122com Data structures and types

David Croft

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2016

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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

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Overview

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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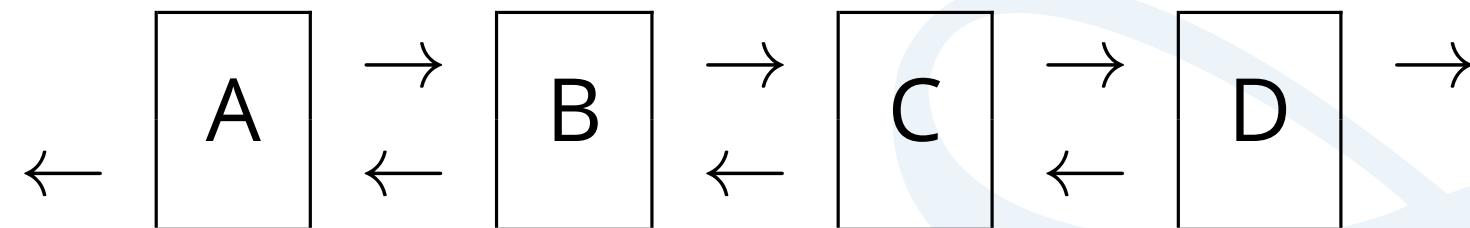University

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   A → B → C → D →
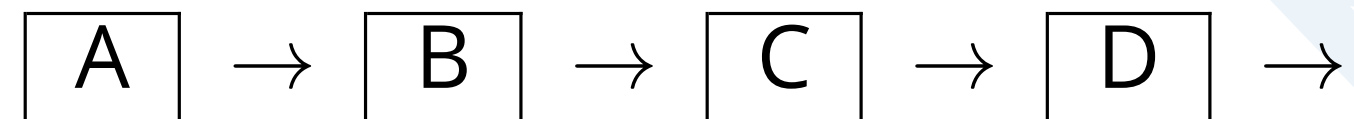
Doubly linked

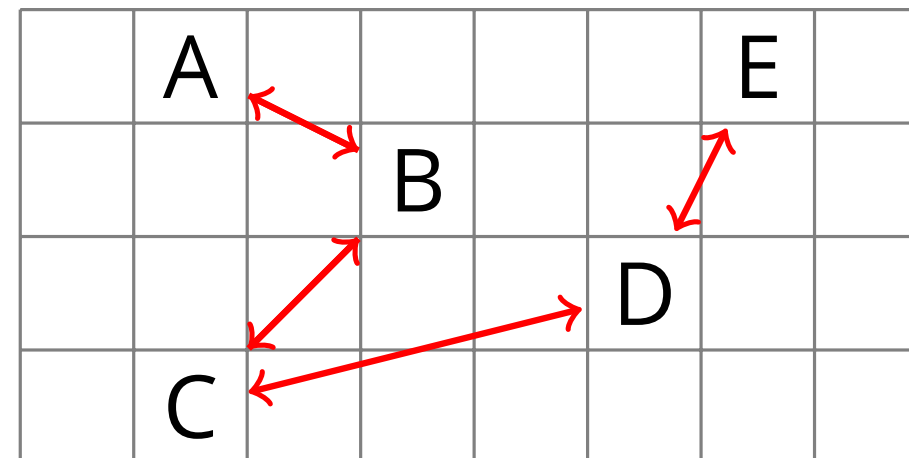← A ⇄ B ⇄ C ⇄ D →

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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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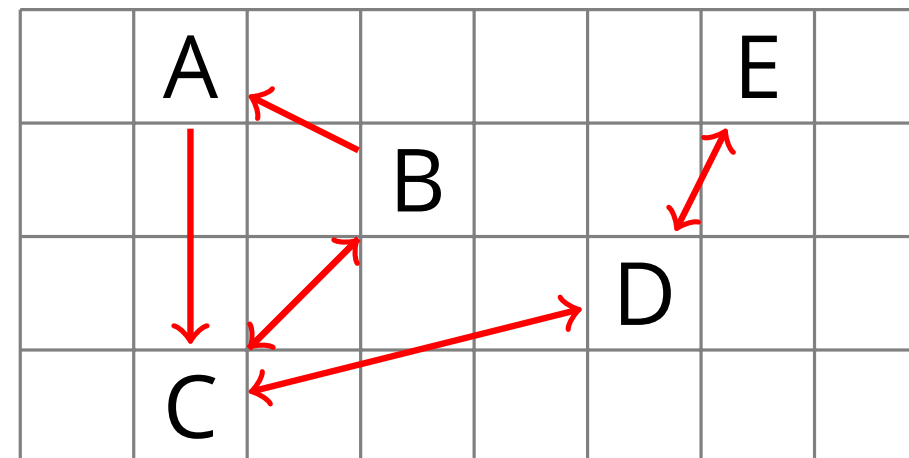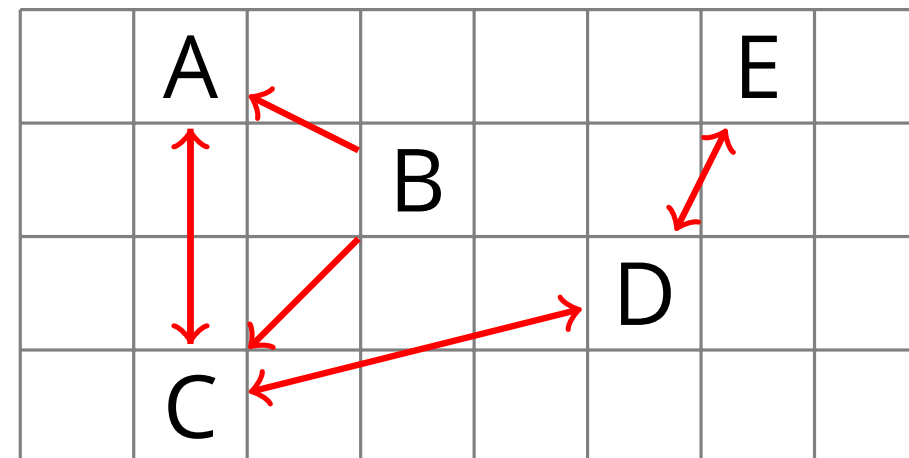
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Removing array elements

C

```
char array[] = {'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?

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Linked lists
Array example
LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

Trees

End

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- How do we remove elements from the middle?
  1. Remove element from the array.

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Linked lists
Array example
LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

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Removing array elements

C

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

| | A | 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.

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Arrays

Linked lists
Array example
LL example

Data structures

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Queues

Stacks

Sets

Other

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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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Removing array elements

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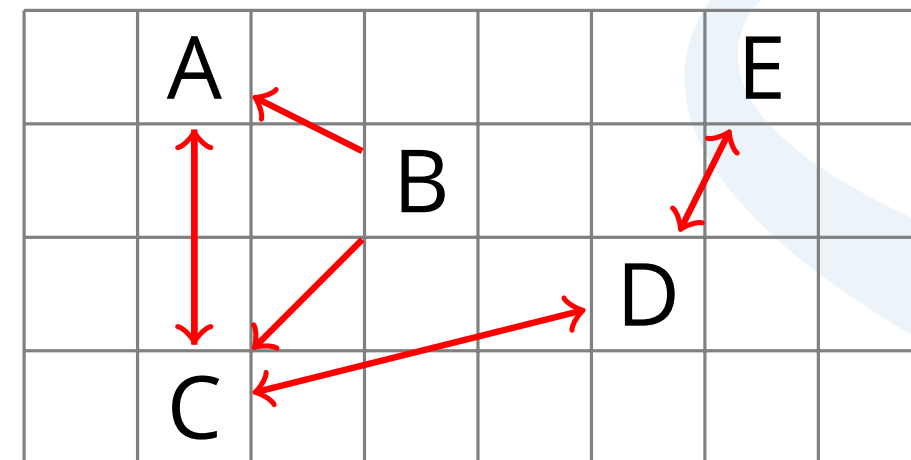 3. Repeat.
- Is very slow with large arrays.
