Lecture 1 - Introduction

CPE112 - Programming with Data Structures
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What to learn?

Programming with Data Structures

- Programs manipulate data to solve problems
- Ways to organize & store information
  - Insert/delete/sort numbers: array
  - Student information: structure

Score
67
78
87
90
82
65
68

Name	Midterm	Final
Alice	7.5	67
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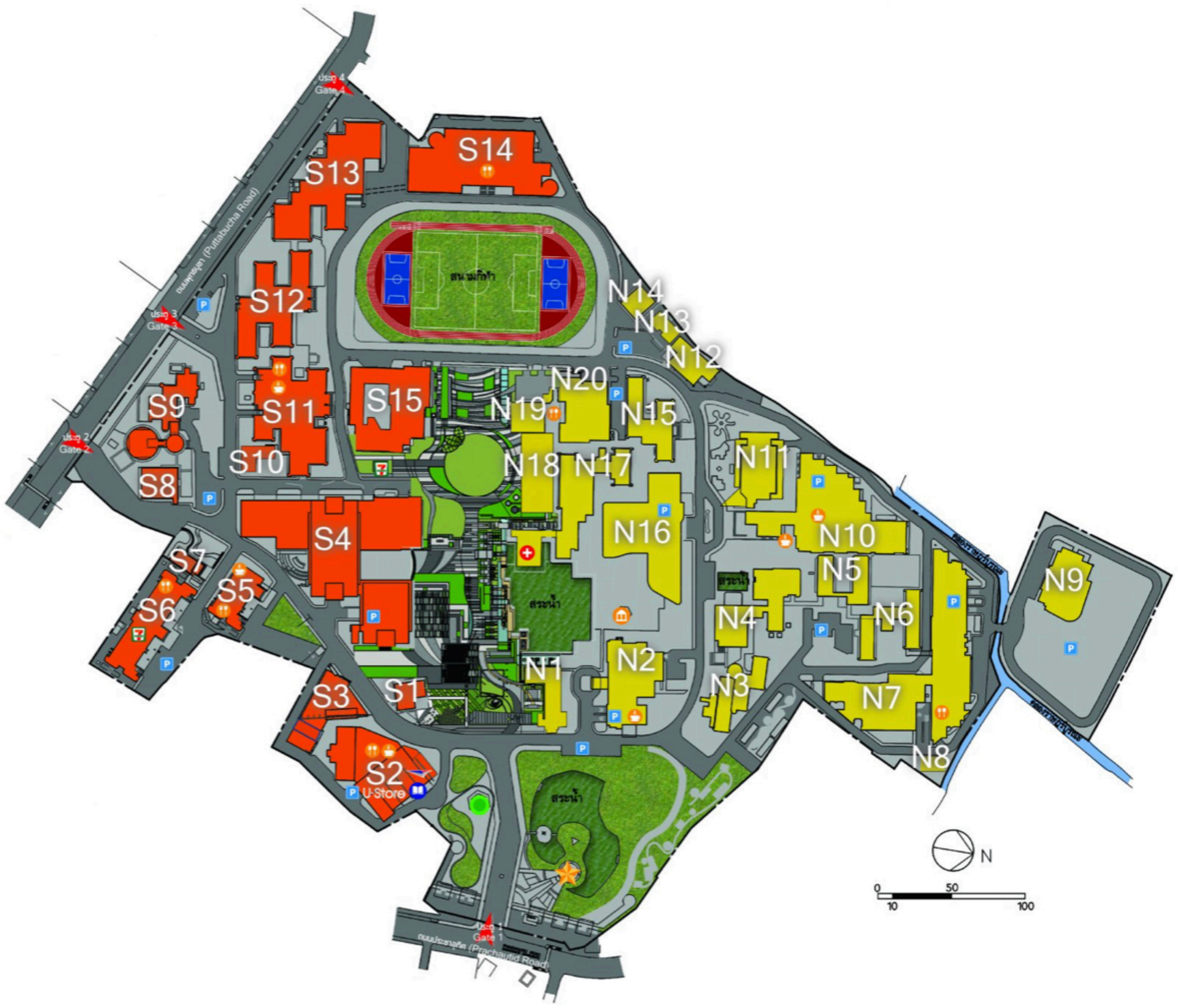
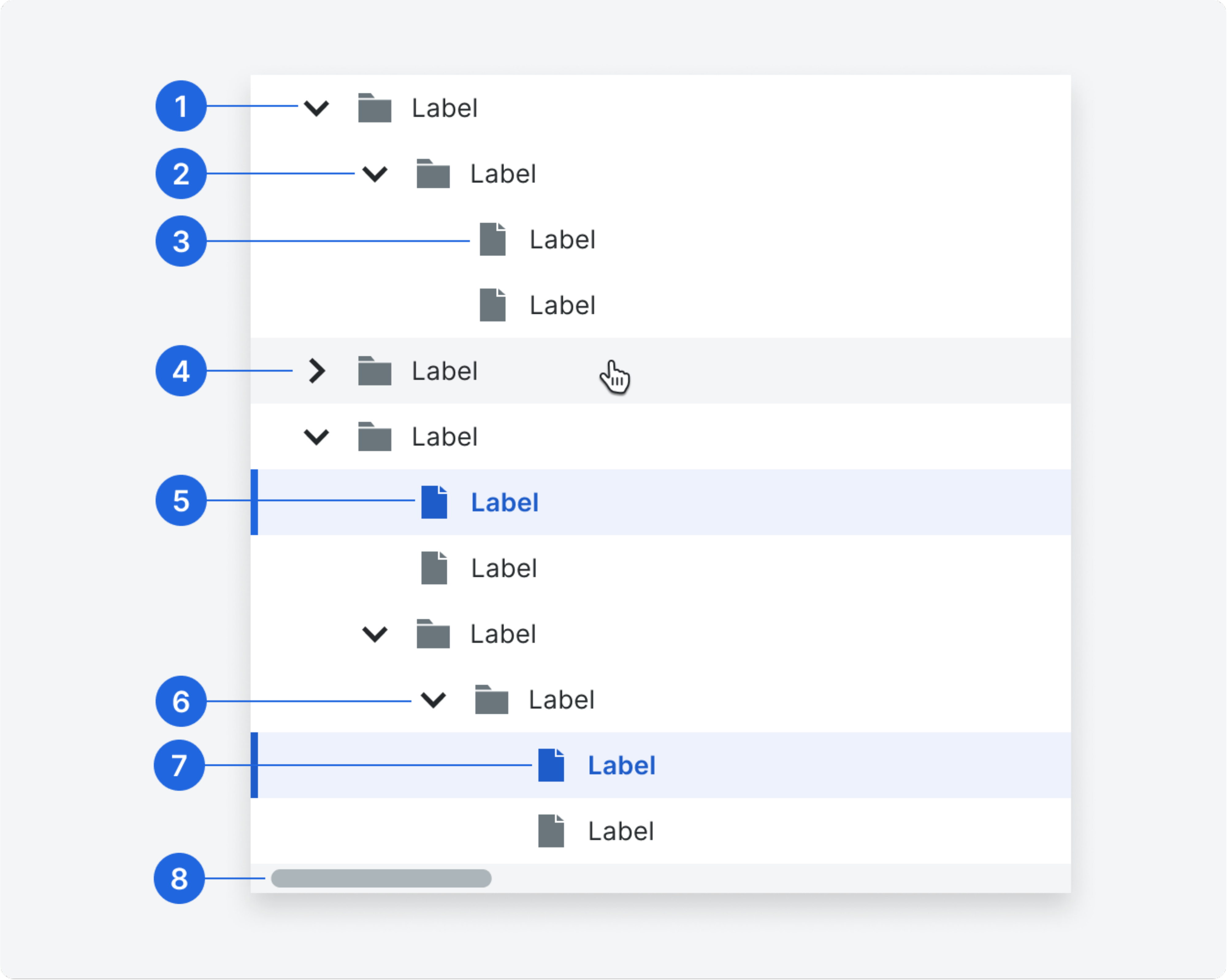
What to learn?

