File Organizations

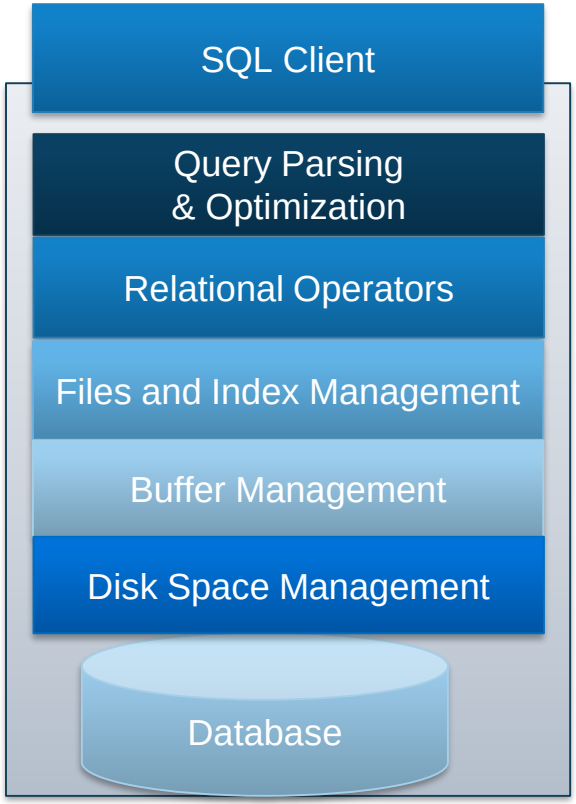
R & G - Chapter 9

Architecture of a DBMS

Completed

And We'll Visit

You are Here



Recall: Heap Files

- Unordered collection of records

- Recall API for higher layers of the DBMS.
  Today we'll ask: "How? At what cost?"
  - Insert/delete/modify record
  - Fetch a particular record by ***record id*** …
    - Record id is a pointer encoding pair of (**pageID, location** on page)
  - Scan all records
    - Possibly with some conditions on the records to be retrieved

Recall: Multiple File Organizations

Many alternatives exist, each good in some situations and less so in others.

This is a theme in DB systems work!

- **Heap Files:** Suitable when typical access is a full scan of all records
- **Sorted Files:** Best for retrieval in order, or when a range of records is needed
- **Clustered Files & Indexes:** Group data into blocks to enable fast lookup *and* efficient modifications.
  - More on this soon …

Bigger Questions

- What is the “best” file organization?
  - Depends on access patterns …
  - How? What are common access patterns anyway?
- Can we be quantitative about tradeoffs?
  - If one is better … by how much?

Goals

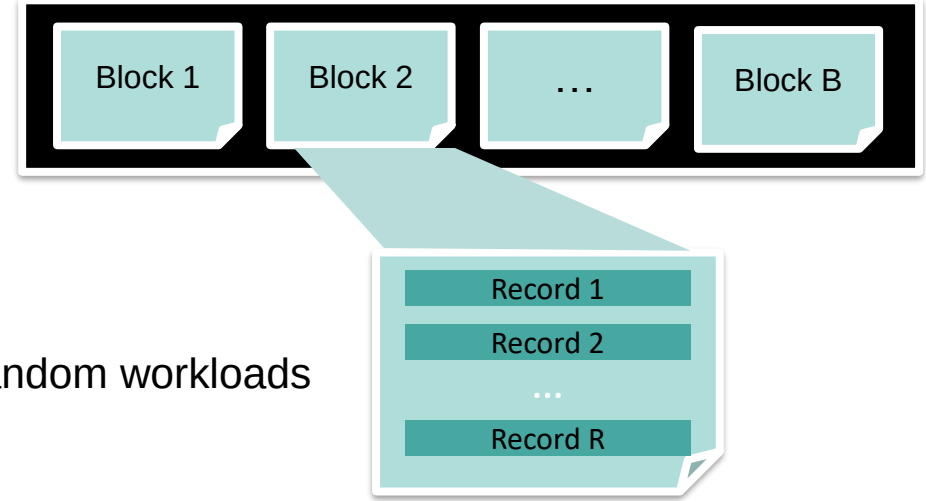
- Big picture overheads for data access
  - We'll (overly) simplify performance models to provide insight, not to get perfect performance
  - Still, a bit of discipline:
    - **Clearly identify assumptions up front**
    - **Then estimate cost in a principled way**

- Foundation for query optimization
  - Can't choose the fastest scheme without an estimate of speed!