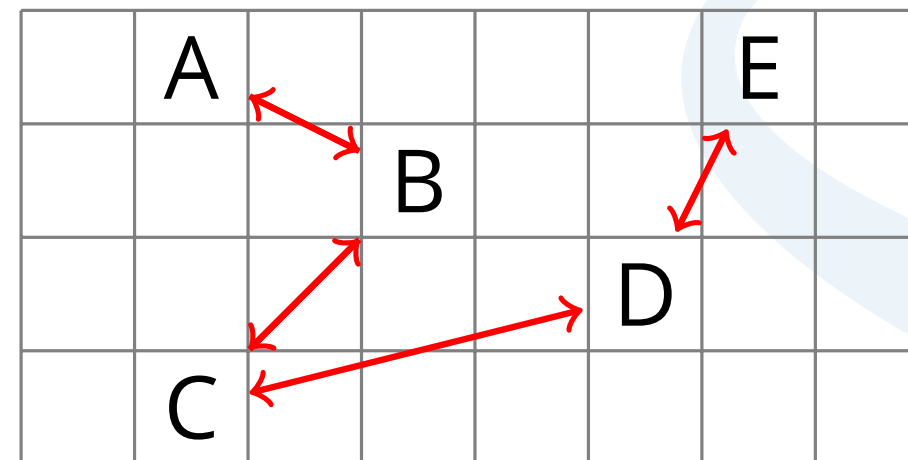
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Removing linked list elements

I

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

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Removing linked list elements

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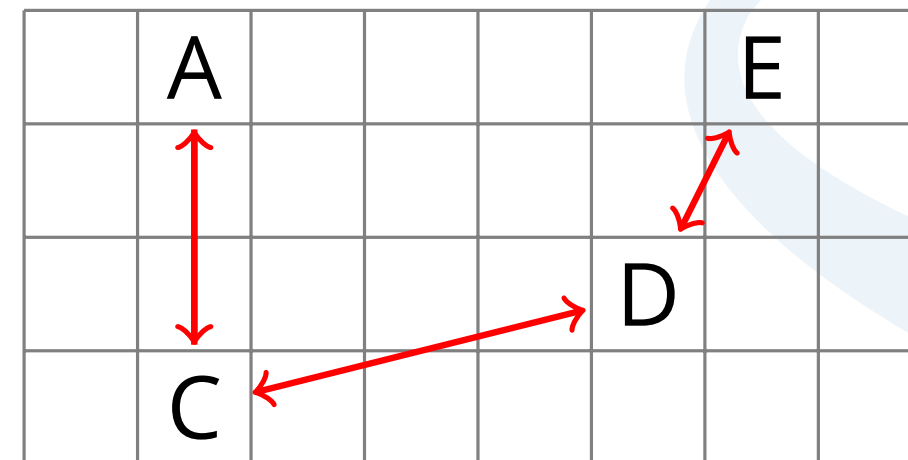
- How do we remove elements?
  1. Change pointers.

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Removing linked list elements
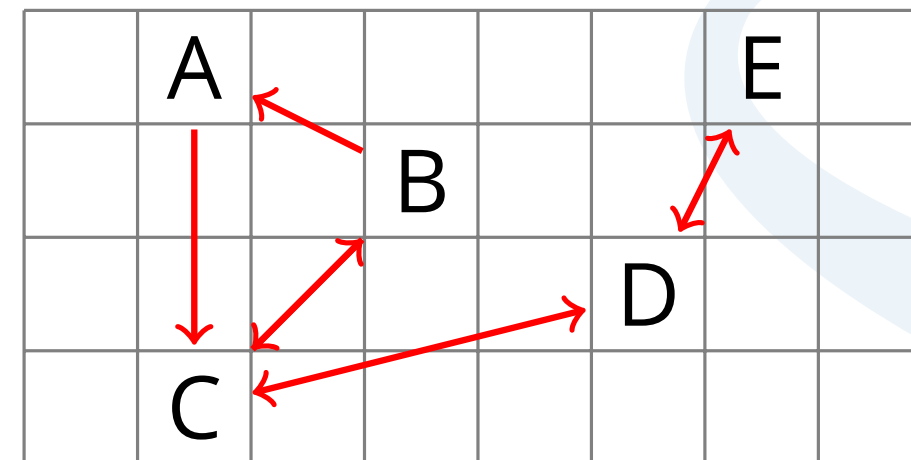
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Removing linked list elements

- 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.

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.

Abstract data types

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- Software engineering principal.
- Keep what a data type can do...

Abstract data types

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  ...and how it does it separate.

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Abstract data types

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

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- Unlike data structure ADTs only concerned with the interface.

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Abstract data types

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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- Don't care how it achieves these.

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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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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.

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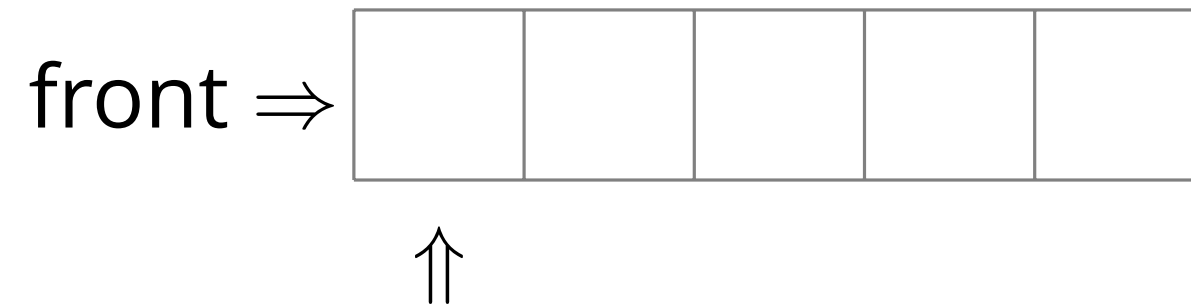
Queues   C
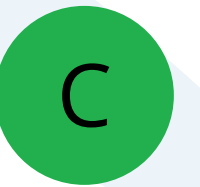
A First In First Out (FIFO) ADT.

- Ends of the queue at 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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Queues C

A FIFO ADT.

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Queues

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Queues

C

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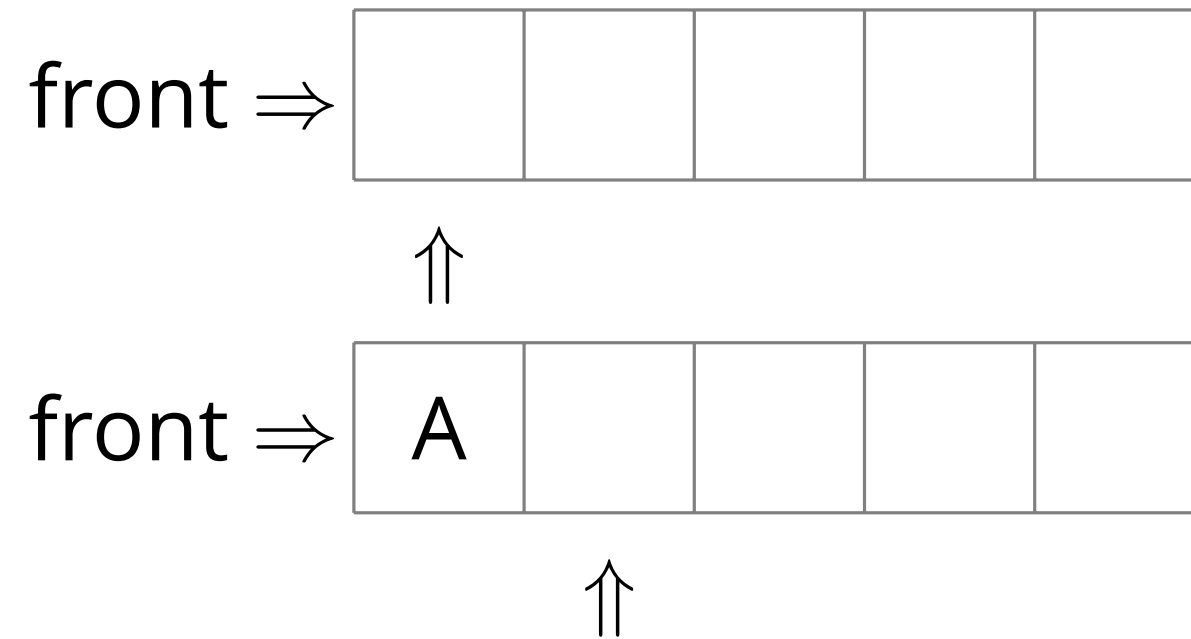   - Linked list.

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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 queue.

I

front $\Rightarrow$

$\Uparrow$

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

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Array as a queue.

front $\Rightarrow$ [| | | |]

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front $\Rightarrow$ [A | | | |]   push(A)

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Queues

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front $\Rightarrow$ | | | | | |

$\Uparrow$

front $\Rightarrow$ | A | | | | | push(A)

$\Uparrow$

front $\Rightarrow$ | A | B | | | | push(B)

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

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Linked lists
Array example
LL example

Data structures

Abstract data types

Queues

Stacks

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Other

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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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Linked lists
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Stacks
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Array as a queue.

