Data structures and Abstract Data Types

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Overview

Arrays

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

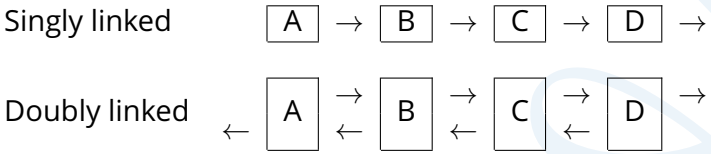
```
array<char,5> arr = {'A', 'B', 'C', 'D', 'E'};
```

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

Linked lists

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.



Linked lists II

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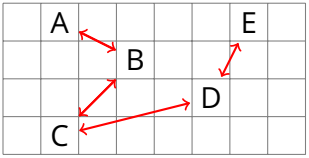
Not in contiguous memory.

- Each node is separate.
- Scattered.
- C++ Dynamic memory (pointers!).



- Why would we use linked lists instead of arrays?
  - Can change size.
  - Can quickly insert and delete elements.

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class Node:
    __prev = None
    __next = None
    value = None
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class Node
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private:
    Node *prev;
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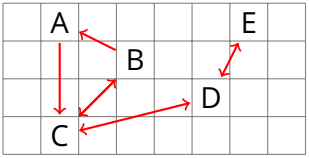

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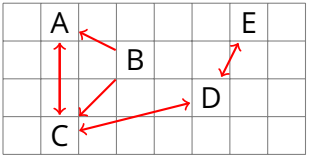

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Removing array elements

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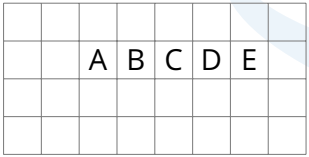

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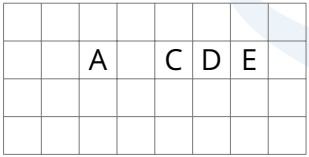

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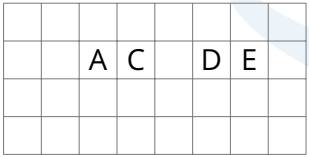

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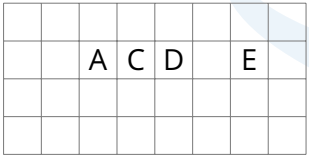

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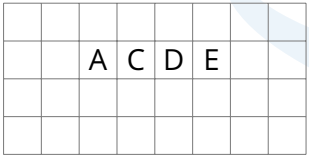

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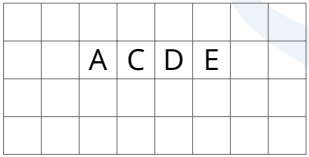

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- How do we remove elements from the middle?
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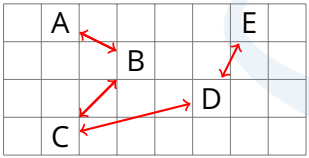
- Is very slow with large arrays.

Removing linked list elements



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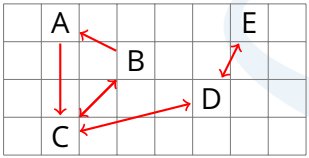

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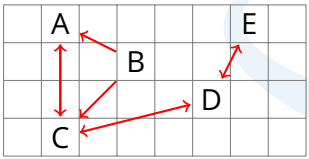

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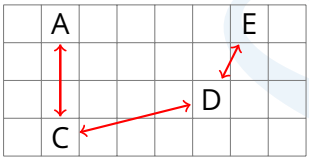

- Linked list, separate elements scattered in memory.
- Each pointing to the next/prev element.
- How do we remove elements?
  1. Change pointers.
  2. Delete old element.

Linked lists III

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.

Data structures

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).

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- Unlike data structure ADTs only concerned with the interface.
- Internals of ADTs can vary widely between implementations.

ADT

Imagine an ADT like a car.

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

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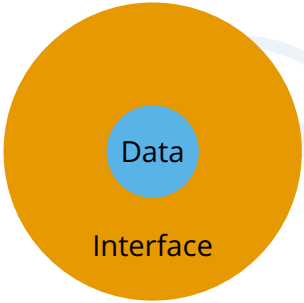
- Only care about the result.
- Keep people away from the internal workings/data.

