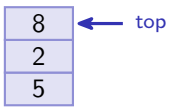
Data Types & Structures

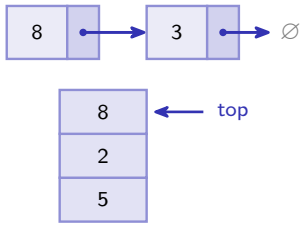
AS Computer Science ▪ Topic 10

A-Level Computer Science



What we will cover

1. Data types & records
2. Arrays
3. Files
4. Stacks, queues, linked lists
5. Implementing with arrays
6. Recap



1 Data types and records

Data types and records

Pick the smallest precise **data type** 数据类型:

- `INTEGER` – a whole number: counts, indexes, IDs
- `REAL` – has a fractional part: money, measurements
- `STRING` – characters in quotes, for text
- `CHAR` – one character; `BOOLEAN`; `DATE`

A **record** 记录 groups several types under one name (dot notation `Item1.Category`).

record TStockItem

`ItemID : INTEGER`
`Category : STRING`
`ItemCost : REAL`
`InStock : BOOLEAN`

one name holds four fields of different types

`reach one field: Item1.Category`

Choosing a data type, and when to use a record

`INTEGER` / `REAL`	a whole number; one with a fractional part
`CHAR` / `STRING`	a single character; a sequence of them
`BOOLEAN`	`TRUE` or `FALSE` – for flags
`DATE`	so dates sort and compare correctly
a record structure 记录结构	a group of fields of *different* types, under one name
when to use one	when the values always belong together – a customer, a stock item. Use separate variables for unrelated values

An array holds many of the same type; a record holds one of several types. Most real data needs an array *of* records.

2 Arrays

Arrays

An **array** 数组 holds many values of the same type under one name, reached by an **index** 索引. A **record** 记录 is the opposite: different types, always belonging together.

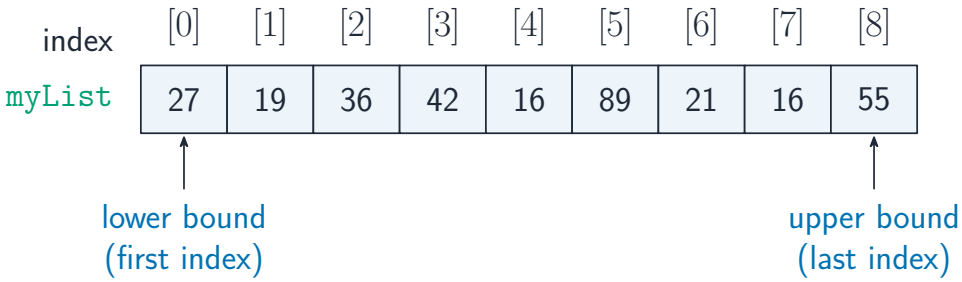
1-D

2-D – `[row, column]`

2	7	4
2	7	4

1-D arrays

One index. `Marks[3]` is the third element – but check the lower bound: Cambridge pseudocode usually starts at 1, most languages at 0.



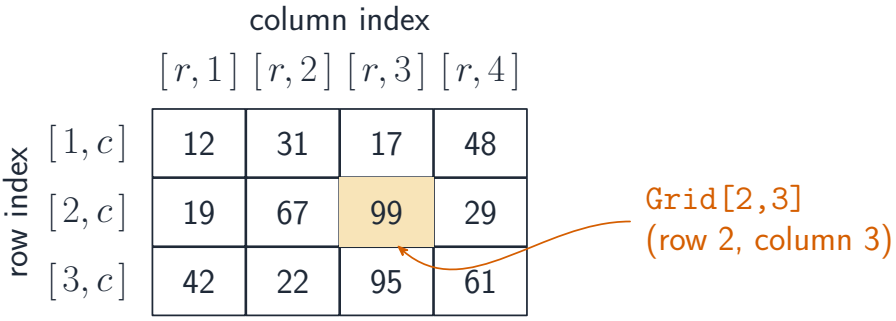
Array vocabulary, and the standard sweep

index 索引	the position of an element within the array
bounds 边界	the lowest and highest valid indices – going outside them is an error
dimension 维度	how many indices are needed: 1-D for a single sequence, 2-D for a table
a 2-D array	the first index is the row, the second the column; nested loops visit every cell
to traverse 遍历	visit every element in turn
the sweep pattern	to find a sum, count, maximum or minimum, set a running variable before the loop and update it inside

The running variable must be initialised outside the loop. Inside, it resets every pass – the single commonest bug in this topic.

