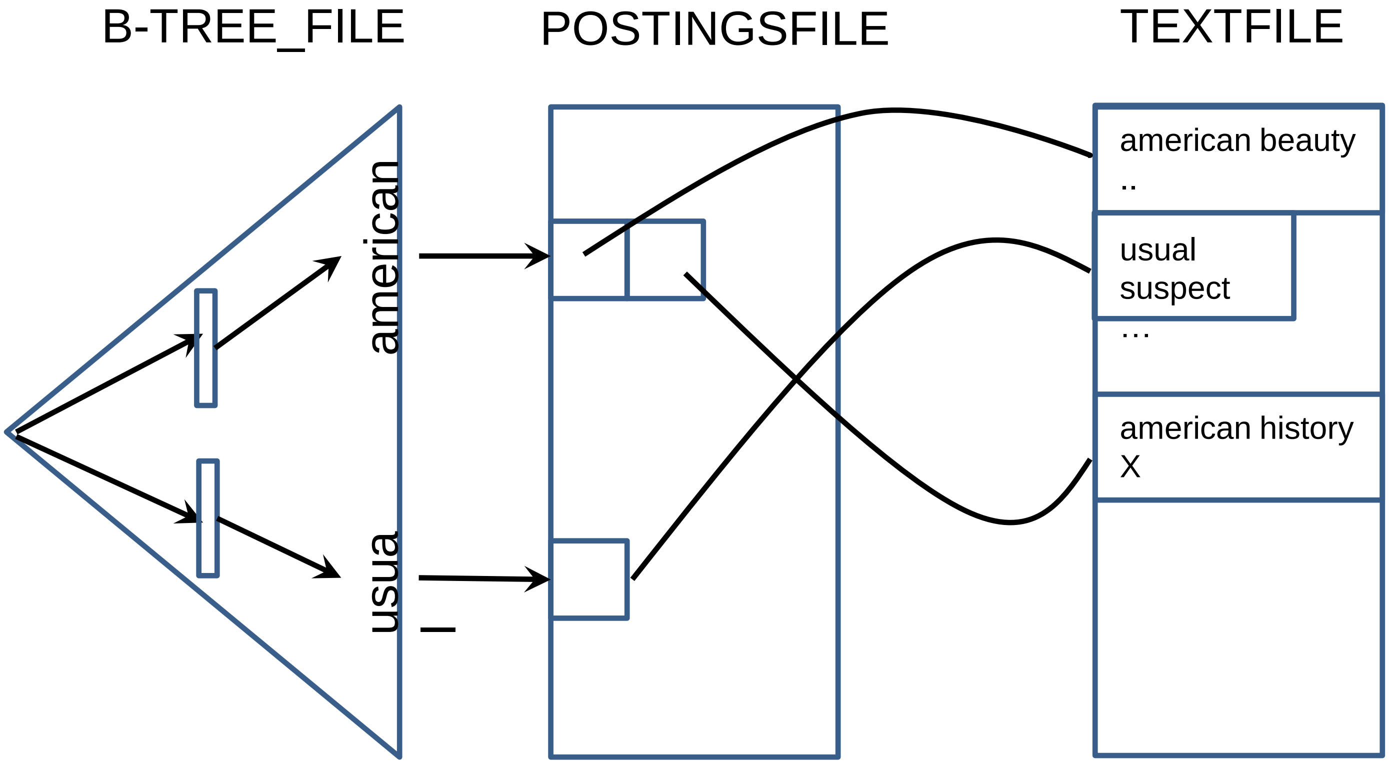
