COMP1819
Algorithms and Data Structures

Lecture 04: Searching – Linear and Binary

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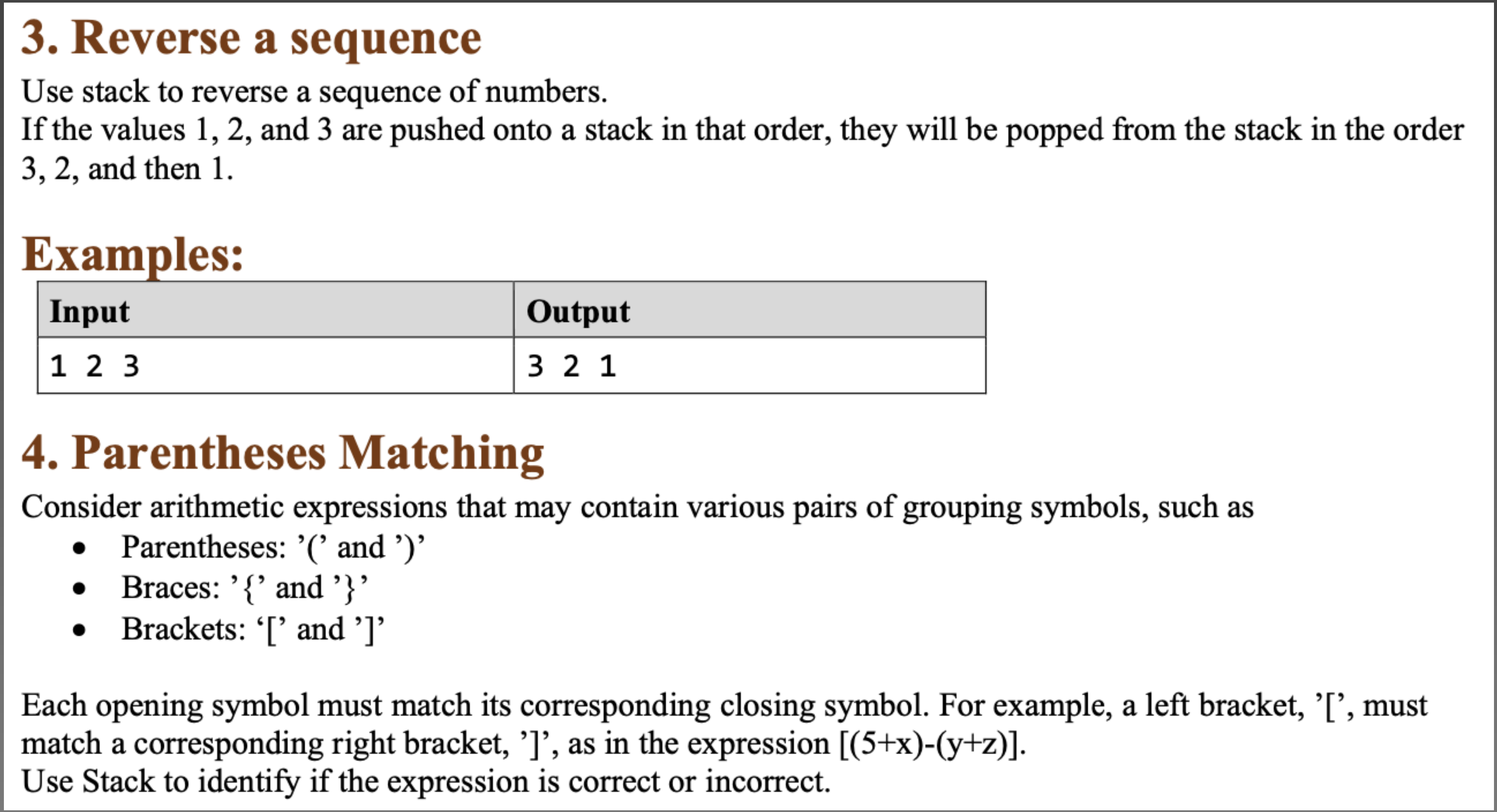
09/02/2021

Content

- Lab 03
- Linear Search
- Binary Search
- Hashing
- Reinforcement

Lab 03



3. Reverse a sequence

Use stack to reverse a sequence of numbers.
If the values 1, 2, and 3 are pushed onto a stack in that order, they will be popped from the stack in the order 3, 2, and then 1.

Examples:

Input	Output
1 2 3	3 2 1

4. Parentheses Matching

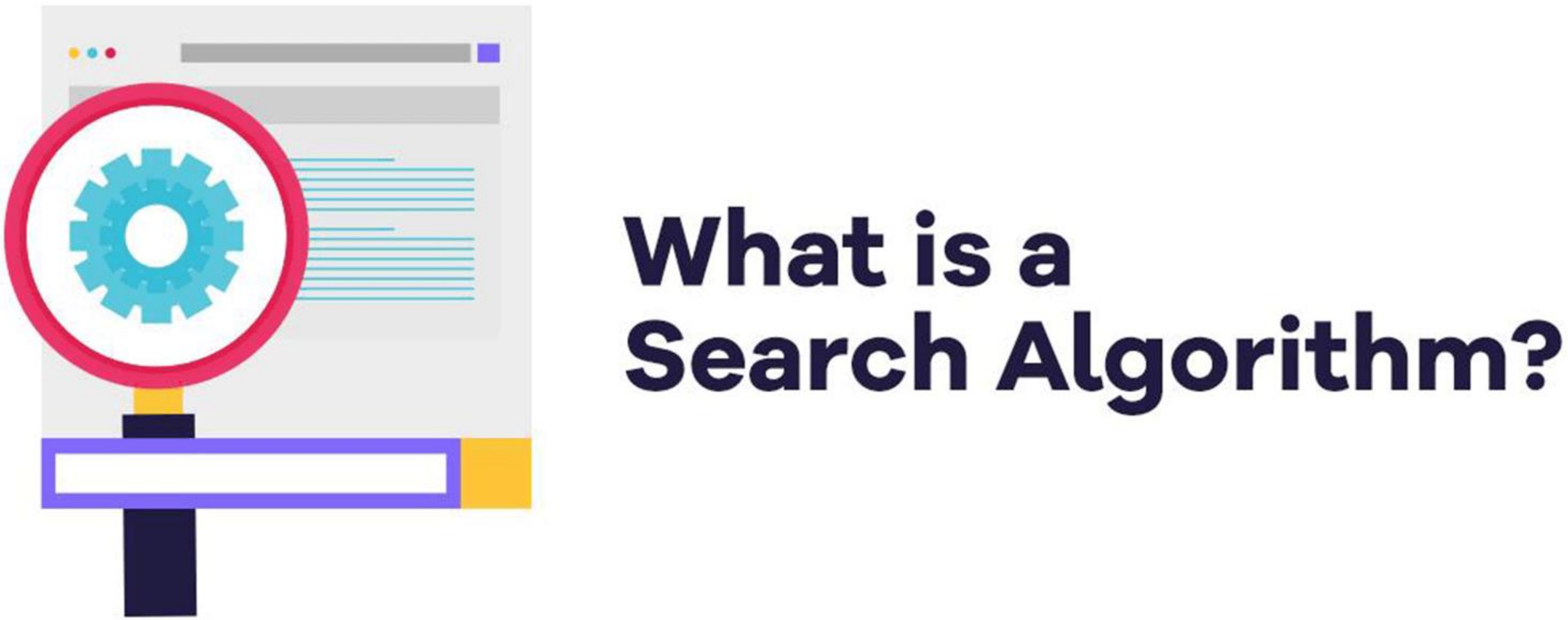
Consider arithmetic expressions that may contain various pairs of grouping symbols, such as

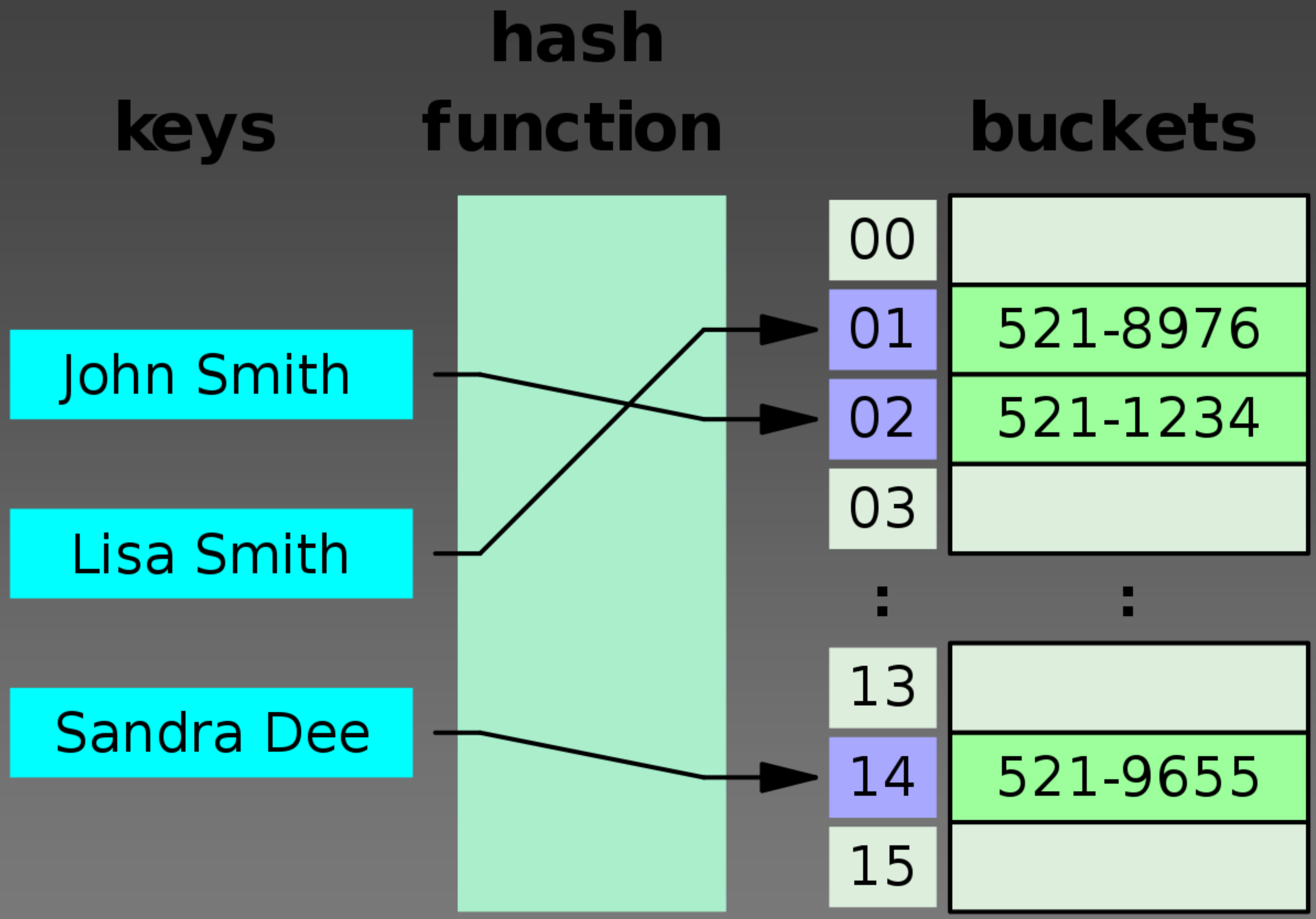
- Parentheses: ’(’ and ’)’
- Braces: ’{’ and ’}’
- Brackets: ‘[’ and ’]’