front ⟹ [ ][ ][ ][ ][ ]

⇑

front ⟹ [A][ ][ ][ ][ ]   push(A)

⇑

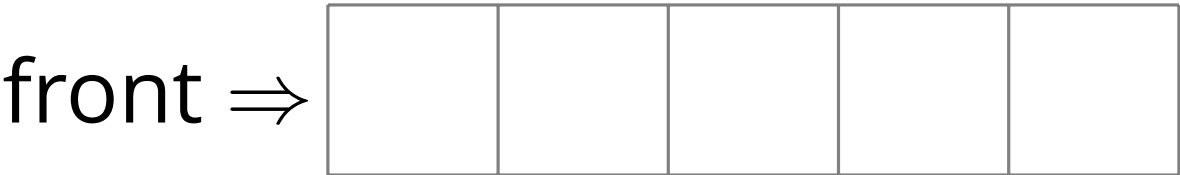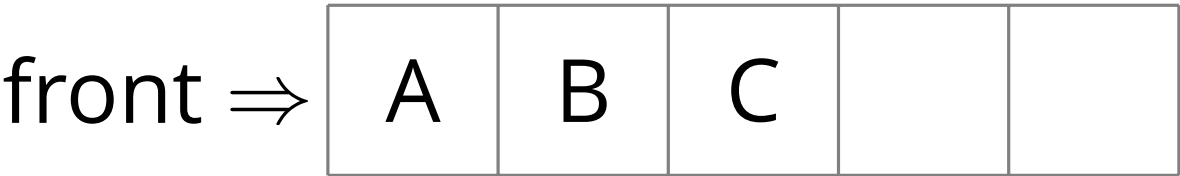front ⟹ [A][B][ ][ ][ ]   push(B)

⇑

front ⟹ [A][B][C][ ][ ]   push(C)
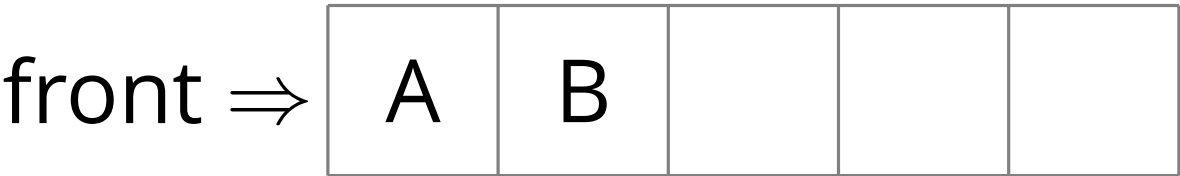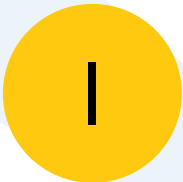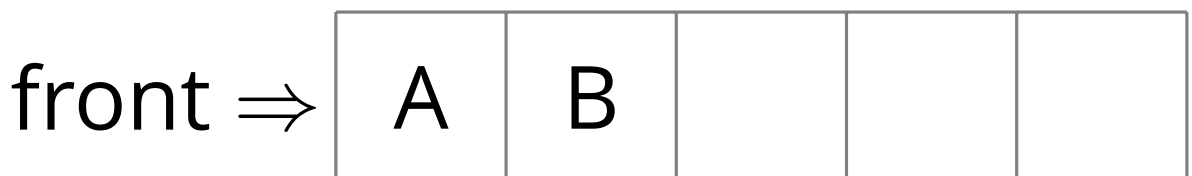
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- Very similar to stacks.
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- What happens when we pop()?
  - Have to shuffle every element forward one space.
  - Inefficient.

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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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front ⇒ | | | | | |

⇑

front ⇒ | A | | | | | push(A)

⇑

front ⇒ | A | B | | | | push(B)

⇑

front ⇒ | A | B | C | | | push(C)

⇑

front ⇒ | | A | B | | | pop()
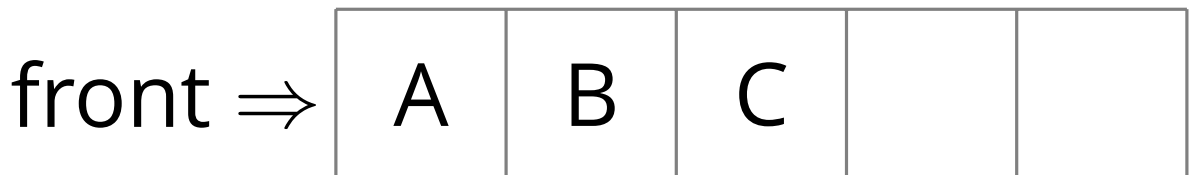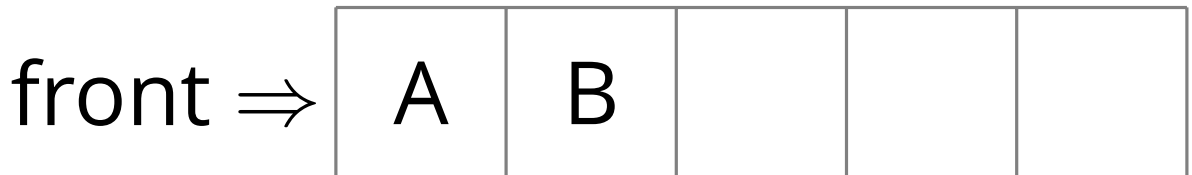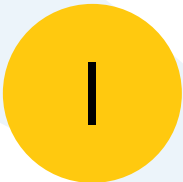
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Arrays

Linked lists
  Array example
  LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

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Array as a queue.

front ⇒ | | | | | |

⇑

front ⇒ | A | | | | | push(A)

⇑

front ⇒ | A | B | | | | push(B)

⇑

front ⇒ | A | B | C | | | push(C)

⇑

front ⇒ | A | | B | | | pop()
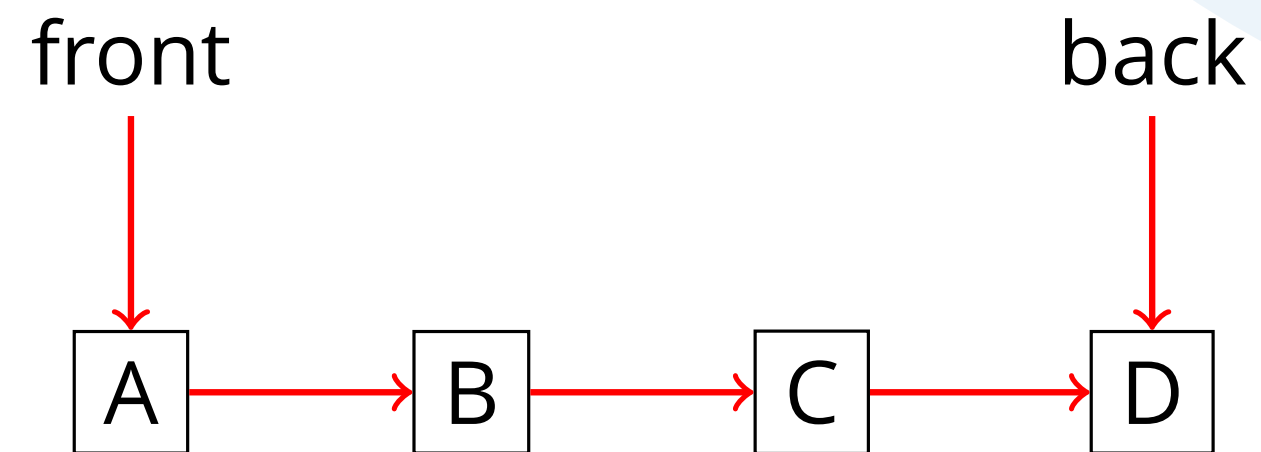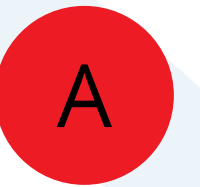
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Arrays

Linked lists
Array example
LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

Trees

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Array as a queue.

I

front ⇒

⇑

front ⇒ | A | | | | | push(A)

⇑

front ⇒ | A | B | | | | push(B)

⇑

front ⇒ | A | B | C | | | push(C)

⇑

front ⇒ | A | B | | | | pop()

⇑

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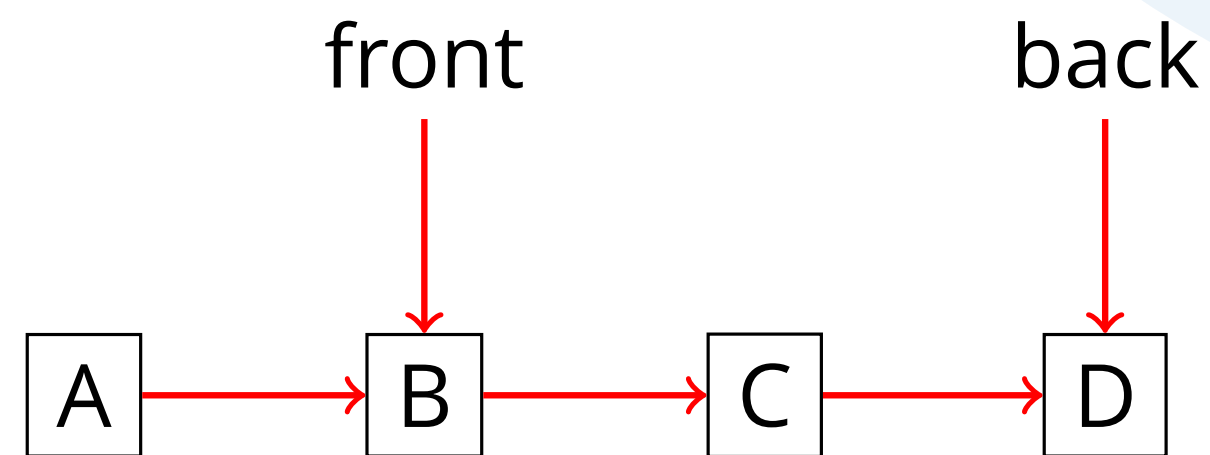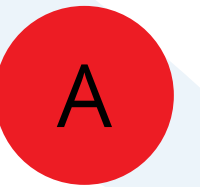 - Have to shuffle every element forward one space.
