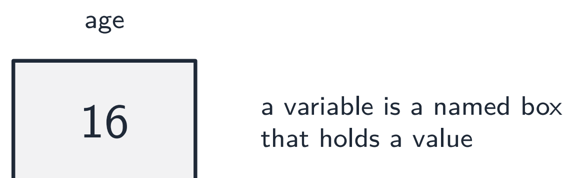
Algorithms and Programming

AP Computer Science Principles

Code below uses the **AP CSP pseudocode** –the exam's language-neutral reference. Assignment is written `a ← expression`, and list indices start at **1**.

Variables and Assignments

A **variable** 变量 is a named place that holds a value. The **assignment** 赋值 operator stores the value on the right into the variable on the left:



A variable is a named store whose value can change

```
a ← 5
b ← a + 3      // b is now 8
```

A variable holds one value at a time; assigning again **replaces** it. Variables let a program store input, remember results, and reuse them.

Data Abstraction

Data abstraction 数据抽象 lets you manage complexity by giving a single name to a collection of data –for example, a **list** rather than dozens of separate variables. It hides detail: you use the named collection without worrying about how it is stored. Lists (below) are the course's main data abstraction.

Mathematical Expressions

Programs compute with the operators `+`, `-`, `*`, `/`, and `MOD` (the **remainder** 余数 of a division, e.g. `17 MOD 5` is 2). Expressions follow the usual order of operations. `MOD` is especially useful for testing divisibility (`n MOD 2 = 0` means `n` is even) and for wrapping values around a range.

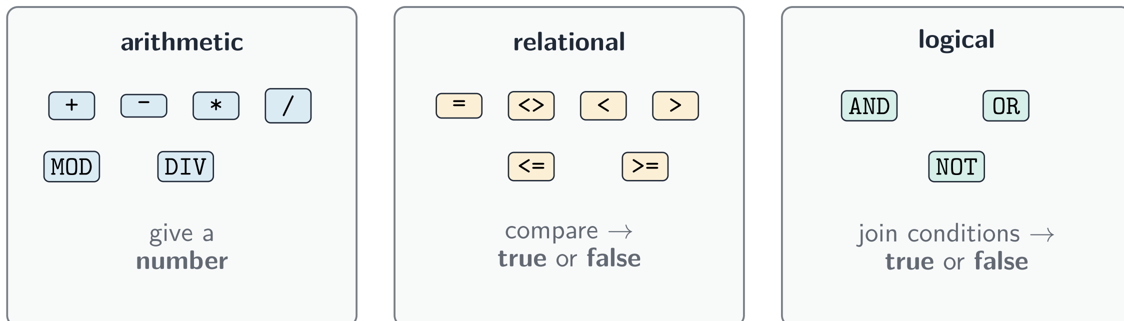
Strings

A **string** 字符串 is an ordered sequence of characters, like `"hello"`. Programs join strings (**concatenation** 拼接) and find their **length**. Strings represent text –names, messages,

sequences –and are a common program input and output.

Boolean Expressions

A **Boolean expression** 布尔表达式 evaluates to `true` or `false`. It uses **relational operators** (=, , <, >, ,) and **logical operators** `NOT`, `AND`, `OR`:



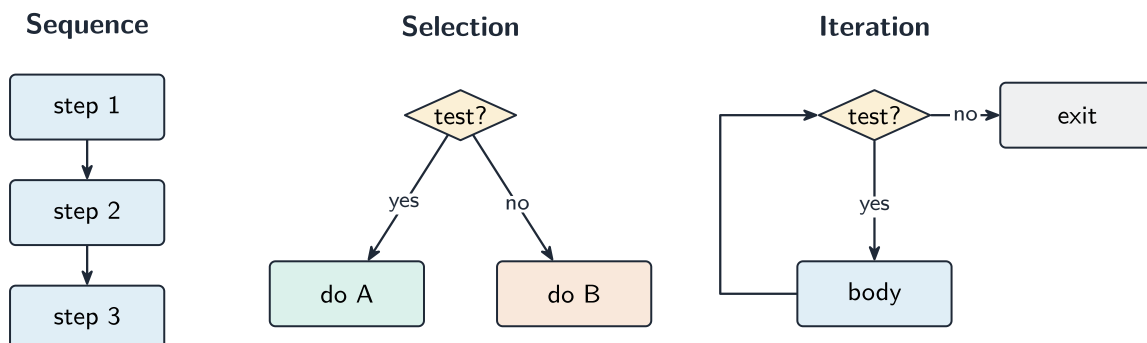
The three families of operators: arithmetic, relational, and logical

- `NOT` reverses a value,
- `AND` is true only when **both** sides are true,
- `OR` is true when **at least one** side is true.

