An Introduction to Data Structures

Measuring Efficiency with BigO Notation

Measuring Efficiency with BigO Notation - Introduction

- We want a quantifiable way to measure how efficient certain data structures are at different tasks we might ask of it
  - Searching through
  - Modifying
  - Accessing

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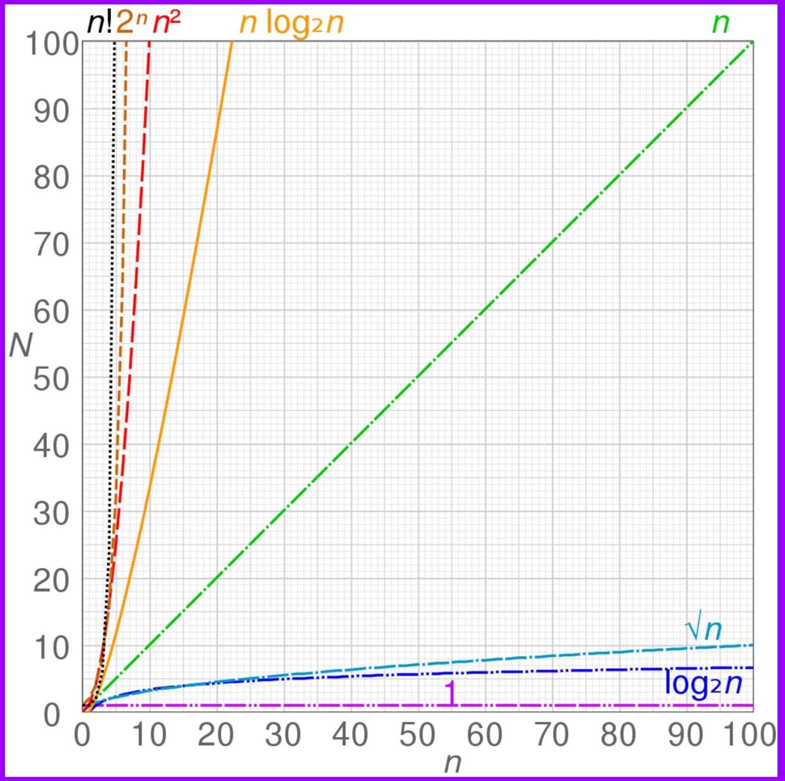
Measuring Efficiency with BigO Notation - Introduction

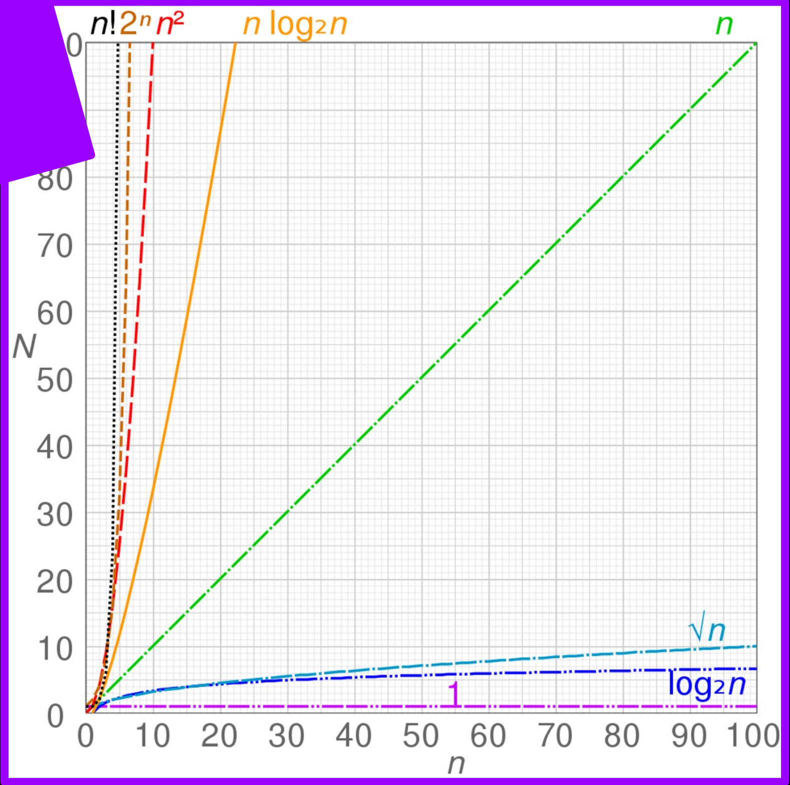
- The **industry standard** for this kind of measurement
  - BigO Notation



Measuring Efficiency with BigO Notation - Introduction

WHAT IS IT?

- y **standard** for is kind of measurement
    - ○ BigO Notation



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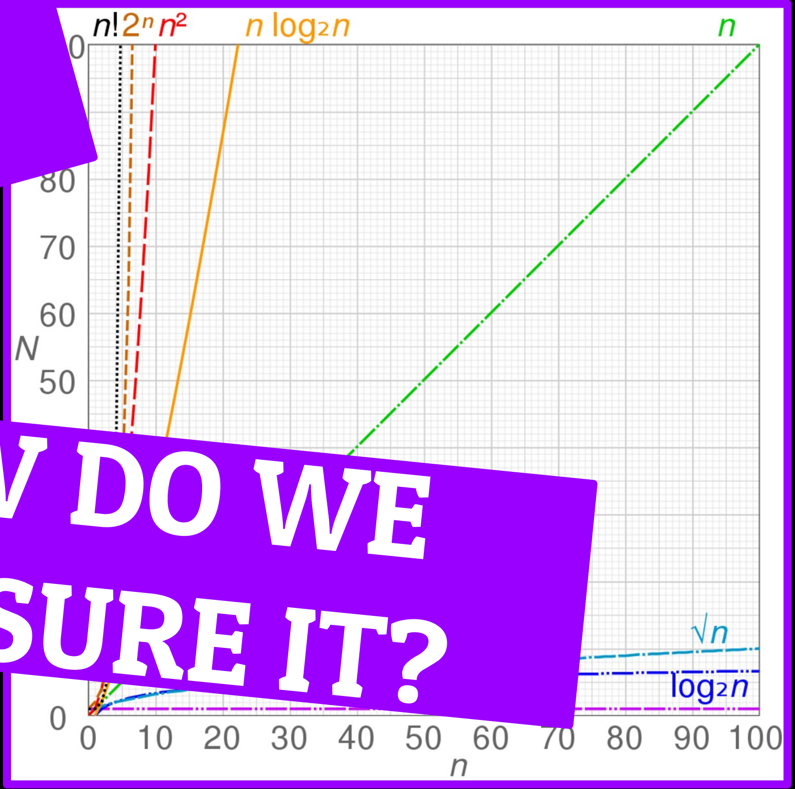
HOW DO WE MEASURE IT?



Measuring Efficiency with BigO Notation - Introduction

- **BigO Notation**
  - A way to basically "**Score**" a data structure based on **4 criteria**
  - The most **common functions** you might want from a data structure
    - Accessing elements
    - Searching for an element
    - Inserting an element
    - Deleting an element

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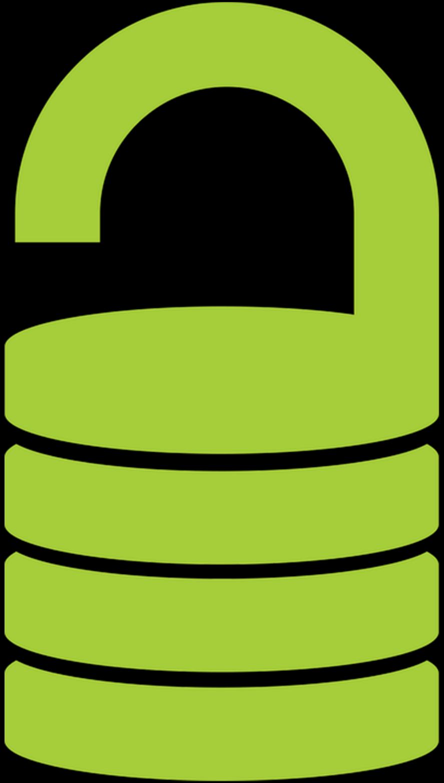

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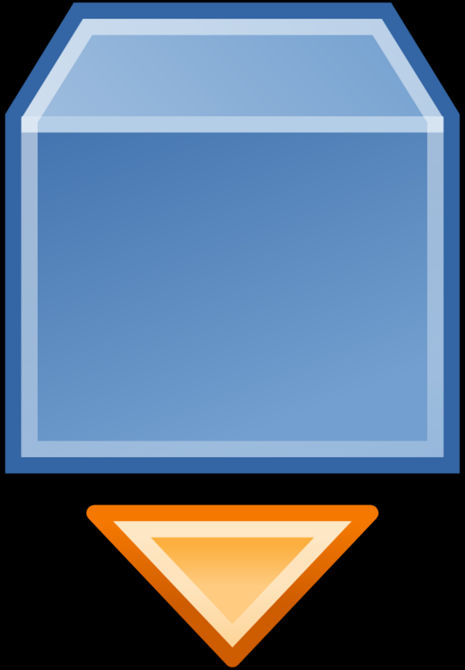

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- By measuring how efficiently a data structure can do these 4 things
    - We can create a “report card”

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Accessing

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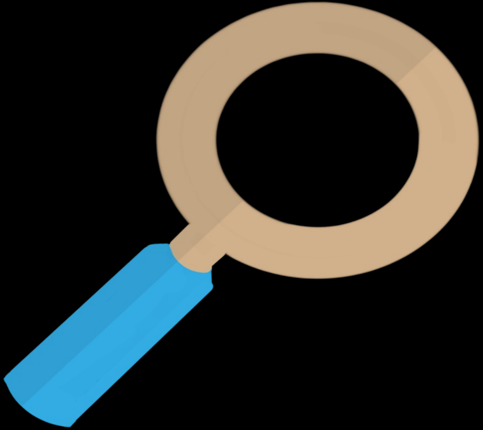

Searching

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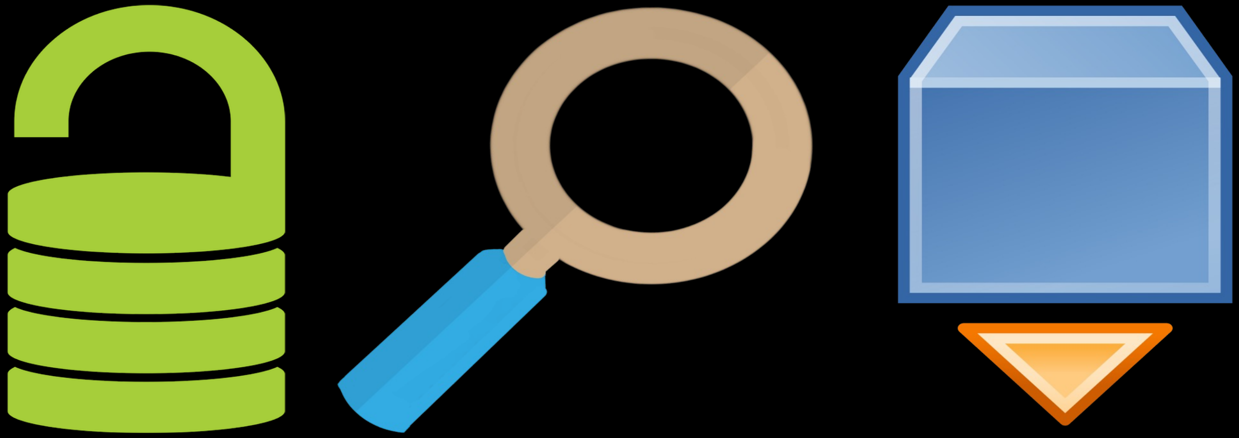