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Arrays

Linked lists
  Array example
  LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

Trees

End

Linked list as a queue.

A

front   back

A → B → C → D

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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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Linked list as a queue.

A

pop()

front   back

A → B → C → D

Linked list as a queue.

A

pop()

Linked list as a queue.
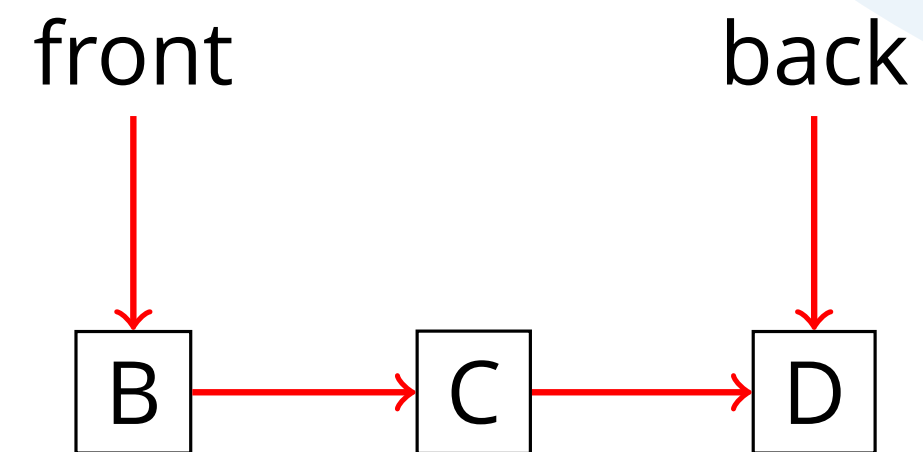
A

pop() , pop()

front   back

B → C → D

Linked list as a queue.

A

pop() , pop()

front   back

C → D

Linked list as a queue.

A

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

front　　back
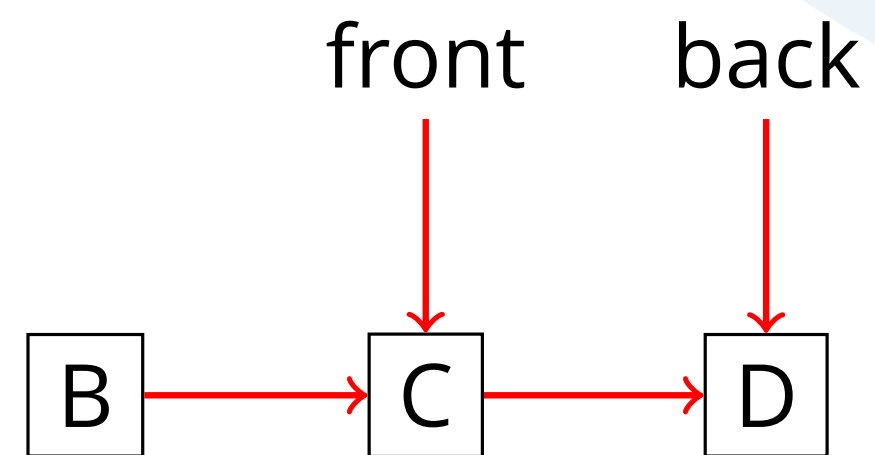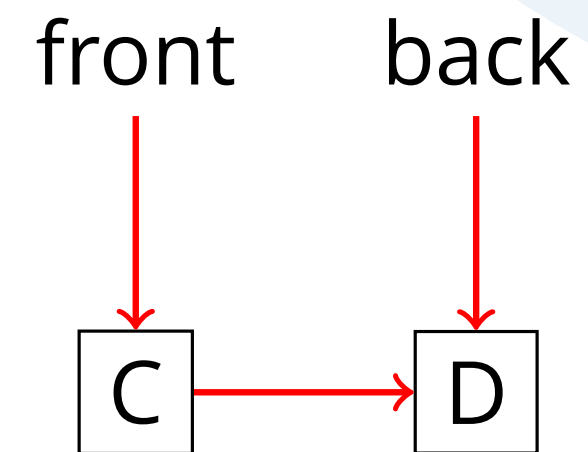
| C | → | D | → | Z |

Linked list as a queue.

A

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

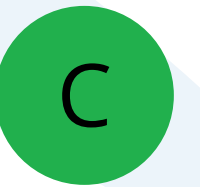front   back

C → D → Z

Stacks C
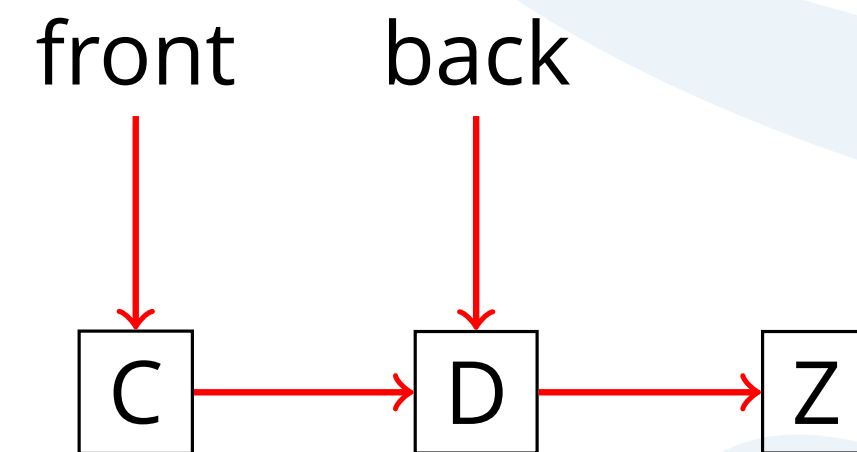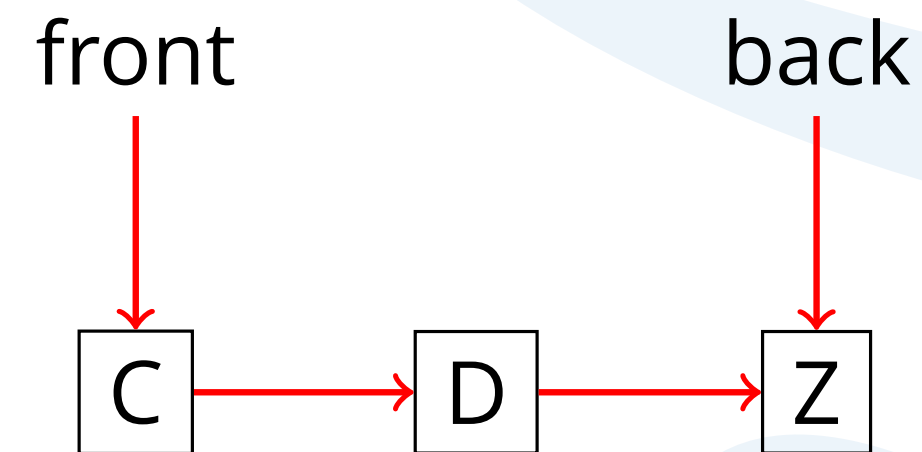
A First In Last Out (FILO) ADT.

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- New elements add to top of stack only.
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Stacks

C

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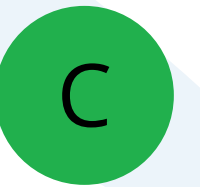
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- No cutting in.

