RDBMS and SQL

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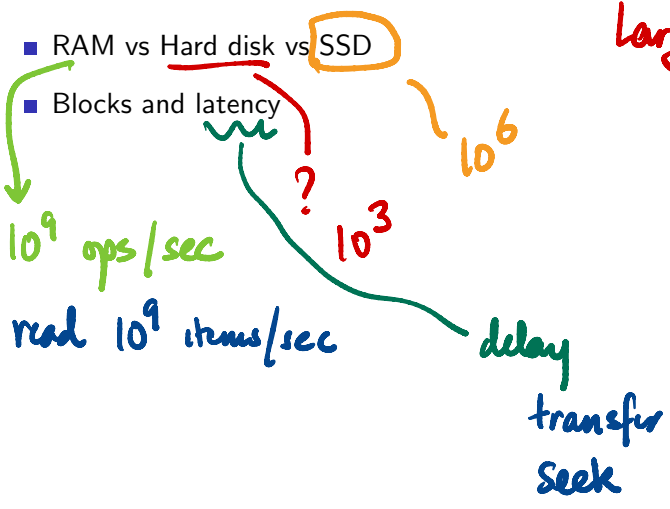
Storing data

- RAM vs Hard disk vs SSD
- Blocks and latency



Large volume → disk

1.4 billion people

× 100 bytes

140×10^9 bytes

140 GB

Storing data

- RAM vs Hard disk vs SSD
- Blocks and latency

"Accounting" — analysis

Ignore memory operations

Only count block seeks & transfers

transfer a chunk of data at a time

Block is 4Kb or more

Storing data

- RAM vs Hard disk vs SSD
- Blocks and latency

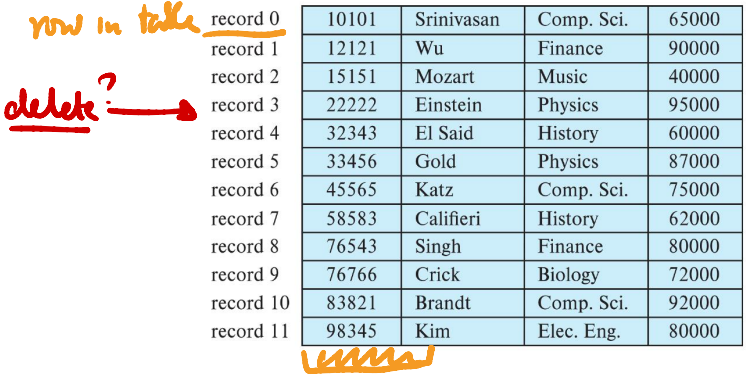
Typical table will be split across blocks

File organisation

— how are these multiple blocks of one table arranged

Fixed length records

- Blocks and block boundaries



record 0	10101	Srinivasan	Comp. Sci.	65000
record 1	12121	Wu	Finance	90000
record 2	15151	Mozart	Music	40000
record 3	22222	Einstein	Physics	95000
record 4	32343	El Said	History	60000
record 5	33456	Gold	Physics	87000
record 6	45565	Katz	Comp. Sci.	75000
record 7	58583	Califieri	History	62000
record 8	76543	Singh	Finance	80000
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record 10	83821	Brandt	Comp. Sci.	92000
record 11	98345	Kim	Elec. Eng.	80000

Deleting a record

- Compress

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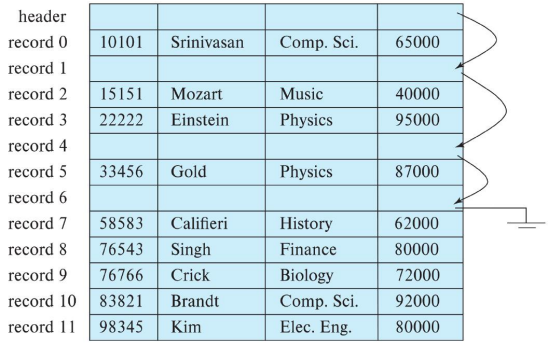
Deleting a record