Programming with Data Structures



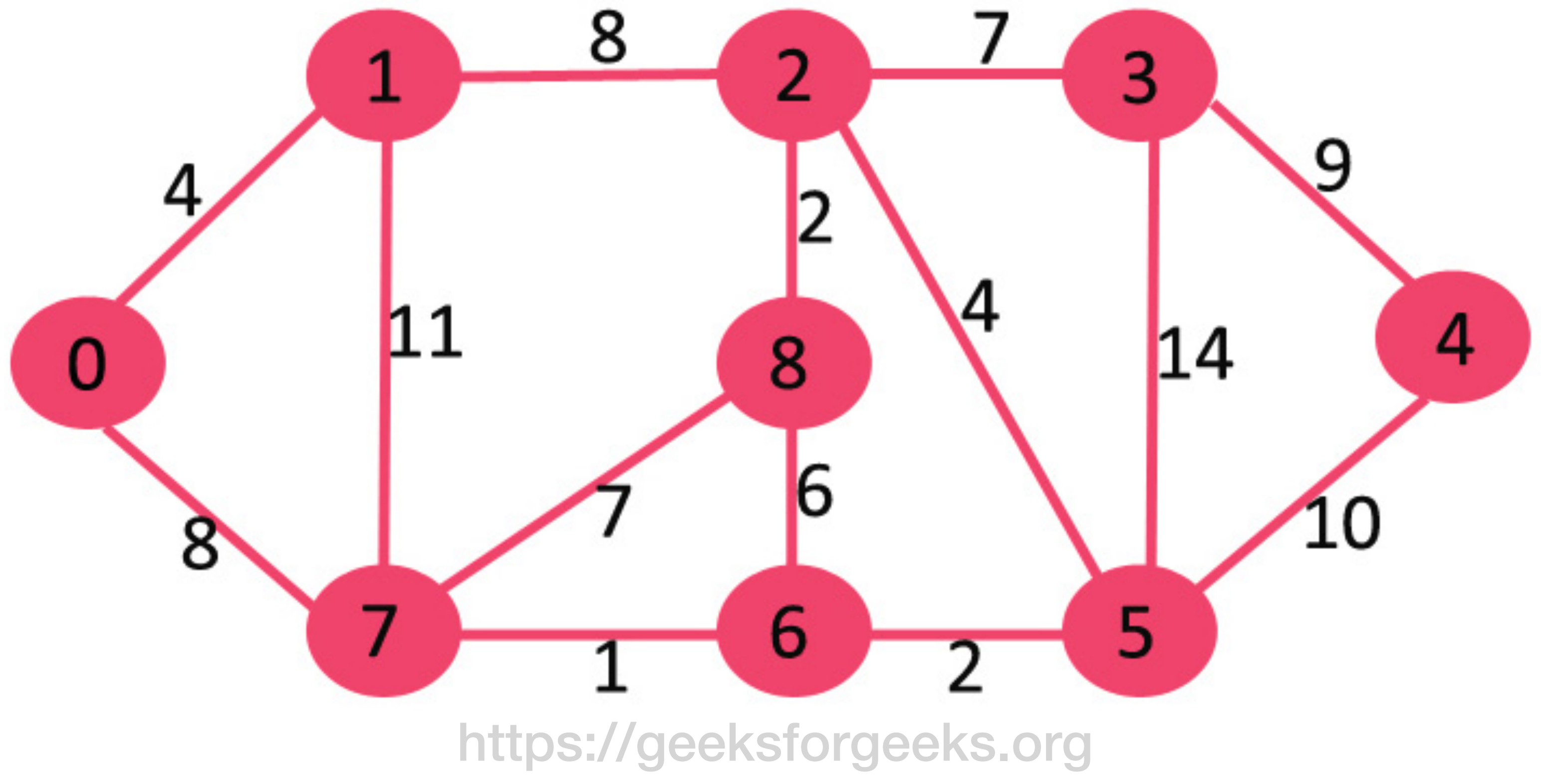


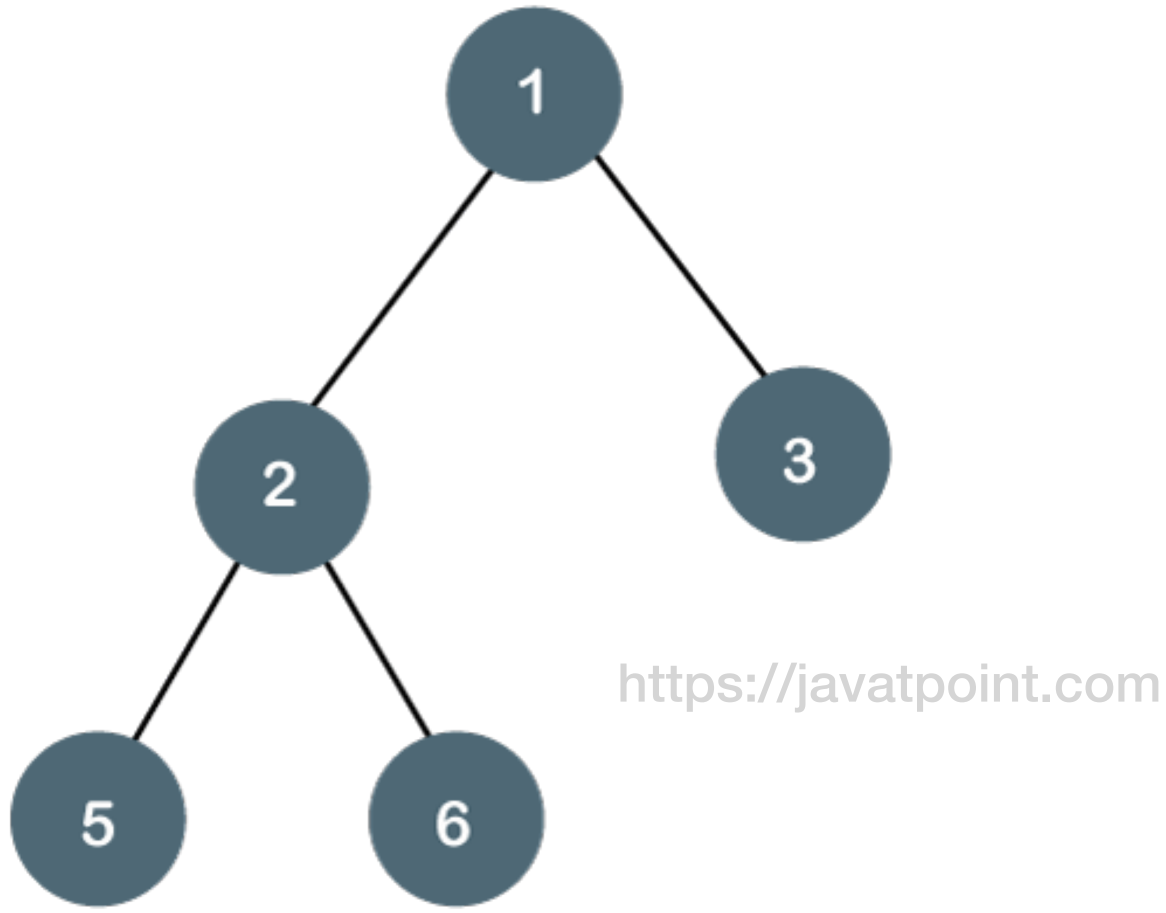
1. Expanded Folder (1st level)
2. Expanded Folder (2nd level)
3. Unselected File (2nd level)
4. Collapsed Folder (1st level) / Hover
5. Selected File (1st level)
6. Expanded Folder (3rd level)
7. Selected File (3rd level)
8. Horizontal Scrollbar

https://design.procore.com

What to learn?

Programming with Data Structures





- Important **data structures** - strategies for organizing information in a program
- Important **algorithms** - well-known methods for accomplishing particular kinds of tasks
- **Efficiency** of different data structure algorithms

Data Structure & Algorithm

Google Coding interview question via phone

Find the first recurring character

“ABCA” -> A
“BCABA” -> B
“ABC” -> NULL

Data Structure & Algorithm

Google Coding interview question via phone

Find the first recurring character

“ABCA” -> A
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“ABC” -> NULL

Your algorithm will be evaluated.

Correctness (work well)
Efficiency (minimum time & memory)
Style (easy to understand & modify)

