COL362/632 Introduction to Database Management Systems

Database Systems – Indexing

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Motivation

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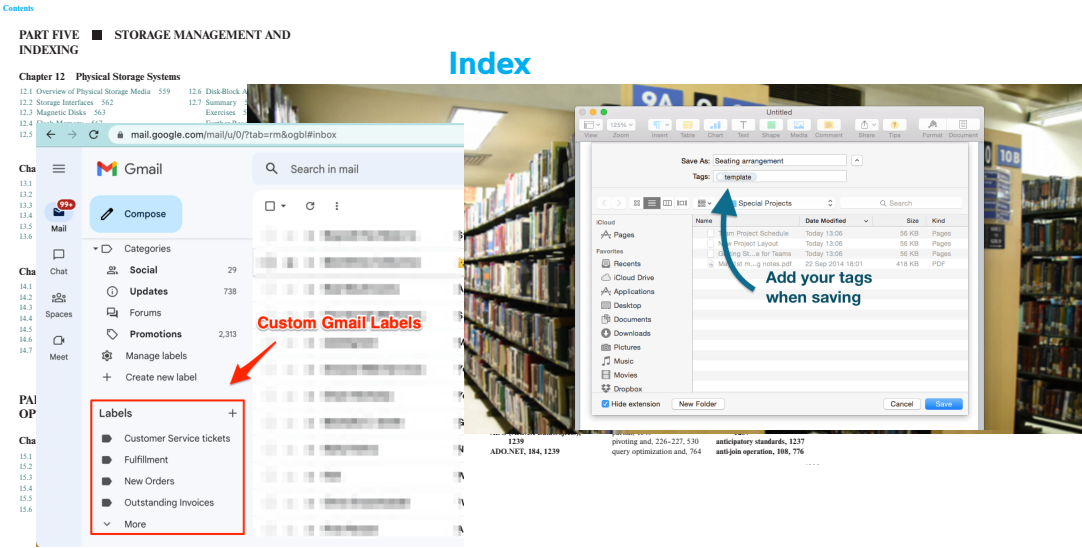
Motivation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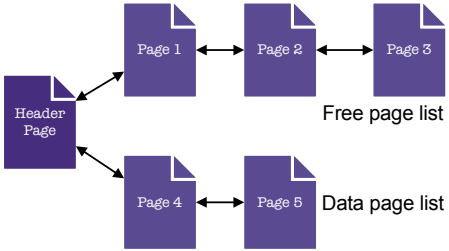
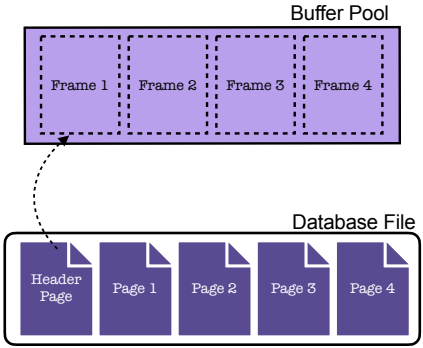
Accessing Records in Databases



Recall: Heap File Organization

- Good for scanning all records



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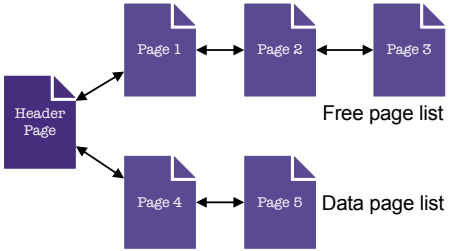

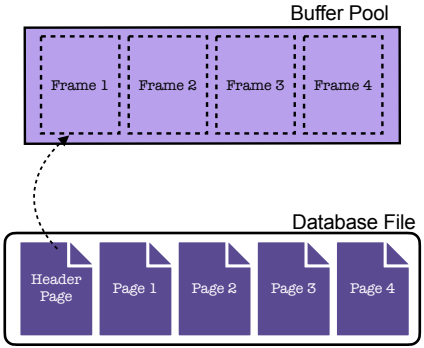

Recall: Heap File Organization

- Good for scanning all records
- But, what if we are looking for "certain" records
  - `select * from Order where return_status = 'I'`
  - `select name from Product where price < 100`