Each opening symbol must match its corresponding closing symbol. For example, a left bracket, ’[’, must match a corresponding right bracket, ’]’, as in the expression [(5+x)-(y+z)].
Use Stack to identify if the expression is correct or incorrect.

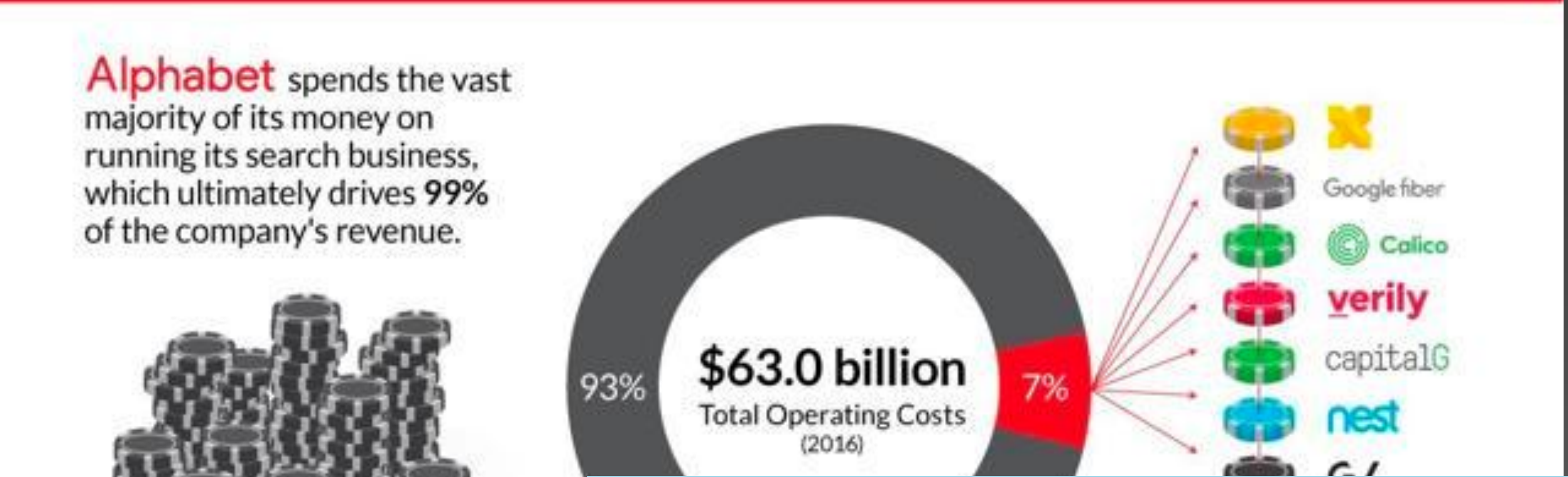
Solving problems with Stacks & Queues

Today

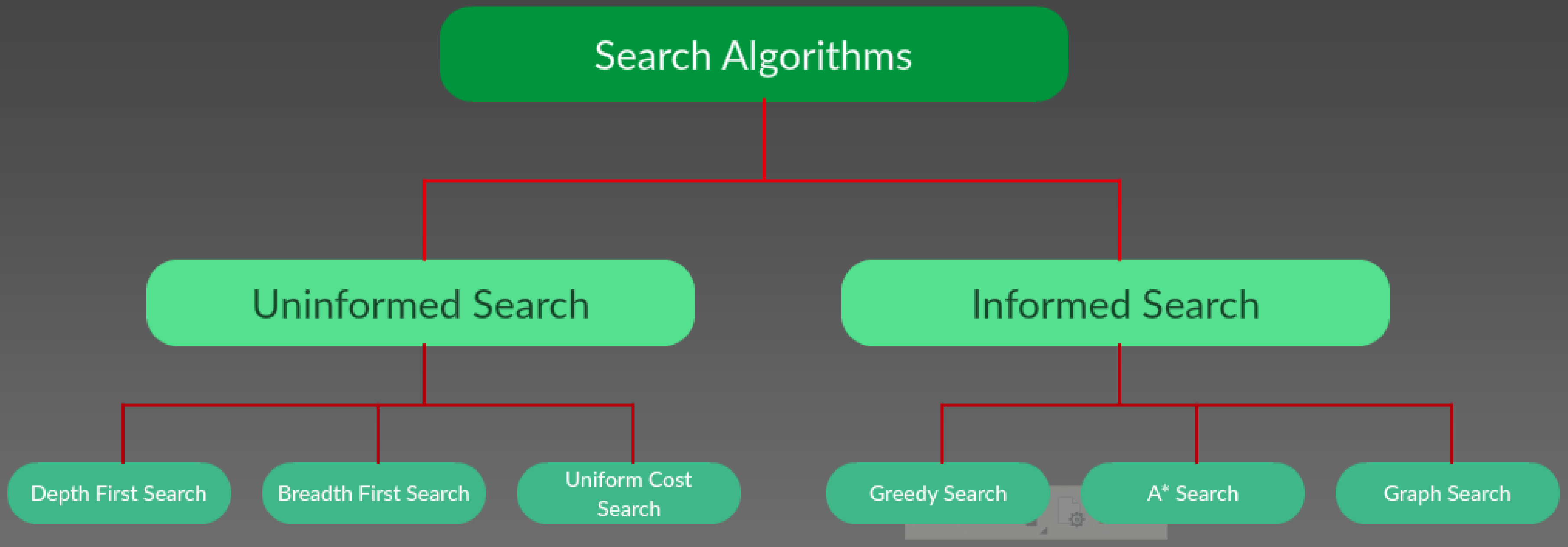




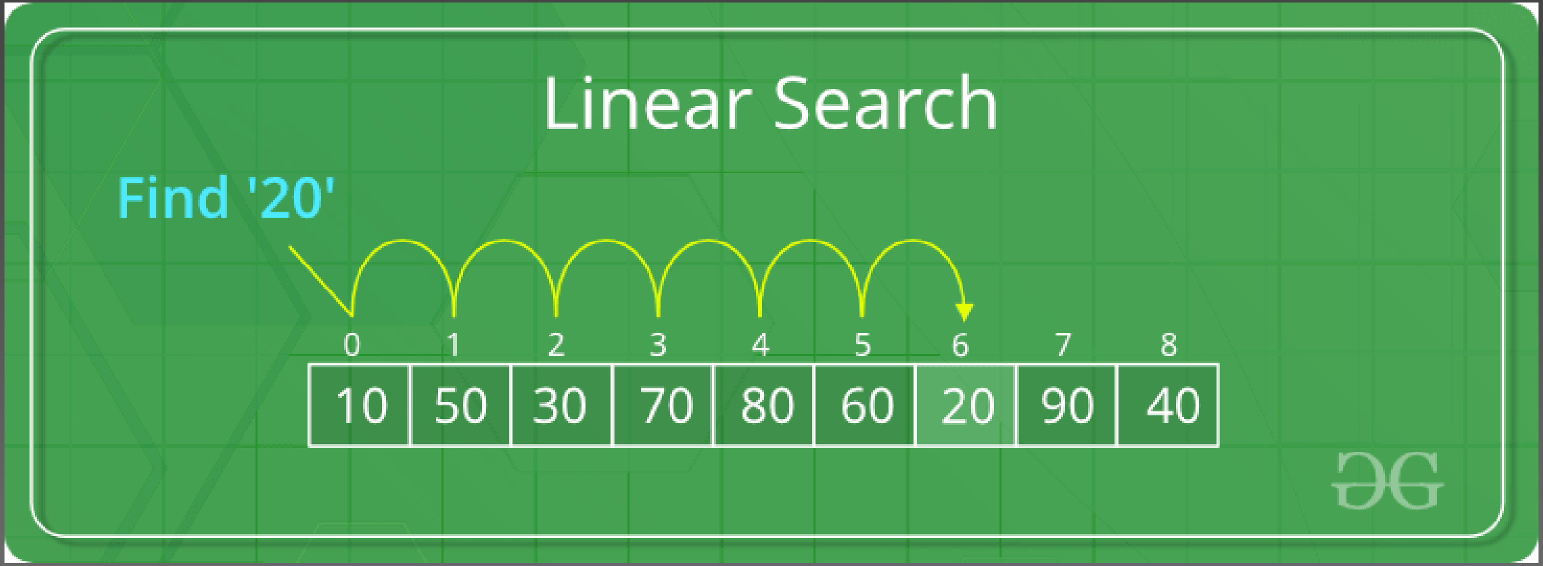
Search algorithm solves the search problem, namely, to retrieve information stored within some data structure, or calculated in the search space of a problem domain, either with discrete or continuous values



Why search? How does Google search works (https://www.youtube.com/watch?v=0eKVizvYSUQ)?

