

122com Data structures and types

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Overview

- 1 Arrays
- 2 Linked lists
 - Array example
 - LL example
- 3 Data structures
- 4 Abstract data types
- 5 Queues
- 6 Stacks
- 7 Sets
- 8 Other
- 9 Trees
- 10 End

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

```
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.

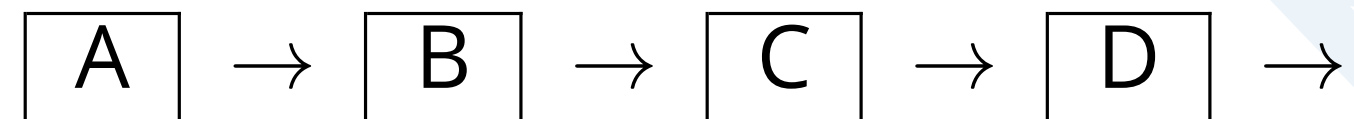
Linked lists

C

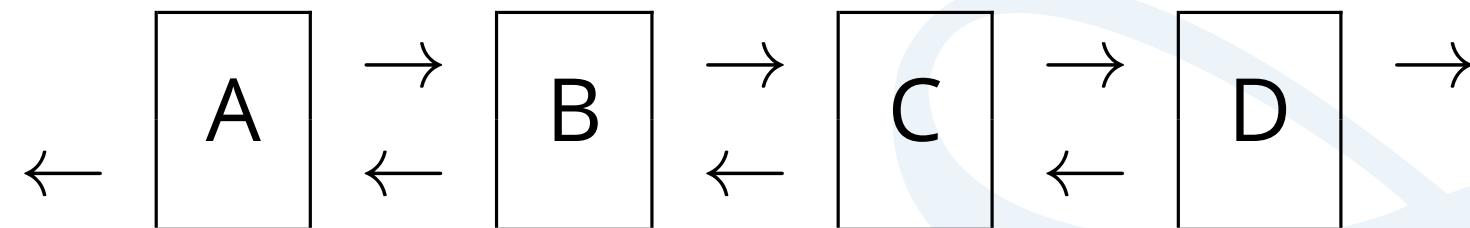
The challenger for array's crown.

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

Singularly linked



Doubly linked

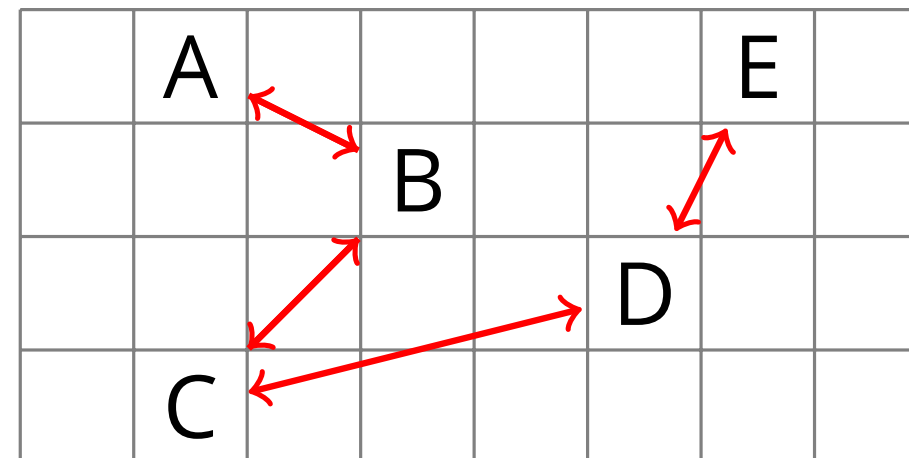


Linked lists II

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.

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

```
class Node
{
private:
    Node *prev;
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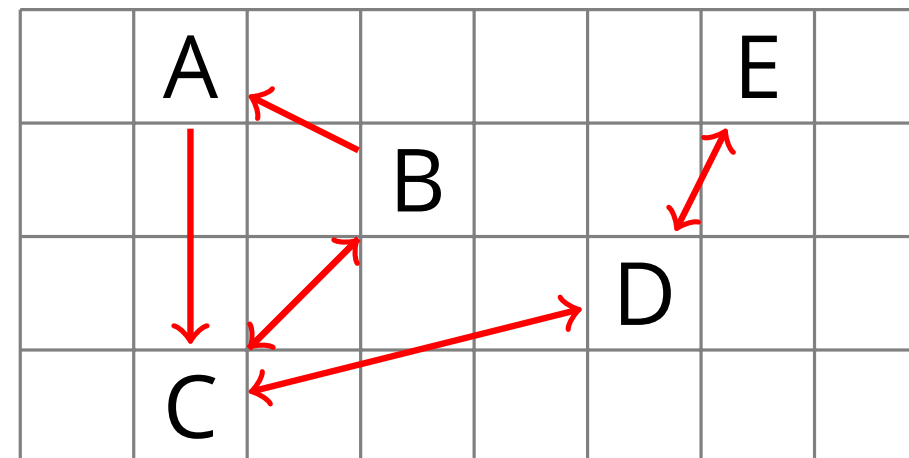
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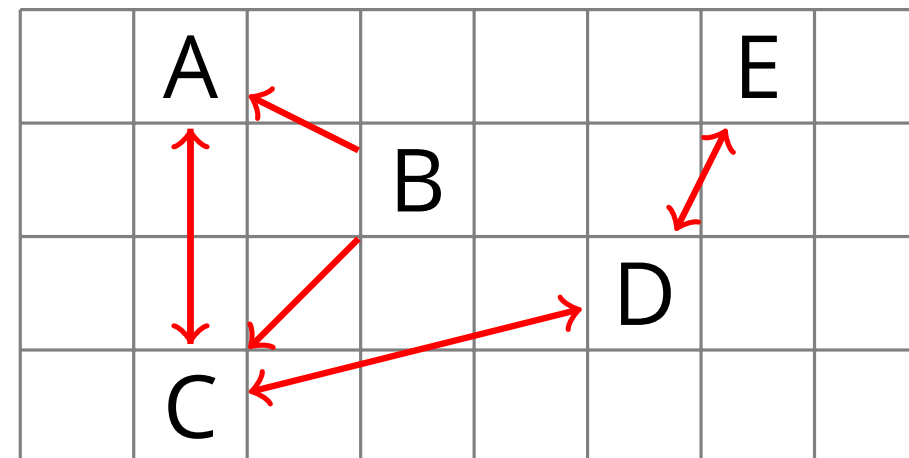
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Removing array elements

C

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

- Array in memory, multiple elements in a contiguous block.
- How do we remove elements from the middle?

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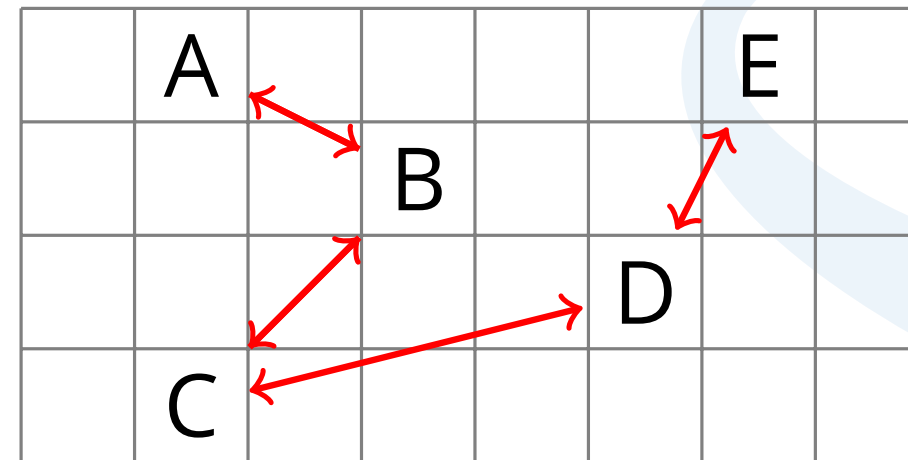
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- Array in memory, multiple elements in a contiguous block.
- How do we remove elements from the middle?
 - 1 Remove element from the array.
 - 2 Move next element to occupy the empty space.
 - 3 Repeat.
- Is very slow with large arrays.

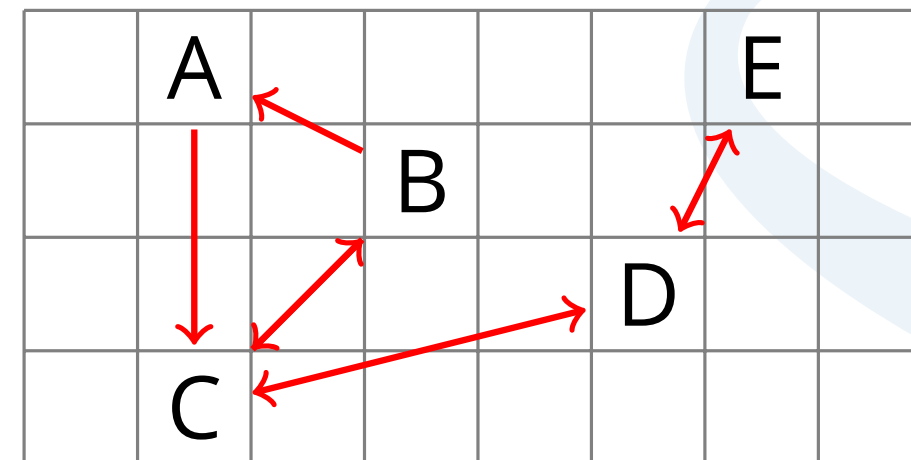
Removing linked list elements

I



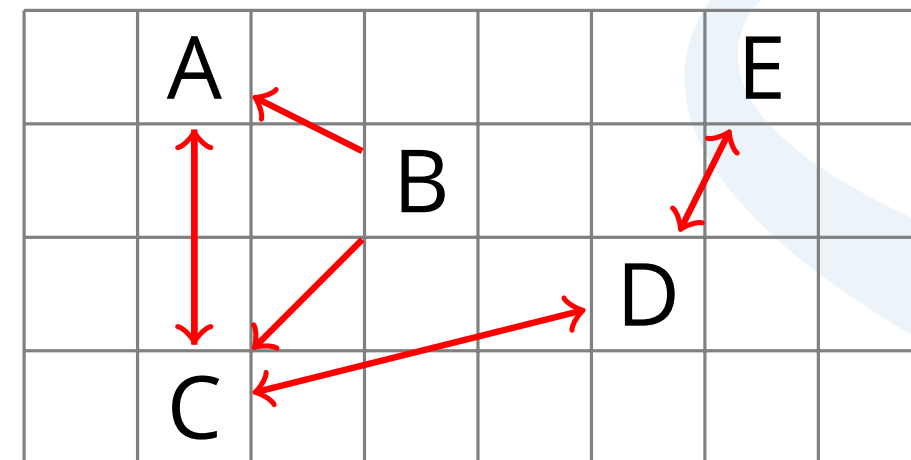
- Linked list, separate elements scattered in memory.
- Each pointing to the next/prev element.
- How do we remove elements?

