# Unit-IV: Storage & Indexing

**Title**: Overview of Storage Techniques and File Organization in DBMS

**Subtitle**: File organization

# Storage System in DBMS

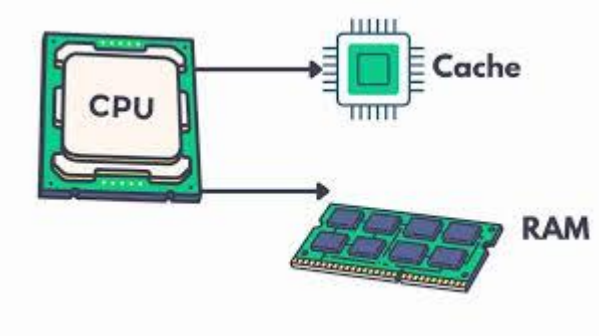
A database system provides an ultimate view of the stored data. However, data in the form of bits, bytes get stored in different storage devices.

**Types of Storage**

**Primary Storage (RAM)**:

Primary storage, also known as main memory or RAM (Random Access Memory), is the computer's immediate storage area. It is used to store data that is actively being worked on by the CPU

Ex: RAM , Cache memory

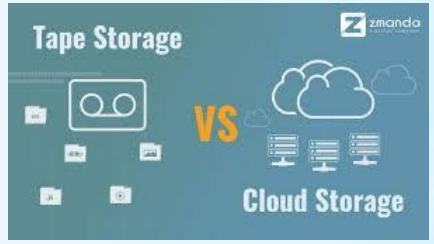


**Secondary Storage**:

Secondary storage refers to storage devices that retain data permanently or semi-permanently. This type of storage is used for long-term data storage

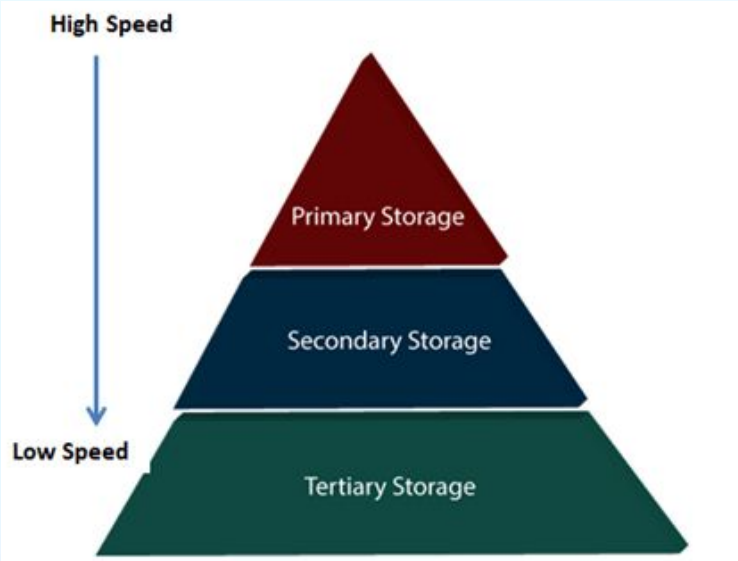
Ex: Hard Disk Drive, Optical disk(CD,DVD), Solid State  Drive.

**Tertiary Storage**




Tertiary storage is used for archiving and long-term data storage. It is often accessed infrequently and is typically slower than primary and secondary storage

Ex: Tape Drivers, Cloud Storage, External Hard Drive.



**Q1** : Which type of storage is the most expensive per byte?
**Answer**: Primary storage (e.g., RAM) is the most expensive per byte.

**Q2** : Which storage type offers the highest speed for data access?
**Answer**: Primary storage (RAM and cache) has the highest data access speed.

**Q3** : Which type of storage is used for long-term data archiving?
**Answer**: Tertiary storage (e.g., tape drives, cloud storage) is used for long-term archiving.

**Q4** : Which storage type has the largest capacity but slower access times?
**Answer**: Tertiary storage has the largest capacity and slower access times compared to primary and secondary.