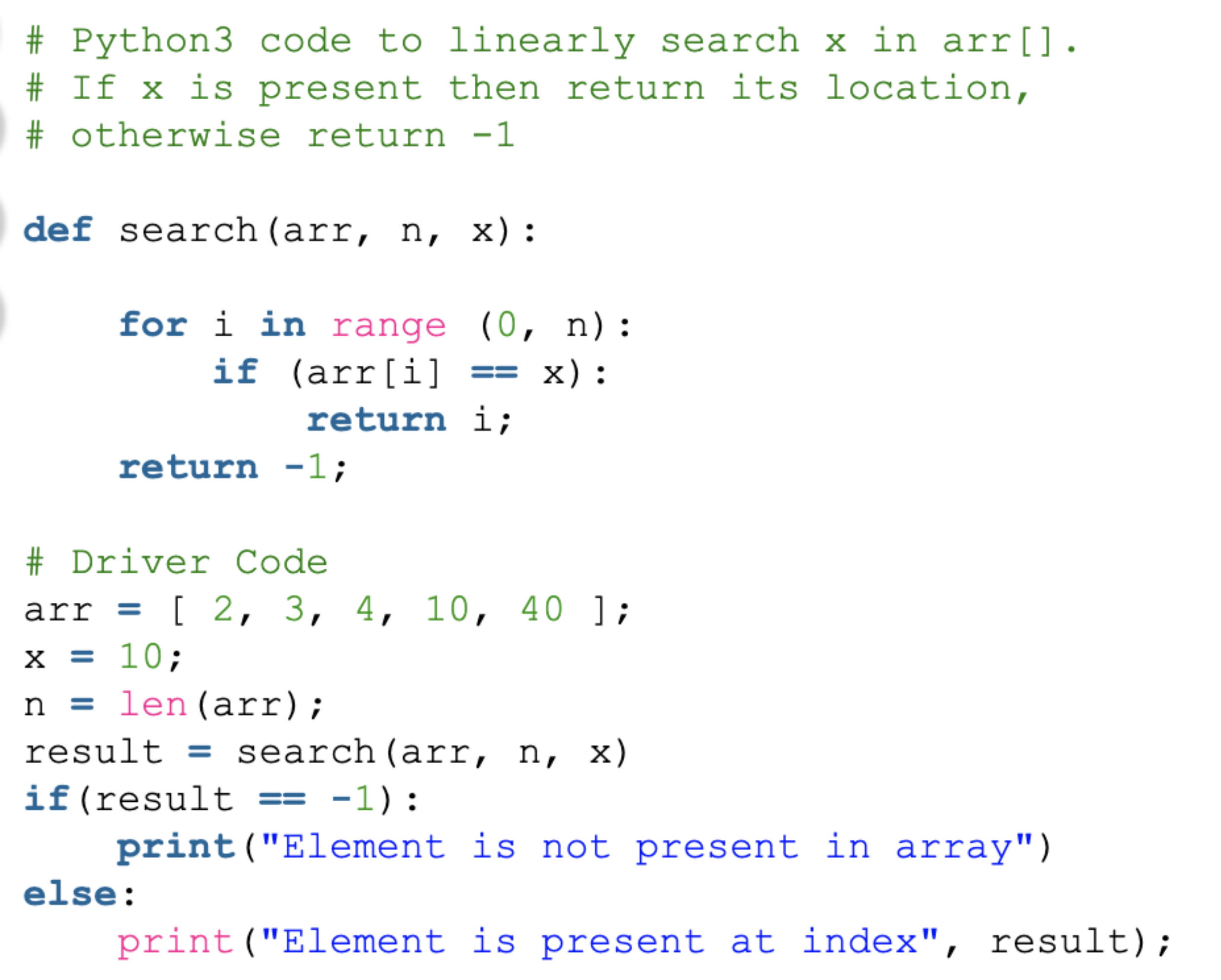


Search algorithms: Sequential Search, Binary Search



0	1	2	3	4	5	6	7	8
10	50	30	70	80	60	20	90	40

Sequential Search/Linear Search. How many comparisons would you need to do in order to find ‘20’?

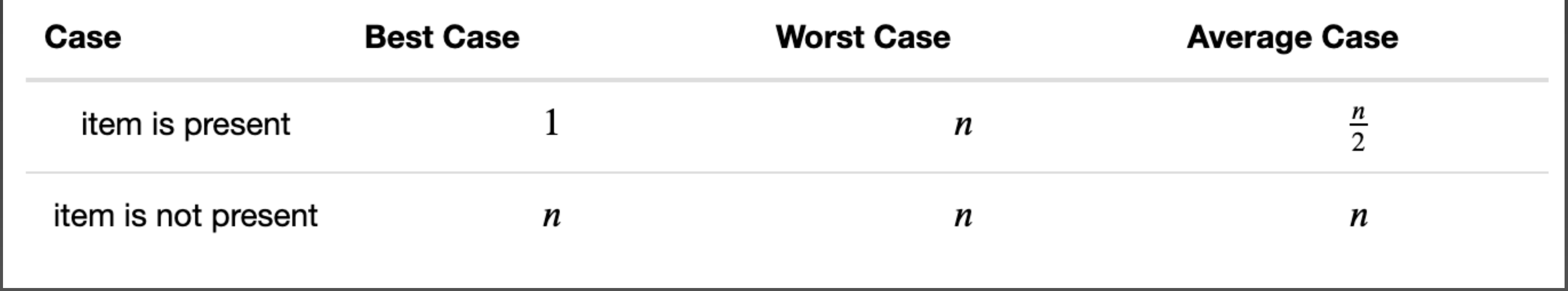


```
# Python3 code to linearly search x in arr[].
# If x is present then return its location,
# otherwise return -1

def search(arr, n, x):

    for i in range (0, n):
        if (arr[i] == x):
            return i;
    return -1;

# Driver Code
arr = [ 2, 3, 4, 10, 40 ];
x = 10;
n = len(arr);
result = search(arr, n, x)
if(result == -1):
    print("Element is not present in array")
else:
    print("Element is present at index", result);
```

Search algorithms: Sequential Search

Analysis of Algorithms

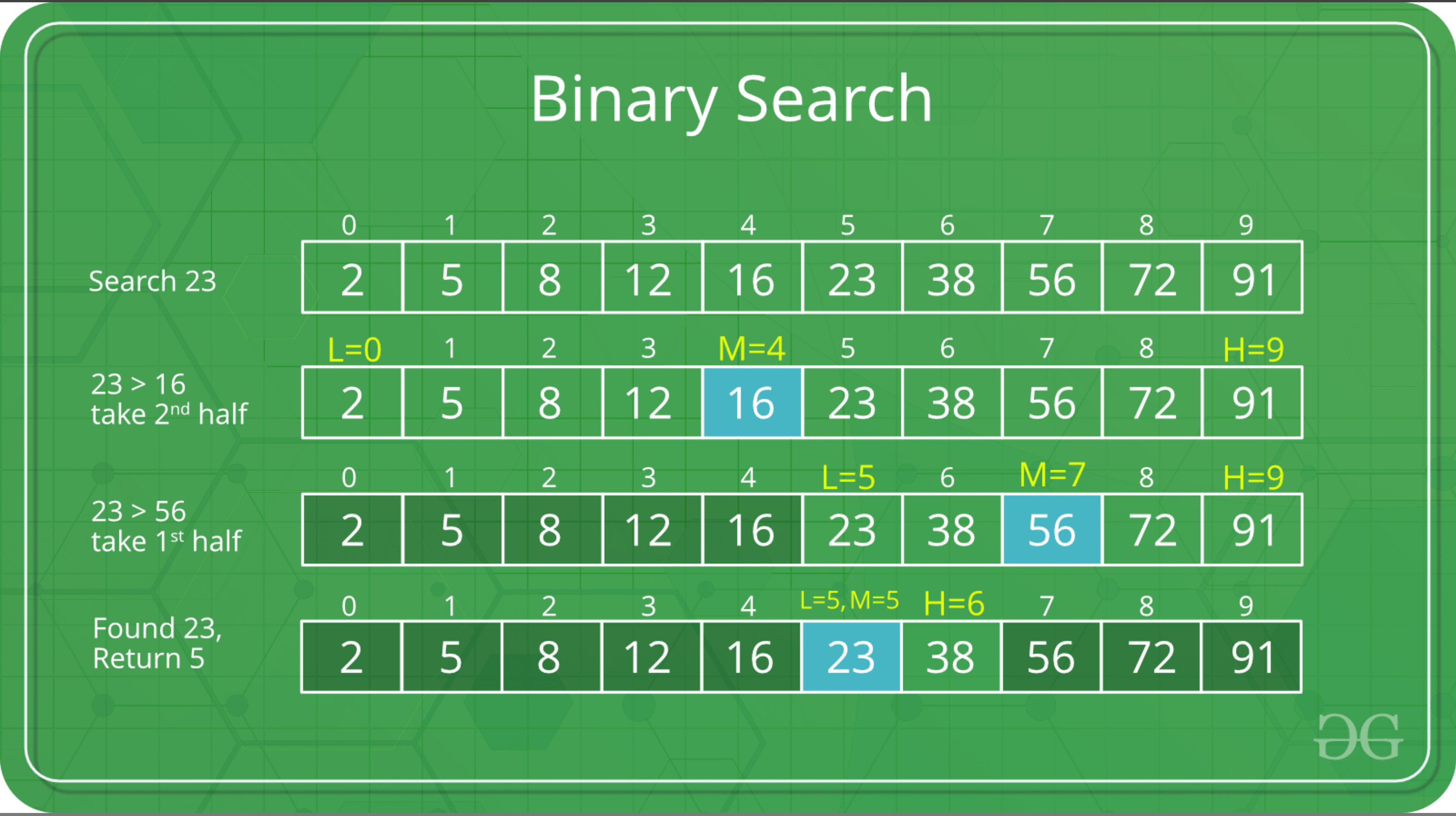
- In addition to describing the algorithms – analyse them
- What does analysis of algorithms involve ?
  - element comparisons
  - the number of element comparisons
- What is the best/worst/average case? When?



