# File Organisations and Indexes

# File organisations

- Three types of file organisations
  - Heap, Sorted and Hashed
- The COST of processing DB queries
  - SCAN, Search (Single, Range), Insert, Delete

# File Organisations

- A bit of recall
  - The basic store unit on disk (in memory) is block (page)
  - We will use page/block interchangeably.
  - One page consists of multiple data records.

- Three types
  - Heap Files (The simplest)
    - Page after page, always insert at the end
  - Sorted Files
    - Records are sorted (within and among pages) w.r.t. the search key
  - Hashed Files.
    - The pages are assigned to multiple buckets, each containing several pages
    - Each page has been assigned with an ID (bucket ID) to tell where to find the page

# COST MODEL

- Notations
  - **B**: the number of pages (blocks)
  - **R**: the average number of records in a page.
  - **D**: average time to read or write a disk page.
  - **C**: average time to process a record.
  - **H**: the time required to apply a hash function to a record.

# Operations to be investigated

- ***Scan***: fetch all records in a table.
- Search with equality selection (***SWES***)
  - "Find the students record with sid = z3087251"
- Search with Range Selection (***SWRS***)
  - "Find all students with name alphabetically after 'Smith'"
- ***Insert***: Insert a given record into the table.
- ***Delete***: Delete a record with given rid.

Below, we examine the costs of these operations with respect to the 3 different file organisations.

# Heap Files

- Scan:
  - B(D + RC )
- SWES:
  - 0.5B(D + RC ) on average if the selection is specified on a key.
  - Otherwise B(D + RC ).

**B**: the number of pages
**R**: the average number of records in a page (block).
**D**: average time to read or write a disk page.
**C**: average time to process a record.

# Heap Files

- SWRS:
  - B(D + RC )
- Insert:
  - (D + C) + D = 2D + C (Always insert to the end of the file)
- Delete:
  - Only one record is involved.
    - The average cost is 0.5B(D + RC ) + D if rid is not given;
    - otherwise (D + C ) + D.
  - Several records are involved. Expensive.

B: the number of pages
R: the average number of records in a page (block).
D: average time to read or write a disk page.
C: average time to process a record.

# Sorted Files

Sorted on a search key
(a combination of one or more fields)

Querying against the search key:

- Scan: B(D + RC ).
- SWES:
  - O(D **$\log_2$ B** + C **$\log_2$** R) if single record. (log comes from binary search)
  - O(D **$\log_2$** B + C **$\log_2$** R + #matches).
- SWRS: O (D $\log_2$ B + C $\log_2$ R + #matches).
- Insert: expensive.
  - Search cost plus 2 * (0.5B(D + RC )).
- Delete: expensive.
  - Search cost plus 2 * (0.5B(D + RC )).

# Hashed Files

- The pages in a file are grouped into buckets.
- The buckets are defined by a hash function.
- Pages are kept at about 80% occupancy.

Assume the data manipulation is based on the hash key.

- Scan: **1.25**B(D + RC ).
- SWES: H + D + 0.5RC if each hash bucket contains only one page.
- SWRS: 1.25B(D + RC ). (No help from the hash structure)
- Insert: Search cost plus C + D if one block involved.
- Delete: Search cost plus C + D if one block involved.

# Summary

| File Type | Scan | Equality Search | Range Search | Insert | Delete |
|---|---|---|---|---|---|
| **Heap** | BD | 0.5 BD | BD | Search + D | Search + D |
| **Sorted** | BD | D log B | D log B + # matches | Search + BD | Search + BD |
| **Hashed** | 1.25 BD | D | 1.25 BD | 2 D | Search + BD |

A Comparison of **I/O** Costs

(**I/O** Costs: The cost of reading from or writing to disk)

# Introduction to Index

- What is index?