- 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

⇑

- 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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Linked lists
  Array example
  LL example

Data structures

Abstract data types

Queues

Stacks
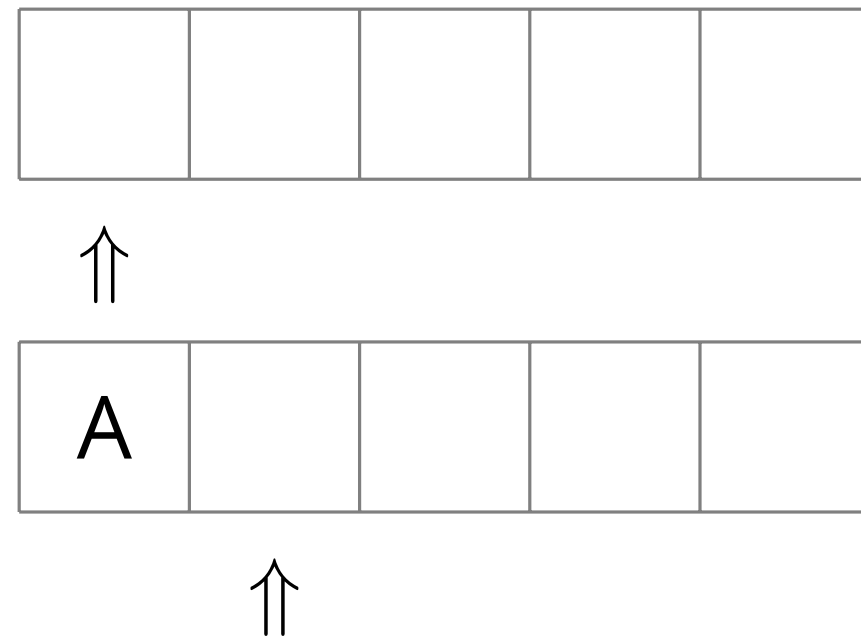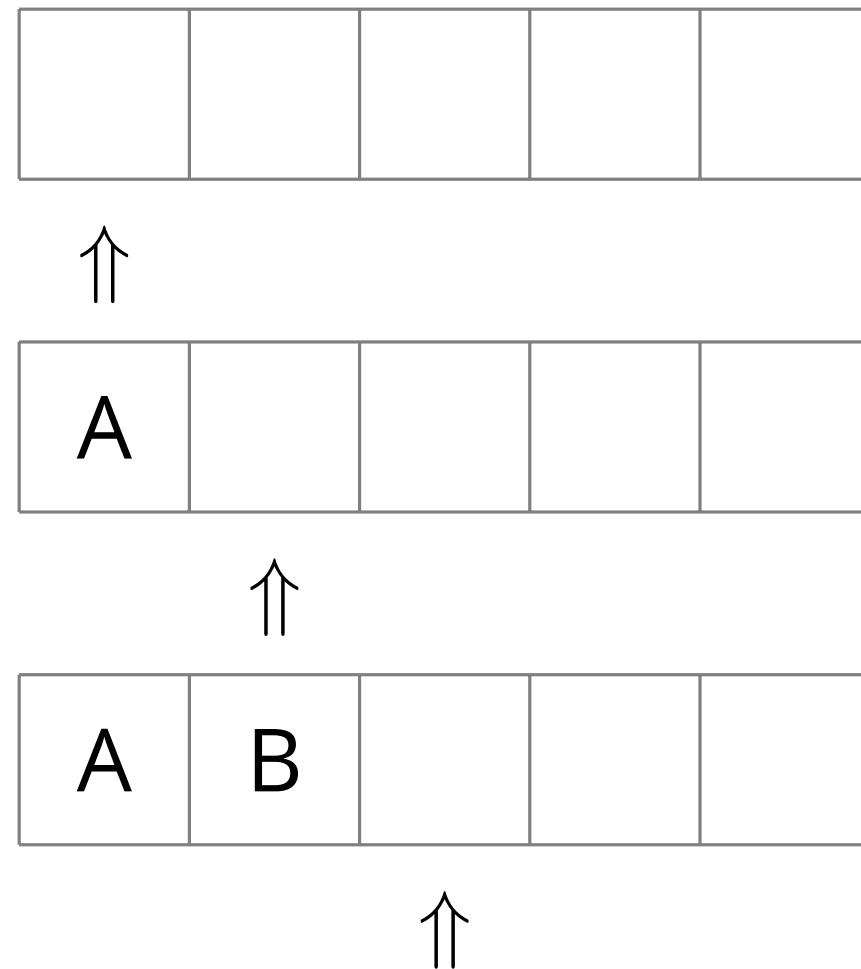
Sets

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Array as a stack.

push(A)

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Array as a stack.

⇑

| A | | | | |

push(A)

⇑

| A | B | | | |

push(B)

⇑

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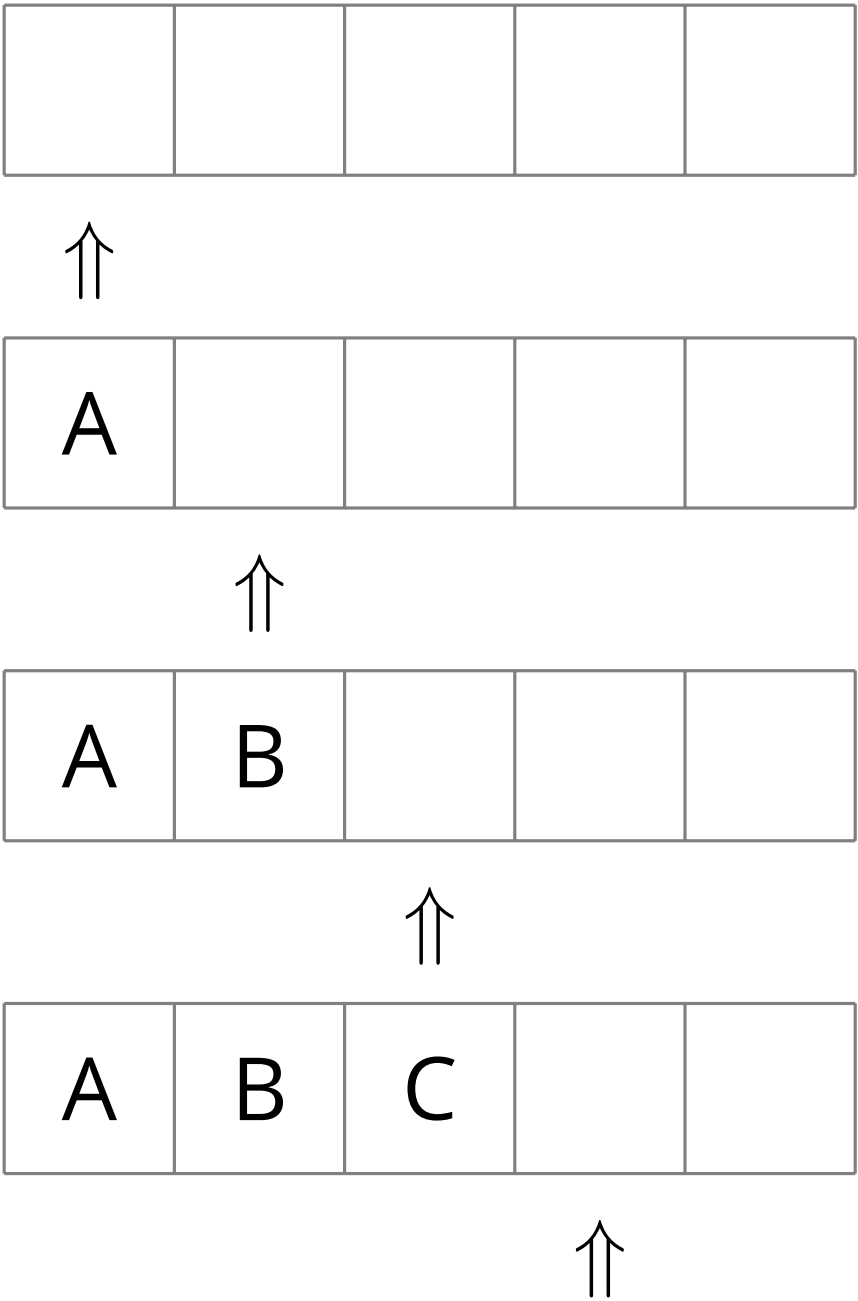
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Arrays

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)

⇑

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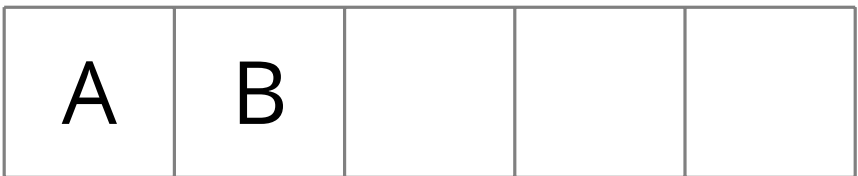 - ■ Can't hold more values than we have space for.

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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.

I

⇑

A				

push(A)

⇑

A	B			

push(B)

⇑

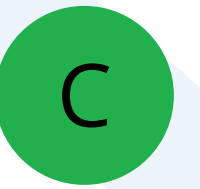| A	B	C		

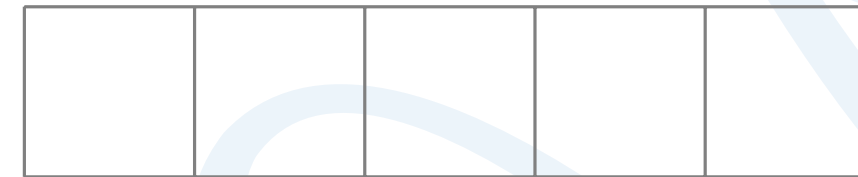push(C)

⇑

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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Arrays

Linked lists
Array example
LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

Trees

End

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.