Case	Best Case	Worst Case	Average Case
item is present	1	n	$\frac{n}{2}$
item is not present	n	n	n

- Suppose you are doing a sequential search of the ordered list [3, 5, 6, 8, 11, 12, 14, 15, 17, 18]. How many comparisons would you need to do in order to find the key 11?

Is the list sorted? What if sorted?



Binary Search

Search 23

0	1	2	3	4	5	6	7	8	9
2	5	8	12	16	23	38	56	72	91

23 > 16
take 2nd half

L=0	1	2	3	M=4	5	6	7	8	H=9
2	5	8	12	16	23	38	56	72	91

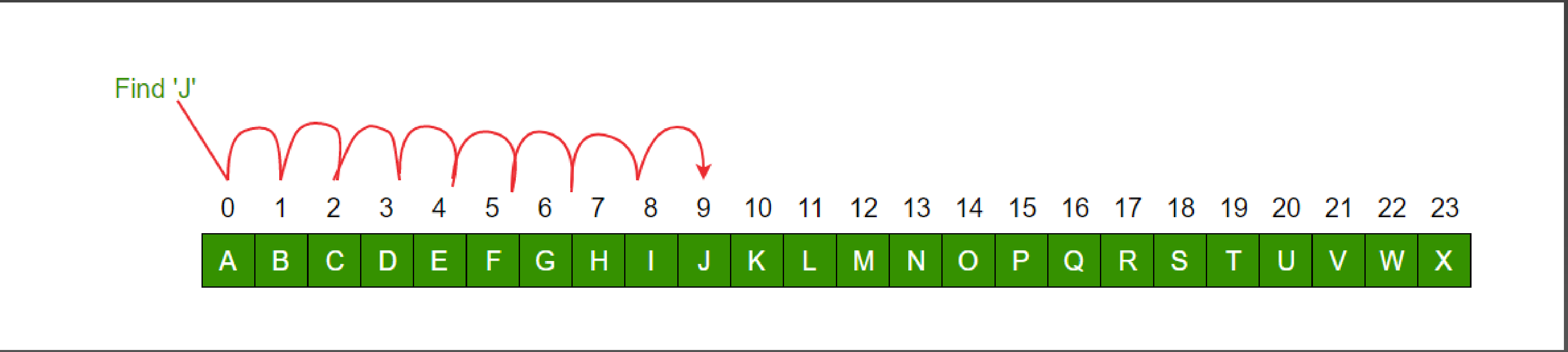
23 > 56
take 1st half

0	1	2	3	4	L=5	6	M=7	8	H=9
2	5	8	12	16	23	38	56	72	91

Found 23,
Return 5

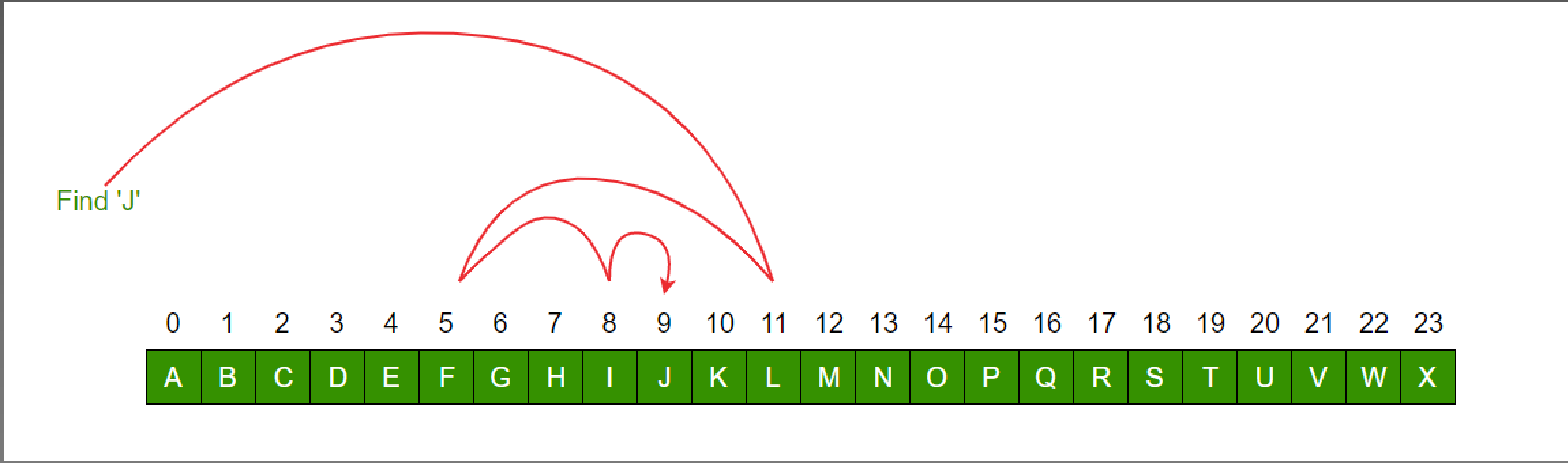
0	1	2	3	4	L=5, M=5	H=6	7	8	9
2	5	8	12	16	23	38	56	72	91

Binary Search on Sorted list.



Find 'J'

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X



Find 'J'

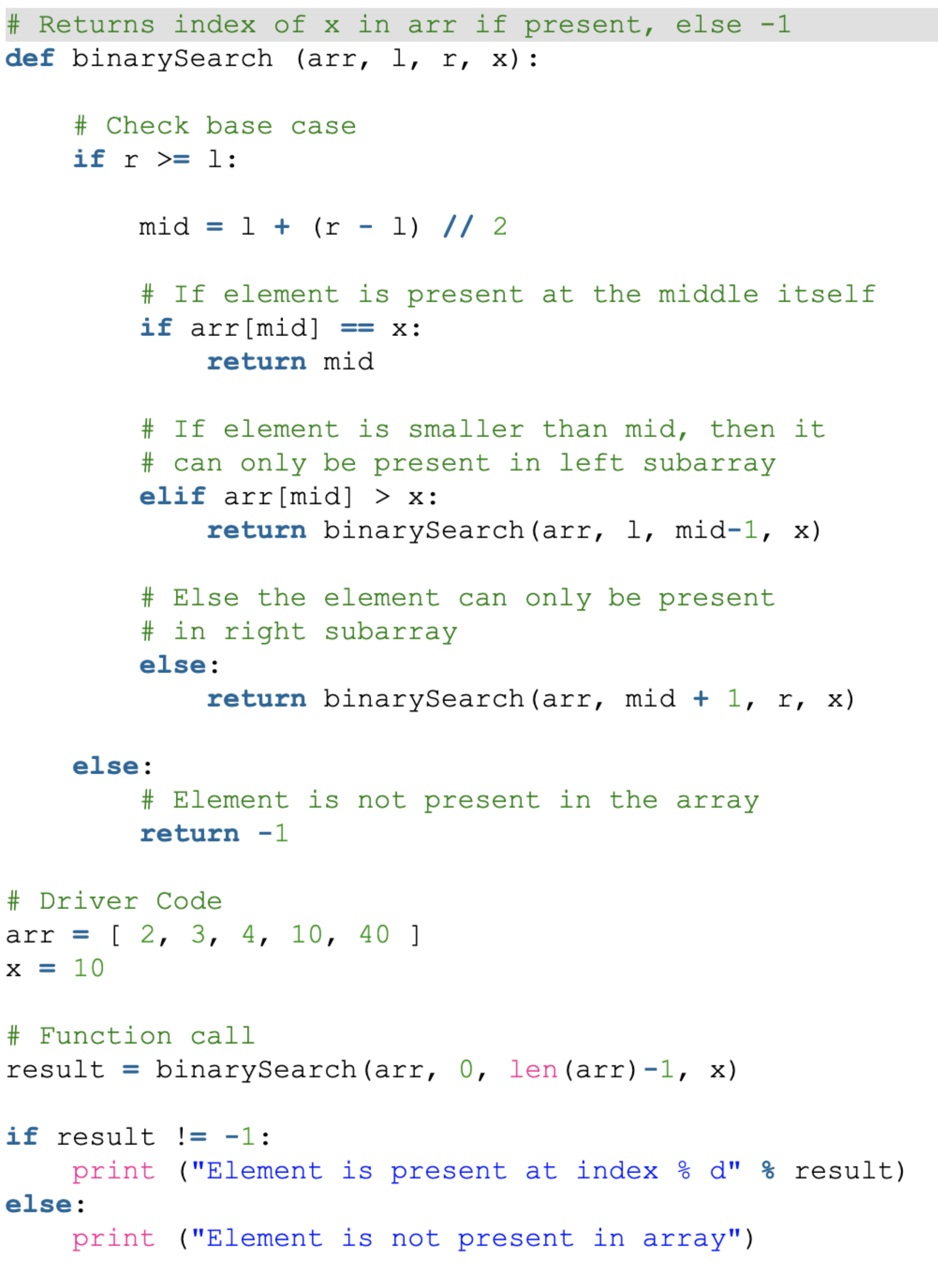
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X

