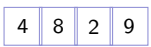
Data Collections

AP Computer Science A ▪ Unit 4

AP Computer Science A



What we will cover

1. Ethics of collecting data
2. Arrays
3. ArrayList
4. 2D arrays (grids)
5. Searching & sorting
6. Recursion

1 Ethics

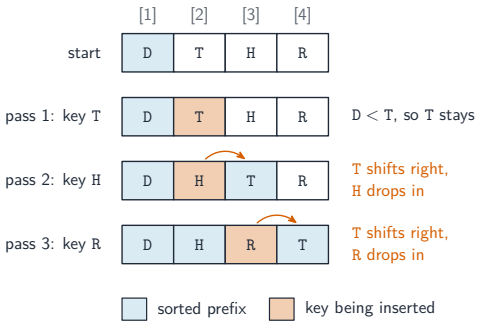
The ethics of collecting data

Programs that collect and process personal data carry real responsibility.

> Collect only what you need, protect **privacy** 隐私, be honest about how data is used, and guard against **bias** 偏差 in what you gather. Legal is not always ethical.

Data centre

An insertion sort



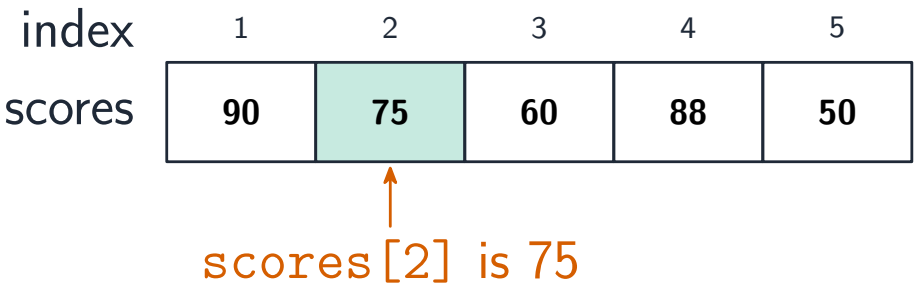
An insertion sort, shifting each key into place pass by pass

Making and Reading an Array

An **array** 数组 is a fixed-size, ordered collection of same-type values.

> Indices run from `0` to `length - 1`:

Making and Reading an Array, in detail



A one-dimensional array (a list) with its indices and bounds

The five standard array algorithms

sum or average	an accumulator declared outside the loop; divide by `length` at the end
max or min	start from `arr[0]`, not from zero – an array of negatives has no element above zero
count matching	a counter, incremented only when the element passes the test
check for a duplicate	a nested loop, with the inner one starting at `i+1` so no pair is checked twice
reverse or copy	build into a new array, or swap ends inward for an in-place reverse

Every one of these is a traversal plus a small body. Recognising which one a question wants is most of the work.

Visiting Every Element of an Array

Traverse 遍历 an array with a `for` loop (gives the index) or an **enhanced for / for-each** loop (gives each value, read-only):

Wrapping a Number in an Object

An `ArrayList` stores **objects**, not primitives, so a primitive is **wrapped** in an object: `Integer` wraps `int`, `Double` wraps `double`.

> Java does this with **autoboxing 自动装箱** (`int` to `Integer`) and **unboxing** (back again) automatically.

2 Arrays

Arrays

4	8	2	9	5	7
0	1	2	3	4	5

An **array** 数组 stores a fixed number of same-type values, reached by **index** 索引 (from **0**). Visit every element with a loop:

```
for (int i = 0; i < a.length; i++) ...
```

Standard algorithms: find the **max/min**, **sum/average**, or count matches by traversing once.

Filing cabinet

Why a data structure at all

the problem	a single variable holds one value; real problems need many related values – a class roster, pixels, sensor readings
a data structure 数据结构	holds many values under one name, reached by index
an array	fixed length, set when it is created, and `arr.length` is a field, not a method
the bounds	valid indices run 0 to `length-1`; anything outside throws an `ArrayIndexOutOfBoundsException`
the run-time cost	reaching any element takes the same time whatever the index – that is the point of an array

Off-by-one at the top end is the classic array bug: `i <= arr.length` throws, `i < arr.length` does not.

3 ArrayList

The ArrayList toolbox

An **ArrayList** 动态数组 grows and shrinks, unlike a fixed array. It stores objects, so numbers are **wrapped** 包装 (`Integer`, `Double`).