Programmer



Queues

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.
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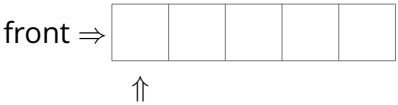

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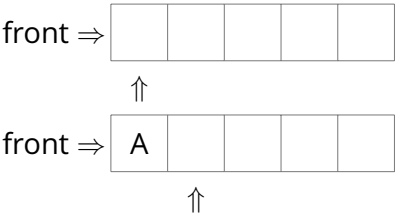

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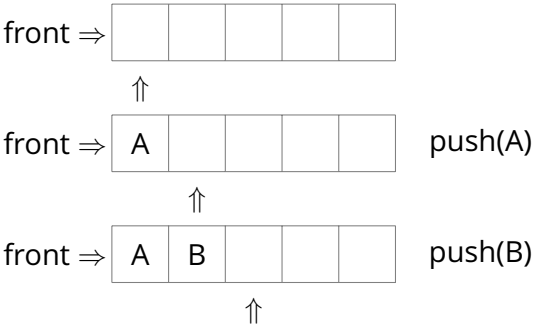

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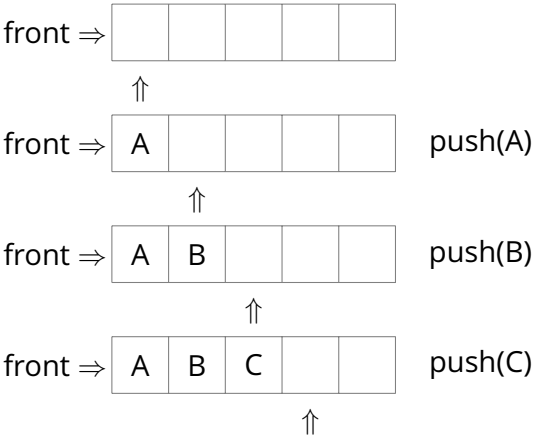

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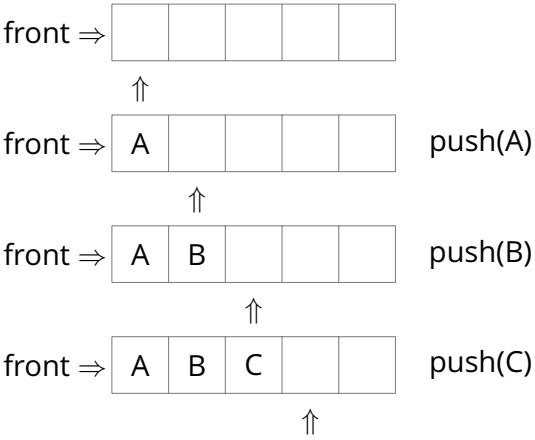

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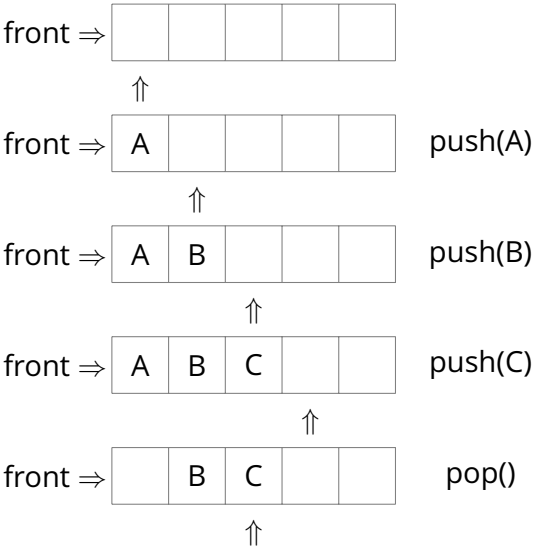

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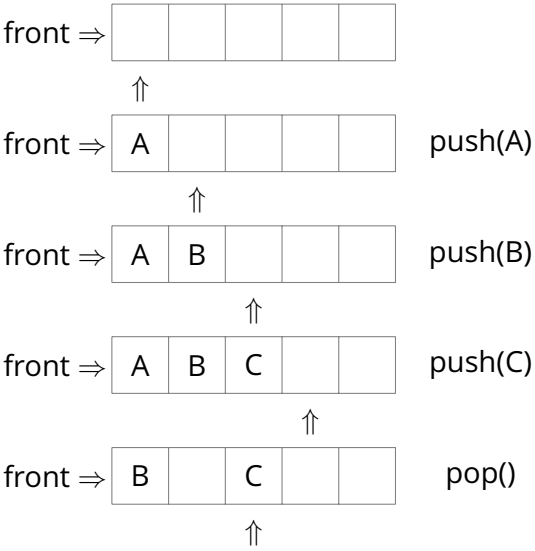