Linear Search vs Binary Search

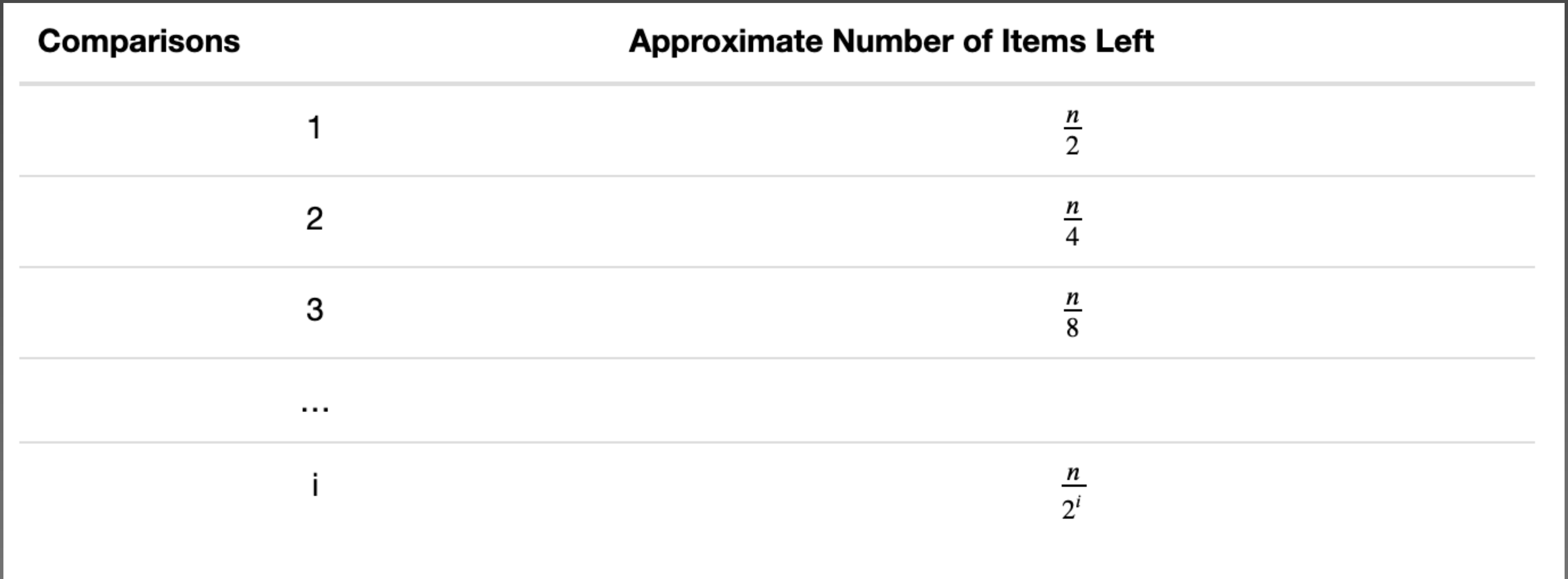
How about some recursive implementation?

Let’s debug.

```
Mid  = (right + left) // 2
Or same as left + (right –
left) // 2
```

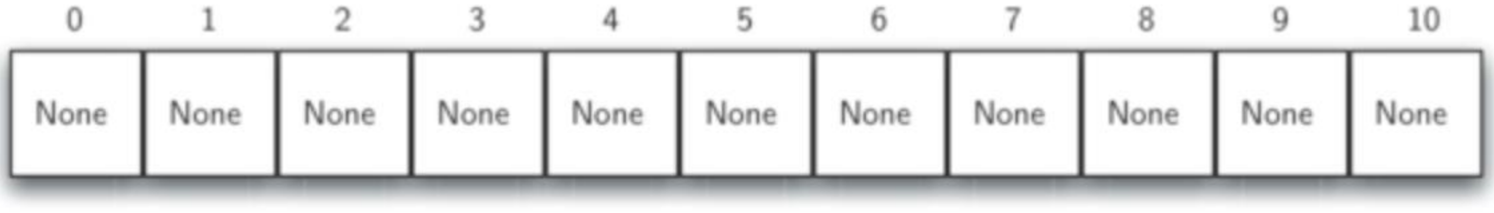


```python
# Returns index of x in arr if present, else -1
def binarySearch (arr, l, r, x):

    # Check base case
    if r >= l:

        mid = l + (r - l) // 2

        # If element is present at the middle itself
        if arr[mid] == x:
            return mid

        # If element is smaller than mid, then it
        # can only be present in left subarray
        elif arr[mid] > x:
            return binarySearch(arr, l, mid-1, x)

        # Else the element can only be present
        # in right subarray
        else:
            return binarySearch(arr, mid + 1, r, x)

    else:
        # Element is not present in the array
        return -1

# Driver Code
arr = [ 2, 3, 4, 10, 40 ]
x = 10

# Function call
result = binarySearch(arr, 0, len(arr)-1, x)

if result != -1:
    print ("Element is present at index % d" % result)
else:
    print ("Element is not present in array")
```



Comparisons	Approximate Number of Items Left
1	$\frac{n}{2}$
2	$\frac{n}{4}$
3	$\frac{n}{8}$
...	
i	$\frac{n}{2^i}$

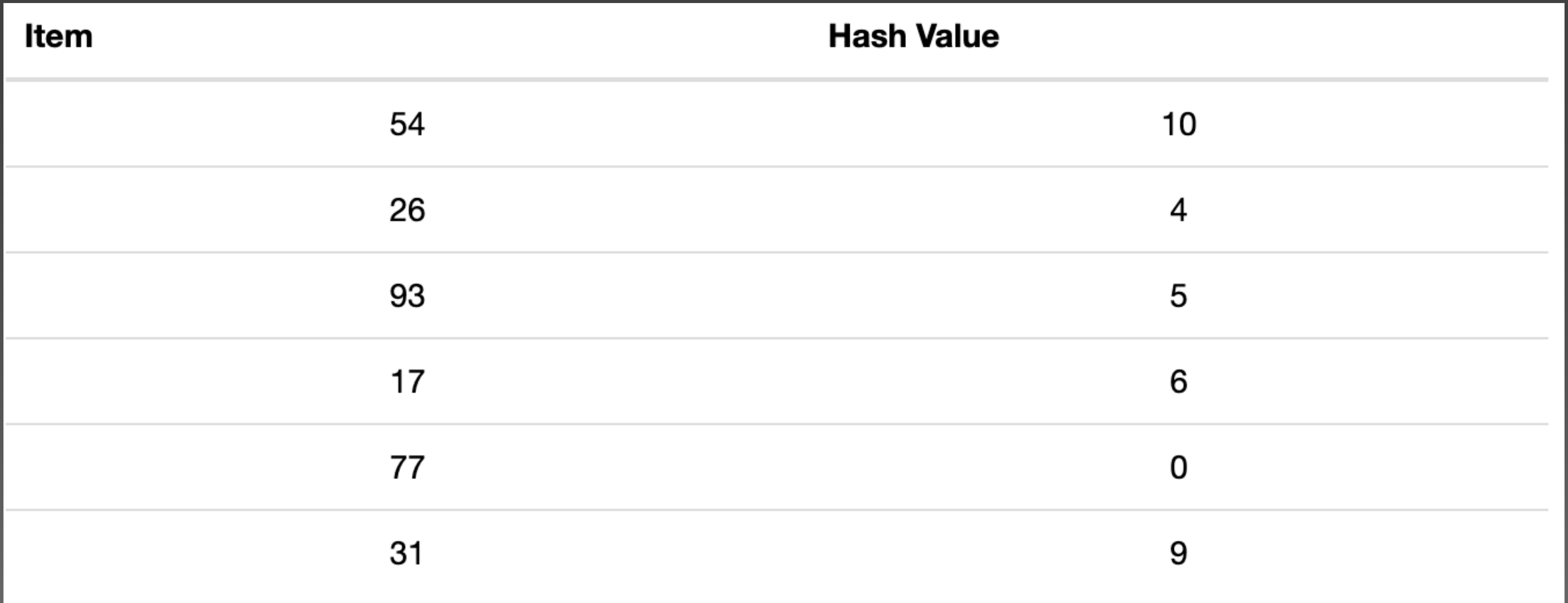
Algorithm Complexity ? O (log n)



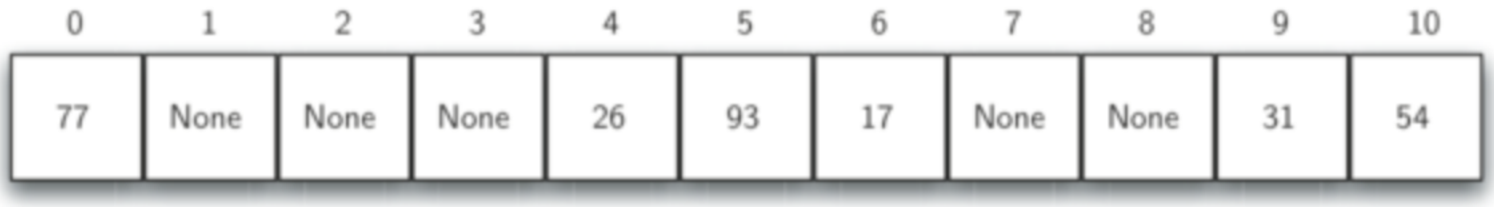
0	1	2	3	4	5	6	7	8	9	10
None	None	None	None	None	None	None	None	None	None	None

Figure 4: Hash Table with 11 Empty Slots

Improve further? Have you heard of “Hashing”?
Insert the following numbers into the Hash table: 54, 26, 93, 17, 77, and 31.



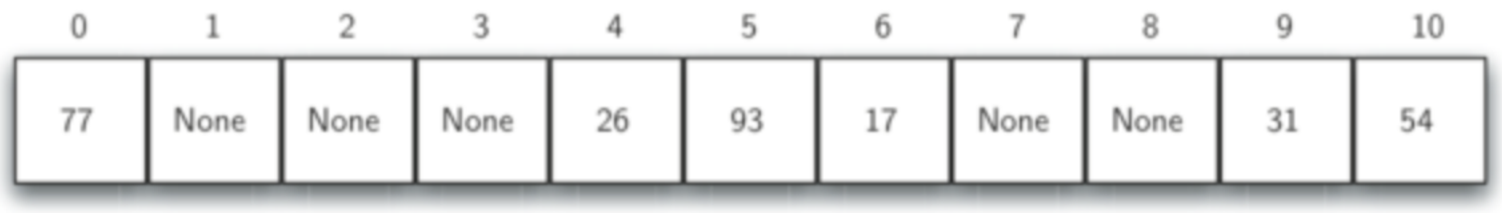
Item	Hash Value
54	10
26	4
93	5
17	6
77	0
31	9