Major Contents

Introduction	Pointer	Array	Structure
Lists	Stack & Queue	Tree	Graph
…	…	…	…

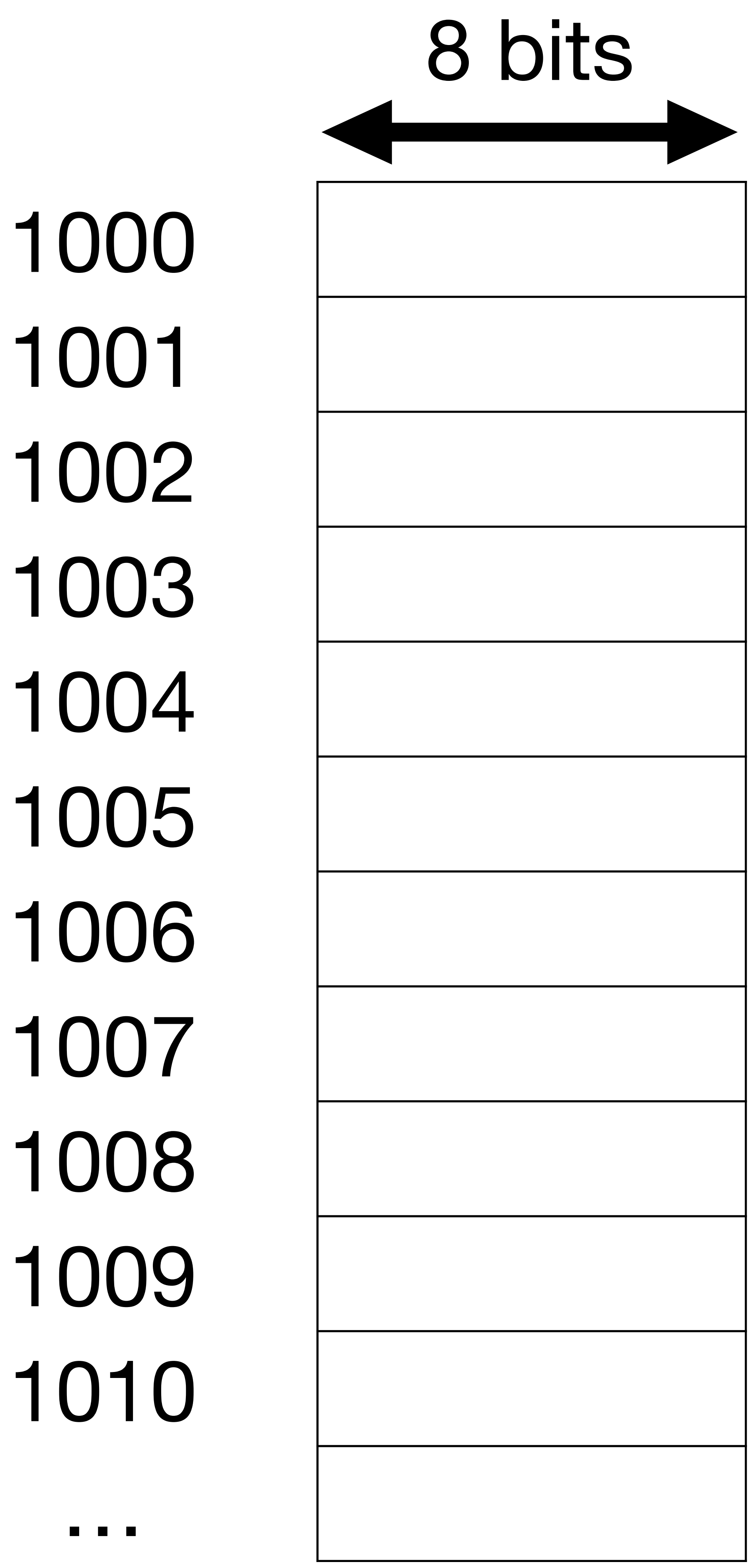
Review

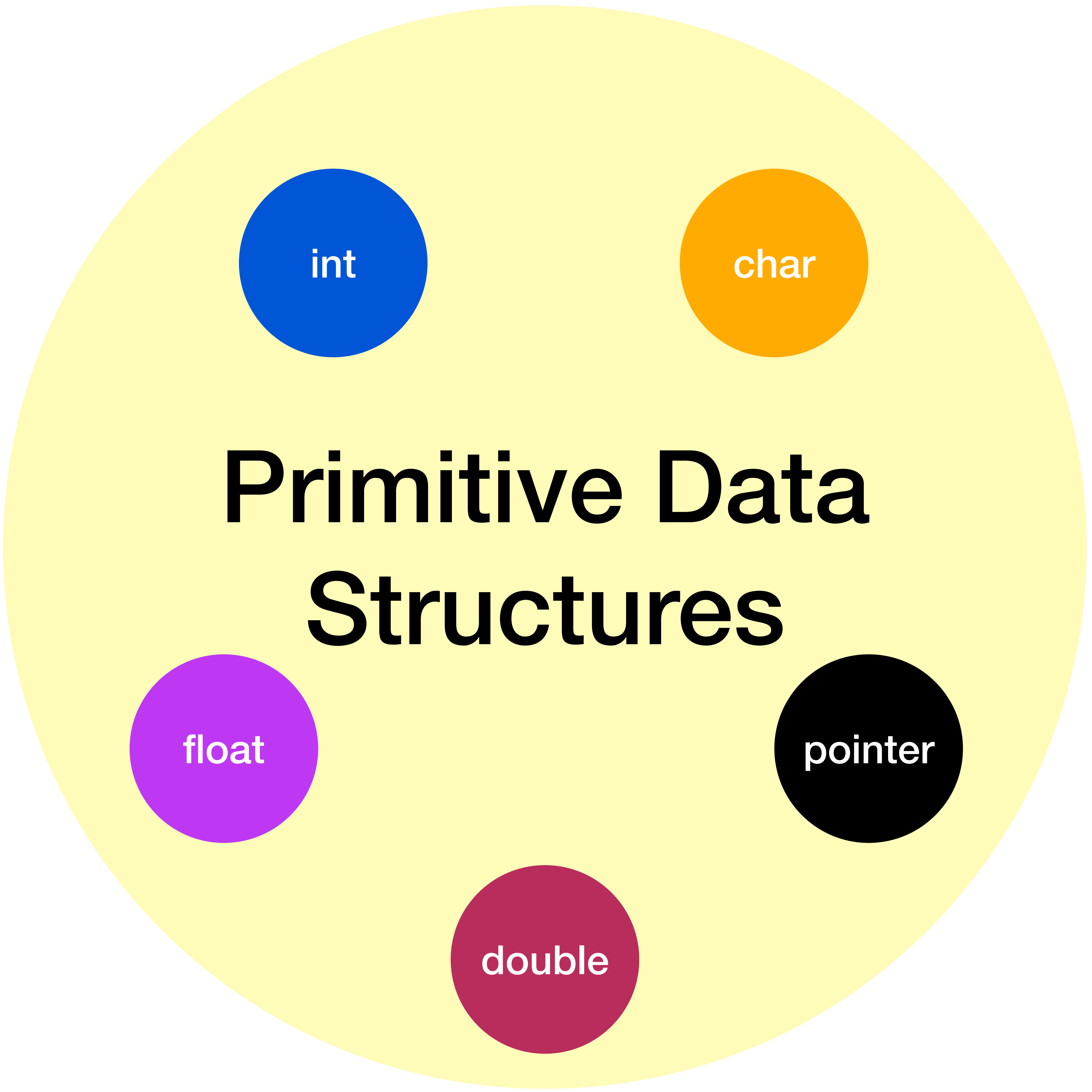
Why we learn CPE100?

- Programmers need to translate **problems** and/or **user requirements** into **source codes** that a computer can understand.
- Two questions that every programmers should solve
  - How we store data in our computer memory? => *Data Structure (CPE112)*
  - How can process the data efficiently?
    - Procedures to solve common (programming) problems => *Algorithm (CPE223)*
    - Domain specific algorithms e.g. speech recognition, image processing, data analytics => *Elective courses (CPE3xx, CPE4xx)*

Review

Memory





Review

Pointer

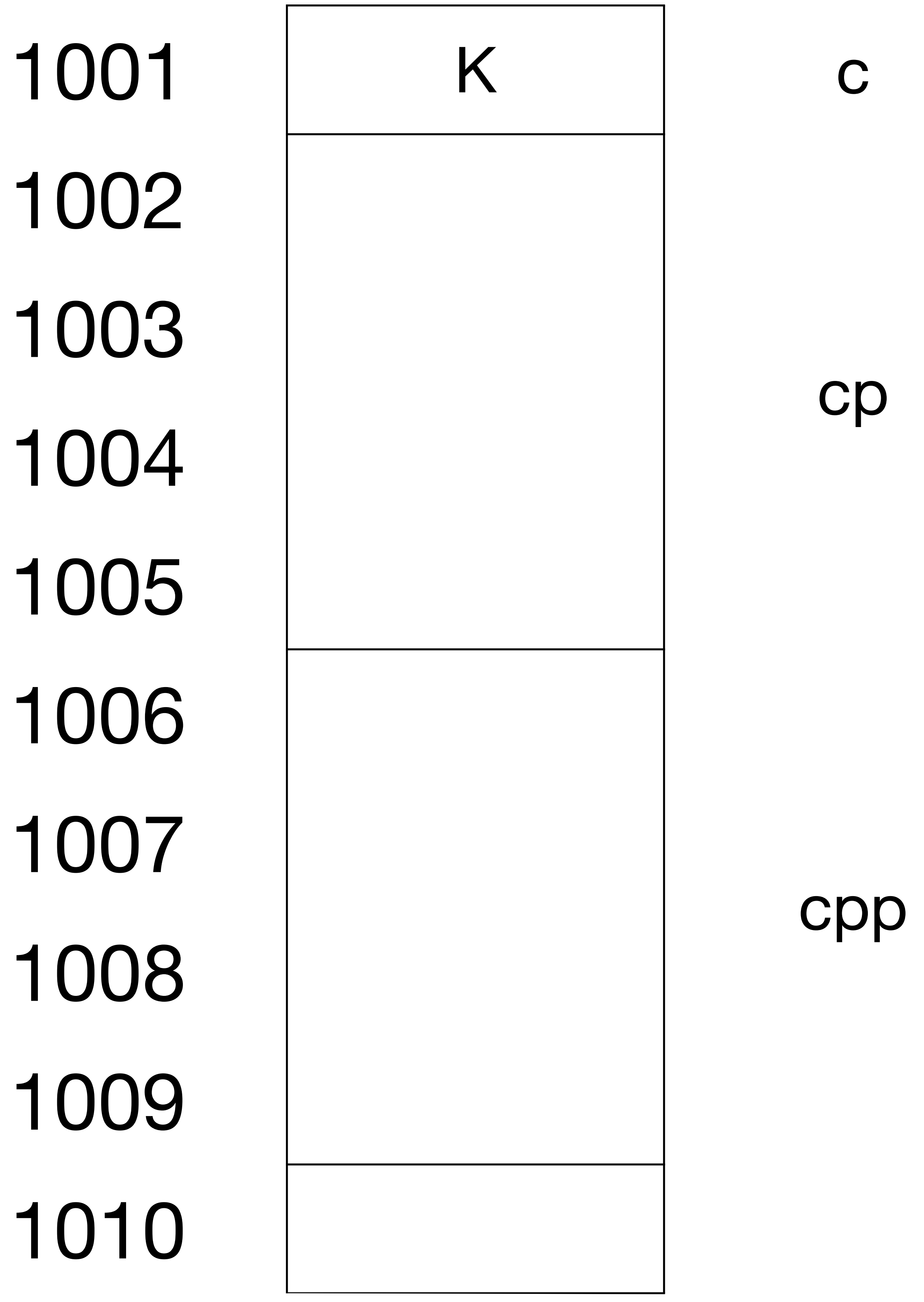
- A variable type - store the address of some value