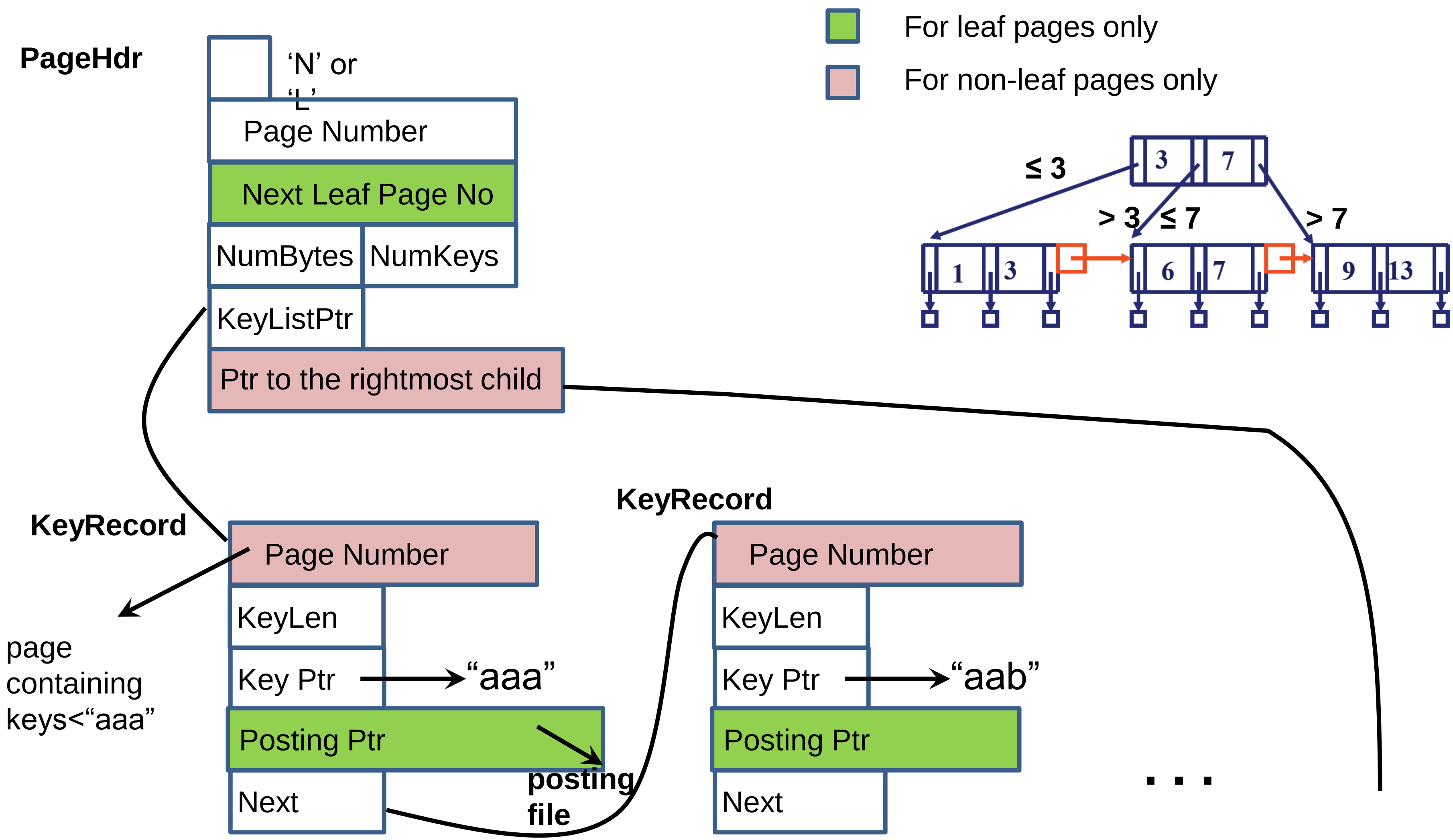
# B+ Tree Package