# Overview of Physical Storage Media

Physical storage media is used to **store and retrieve data in a computing system**. It provides a way to keep data available for immediate access (like in RAM and cache for active processes), long-term storage (like on hard drives), and archival purposes (such as magnetic tapes or cloud storage). Physical storage media enables different levels of **data access speed, capacity, and durability**, depending on the type of media used. This hierarchy supports a balance between performance needs (fast access) and **cost** efficiency (large, affordable storage).

We can delve into the six specific levels within the hierarchy:

1. Cache
2. Main Memory (RAM)
3. SSD
4. HDD
5. Tertiary Storage
6. Cloud Storage

# 1. Cache Memory

- Cache memory is a **small, ultra-fast memory** located close to or within the CPU, storing frequently accessed data and instructions
- .
- Its purpose is to **reduce the time** the CPU takes to access data, as retrieving information from main memory (RAM) is slower.

- It's **volatile** (data is lost when power is off) and **expensive** per byte but essential for improving system speed.

# 2. Main Memory (RAM)

- RAM (Random Access Memory) is a **primary storage** type that holds data and instructions actively used by the CPU.

- It is **faster than secondary storage** (like hard drives) but **slower than cache**.

- RAM is also **volatile**, meaning data is cleared when the device is powered off, and it provides a larger, affordable workspace for active processes.

## 3. Flash Memory

•Flash memory is a **non-volatile storage** that retains data without power, often used in Solid-State Drives (SSDs), USB drives, and memory cards.

•It's **faster than traditional hard drives** and offers durability since it has no moving parts.

•Flash memory provides **faster access** and is portable, though it's generally more expensive per byte compared to magnetic storage.

## 4. Magnetic Disk (Hard Disk Drive)

•Magnetic disks store data using magnetization on a spinning platter and are used in traditional Hard Disk Drives (HDDs).

•They offer **high capacity at a relatively low cost**, though access speed is slower than SSDs.

•Magnetic disks are **non-volatil**e, making them suitable for long-term data storage.

# 5. Optical Disk

•Optical disks use **laser technology** to read and write data, storing information in pits and lands on the disk's surface.

•They are typically **used for media storage**, backups, and distribution due to their portability and affordability.

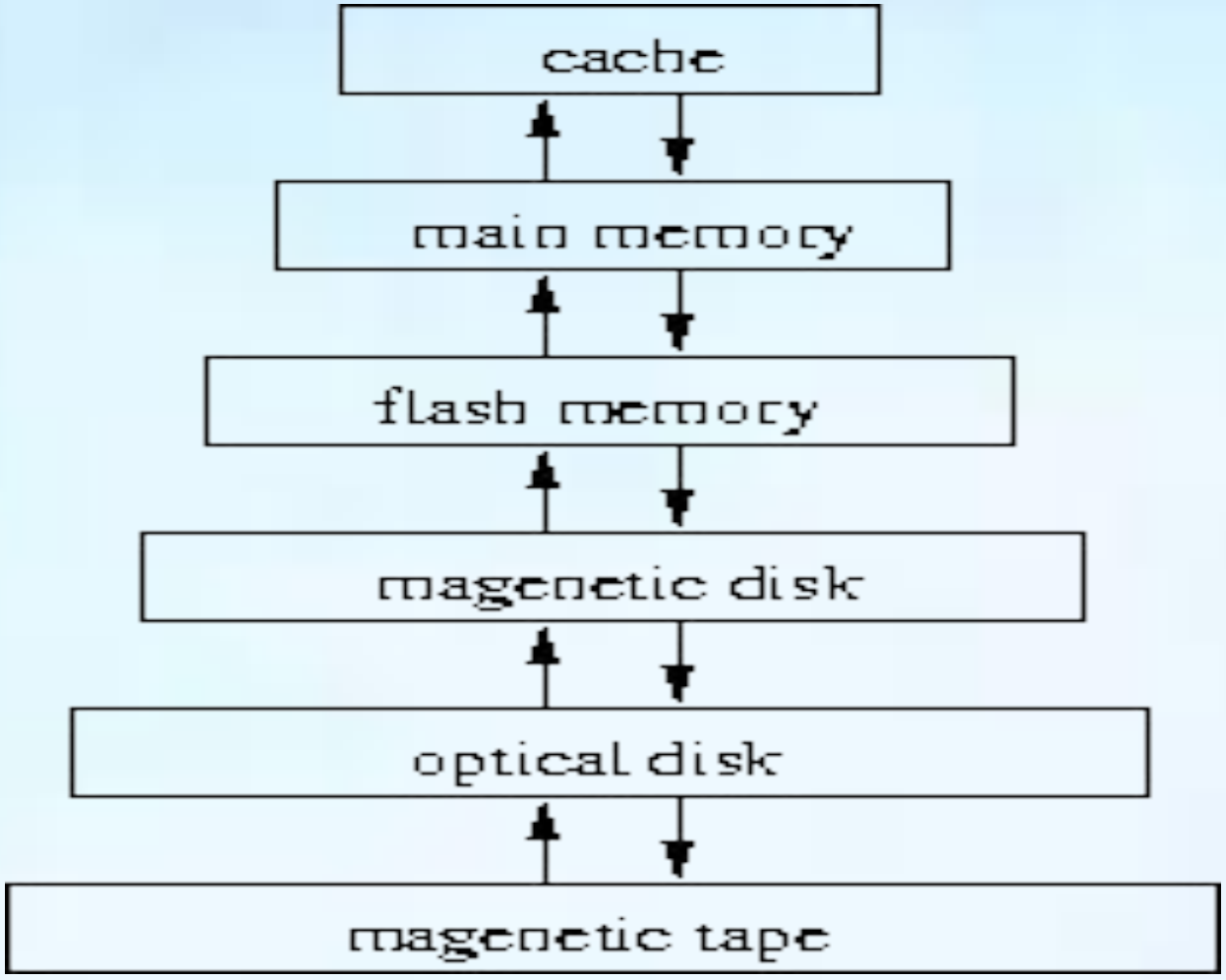
•Optical disks are **non-volatile** and have moderate storage capacity, though they are slower than SSDs and HDDs.