COST MODEL AND ANALYSIS

Cost Model for Analysis

- **B**: The number of data blocks in the file
- **R**: Number of records per block
- **D**: (Average) time to read/write disk block



- Focus: Average case analysis for uniform random workloads
- For now, we will ignore
  - Sequential vs Random I/O
  - Pre-fetching
  - Any in-memory costs
- Good enough to show the overall trends

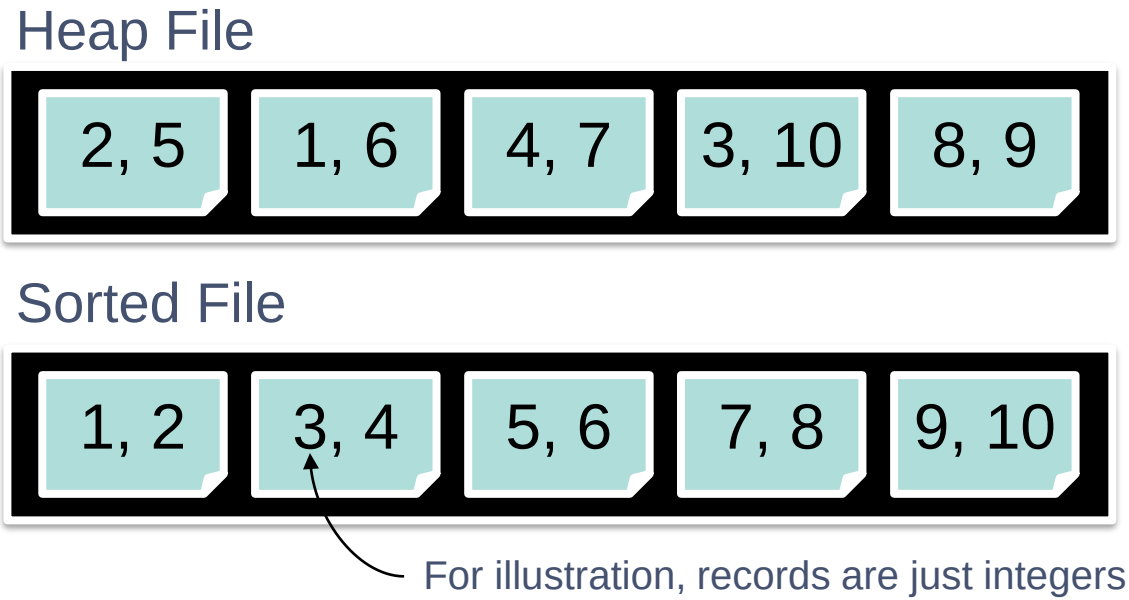
More Assumptions

- **Single record** insert and delete
- Equality selection – **exactly one match**
- For Heap Files:
  - Insert always **appends to end of file.**
- For Sorted Files:
  - **Packed**: Files compacted after deletions.
  - Sorted according to search key

Extra Challenge

- After understanding these slides …
  - You should question all these assumptions and rework
  - Good exercise to study for tests, and generate ideas

Heap Files & Sorted Files



- **B:** The number of data blocks = 5
- **R:** Number of records per block = 2
- **D:** (Average) time to read/write disk block = 5ms

Cost of Operations: Scan?