- Folders
  - **DOC**: documentation
  - **SRC**: source code
  - **Datafiles** : sample document data
  - **Tests**: test files
- B-TREE_FILE, POSTINGSFILE, TEXTFILE, parms are created by the b+ tree.
  - Want a new tree? Delete them

# B+ Tree Structure



# Structure of a Page (def.h)



🟩 For leaf pages only

🟥 For non-leaf pages only

**PageHdr**

- ‘N’ or ‘L’
- Page Number
- Next Leaf Page No
- NumBytes
- NumKeys
- KeyListPtr
- Ptr to the rightmost child

**KeyRecord**

- Page Number
- KeyLen
- Key Ptr → “aaa”
- Posting Ptr → **posting file**
- Next

page containing keys<“aaa”

**KeyRecord**

- Page Number
- KeyLen
- Key Ptr → “aab”
- Posting Ptr
- Next

. . .

# Existing Functions

- **C** : print all the keys
- **i <document_name>** : insert the document
  - key: word, value: document_name
- **p <page_no>** : print the info on the page
- **s <key>** : search the key
- **S <key>** : search the key, and print the documents
- **T** : print the tree

# Example code, for searching

- search.c
  - search function entrance, used in main.c
  - calls *treesearch* to locate the page to which the key belongs
- treesearch.c (study this carefully!)
  - recursive call to locate the page for the key
  - calls *FindPageNumOfChild* to find the correct children (looks down)
- FindPageNumOfChild.c
  - traverse a non-leaf page

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# To be implemented: count (#)

- Should display the number of pages fetched by the command prior to this
- Print and reset
- Hint: Try to leverage existing functionalities

# To be implemented: Left & Right Bracket Ops

- Right bracket – “]”

  Print next key without given prefix
- Left bracket – “[”

  Print previous key without given prefix
- Return *NONE* if no key satisfies the requirement
  - Note the *’s

# Left & Right Bracket Examples

- Dictionary: {“abraham”, “clara”, “peter”, “peterson”, “tom”}
- [ “pet” -> “clara”
- ] “pet” -> “tom”
- ] “zebra” -> *NONE*
- [ “ab” -> *NONE*

# Keep in Mind

- The ‘count’ is not a hard limit.
  - May not exactly match the reference count
  - Should be reasonable
- A fully sequential scan is a strict no-no
  - Will show up as a very large count
- Will be graded to check for efficiency later.
  - Again ‘sequential’ scans will be penalized
- Understand the provided infrastructure before starting!

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# Build Infra (makefile)

- make load
  - Initialize the tree
  - Insert all datafiles
- make test_sanity
  - Runs load
  - Tests the very minimal functionality. No diffs = test pass!
  - make sure the **output is formatted correctly**. This is **absolutely** necessary for autograding.
- make test_leftbracket/make test_rightbracket
  - The questions asked in the handout

# Testing Mechanism

- Correctness
  - output the correct list of words (don’t forget to check all the corner cases!)
- Format
  - Make sure the output follows the **same format as the sanity test** solutions.

# Hand-in

- Create a **tar file** of your source code, as well as the makefile. (make handin)
- **Hard-copy** of a document with the functions that you modified/added.
- Please make sure that the “make” command compiles all the source code without any errors
- Submit **your code** on blackboard.

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# Insertion Visualized

- insert [3, 7, 13, 9, 1, 6] into an empty tree
- B+ tree is of order 3
- note the number of children allowed