0	1	2	3	4	5	6	7	8	9	10
77	None	None	None	26	93	17	None	None	31	54

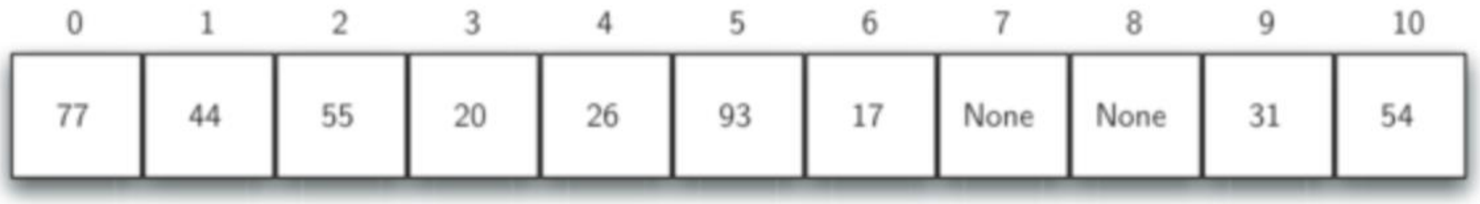
Figure 5: Hash Table with Six Items

Insert the following numbers into the Hash table: 54, 26, 93, 17, 77, and 31, using “remainder method” ~ $h(item)=item\%11$



0	1	2	3	4	5	6	7	8	9	10
77	None	None	None	26	93	17	None	None	31	54

Figure 5: Hash Table with Six Items

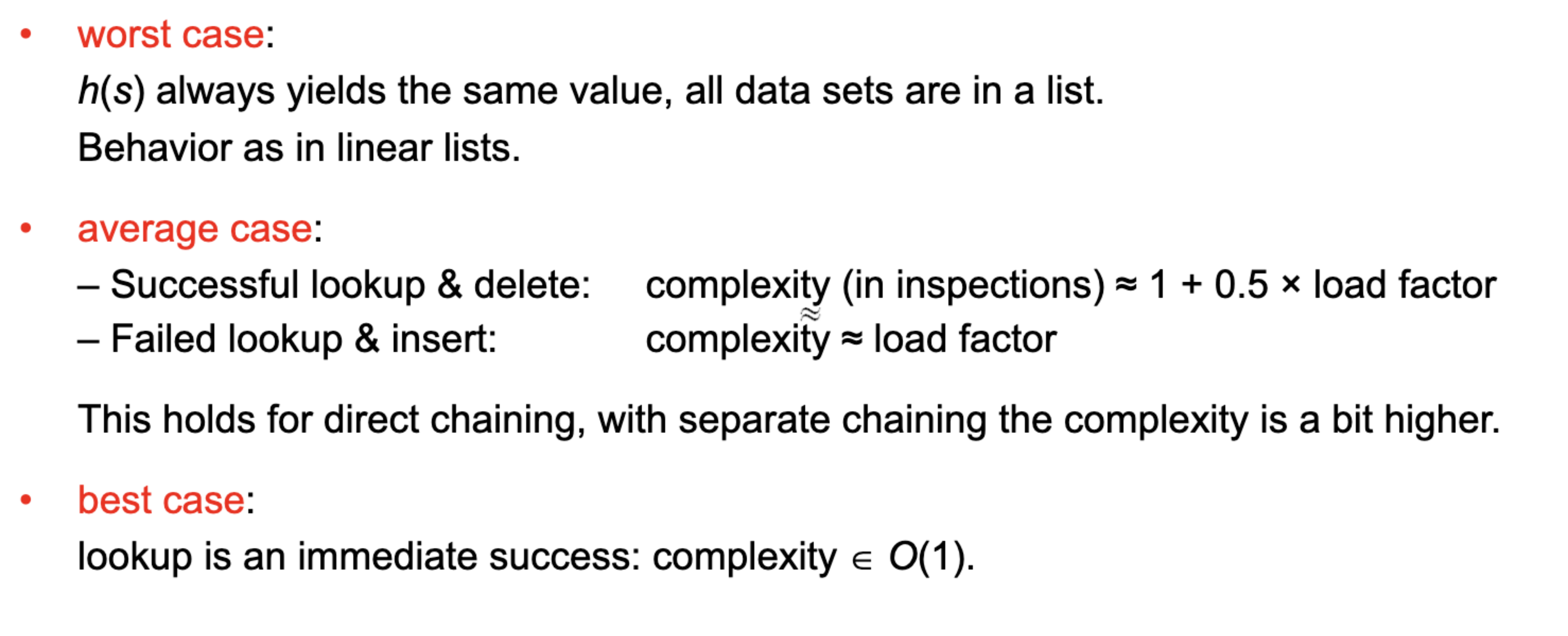


0	1	2	3	4	5	6	7	8	9	10
77	44	55	20	26	93	17	None	None	31	54

Figure 8: Collision Resolution with Linear Probing

Collision when inserting 44, 45, 20 into the Hash table.
Collision Resolution with Linear Probing

Analysis of Hashing



- worst case:

  $h(s)$ always yields the same value, all data sets are in a list.

  Behavior as in linear lists.

- average case:

  – Successful lookup & delete: complexity (in inspections) ≈ 1 + 0.5 × load factor

  – Failed lookup & insert: complexity ≈ load factor

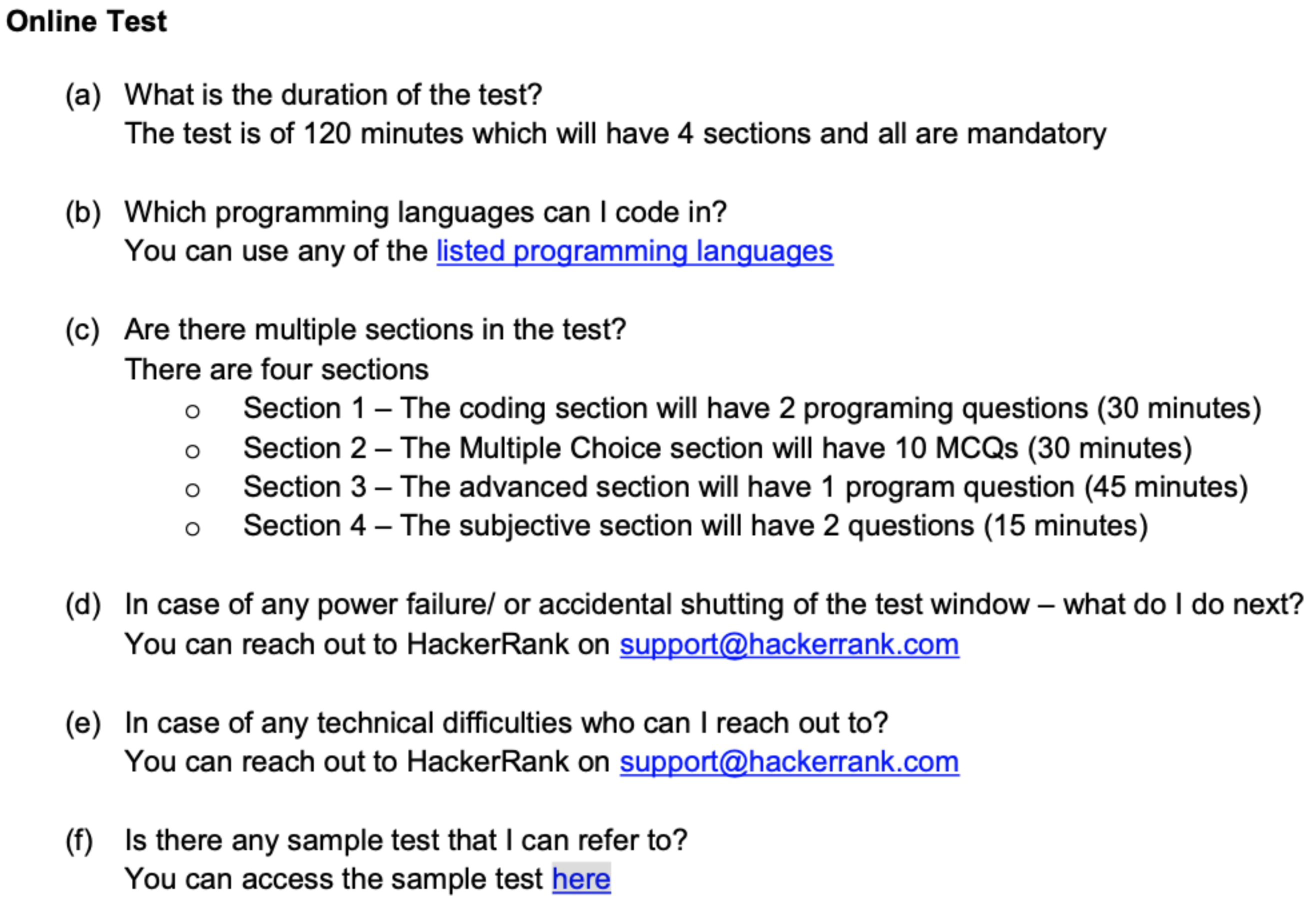
  This holds for direct chaining, with separate chaining the complexity is a bit higher.

- best case:

  lookup is an immediate success: complexity $\in O(1)$.