- Compress
- Move last record
- Maintain free list of empty slots



header				
record 0	10101	Srinivasan	Comp. Sci.	65000
record 1				
record 2	15151	Mozart	Music	40000
record 3	22222	Einstein	Physics	95000
record 4				
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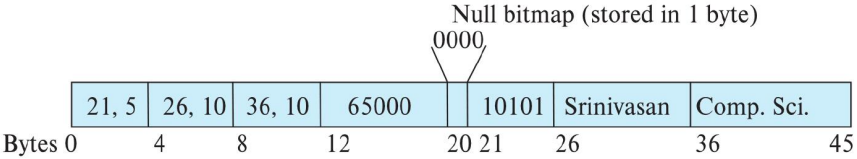
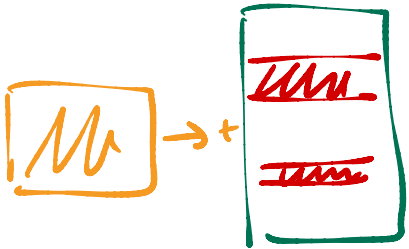
Variable length records

- Single record structure





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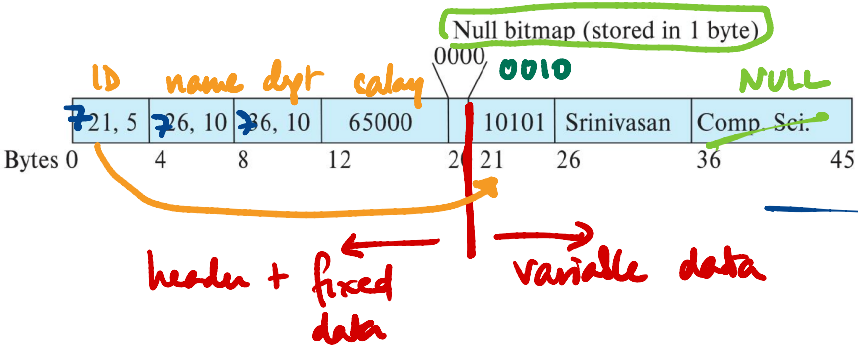

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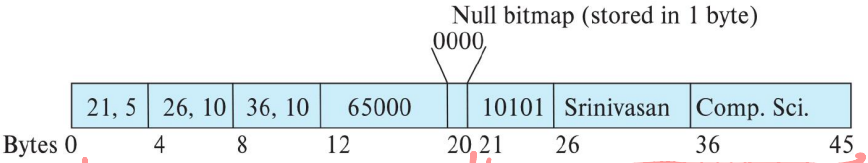
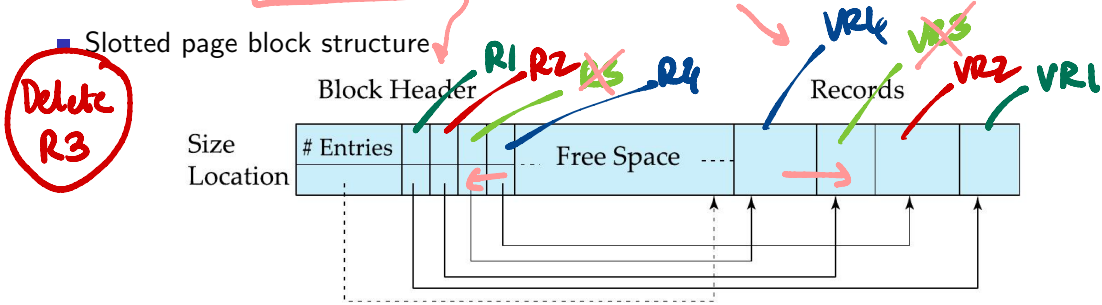