& - Get address

**** - Look into address***

```
data-type *pointer-variable-name;
```

```
char c='K';
char *cp=&c;
char **cpp=&cp;
```



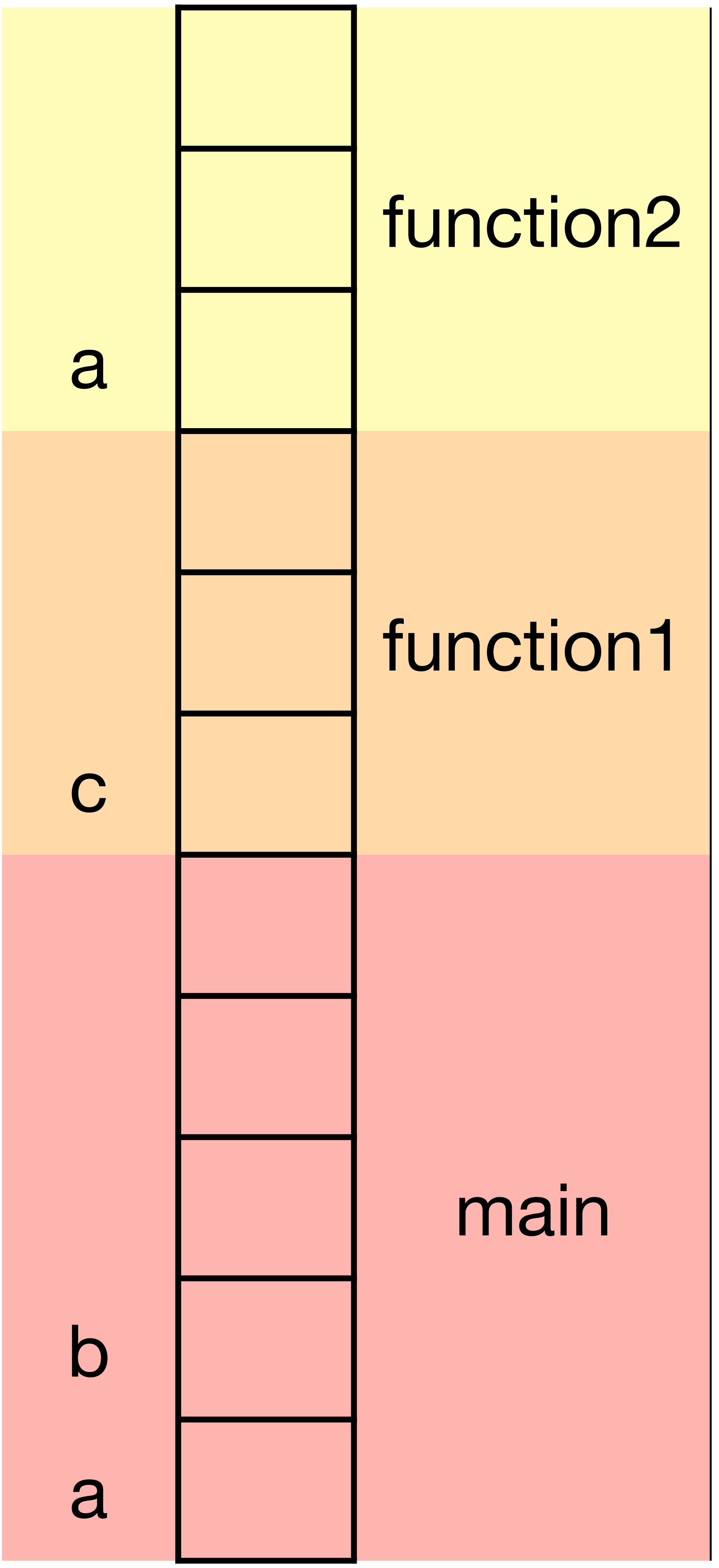
Review

Types of Memory - Stack

```
void function2()
{
  int a;
}

void function1()
{
  int c;
  function2();
}

int main ()
{
  int a,b;
  function1();
  return 0;
}
```

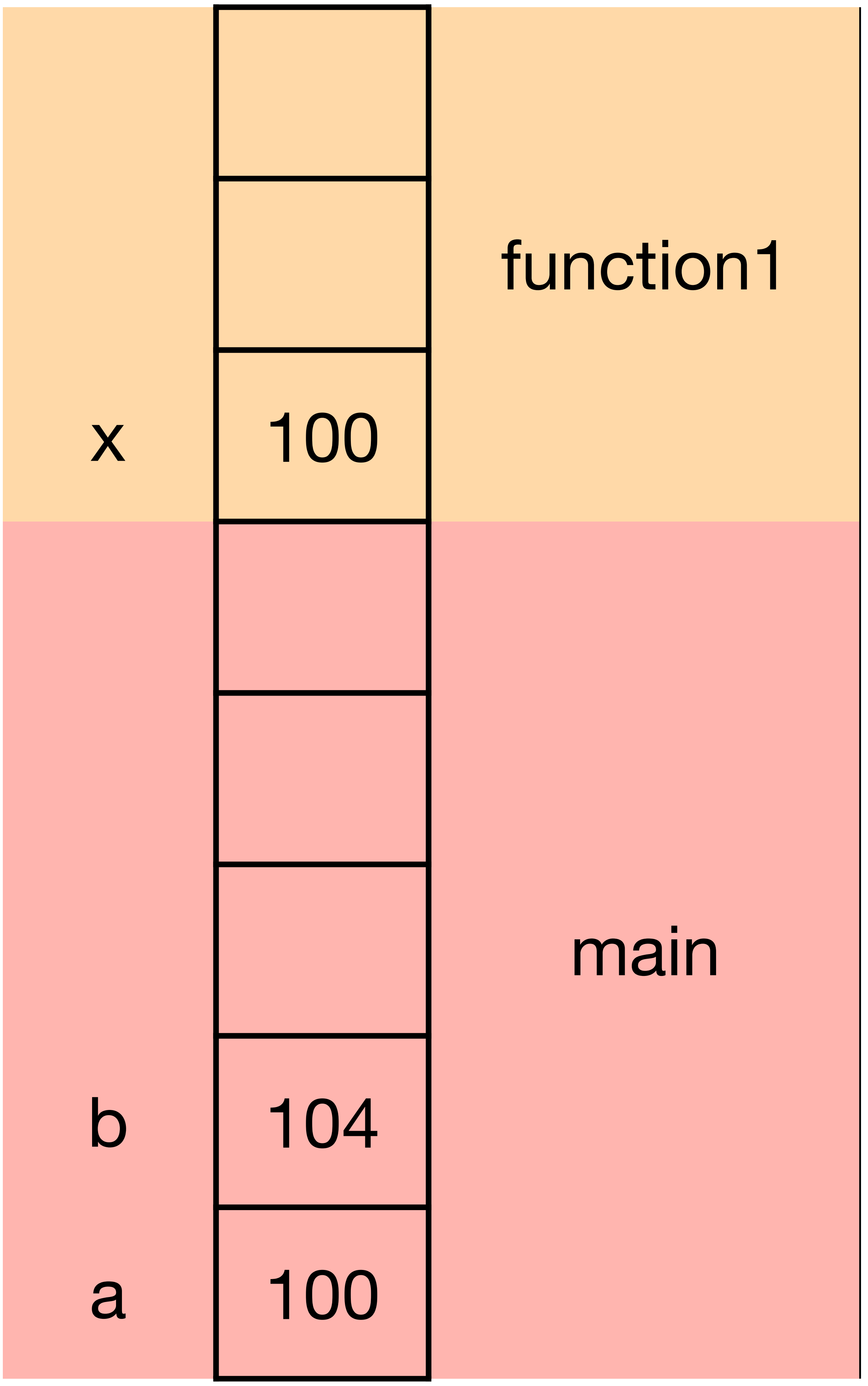


Review

Types of Memory - Heap

```
void function1(int* x)
{
  x[0] = /*…*/;
}

int main ()
{
  int *a = malloc(4);
  int *b = malloc(6);
  function1(a);
  free(a);
  free(b);
  return 0;
}
```



Review

Types of Memory

	Life cycle (How & when they are allocated/deallocated)	Scope (Where they can be accessed)
Stack	**Allocate** - program enters the function that they are declared **Deallocate** - program leaves the function	Can be accessed and will have valid value within their own block
Static	**Allocate** - program starts running **Deallocate** - program exits	Can be accessed by any code in C module
Dynamic	**Allocate** - call calloc **Deallocate** - call free	Can be accessed and will have valid values anywhere in the program, by passing around variables that hold the start address