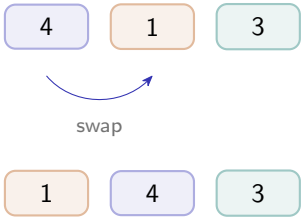
2-D arrays: a table

Two indices, row first: `Grid[2,5]` is row 2, column 5.



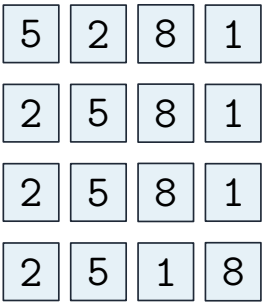
Searching and sorting

Linear search walks from the start until it finds the target – works on any list, $O(n)$. **Bubble sort** swaps adjacent pairs that are out of order, so the largest "bubbles" to the end each pass – $O(n^2)$.



One pass of a bubble sort

One pass of a bubble sort: adjacent pairs are compared and swapped, bubbling the largest value to the end



Worked example: find the largest

```
DECLARE Marks : ARRAY[1:4] OF INTEGER
Max ← Marks[1]
FOR i ← 2 TO 4
  IF Marks[i] > Max THEN
    Max ← Marks[i]
  ENDIF
NEXT i
OUTPUT Max
```

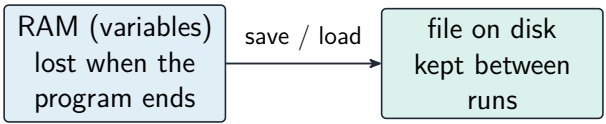
[1]	[2]	[3]	[4]
7	3	9	2

i	Marks[i]	Max
–	–	7
2	3	7
3	9	**9**
4	2	9

output: **9**

Start `Max` at the first element, not at 0 – then compare from the second.

Files



A **file** 文件 keeps data on disk between runs (RAM is lost at exit).

- `OPENFILE` for READ/WRITE/APPEND
- `EOF` tests the **end of file** 文件结束
- always `CLOSEFILE` – or buffered writes are lost

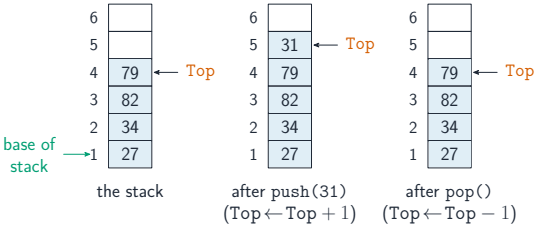
Files, stacks and queues

a file 文件	data on **secondary storage** 辅助存储器, kept between program runs
why needed	variables live in RAM and disappear when the program stops
a text file 文本文件	read and written line by line, and readable by a person
a stack	add and remove at the top only – LIFO. A pile of books: the last one on is the first one off
a queue	join at the back, served from the front – FIFO. Whoever waited longest is served first
the operations	stack: push and pop. Queue: enqueue and dequeue. Both need an empty and a full check

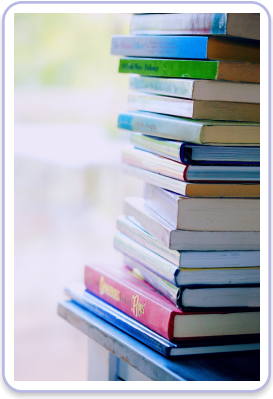
Choose by which end you need: undo history and call returns are stacks; print jobs and buffers are queues.

3 ADTs

Abstract data types: the stack

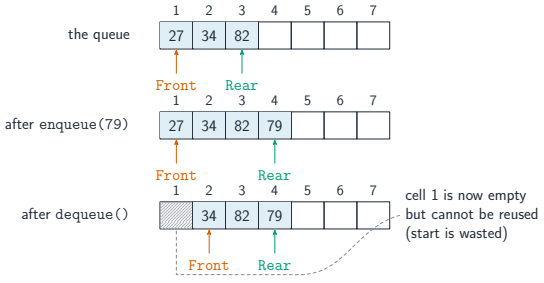


A **stack** 栈 is **LIFO** 后进先出: `push` and `pop` happen at the top – undo history, procedure calls.