- Slotted page block structure



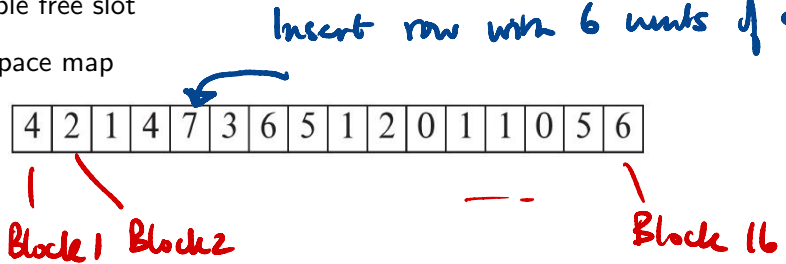
Storing tables — heap file organization

- Use first available free slot

Arbitrary order

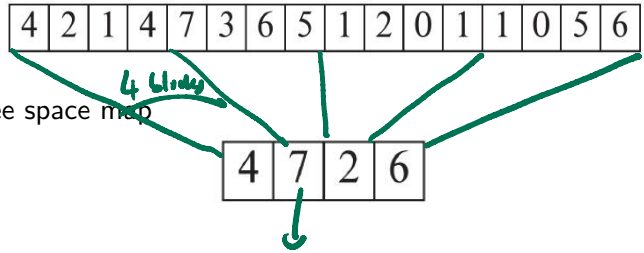
Storing tables — heap file organization

- Use first available free slot
- Maintain free space map



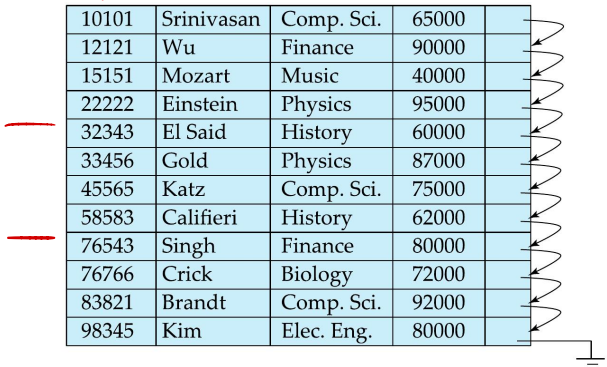
Storing tables — heap file organization

- Use first available free slot
- Maintain free space map
- Second level free space map



Storing tables — sequential file organization

Sorted



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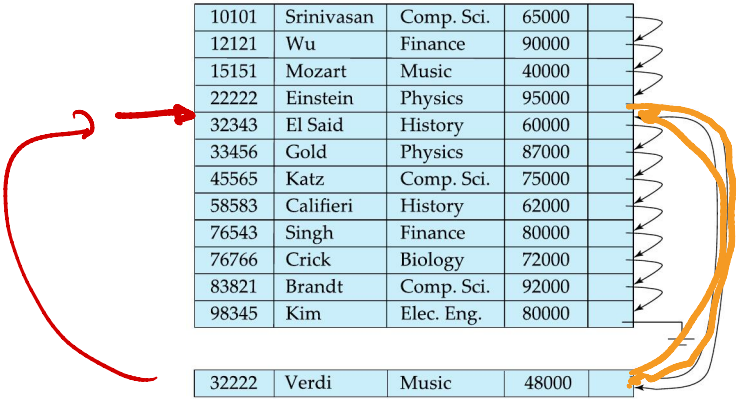
Storing tables — sequential file organization

- Overflow block



Indexing

- Why build an index?

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- Search key
  - As opposed to superkey, candidate key, ...
  - May need multiple search keys for a table

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- Types of queries — point vs range
  - `ID = "10102"`
  - `salary > 75000`

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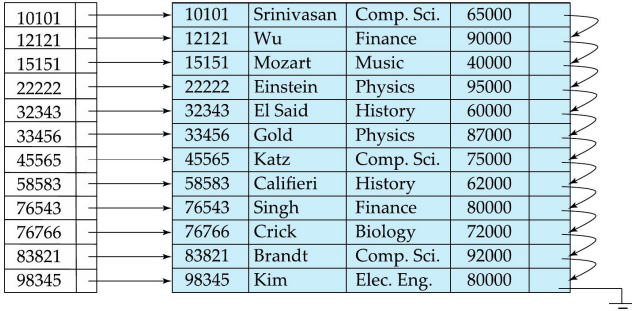
- Search key
  - As opposed to superkey, candidate key, ...
  - May need multiple search keys for a table
- Types of queries — point vs range
  - `ID = "10102"`
  - `salary > 75000`
- Maintaining an index
  - Inserts, deletes
  - Space