- The COST of processing DB queries
  - SCAN, Search (Single, Range), Insert, Delete

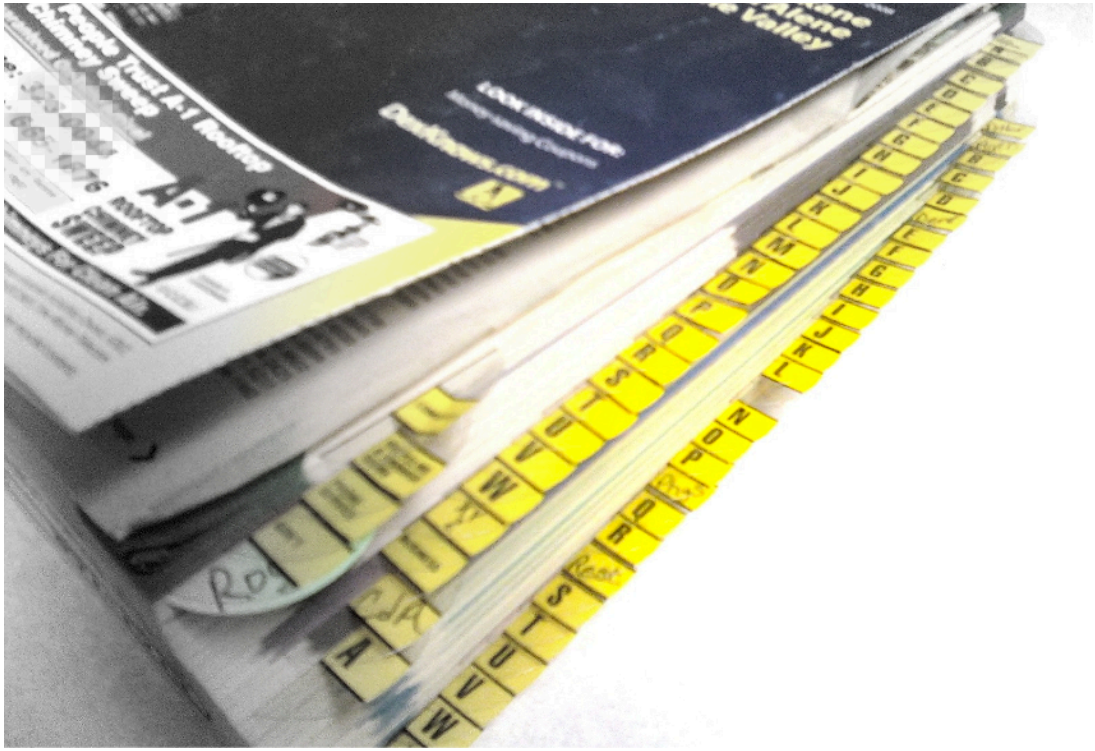
# What is index?


Book has been arranged via categories, subjects.

Same categories will be stored in the same area.

Book is data, then Catalogue is the index

# What is index?



Phone number has been arranged in Alphabets, groups (work, friends, …)

Phone number is the data
The Alphabets and groups are the index.

# What is index?

- Auxiliary data
- Properly organised (data structure)
- To facilitate data search