Review

Dynamic Memory Allocation

Stack Memory

1000	H
1001	i
1002	\0
1003	C
1004	P
1005	E
1006	1
1007	1
1008	2
1009	\0
1010	
…	

Example:

char word1[3] = “Hi”;
char word2[10] = “CPE112”

“Hi” -> “Hello”

Heap Memory

calloc
free

Example:

```
#define ARRAYSIZE 300
int* myValues = calloc(ARRAYSIZE,sizeof(int));
```

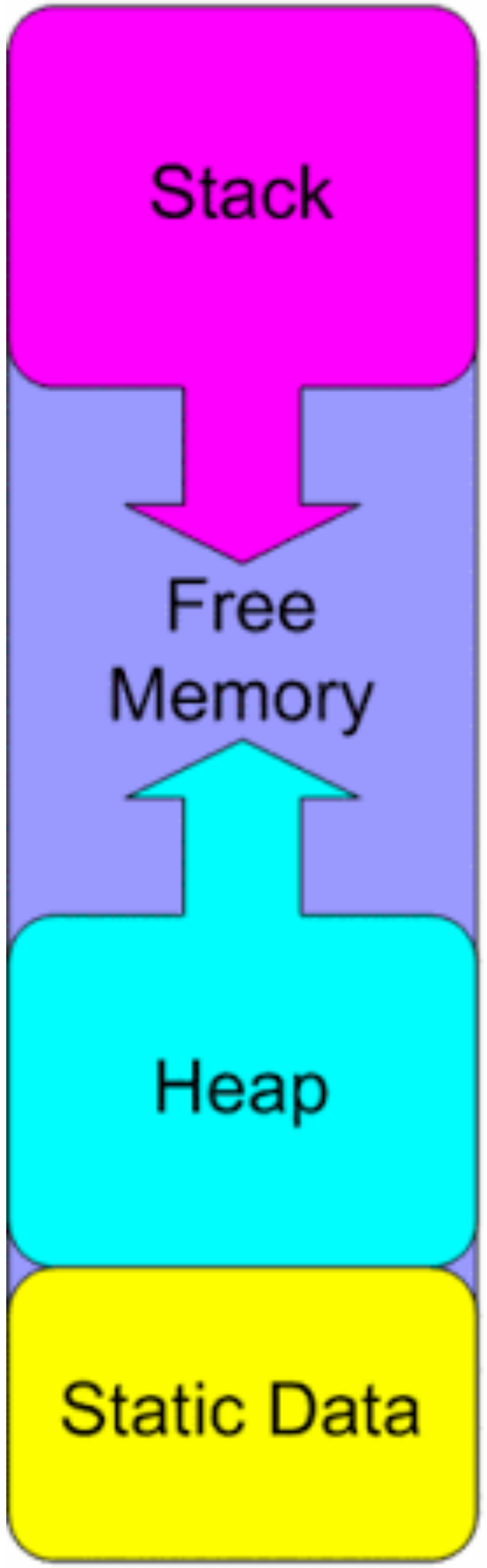
Address

Review

Dynamic Memory Allocation

calloc
but not free

Memory crash!!!



https://esp8266.com

Review

Structure

- Create own custom data type that is a composition of multiple other data types

Name	Midterm	Final
Alice	7.5	67
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Carol	6.0	87
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```
typedef struct {
   char name[100];
   float midterm;
   int final;
} student_info;
```

Review

Structure

```
void selectionSort (student_info data[], int count)
{
  int i, j, minPos;
  for (i = 0, i<count-1; i++)
  {
    minPos = i;
    for (j=i+1; j<count; j++)
    {
      if (data[j].final < data[minPos].final)
        minPos = j;
    }
    swap(&data[i], &data[minPos]);
  }
}
```