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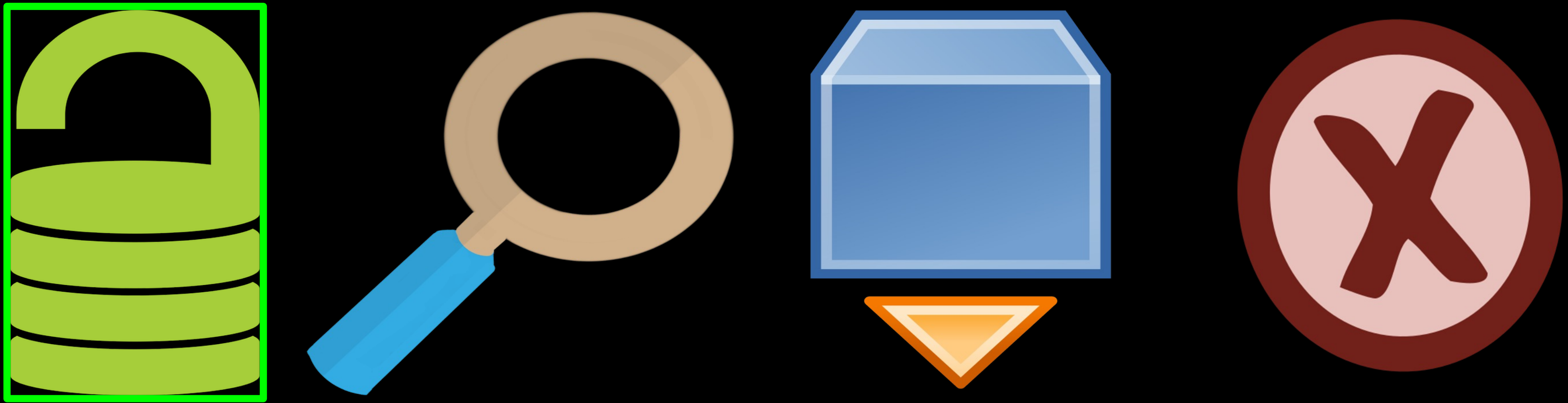

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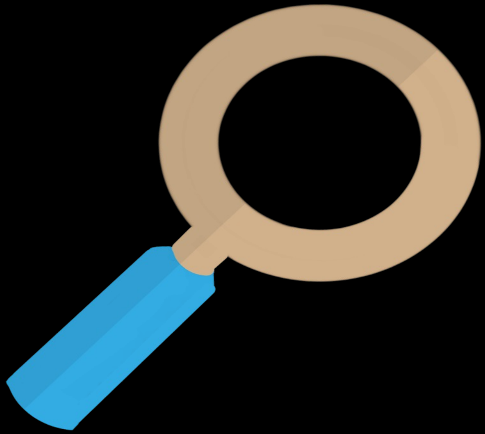

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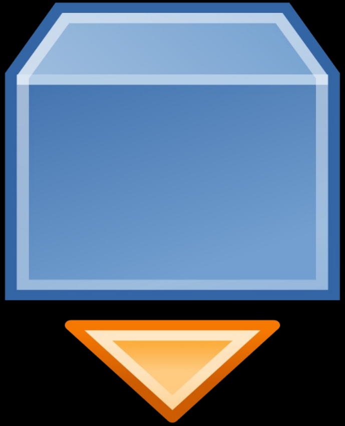

Inserting

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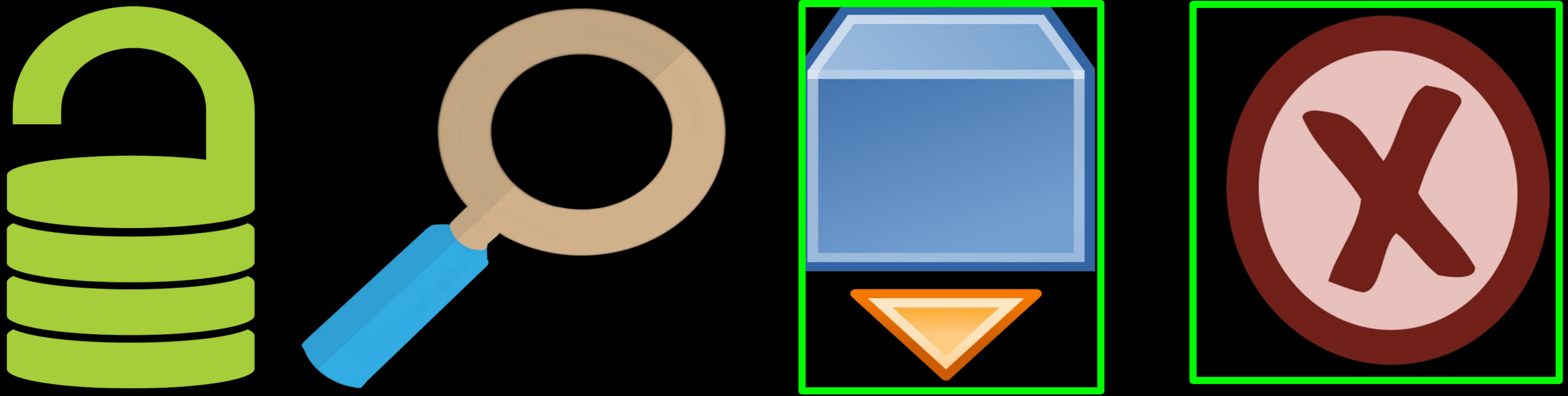

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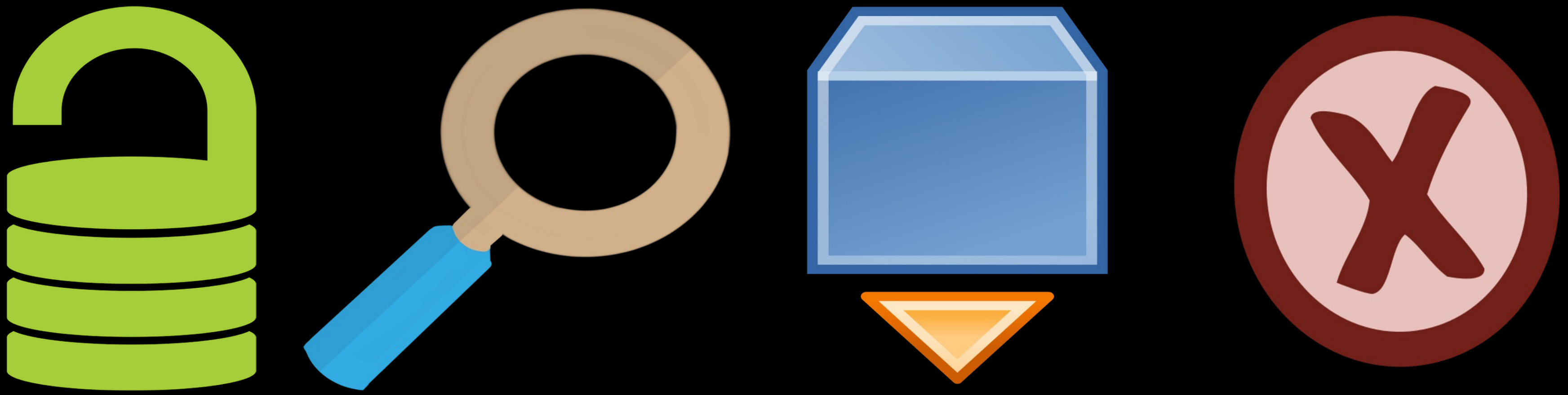

Accessing **Searching** **Inserting** **Deleting**

Measuring Efficiency with BigO Notation - Time Complexity Equations

- A Time Complexity Equation works by inserting the size of the data-set as an integer n, and returning the number of operations that need to be conducted by the computer before the function can finish

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N = The Size of the Data Set (Amount of elements contained within the Data Structure)

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N = 10

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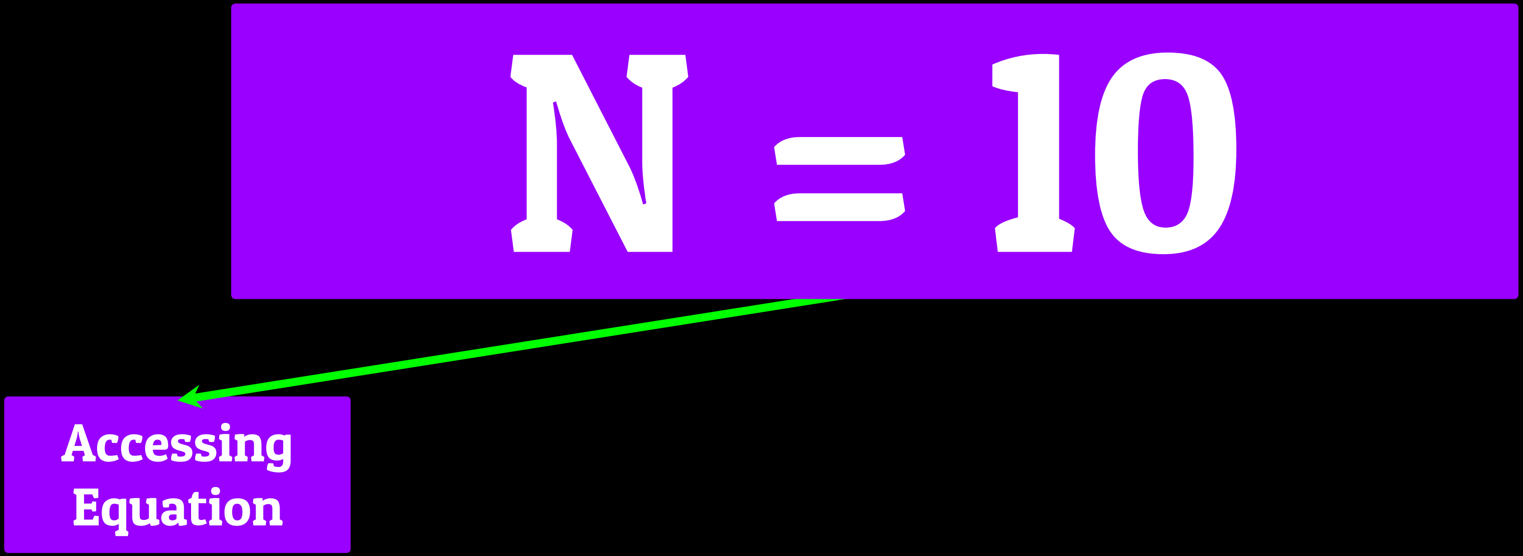