Clustering index

- File is ordered with respect to index values
- Index sequential file
- Dense index — every value is present in the index



Clustering index

- File is ordered with respect to index values
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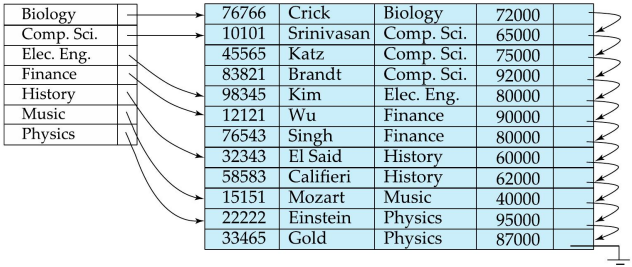
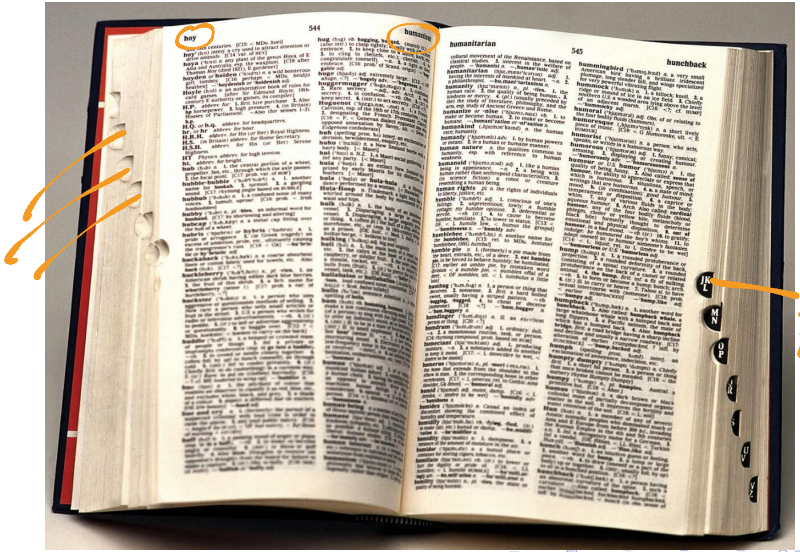
- Dense index — every value is present in the index
  - Index value may match multiple records



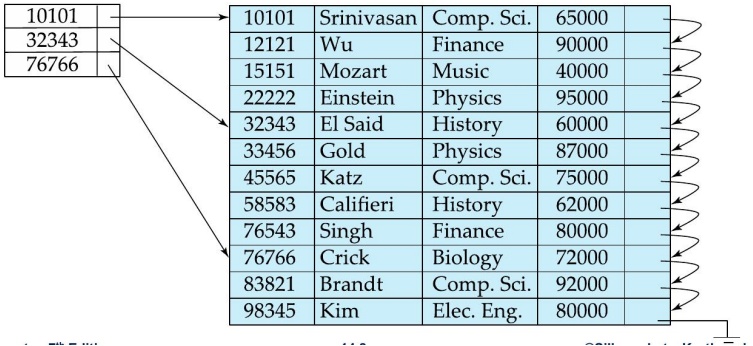
Indexing — sparse indices

- Maintain indices for a subset of values
  - Page headers in a dictionary



Indexing — sparse indices

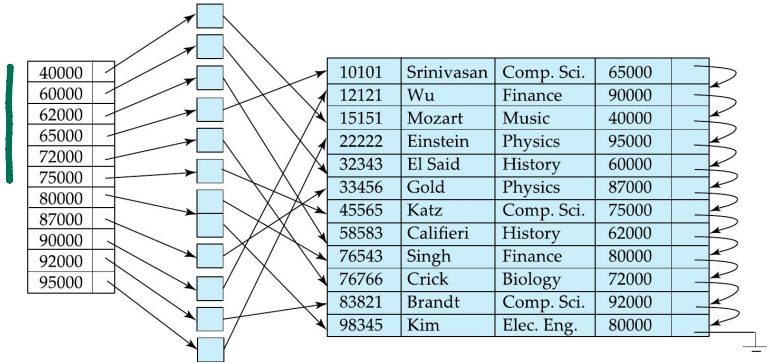
- Maintain indices for a subset of values
  - Page headers in a dictionary
- Align to block boundaries
  - Records are still sequential with respect to index
  - Sparse index identifies first record in each block