**Singleton: [1, b-1]**

**Root: [2, b]**

**Internal: [ceil(b/2), b]**

**Leaf: [ceil(b/2), b-1]**

# Insertion: 3 -> []

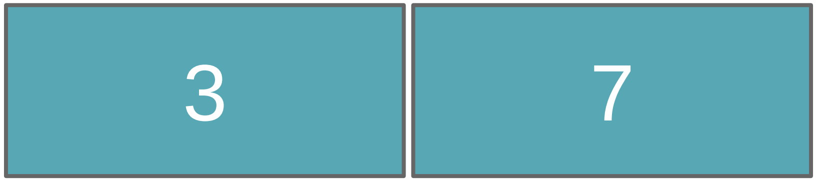
**Singleton: [1, b-1]**

**Root: [2, b]**

**Internal: [ceil(b/2), b]**

**Leaf: [ceil(b/2), b-1]**

# Insertion: 7 -> [3]



**Singleton: [1, b-1]**

**Root: [2, b]**

**Internal: [ceil(b/2), b]**

**Leaf: [ceil(b/2), b-1]**

# Insertion: 13 -> [3, 7]

| | | |
|---|---|---|
| 3 | 7 | 13 |

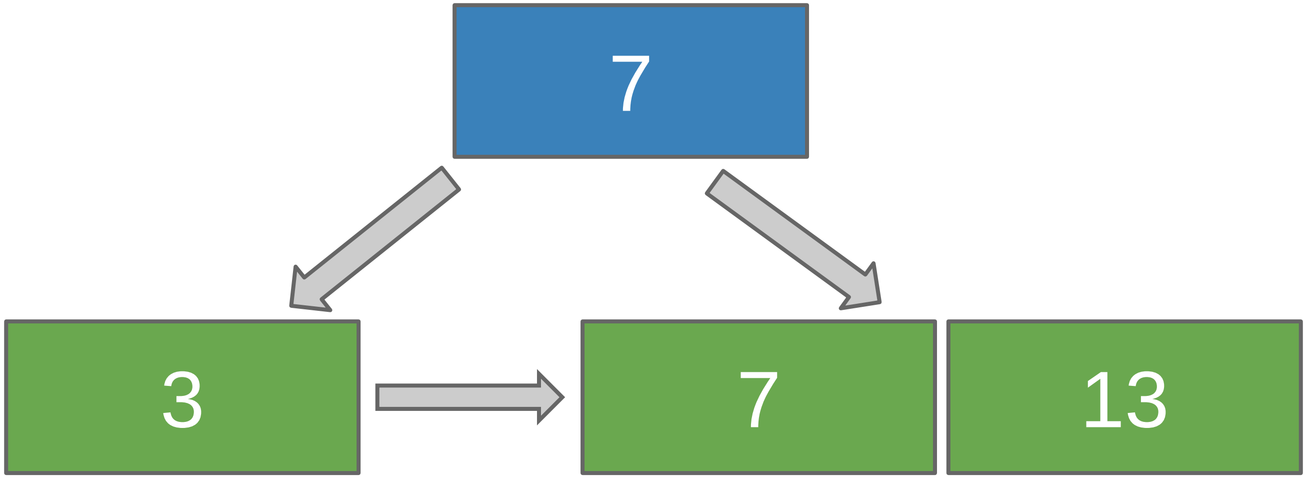
Singleton: [1, b-1]

Root: [2, b]

Internal: [ceil(b/2), b]

Leaf: [ceil(b/2), b-1]

# Insertion: 13 -> [3, 7]



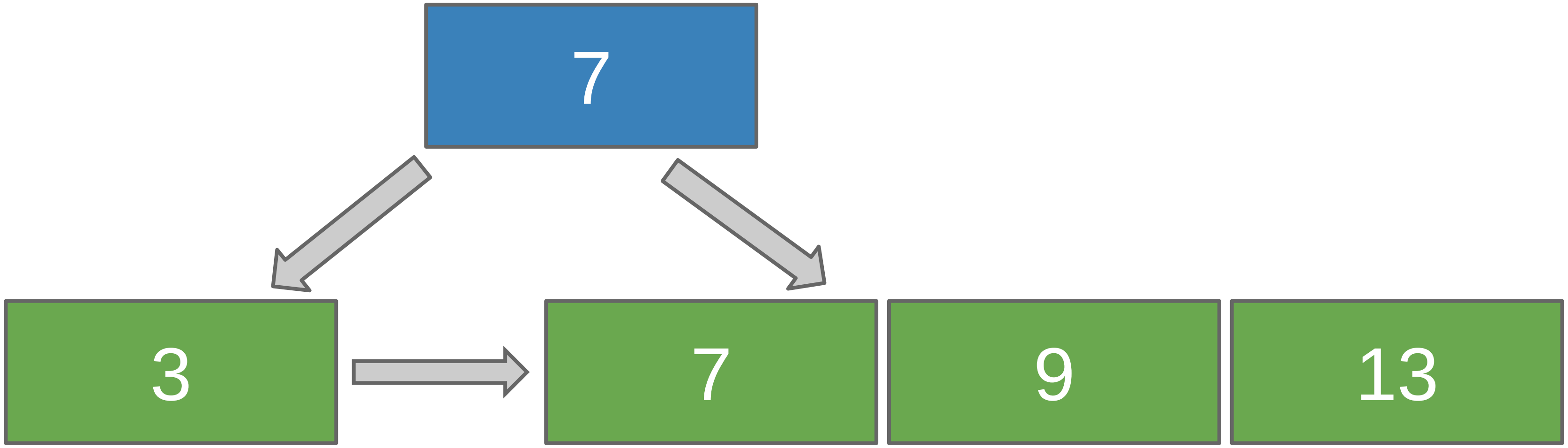
Singleton: [1, b-1]

Root: [2, b]

Internal: [ceil(b/2), b]

Leaf: [ceil(b/2), b-1]