# 6. **Magnetic Tape**

•Magnetic tape is a **sequential storage medium** primarily used for archiving and long-term backups.

•It offers **very high capacity** at a low cost but is **much slower** than other media because it stores data sequentially, requiring a linear search.

•Magnetic tape is **non-volatile** and has excellent durability, making it ideal for storing data that isn't frequently accessed.




In the image, the higher levels are expensive but fast. On moving down, the cost per bit is decreasing, and the access time is increasing. Also, the storage media from the main memory to up represents the volatile nature, and below the main memory, all are non-volatile devices.

# Storage management techniques:

## Let us see about File Organization

### File Structure:

- Databases are stored as files, with records mapped onto **disk blocks**.
- Files consist of **fixed-length or variable-length records**.
- A file is partitioned into blocks, and blocks are the unit of **storage allocation** and **data transfer**.
- Block Size: Common sizes range from **4KB to 8KB**, though this can be customized.

### Record Organization:

- Records are mapped into blocks, ensuring that **no record exceeds a block size**.

# Fixed-Length Records

**Fixed-Length Record Example:**

- Consider a record for an instructor: ID (5 bytes), Name (20 bytes), Dept Name (20 bytes), Salary (8 bytes).
- Total record size = 53 bytes.

**Challenges**:

- Block Size Mismatch: Records may spill over block boundaries, requiring multiple accesses.
- Deletions: Deleting records can result in fragmentation. Space from deleted records must be reused efficiently.

**Solution**:

- Records fit into blocks, and unused block space is left unused for the time being.
- Deletion Strategy: Instead of shifting all records, delete by moving the last record to fill gaps. A free list is maintained to track deleted records.

# Variable-Length Records

**Variable-Length Record Example**:

- Occur in cases where records have fields that can vary in size (e.g., a VARCHAR field).
- Example: ID, Name, and Dept Name are variable-length strings, while Salary is fixed-length.

**Storage:**

- Fixed Part: The initial part of the record contains fixed-length attributes.
- Variable Part: A pair of offset and length indicates the location of variable-length attributes.