	Heap File	Sorted File
Scan all records		
Equality Search		
Range Search		
Insert		
Delete		

- **B:** The number of data blocks = 5
- **R:** Number of records per block = 2
- **D:** (Average) time to read/write disk block = 5ms

Scan All Records

Heap File

Sorted File

- **B:** The number of data blocks
- **R:** Number of records per block
- **D:** Average time to read/write disk block
- **Pages touched: ?**
- **Time to read the record: ?**

Cost of Operations: Scan Cost

	Heap File	Sorted File
Scan all records	B*D	B*D
Equality Search		
Range Search		
Insert		
Delete		

- **B:** The number of data blocks
- **R:** Number of records per block
- **D:** Average time to read/write disk bloc

Cost of Operations: Equality Search?

	Heap File	Sorted File
Scan all records	B*D	B*D
Equality Search		
Range Search		
Insert		
Delete		

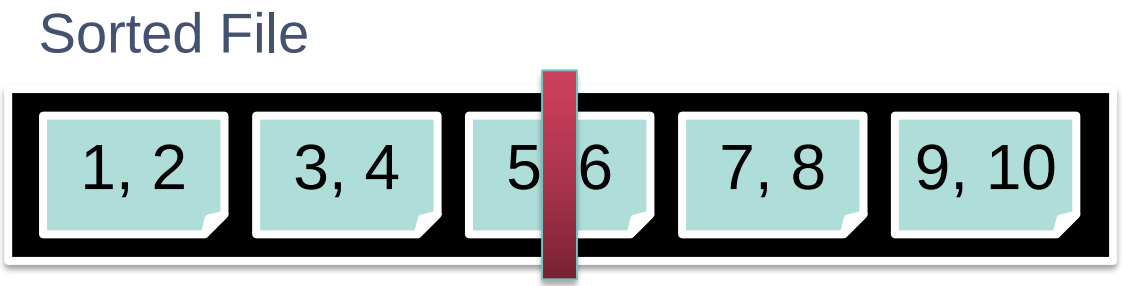
- **B:** The number of data blocks
- **R:** Number of records per block
- **D:** Average time to read/write disk block

Find Key 8: Heap File

- **P(i):** Probability that key is on page ***i*** is **1/B**
- **T(i):** Number of pages touched if key on page ***i*** is **i**
- Therefore the expected number of pages touched
- **Pages touched on average?**

$$\sum_{i=1}^{B} \mathrm{T}(i)\mathbf{P}(i) = \sum_{i=1}^{B} i\frac{1}{B} = \frac{B(B+1)}{2B} \approx \frac{B}{2}$$

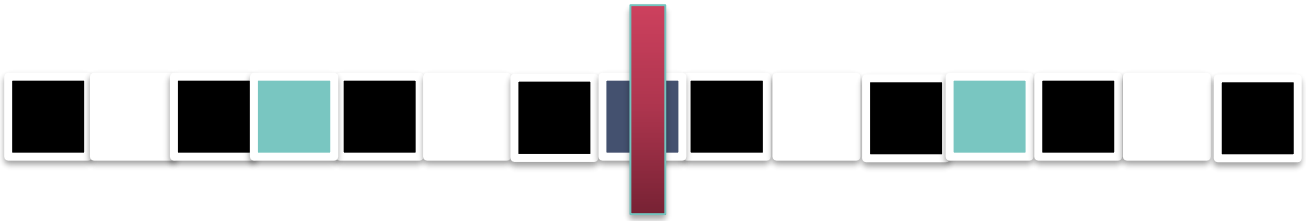
Find Key 8: Sorted File



- **Worst-case:** Pages touched in binary search
  - **$\log_2 B$**
- **Average-case:** Pages touched in binary search
  - **$\log_2 B$?**

Average Case Binary Search

Expected Number of Reads: 1 (1 / B) + 2 (2 / B) + 3 (4 / B) + 4 (8 / B)