# Insertion: 9 -> [3, 7, 13]

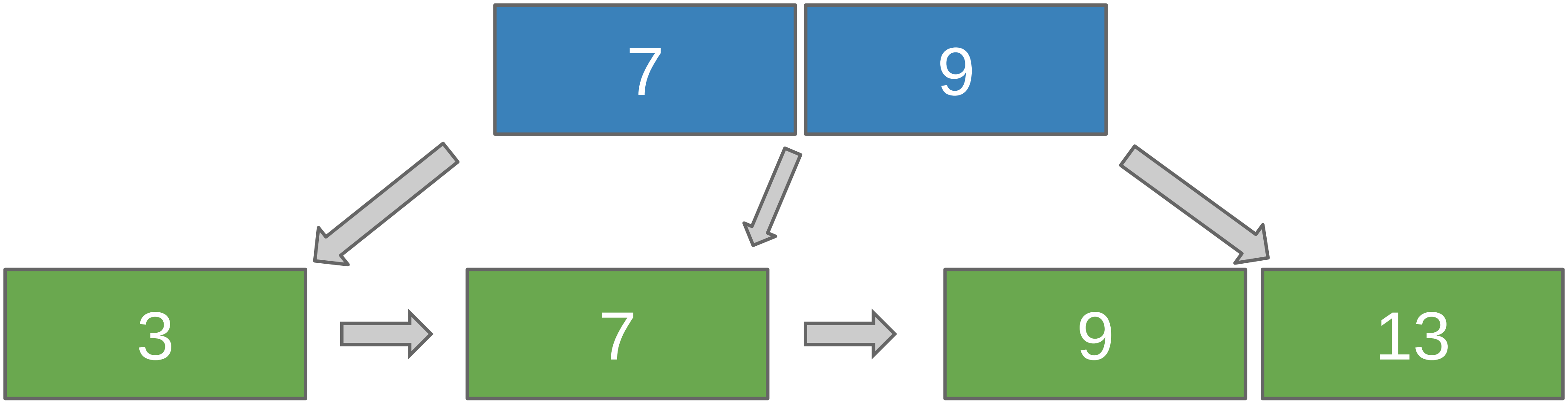


Root: [2, b]

Internal: [ceil(b/2), b]

Leaf: [ceil(b/2), b-1]

# Insertion: 9 -> [3, 7, 13]

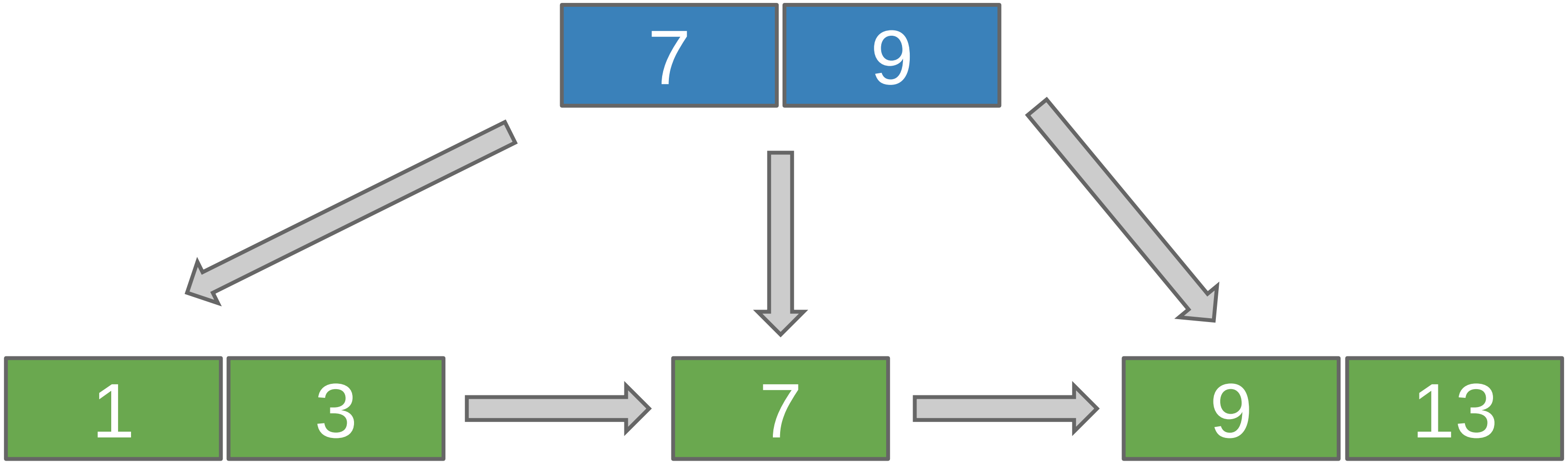


Root: [2, b]

Internal: [ceil(b/2), b]