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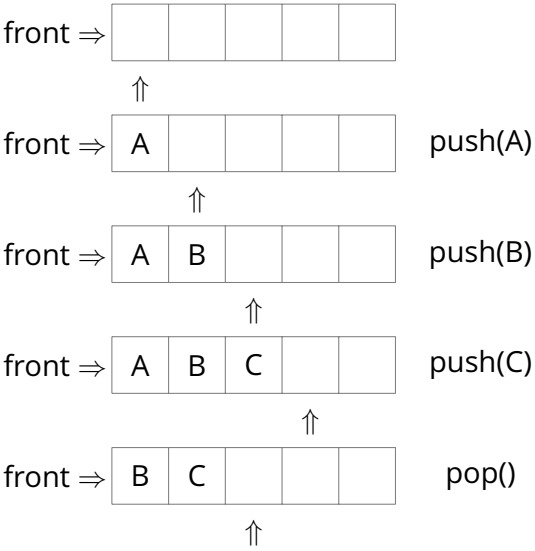

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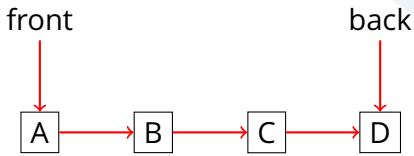

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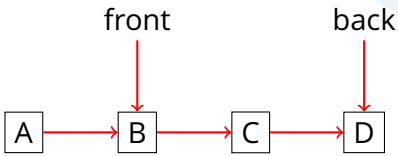

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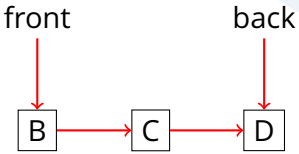

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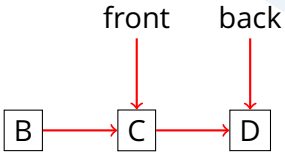

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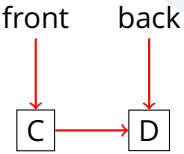

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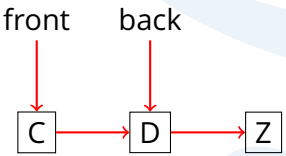

Linked list as a queue.

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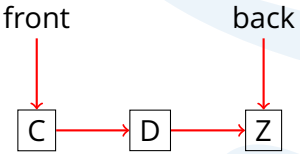

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  - Linked list if *n* is unknown.

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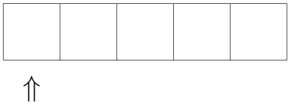

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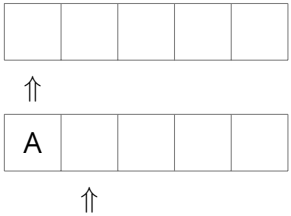

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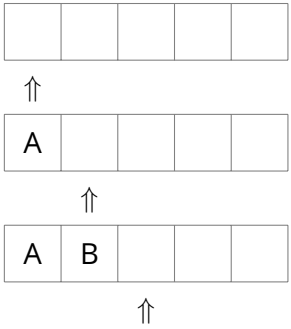

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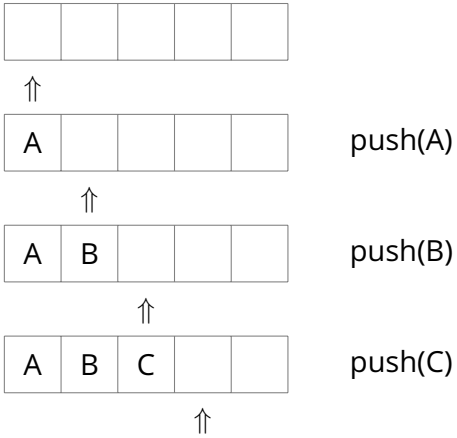

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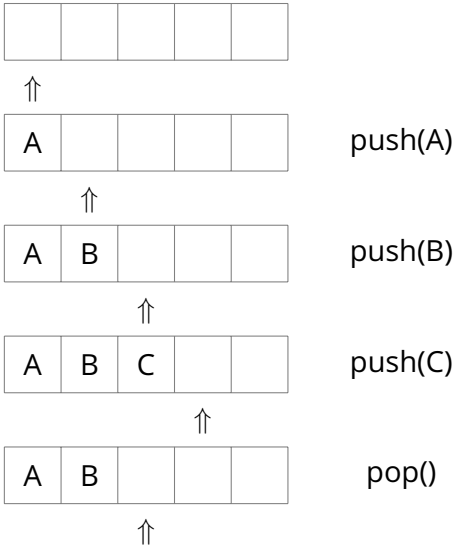

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...and the others

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

Break

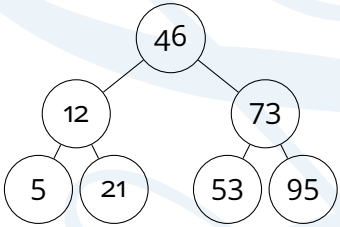
Trees

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.

