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Welcome to this session:

Coding Interview Workshop - Linear Data Structures

The session will start shortly...

Questions? Drop them in the chat. We'll have dedicated moderators answering questions.

Safeguarding & Welfare

We are committed to all our students and staff feeling safe and happy; we want to make sure there is always someone you can turn to if you are worried about anything.

If you are feeling upset or unsafe, are worried about a friend, student or family member, or you feel like something isn't right, speak to our safeguarding team:

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Skills Bootcamp Coding Interview Workshop

- The use of disrespectful language is prohibited in the questions, this is a supportive, learning environment for all - please engage accordingly. **(Fundamental British Values: Mutual Respect and Tolerance)**
- No question is daft or silly - **ask them!**
- There are **Q&A sessions** midway and at the end of the session, should you wish to ask any follow-up questions. Moderators are going to be answering questions as the session progresses as well.
- If you have any questions outside of this lecture, or that are not answered during this lecture, please do submit these for upcoming Academic Sessions. You can submit these questions here: **Questions**

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- For all **non-academic questions**, please submit a query: ***www.hyperiondev.com/support***
- **Report a safeguarding incident: *www.hyperiondev.com/safeguardreporting***
- We would love your feedback on lectures: **Feedback on Lectures**
- If you are hearing impaired, please kindly use your computer's function through Google chrome to enable captions.

Learning Outcomes

- **Explain the fundamental characteristics** of arrays, linked lists, stacks, queues, and hash tables.
- **Implement insertion, deletion, searching, and traversal operations** for each structure.
- **Solve interview problems** that require efficient use of stacks, queues, and hash tables, such as valid parentheses, next greater element, queue reconstruction, and anagram grouping.
- **Analyse the time and space complexity** of different data structure operations.

You are building a text editor with an undo feature. Which data structure would be the best choice?

A. Array

B. Stack

C. Queue

D. Linked List

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Which data structure would be best for fast lookups in a dictionary application?

A. Array
B. Linked List
C. Hash Table
D. Queue

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Lecture Overview

→ Linked Lists
→ Stacks and Queues
→ Hash Tables

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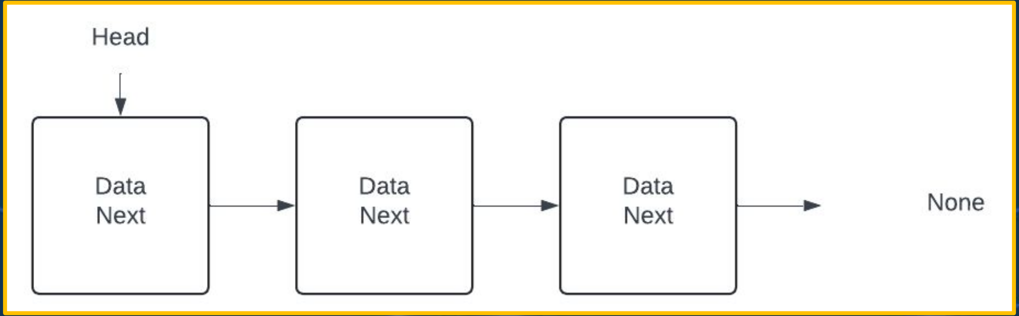
Linked Lists

A linear data structure consisting of a sequence of nodes, each node contains data and a reference (link) to the next node in the sequence

- Components of a node:
  - **Data:** The actual information stored in the node
  - **Next pointer:** A reference to the next node in the linked list
  - **Previous pointer (for doubly linked lists):** A reference to the previous node in the linked list
- Nodes are **connected to form a linked list**, allowing for efficient insertion and deletion of elements at any position in the sequence

Singly Linked Lists

- Pros:
  - **Dynamic size:** Linked lists can grow or shrink as needed during runtime
  - **Efficient insertion and deletion:** O(1) time complexity for inserting or deleting elements at the beginning of the list