Reinforcement

Recruiting



Online Test

(a) What is the duration of the test?
The test is of 120 minutes which will have 4 sections and all are mandatory

(b) Which programming languages can I code in?
You can use any of the listed programming languages

(c) Are there multiple sections in the test?
There are four sections

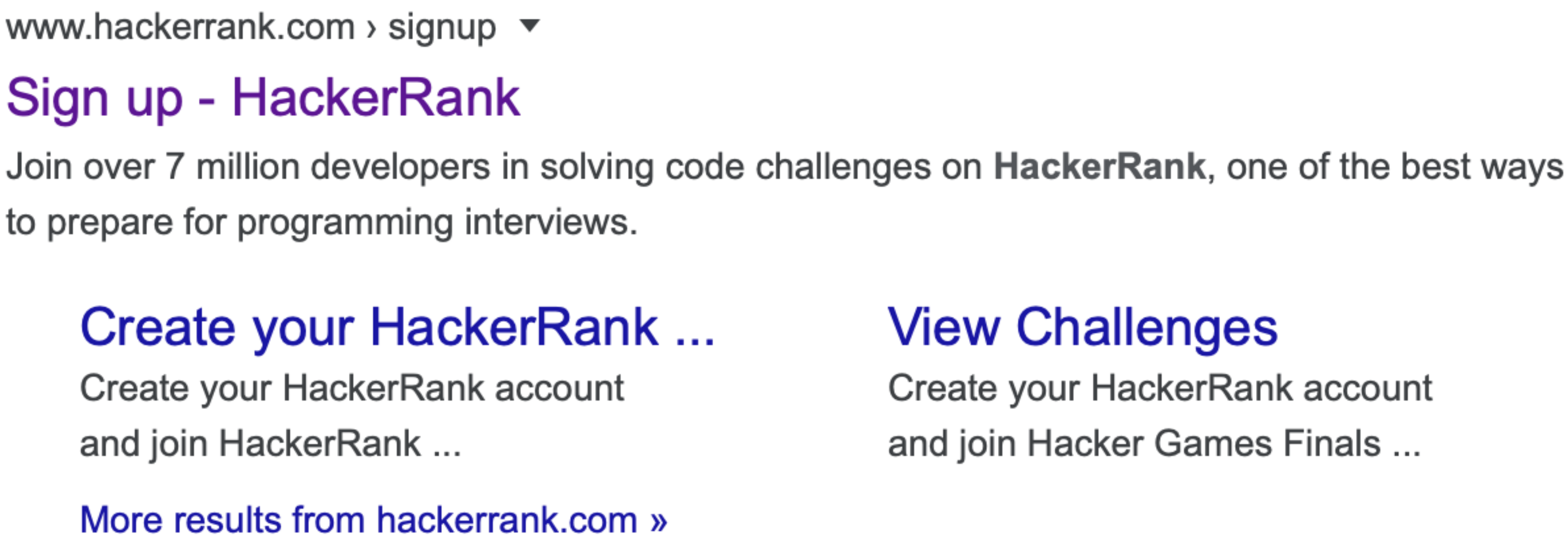
- Section 1 – The coding section will have 2 programing questions (30 minutes)
- Section 2 – The Multiple Choice section will have 10 MCQs (30 minutes)
- Section 3 – The advanced section will have 1 program question (45 minutes)
- Section 4 – The subjective section will have 2 questions (15 minutes)

(d) In case of any power failure/ or accidental shutting of the test window – what do I do next?
You can reach out to HackerRank on support@hackerrank.com

(e) In case of any technical difficulties who can I reach out to?
You can reach out to HackerRank on support@hackerrank.com

(f) Is there any sample test that I can refer to?
You can access the sample test here

Signup



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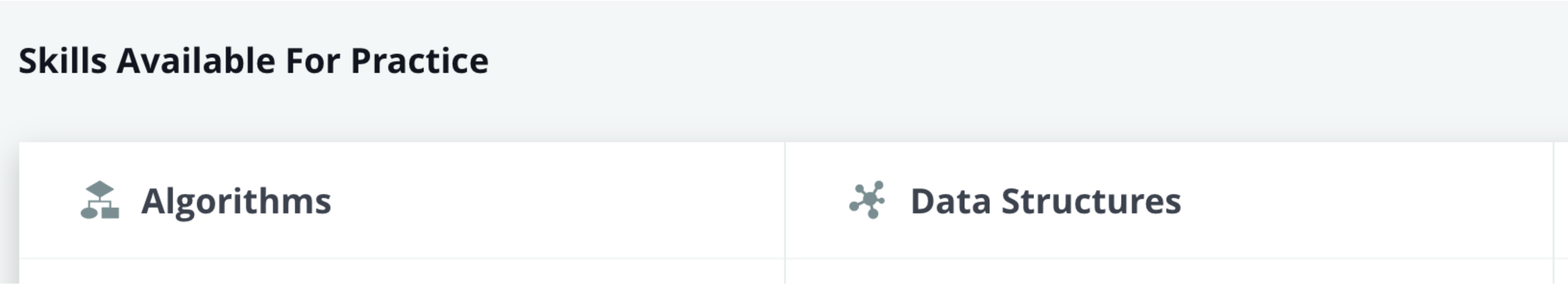
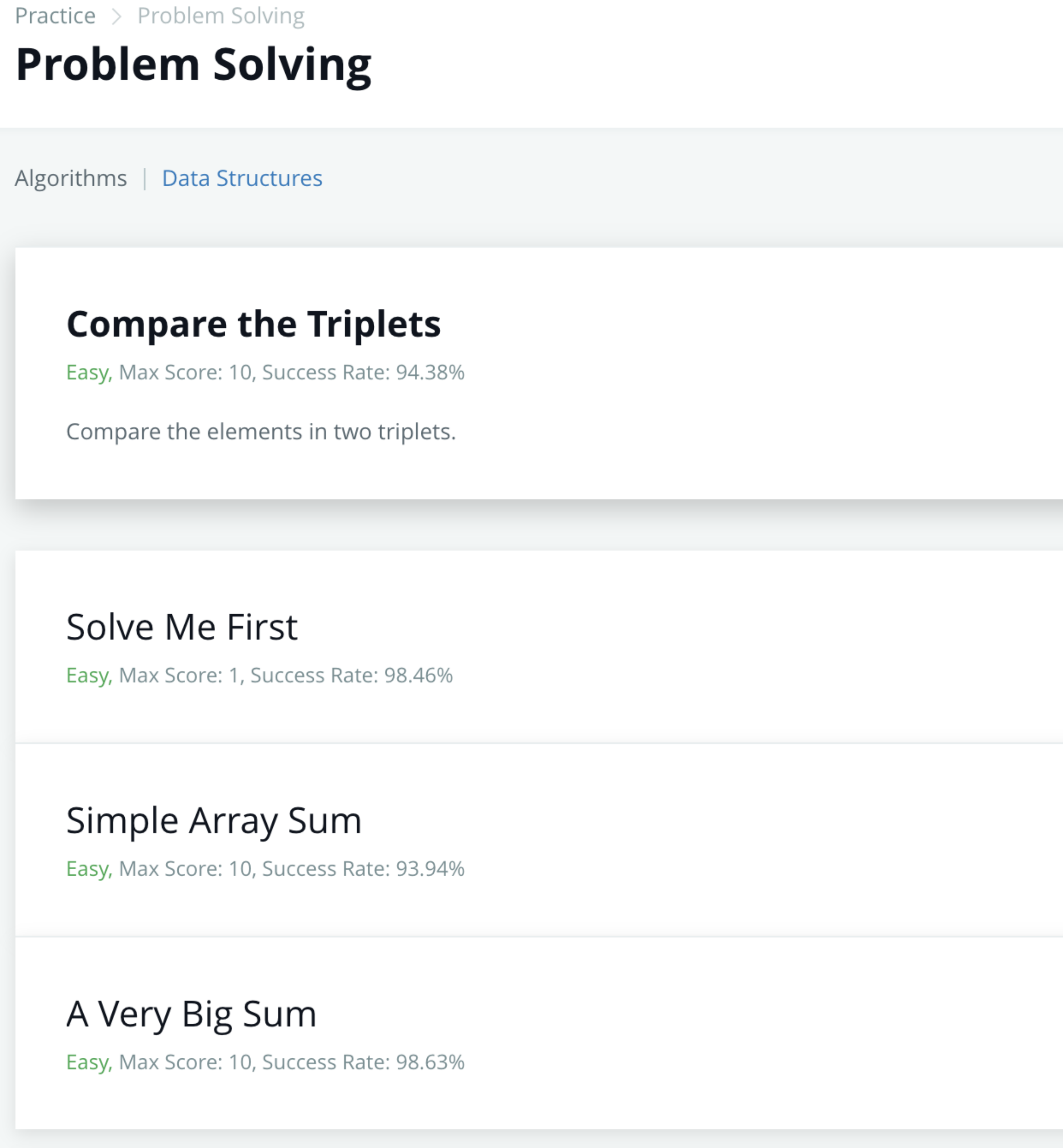


Skills Available For Practice

Algorithms

Data Structures



Practice > Problem Solving

Problem Solving

Algorithms | Data Structures

Compare the Triplets

Easy, Max Score: 10, Success Rate: 94.38%

Compare the elements in two triplets.

Solve Me First

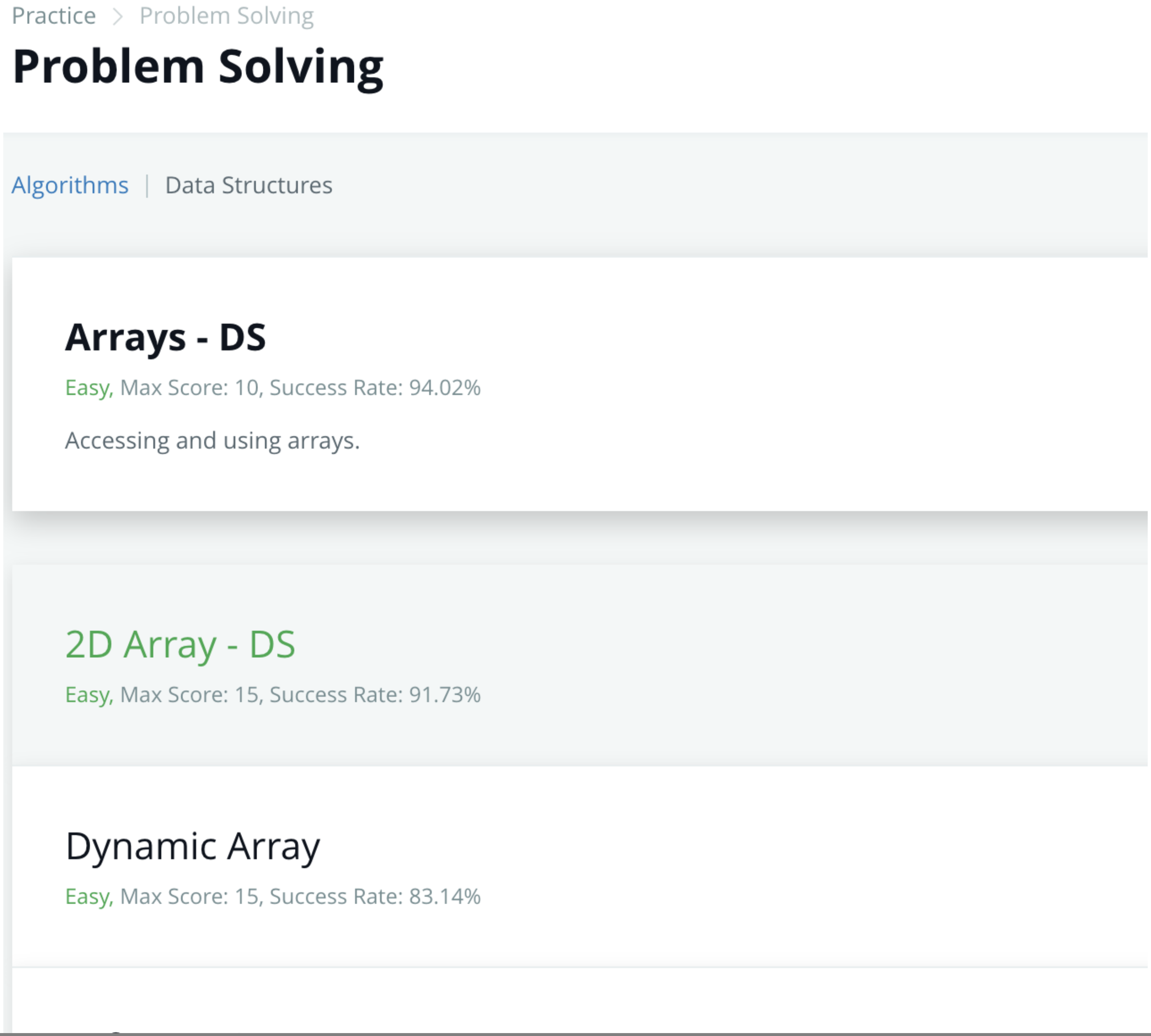
Easy, Max Score: 1, Success Rate: 98.46%