`add(x)`	`get(i)`	`set(i,x)`	`remove(i)`
append	read	replace	delete

Traverse it with a `for` or an enhanced for-each loop: `for (int x : list)`.

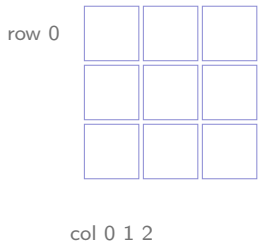
Removing from a list while looping over it

the problem	`remove(i)` shifts every later element down, so the element after the removed one is skipped
fix one	loop backwards, from `size()-1` down to `0` – later shifts cannot affect indices you have passed
fix two	do not increment `i` after a removal, so the next pass re-examines the same index
never	remove inside an enhanced `for` loop – it throws a `ConcurrentModificationException`
the rest	the array algorithms carry over unchanged, plus insertion and deletion, which arrays cannot do easily

This is the single most-tested ArrayList point. If a question removes items in a loop, it is testing exactly this.

4 2D arrays

2D arrays (grids)

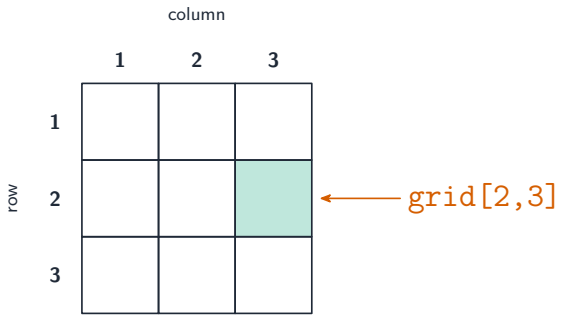


A **2D array** 二维数组 is a grid of rows & columns: `grid[r][c]`.

Walk it with **nested loops** – outer over rows, inner over columns:

```
for r ...
  for c ...
    grid[r][c]
```

Grids: Two-Dimensional Arrays



A two-dimensional array (a table) with row and column indices

Walking Through a Grid

Visit every cell with **nested loops** – the outer over rows, the inner over columns (**row-major order** 行主序):

The standard grid algorithms

sum a row	fix `r`, loop `c` across `grid[r].length`
sum a column	fix `c`, loop `r` down `grid.length`
max in the grid	nested loops, initialised to `grid[0][0]`
count matching cells	nested loops with a counter and a test
sum a diagonal	one loop, using the cells where `r == c`

Every grid task is a nested traversal with a small body – and `grid.length` is the number of rows, `grid[0].length` the number of columns.

5 Search & sort

Searching & sorting

Linear search 线性查找 checks every element; **binary search 二分查找** halves a **sorted** array

Selection 选择排序 & **insertion sort 插入排序** order a list; **merge sort 归并排序** is faster

Binary search needs **sorted** data and does $\sim \log_2 n$ comparisons, far fewer than linear search's n.

Selection sort and insertion sort

selection sort 选择排序	repeatedly find the smallest remaining element and swap it into place
insertion sort 插入排序	take the next element and slide it back into its position among the already-sorted front
both	$O(n^2)$ comparisons in the worst case – fine for small arrays, hopeless for large ones
the difference	insertion sort is much faster on nearly-sorted data; selection sort takes the same time whatever the input
the exam skill	be able to state the array's contents after k passes of either

Trace, do not memorise. The questions ask what the array looks like partway through, which only tracing answers.

Recursion

A **recursive** 递归 method calls itself on a smaller input, stopping at a **base case** 基本情形.

Factorial

`factorial(n) = n * factorial(n-1)`, with `factorial(0) = 1`.

Each call shrinks *n* until the base case, then the results multiply back up. **Merge sort** 归并排序 uses the same divide-and-conquer idea.

Reading a file, and the two exceptions it can throw

the import	`File` and `IOException` live in `java.io`, so a file-reading program needs `import java.io.*;`
why it can fail	the file might not exist, so Java forces you to handle or declare the exception
the two ways	wrap the call in `try/catch`, or add `throws IOException` to the method header
typed tokens	`nextInt()`, `nextDouble()` and `nextBoolean()` throw an `InputMismatchException` if the next token is the wrong type
the usual cause	a line of text where a number was expected, or a stray blank line

File input is the one place a beginner's program meets the outside world, which is exactly why the language insists you say what happens when it goes wrong.