Removing linked list elements



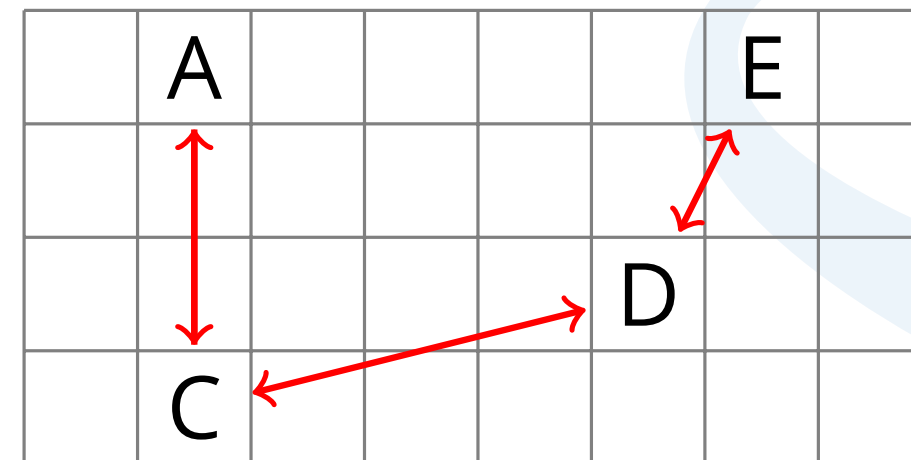
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 - 1 Change pointers.

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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.
 - 2 Delete old element.

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 20th 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.

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

I

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

- Software engineering principal.

Abstract data types

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Abstract data types

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As we move to storing more complex information in our software we will 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.

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.

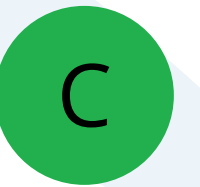
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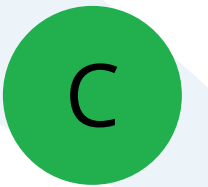
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- It has a set of supported operations, go faster, go slower, turn left, turn right.
- Don't care how it achieves these.
- Don't care if, internally, it's using a combustion engine or an electric motor.
- Only care about the result.



A First In First Out (FIFO) ADT.

- Ends of the queue are 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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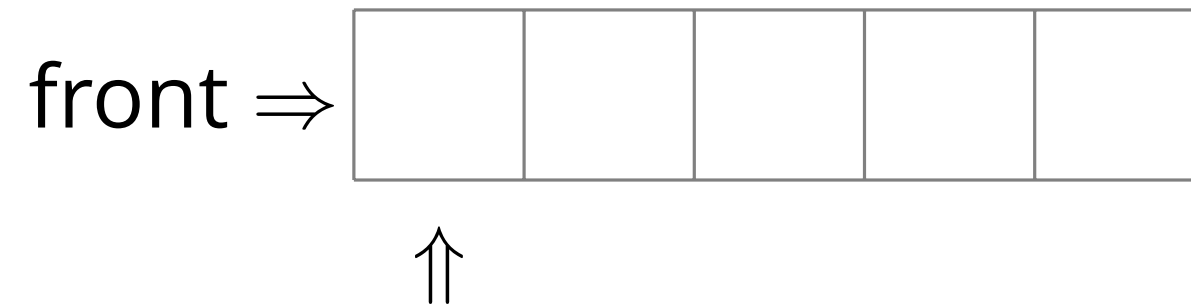
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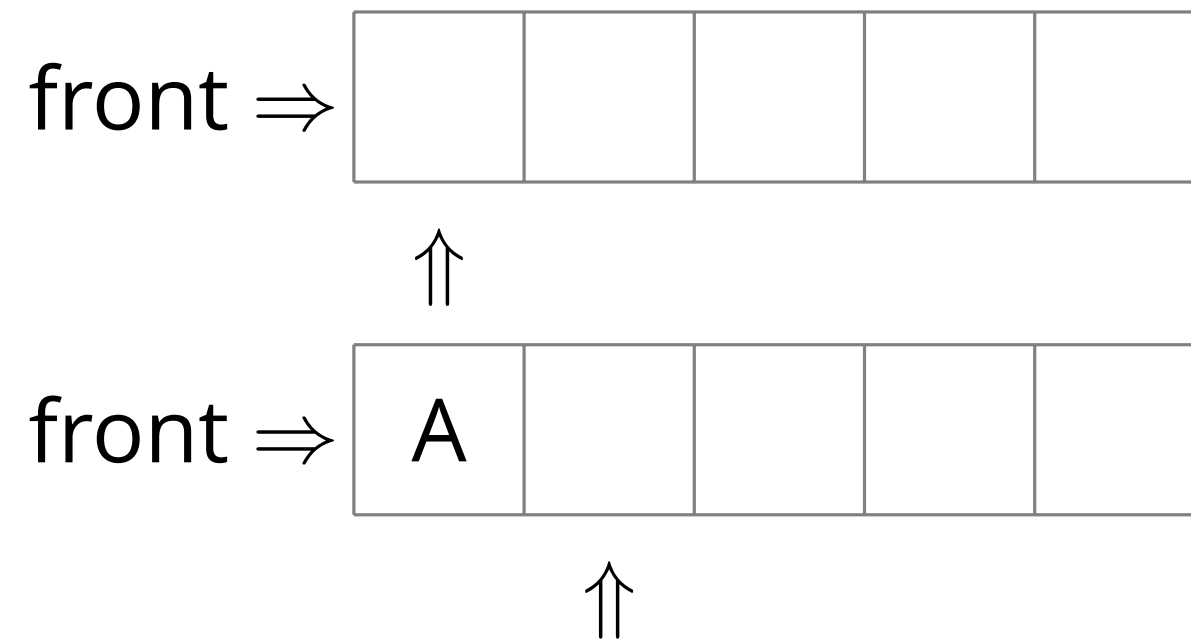
Array as a queue.



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

Array as a queue.

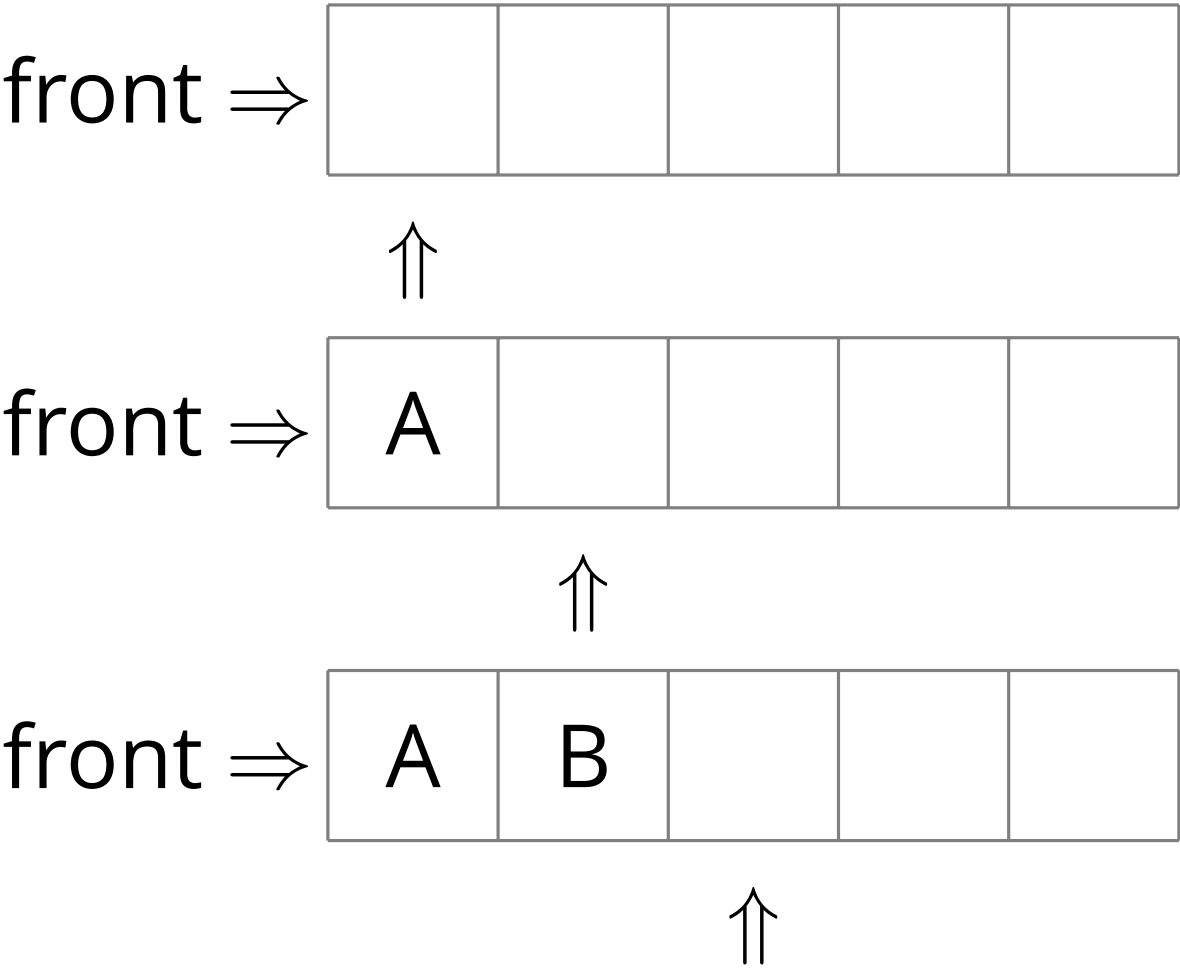
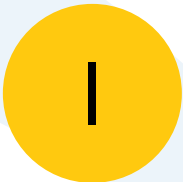
1



push(A)