Average Case Binary Search cont

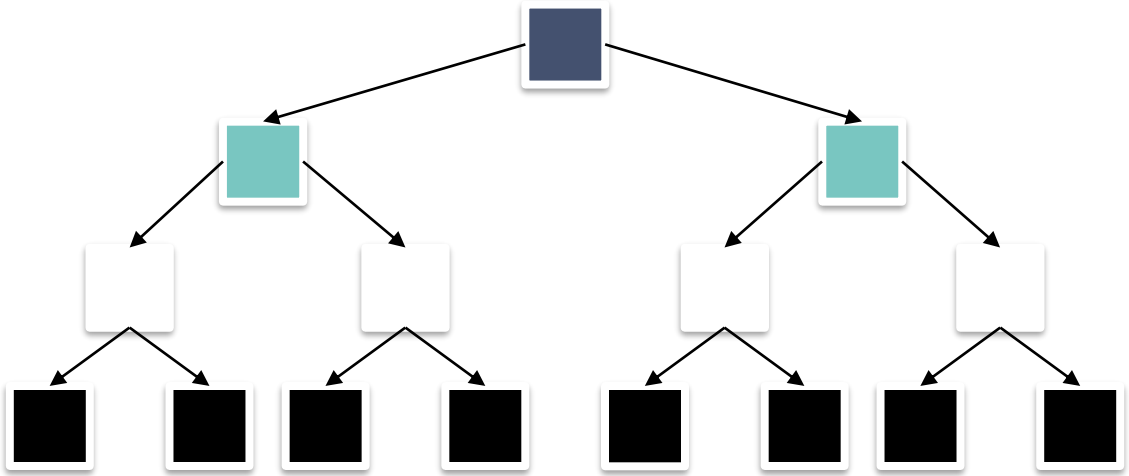
Expected Number of Reads: 1 (1 / B) + 2 (2 / B) + 3 (4 / B) + 4 (8 / B)

1 IO

2 IOs

3 IOs

4 IOs



$$\sum_{i=1}^{\log_2 B} i\frac{2^{i-1}}{B} = \frac{1}{B}\sum_{i=1}^{\log_2 B} i2^{i-1} = \log_2 B - \frac{B-1}{B}$$

Cost of Operations: Equation Search Cost

	Heap File	Sorted File
Scan all records	B*D	B*D
Equality Search	0.5*B*D	$(\log_2 B)*D$
Range Search		
Insert		
Delete		

- **B:** The number of data blocks
- **R:** Number of records per block
- **D:** Average time to read/write disk block

Cost of Operations: Range Search?

	Heap File	Sorted File
Scan all records	B*D	B*D
Equality Search	0.5*B*D	$(\log_2 B)*D$
Range Search		
Insert		
Delete		

- **B:** The number of data blocks
- **R:** Number of records per block
- **D:** Average time to read/write disk block

Find Keys Between 7 and 9: Heap File

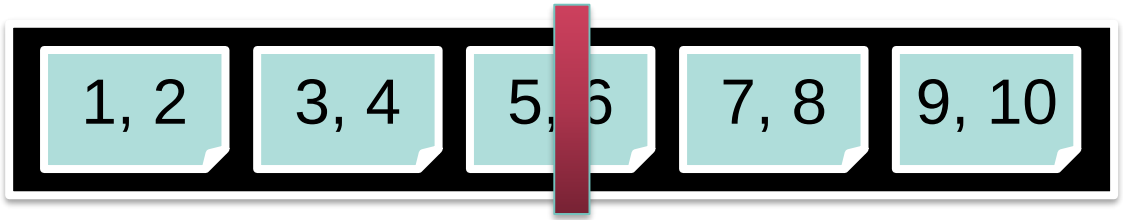
- Always touch all blocks. Why?

Find Keys Between 7 and 9: Comparison

Heap File

- Find beginning of range

Sorted File



- Search for start of range
- Scan right

Cost of Operations: Range Search Cost

	Heap File	Sorted File
Scan all records	B*D	B*D
Equality Search	0.5*B*D	$(\log_2 B)*D$
Range Search	B*D	$((\log_2 B)+pages)*D$
Insert		
Delete		

- **B:** The number of data blocks
- **R:** Number of records per block
- **D:** Average time to read/write disk block