# Indexes

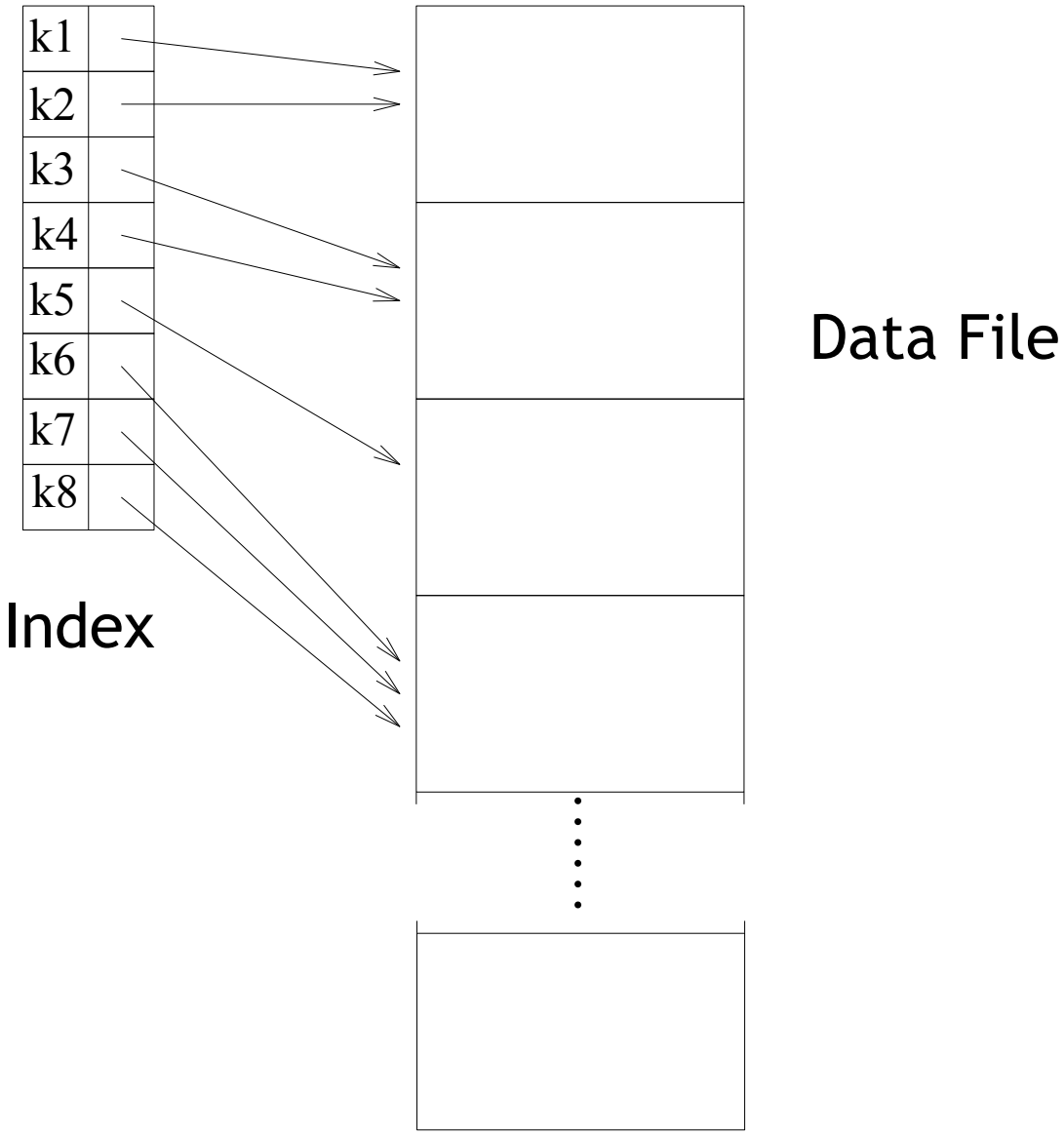
Word indexes in a book:

INDEXES

| | |
|---|---|
| aardvark 25,36 | lion . . . . . 18 |
| bat . . . . . 12 | llama 17,21,22 |
| cat . . . . 1,5,12 | sloth . . . . . 18 |
| dog . . . . . .3 | tiger . . . . . 18 |
| elephant . . 17 | wombat . . . 27 |
| emu . . . . . 28 | zebra . . . . . 19 |

- A table of key values, where each entry gives places where key is used.
- Aim: efficient access to records via key.

# Indexing Structure



# Indexing Structure

- Index is collection of data entries k*:
  - Each data entry $k*$ contains enough information to retrieve (one or more) records with search key value k.

- Indexing:
  - How are data entries organised in order to support efficient retrieval of data entries with a given search key value?
  - What is stored as a data entry?