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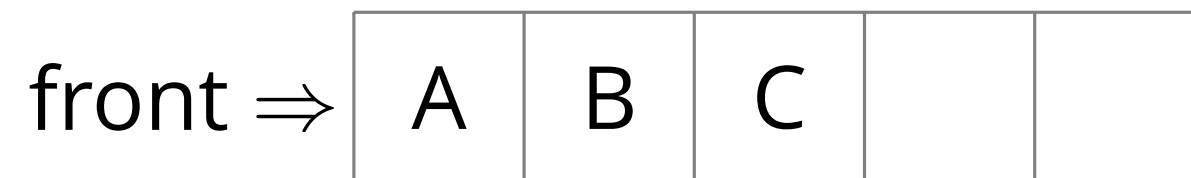
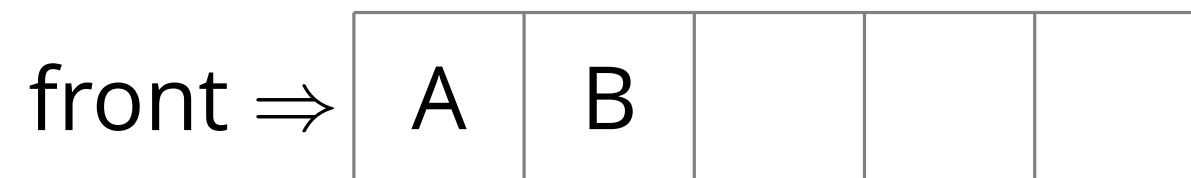
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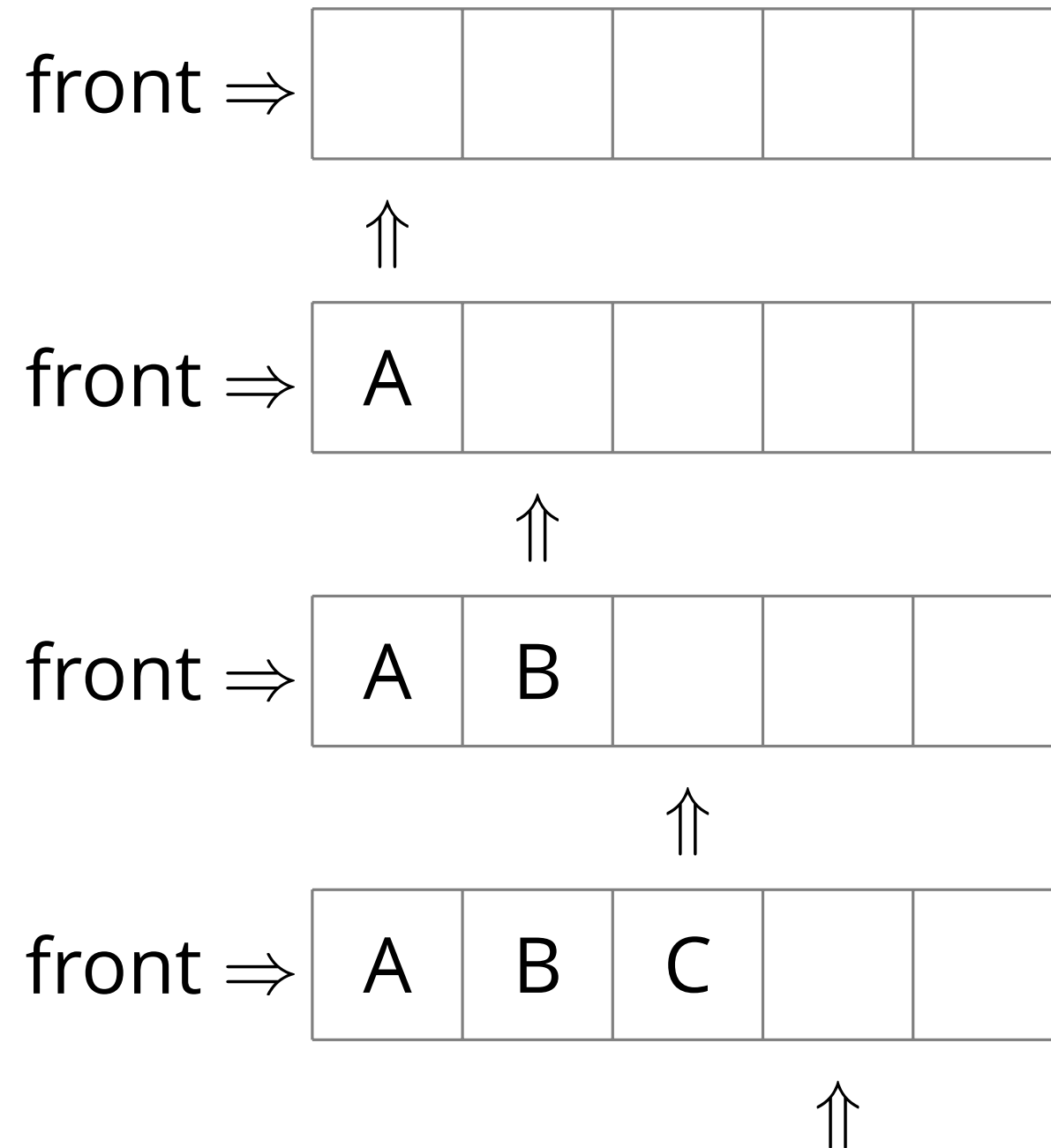
push(B)

push(C)

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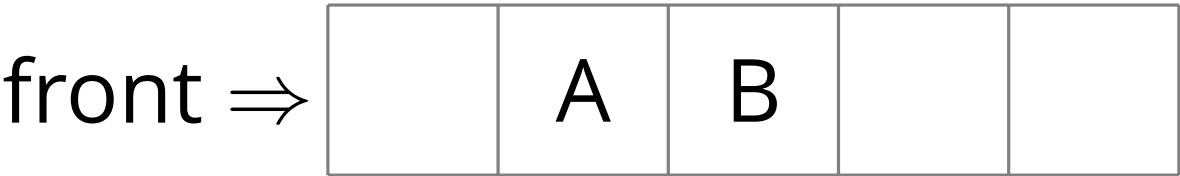
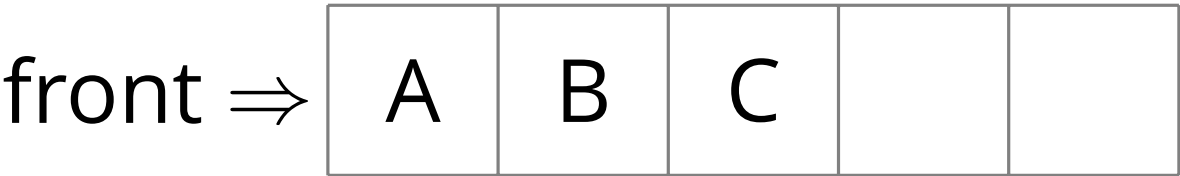
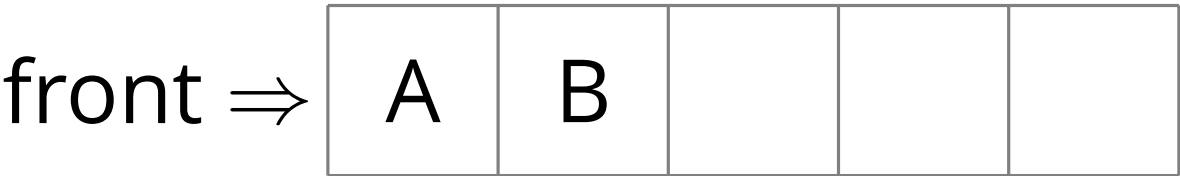
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- What happens when we pop()?
 - Have to shuffle every element forward one space.
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Array as a queue.