Indexing — secondary index

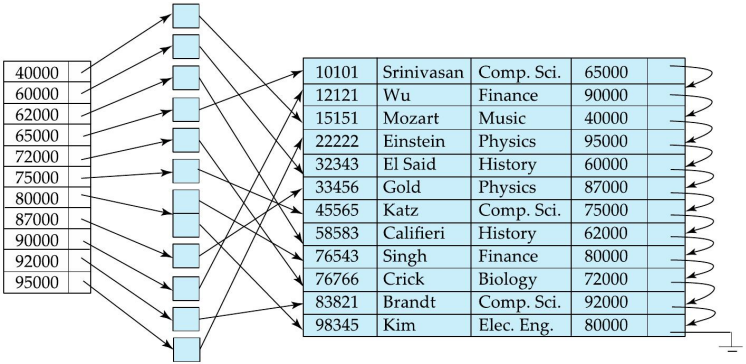
- Index for an attribute that does not match sequence in which table is stored

Salaries ≤ 75000



Indexing — secondary index

- Index for an attribute that does not match sequence in which table is stored
- Key points to block that contains pointers to matching records
  - Can have multiple records for same search key



Storage

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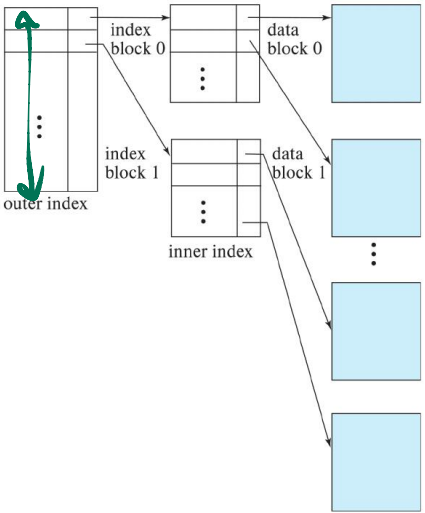
  - Build a sparse index for the index file
  - Multi-level, till sparse index fits in one block



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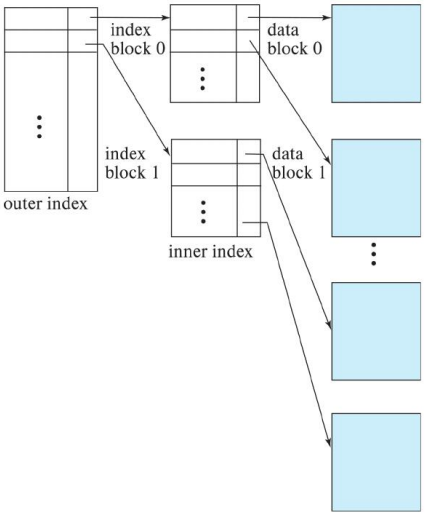
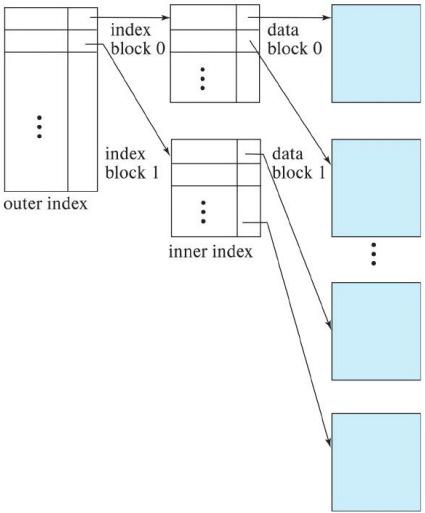