A stack is last-in, first-out

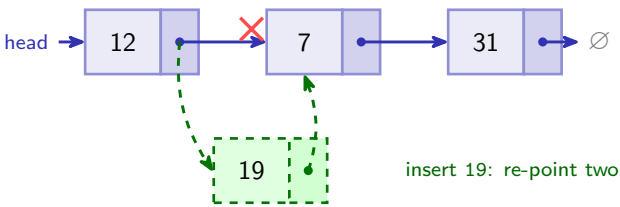
Abstract data types: the queue



A queue is first-in, first-out

A **queue** 队列 is **FIFO** 先进先出: enqueue at the back, dequeue at the front – print **spooling** 排队打印, scheduling.

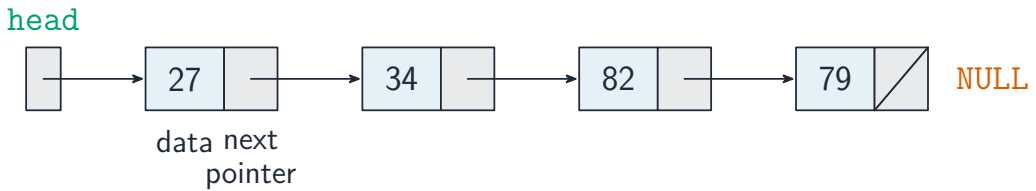
Linked list



A **linked list** 链表 chains **nodes** 节点, each a value + a **pointer** 指针 to the next.

- + cheap insert/delete – nothing shifts
- − slow random access

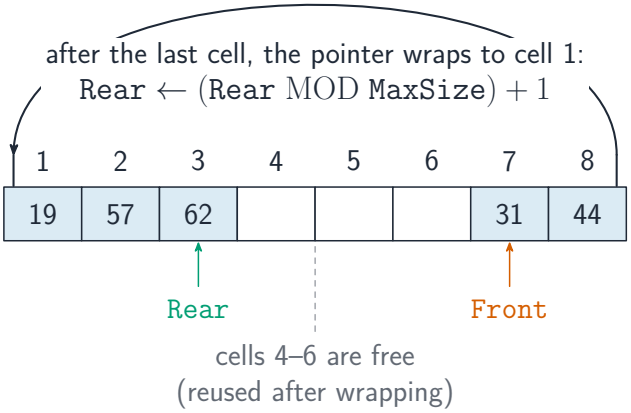
A linked list, drawn out



Each node carries its data and a pointer to the next; the last points at null.

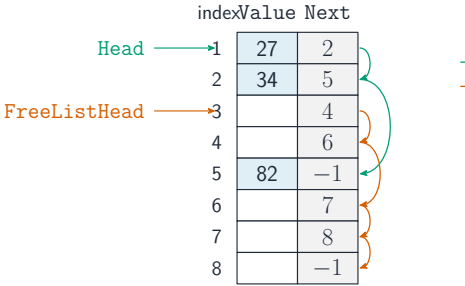
4 Implementing

ADTs with arrays



- stack: a `Top` index; full = **overflow** 溢出, empty = **underflow** 下溢
- queue: a **circular array** 循环数组 – pointers wrap with `(p MOD MaxSize) + 1`

Linked list in an array



Store nodes in an array of records, each with a `Next` index. A **free list** 空闲列表 chains the unused slots – linked-structure flexibility with static allocation.

Worked example – a circular queue

A circular queue in an array of size 5 has `Front = 3`, `Rear = 3` and one item. Two items are added, then two removed. Where are the pointers?

- Every move is `(pointer + 1) MOD size`, so the pointers **wrap**.
- Adding twice moves `Rear`: $3 \to 4 \to 0$ (since $(4+1) \bmod 5 = 0$), leaving `Rear = 0` and three items stored.
- Removing twice moves `Front` the same way, leaving `Front = 0` and one item.

The wrap is the point: in a linear array queue the pointers march to the end and the freed space at the front can never be reused.

Exam tips

- Choose the right **data structure** and justify it (a record for mixed fields, a 2-D array for a grid).
- Know how to implement a **stack, queue and linked list** with an array and pointers (top; front/rear; next).
- Distinguish an **ADT** (its behaviour) from its implementation (array plus pointers).

5 Recap

Topic 10 – key takeaways

1 Records & arrays

records mix types; arrays hold one type

2 Files

persist data; open, read/write, close

3 Stack & queue

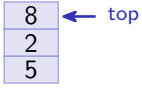
LIFO vs FIFO

4 Linked list

nodes with pointers; cheap insert/delete

Check yourself

1. Which holds several different types together?
2. Which ADT is FIFO?
3. Why use a circular array for a queue?
4. One advantage of a linked list over an array?



Answers **1.** a record **2.** a queue **3.** reuse the wrapped-round cells **4.** cheap insertion/deletion