N = 10

Accessing Equation

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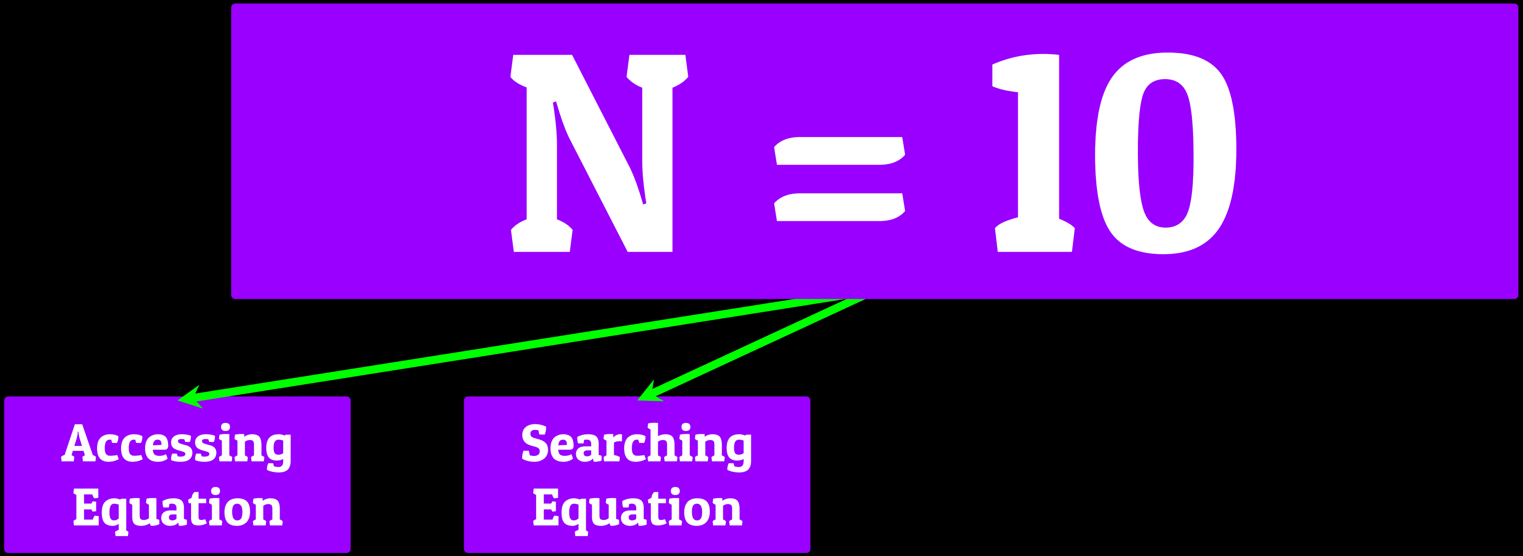

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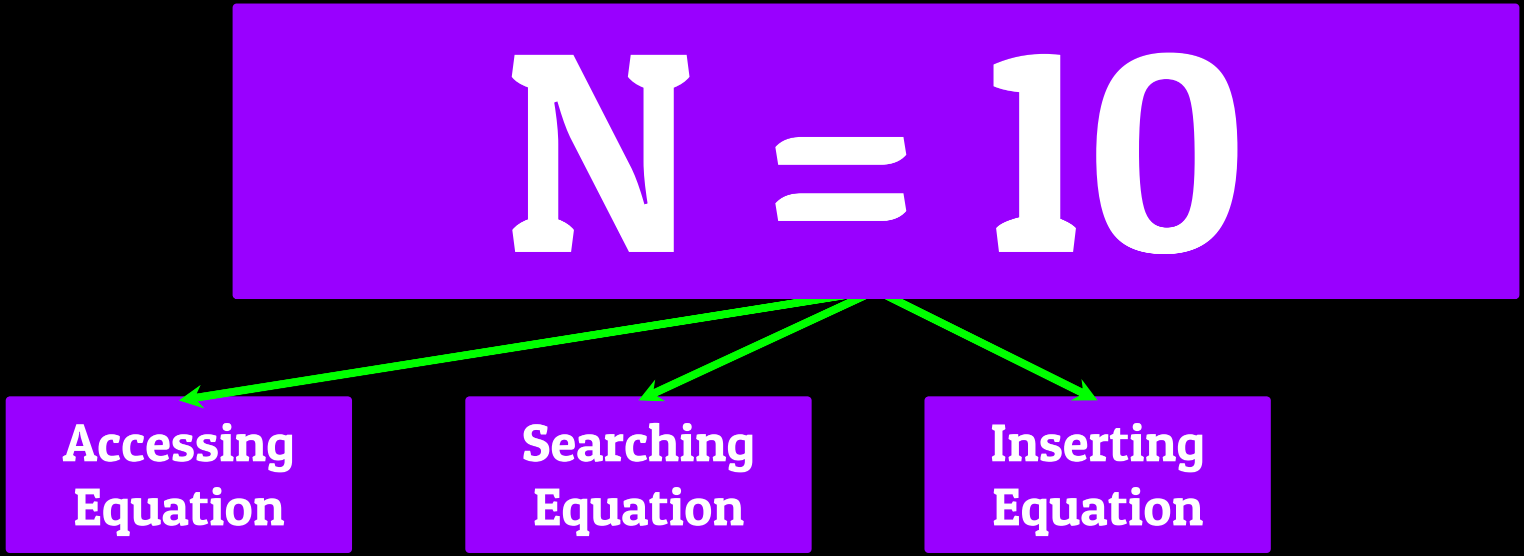

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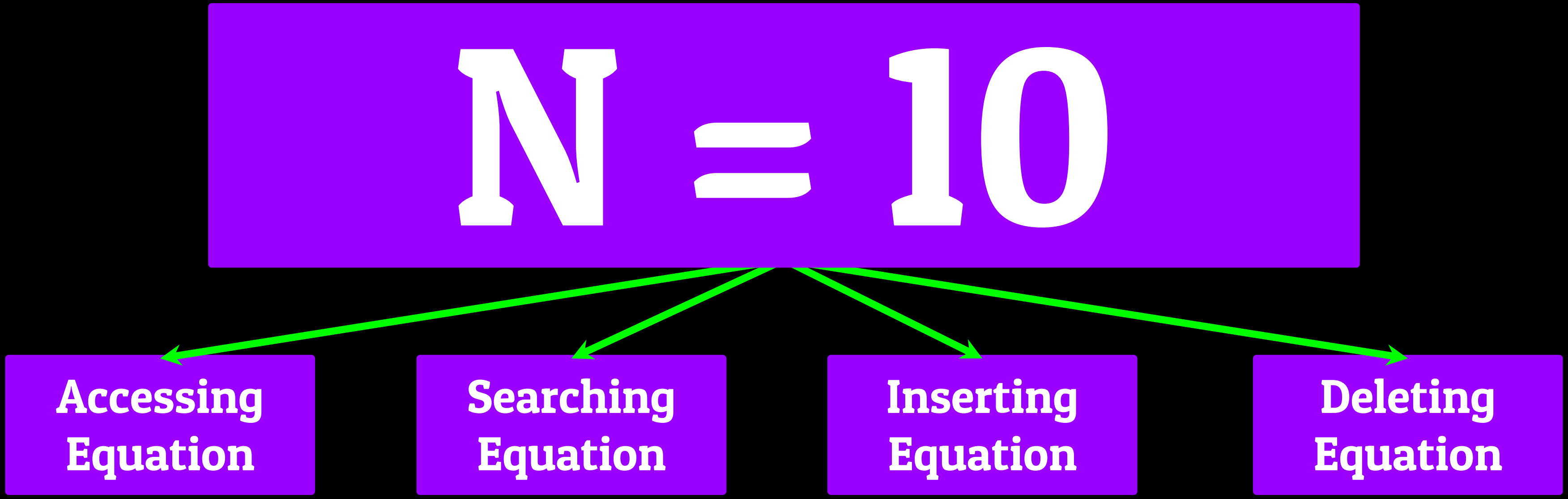

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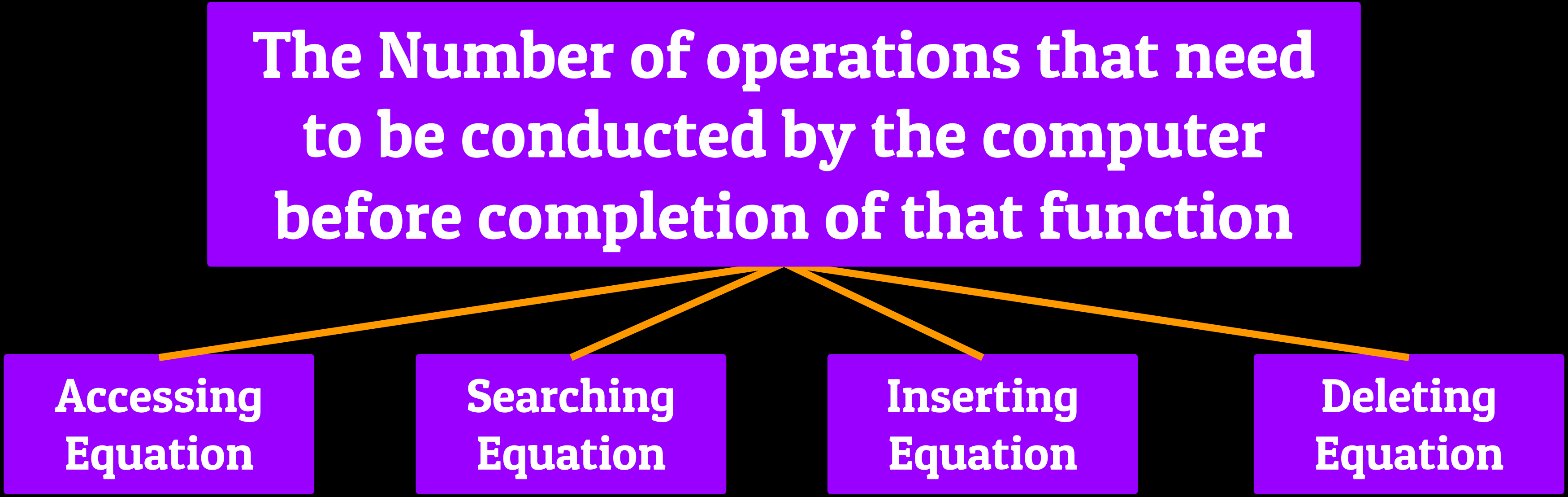

The Number of operations that need to be conducted by the computer before completion of that function

Accessing Equation

Searching Equation

Inserting Equation

Deleting Equation

Measuring Efficiency with BigO Notation - Time Complexity Equations

- We always use the **worst-case scenario** when judging these data structures

8 Operations

2 Operations

50 Operations

42 Operations

1898 Operations

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Measuring Efficiency with BigO Notation - The Meaning of BigO

- It's called BigO notation because the syntax for the Time Complexity equations includes a BigO and then a set of parentheses
    - The parenthesis houses the function

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A Function

Random Function()

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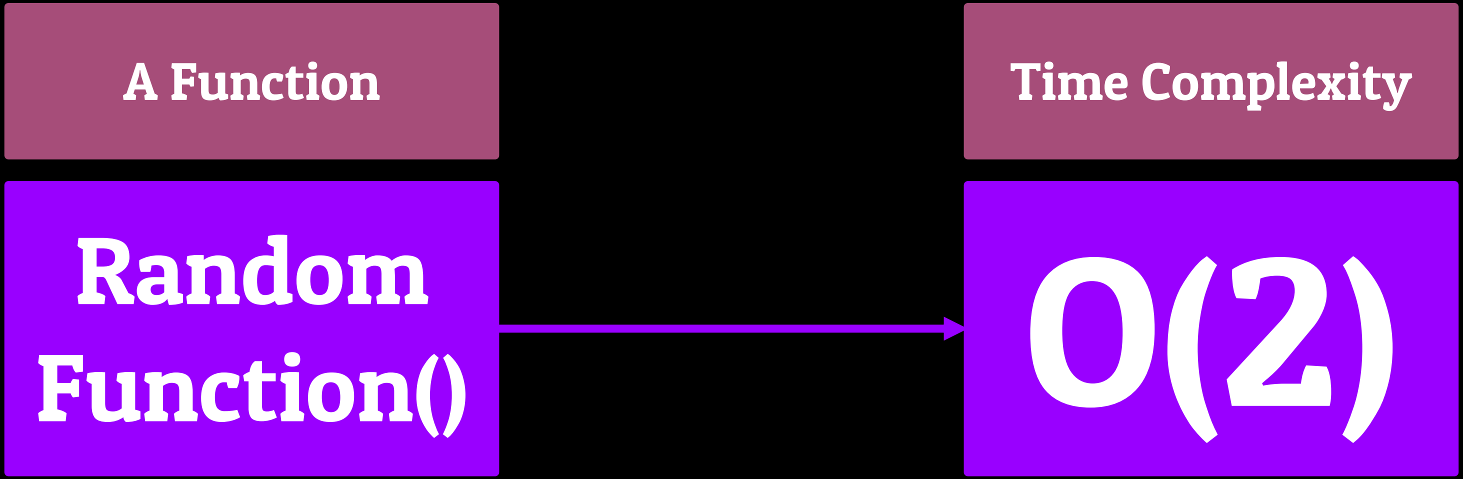