# Alternatives for Data Entries in an Index

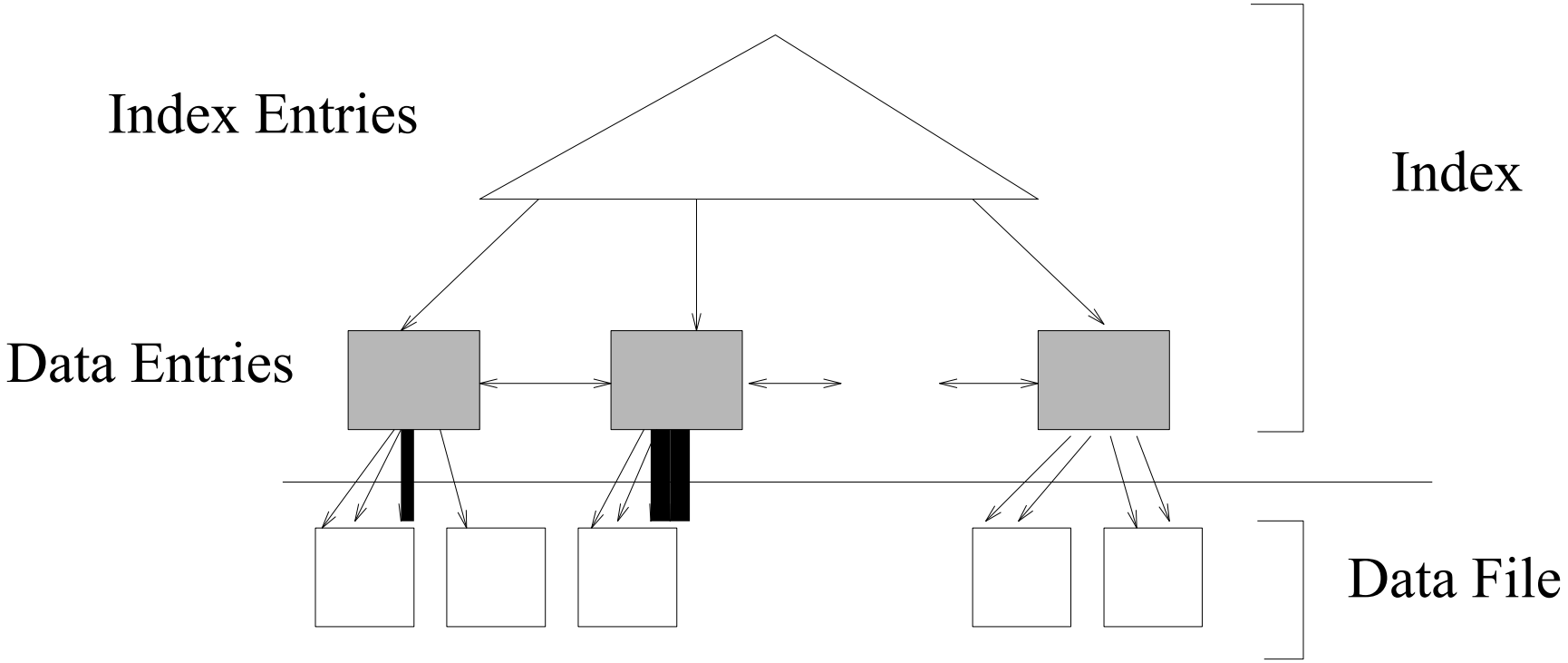
- A data entry $k*$ is an actual data record (with search key value k).