```
void swap (student_info *x,
student_info *y)
{
  student_info tmp;
  tmp = *x; *x=*y; *y=tmp;
}
```

Data Structure

- A data structure - a way to organize information stored in computer memory.
- Different kinds of data structures works better for different sorts of problems.
- Appropriate structure -> Good solution

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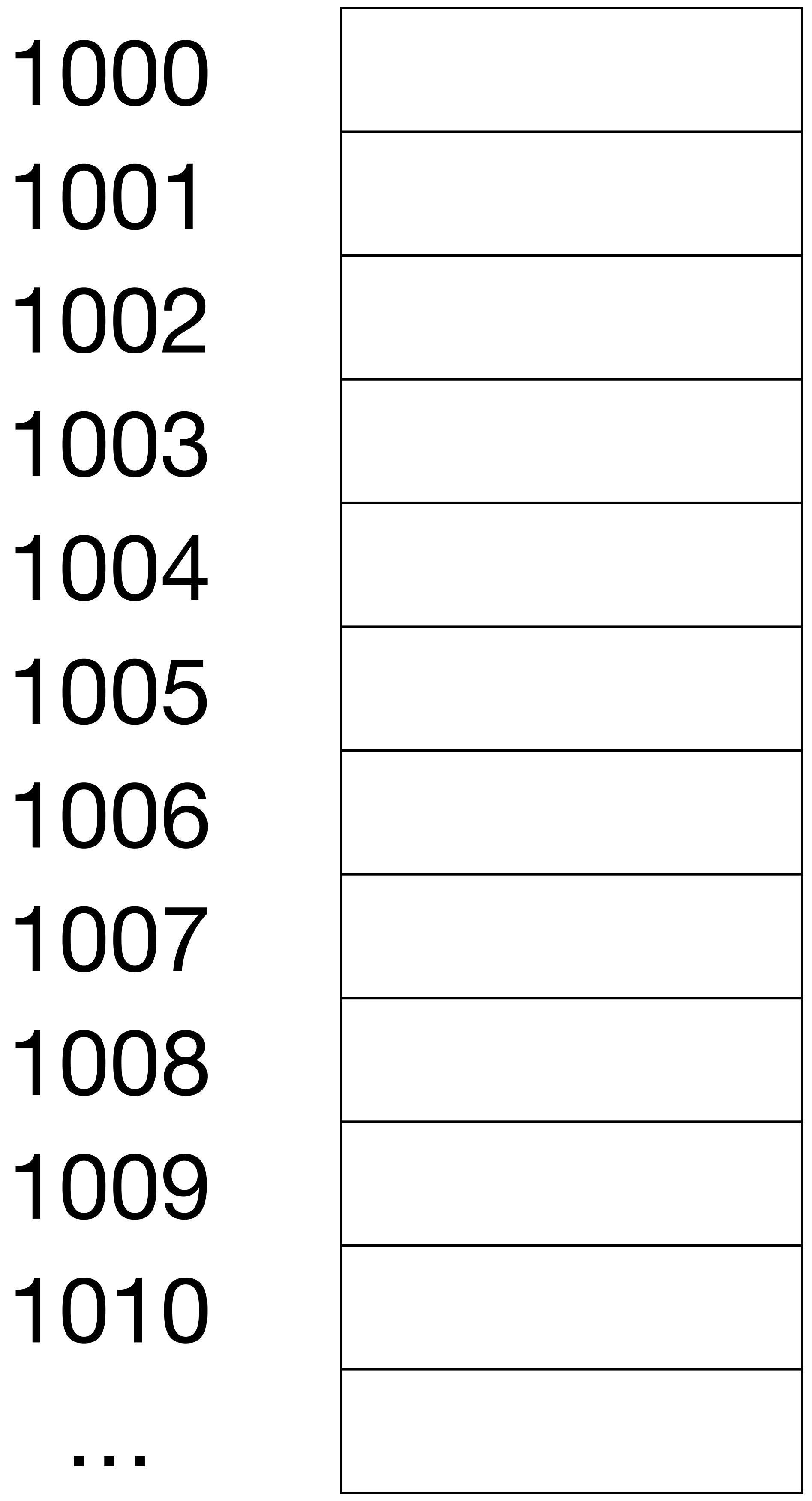
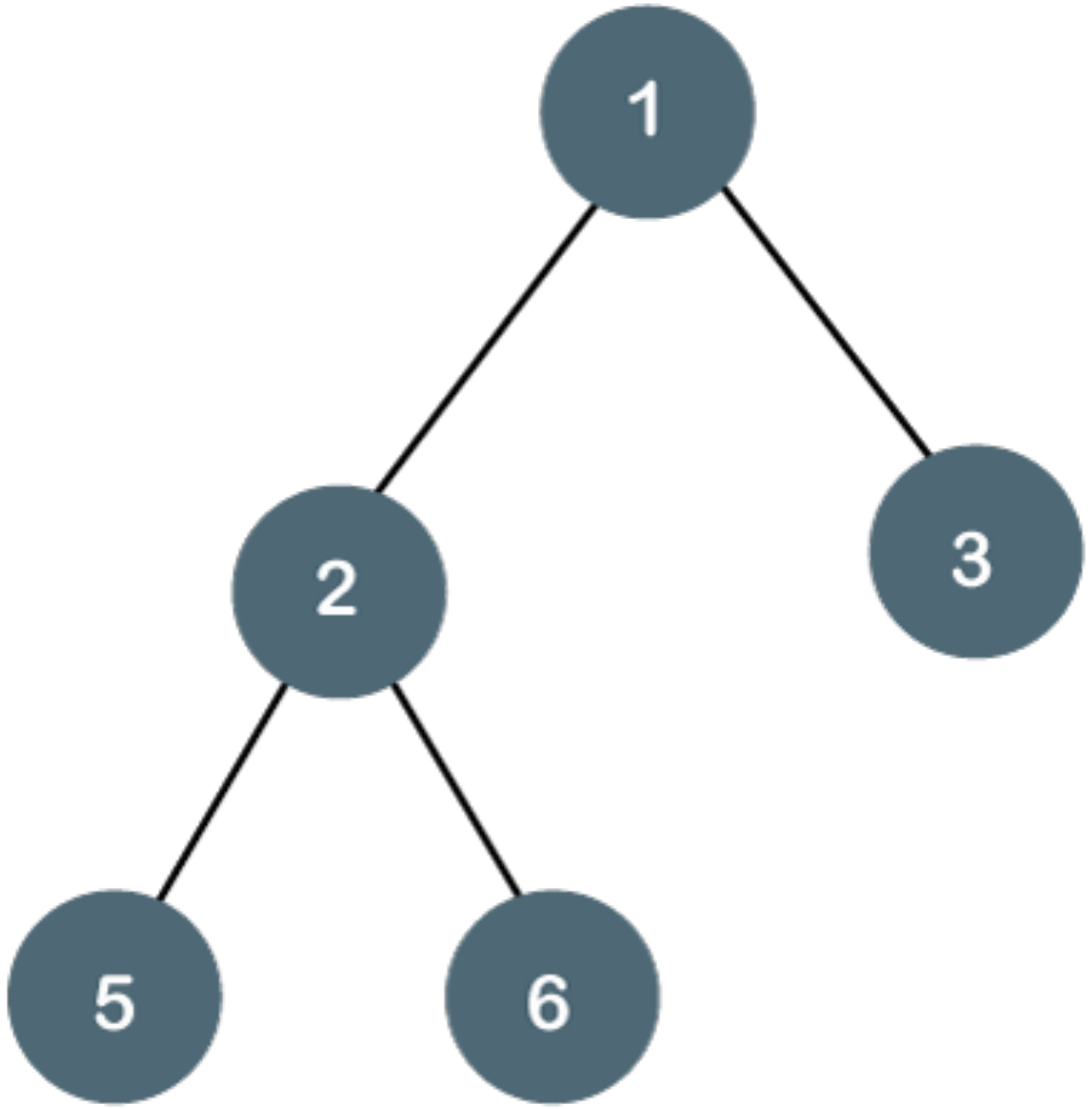
Data Structure

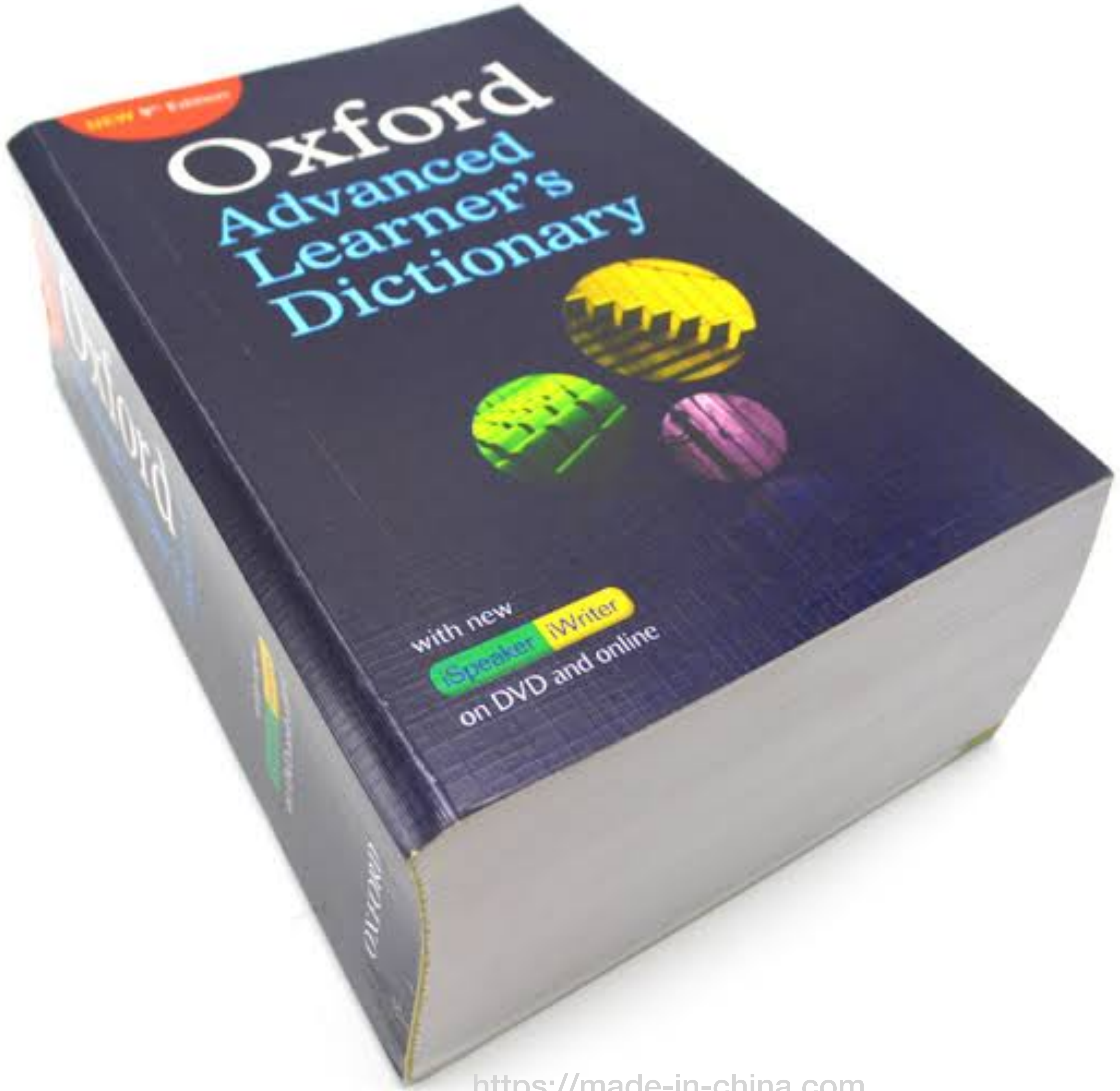
- Creating a data structure
  - Ability to refer to different memory locations
  - Stitch them together into a custom shape





Data Structure & Algorithm

Example



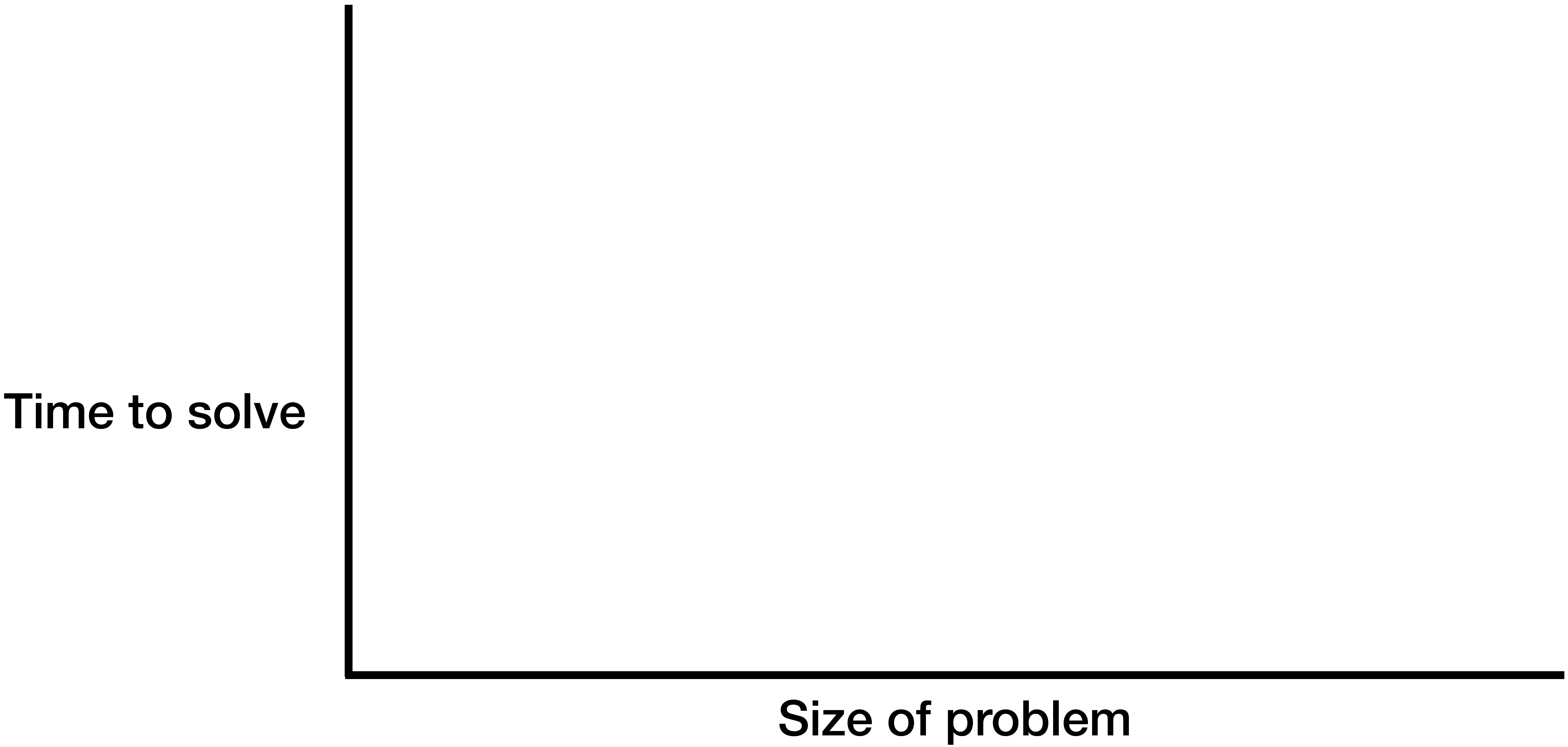
https://made-in-china.com

How to find "Structure"?

Algorithm Efficiency

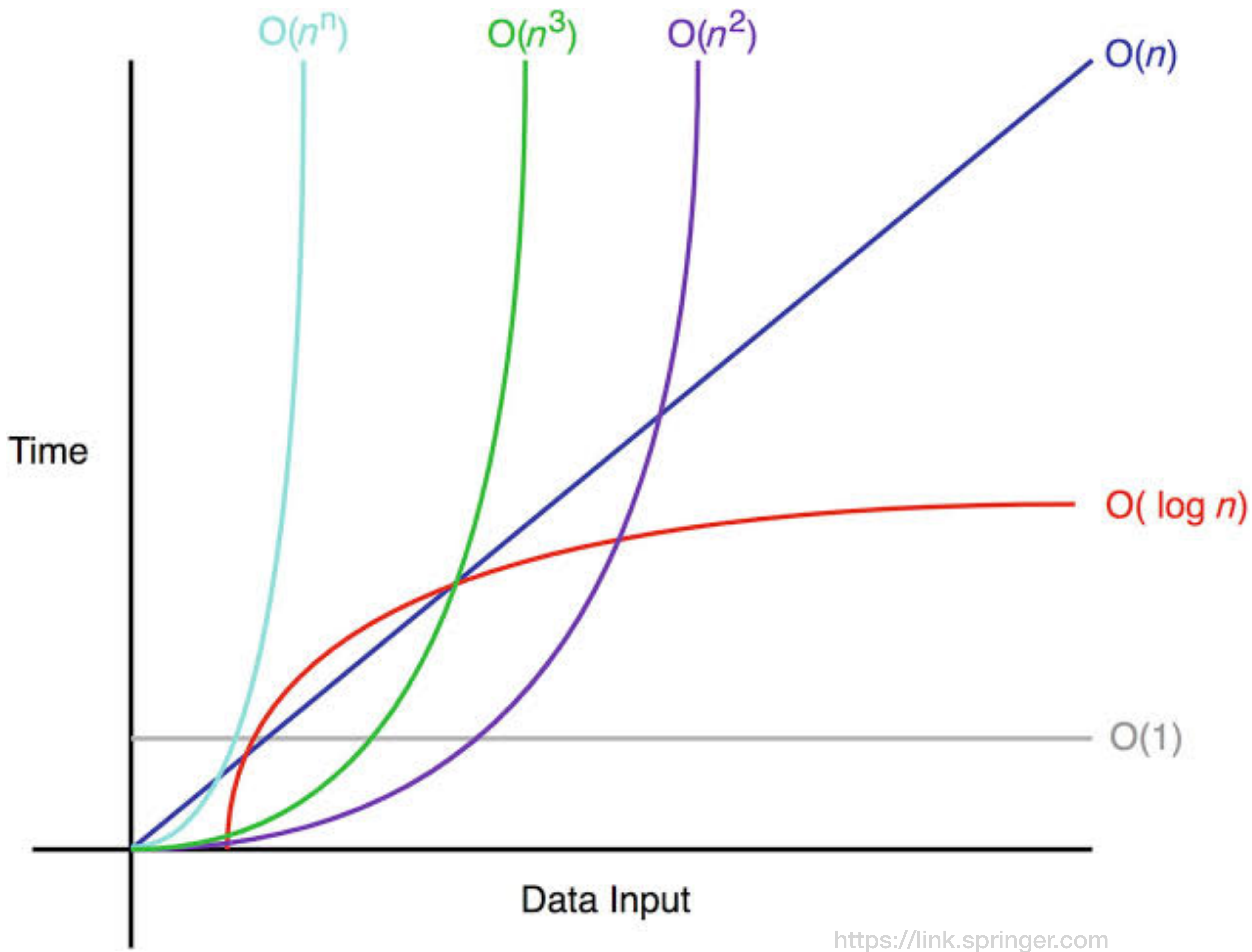
	#operations for 1 page	#operations for 100 page	#operations for 1000 page	…
Method#1				
Method#2				
…				

Algorithm Efficiency

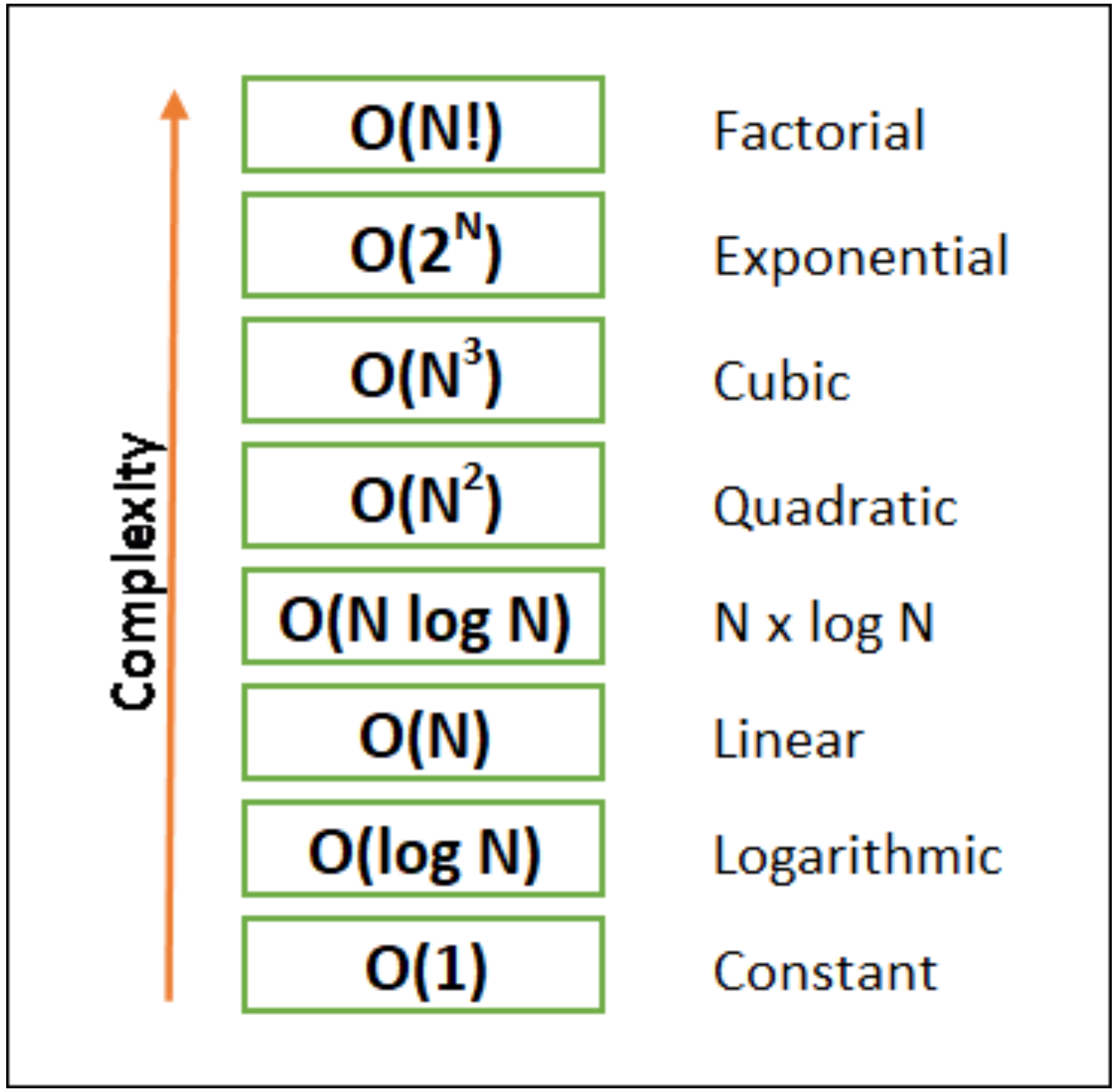


Algorithm Efficiency

Big O Notation



https://link.springer.com



https://towardsdatascience.com

Algorithm Efficiency

Big O Notation

1. Understand how the algorithm works
2. Identify a basic unit of the algorithm to count