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Time Complexity

O(2)

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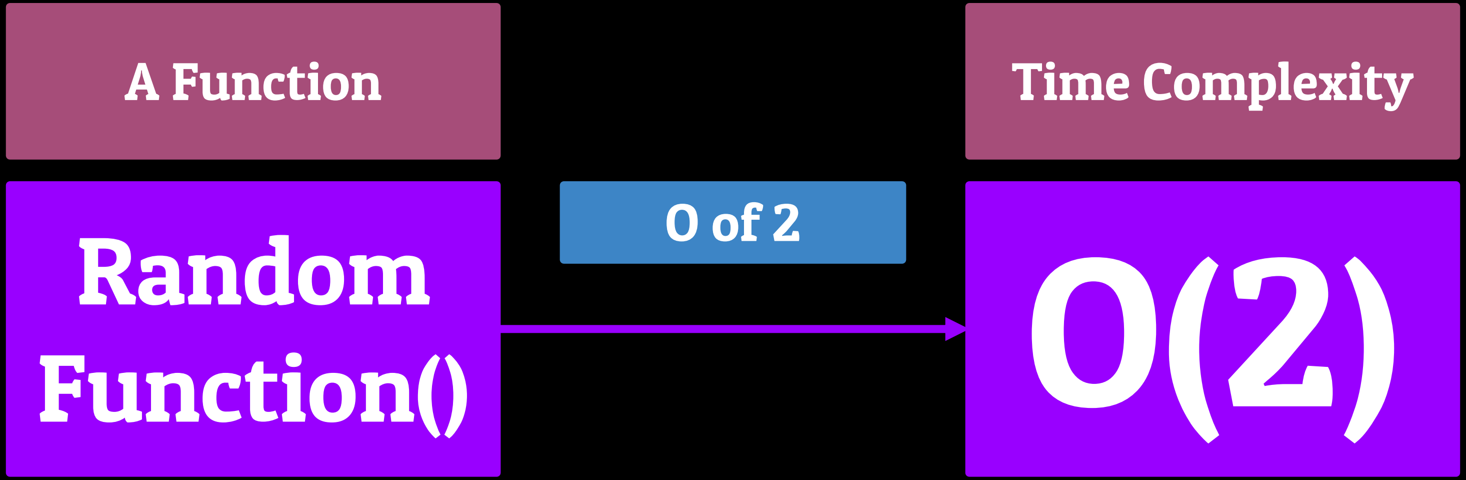

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Time Complexity

Random Function()

O of 2

O(2)

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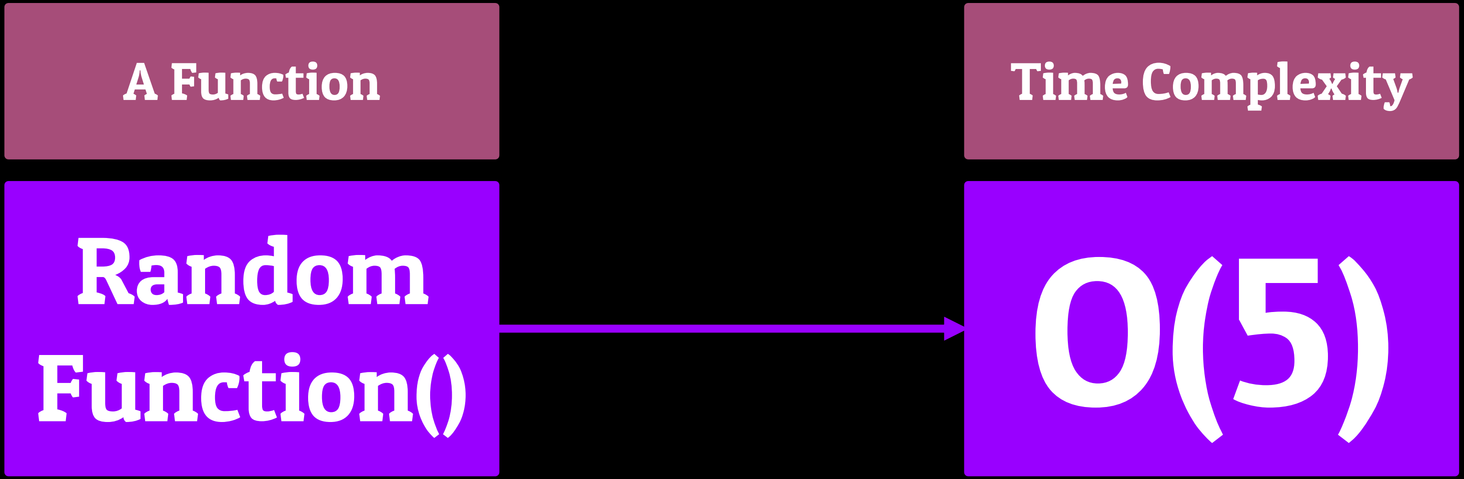

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Time Complexity

O(5)

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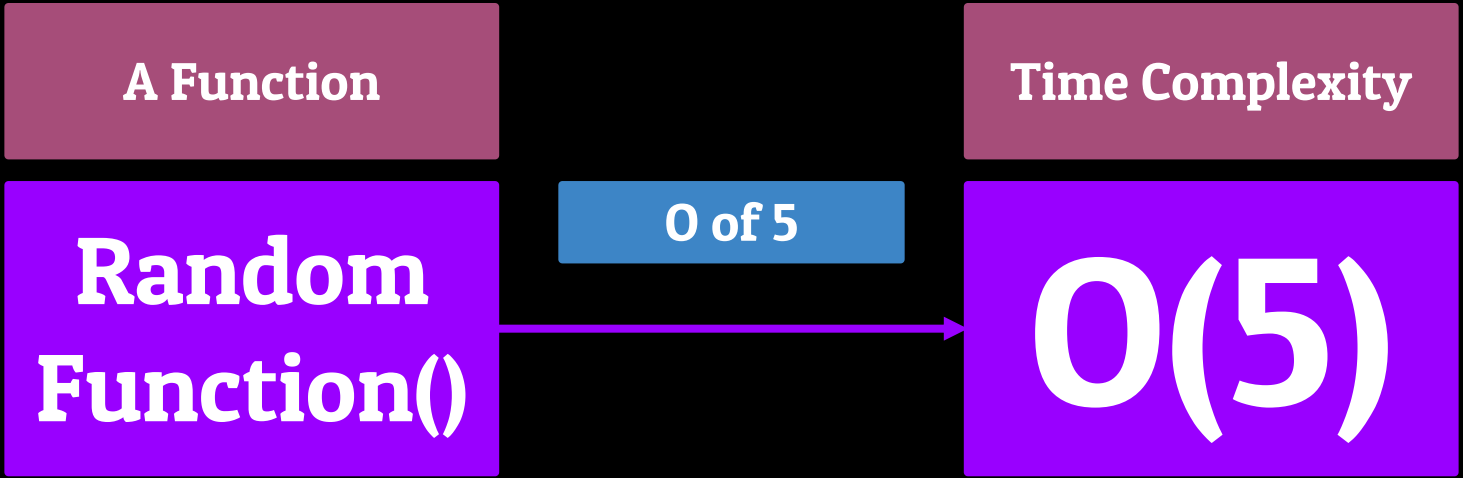

A Function

Time Complexity

Random Function()

O of 5

O(5)

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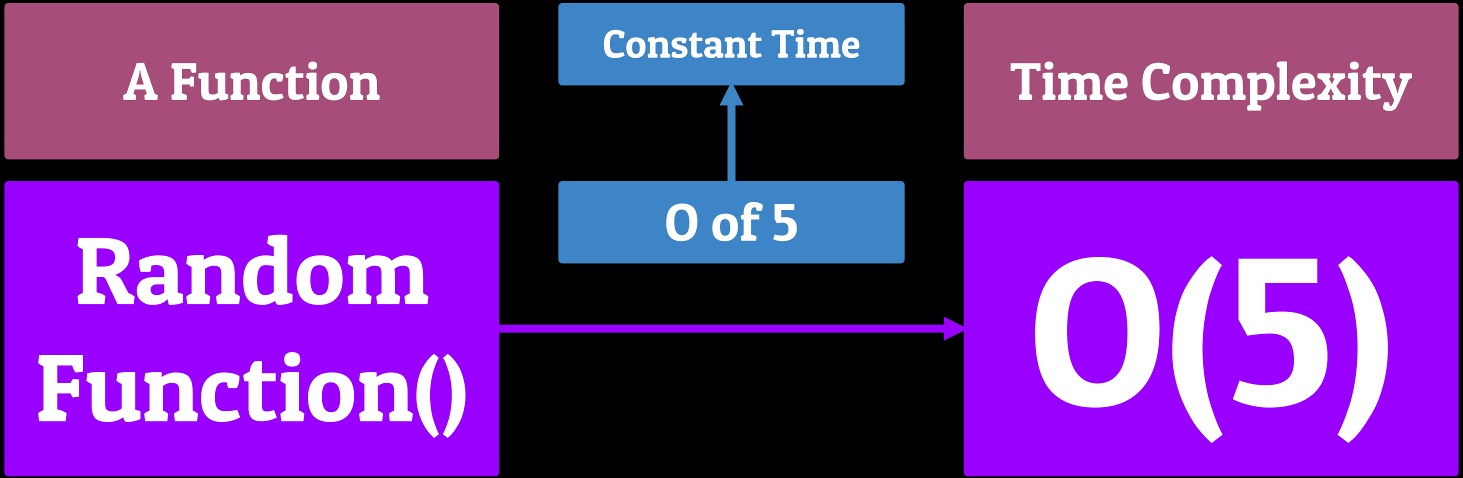

A Function

Constant Time

Time Complexity

Random Function()

O of 5

O(5)

