122com Data structures and types

David Croft

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122com Data structs & types

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Arrays

Linked lists
Array example
LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

Trees

End

Overview

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Arrays C

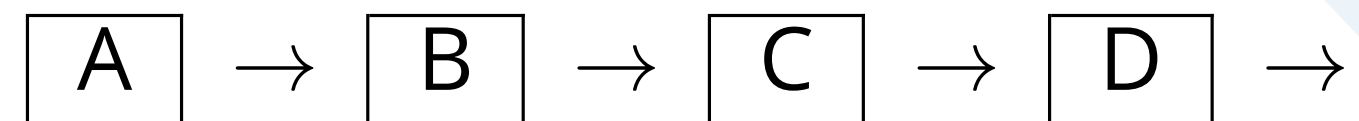A series of objects all of the same size and type.

```c
char array[] = {'A', 'B', 'C', 'D', 'E'};
```

- Stored in contiguous blocks of memory.
- Python lists are functionally closest.
    - But are not arrays.
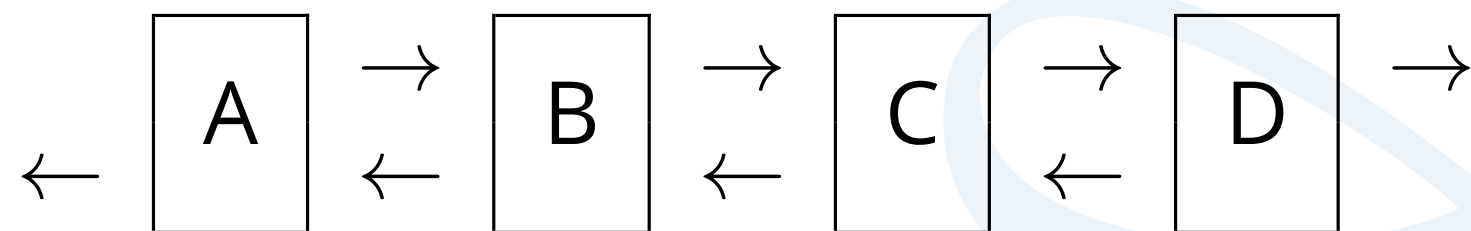- Can't be resized.

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Linked lists

The challenger for array's crown.

- Series of nodes, each of which points to the next element.
  - And to the previous element if it's a doubly linked list.

Singly linked $\quad$ A $\rightarrow$ B $\rightarrow$ C $\rightarrow$ D $\rightarrow$

Doubly linked $\quad \leftarrow$ A $\begin{matrix}\rightarrow \\ \leftarrow\end{matrix}$ B $\begin{matrix}\rightarrow \\ \leftarrow\end{matrix}$ C $\begin{matrix}\rightarrow \\ \leftarrow\end{matrix}$ D $\rightarrow$
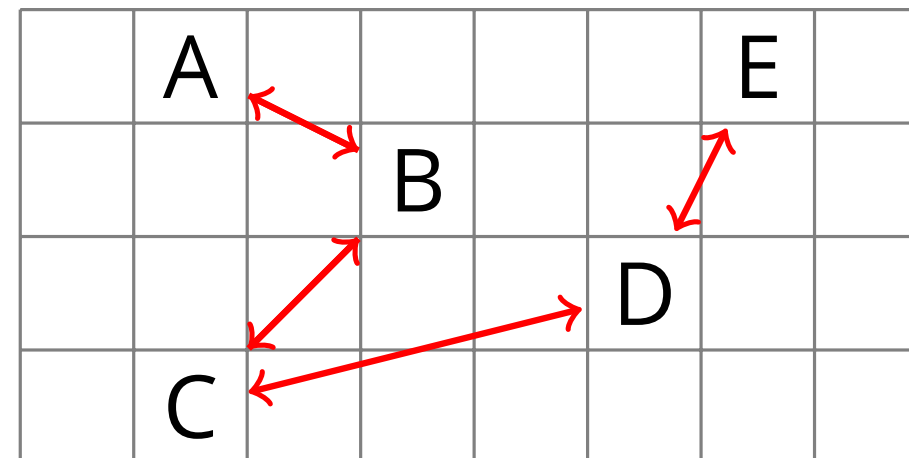
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Linked lists II

A

Not in contiguous memory.

- Each node is separate.

- Scattered.

- Dynamic memory (pointers!).

- Why would we use linked lists instead of arrays?

  - Can change size.

  - Can quickly insert and delete elements.

```python
class Node:
    __prev = None
    __next = None
    value = None
```

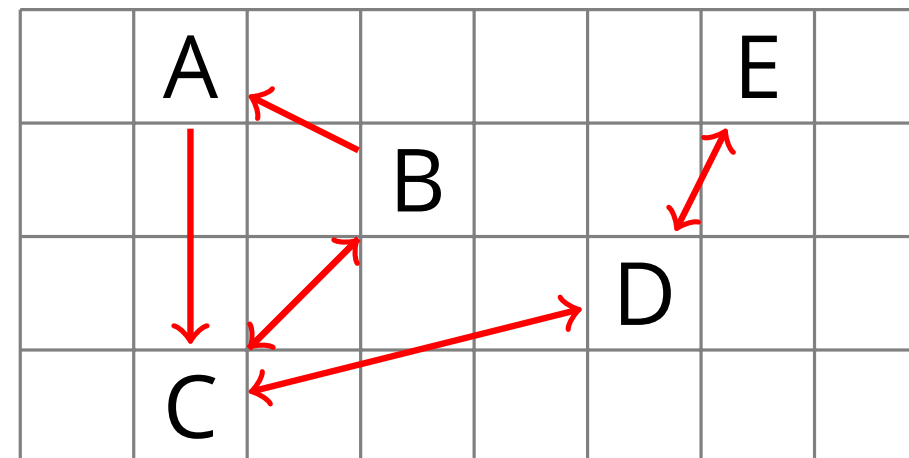```cpp
class Node
{
private:
    Node *prev;
    Node *next;

public:
    int value;
};
```

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# Linked lists II

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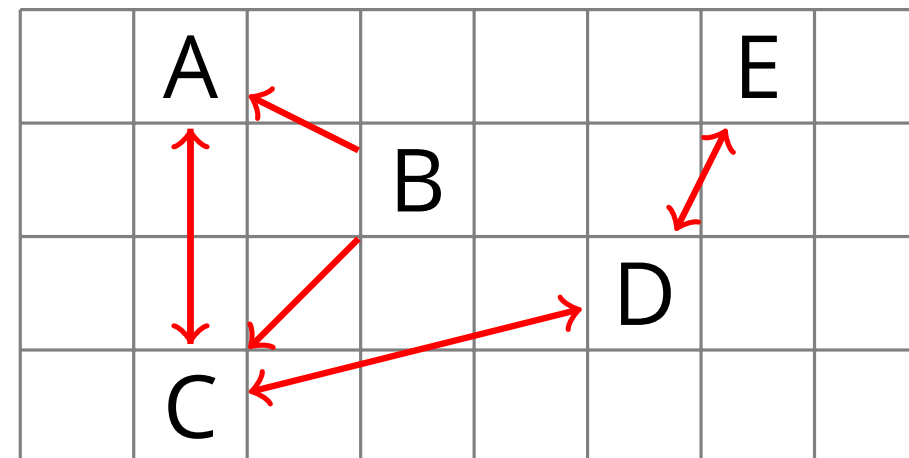```

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Removing array elements

C

```c
char array[] = {'A', 'B', 'C', 'D', 'E'};
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- Array in memory, multiple elements in a contiguous block.
- How do we remove elements from the middle?

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Removing array elements

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```

		A		C	D	E	

- Array in memory, multiple elements in a contiguous block.
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  1. Remove element from the array.

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Removing array elements

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Removing array elements

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 2. Move next element to occupy the empty space.
  3. Repeat.

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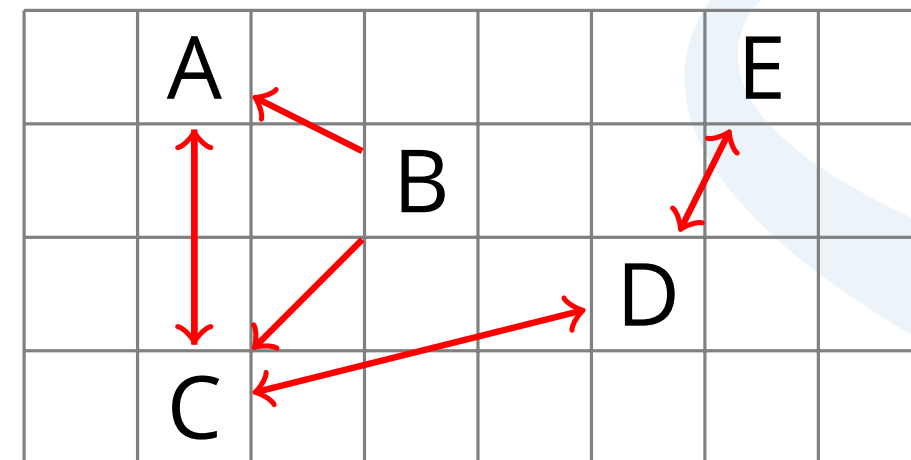- Is very slow with large arrays.