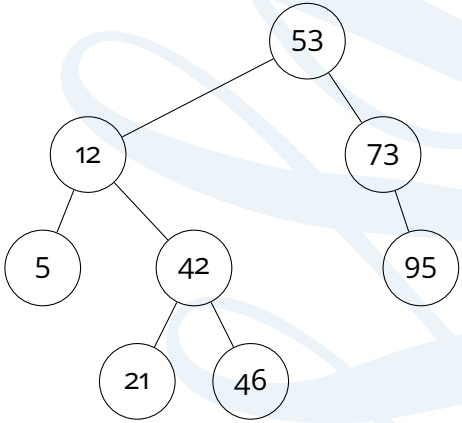


Balance

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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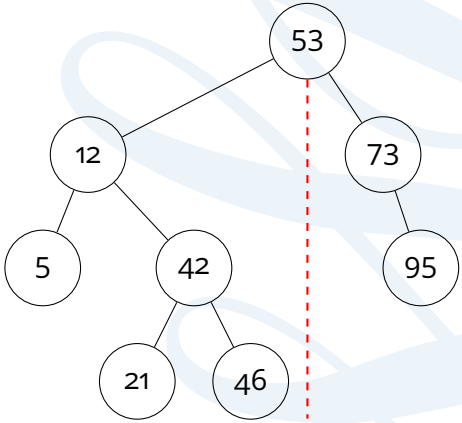
  - For the whole tree...



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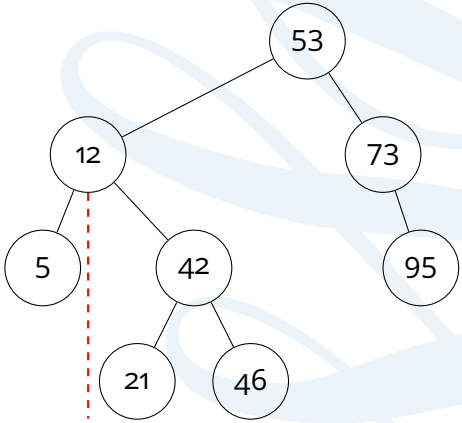
  - ...and one of the subtrees.



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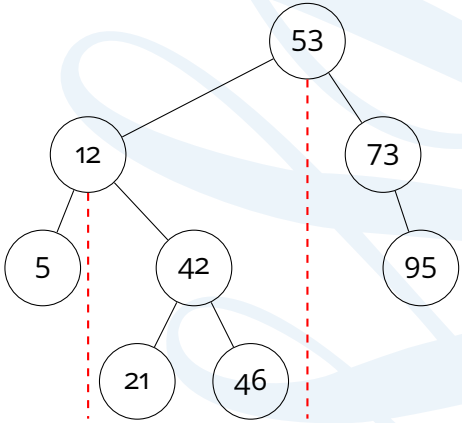
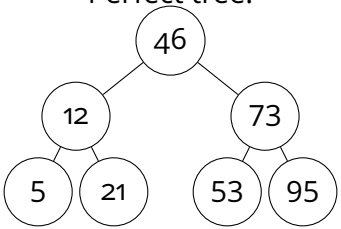


Balance

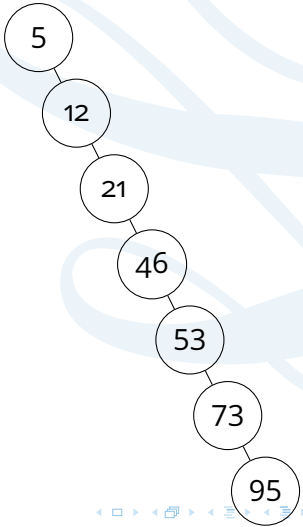
A

Important that you keep your BSTs balanced.

Perfect tree.



Degenerate tree.



Why do I care?

Everyone

- Need to understand the structures before we can pick the right one.
- Different data structures have very different characteristics.
- Huge effect on efficiency of your code.
- If you pick the right ADT it can save you a lot of code.
  - E.g. why write code to check for duplicates? Use a set and they can't exist.
  - E.g. why write code to find the most recent addition to a list, use a stack.

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.

The End