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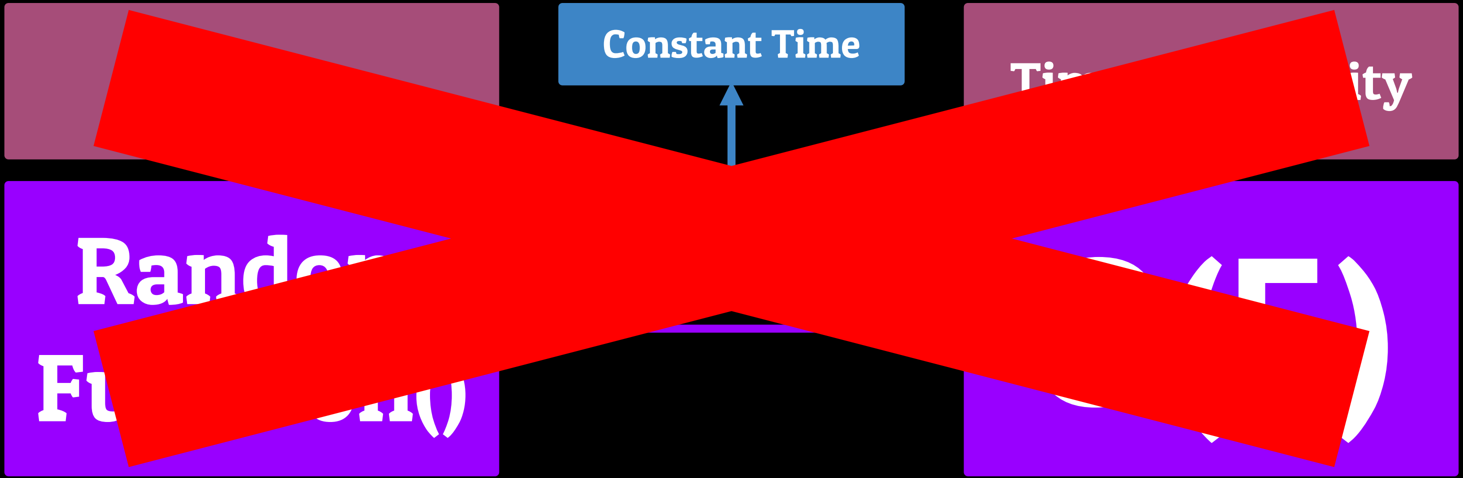

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Most of the time, our integer n, is going to have some adverse-effect on how many operations it takes

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Larger Data Set

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Larger Data Set

More Instructions

Measuring Efficiency with BigO Notation - Why BigO?

- We measure efficiency in # of operations performed because measuring by how long the function takes to run would be silly
    - Measuring by time is biased towards better hardware

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Speed

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=

Operations

Measuring Efficiency with BigO Notation - Quick Recap

We measure efficiency based on 4 metrics

Measuring Efficiency with BigO Notation - Quick Recap

We measure efficiency based on 4 metrics

Accessing

Measuring Efficiency with BigO Notation - Quick Recap

We measure efficiency based on 4 metrics

Accessing

Searching

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We measure efficiency based on 4 metrics

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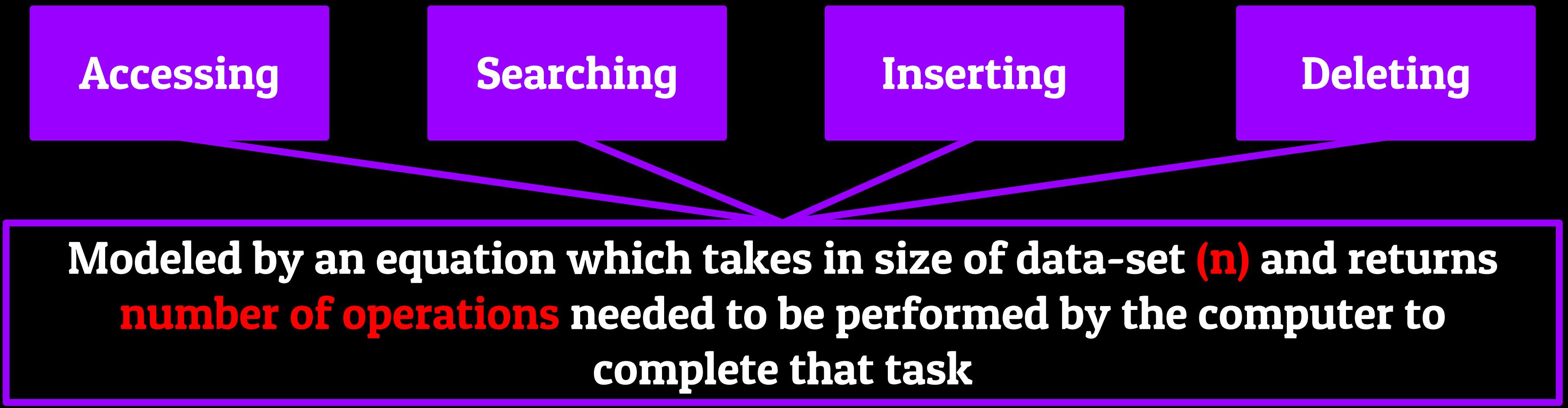

Accessing

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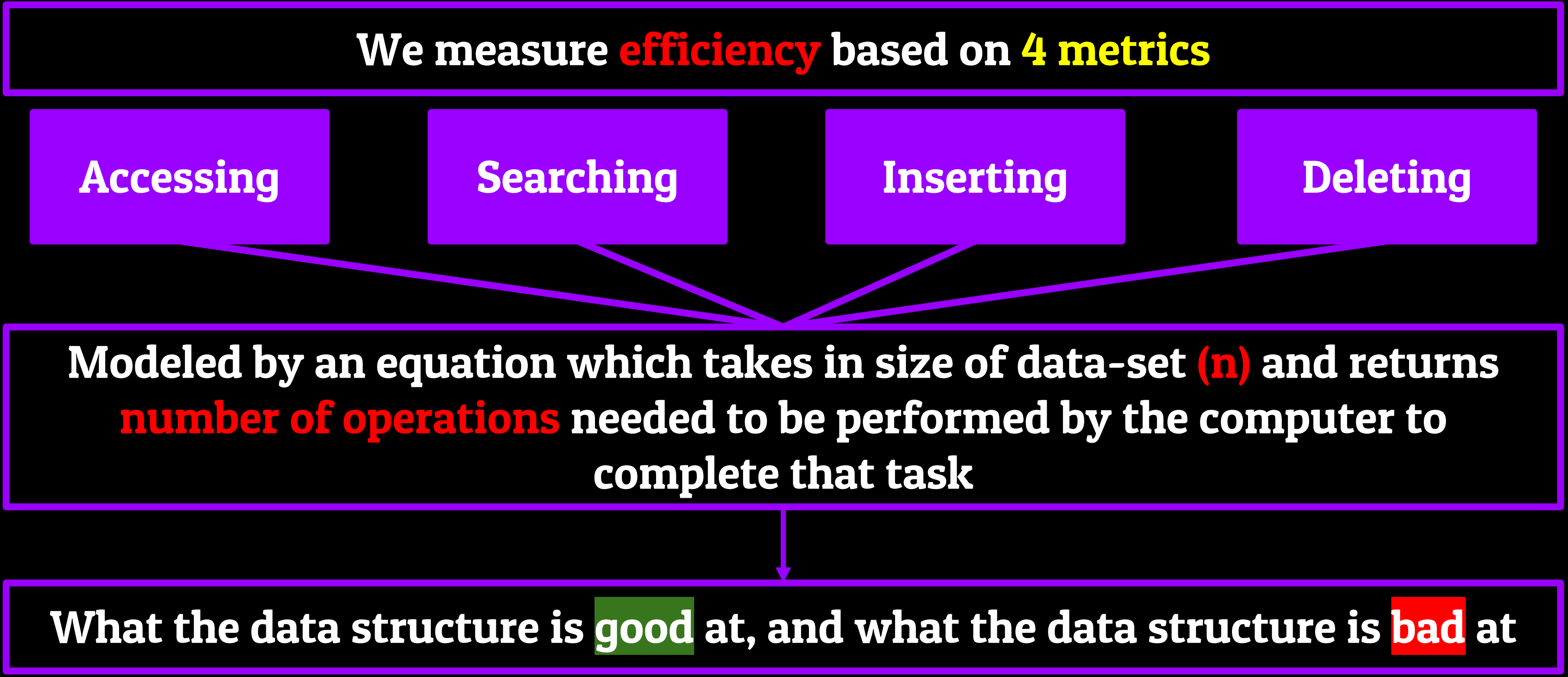
Modeled by an equation which takes in size of data-set (n) and returns number of operations needed to be performed by the computer to complete that task

Measuring Efficiency with BigO Notation - Quick Recap



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Modeled by an equation which takes in size of data-set (n) and returns number of operations needed to be performed by the computer to complete that task

What the data structure is good at, and what the data structure is bad at

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- A Data Structures efficiency isn’t the end all be all for deciding on which data structure to use in your program
  - Some have specific quarks or features which separate them

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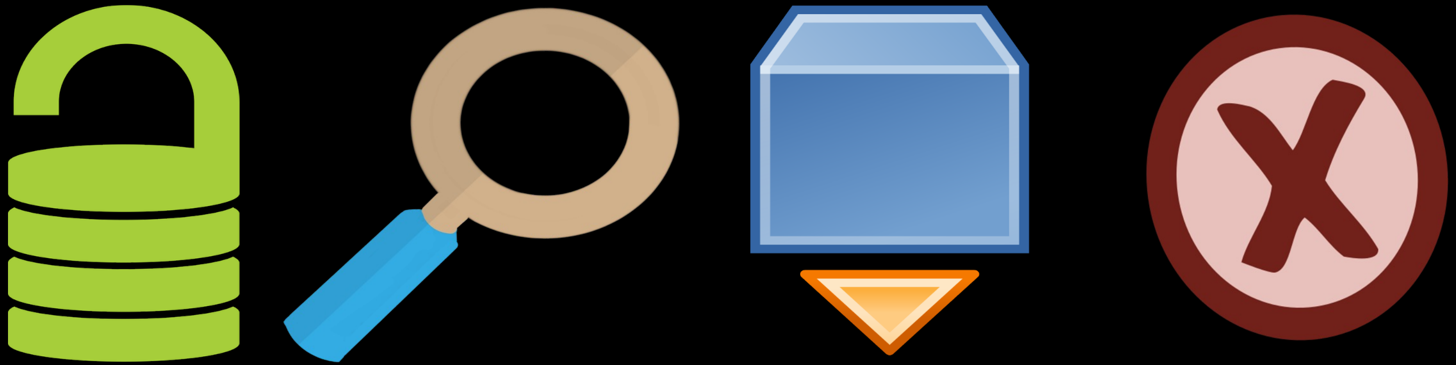

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Should not be the ONLY metric used

Measuring Efficiency with BigO Notation - Types of Time Complexity Equations

- Let’s dive straight into what the actual equations mean in terms of efficiency
  - 6 most common Time Complexity Equations

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O(1)

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O(1)

O(n)

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O(1)

O(n)

O(log n)

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O(n log n)

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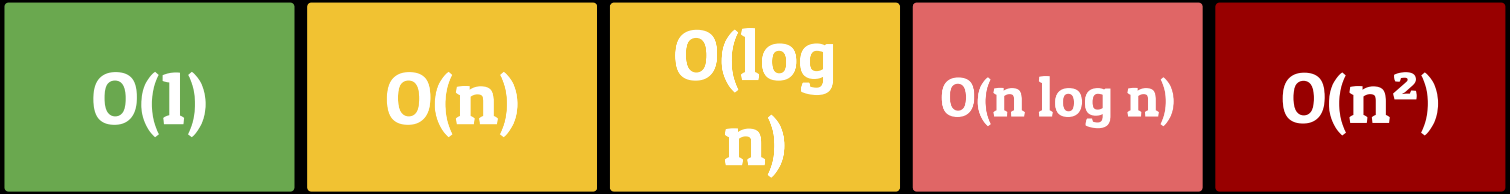

$O(1)$

$O(n)$

$O(\log n)$

$O(n \log n)$

$O(n^2)$

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$O(1)$ | $O(n)$ | $O(\log n)$ | $O(n \log n)$ | $O(n^2)$ | $O(2^n)$