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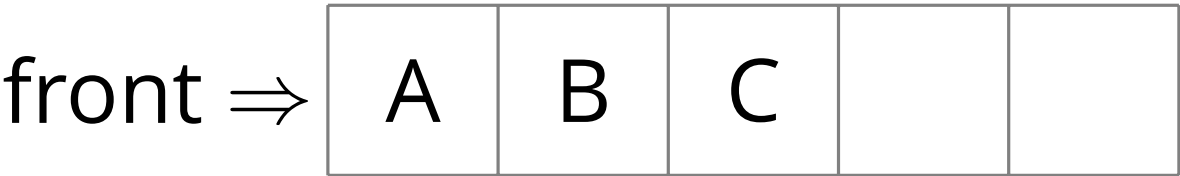
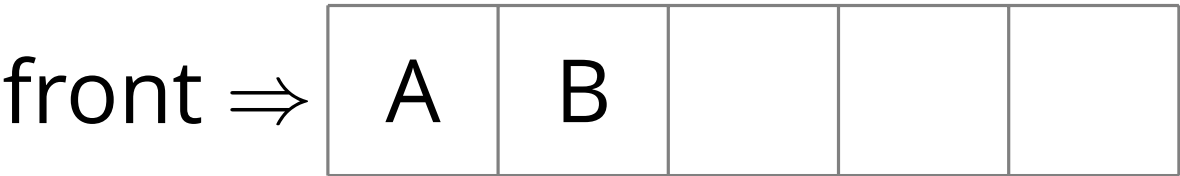
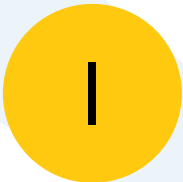
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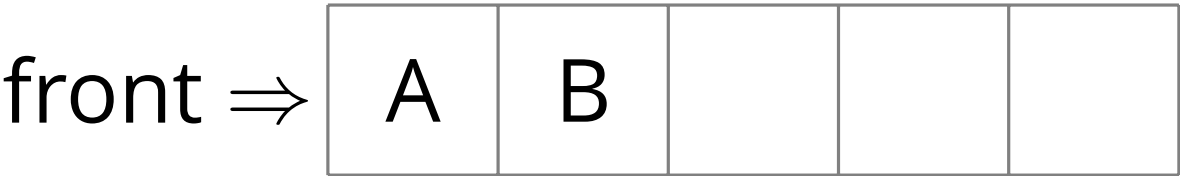
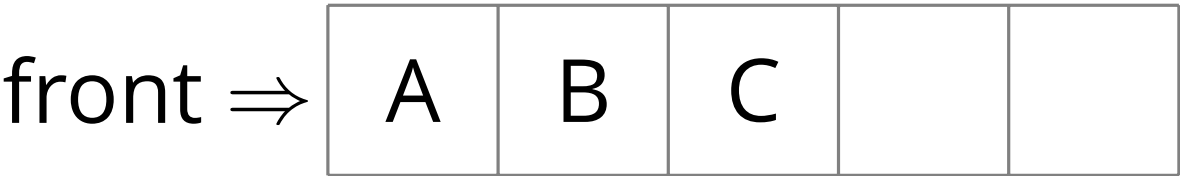
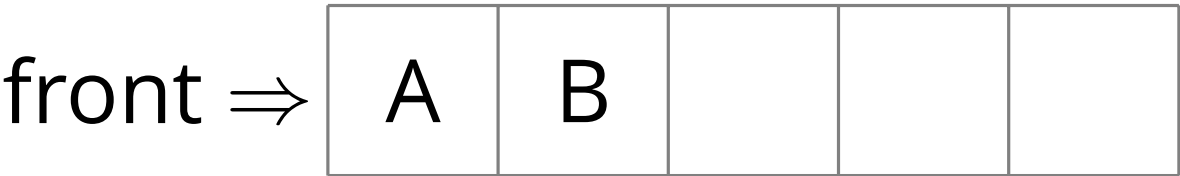
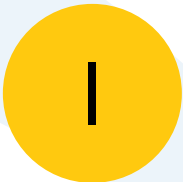
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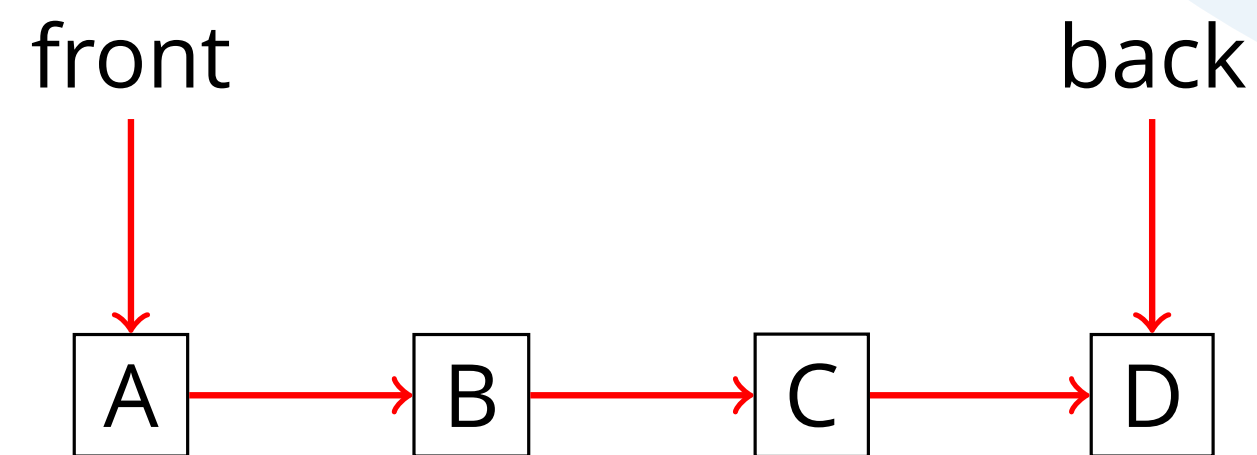
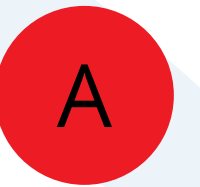
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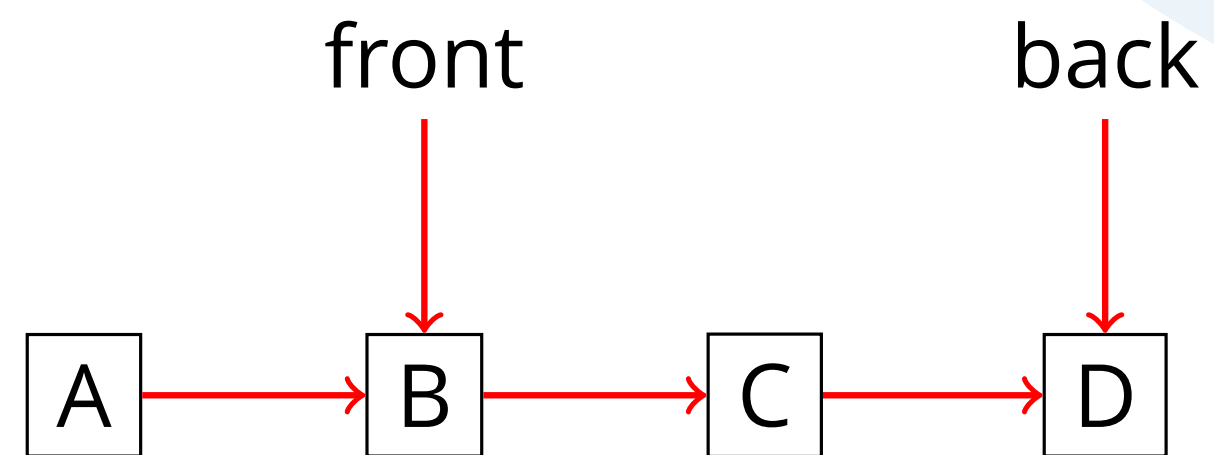
Linked list as a queue.



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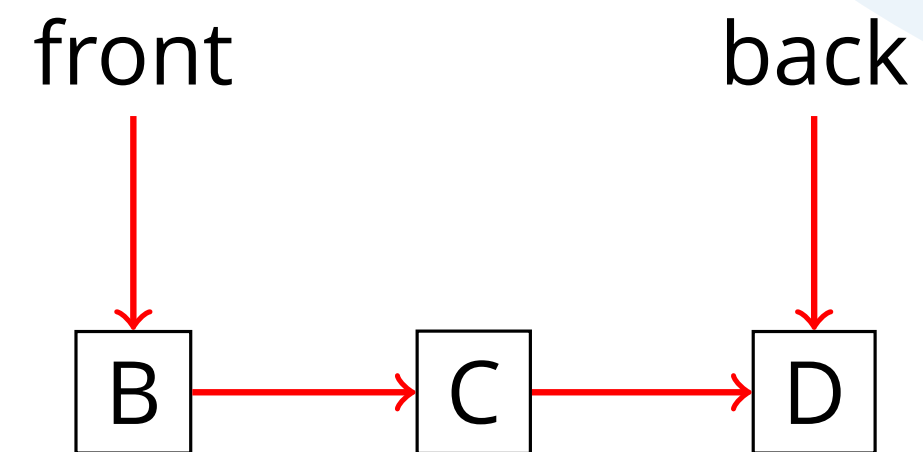
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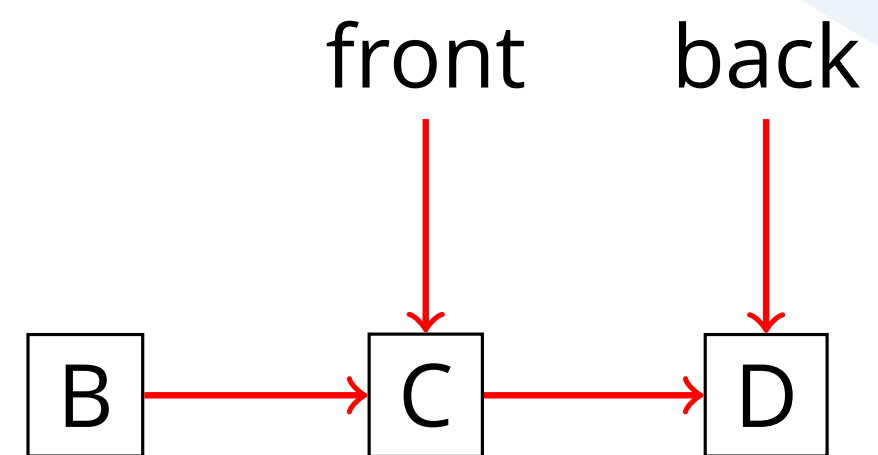
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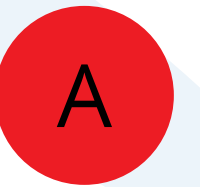
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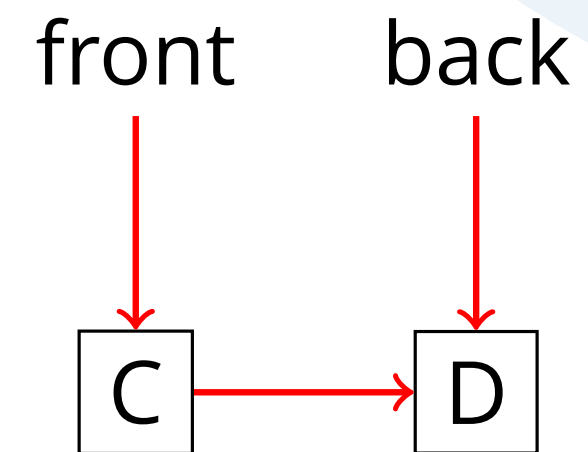
pop() , pop()