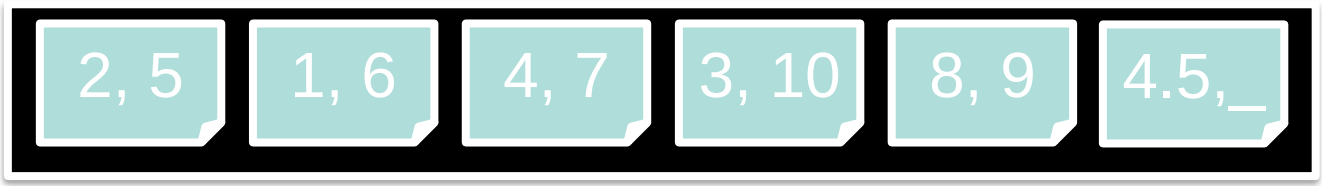
Cost of Operations: Insert?

	Heap File	Sorted File
Scan all records	B*D	B*D
Equality Search	0.5*B*D	$(\log_2 B)*D$
Range Search	B*D	$((\log_2 B)+pages)*D$
Insert		
Delete		

- **B:** The number of data blocks
- **R:** Number of records per block
- **D:** Average time to read/write disk block

Insert 4.5: Heap File

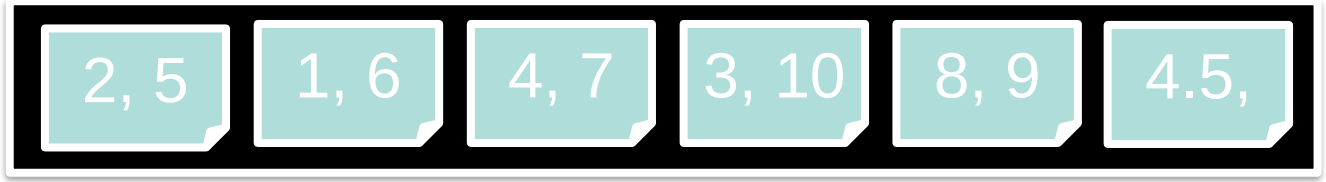
Heap File



- Stick at end of file
- Cost = 2*D
- Why 2?

Insert 4.5: Heap VS Sorted File

Heap File



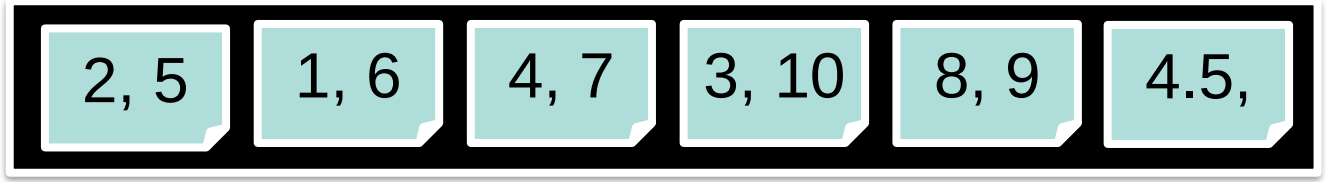
- Read last page, append, write. Cost = 2*D