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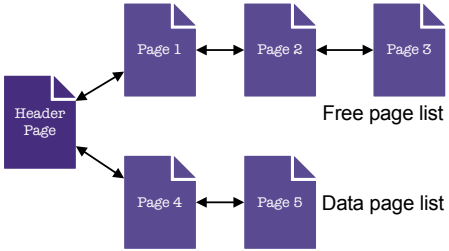

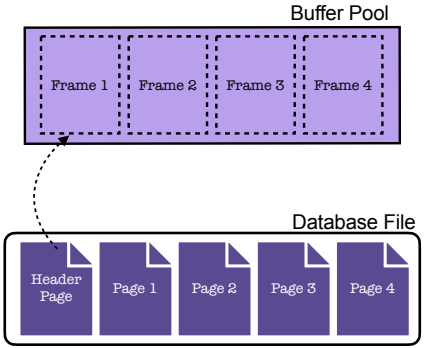

Recall: Heap File Organization

- Good for scanning all records
- But, what if we are looking for "certain" records
  - `select * from Order where return_status = 'I'`
  - `select name from Product where price < 100`
- How to **optimally** retrieve records?

Accessing Records in Database

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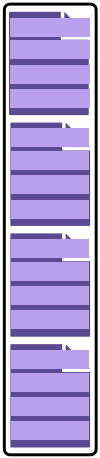
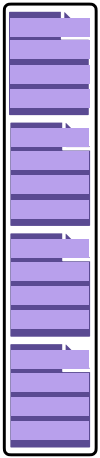


Accessing Records in Database

- Assume block is b (KB), each record is r (KB), and n records



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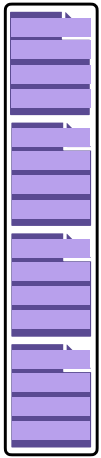

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- Improve access by
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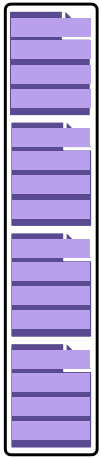
  - $O(\log_2 \frac{nr}{b})$ for binary search



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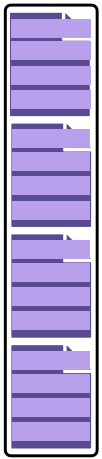

- Improve access by
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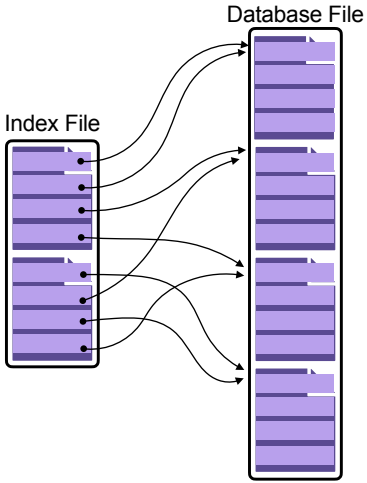
  - $O(\log_2 \frac{nr}{b})$ for binary search
  - **Using Indexes!**
  - B+ trees
  - Hash Index
  - Bit Maps
  - Bloom Filters
  - ...

Indexing - basics

Index

- Data structure that organizes records of a file
- Enables efficiently searching records using **search key**



Indexing - basics

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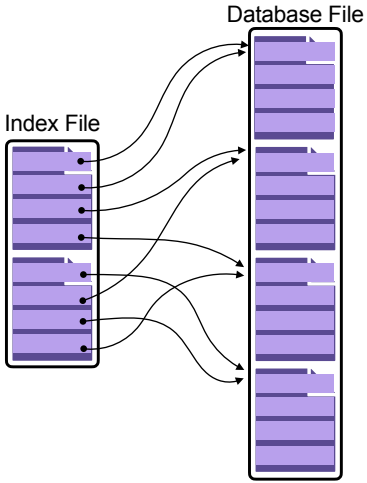
- **Note:** Index is also a database file!