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    - No matter what the size of your data set is, the task will be completed in a single instruction

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Size of Data Set (N)

1

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Operations Required	Size of Data Set (N)
1	1

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Operations Required	Size of Data Set (N)
1	100

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Operations Required	Size of Data Set (N)
1	1,000,000

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Operations Required	Size of Data Set (N)
1	800 Quadrillion

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When we graph Volume of Data vs # Of Instructions Required

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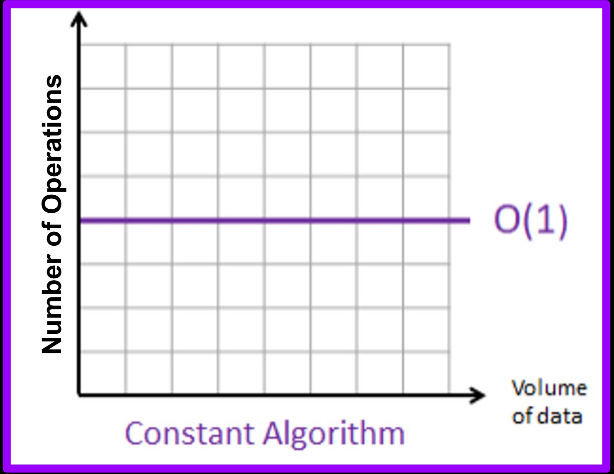

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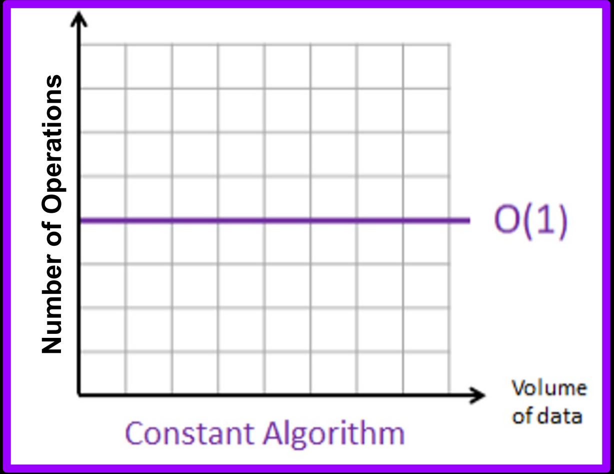
# Of Operations remains constant



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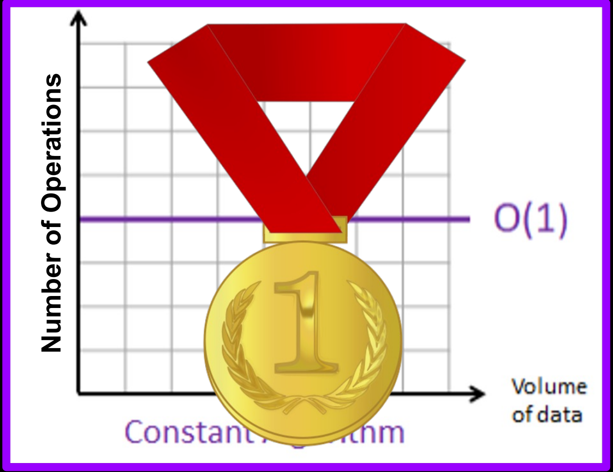
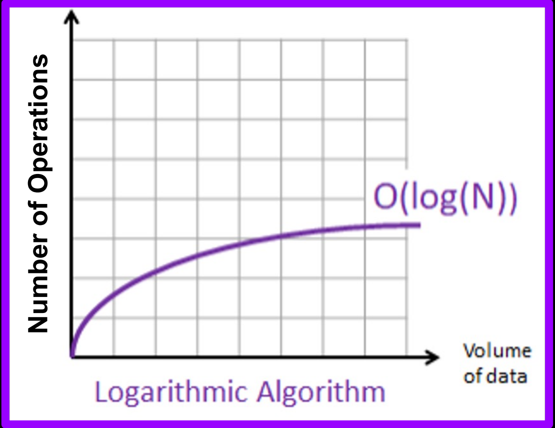
When we graph Volume of Data vs # Of Instructions Required

# Of Operations remains constant



Measuring Efficiency with BigO Notation - Types of Time Complexity Equations

- The next fastest type of time complexity equation os O(log n)
  - Still provides fast completion time
  - Gets more efficient as the size of the data set increases



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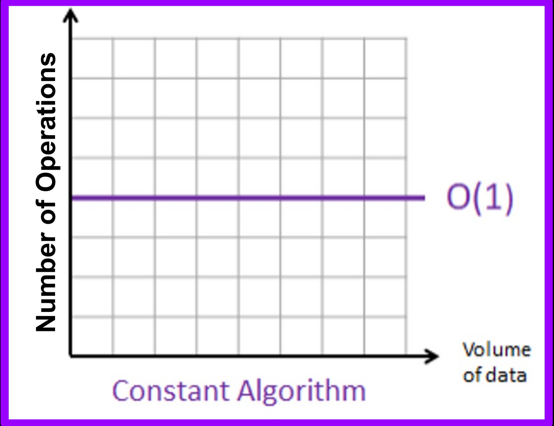

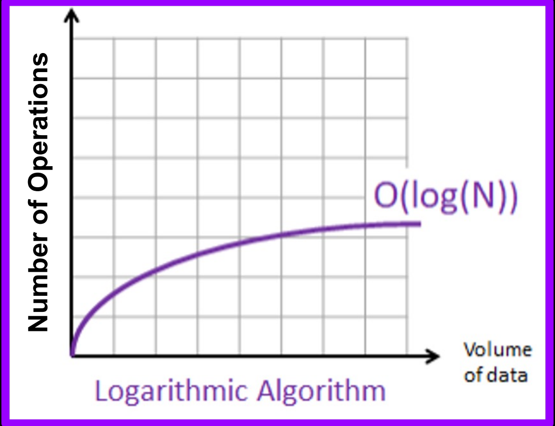

Slower Than

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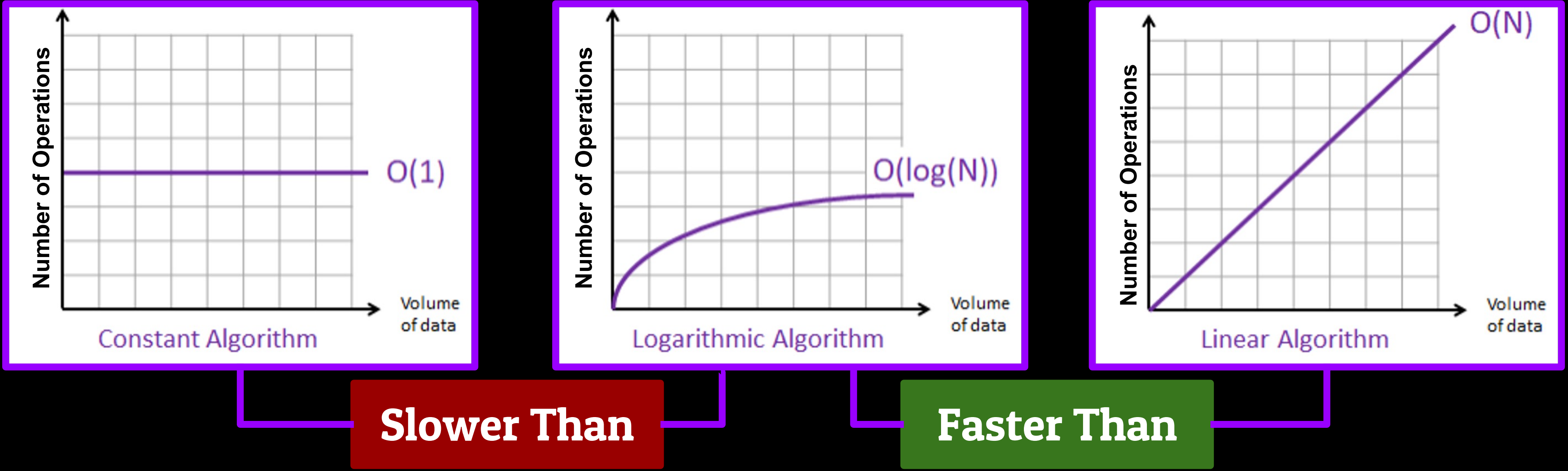

Slower Than

Faster Than

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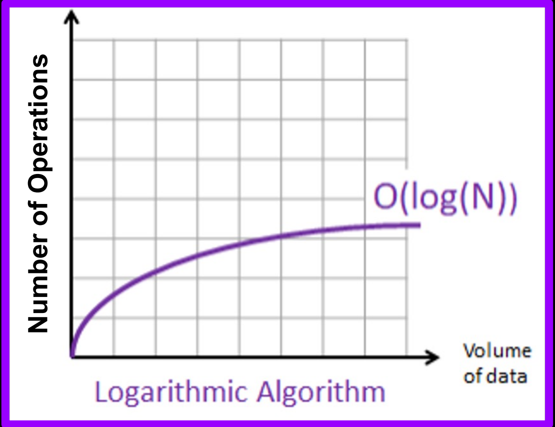

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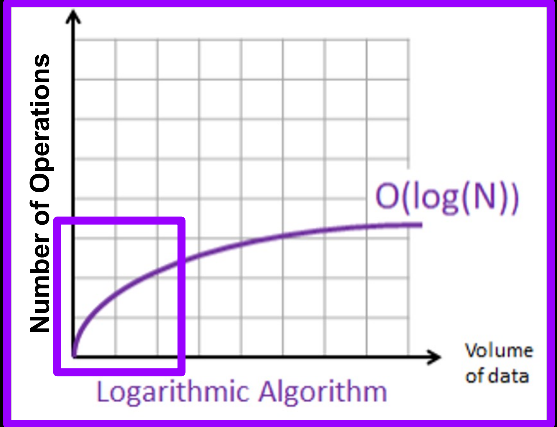

Skyrockets

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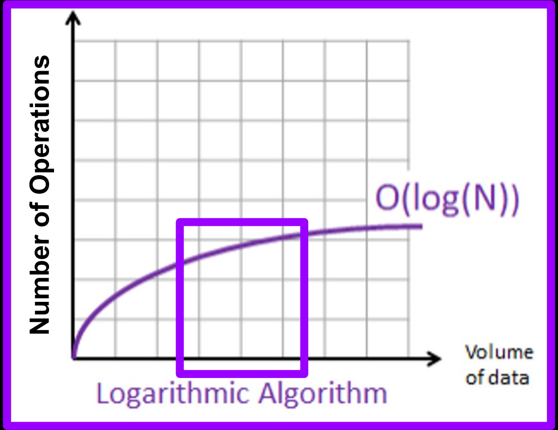

Increases More Slowly

Measuring Efficiency with BigO Notation - Types of Time Complexity Equations

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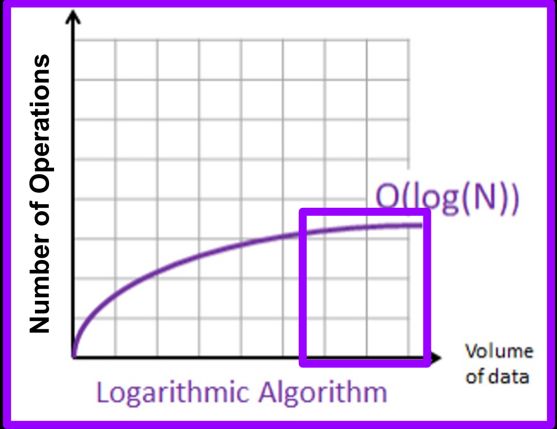