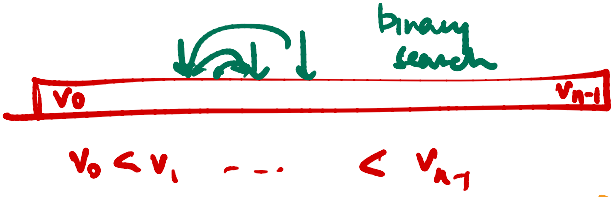
Storage

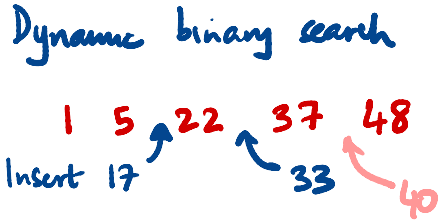
- Typically, index will not fit in RAM
- Store index as a sequential file
  - Build a sparse index for the index file
  - Multi-level, till sparse index fits in one block
- Binary search to find required key
- Idea leads to a more efficient structure

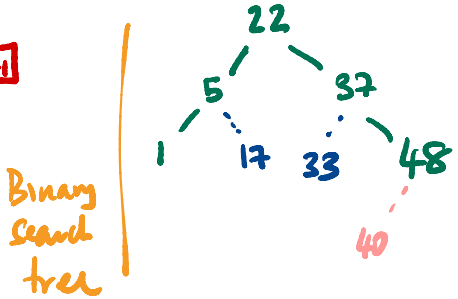


Search trees

- Binary search trees
  - Binary search on dynamic data
  - Balanced tree has logarithmic height







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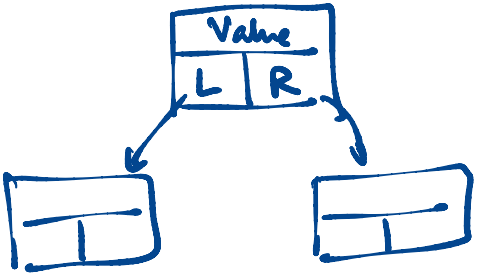

Search trees

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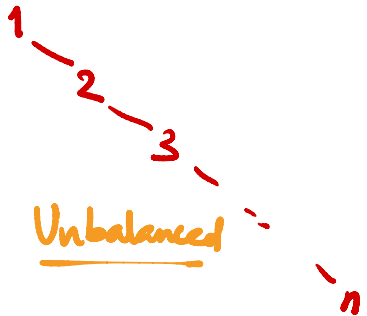
Bad case

Insert 1

Insert 2

⋮

Insert n



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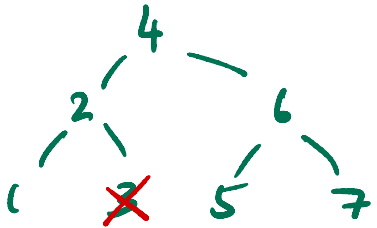
Perfectly balanced

$2^n - 1$ elements



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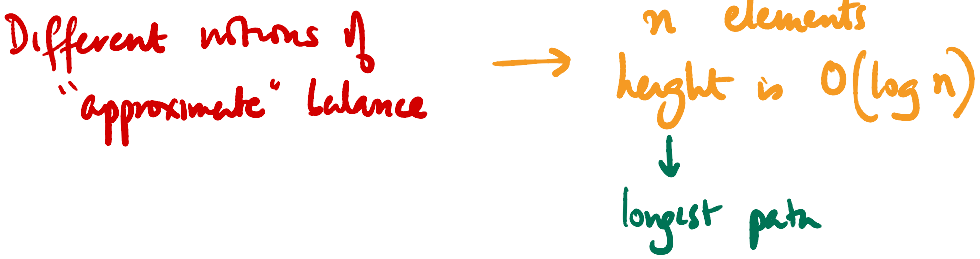

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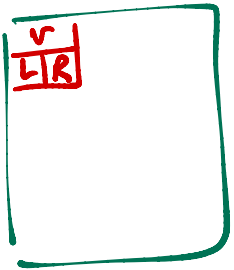
"Binary tree" on disk