3. Map growth of count from step 2 to appropriate Big O class

Algorithm Efficiency

Big O - Examples

1	x = 5 + (5 * 5);	O(…)
2	for (i = 0; i < N; i++) printf(“%d”, i);	O(…)

3	for (i = 0; i < N; i++)
	for (j = 0; i < N; i++)
	printf(“%ld”, i*j);
		O(…)

4	x = 5 + (5 * 5);
	for (i = 0; i < N; i++)
	printf(“%d”, i);
	for (i = 0; i < N; i++)
	for (j = 0; i < N; i++)
	printf(“%ld”, i*j);
		?

Algorithm Efficiency

Big O Definition

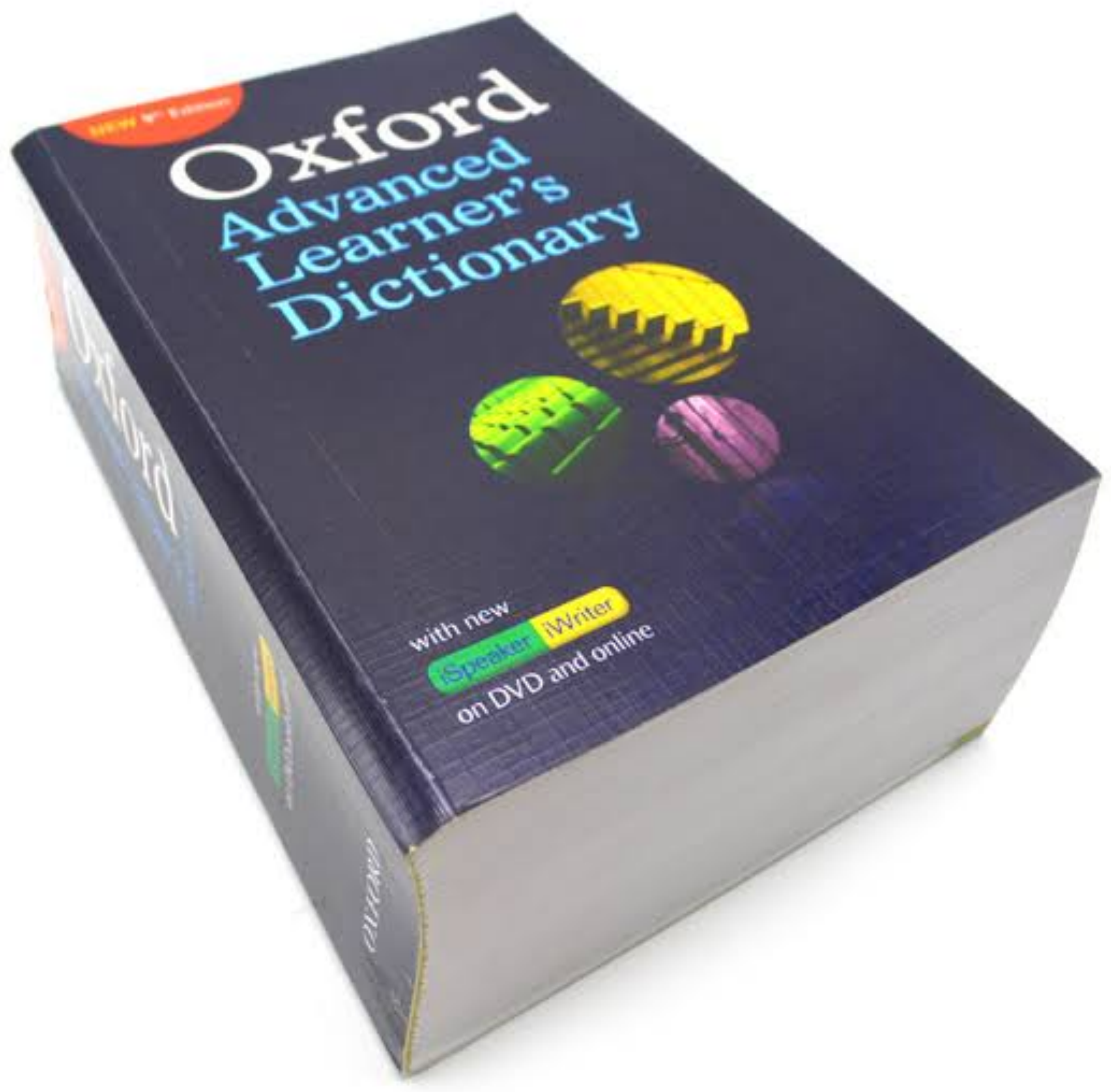
Let f(n) and g(n) be functions from positive integers to positive reals.

*f(n) = O(g(n)) if there is a constant c > 0 such that f(n) $\leq$ c*g(n) for large n*

นิยาม 1: f(n) และ g(n) เป็นฟังก์ชันซึ่งมีโดเมนเป็นเลขจำนวนเต็มบวก และมี ranges เป็นจำนวนจริงบวก
<u>สามารถเขียนได้เป็น</u>
f(n) = O(g(n)) ถ้ามีค่าคงที่บวก c ที่ทำให้ f(n) $\leq$ c*g(n) เป็นจริงทุกค่าสำหรับ x ที่เป็นจำนวนเต็มบวก

Algorithm Efficiency

Big O - Examples



Find “Ant”, “List”, “Zombie”, …

Algorithm Efficiency

Cases

Find character ‘A’ in a given string length n

Best case $C(n) = 1$

Worst case $C(n) = n$

Average case

$$
\begin{aligned}
C(n) &= (1+2+3+\ldots+n)1/n \\
&= [n(n+1)/2] * [1/n] \\
&= (n+1)/2
\end{aligned}
$$

Algorithm Efficiency

Big O