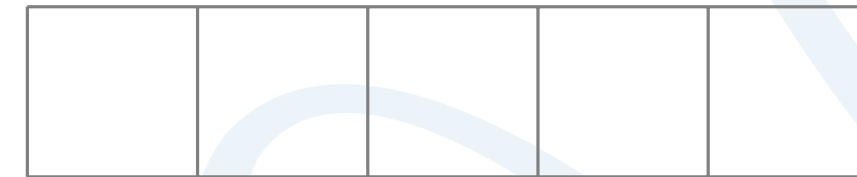 - It's unordered remember.
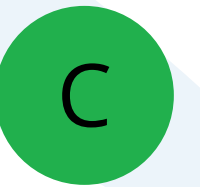
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Sets

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)

Sets

C

- An unordered ADT.
    - Items ordered by the set.
    - You have no control over it.
- Sets contain unique elements.
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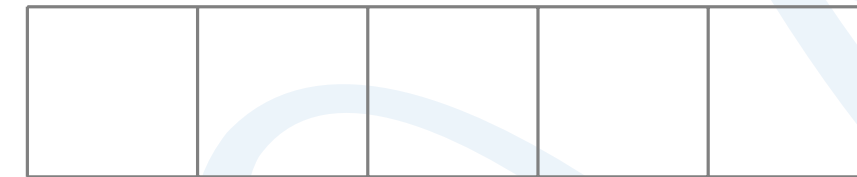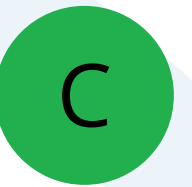   - It's unordered remember.

A				

add(A)

A	B			

add(B)

- ■ 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.
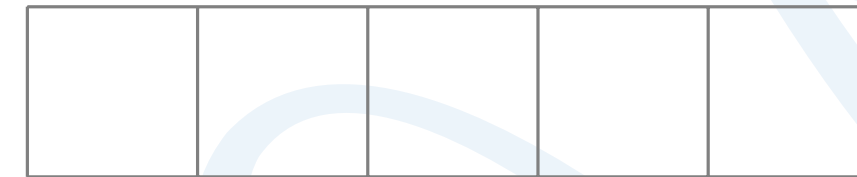- ■ Can't get the nth element.
  - ■ It's unordered remember.

A				

add(A)

A	B			

add(B)

A	B			

add(A)

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David Croft

Arrays

Linked lists
  Array example
  LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

Trees

End

Sets

- An unordered ADT.
  - Items ordered by the set.

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- Sets contain unique elements.
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- Can remove items from a set.
- Can see if an item is in a set.
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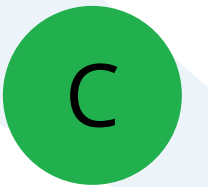 - It's unordered remember.

add(A)

add(B)

add(A)

remove(A)

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Arrays

Linked lists
   Array example
   LL example

Data structures

Abstract data types

Queues

Stacks
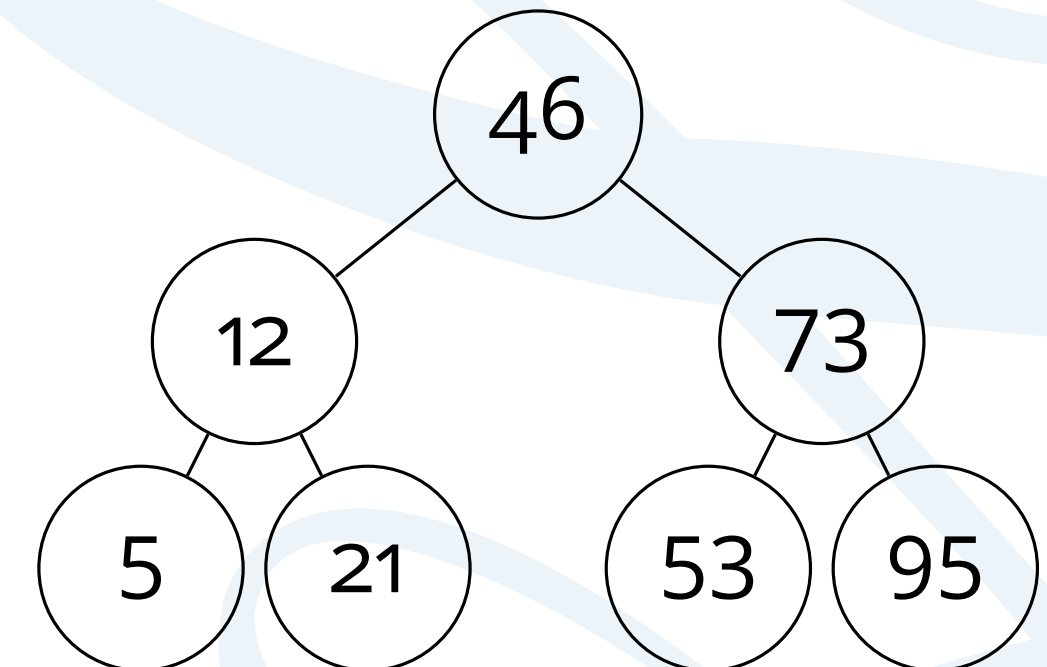
Sets

Other

Trees

End

...and the others

■ 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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Arrays

Linked lists
Array example
LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

Trees

End

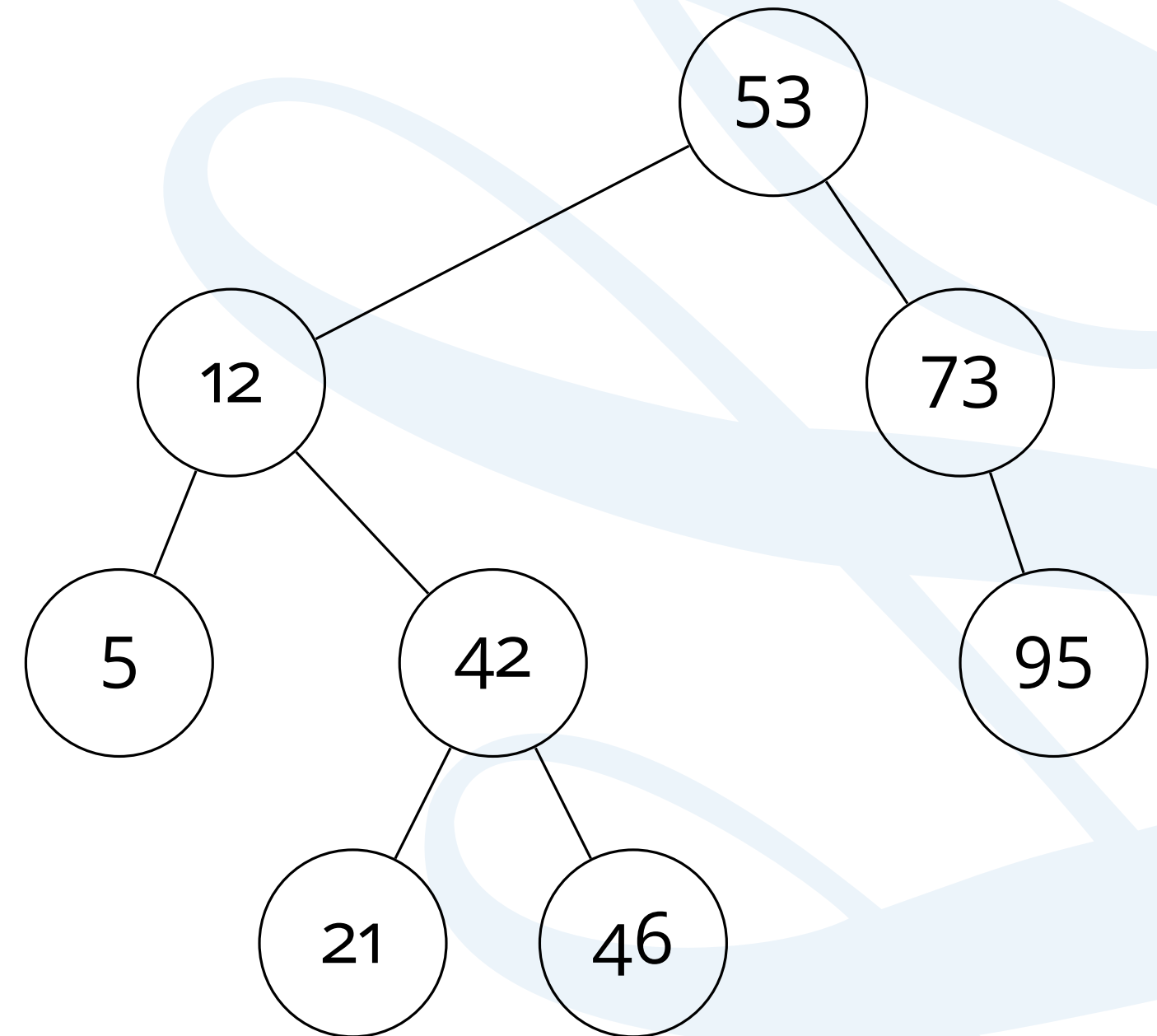Variation on linked lists.

- 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.