Each node = 1 block



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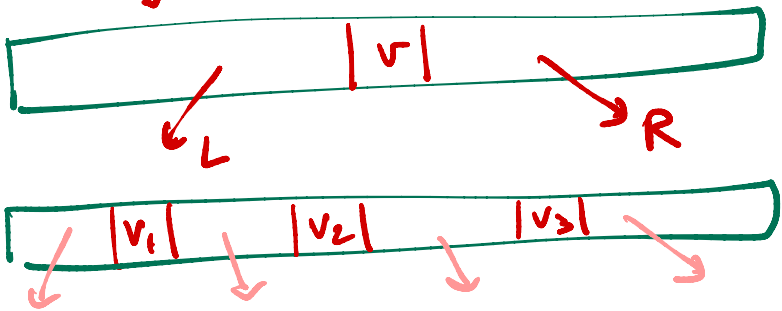
Instead, multiway branch



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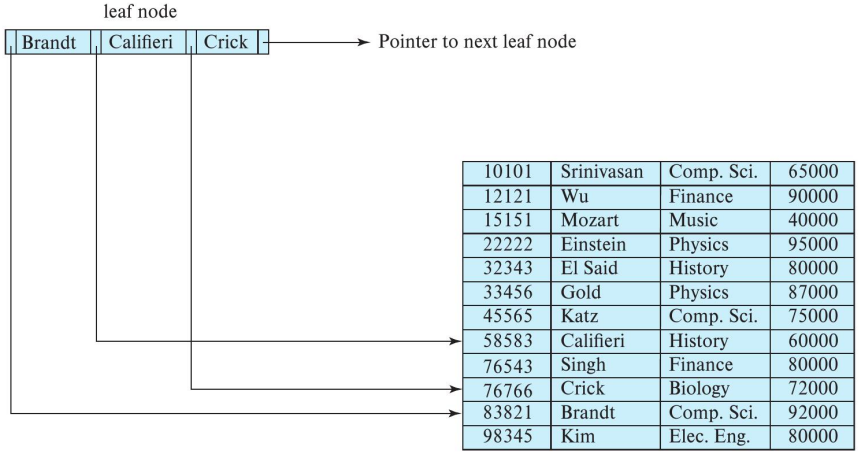
  - Balanced tree has logarithmic height
- Block-based access
  - Binary tree node has one search key value, two pointers
  - Block can hold much more

Search trees

- Binary search trees
  - Binary search on dynamic data
  - Balanced tree has logarithmic height
- Block-based access
  - Binary tree node has one search key value, two pointers
  - Block can hold much more
- Generalize to multiple key values, multiple pointers

B+ trees

- Leaf nodes form a dense index — linked list of leaves, each one block



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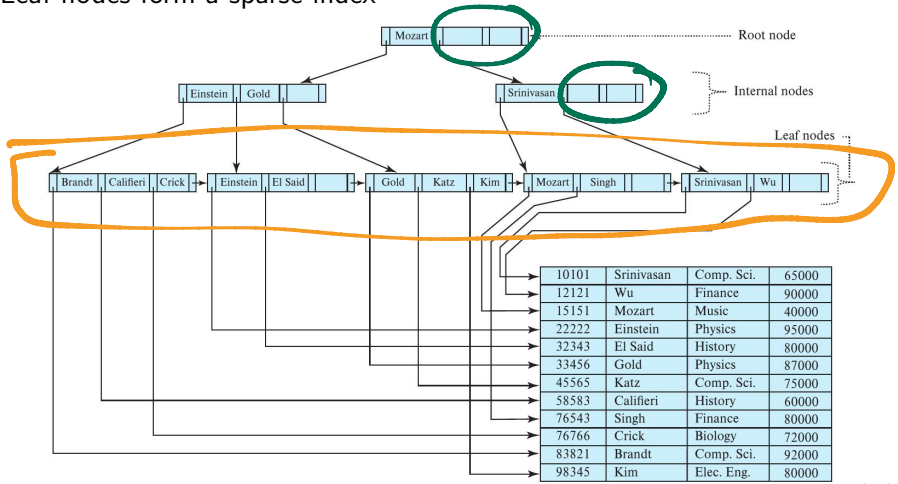
instructor file

B+ trees

- Leaf nodes form a dense index — linked list of leaves
- Non-Leaf nodes form a sparse index



Secondary index in sorted order