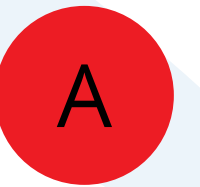
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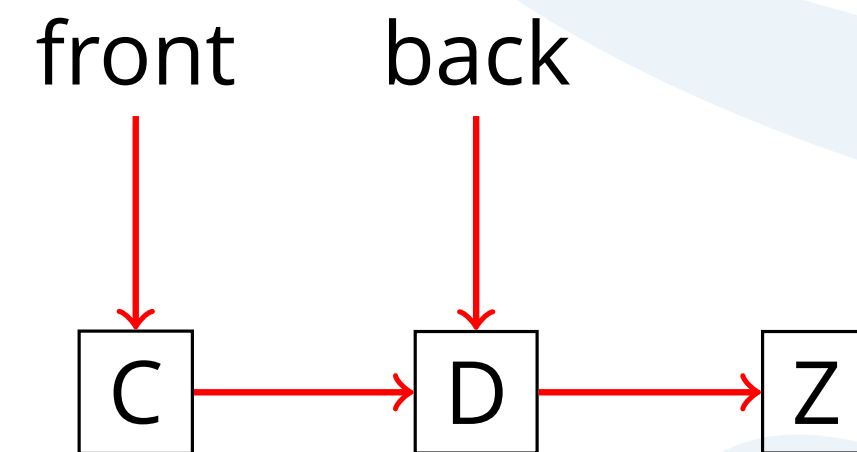
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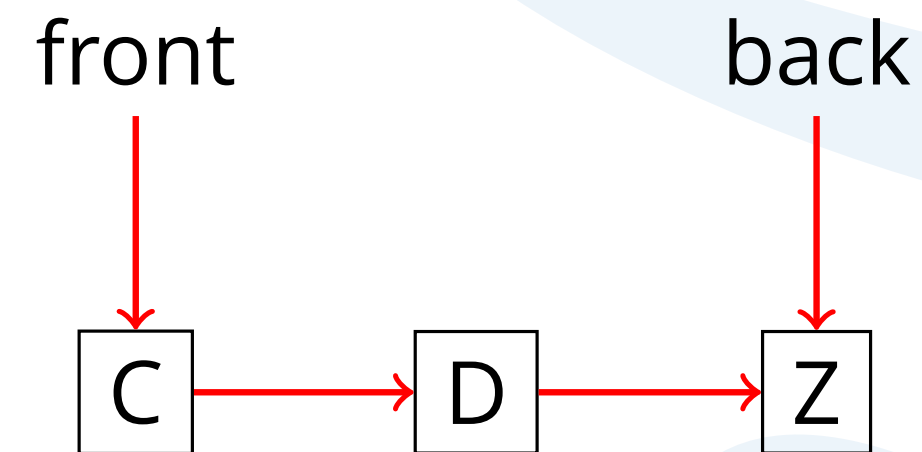
pop() , pop() , push(Z)

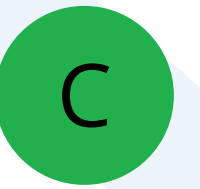


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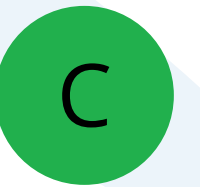
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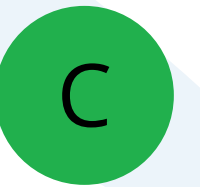
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 - Linked list if n is unknown.

Array as a stack.

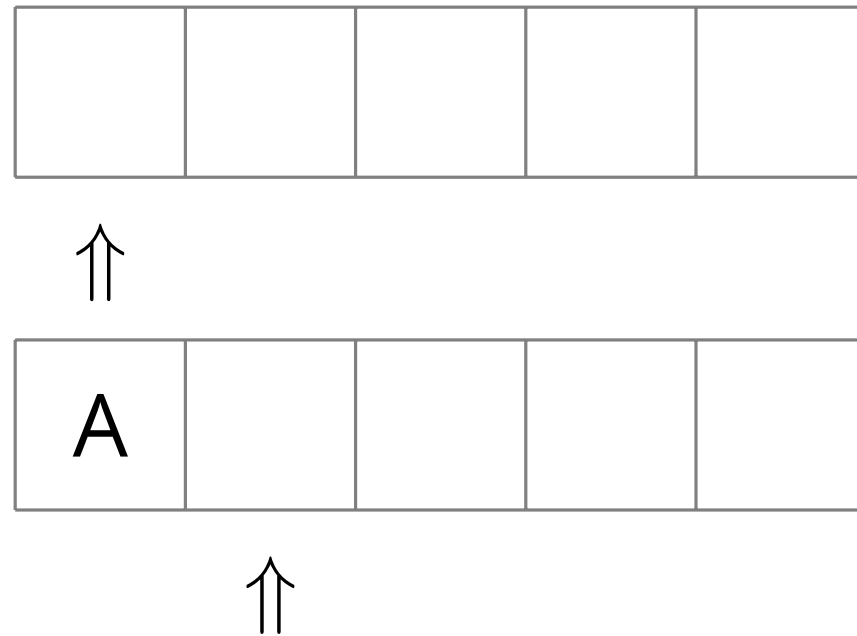
I



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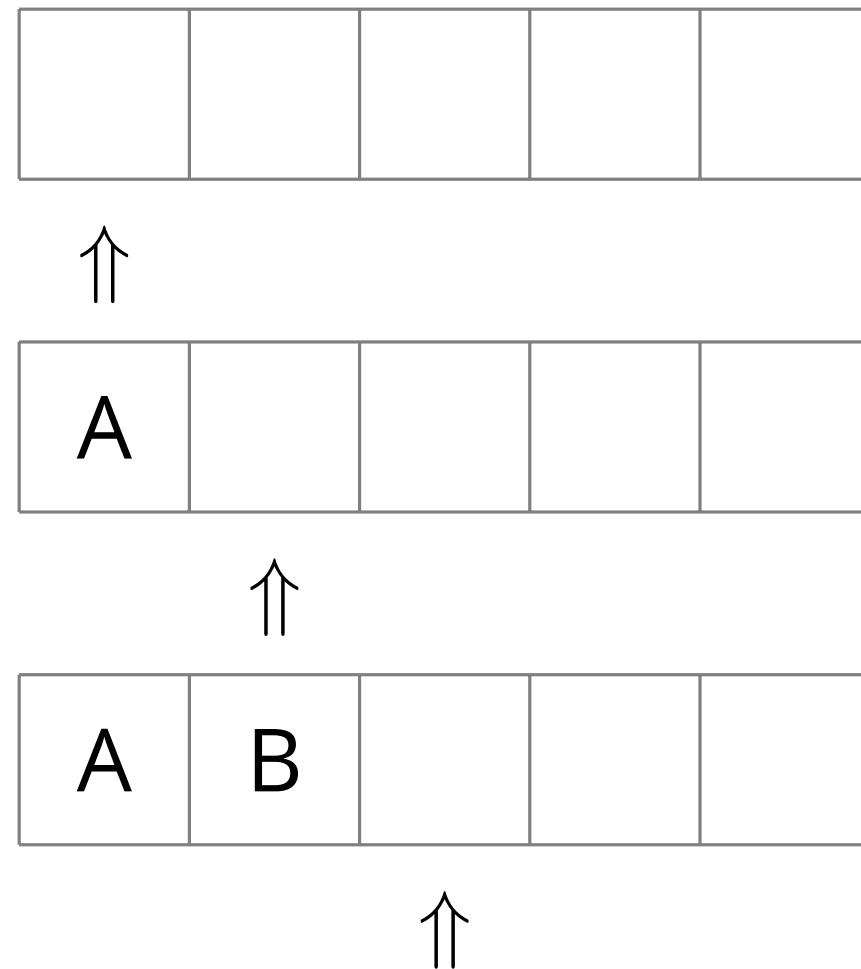
Array as a stack.

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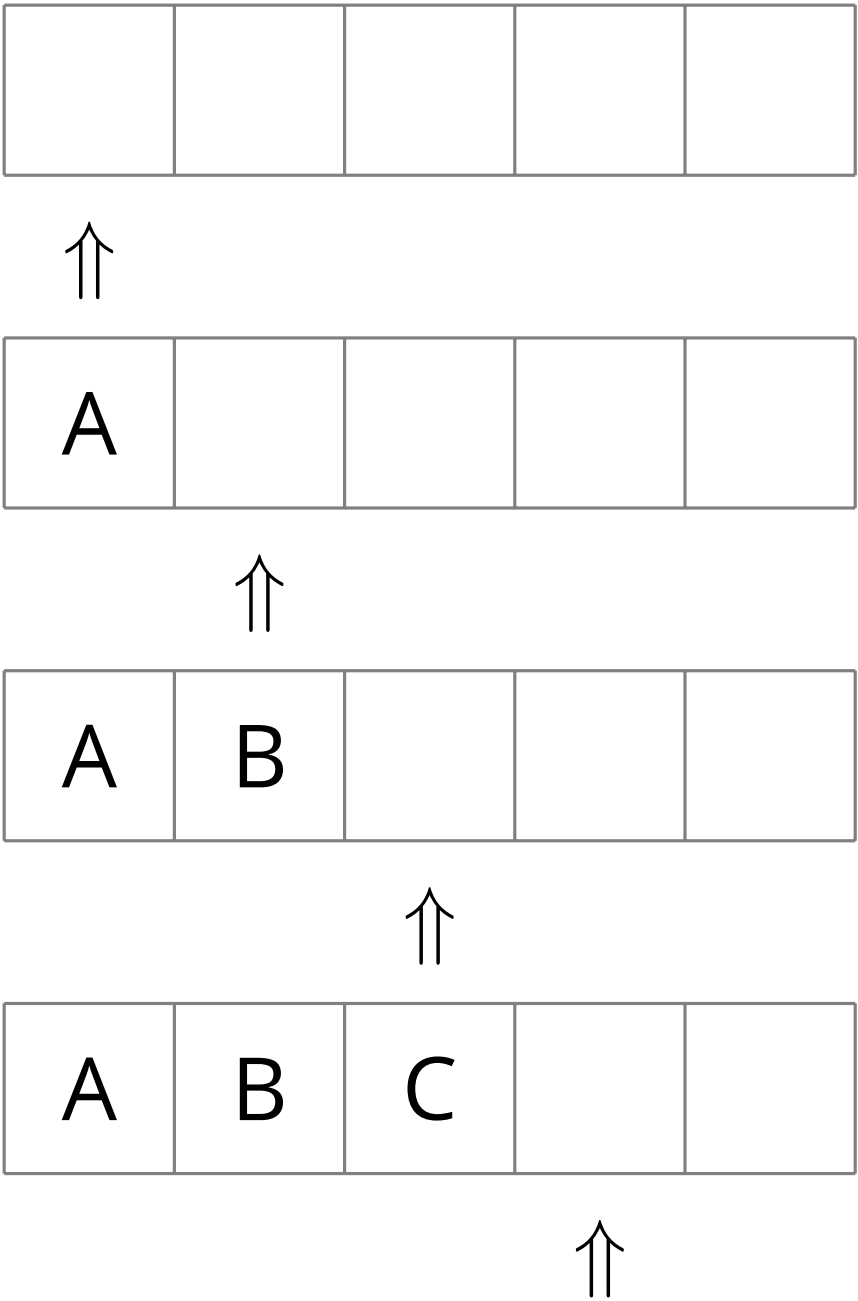
push(A)

push(B)

Array as a stack.