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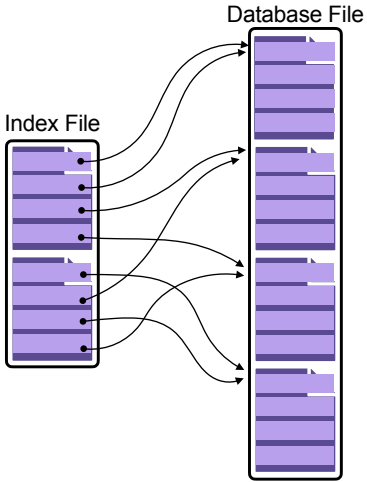

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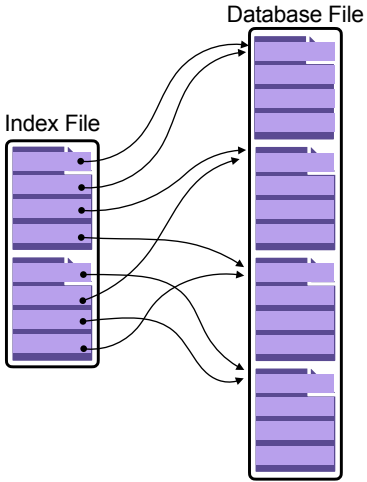
  1. Ordered Index – Search keys are stored in sorted order
  2. Hash Index – Search keys are distributed uniformly across *buckets* using a hash function



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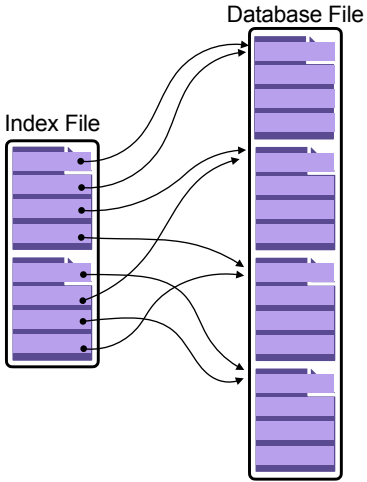

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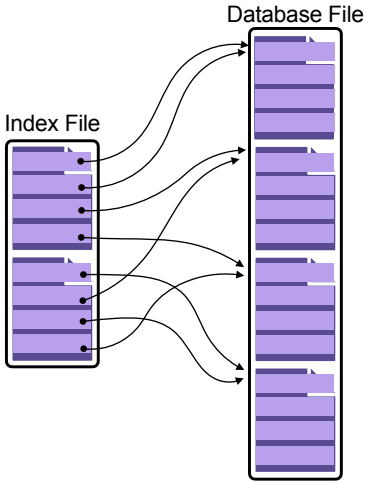
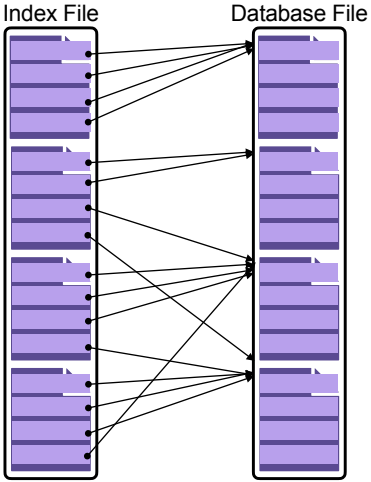
- Updating file also requires updating the index



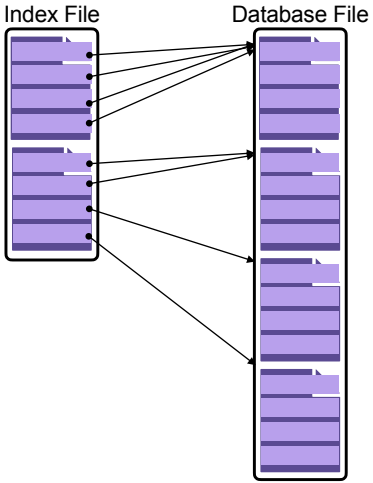
Dense Index

- Data entries based on sorted ordering of values
- There is an entry in the index **for every** search-key value in the file



Sparse Index

- Data entries based on sorted ordering of values
- There is an entry in the index **for only some** search-key value in the file
- **Note** Can only be used if the table is stored in sorted order of the search key