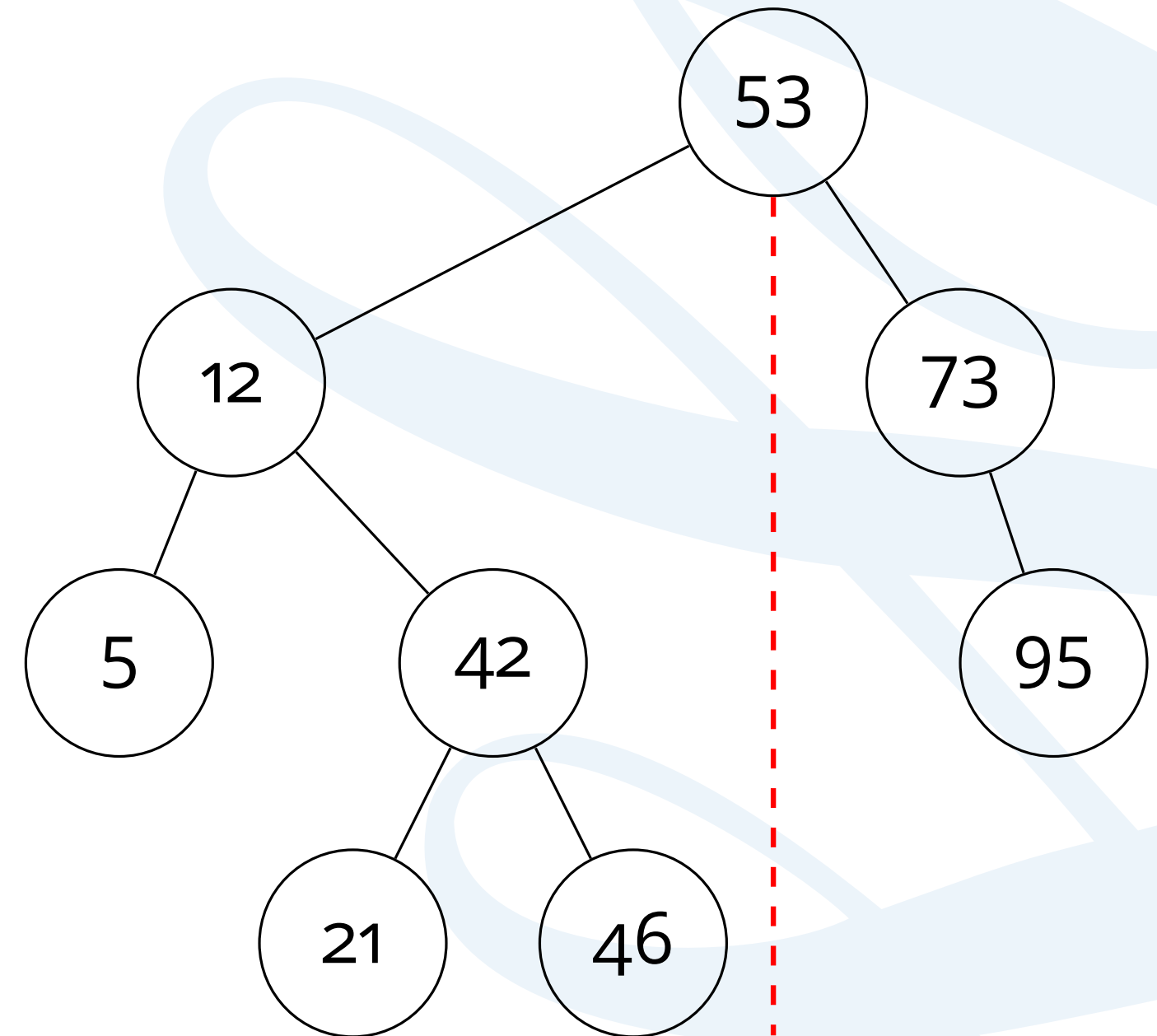**122com Data structs & types**

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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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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.
    - For the whole tree...

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Balance

A

- Trees can be balanced or unbalanced.

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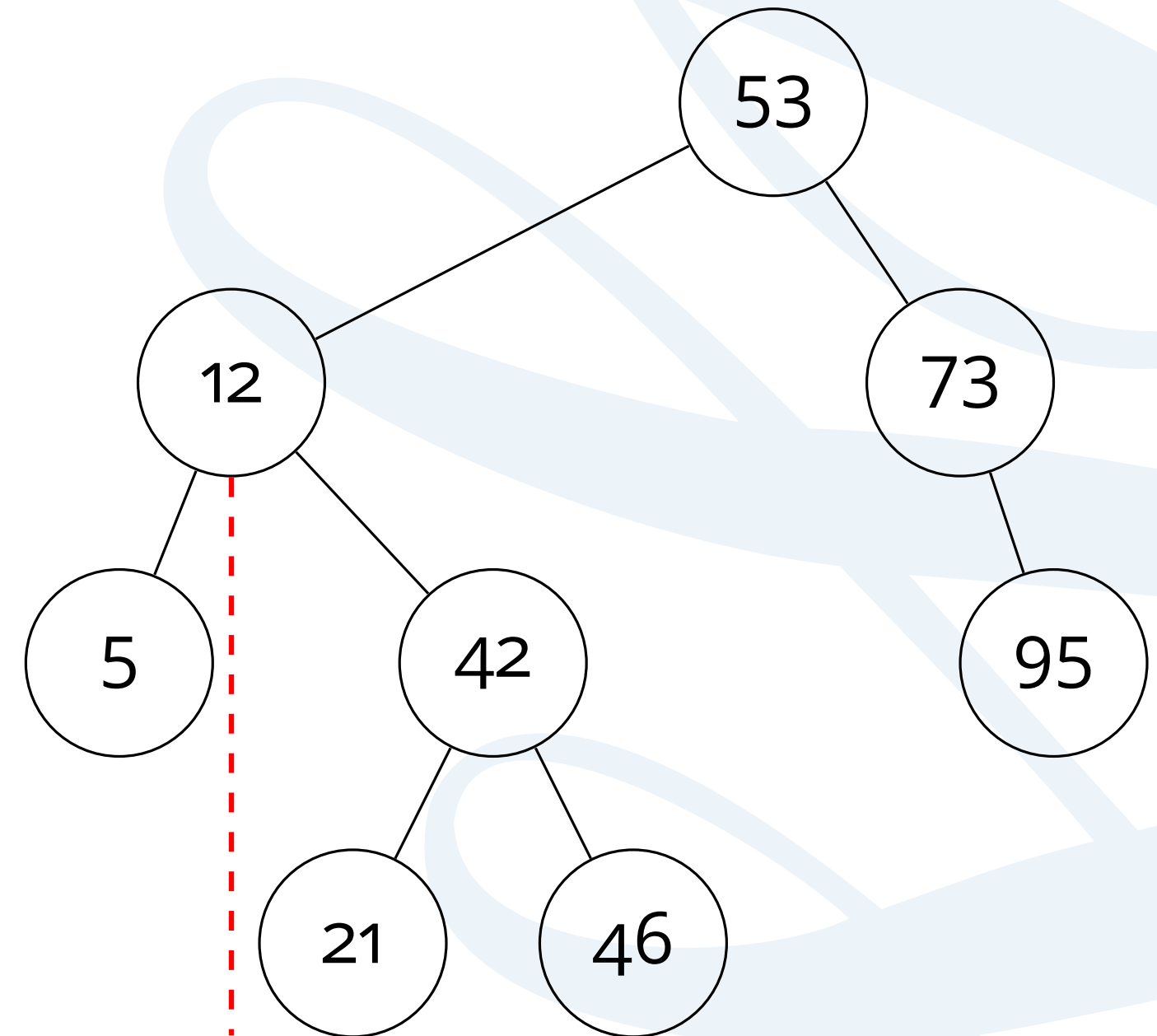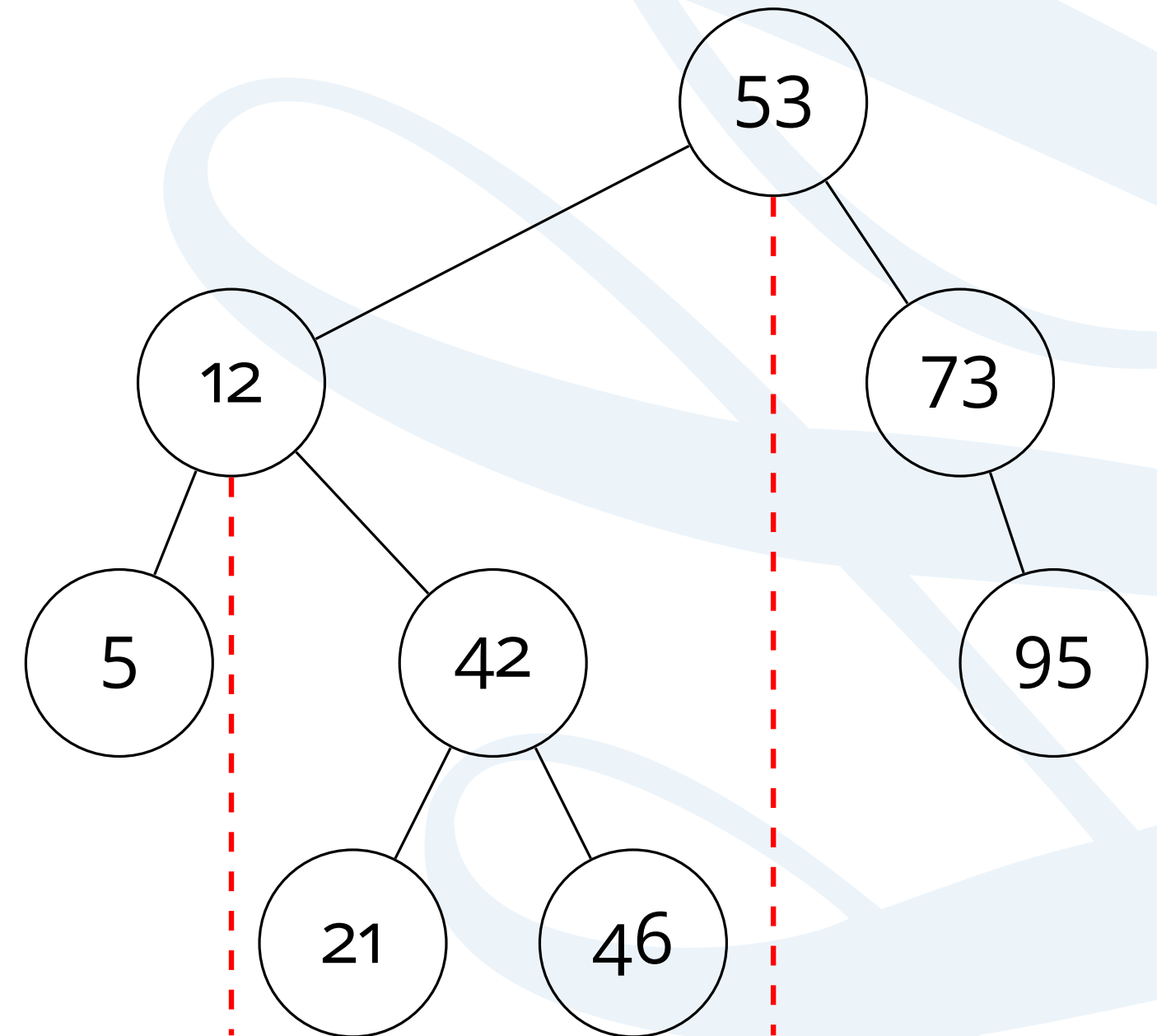 - For the whole tree…
  - …and one of the subtrees.

