

122com Data structures and types

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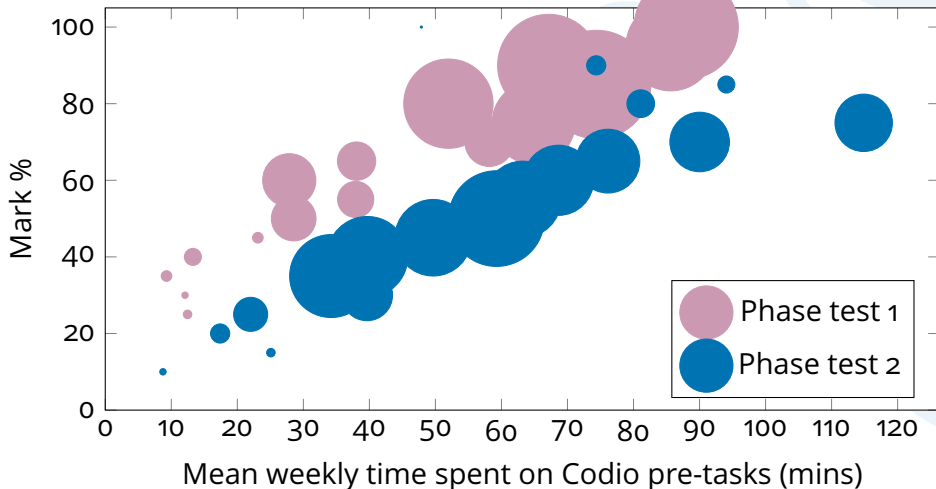
2018

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 Quiz
- 11 Recap

You have all attempted the green Codio exercises for this week.

122COM results 2016-17 September starters.



Arrays

Linked lists

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Quiz

Recap

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.

The challenger for array's crown.

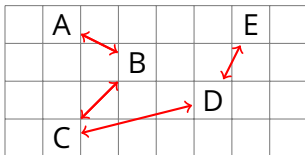
- Series of nodes, each of which points to the next element.
 - And to the previous element if it's a doubly linked list.

Singly linked $\boxed{A} \rightarrow \boxed{B} \rightarrow \boxed{C} \rightarrow \boxed{D} \rightarrow$

Doubly linked $\leftarrow \boxed{A} \xrightarrow{\quad} \boxed{B} \xrightarrow{\quad} \boxed{C} \xrightarrow{\quad} \boxed{D} \rightarrow$
 $\leftarrow \quad \leftarrow \quad \leftarrow \quad \leftarrow$

Not in contiguous memory.

- Each node is separate.
- Scattered.
- C++ Dynamic memory (pointers!).
 - Discussed in depth later in module.



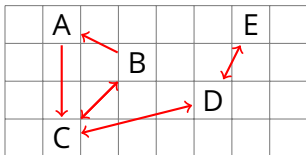
- Why would we use linked lists instead of arrays?
 - Can change size.
 - Can quickly insert and delete elements.

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

```
class Node  
{  
private:  
    Node *prev;  
    Node *next;  
  
public:  
    int value;  
};
```

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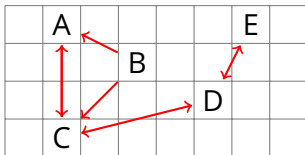
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Removing array elements

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?

Removing array elements

C

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temp = ['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?
 - 1 Remove element from the array.

Removing array elements

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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.

Removing array elements

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temp = ['A', 'B', 'C', 'D', 'E']  
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- Array in memory, multiple elements in a contiguous block.
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 - 3 Repeat.

Removing array elements

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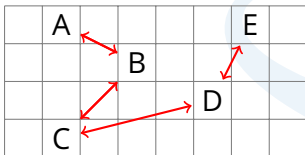
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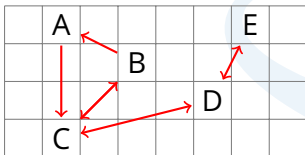
- Array in memory, multiple elements in a contiguous block.
- How do we remove elements from the middle?
 - 1 Remove element from the array.
 - 2 Move next element to occupy the empty space.
 - 3 Repeat.
- Is very slow with large arrays.