Sorted File

- Find location for record. Cost = $\log_2 BD$

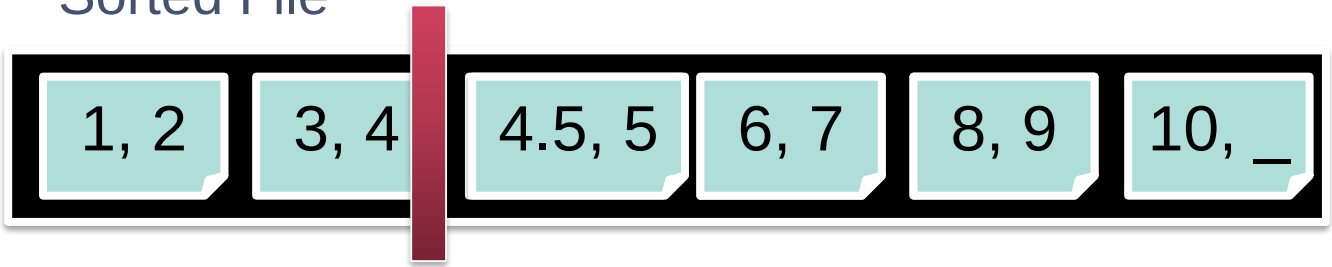
Insert 4.5: Heap Vs Sorted Pt 2

Heap File



- Read last page, append, write. Cost = 2*D

Sorted File



- Find location for record. Cost = $\log_2 BD$
- Insert and shift rest of file

Cost of Operations: Insert Cost

	Heap File	Sorted File
Scan all records	B*D	B*D
Equality Search	0.5*B*D	$(\log_2 B)*D$
Range Search	B*D	$((\log_2 B)+pages)*D$
Insert	2*D	$((\log_2 B)+B)*D$
Delete		

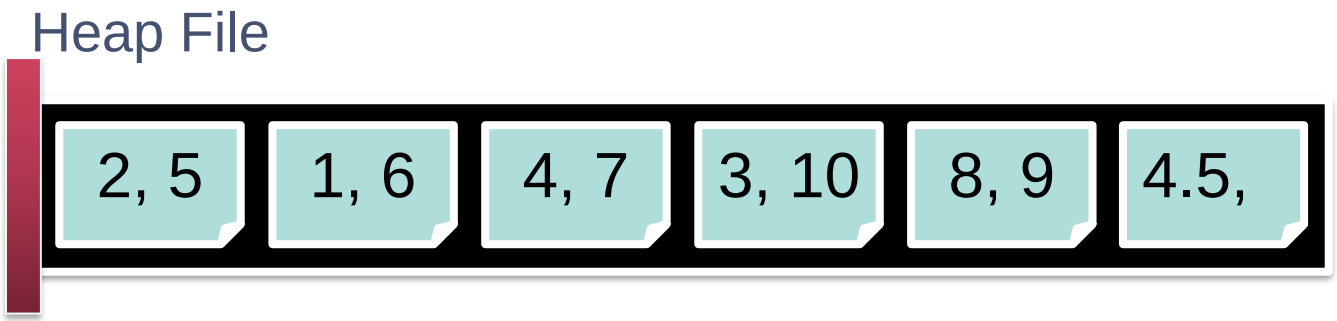
- **B:** The number of data blocks
- **R:** Number of records per block
- **D:** Average time to read/write disk block

Cost of Operations: Delete?

	Heap File	Sorted File
Scan all records	B*D	B*D
Equality Search	0.5*B*D	$(\log_2 B)*D$
Range Search	B*D	$((\log_2 B)+pages)*D$
Insert	2*D	$((\log_2 B)+B)*D$
Delete		

- **B:** The number of data blocks
- **R:** Number of records per block
- **D:** Average time to read/write disk block

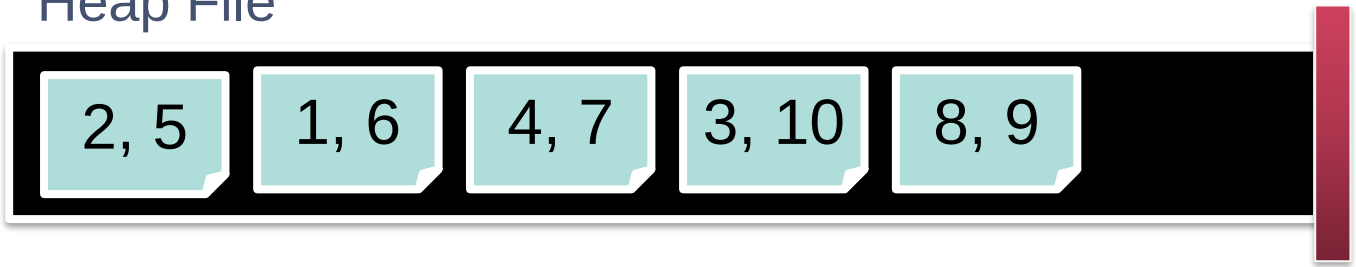
Delete 4.5: Heap File



- Average case to find the record: **B/2 reads**
- Delete record from page
- Cost = (B/2 + 1) * D
  - Why + 1?