Primary Index and Secondary Index

Primary Index

- Search key contains the primary key
- No duplicate search keys
- A table can have only one primary index

Secondary Index

- Any index other than primary index

Note: Index on candiate key is called a **unique index**

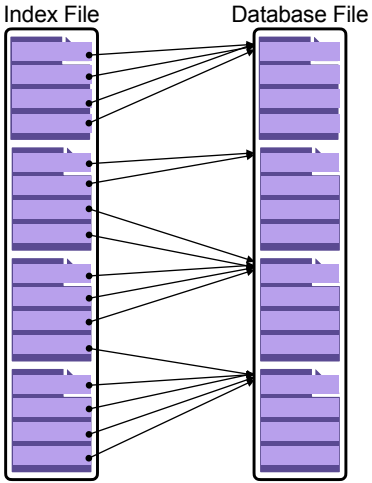
Clustered Index

- Search key also defines the sequential order of the file
- Search key often the primary key
- Can be both dense and sparse

Dense Clustered Index

- Data entry only points to block containing the first record

Note: Sparse Index $\implies$ Clustered Index



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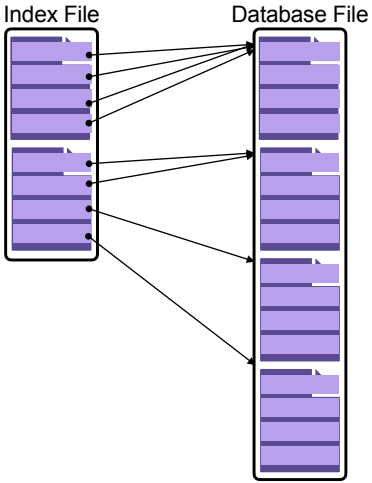
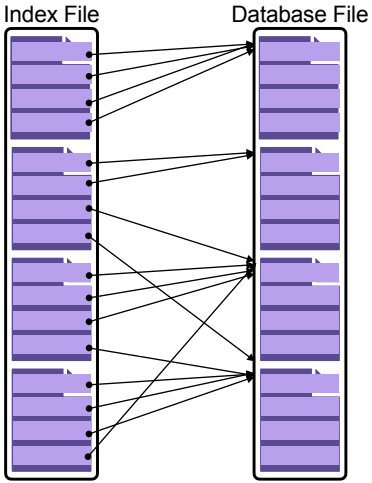


Non-clustered Index

- Search key specifies an order different from the sequential order of the file

Dense Non-clustered Index

- Data entry must store block pointers to all records with the same search key value