Removing linked list elements



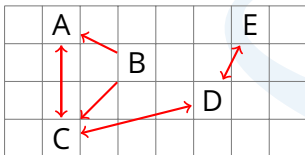
- Linked list, separate elements scattered in memory.
- Each pointing to the next/prev element.
- How do we remove elements?

Removing linked list elements



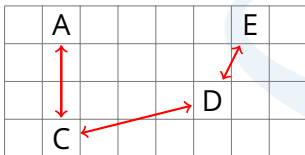
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 - 1 Change pointers.

Removing linked list elements



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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.

Arrays

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Recap

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 will start to encounter Abstract Data Types (ADTs).

- Software engineering principal.

Abstract data types



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- Keep what a data type can do...

Abstract data types



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- Keep what a data type can do...
...and how it does it separate.

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- Keep what a data type can do...
...and how it does it separate.
- Unlike data structure ADTs only concerned with the interface.

Abstract data types



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.

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Imagine an ADT like a car.

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

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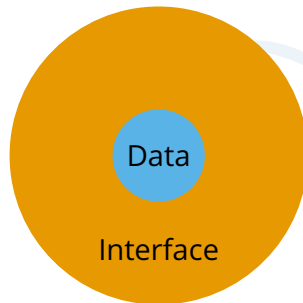
Recap

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



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.

A FIFO ADT.

- Ends of the queue called the front and back.
- New elements added to back of queue only.
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- Buffer to hold items for processing in the order in which they arrive.

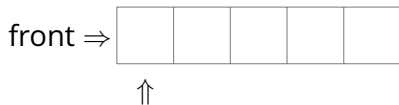
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- Which would be better for a queue? An array or a linked list?

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

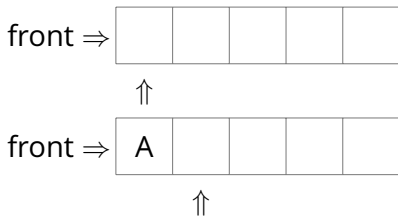
Array as a queue.



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

Array as a queue.

1

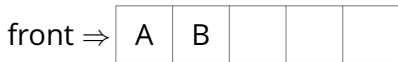


push(A)

- Very similar to stacks.
 - Keep track of next free space.
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Array as a queue.

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push(A)

push(B)

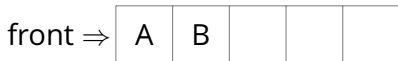
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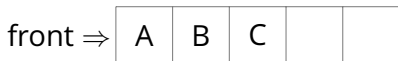
1



push(A)



push(B)



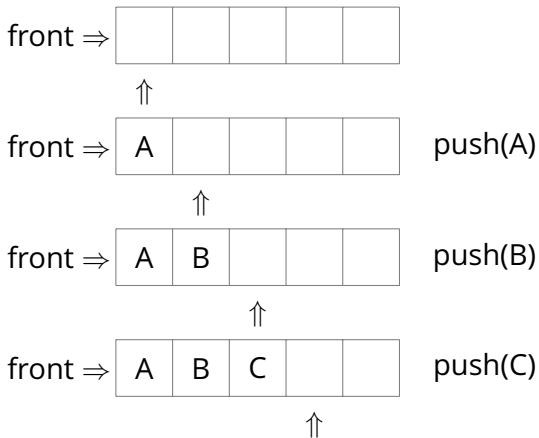
push(C)



- Very similar to stacks.
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Array as a queue.

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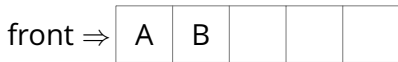
- Very similar to stacks.
 - Keep track of next free space.
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- What happens when we pop()?
 - Have to shuffle every element forward one space.
 - Inefficient.

Array as a queue.