Delete 4.5: Heap File Vs Sorted File

Heap File



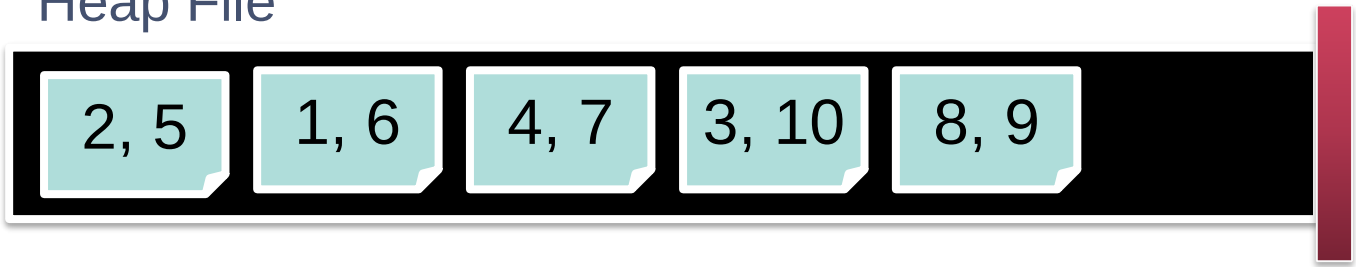
- Average case runtime: **(B/2+1) * D**

Sorted File

- Find location for record: **$\log_2 B$**
- Delete record in page → Gap

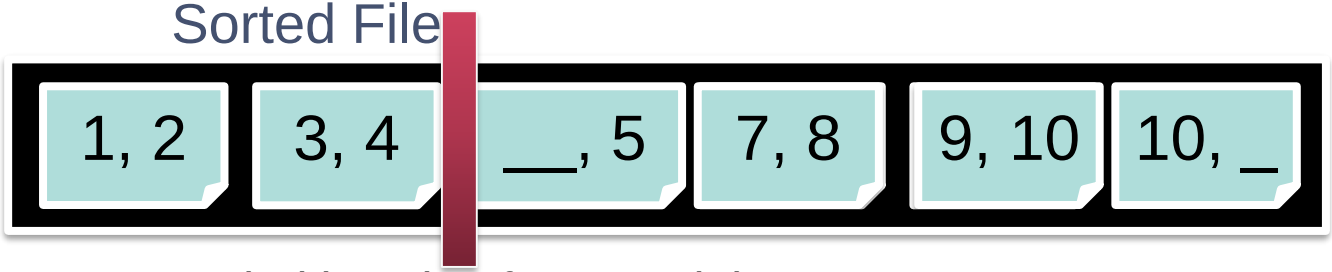
Delete 4.5: Heap File Vs Sorted File Pt 2

Heap File



- Average case runtime: (B/2+1) * D

Sorted File



- Find location for record: log2B
- Shift the rest by 1 record 2 * (B/2)

Cost of Operations Complete

	Heap File	Sorted File
Scan all records	B*D	B*D
Equality Search	0.5*B*D	$(\log_2 B)*D$
Range Search	B*D	$((\log_2 B)+pages)*D$
Insert	2*D	$((\log_2 B)+B)*D$
Delete	(0.5*B+1)*D	$((\log_2 B)+B)*D$

- **B:** The number of data blocks
- **R:** Number of records per block
- **D:** Average time to read/write disk block

Cost of Operations Complete Pt 2

	Heap File	Sorted File
Scan all records	B*D	B*D
Equality Search	0.5*B*D	$(\log_2 B)*D$
Range Search	B*D	$((\log_2 B)+pages)*D$
Insert	2*D	$((\log_2 B)+B)*D$
Delete	(0.5*B+1)*D	$((\log_2 B)+B)*D$

- **B:** The number of data blocks
- **R:** Number of records per block
- **D:** Average time to read/write disk block
- Can we do better?
  - Indexes!