CS50-V

Data Structures

Data Structures essentially are forms of organisation in Memory.

Abstract D-S are those that we can conceptually imagine.
Learning these will make it easier later to understand how to implement more concrete D-S.

Stacks and Queues

Queues are one form of abstract data structure.

Queues have specific properties. Namely they are FIFO or "First In First Out".

They have specific actions associated with them.
- An item can be enqueued; that is the item can join the queue.
- Further, an item can be dequeued or leave the queue once it reaches the front.

Queues contrast a stack. Stacks are LIFO or "Last In First Out".

Stacks have specific actions associated with them.
- Push places something on top of a stack.
- Pop is removing something from the top.

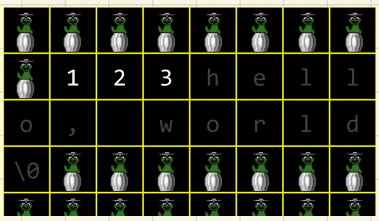
```
const int CAPACITY = 50;

typedef struct
{
    person people[CAPACITY];
    int size;
}
stack;
```

Resizing Arrays

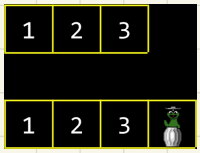
An array is a block of contiguous memory.

In memory, there are other values being stored by other programs, functions, and variables.
Many of these may be unused garbage values that were utilized at one point but are available now for use.



Imagine you wanted to store a 4th value in an array.
What would be needed is to allocate a new area of memory and move the old array to a new one.

old garbage value would be overwritten with the new data.



One of the drawbacks of this approach is that it's bad design;
Every time we add a number, we have to copy the array item by item.

C comes with a very useful function called **realloc**. It takes two arguments:
- The array you are attempting to copy.
- The size the final array should be.

```
int *tmp = realloc(list, 4 * sizeof(int));
```

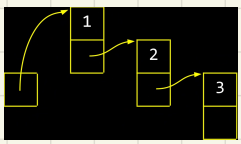
Linked Lists

A struct is a data type that you can define yourself.
A . operator in dot notation allows to access variables inside that structure.
The * operator is used to declare a pointer or dereference a variable.

→ operator: goes to an address and looks inside of a structure

A linked list is one of the most powerful data structures within C.
It allows you to include values that are located at varying ares of memory.
Further, they allow to dynamically grow and shrink the list as desired.

We could use more memory to keep track of where the next item is
By convention, we would keep one more element in memory, a pointer, that keeps track of the first item in the list



These boxes are called nodes.
A node contains both an item and a pointer.

```
typedef struct node
{
    int number;
    struct node *next;
}
node;
```

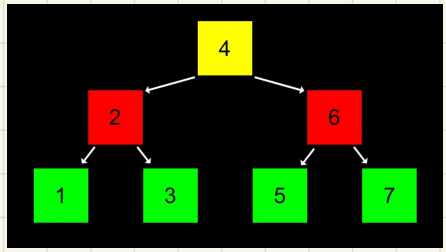
Linked List are not stored in a contiguous block of memory.
They can grow as large as wished, provided that enough system ressources exist.
The downside, however, is that more memory is required to keep track of the list instead of an array.
This is because for each element, you must store not just the value of the element, but also a pointer to the next node.
Further, Linked List cannot be indexed into like is possible in an array because we need to pass through the first n-1 elements to find the location of the n^{th} element.
Because of this, Linke List must be linearly searche. Binary search, therefore, is not possible.

Considering the amount of time required to search this list, it is in the orde of O (n), as in the worst case the entire list must be always be searched to find an item.
The time complexity for adding a new element to the list will depend on where that element is added.
- O (n), if adding to the end of the list.
- O (1), if adding at the start of the list.

Trees

Binary Search trees are another data structure that can be used to store data more efficiently such that it can be searched and retrieved.

You can imagine a sorted sequence of numbers.



Imagine then that the center value becomes the top of a tree.
Those that are less than this value are placed to the left.
Those values that are more than this value are to the right.

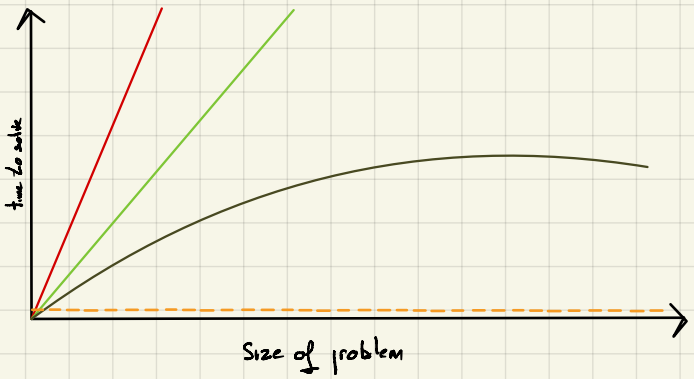
Pointers can then be used to point to the correct locations of each area of memory such that each of these nodes can be connected.

A tree offers dynamism that an array does not.
It can grow and shrink as we wish.

Dictionaries

Dictionaries are another data structure.
Dictionaries have a key and a value.

The holy grail of time complexity is O(1) or constant time.



Dictionaries can offer this speed of access.

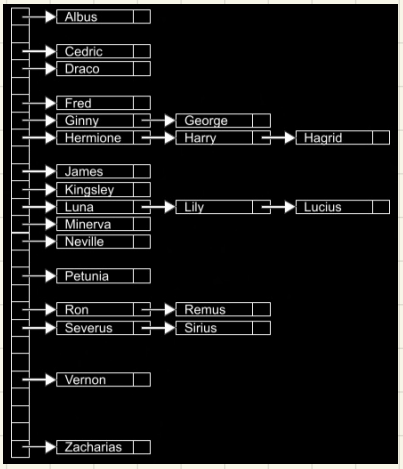
Hashing and Hash Tables

Hashing is the idea of taking a value and being able to output a value that becomes a shortcut to it later.

For example, hashing apple may hash as a value of 1, and berry may be hashed as 2.
Therefore finding apple is as easy as asking the hash algorithm where apple is stored.
While no ideal in term of design, ultimately, putting all a's in one bucket and b's in another,
this concept of bucketizing hashed values illustrates how you can use this concept:
a hashed value can be used to shortcut finding such a value.

A hash function is an algorithm that reduces a larger value to something small and predictable.
Generally, this function takes in an item you wish to add to your hash table, and returns an integer
representing the array index in which the item should be placed.

A hash table is a fantastic combination of both array and linked lists.
When implemented in code, a hash table is an array of pointers to nodes.



Collisions are when you add values to the hash table, and
something already exists at the hashed location.
Collisions can simply be appended to the end of the list.

Collisions can be reduce by better programming your hash
table and hash algorithm.

The programmer has to make a decision about the advantages of using more memory
to have a large hash table and potentially reducing search time or using less memory and
potentially increasing search time.

Tries

Tries are another form of data structure.

Tries are always searchable in constant time.

One downside to Tries is that they tend to take up a large amount of memory.