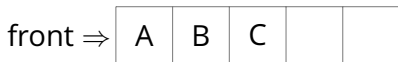
1



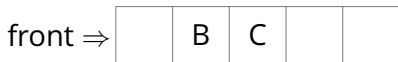
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push(B)



push(C)



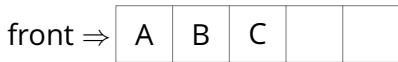
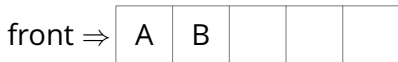
pop()



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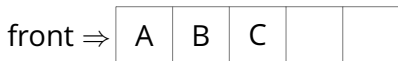
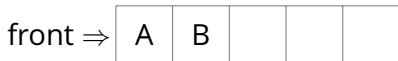
push(C)

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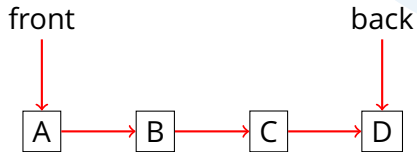
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pop()

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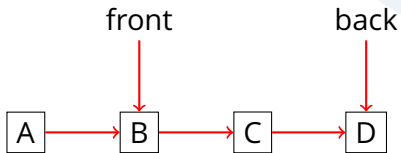
A



Linked list as a queue.

A

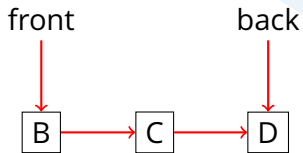
pop()



Linked list as a queue.

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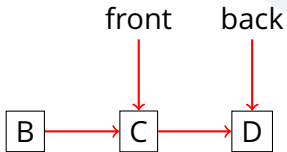
pop()



Linked list as a queue.

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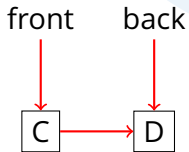
pop() , pop()



Linked list as a queue.

A

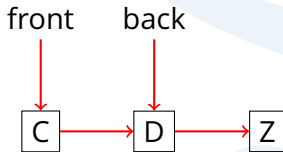
pop() , pop()



Linked list as a queue.

A

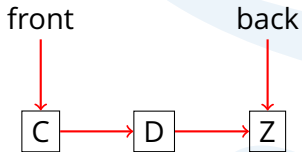
pop() , pop() , push(Z)



Linked list as a queue.

A

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



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.
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A FILO ADT.

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

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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.

Array as a stack.



- 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.

Array as a stack.



push(A)

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Array as a stack.

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push(A)



push(B)



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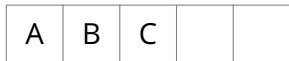
1



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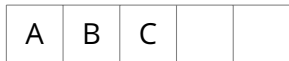
push(C)



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Array as a stack.

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push(A)

push(B)

push(C)

pop()

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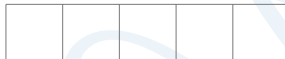
Quiz

Recap

- 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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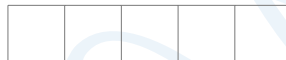
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add(A)



add(B)

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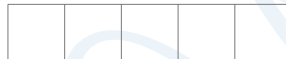
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add(A)



add(B)



add(A)

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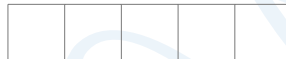
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add(A)



add(B)



add(A)



remove(A)

- 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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Sets

Other

Trees

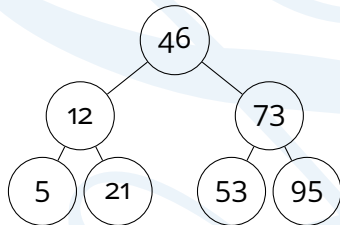
Quiz

Recap

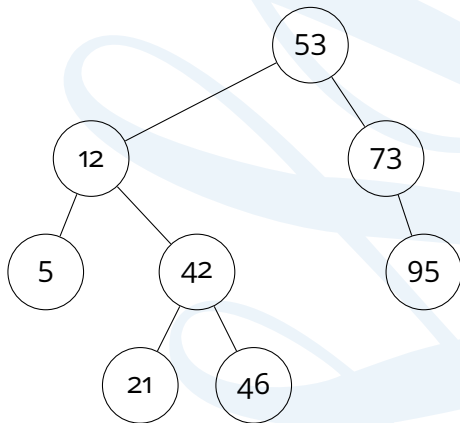
Break

Variation on linked lists.