Increases Way More Slowly

Measuring Efficiency with BigO Notation - Types of Time Complexity Equations

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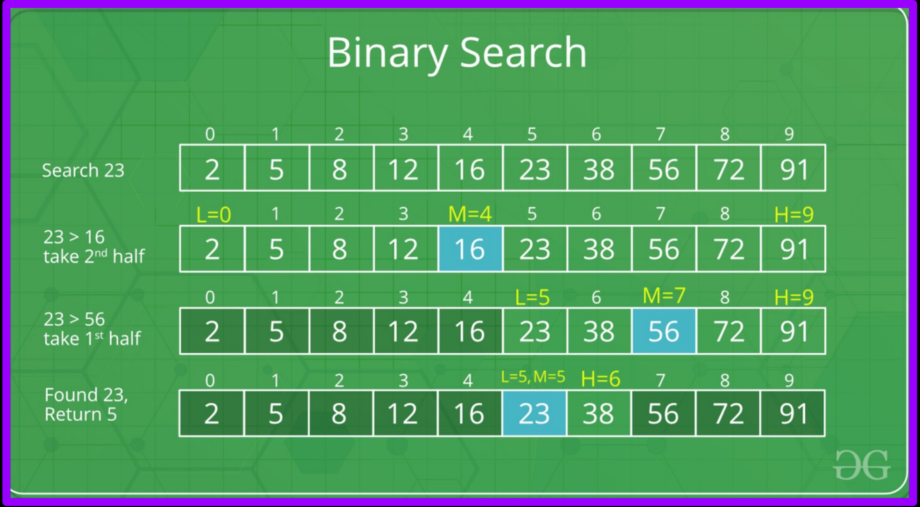

Binary Search

	0	1	2	3	4	5	6	7	8	9
Search 23	2	5	8	12	16	23	38	56	72	91
	L=0	1	2	3	M=4	5	6	7	8	H=9
23 > 16 take 2nd half	2	5	8	12	16	23	38	56	72	91
	0	1	2	3	4	L=5	6	M=7	8	H=9
23 > 56 take 1st half	2	5	8	12	16	23	38	56	72	91
	0	1	2	3	4	L=5, M=5	H=6	7	8	9
Found 23, Return 5	2	5	8	12	16	23	38	56	72	91

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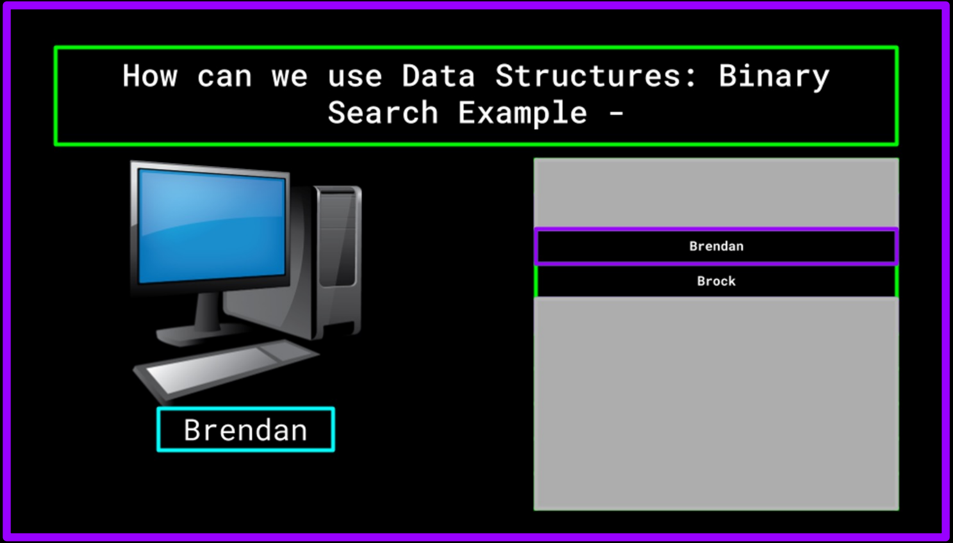

How can we use Data Structures: Binary Search Example -

Measuring Efficiency with BigO Notation - Types of Time Complexity Equations

- The next common time complexity efficiency equation type that's going to come up is O(n)
  - The last of the "decent" equations

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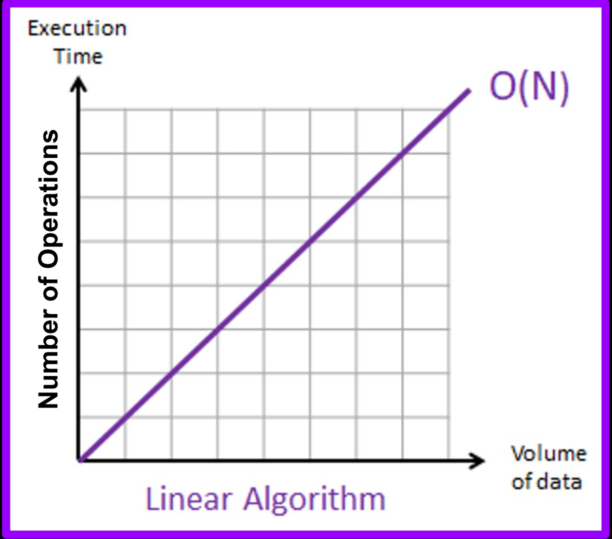

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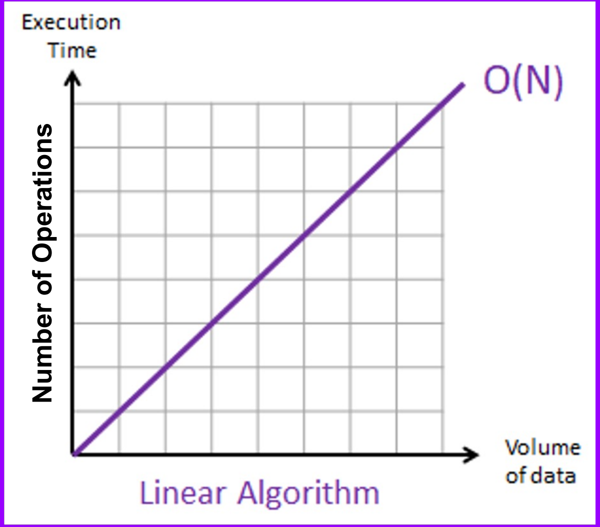

Size of Data Set (N)

10

Measuring Efficiency with BigO Notation - Types of Time Complexity Equations

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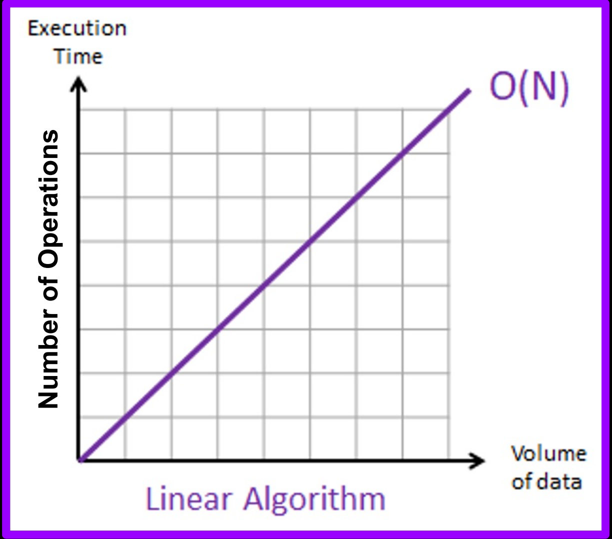

Operations Required	Size of Data Set (N)
10	10

Measuring Efficiency with BigO Notation - Types of Time Complexity Equations

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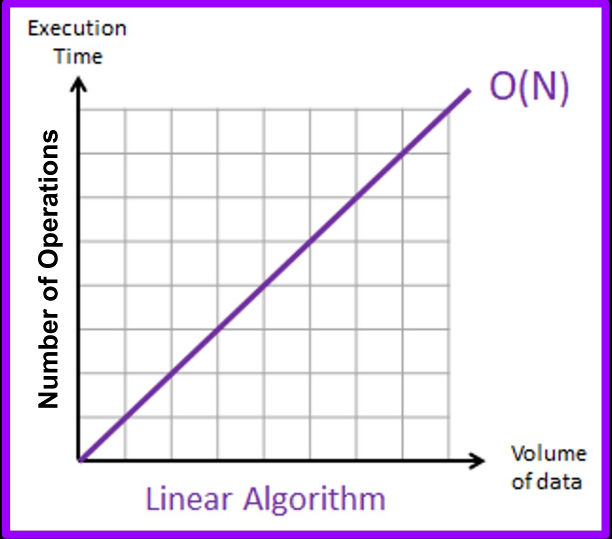

Operations Required	Size of Data Set (N)
50	50

Measuring Efficiency with BigO Notation - Types of Time Complexity Equations

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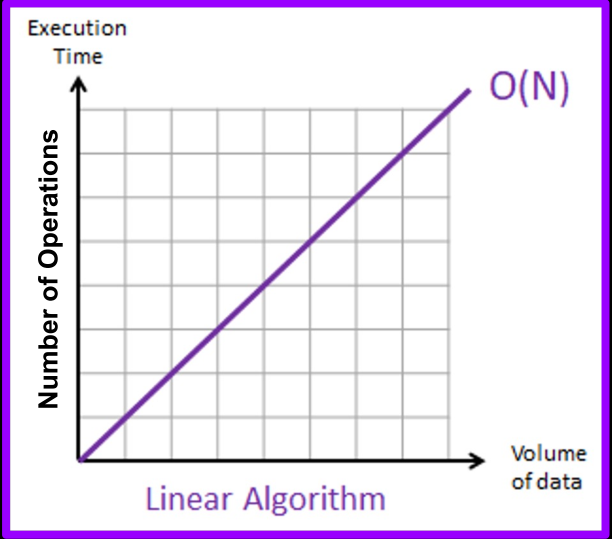

Operations Required	Size of Data Set (N)
1,000	1,000

Measuring Efficiency with BigO Notation - Types of Time Complexity Equations

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    - The first which is relatively bad in terms of efficiency

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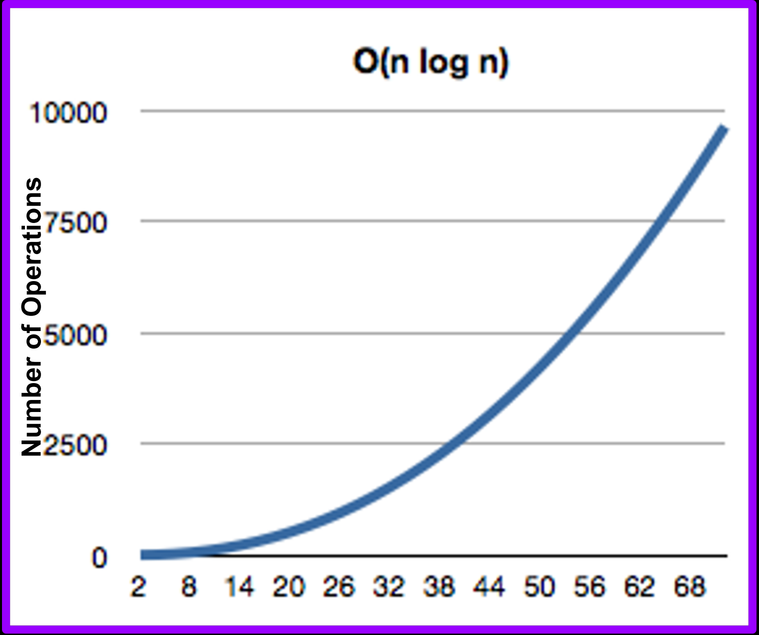