Removing linked list elements
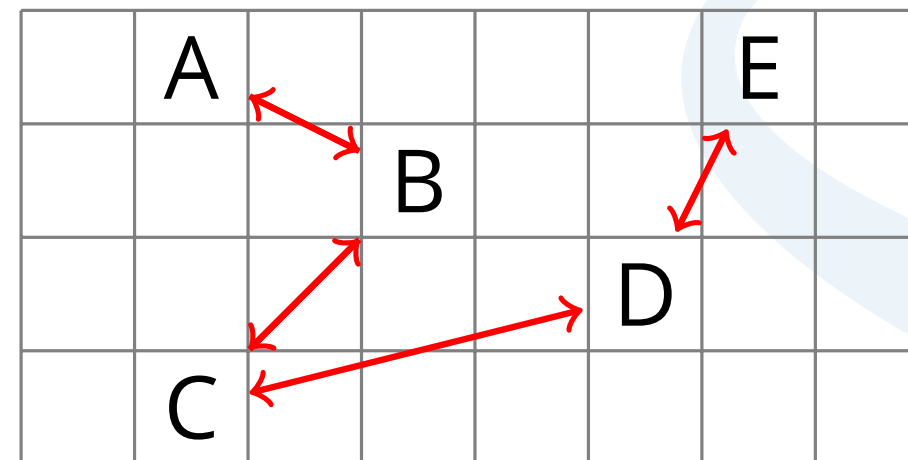
- Linked list, separate elements scattered in memory.

- Each pointing to the next/prev element.

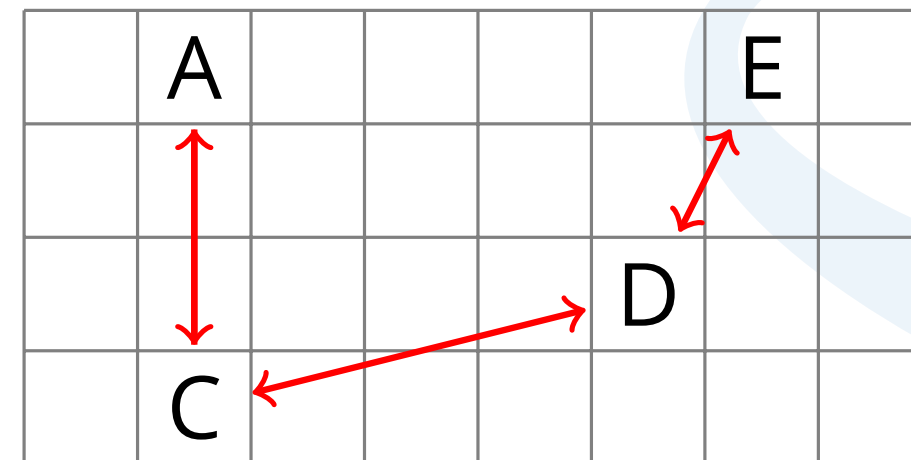- How do we remove elements?

Removing linked list elements
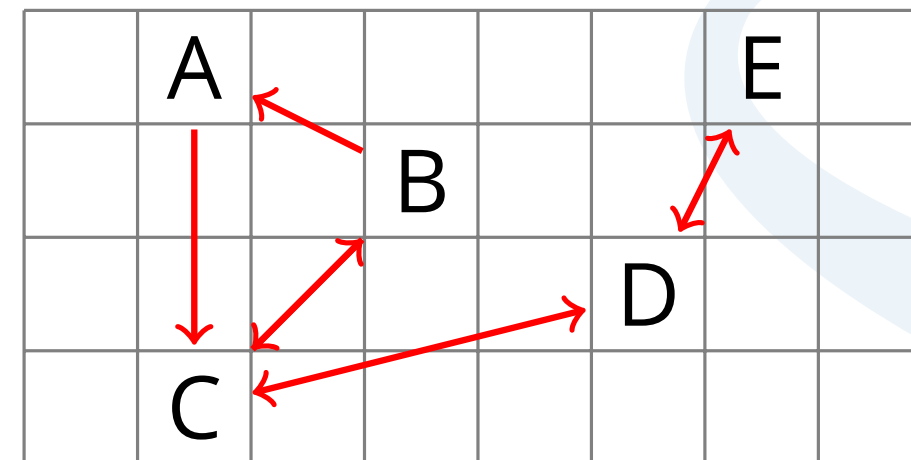
I

- Linked list, separate elements scattered in memory.

- Each pointing to the next/prev element.

- How do we remove elements?
  1. Change pointers.

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Removing linked list elements

■ Linked list, separate elements scattered in memory.

■ Each pointing to the next/prev element.

■ How do we remove elements?

1 Change pointers.

Removing linked list elements

- Linked list, separate elements scattered in memory.

- Each pointing to the next/prev element.

- How do we remove elements?
  1. Change pointers.
  2. Delete old element.

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Advantages

- Inserting and deleting elements is very fast.
  - $O(1)$.
- No size limits, can keep adding new elements.
- Doesn't waste memory.

Disadvantages

- Not indexed.
  - Can't ask for the 20[th] element etc.
  - Have to step through the list (slow).
- Needs more memory than an array to store the same number of elements.
  - Have to keep track of where the next/prev nodes are.

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Data structures   C

Arrays and linked lists are data structures.

- A specific way of storing data.

- Can see how the various elements of the structure are laid out in memory.

- Direct access to the underlying memory.

Abstract data types

As we move to storing more complex information in our software we well start to encounter Abstract Data Types (ADTs).

- Software engineering principal.

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Abstract data types

I

As we move to storing more complex information in our software we well start to encounter ADTs.

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- Keep what a data type can do...

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Abstract data types

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- Unlike data structure ADTs only concerned with the interface.

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Abstract data types

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As we move to storing more complex information in our software we well start to encounter ADTs.

- Software engineering principal.

- Keep what a data type can do...

  ...and how it does it separate.

- Unlike data structure ADTs only concerned with the interface.

- Internals of ADTs can vary widely between implementations.

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Imagine an ADT like a car.

- It has a set of supported operations, go faster, go slower, turn left, turn right.

Imagine an ADT like a car.

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Imagine an ADT like a car.

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- Don't care how it achieves these.

- Don't care if, internally, it's using a combustion engine or an electric motor.

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Imagine an ADT like a car.

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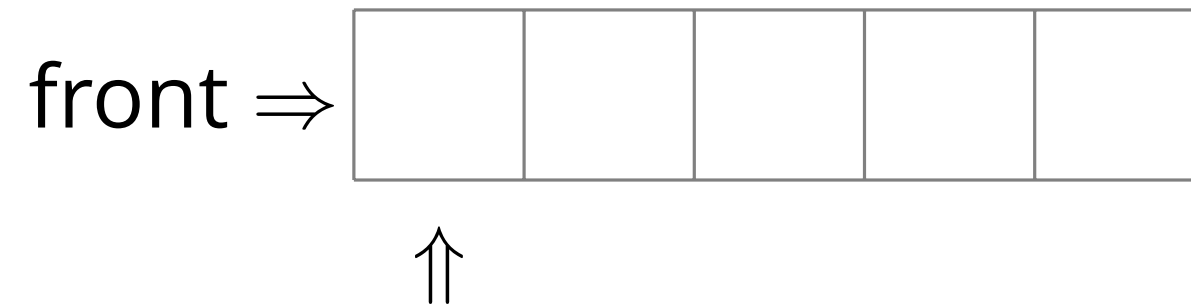- ■ Only care about the result.

Queues

C

A First In First Out (FIFO) ADT.

- Ends of the queue called the front and back.
- New elements added to back of queue only.
    - Pushing - push(value)
- Old elements removed from front of queue only.
    - Popping - pop()
- No cutting in.

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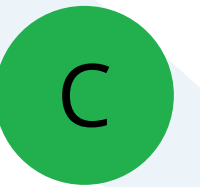
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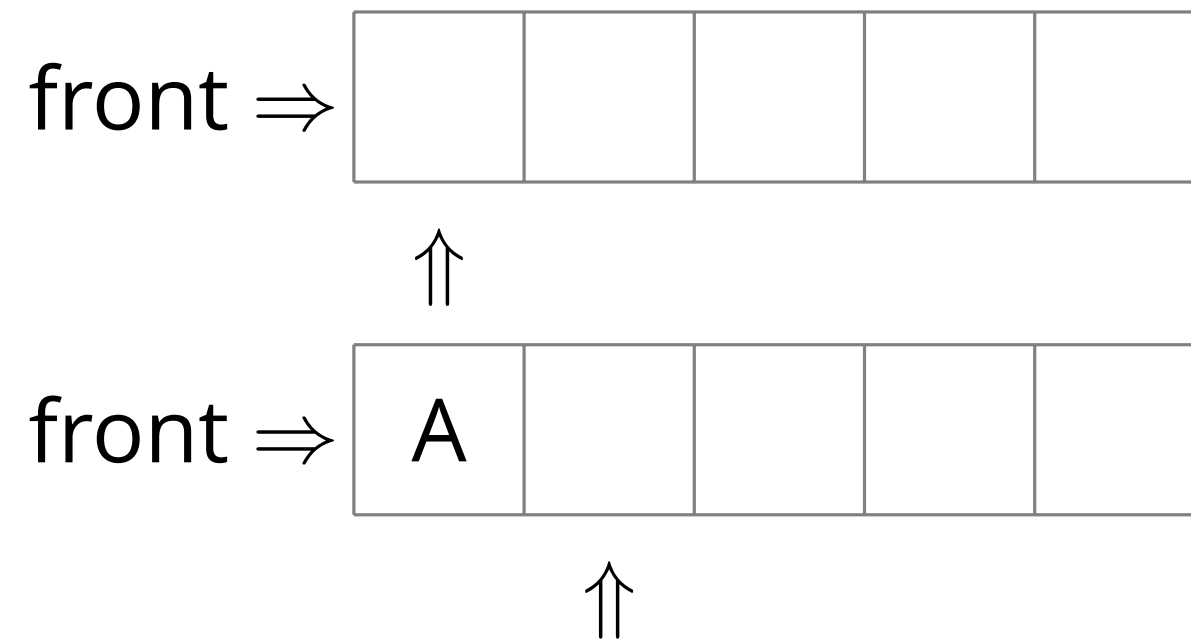- Which would be better for a queue? An array or a linked list?

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- Which would be better for a queue? An array or a linked list?
    - Linked list.

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Array as a queue.

I

front ⇒

⇑

- Very similar to stacks.
  - Keep track of next free space.
  - Limited size.