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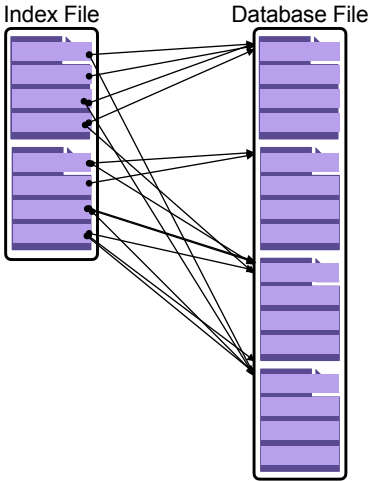
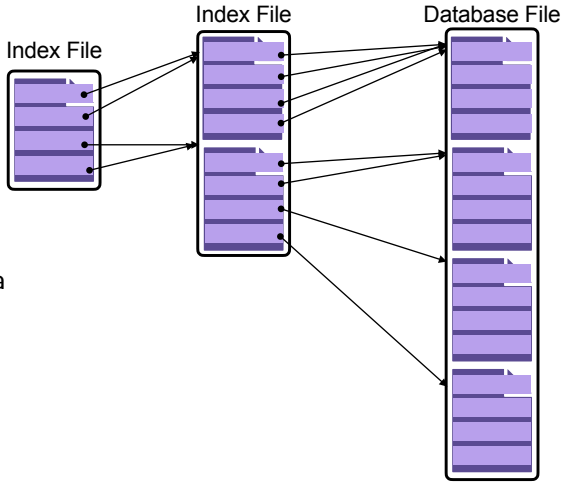
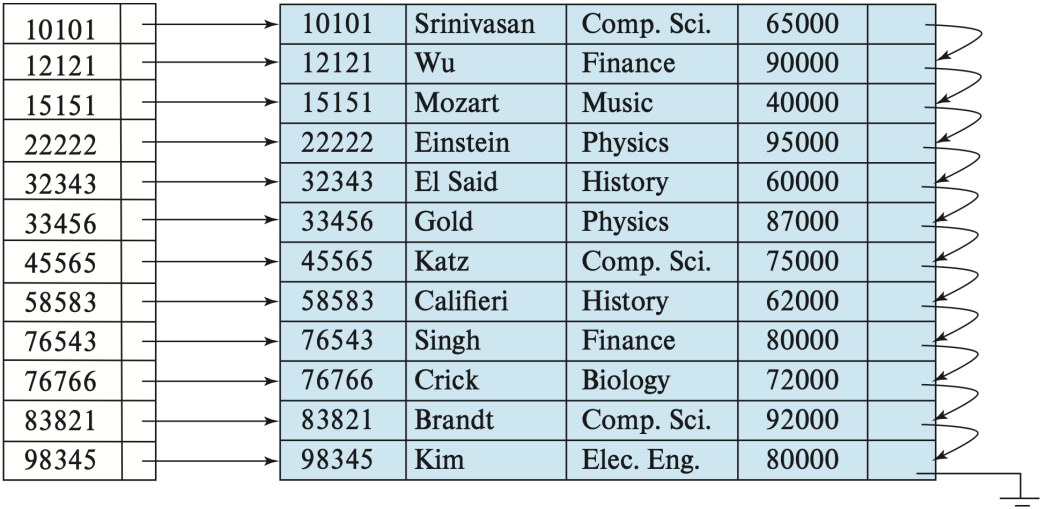


Multi-level Index

- Sometimes, index may not fit in memory
- Treat index as sequential file and create a **sparse outer** index
- Can be repeated



Examples (from Book B1)



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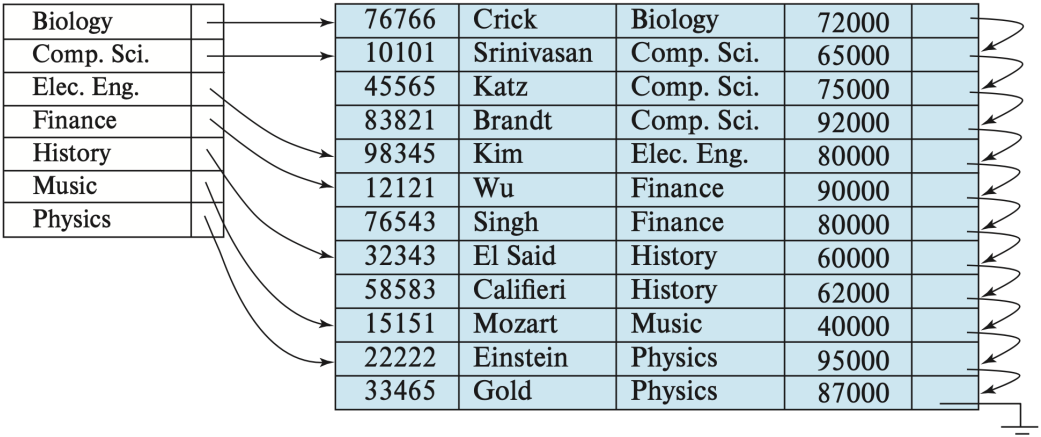