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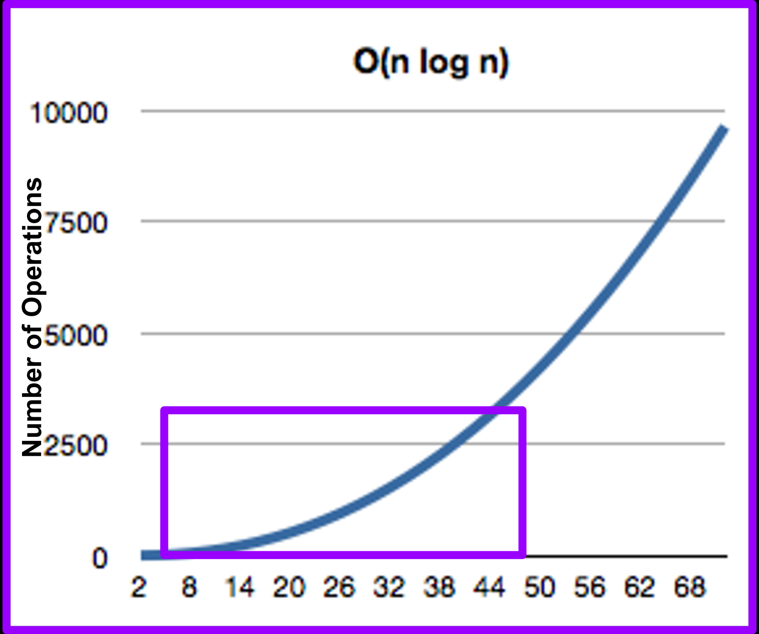

Measuring Efficiency with BigO Notation - Types of Time Complexity Equations

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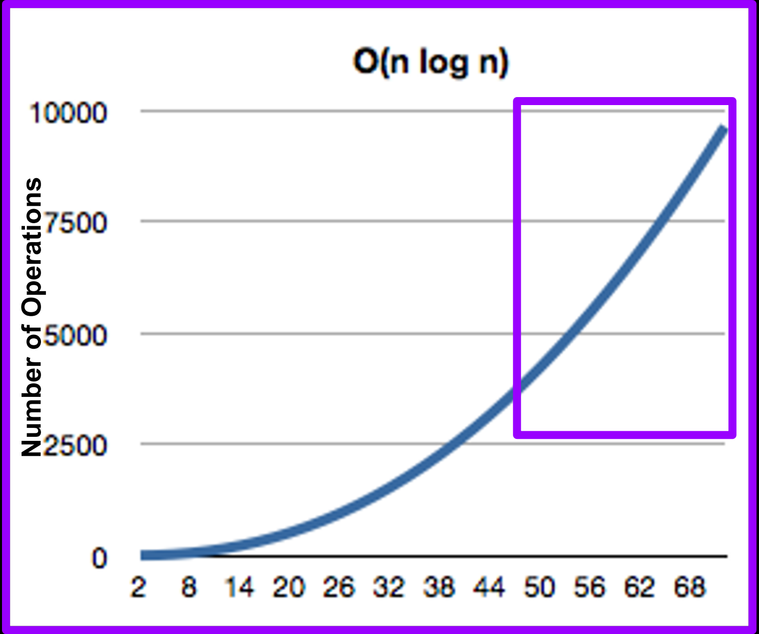

Slope Increases

Measuring Efficiency with BigO Notation - Types of Time Complexity Equations

- The last 2 types of equations are $O(n^2)$ and $O(2^n)$
    - Very bad in terms of efficiency
    - Exponential in structure

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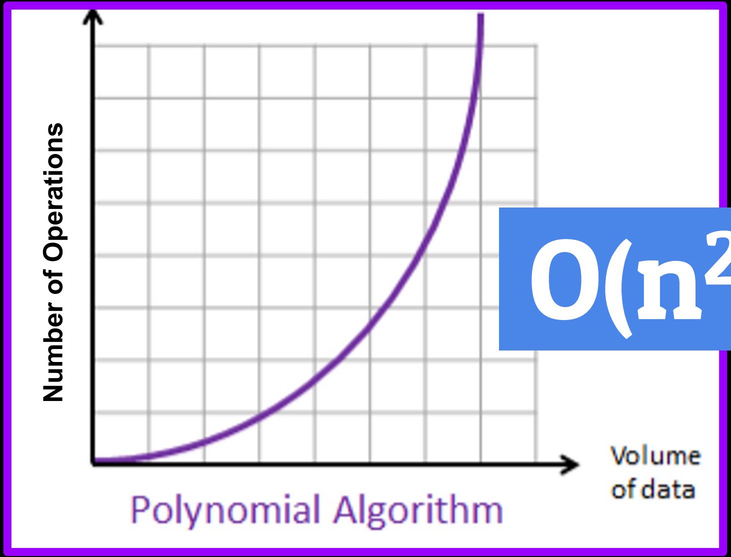

$O(n^2)$

Measuring Efficiency with BigO Notation - Types of Time Complexity Equations

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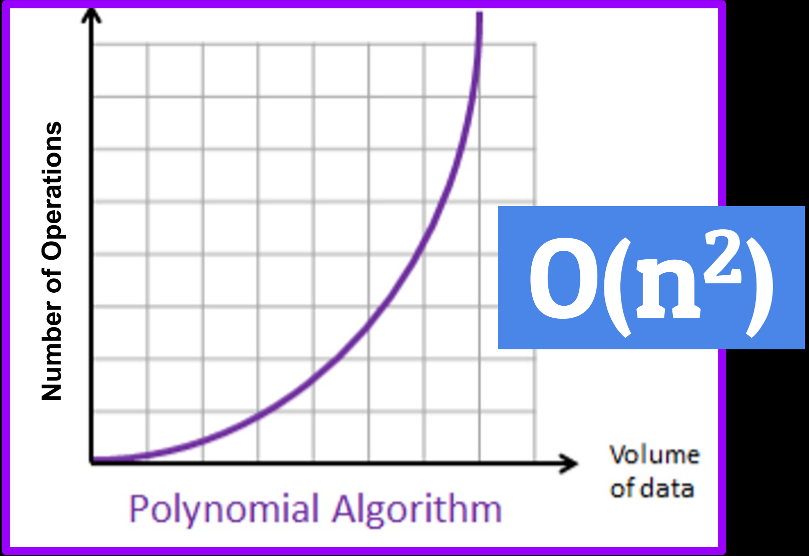

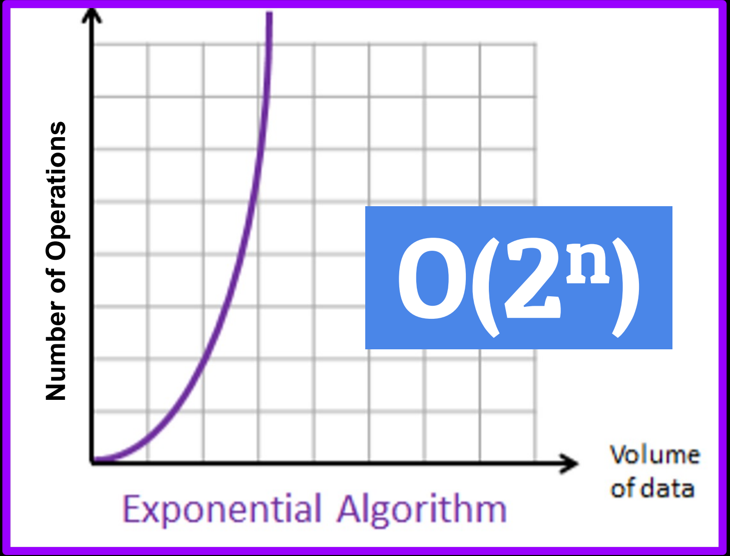

Measuring Efficiency with BigO Notation - Final Note on Time Complexity Equations

- Time Complexity Equations are **NOT** the only metric you should be using the gauge which data structure to use
    - Some provide other functionality that make them extremely useful

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Some Data Structure

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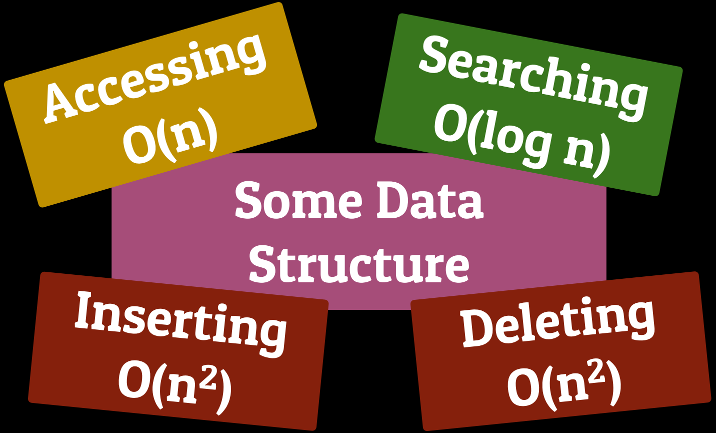

Accessing O(n)

Searching O(log n)

Some Data Structure

Inserting $O(n^2)$

Deleting $O(n^2)$

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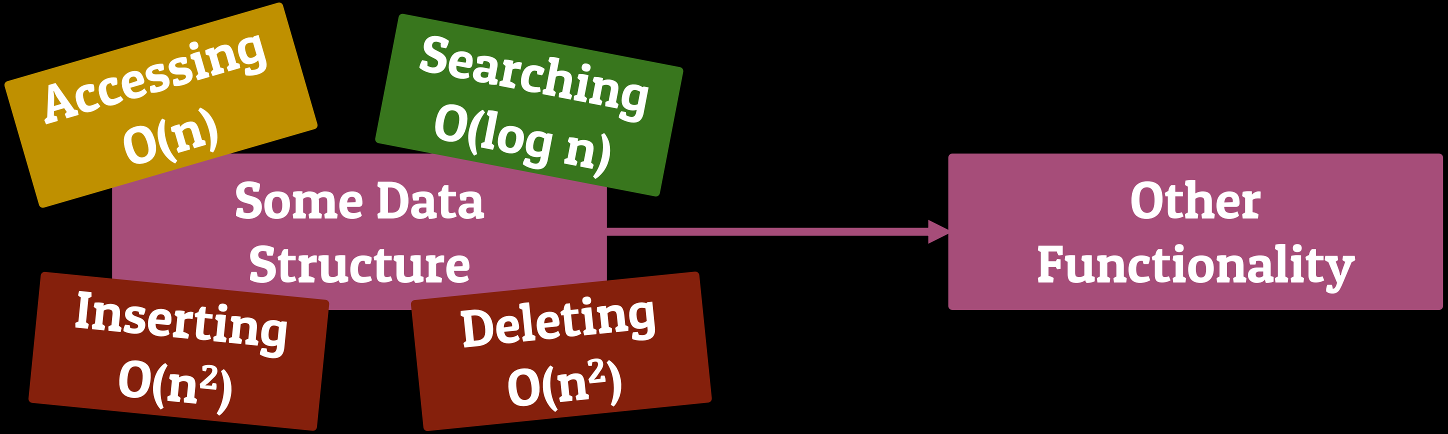
Accessing
O(n)
Searching
O(log n)
Some Data Structure
Inserting
O(n²)
Deleting
O(n²)
Other Functionality