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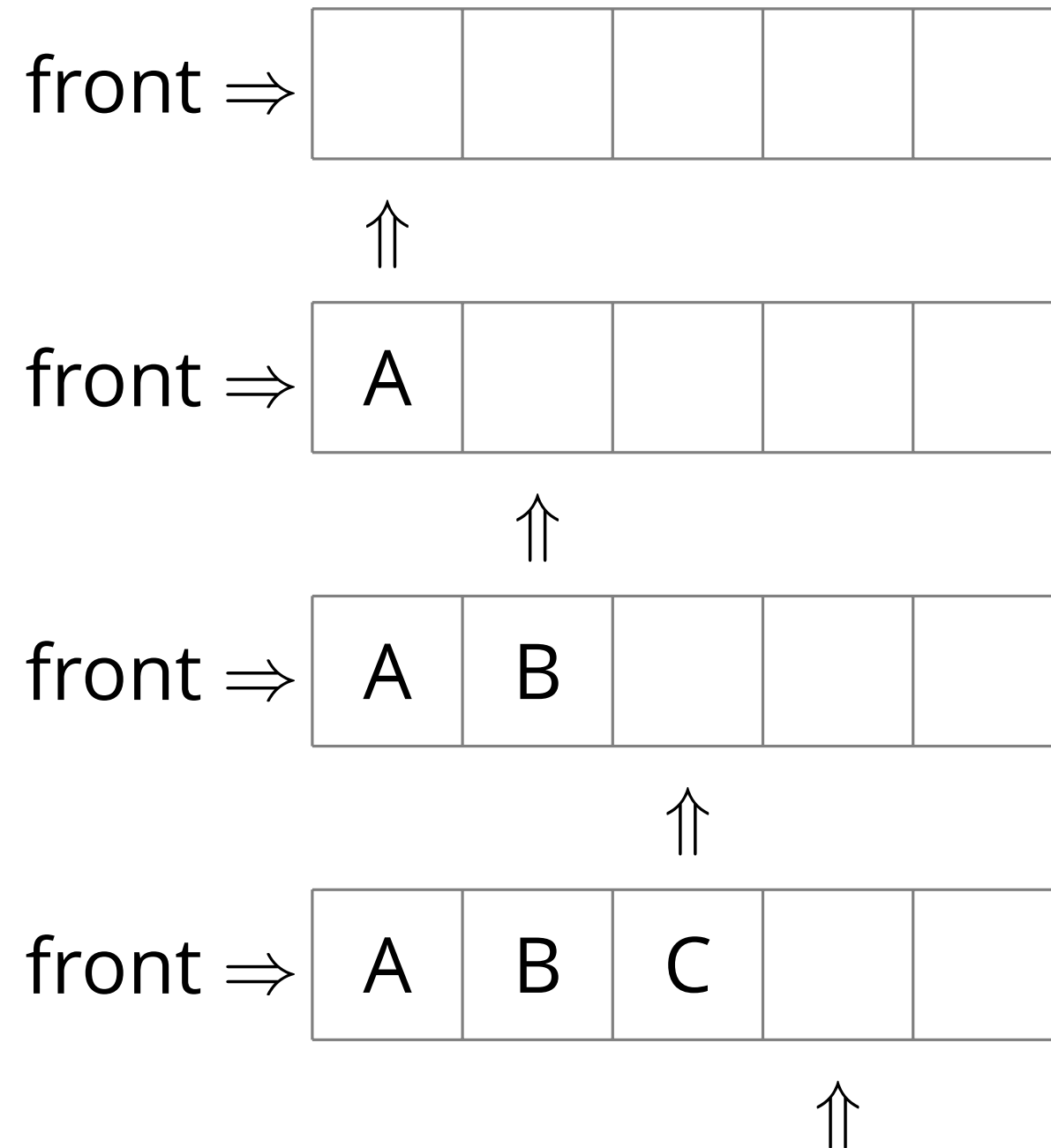# Array as a queue.

front ⇒ | | | | | |

⇑

front ⇒ | A | | | | | push(A)

⇑

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Array as a queue.

front ⇒ [ ][ ][ ][ ][ ]

⇑

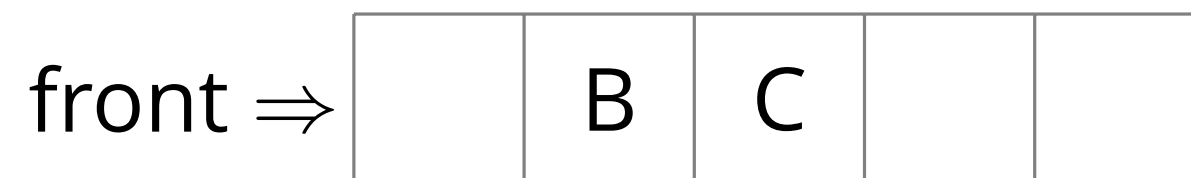front ⇒ [A][ ][ ][ ][ ]   push(A)

⇑

front ⇒ [A][B][ ][ ][ ]   push(B)

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Array as a queue.

front ⇒ | | | | | |

⇑

front ⇒ | A | | | | | push(A)

⇑

front ⇒ | A | B | | | | push(B)

⇑

front ⇒ | A | B | C | | | push(C)

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front ⇒ [| | | |]

⇑

front ⇒ [A | | | |] push(A)

⇑

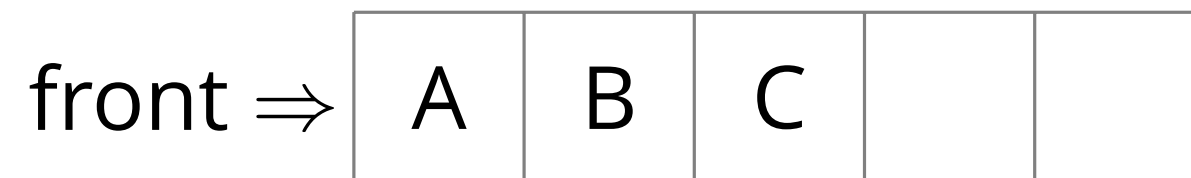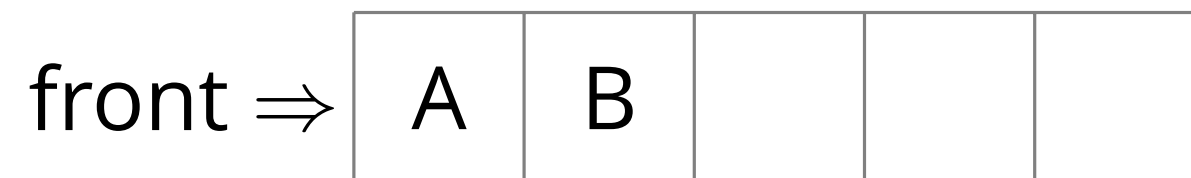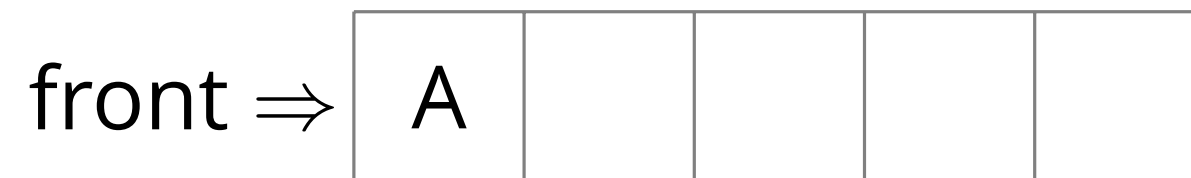front ⇒ [A | B | | |] push(B)

⇑

front ⇒ [A | B | C | |] push(C)
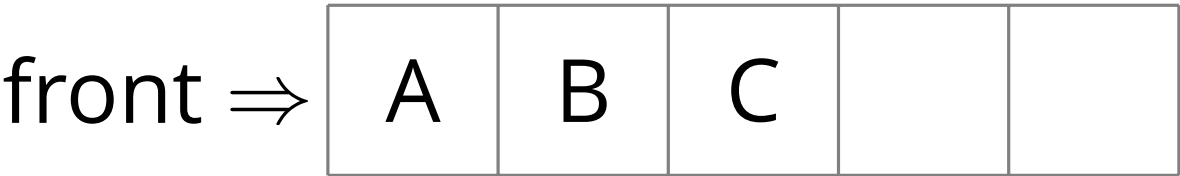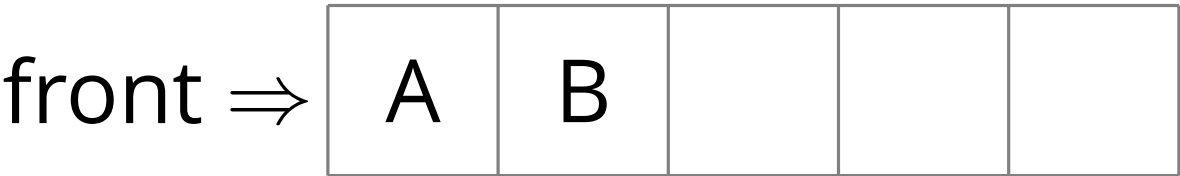
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- Very similar to stacks.
  - Keep track of next free space.
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- What happens when we pop()?
  - Have to shuffle every element forward one space.
  - Inefficient.