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- 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...
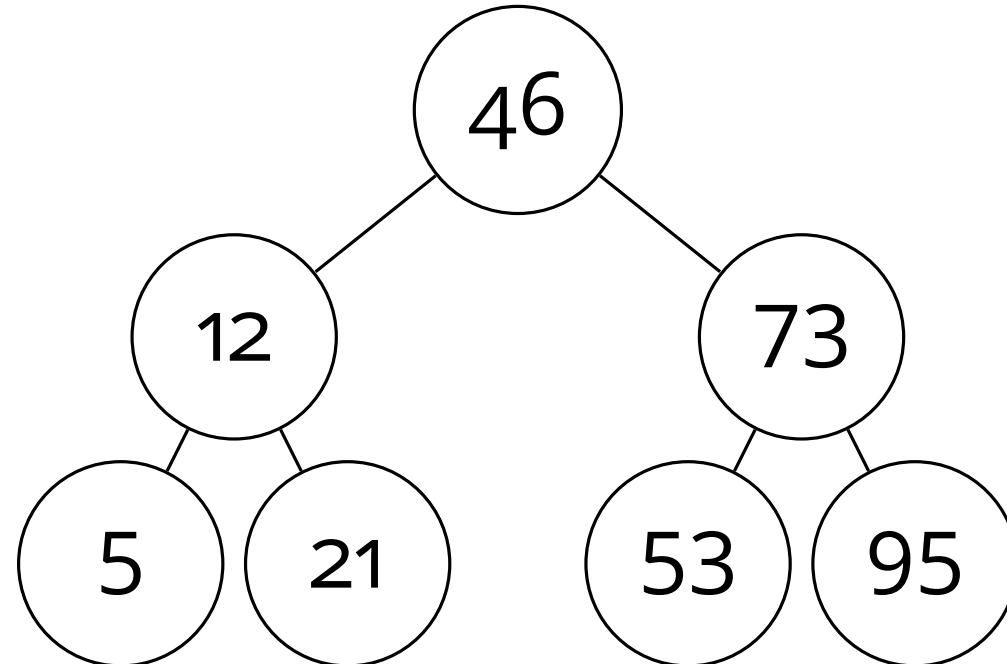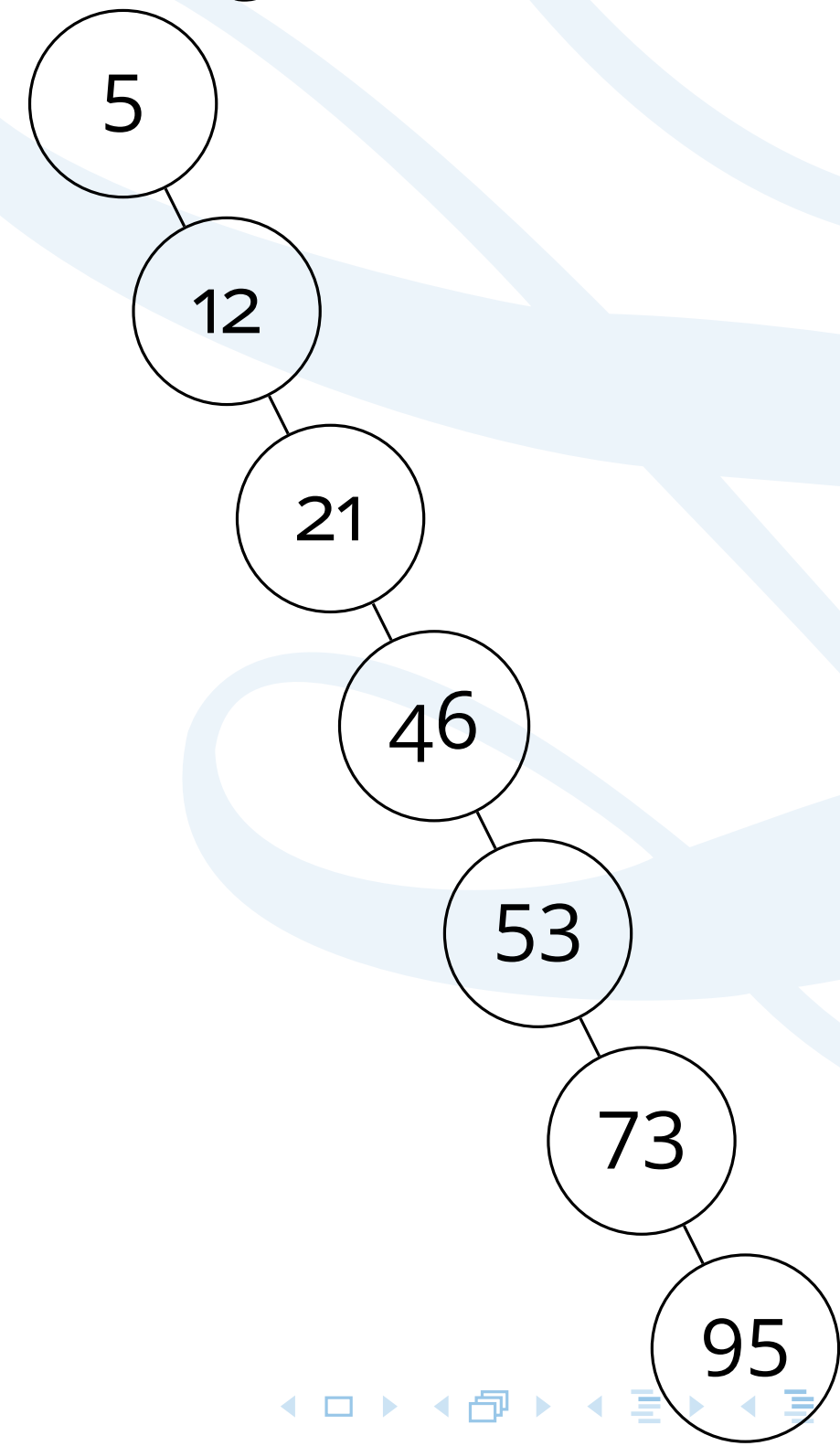
  - ...and one of the subtrees.

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Arrays

Linked lists
Array example
LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

Trees

End

A

Important that you keep your BSTs balanced.

Degenerate tree.

Perfect tree.

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Quiz

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Recap

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Arrays

Linked lists
Array example
LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

Trees

End

- 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

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