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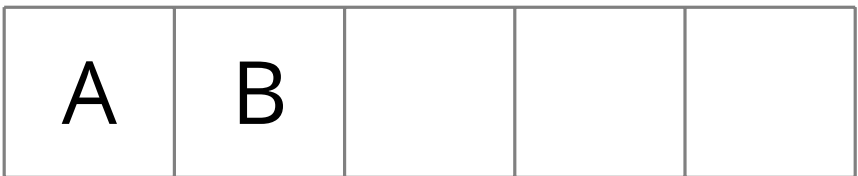
push(B)

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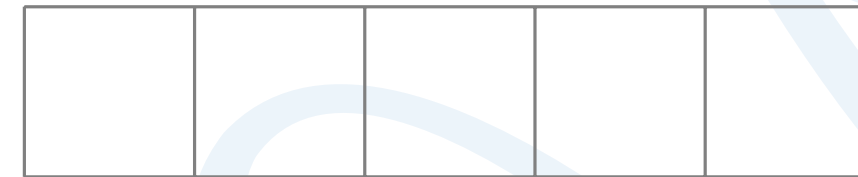
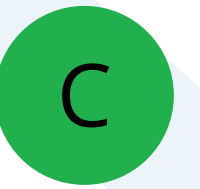
pop()

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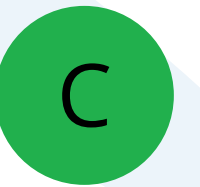
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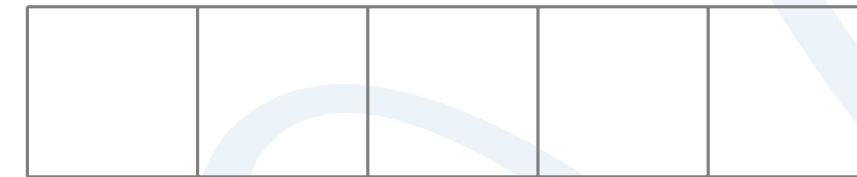


- An unordered ADT.
 - Items can be rearranged.
- Sets contain unique elements.
 - Can't contain duplicates.
- Can add items to a set.
- Can remove items from a set.
- Can see if an item is in a set.
- Can't get the n^{th} element.

Sets

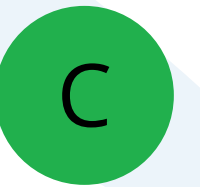


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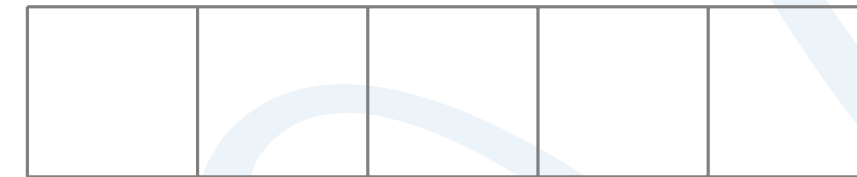


add(A)

Sets



- An unordered ADT.
 - Items can be rearranged.
- 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.

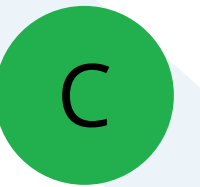


add(A)

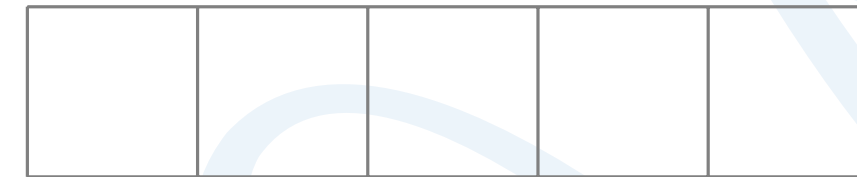


add(B)

Sets



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add(A)



add(B)



add(A)

Sets



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add(A)



add(B)

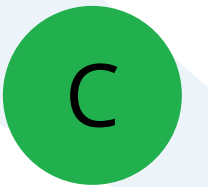


add(A)



remove(A)

...and the others



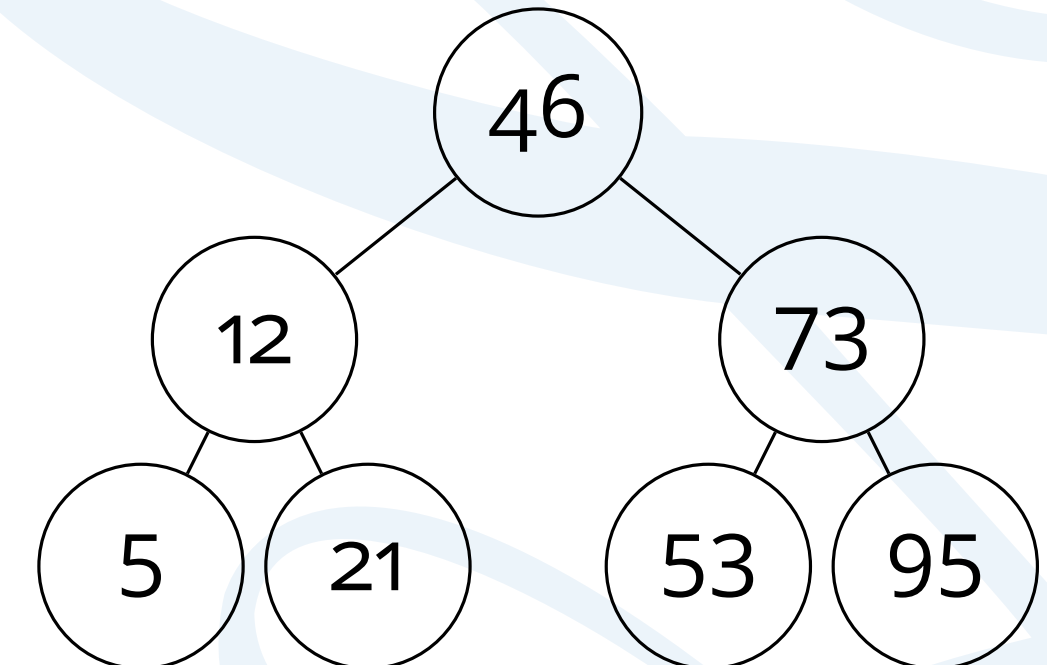
- Lots of other ADTs.
- Different names in different languages.
- Lists.
- Circular lists.
- Associative arrays.
 - Dictionaries/Maps.
- Double-ended queues.
- Trees.
- Graphs.

Trees

A

Variation on linked lists.

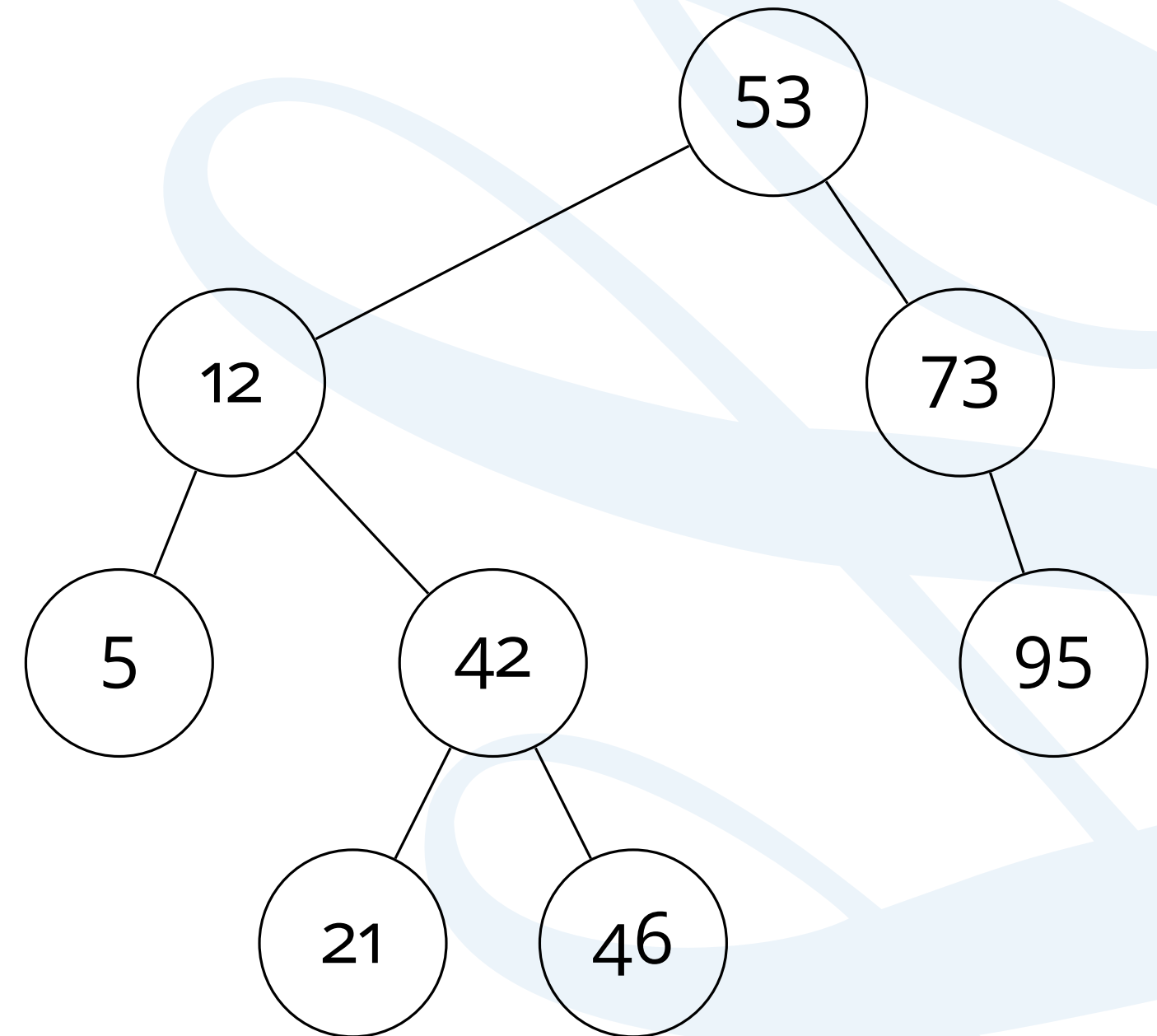
- Made of nodes and relationships.
- Root node at top.
- Each node can have ≥ 0 children.
- Binary search tree.
 - Very common type.
 - Ordered.
 - Max two children.
 - Binary searching.
 - Very good for sets.