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⇑

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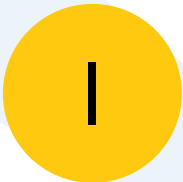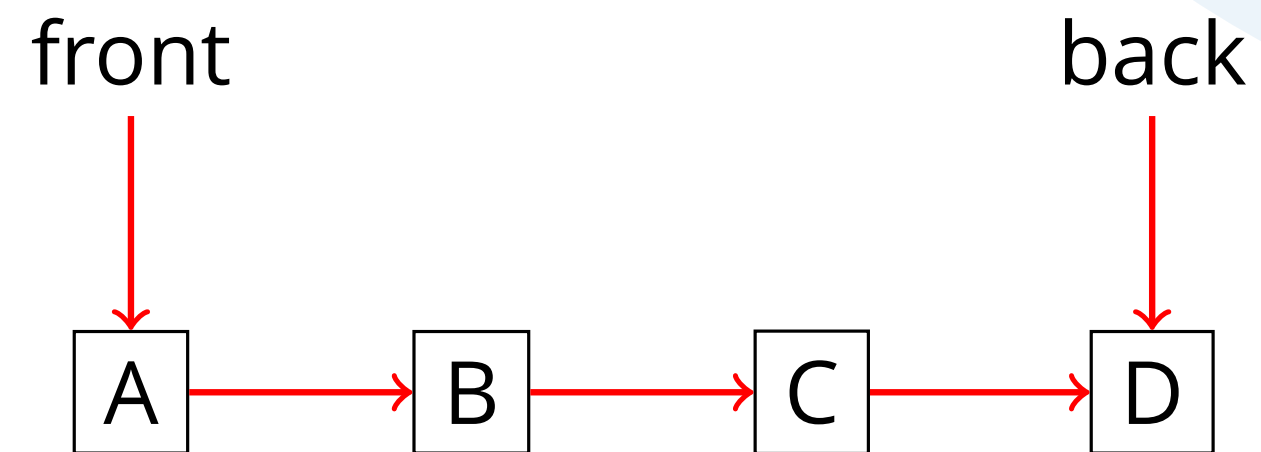
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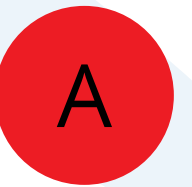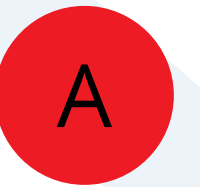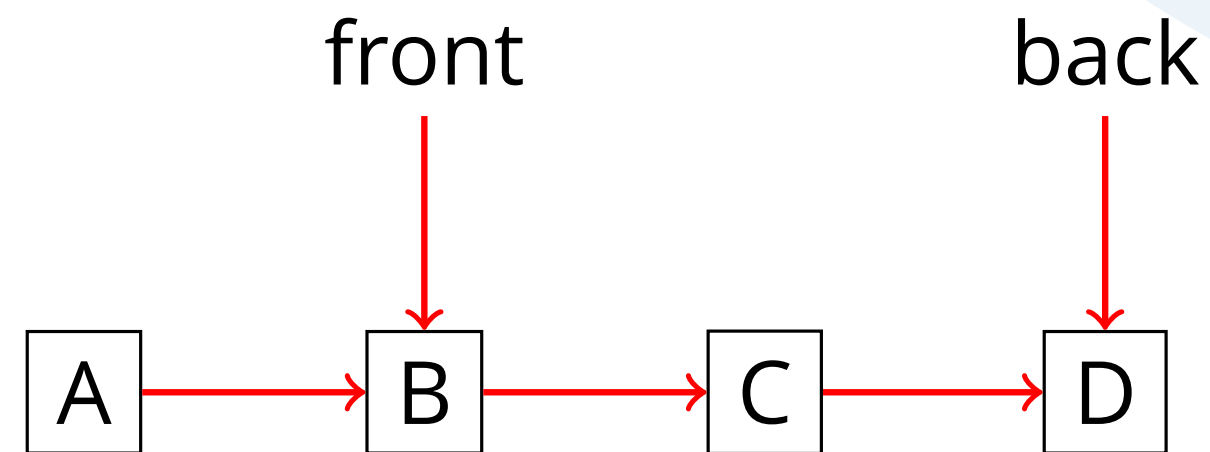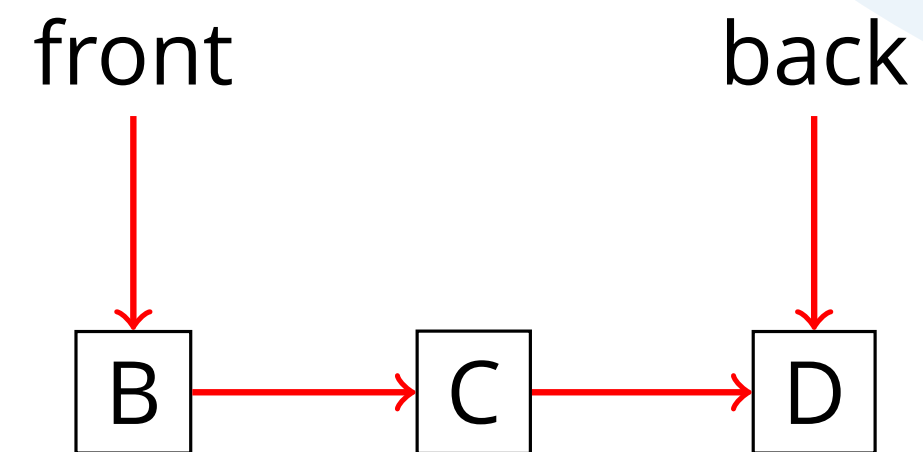 - Inefficient.

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⇑

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Linked list as a queue.

A

front   back

A → B → C → D

Linked list as a queue.

A

pop()

front   back

A → B → C → D

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Linked list as a queue.

A

pop()

front   back

B → C → D

Linked list as a queue.

A

pop() , pop()

front   back

B → C → D

Linked list as a queue.

pop() , pop()

front   back

C → D

Linked list as a queue.

A

pop() , pop() , push(Z)

front   back
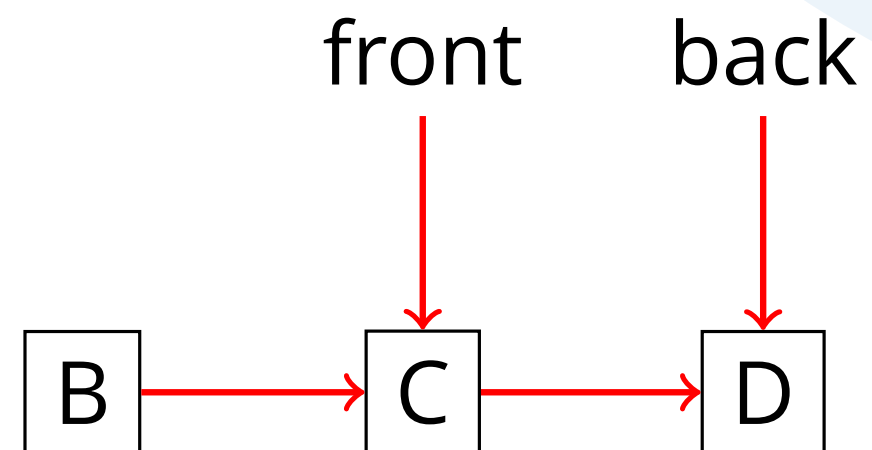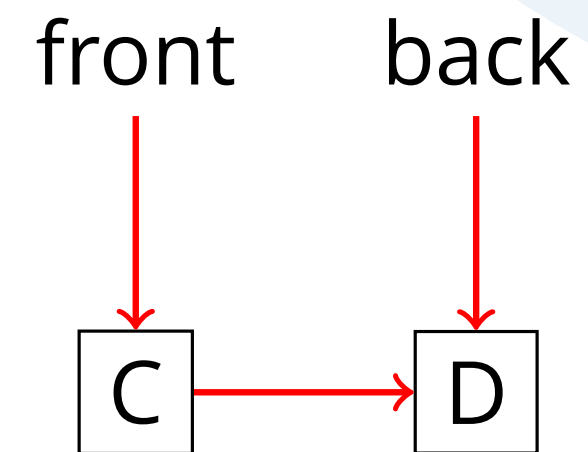
| C | → | D | → | Z |

Linked list as a queue.

A

pop() , pop() , push(Z)

front   back
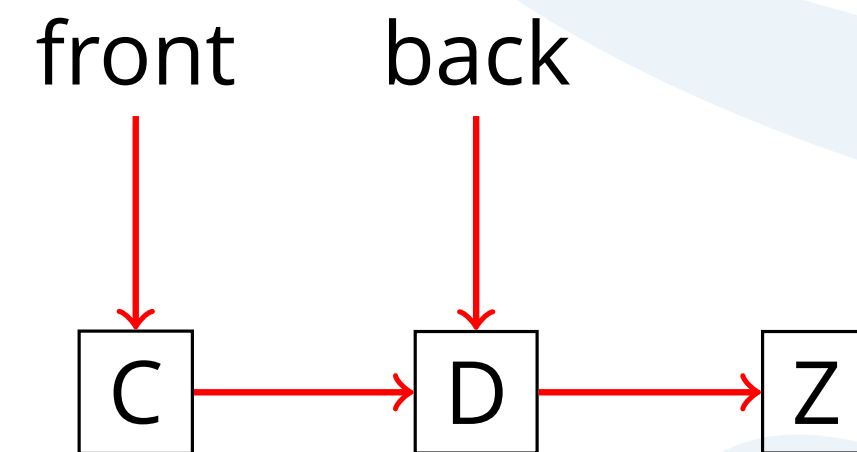
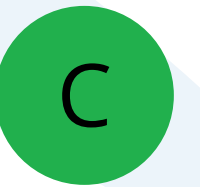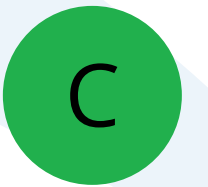| C | → | D | → | Z |
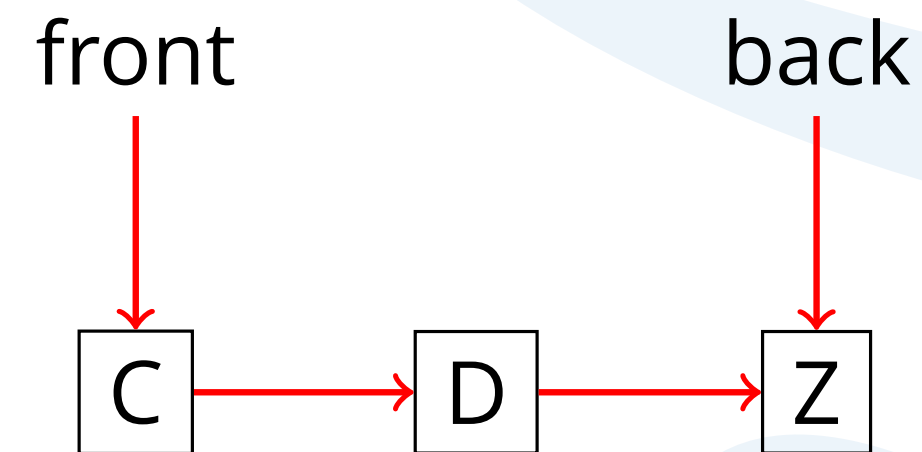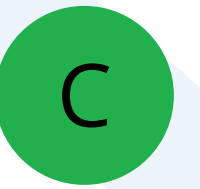
A First In Last Out (FILO) ADT.