Simple Array Sum

Easy, Max Score: 10, Success Rate: 93.94%

A Very Big Sum

Easy, Max Score: 10, Success Rate: 98.63%



Practice > Problem Solving

Problem Solving

Algorithms | Data Structures

Arrays - DS

Easy, Max Score: 10, Success Rate: 94.02%

Accessing and using arrays.

2D Array - DS

Easy, Max Score: 15, Success Rate: 91.73%

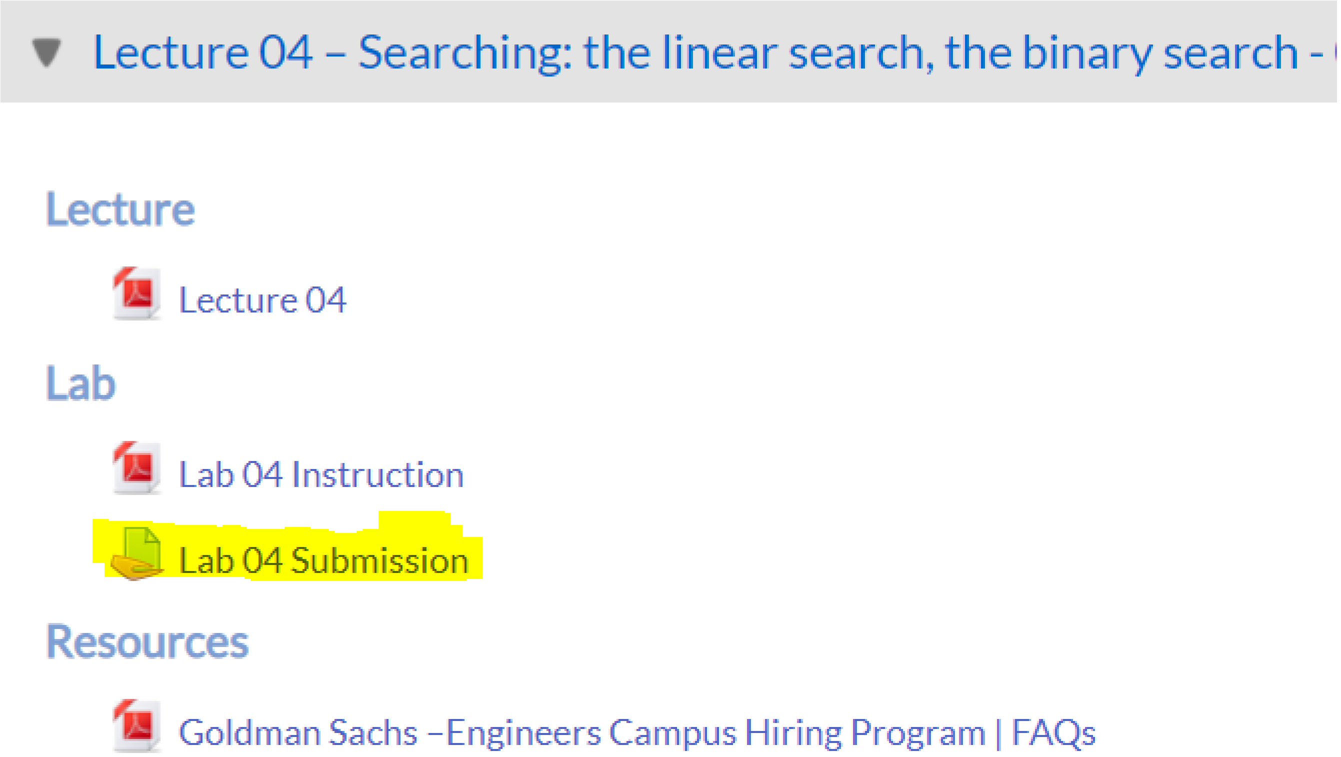
Dynamic Array

Easy, Max Score: 15, Success Rate: 83.14%

Left Rotation

Easy, Max Score: 20, Success Rate: 87.68%

These will help to complete the coursework.



▼ Lecture 04 – Searching: the linear search, the binary search -

Lecture

Lecture 04

Lab

Lab 04 Instruction

Lab 04 Submission

Resources

Goldman Sachs –Engineers Campus Hiring Program | FAQs

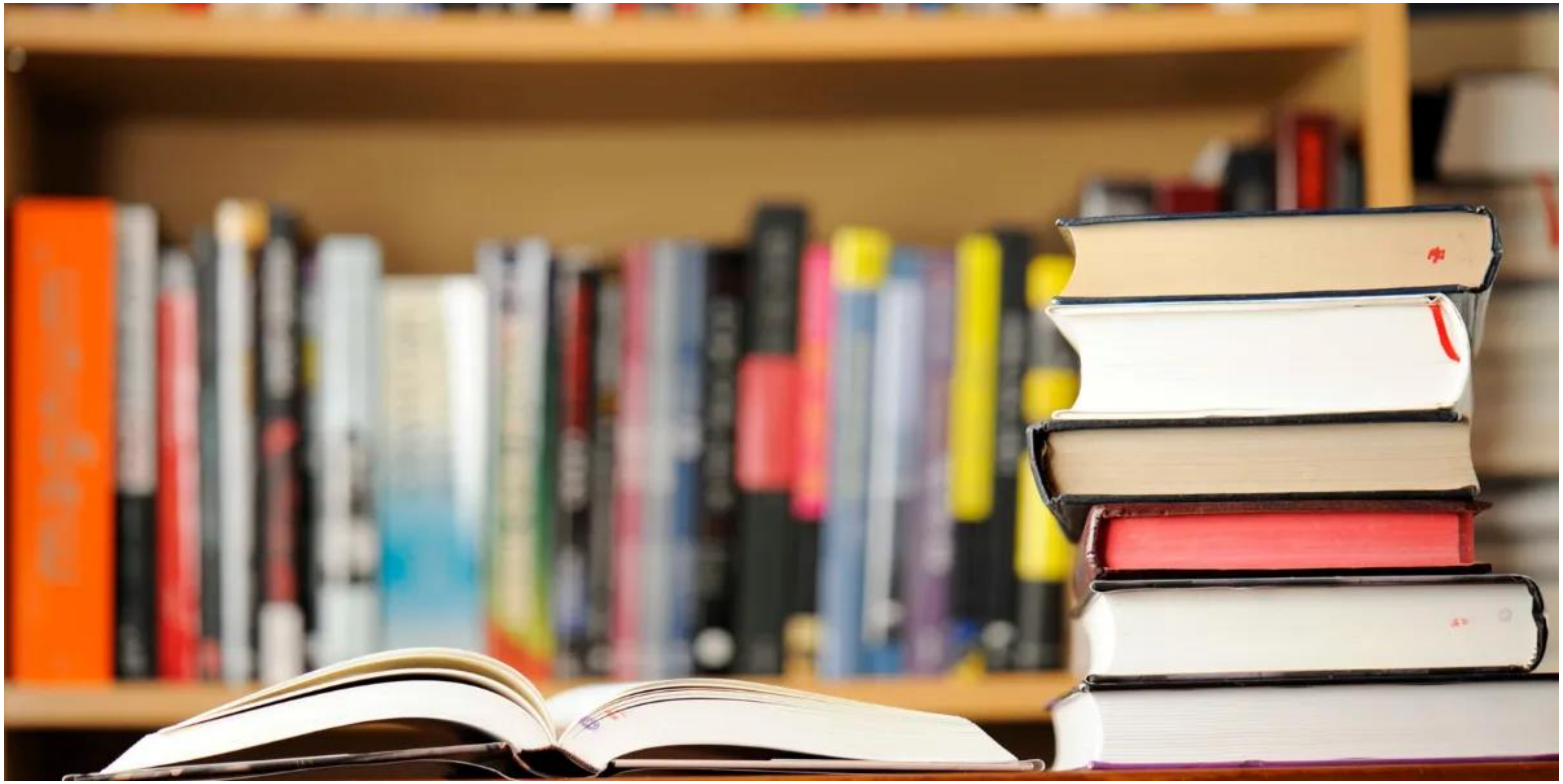
Please submit the screenshots by 16/02/2021. Instruction in Lab 04.

Quick overview

- A sequential search is O(n) for ordered and unordered lists.
- A binary search of an ordered list is O(log n) in the worst case.
- Hash tables can provide constant time searching.
- Join Hackerrank

Extra reading

- Implementation of Hashing with Python



Next week