Leaf: [ceil(b/2), b-1]

# Insertion: 1 -> [3, 7, 9, 13]

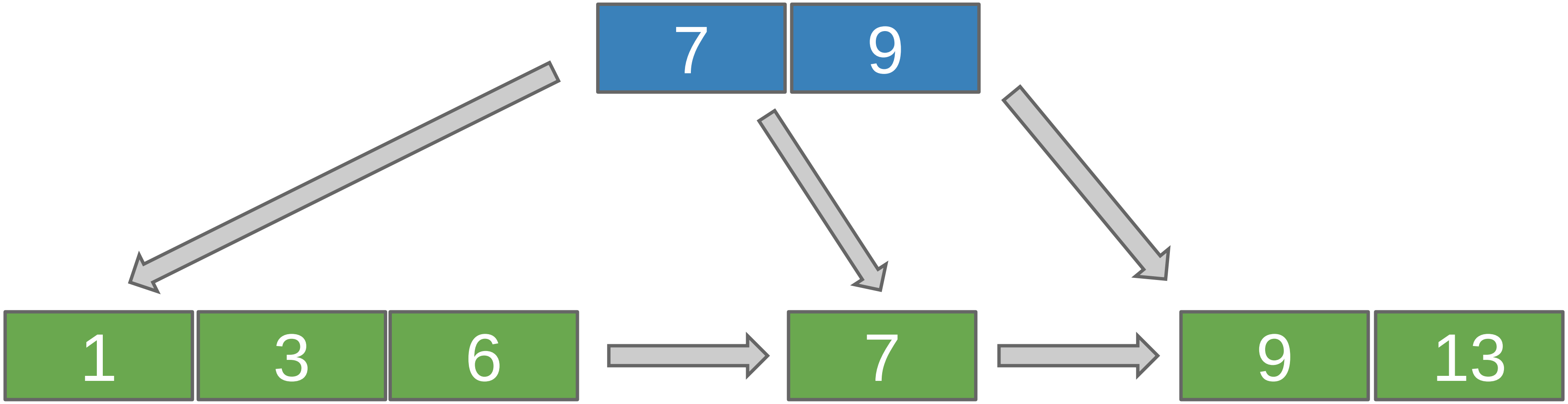


Root: [2, b]

Internal: [ceil(b/2), b]

Leaf: [ceil(b/2), b-1]

# Insertion: 6 -> [1, 3, 7, 9, 13]

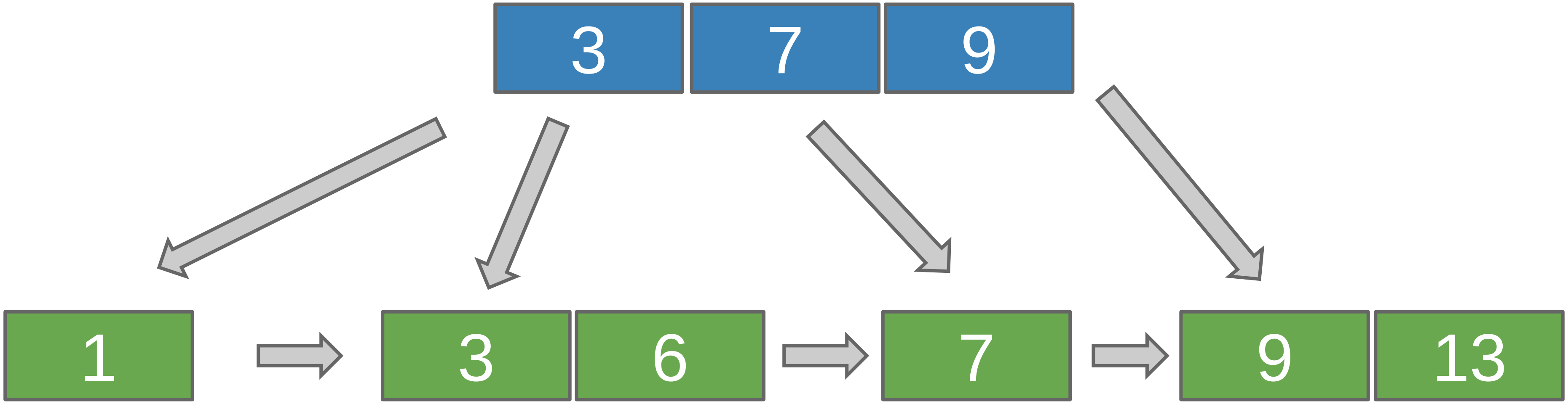


Root: [2, b]