Balance

A

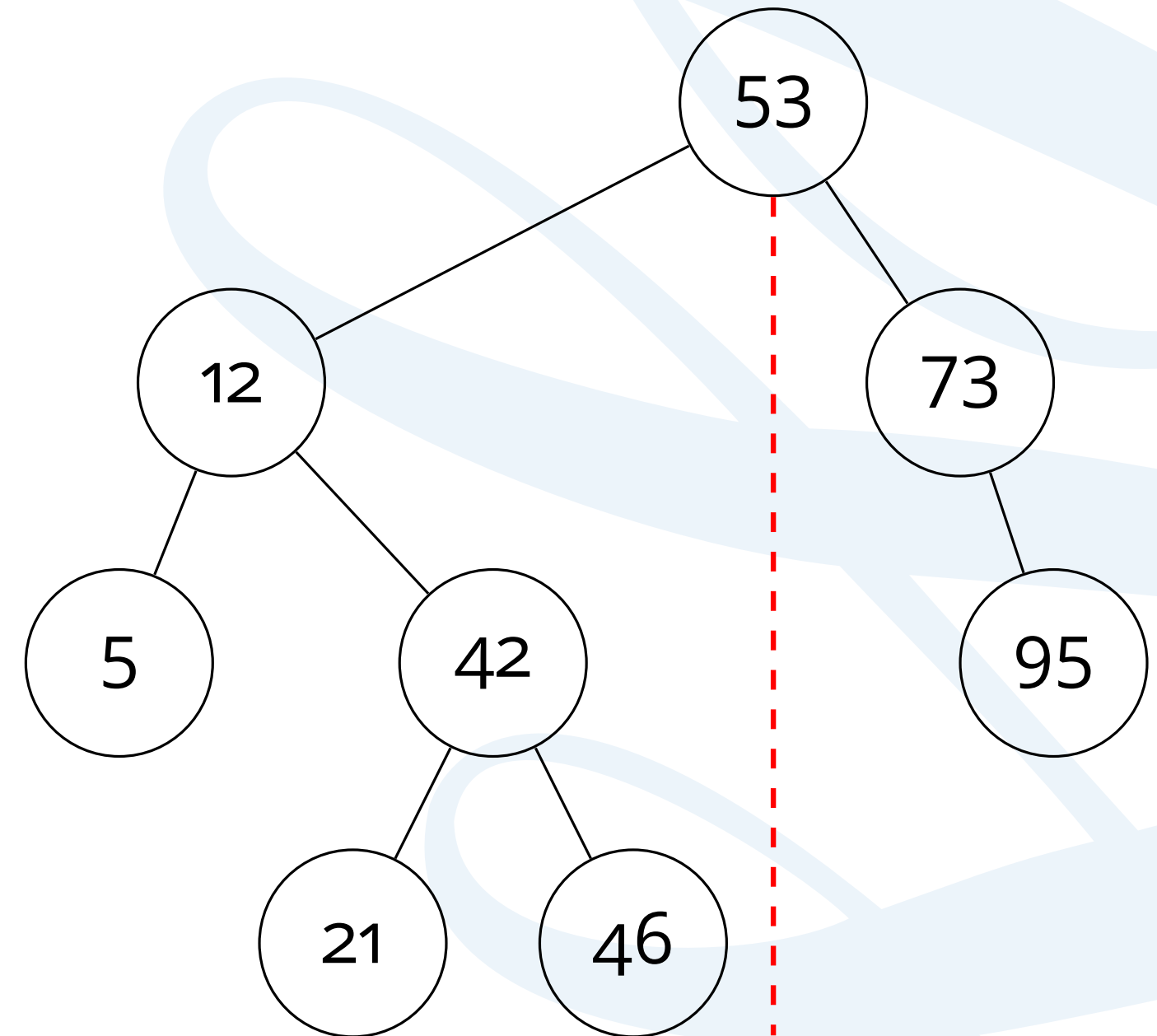
- Trees can be balanced or unbalanced.
- Not required for all trees.
- Going to be talking about BSTs from here on.
- Unbalanced because more than a one node difference between the two halves.



Balance

A

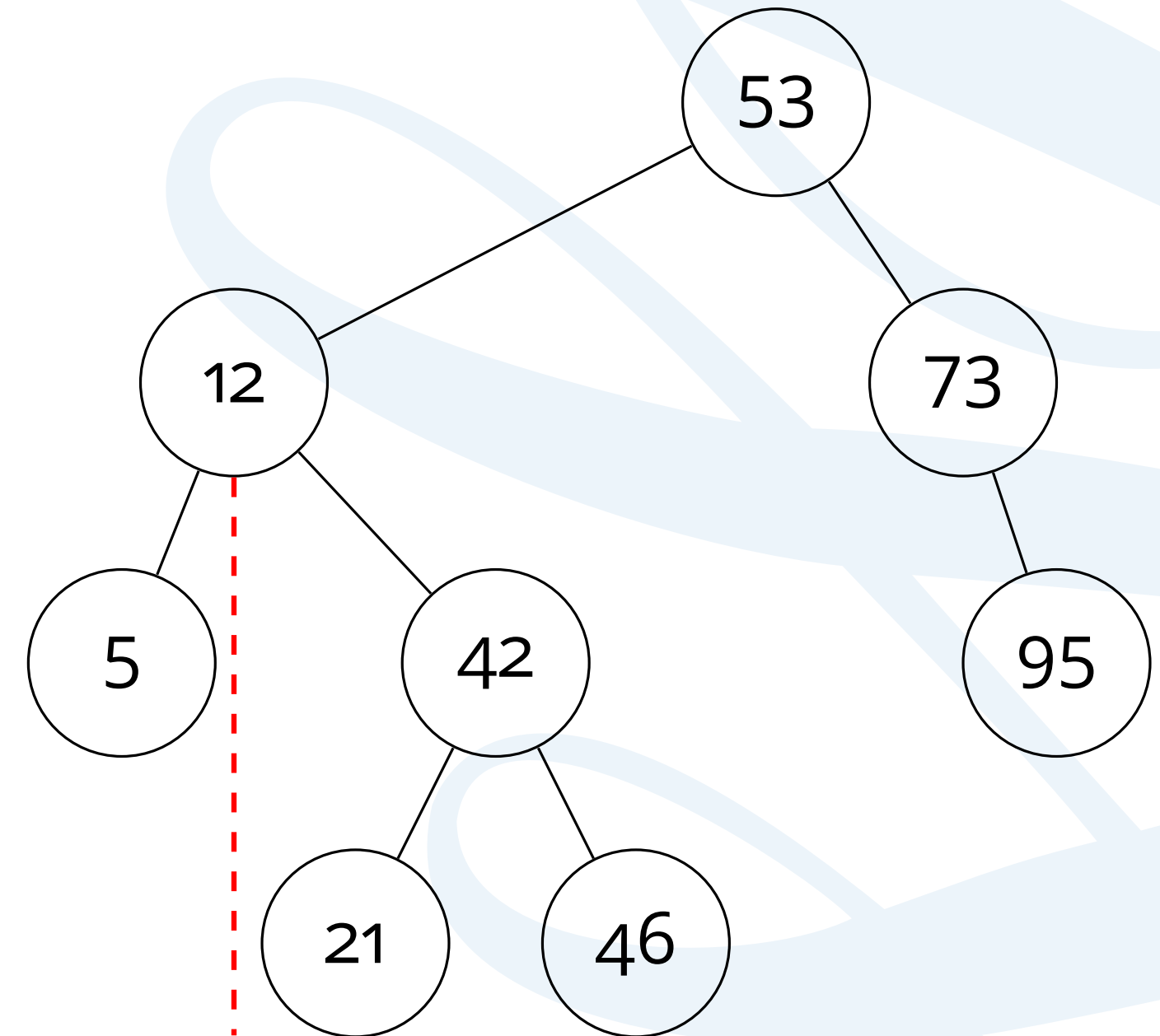
- Trees can be balanced or unbalanced.
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- Unbalanced because more than a one node difference between the two halves.
 - For the whole tree...