Key points

Arrays are fixed; **ArrayLists** grow & hold objects

A **2D array** is a grid, walked with nested loops

Binary search & **merge sort** beat the simple versions

Recursion solves a problem via a smaller copy

Worked example – tracing recursion

Trace `factorial(4)`

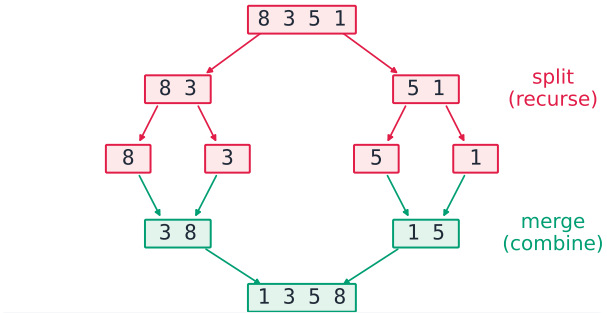
Each call defers to a smaller one:

$$4 \cdot f(3) = 4 \cdot 3 \cdot f(2) = 4 \cdot 3 \cdot 2 \cdot f(1)$$

`factorial(1)` hits the base case and returns 1, so the calls unwind inward: $2 \cdot 1 = 2$, then $3 \cdot 2 = 6$, then $4 \cdot 6 = 24$.

Writing each call above its returned value is the reliable way to trace recursion – and the base case is what stops it.

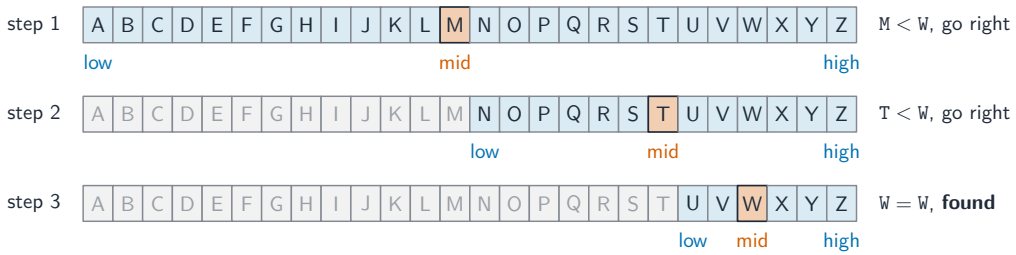
Merge sort splits the array to single elements



merge sort: $O(n \log n)$ time · needs extra $O(n)$ space

Merge sort splits the array to single elements, then merges sorted halves back up

Binary search halves the range at each step – one

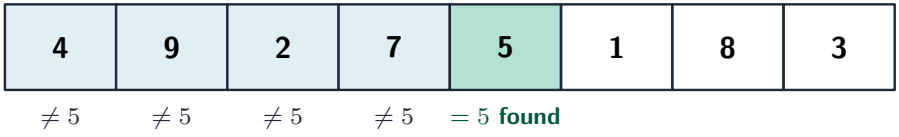


Binary search halves the range at each step

Binary search halves the range at each step

Binary search halves the range at each step – two

search for 5: check each item in turn (left to right)



Linear search checks every element in turn until the target is found

Linear search checks every element in turn until the target is found

Exam tips

- Weigh both benefits and harms of collecting data – this unit is tested through short written justification, not code.
- Protect **personally identifiable information (PII)** and explain privacy and security risks in context.
- Name real harms: data breaches, surveillance, and algorithmic **bias** from unrepresentative data.
- Respect intellectual property and licensing when you reuse code or data.
- Give a specific, reasoned answer – a vague "it could be bad" earns no marks.

6 Recap

Unit 4 – key takeaways

1 Both sides

benefits and harms of collecting data

2 PII

privacy and security risks in context

3 Harms

breaches, surveillance, algorithmic bias

4 IP

respect licensing; a vague ‘it could be bad’ scores zero

Check yourself

1. `factorial(4)` returns what?
2. What happens to recursion with no base case?
3. Binary search needs the array to be ...?
4. Array or ArrayList: which resizes itself?

Answers **1.** 24 **2.** it never stops – a StackOverflowError **3.** sorted **4.** ArrayList