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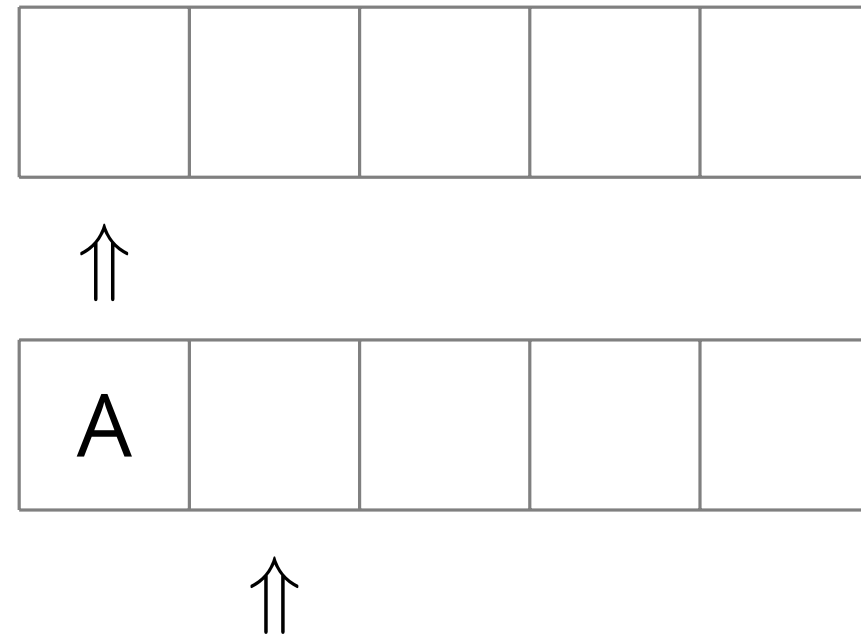
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- Which would be better for a stack? An array or a linked list?
    - Doesn't matter performance wise.
    - Linked list if n is unknown.

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Array as a stack.

I

⇑

- Keep track of position of the next free space in the array.
- Arrays have a fixed size.
    - Can't hold more values than we have space for.

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⇑

A				

⇑

push(A)

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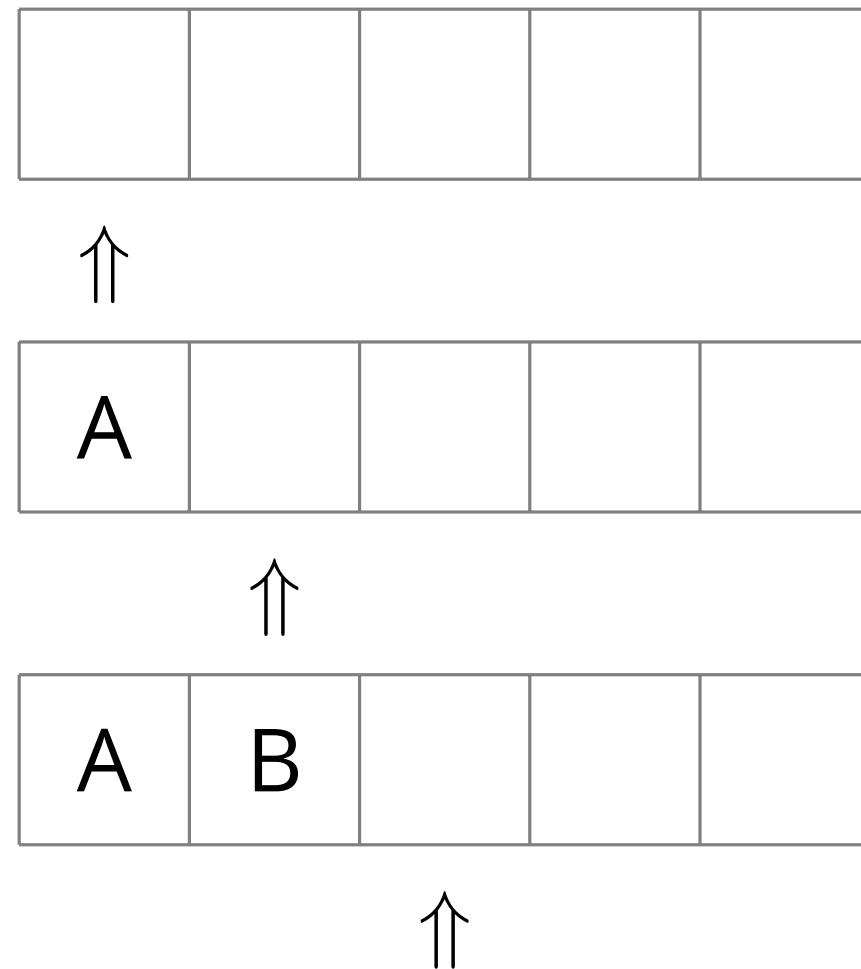   - Can't hold more values than we have space for.

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push(A)

push(B)

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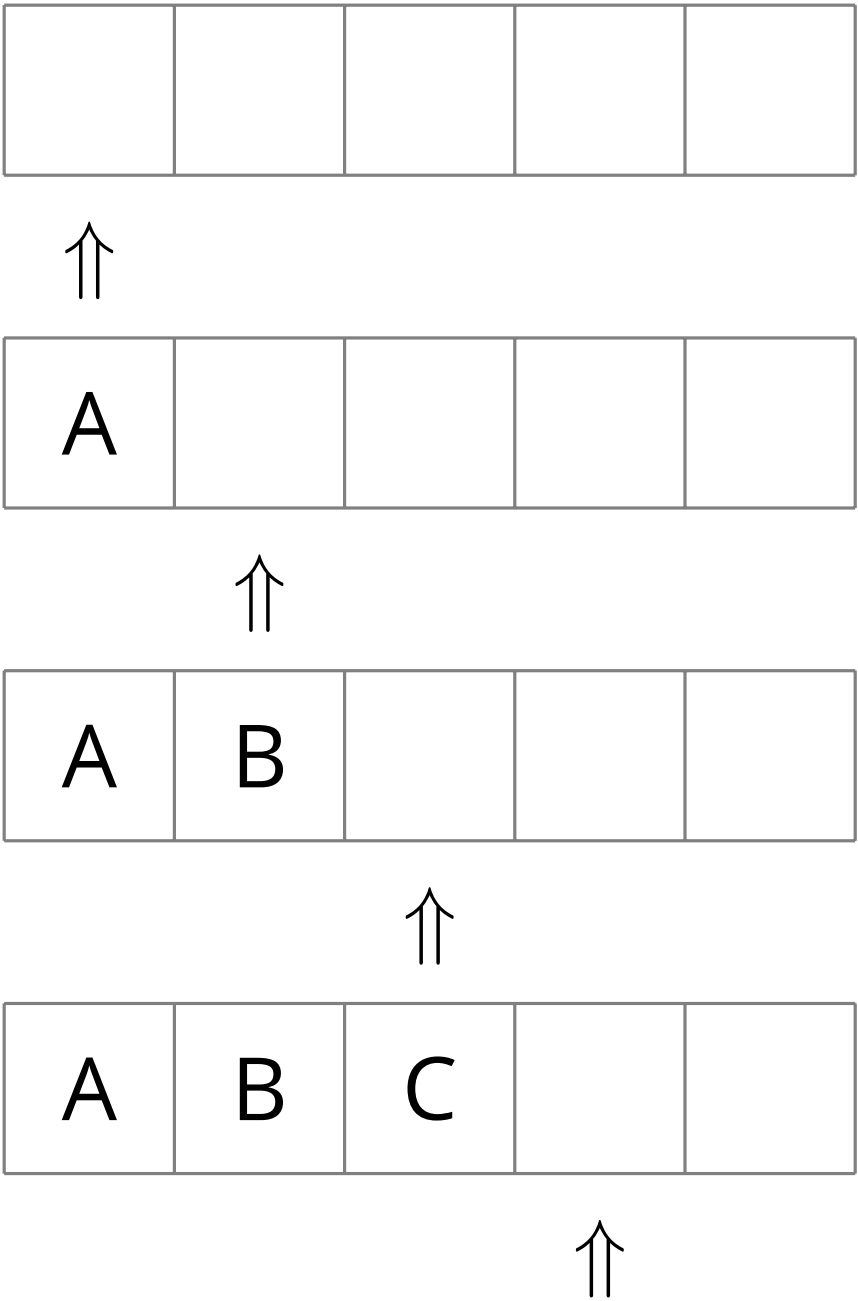 - Can't hold more values than we have space for.

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Array as a stack.