Balance

A

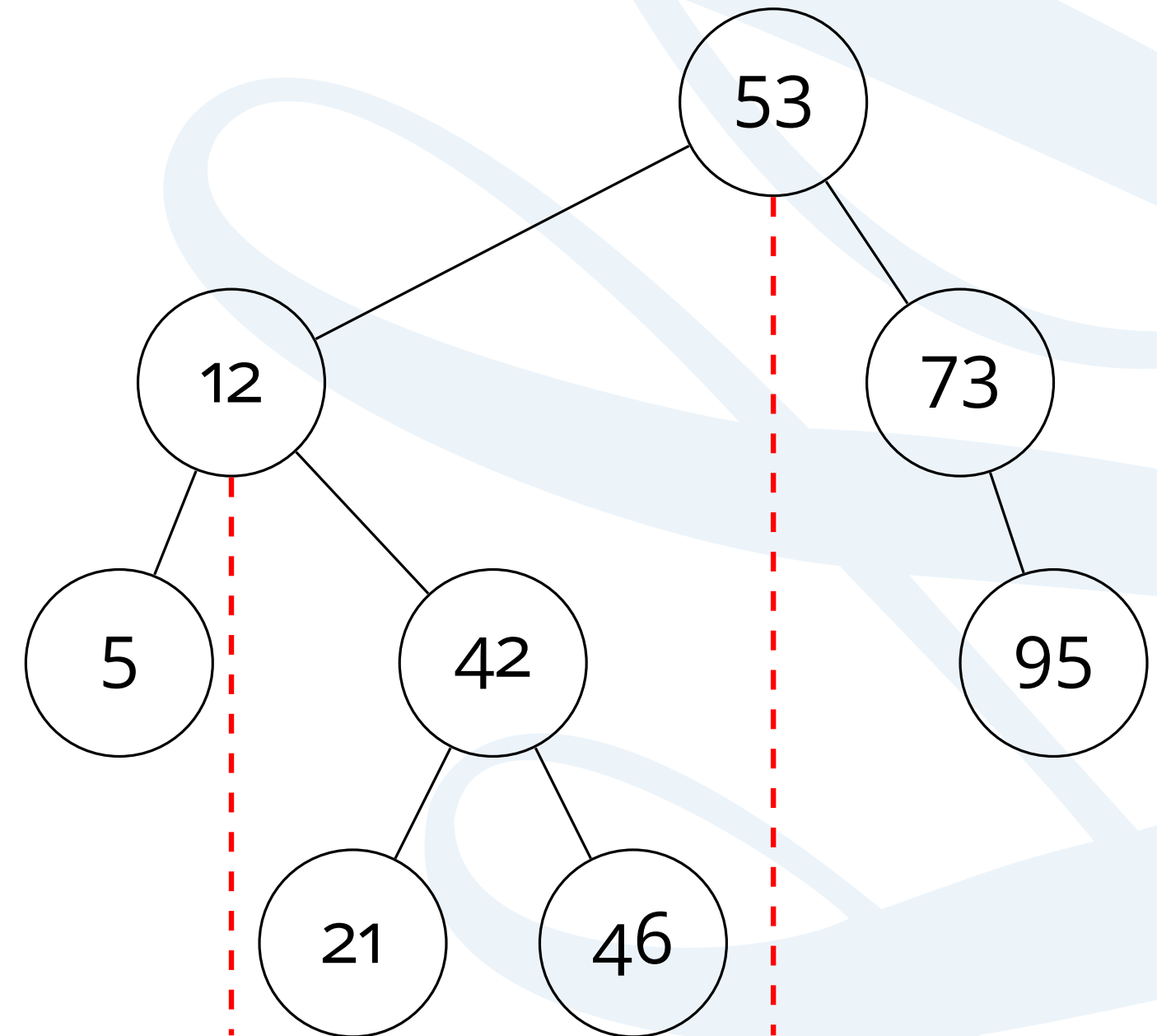
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 - For the whole tree...
 - ...and one of the subtrees.



Balance

A

- Trees can be balanced or unbalanced.
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- Unbalanced because more than a one node difference between the two halves.
 - For the whole tree...
 - ...and one of the subtrees.

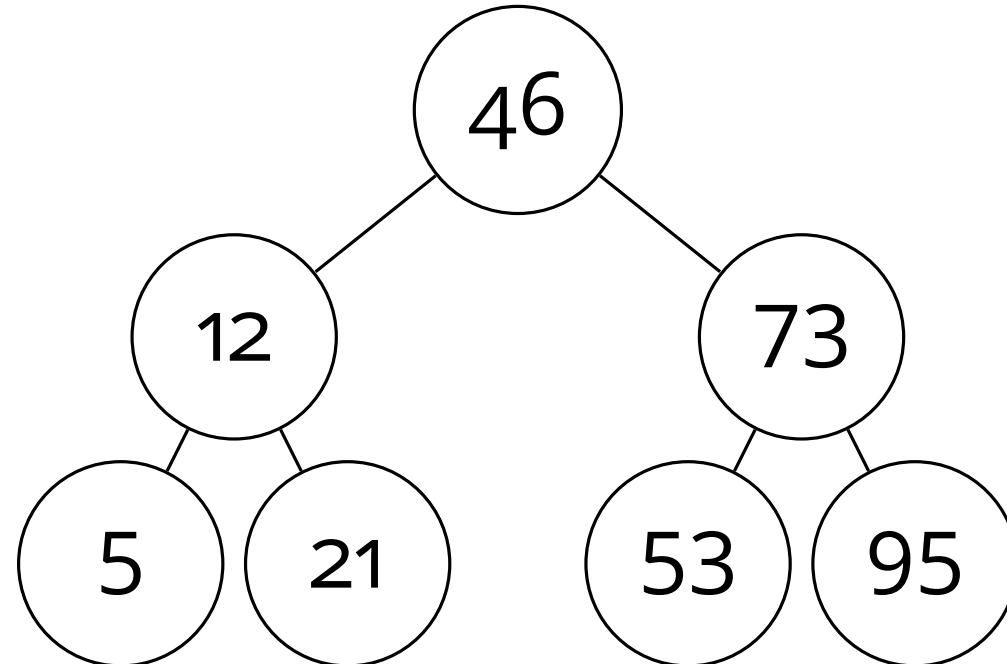


Balance

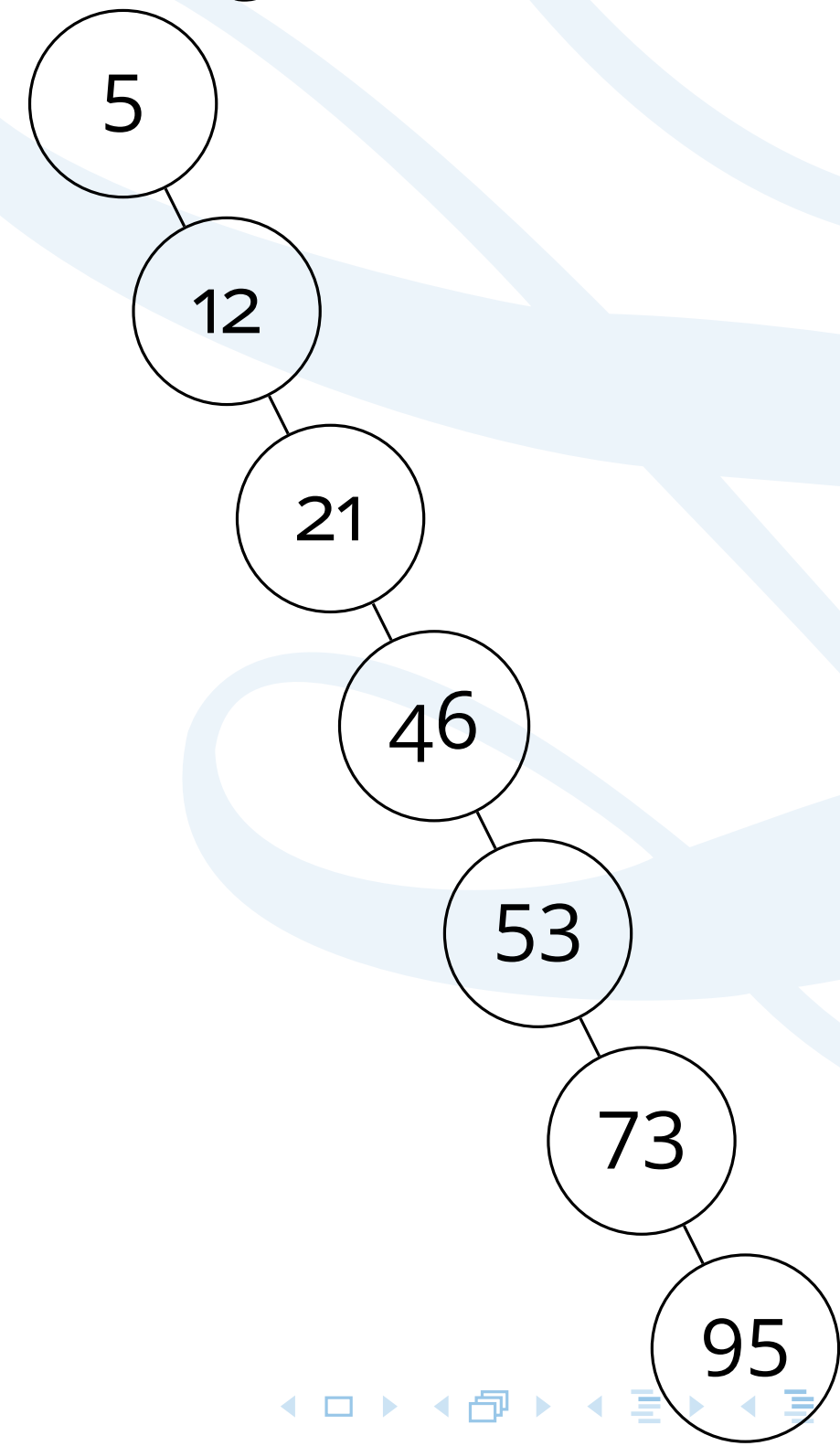
A

Important that you keep your BSTs balanced.

Perfect tree.



Degenerate tree.



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.

The End