**Slotted-Page Structure:**

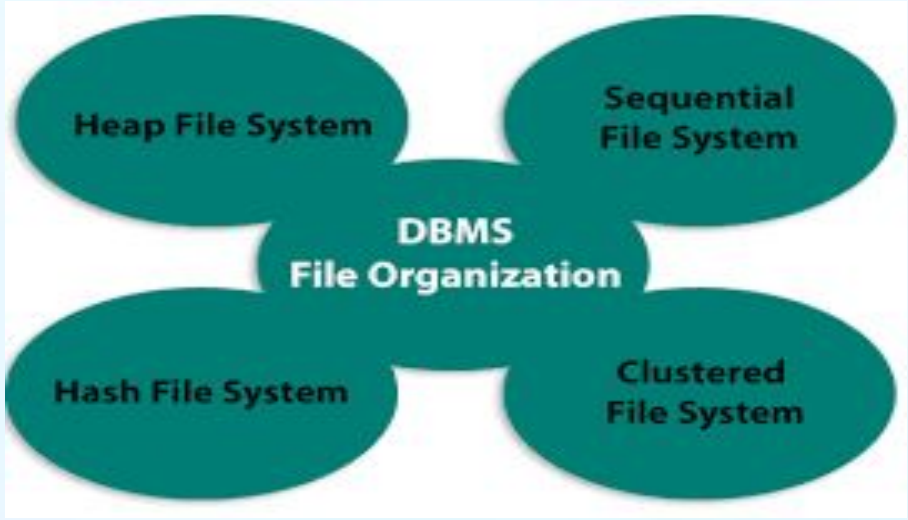
- Used to organize records in a block with an entry header that stores location and size information of each record.
- Free Space Management: When records are deleted, the space is reclaimed by adjusting pointers and managing free space.

# Storage management techniques:

- File Organization
- RAID
- Indexing etc,;

## Organization of Records in Files

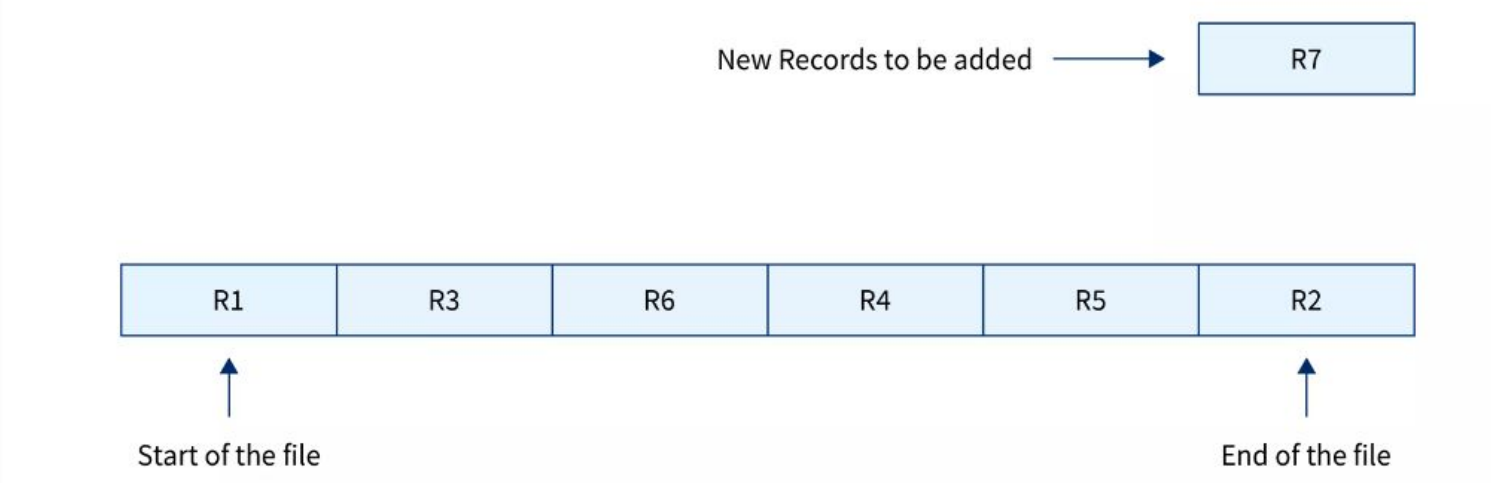
The **File** is a collection of records. Using the primary key, we can access the records. The type and frequency of access can be determined by the type of file organization which was used for a given set of records. Files of fixed length records are easier to implement than the files of variable length records.