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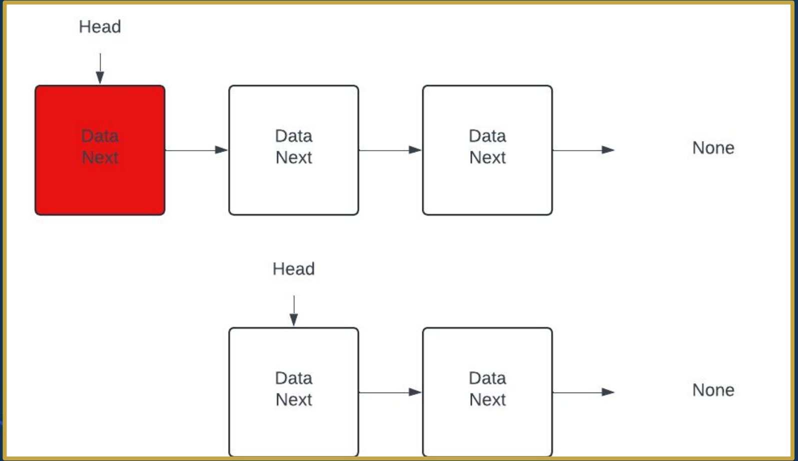
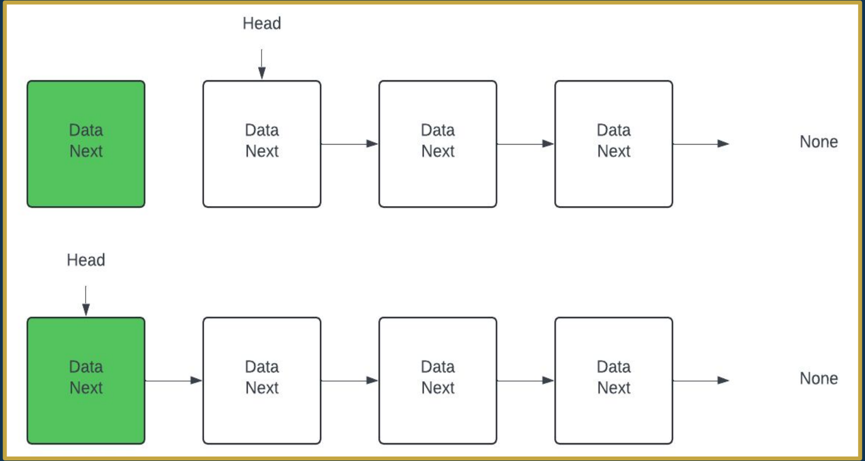
Singly Linked Lists

❖ Why O(1)? Glad you asked, so 🤓...





❖ For removal we only take **1 step no matter the size of the list**, and the same for insertion, thus O(1) for worst case

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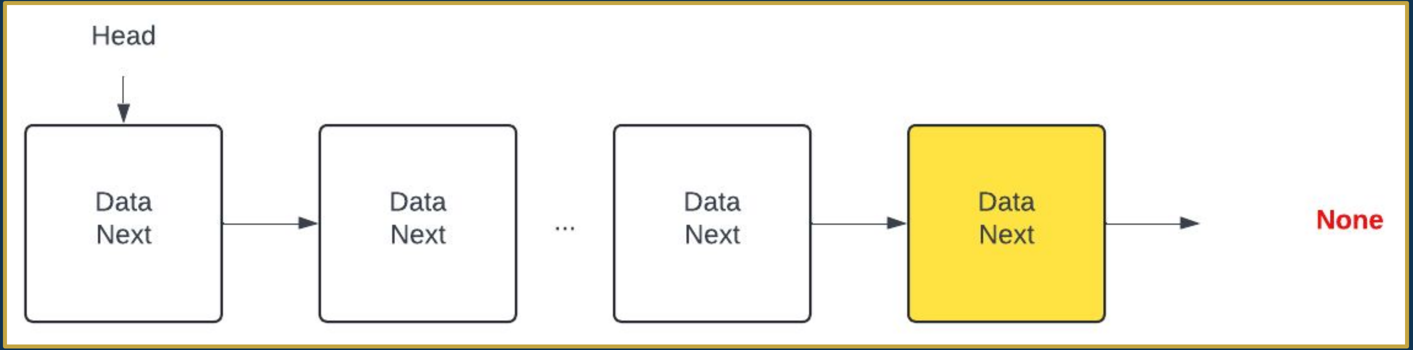
Singly Linked Lists

- Cons:
  - **No random access:** Accessing an element at a specific index requires traversing the list from the beginning, resulting in O(n) time complexity
  - **Extra memory:** Linked lists require additional memory for storing the next pointers

Singly Linked Lists

❖ Why O(n)? You flatter me ☺️...



