122com Data structures and types

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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

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Recap

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Arrays C

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.

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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 $\boxed{A}$ → $\boxed{B}$ → $\boxed{C}$ → $\boxed{D}$ →

Doubly linked   ← $\boxed{A}$ $\overset{\rightarrow}{\leftarrow}$ $\boxed{B}$ $\overset{\rightarrow}{\leftarrow}$ $\boxed{C}$ $\overset{\rightarrow}{\leftarrow}$ $\boxed{D}$ →

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A

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Not in contiguous memory.

- Each node is separate.
- Scattered.
- C++ Dynamic memory (pointers!).
  - Discussed in depth later in module.
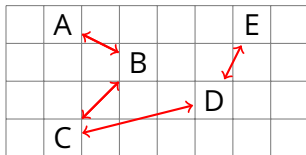
- Why would we use linked lists instead of arrays?
  - Can change size.
  - Can quickly insert and delete elements.

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

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

public:
    int value;
};
```

C

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

		A	B	C	D	E	

- 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.

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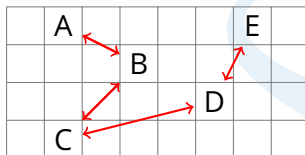# Removing linked list elements

- 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.

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 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.

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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.

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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.
- 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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ADT I

Imagine an ADT like a car.

- 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.
- Keep people away from the internal workings/data.

Programmer

Data

Interface

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Queues   C
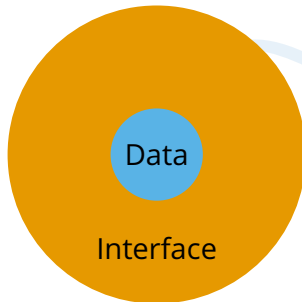
A First In First Out (FIFO) ADT.

- 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.
- Buffer to hold items for processing in the order in which they arrive.

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

Array as a queue.

front ⇒ [| | | |]

front ⇒ [A | | | |]   push(A)

front ⇒ [A | B | | |]   push(B)

front ⇒ [A | B | C | |]   push(C)
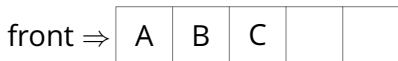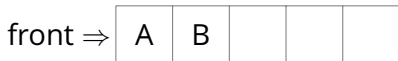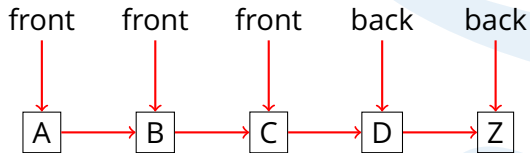
front ⇒ [B | C | | |]   pop()

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

  - Limited size.
- What happens when we pop()?
  - Have to shuffle every element forward one space.

  - Inefficient.
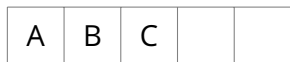
Linked list as a queue.

A

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

front   front   front   back   back

A → B → C → D → Z

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Stacks   C

A First In Last Out (FILO) ADT.

- Ends of the stack are called the top and bottom.
- New elements add to top of stack only.
  - Pushing - push(value)
- Old elements removed from top of stack only.
  - Popping - pop()
- No cutting in.

- 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

push(A)

push(B)

push(C)

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 nth element.
  - It's unordered remember.

A					add(A)

A	B				add(B)

A	B				add(A)

	B				remove(A)

...and the others

C

- Lots of other ADTs.
- Different names in different languages.

- Lists.
- Circular lists.
- Associative arrays.
    - Dictionaries/Maps.
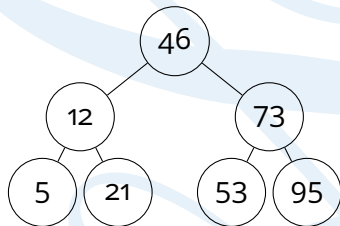- Double-ended queues.
- Trees.
- Graphs.

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Break

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.

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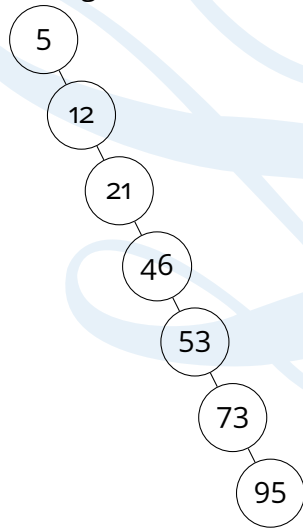 - ...and one of the subtrees.

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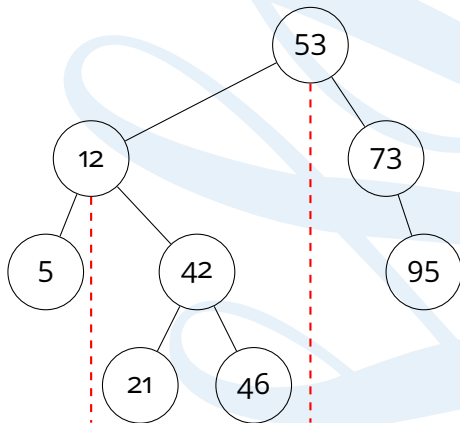
Recap

Balance A

Important that you keep your BSTs balanced.
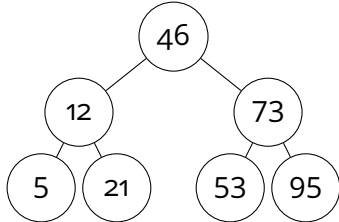
Degenerate tree.

Perfect tree.

Quiz

Stacks and queues are examples of ____

- Data structures.
- Linked lists.
- Arrays.
- Abstract Data Types.

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One advantage of linked lists over arrays is that ____

- They use less memory.
- They don't waste memory.
- They can be used for queues.
- They are faster to search though.

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Stacks are a ＿＿＿ type.

- ■ FIFO.
- ■ FOFI.
- ■ FILO.
- ■ FIDO.

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The elements of a set can't _____

- Contain duplicates.
- Be sequences, ie. lists, strings.
- Be out of order.
- Be removed.

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ADTs separate the _____ of the type.

■ Input and output.

■ Attributes and methods.

■ Implementation and interface.

■ Code and software.

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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.

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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