# 1. Sequential File Organization

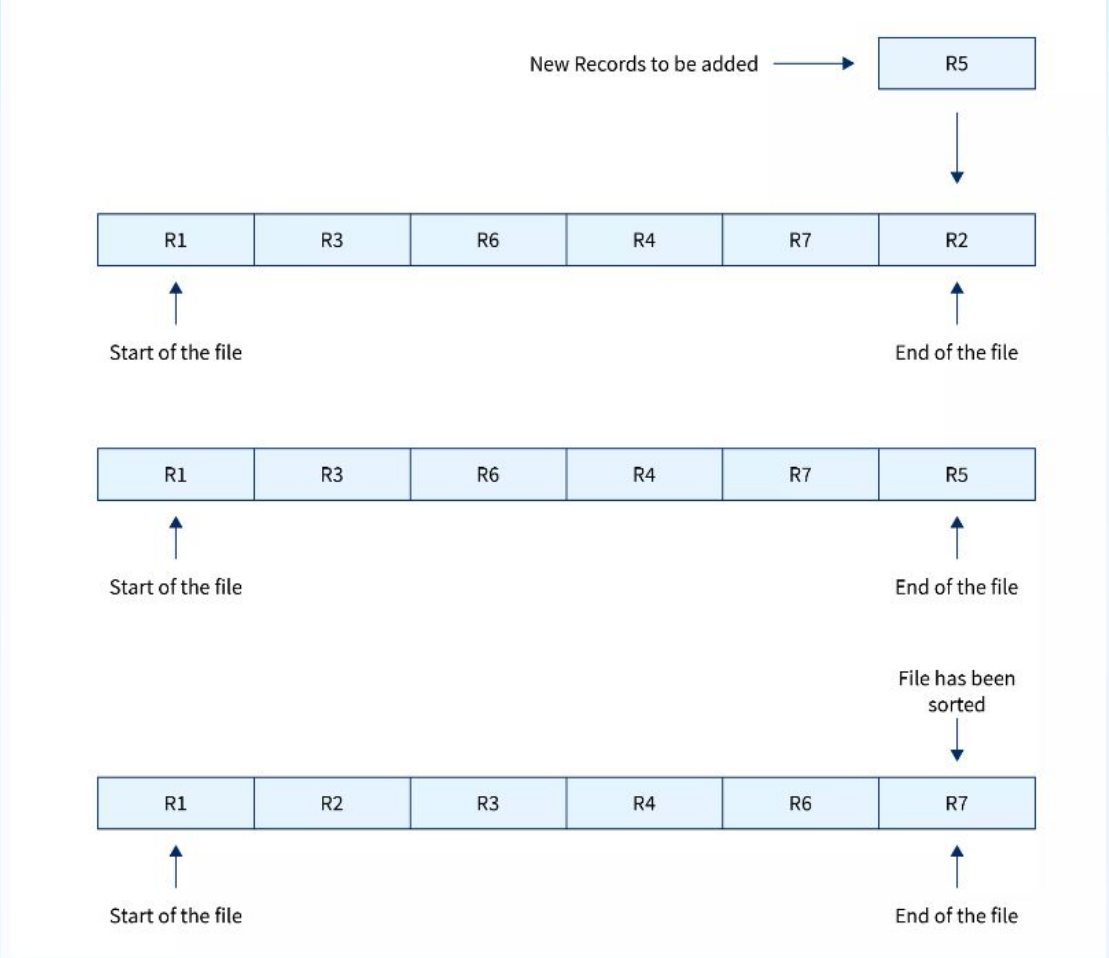
Sequential file organization arranges records in a sorted order based on a key field, facilitating efficient range queries and batch processing. However, insertions and deletions can be slow, as the file must remain sorted. This method is suited for applications with frequent read operations on ordered data.

## a) Pile file method




In this file, the new R7 record will be inserted at the end of the file, and we do not bother about the order in this method.