⇑

A				

push(A)

⇑

A	B			

push(B)

⇑

A	B	C		

push(C)

⇑

- ■ Keep track of position of the next free space in the array.
- ■ Arrays have a fixed size.
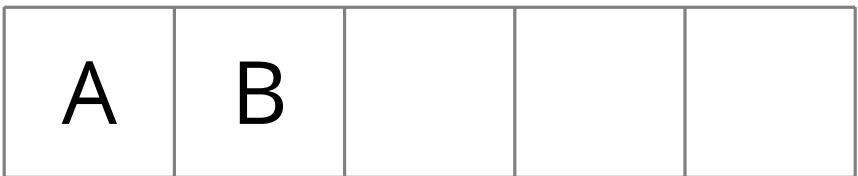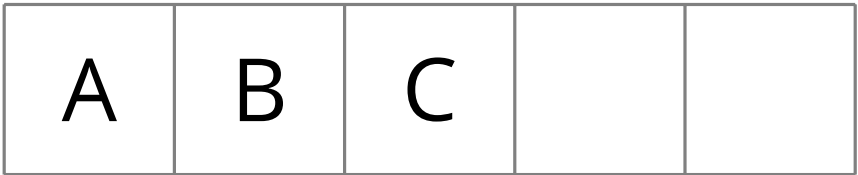 - ■ Can't hold more values than we have space for.

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Arrays

Linked lists
Array example
LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

Trees

End

Array as a stack.

⇑

A				

push(A)

⇑

A	B			

push(B)

⇑

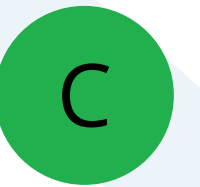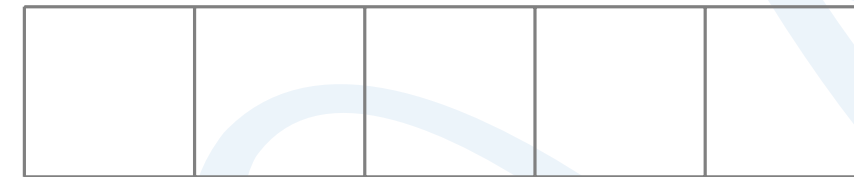| A	B	C		

push(C)

⇑

A	B			

pop()

⇑

- Keep track of position of the next free space in the array.
- Arrays have a fixed size.
  - Can't hold more values than we have space for.

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Sets   C

- An unordered ADT.
    - Items ordered by the set.
    - You have no control over it.
- Sets contain unique elements.
    - Can't contain duplicates.

- Can add items to a set.
- Can remove items from a set.
- Can see if an item is in a set.
- Can't get the n^{th} element.
    - It's unordered remember.
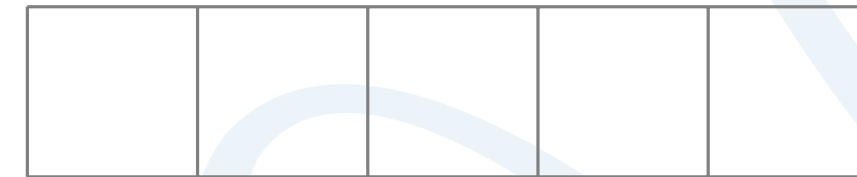
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add(A)

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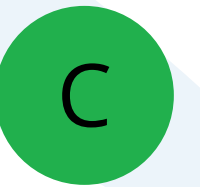
Trees

End

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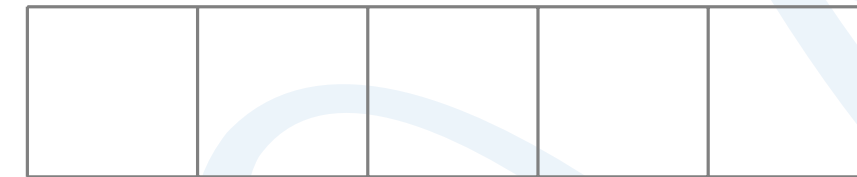- Can't get the n^{th} element.
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A				

add(A)

A	B			

add(B)

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■ An unordered ADT.

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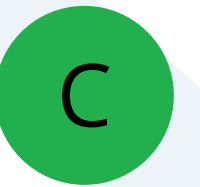■ Can't get the n^{th} element.

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add(A)

A	B			

add(B)

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add(A)

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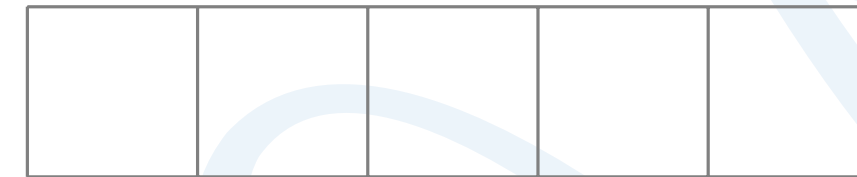
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A				

add(A)

A	B			

add(B)

A	B			

add(A)

	B			

remove(A)

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End
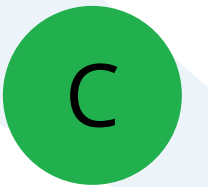
...and the others

C

- Lots of other ADTs.

- Different names in different languages.

- Lists.

- Circular lists.

- Associative arrays.
  - Dictionaries/Maps.

- Double-ended queues.

- Trees.

- Graphs.

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Trees
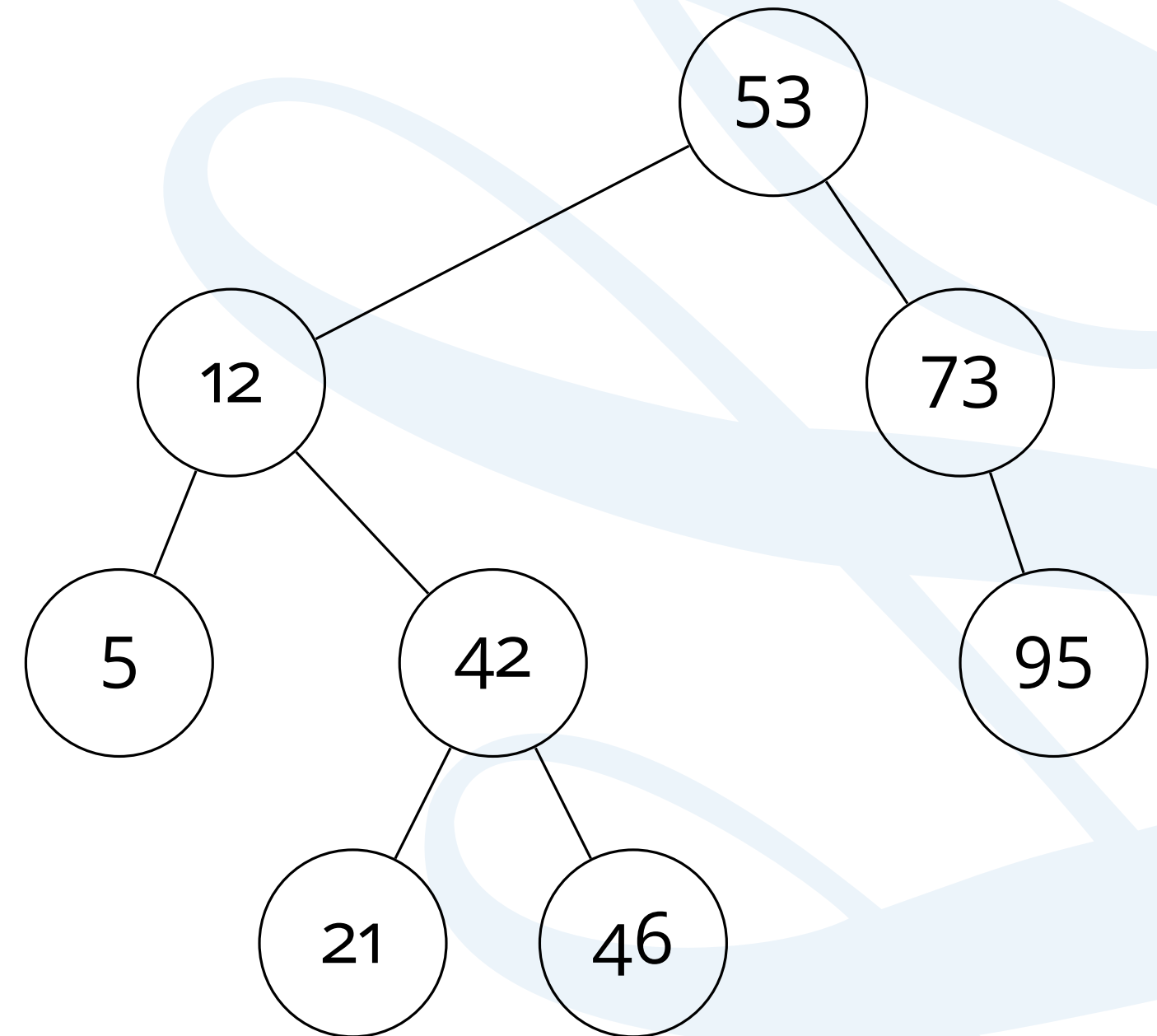
A

Variation on linked lists.

- Made of nodes and relationships.

- Root node at top.

- Each node can have $\geq$ 0 children.