Internal: [ceil(b/2), b]

Leaf: [ceil(b/2), b-1]

# Insertion: 6 -> [1, 3, 7, 9, 13]

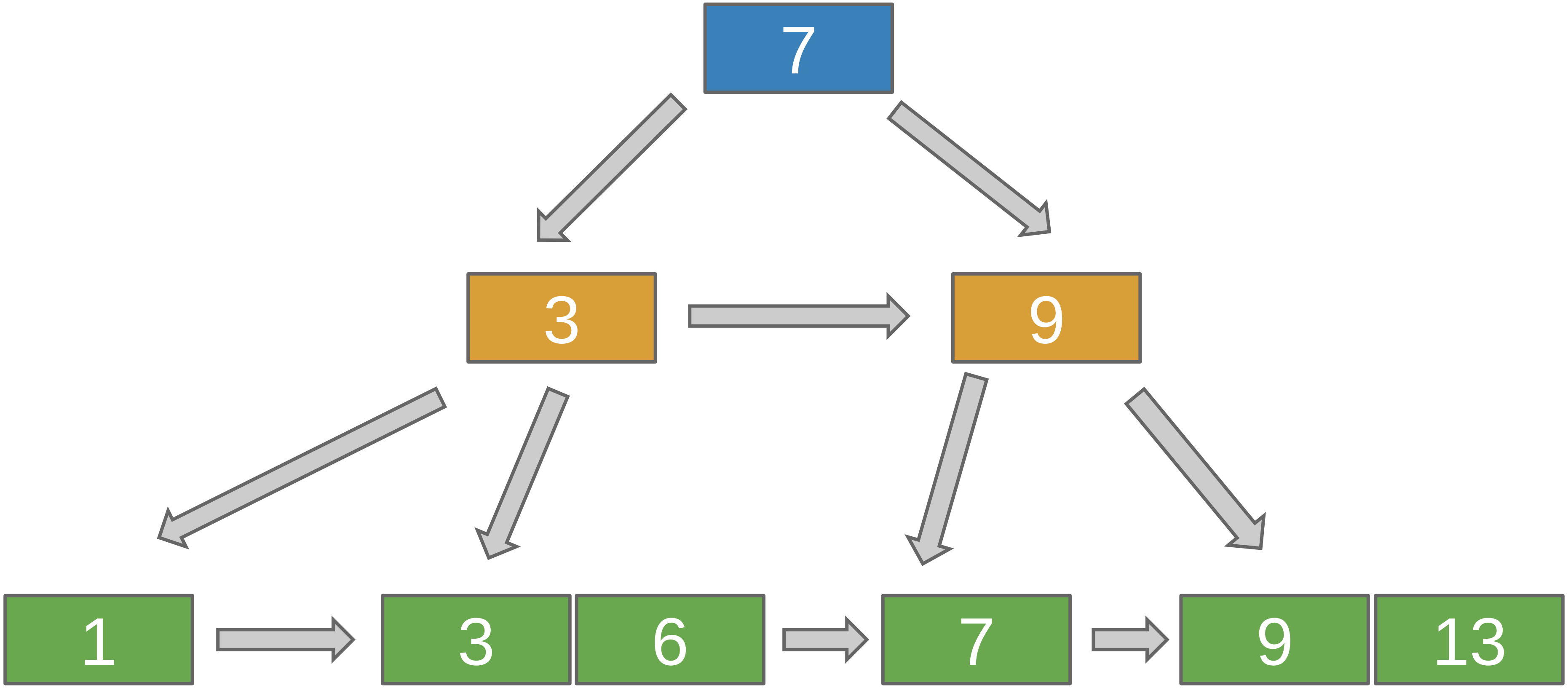


Root: [2, b]

Internal: [ceil(b/2), b]

Leaf: [ceil(b/2), b-1]

# Insertion: [1, 3, 6, 7, 9, 13]



Leaf: [ceil(b/2), b-1]

Root: [2, b]

Internal: [ceil(b/2), b]

# Questions?

- Come to office hours (5 TAs + instructor)
- Read the handout before starting
- Post your questions on blackboard
- Start early