❖ This list has n nodes, to get to the yellow (last) one we need to pass n nodes, so in worst case O(n)

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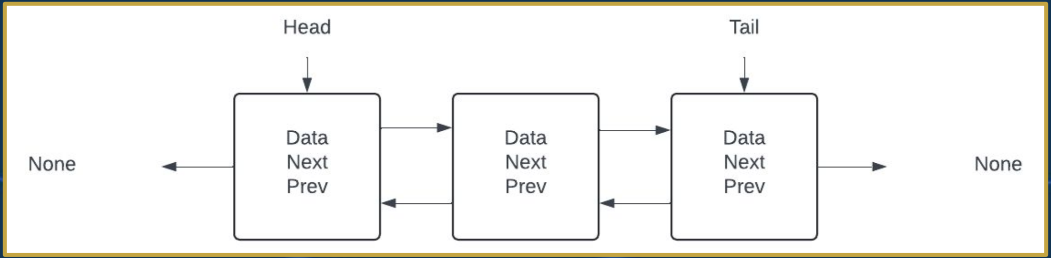
Doubly Linked Lists

- Pros:
  - **Efficient insertion and deletion:** O(1) time complexity for inserting or deleting elements at both ends of the list
  - **Backward traversal:** Doubly linked lists allow traversal in both forward and backward directions



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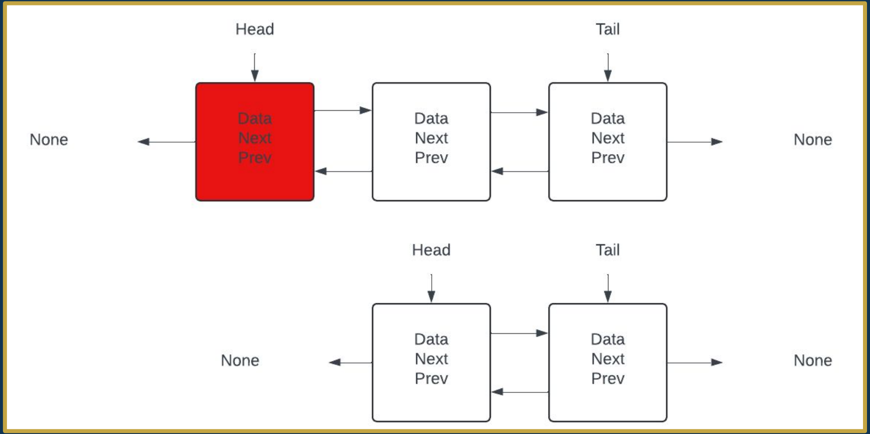
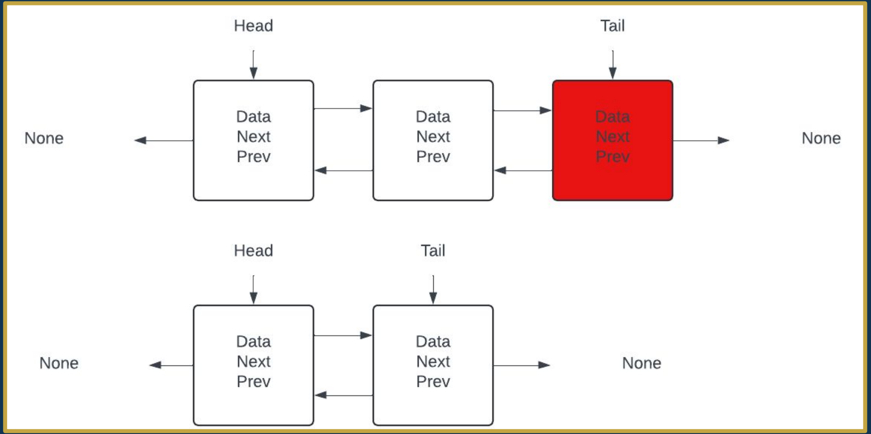
Doubly Linked Lists

❖ Why O(1)?