Complexity Summary of Array Sorting Algorithms

Algorithm	Time Complexity		
	Best	Average	Worst
Quicksort	Ω(n log(n))	Θ(n log(n))	O(n^2)
Mergesort	Ω(n log(n))	Θ(n log(n))	O(n log(n))
Timsort	Ω(n)	Θ(n log(n))	O(n log(n))
Heapsort	Ω(n log(n))	Θ(n log(n))	O(n log(n))
Bubble Sort	Ω(n)	Θ(n^2)	O(n^2)
Insertion Sort	Ω(n)	Θ(n^2)	O(n^2)
Selection Sort	Ω(n^2)	Θ(n^2)	O(n^2)
Tree Sort	Ω(n log(n))	Θ(n log(n))	O(n^2)
Shell Sort	Ω(n log(n))	Θ(n(log(n))^2)	O(n(log(n))^2)
Bucket Sort	Ω(n+k)	Θ(n+k)	O(n^2)
Radix Sort	Ω(nk)	Θ(nk)	O(nk)
Counting Sort	Ω(n+k)	Θ(n+k)	O(n+k)
Cubesort	Ω(n)	Θ(n log(n))	O(n log(n))

https://tonysispblog.wordpress.com

Designing an Algorithm

- Perform operations on the stored data contained in data structures.
- **Modularization process** - a complex algorithm is often divided into smaller units called modules.
  - Top-down approach - dividing the complex algorithm into one or more modules
  - Bottom-up approach - designing the most basic or concrete modules and then proceed towards designing higher level modules

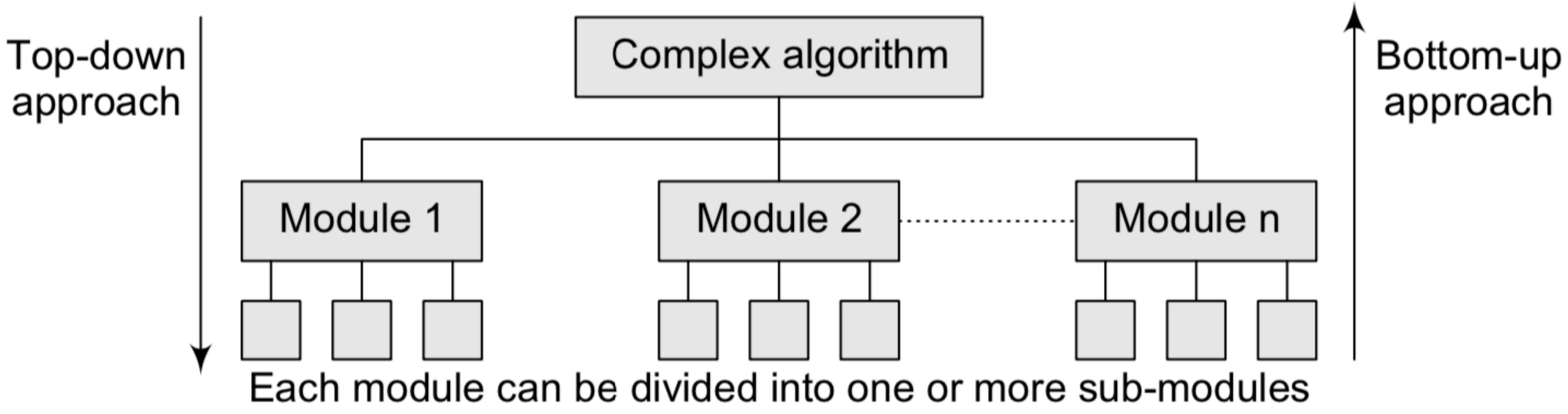


Figure 2.9 Different approaches of designing an algorithm

Wrap up

- Course introduction
- What to learn?
- Data structures & algorithms
- Review CPE100
- Big O