- Binary search tree.
  - Very common type.
  - Ordered.
  - Max two children.
  - Binary searching.
  - Very good for sets.
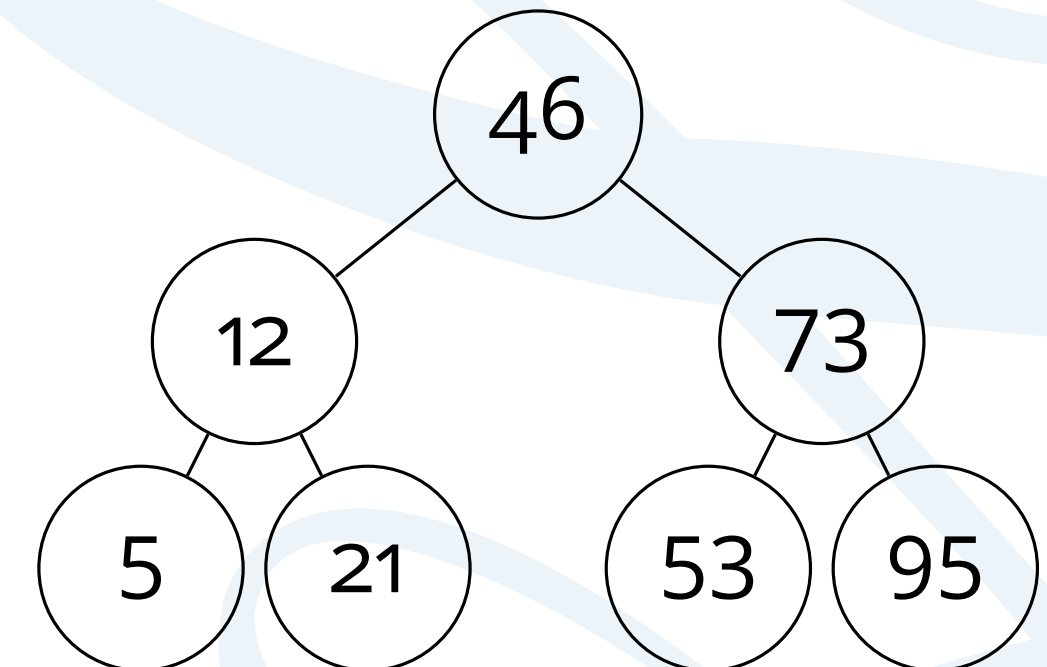
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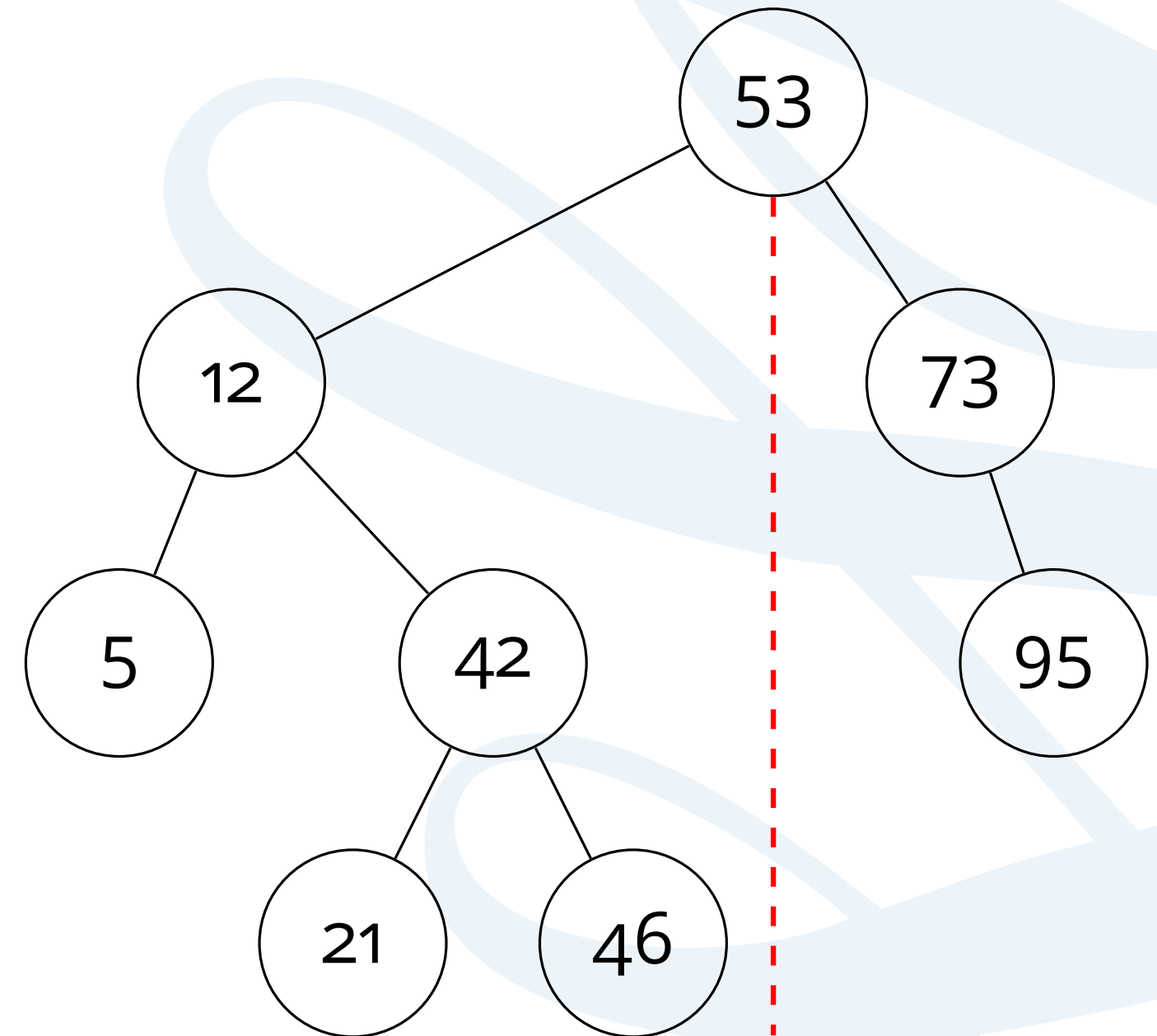Coventry University

Balance

A

- Trees can be balanced or unbalanced.

- Not required for all trees.

- Going to be talking about BSTs from here on.

- Unbalanced because more than a one node difference between the two halves.
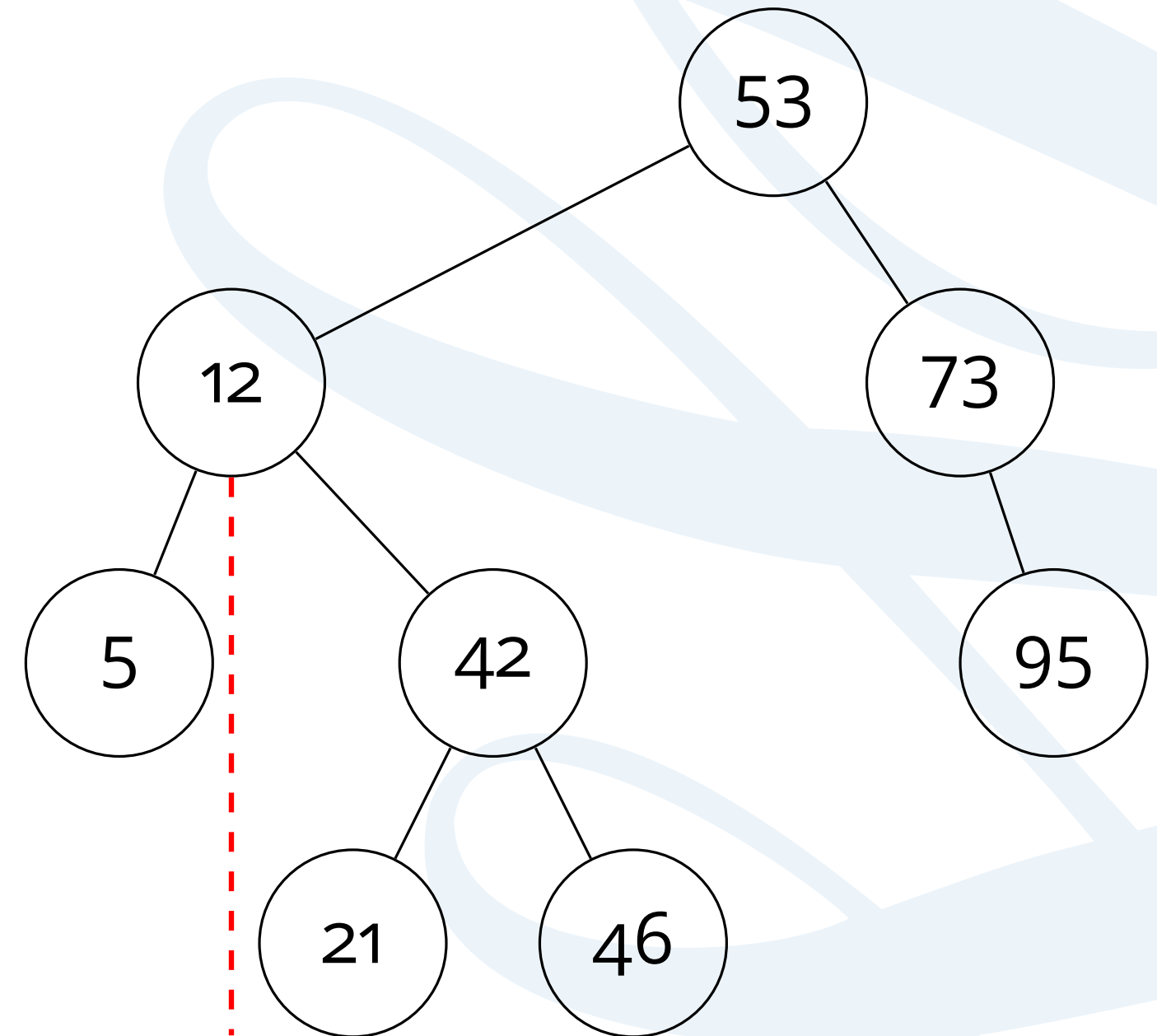
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  - For the whole tree…