❖ Thanks to the tail pointer deletion or addition on either sides **take 1 step at worst**, thus O(1)

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Doubly Linked Lists

- Cons:
  - **Extra memory:** Doubly linked lists require more memory than singly linked lists due to the additional previous pointers
  - **More complex implementation:** Maintaining the previous pointers requires more careful management of node connections

Stacks and Queues

Types of linear data structures that allow for storage and retrieval of data based on a specific method of ordering.

- ❖ Data structures allow us to **organise storage** so that data can be accessed **faster and more efficiently**.
- ❖ Stacks and queues are simple, easy to implement and widely applicable.
- ❖ Each has defined methods of **ordering** and **operations** for adding and removing elements to and from the structure.
- ❖ Can be implemented using an Array, Linked List or the `deque` or `queue` modules in Python.

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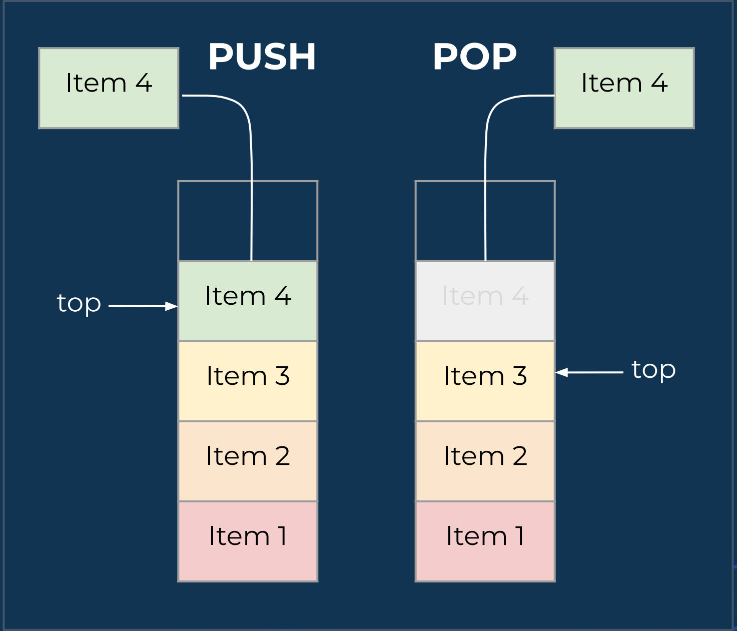
Stacks

Method of Ordering

- ❖ **LIFO:** Last element added to the stack is the first to be removed
- ❖ Elements are added on **top** of one another in a "stack"
- ❖ A pointer points to the element at the **top** of the stack

Operations

- ❖ **Push:** Adds an element to the top of the stack
- ❖ **Pop:** Removes the element from the top of the stack



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Stacks

Complexity Analysis

- **Push**
  - **Space: O(1)**
    No extra space is used
  - **Time: O(1)**
    A single memory allocation done in constant time

- **Pop**
  - **Space: O(1)**
    No extra space is used
  - **Time: O(1)**
    Pointer is decremented by 1

Common Uses

- Function and Recursive Calls
- Undo and Redo Mechanisms
- “Most recently used” features
- Backtracking algorithms
- Expression evaluations and syntax parsing

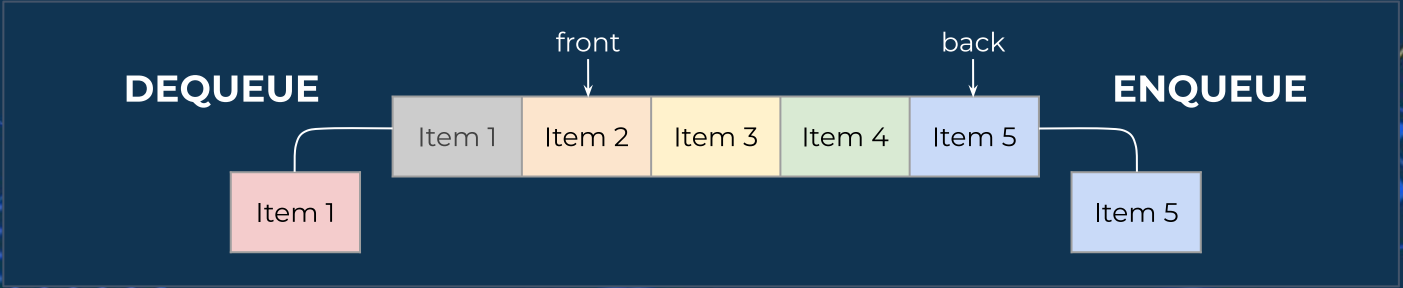
Queues

Method of Ordering

- **FIFO:** First element added to the stack is the first to be removed
- Elements added to **rear** of a “queue” and removed from **front**
- Two pointers point to the **front** and the **rear**