- A data entry is (k, rid) pair (rid is the record id of a data record with search key valued k).
  - e.g. (Xuemin Lin, page 12), (Xuemin Lin, page 100)

- A data entry is a (k, rid − list) pair.
  - e.g. ( Xuemin Lin, [page 12, page 100,] )

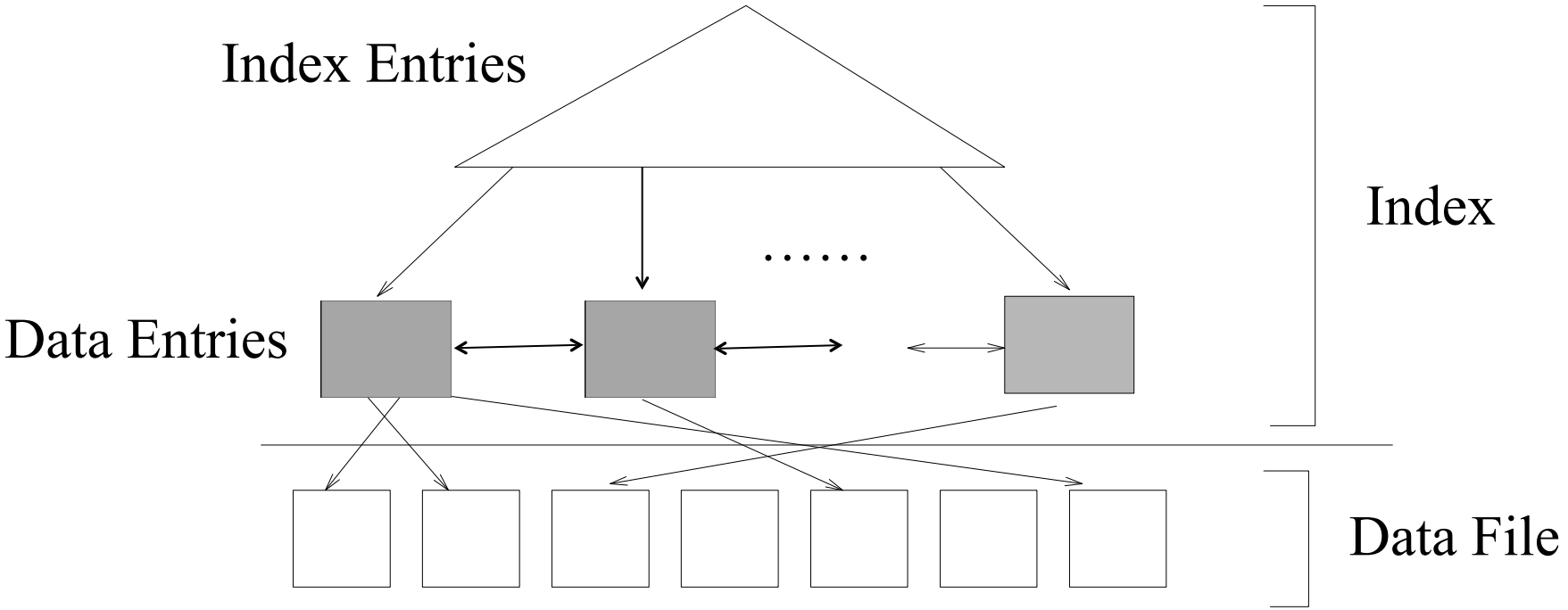
# Clustered Index

- Clustered: Sort and store the data records in the table or view based on the search keys.
- Typically, the search key of file is the same as the search key of index.



# Unclustered Index

- Clustered indexes are relatively expensive to maintain.
- A data file can be clustered (indexed) on **at most one** search key.