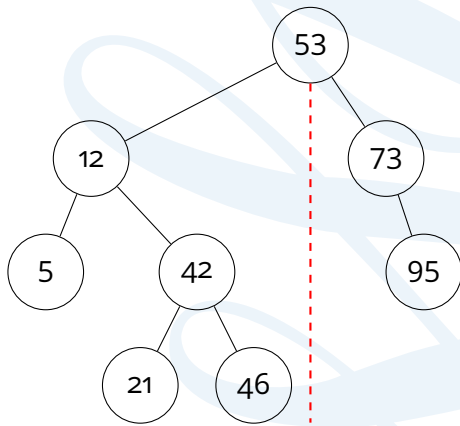
- Made of nodes and relationships.
- Root node at top.
- Each node can have ≥ 0 children.
- Binary search tree.
 - Very common type.
 - Ordered.
 - Max two children.
 - Binary searching.
 - Very good for sets.



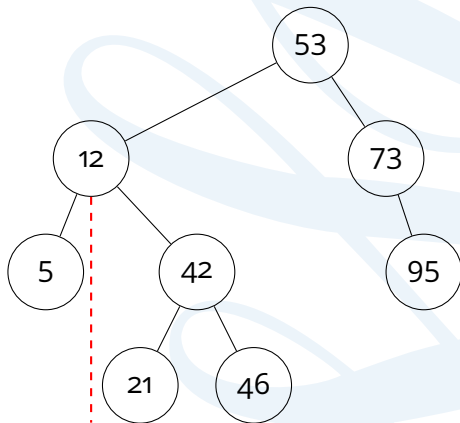
- Trees can be balanced or unbalanced.
- Not required for all trees.
- Going to be talking about BSTs from here on.
- Unbalanced because more than a one node difference between the two halves.



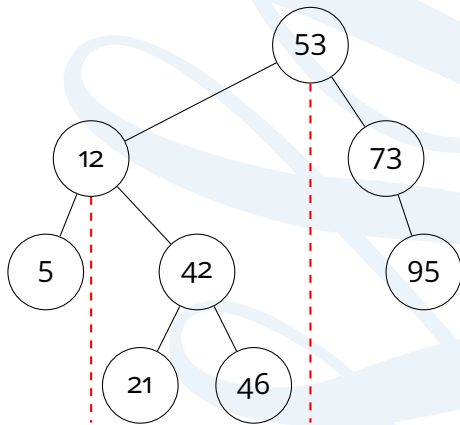
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 - ...and one of the subtrees.

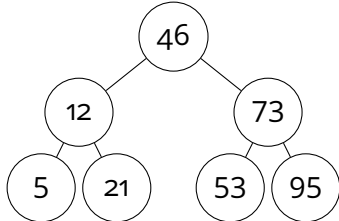


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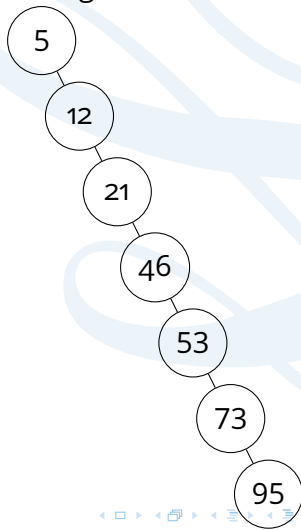


Important that you keep your BSTs balanced.

Perfect tree.



Degenerate tree.



Arrays

Linked lists

Array example

LL example

Data
structures

Abstract data
types

Queues

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Quiz

Stacks and queues are examples of _____

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

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

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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- **They don't waste memory.**
- They can be used for queues.
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Stacks are a _____ type.

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

Stacks are a _____ type.

- FIFO.
- FOFI.
- **FILO.**
- FIDO.

The elements of a set can't _____

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

The elements of a set can't _____

- **Contain duplicates.**
- Be sequences, ie. lists, strings.
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ADTs separate the _____ of the type.

- Input and output.
- Attributes and methods.
- Implementation and interface.
- Code and software.

ADTs separate the _____ of the type.

- Input and output.
- Attributes and methods.
- **Implementation and interface.**
- Code and software.

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.
- Sets.
 - No duplicates.
 - Unordered.
- Trees.
 - Balanced/unbalanced.

- Complete the yellow Codio exercises for this week.
- Attempt the green Codio exercises for next week.
- If you have spare time attempt the red Codio exercises.
- If you are having issues come to the PSC.
<https://gitlab.com/coventry-university/programming-support-lab/wikis/home>

Arrays

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The End