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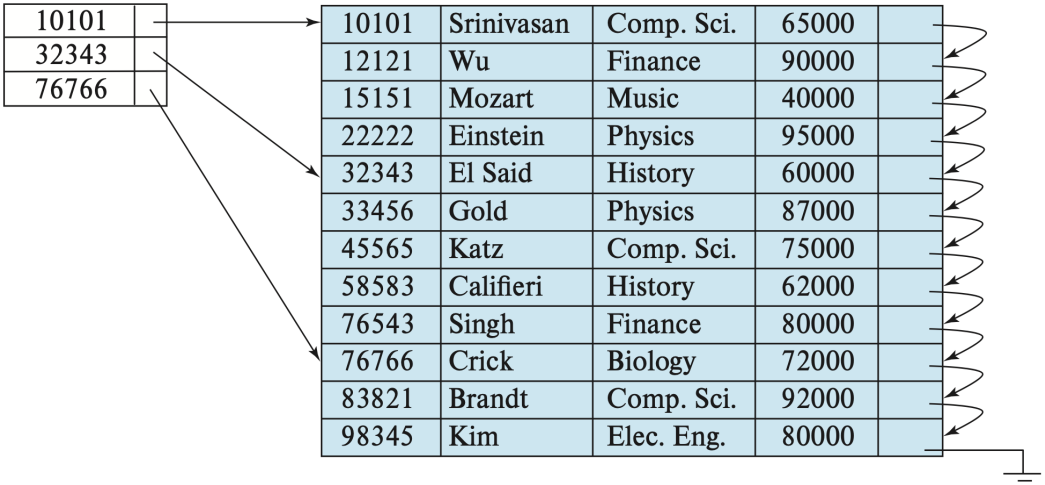

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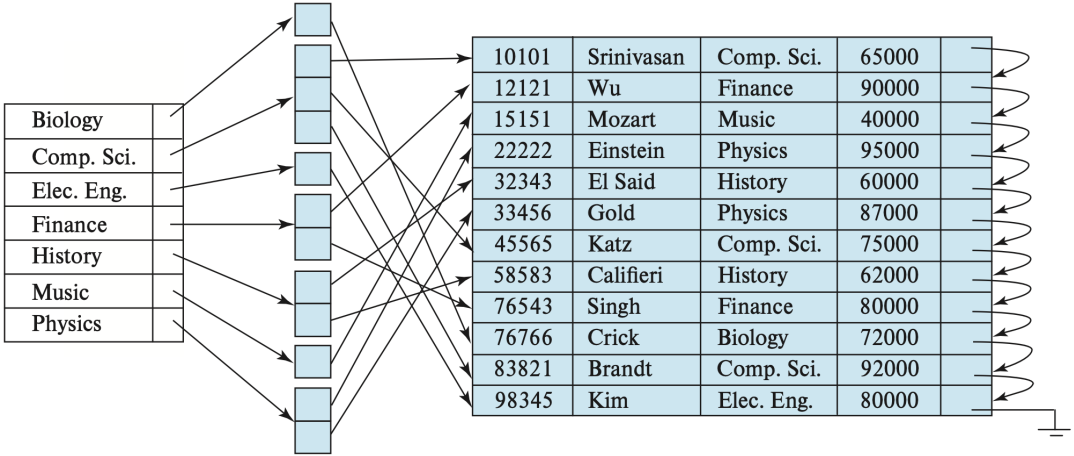

Updating Index – Insertions

Dense Index

- If search key !in index
  add a data entry at appropriate position
- Else If non-clustering index, add pointer to data entry
- Else place the **record** appropriately

Sparse Index

- If new block, add new data entry
- If new record has least search-key value, update the data entry!

Updating Index – Deletions

Dense Index

- It it was the only record, delete the index entry
- Else, for non-clustering index, delete the pointer
- Else, update the data entry by pointing the next record

Sparse Index

- If the index does not contain data entry with search key value, do nothing; Else,
- If it was the only record, update the index entry with next search key value
- If next search key value present in index, delete the index entry
- Else, if index entry points to recorded being deleted, update the index to point to the next record with the same search key value (record can be in another block)

HomeWork

- Find out which is the largest table
- Check if it has index
- create index if there is none for some attribute
- benchmark multiple queries with and without index

Creating/dropping an index in PostgreSql

- `CREATE UNIQUE INDEX title_idx ON films (title)`
- `CREATE INDEX title_idx ON films (title) WITH (deduplicate_items = off)`
- More examples on https://www.postgresql.org/docs/current/sql-createindex.html
- `drop index index_name`

On a side note

Which one is clustered and which is non-clustered?

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