Operations

- **Enqueue:** Adds an element to the end of the queue
- **Dequeue:** Removes the element from the front of the queue



Queues

Complexity Analysis

- **Enqueue**
  - **Space: O(1)**
    No extra space used
  - **Time: O(1)**
    Single memory allocation done in constant time
- **Dequeue**
  - **Space: O(1)**
    No extra space used
  - **Time: O(1)**
    Front pointer incremented by 1 and node deallocated

Common Uses

- Task Scheduling
- Resource Allocation
- Network Protocols a
- Printing Queues
- Web Servers
- Breadth-First Search

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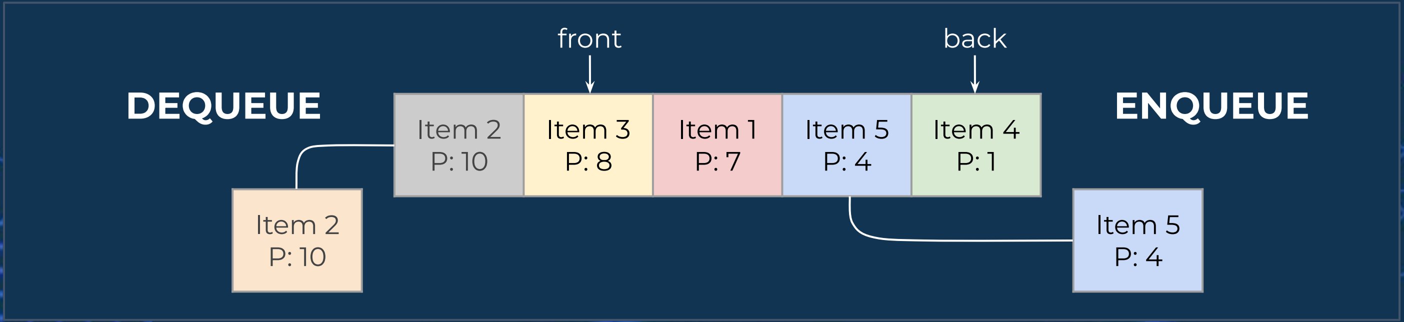
Priority Queues

Method of Ordering

- Arranged according to the assigned **priority** of elements
- Order direction doesn't matter, as long as **the highest priority elements are removed first**

Operations

- **Enqueue:** Adds an element to the queue based on its priority
- **Dequeue:** Removes the highest priority element from the queue



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Priority Queues

Complexity Analysis

- **Enqueue**
  - **Space:**
    - **List - O(1)**
      No extra space is used
    - **PriorityQueue - O(1)**
      No extra space is used
  - **Time:**
    - **List - O(n)**
      Each element's priority must be checked and compared
    - **PriorityQueue - O(log n)**
      Adding node to heap