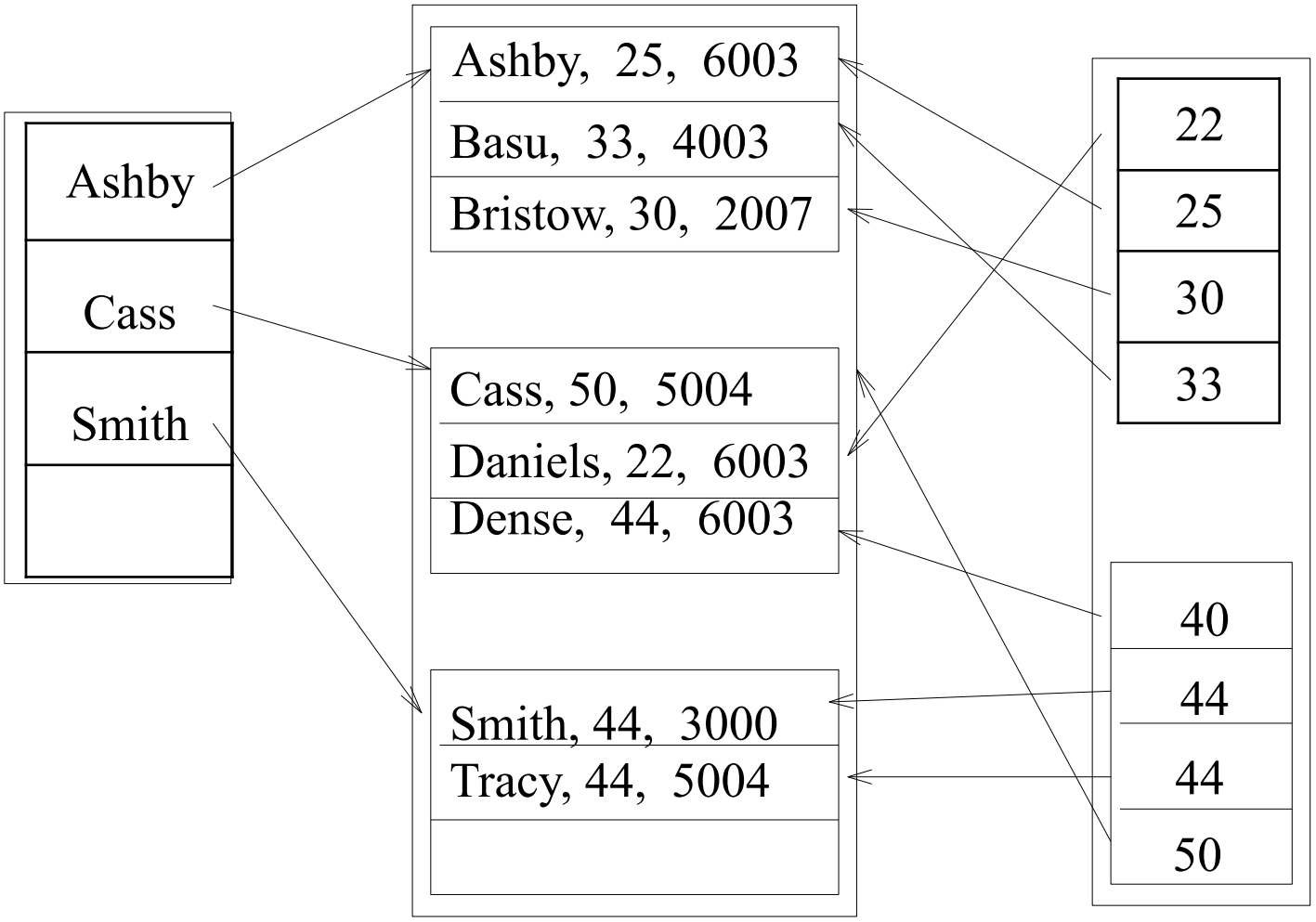


# Dense VS Sparse Indexes

- Dense Index and Sparse Index
  - Dense Index contains (**at least**) one data entry for every search key value.
  - Sparse Index may note and one search key can points to a set of data entries

Q: Can we build a sparse index that is not clustered?

# Dense VS Sparse Indexes




Sparse Index

Dense Index

# Primary and Secondary Indexes

- Primary: Indexing fields include **primary key**.
  - There can be at most one primary index for a table

- Secondary: otherwise.
  - Composite search keys: search key contains several fields.