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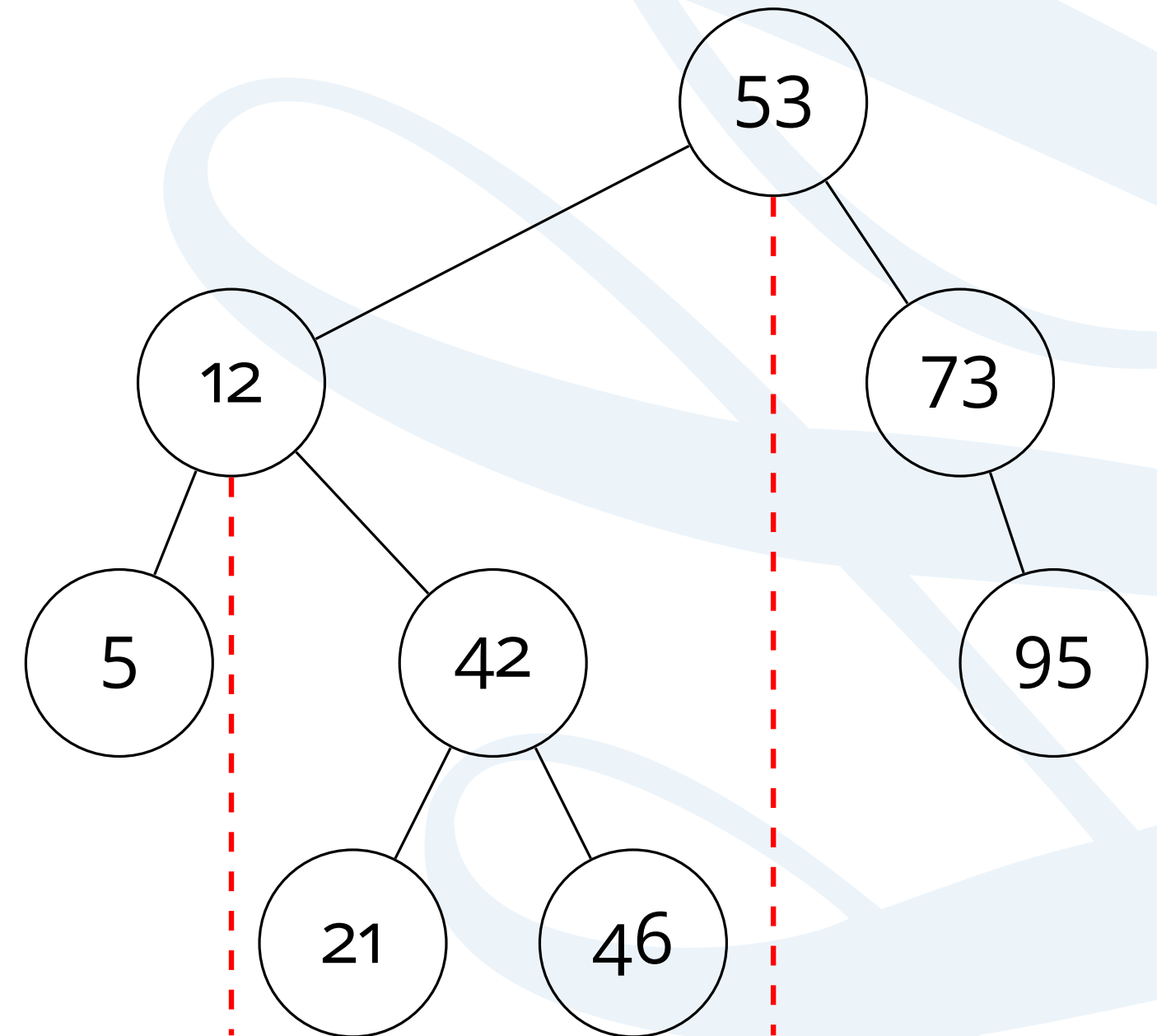Stacks

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  - ...and one of the subtrees.

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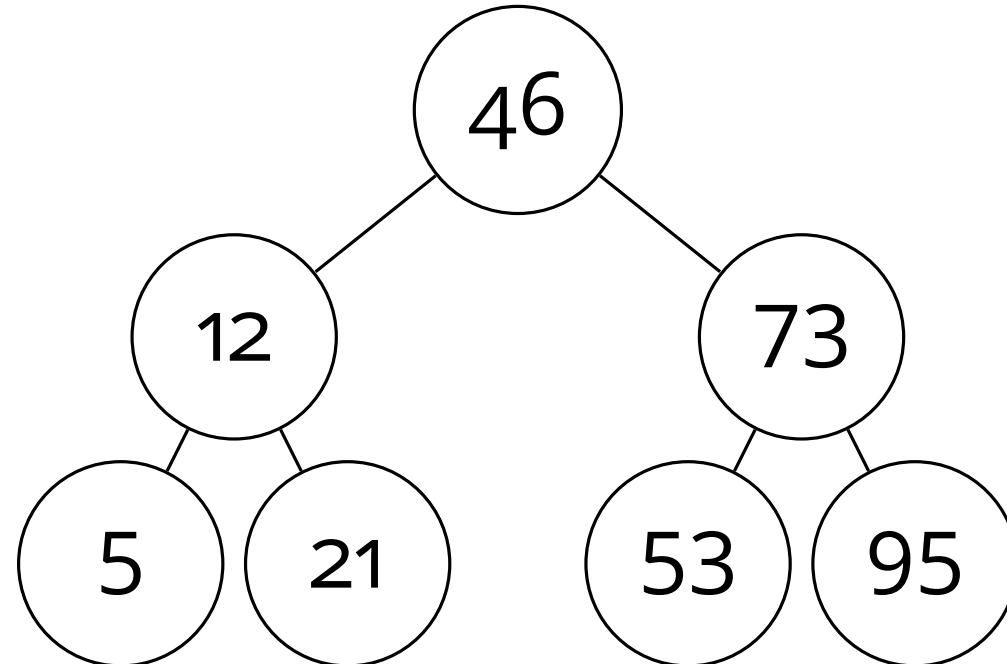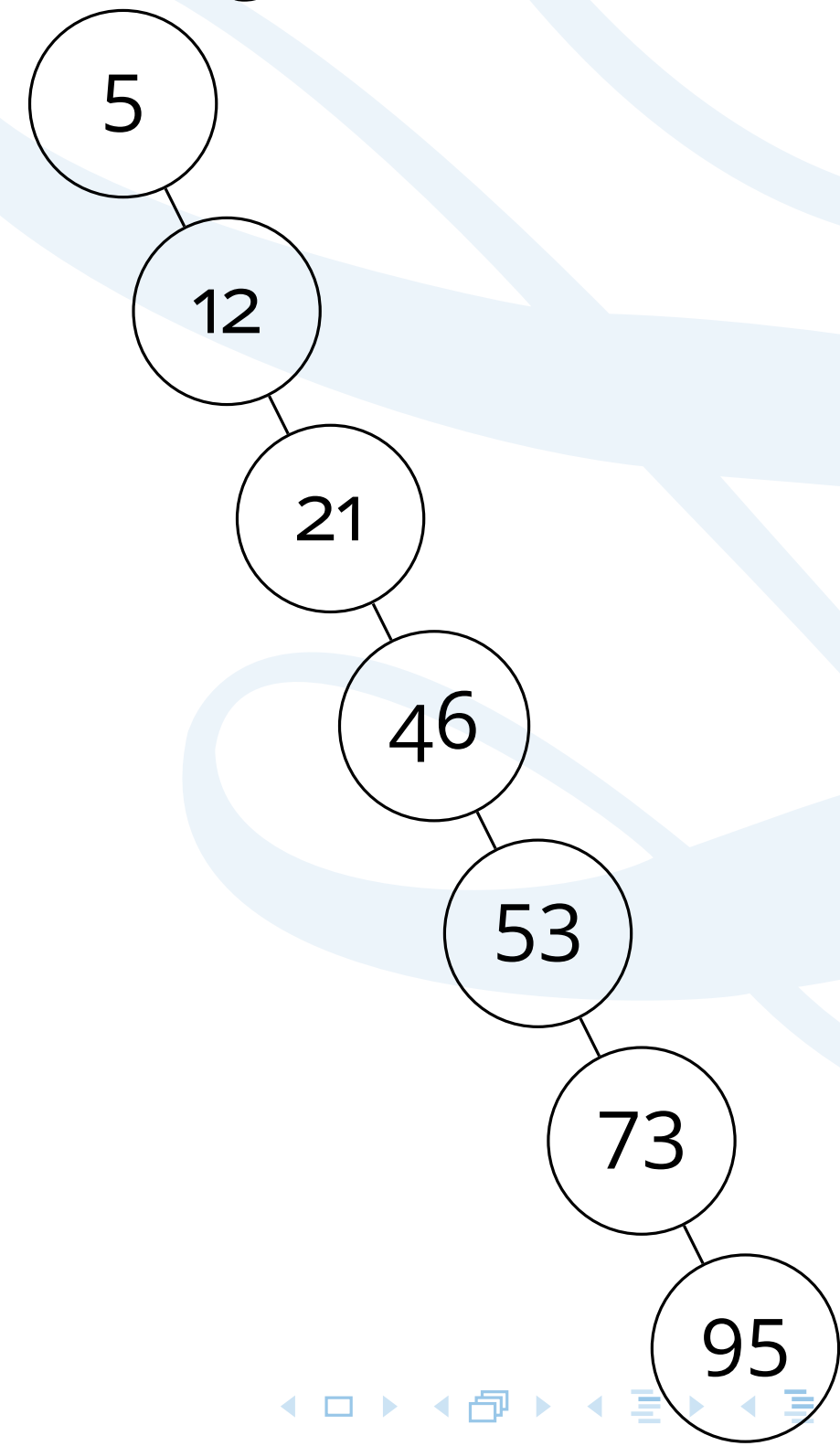
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Balance

A

Important that you keep your BSTs balanced.

Degenerate tree.

Perfect tree.

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Quiz

Recap

- Arrays.
  - Advantages/disadvantages.
- Linked lists .
  - Advantages/disadvantages.
  - How to insert/delete.
- Difference between data structure and ADTs.
- Stack.
  - FILO.
  - Using an array as one.
  - Using a LL as one.

- Queue.
  - FIFO.
  - Using an array as one.
  - Using a LL as one.
- Sets.
  - No duplicates.
  - Unordered.
- Trees.
  - Balanced/unbalanced.

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The End