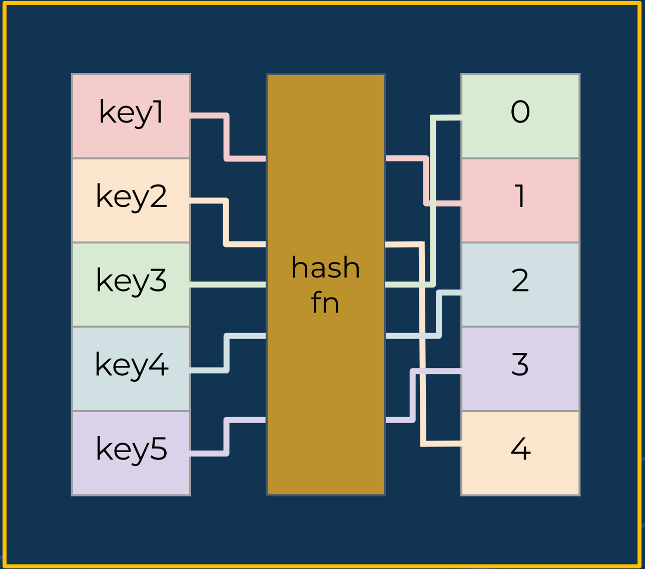
Dequeue

- **Space:**
  - **List - O(1)**
    No extra space is used
  - **PriorityQueue - O(1)**
    No extra space is used
- **Time:**
  - **List - O(1)**
    Pointer is updated or last element is removed
  - **PriorityQueue - O(log n)**
    Removing node from heap

Hash Tables

A data structure that is used to store key-value pairs which uses a hash function to transform the key into the index of an associated array element where the data will be stored.

- Hash tables allow for **efficient and fast** insertions, deletions and look-ups due to the manner in which values are stored.
- Since the **index where the values is stored is a function of the value**, the position where the value must be stored is always known.



Click here to visualize this data structure!

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- ❖ **Hashing** refers to using the hash function to calculate **the hash** which is the index of the array element where the key-value pair will be stored.
- ❖ Each array element is called a **bucket or slot** and can store one or more key-value pairs.
- ❖ The **hash function** can be any **deterministic** function which maps a key to the range of indices but the aim is that the function is **efficient**, it distributes keys **uniformly** and **multiple keys being mapped to the same index** is avoided.
- ❖ The **load factor** is the ratio of the number of stored elements to the total number of buckets and is used to determine whether the table can be downsized to improve performance.

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Hash Collisions

When two or more distinct keys hash to the same array index.

- ❖ Although we try to avoid hash collisions, they are inevitable so we have to implement a **collision-resolution** process.
- ❖ When searching or storing data, a hash collision **increases the time complexity** of the task.

Operation	Average Case	Worst Case
Insert	O(1)	O(n)
Lookup/Search	O(1)	O(n)
Delete	O(1)	O(n)

Collision-Resolution

- **Chaining**: Linked Lists are used for each bucket, so multiple key-value pairs can be stored in the same bucket.
  - Pros: Simple to implement, dynamic resizing
  - Cons: Memory overhead implications, space inefficiencies
- **Linear Probing**: If there is a collision, place the pair in the next available slot in the hash table (linearly).
  - Pros: Simple to implement, memory-efficient
  - Cons: Primary clustering (large blocks of occupied elements), clustering results in more time inefficiencies

Built-in Hash Tables

- **Dictionaries** (Python) and **Maps** (JavaScript) are data structures which store key-value pairs.
- They are implemented internally using a **hash table**, using built-in hash functions.
- They are the easiest way to implement a hash table, since all the complexities involved in ensuring efficiency is abstracted away.
- A custom hash table would be primarily used when a **custom hash function** needs to be implemented.
- This is useful in the case where keys are of **custom or non-hashable data types.**

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Practice the Structures

Let’s practice using different linear data structures by solving some classic problems for each paradigm.

Then we’ll do the following problems together:

- ➢ LRU Cache
- ➢ First Unique Character
- ➢ Group Anagrams

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You’re implementing an autocomplete feature that must store and retrieve words efficiently. Which data structure would you use?

A. Stack

B. Queue

C. Hash Table

D. Linked List

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What was the most valuable part of today's lecture?

A. Stack

B. Queue

C. Linked List

D. Hash Table

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Homework

Practise the skills we've developed by completing the rest of the LeetCode questions:

- ❖ Practise speaking through your solutions and explaining how you approached each problem.
- ❖ In the next lecture we'll be covering the topic: “Non-Linear Data Structures”
- ❖ You can have a look at the following LeetCode questions to prepare:
  - ➢ Example 1
  - ➢ Example 2
  - ➢ Example 3

Summary

★ **Arrays** allow fast indexing but slow insertions.

★ **Linked Lists** enable dynamic memory allocation but have slow searches.

★ **Stacks** handle undo/redo operations and recursion.

★ **Queues** are best for processing tasks in order.

★ **Hash Tables** provide fast lookups for key-value pairs.

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Q & A SECTION

Please use this time to ask any questions relating to the topic, should you have any.

Thank you for attending

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