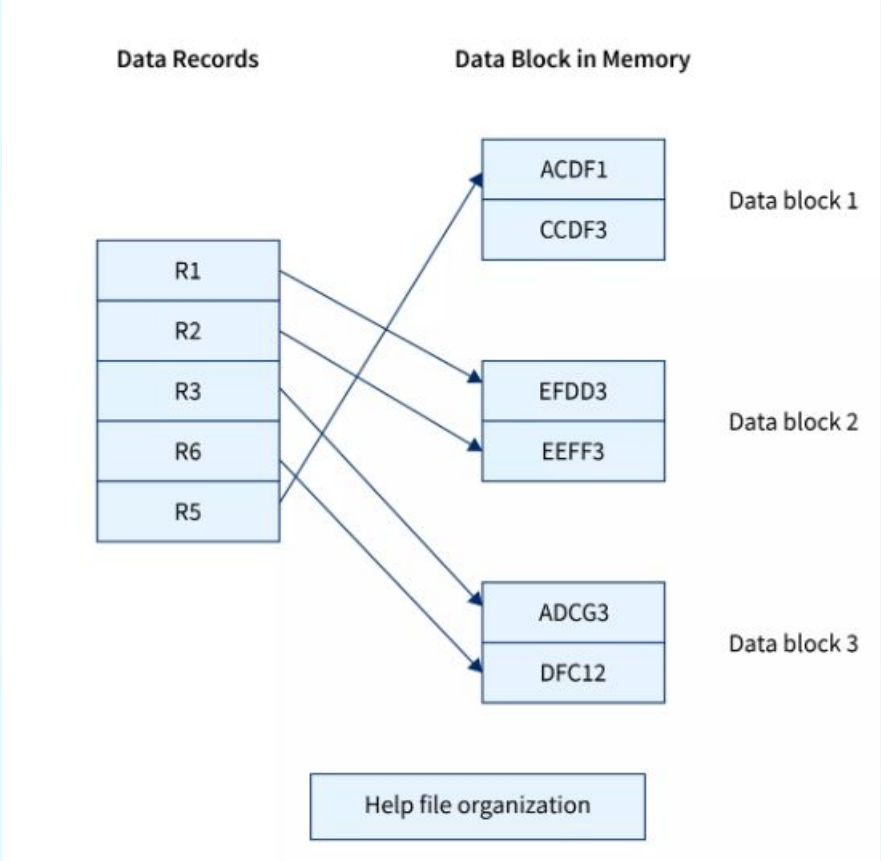
# b) Sorted file method




In this image, the records R1, R2, R3, R4, R6, R7 are there in the file, and the record R5 is inserted at the end of the file, then in the second step, the file is sorted such that the record R5 takes its right place in the file.

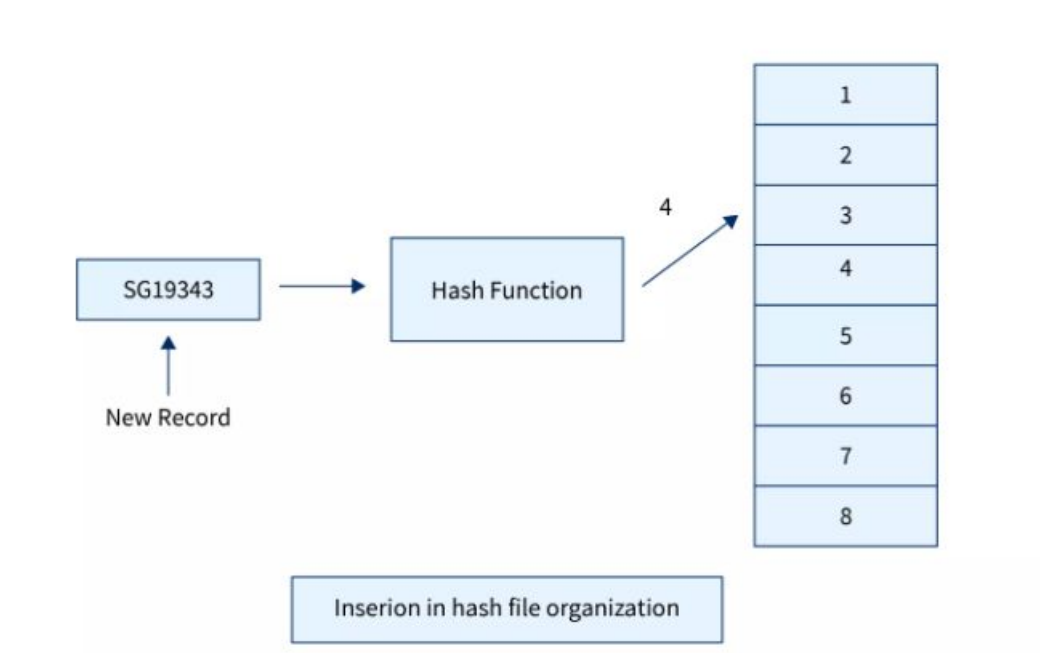
# 2. Heap file organization

Unlike the sequential file method, the data blocks are not allocated sequentially DBMS can choose any data block for the record to be inserted. There is no ordering of records in heap file organization once the data block is full, the next record is stored in the new data block, which might not be the next data block



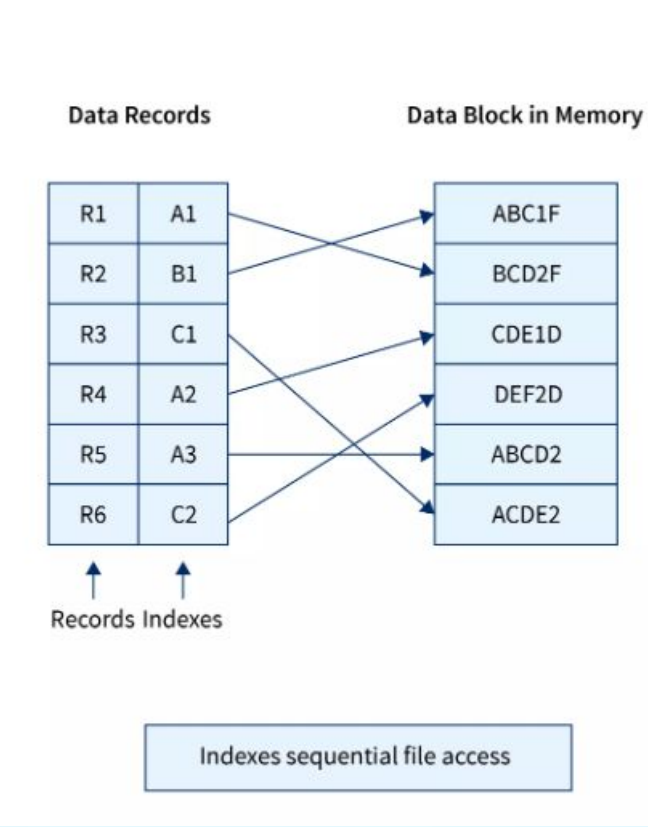
# 3. Hash file organisation

In hash file organization, Hashing is used to generate the addresses of the memory blocks where actual records are mapped. Basically, a hashing function generates the address of those data blocks using the primary key as input, and those memory locations which are generated by these hash functions are called data buckets or data blocks.



# 4. Clustered file organisation

In clustered file organization, two or more records/tables are combined into a single file based on the clustered key or hash clusters, these files contain two or more tables in the same memory block, and all of them are combined using a single clustered key/hash key to a single table.




- Q1 : Which file organization method stores records in the order they arrive, without any specific sorting?

- Q2 : What is the primary advantage of using hashed file organization for data retrieval?

- Q3 : In which file organization method are related records from multiple tables stored together to optimize query performance?

- Q4 : Which file organization type arranges records based on a key field, facilitating efficient range queries?

# NOW YOU KNOW

- **Answer**: Heap file organization stores records in the order they arrive, without any specific sorting.

- **Answer**: The primary advantage of using hashed file organization is its fast access time for exact-match queries due to direct mapping of keys.

- **Answer**: Clustered file organization stores related records from multiple tables together to optimize query performance.

- **Answer**: Sequential file organization arranges records based on a key field, facilitating efficient range queries

# THANK YOU !