These conditions drive every decision and loop.

Conditionals

A **conditional (selection)** 条件语句 chooses which code to run. `IF` runs a block only when its condition is true; `ELSE` gives an alternative:



Selection chooses between paths based on a condition

```
IF (score   60)
{
    DISPLAY("Pass")
}
```

```
ELSE
{
    DISPLAY("Fail")
}
```

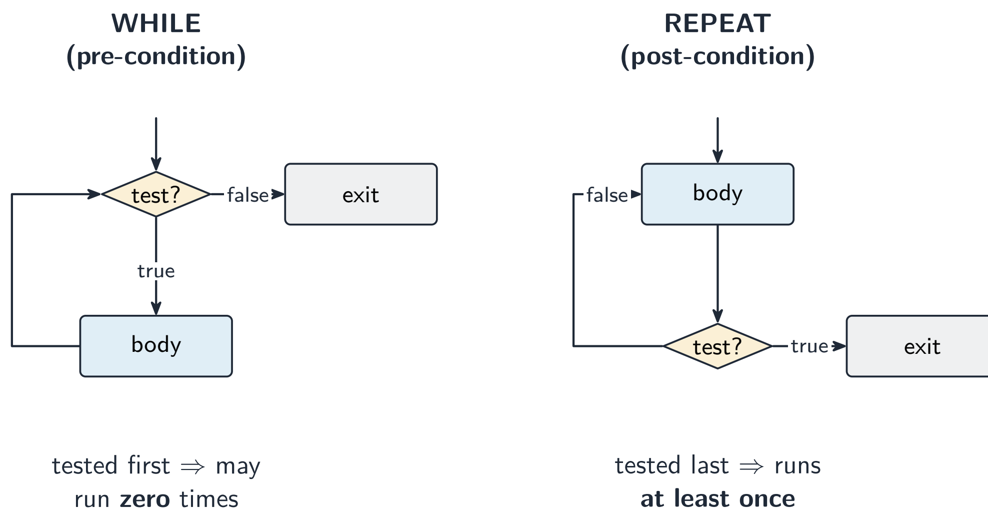
Nested Conditionals

A **nested conditional** 嵌套条件 places one `IF` inside another (or chains `ELSE IF`) to choose among **more than two** paths. Only the first matching branch runs:

```
IF (g   90)       { grade ← "A" }
ELSE IF (g   80) { grade ← "B" }
ELSE              { grade ← "C" }
```

Iteration

Iteration (a loop) 迭代 repeats instructions. AP pseudocode has two forms:



A pre-condition (WHILE) loop tests before the body, so it may run zero times

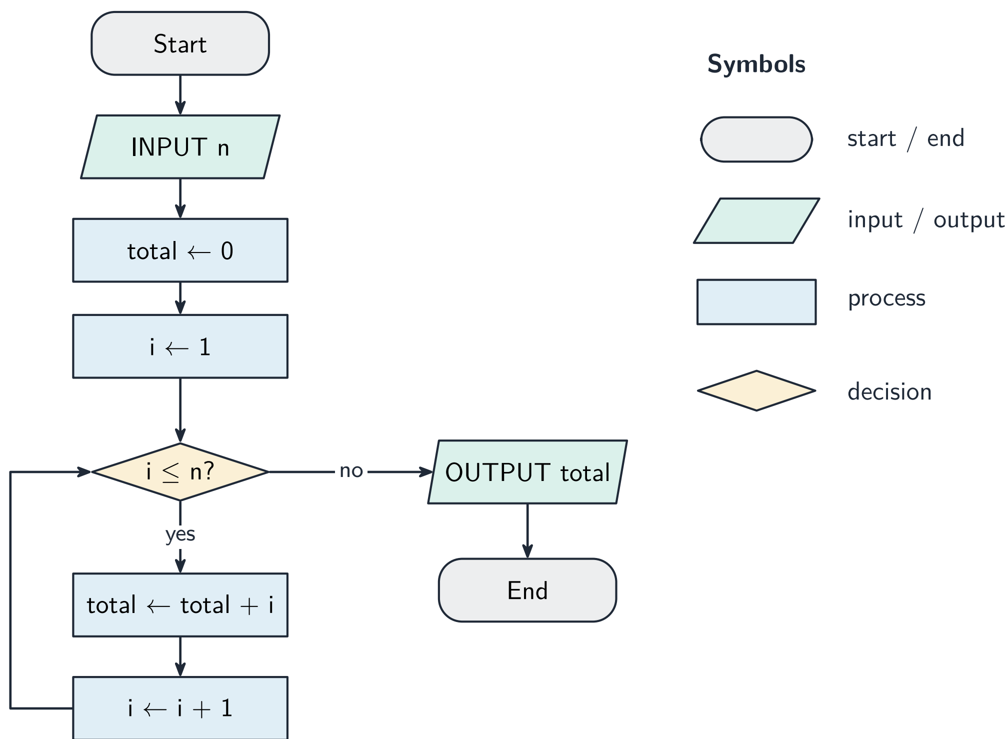
```
REPEAT 5 TIMES         // a fixed count
{
    DISPLAY("hi")
}

REPEAT UNTIL (found)  // until a condition becomes true
{
    ...
}
```

A loop that never meets its stopping condition is an **infinite loop** 无限循环.

Developing Algorithms

An **algorithm** 算法 is a finite sequence of steps that solves a problem, built from **sequencing**, **selection**, and **iteration**. Different algorithms can solve the same problem, and you should be able to combine and modify existing algorithms (for example, count the values in a list that meet a condition, or find the largest). Trace an algorithm by hand to check it is correct.



A flowchart lays out an algorithm using the standard symbols

Lists

A **list** 列表 is an ordered collection of values under one name, the course's key data abstraction. AP pseudocode indexes from **1**:

index	1	2	3	4	5
scores	**90**	**75**	**60**	**88**	**50**

scores[2] is 75

A list holds many values in one variable, each found by its index

```
scores ← [88, 74, 95]
DISPLAY(scores[1])          // 88
```

```
scores[2] ← 80              // replace the 2nd value
APPEND(scores, 60)          // add to the end
INSERT(scores, 1, 100)      // insert at index 1
REMOVE(scores, 3)           // delete the 3rd element
LENGTH(scores)              // how many elements
```

Traverse a list with a loop to sum, count, search, or find a maximum:

```
FOR EACH x IN scores
{
    total ← total + x
}
```

Binary Search

Binary search 二分搜索 finds a value in a **sorted** list far faster than checking each element. It looks at the middle element, then discards the half that cannot contain the target, repeating until found. Each step **halves** the search space, so a list of n items takes about $\log_2 n$ steps. It **requires the data to be sorted** first.

step 1 | A B C D E F G H I J K L M N O P Q R S T U V W X Y Z | M < W, go right
low (A) mid (M) high (Z)

step 2 | A B C D E F G H I J K L M N O P Q R S T U V W X Y Z | T < W, go right
low (N) mid (T) high (Z)

step 3 | A B C D E F G H I J K L M N O P Q R S T U V W X Y Z | W = W, **found**
low (U) mid (W) high (Z)

Binary search halves the range at each step (the list must be sorted)

Worked example. Searching a sorted list of 8 items, binary search halves the range each step: $8 \to 4 \to 2 \to 1$, at most 3 comparisons ($\log_2 8 = 3$), whereas a linear search could take up to 8. The advantage grows explosively: about 1,000 items need only ≈ 10 binary-search steps (but up to 1,000 linear ones), and 1,000,000 items need just ≈ 20. Halving is what makes it a **reasonable-time** algorithm.

Calling Procedures

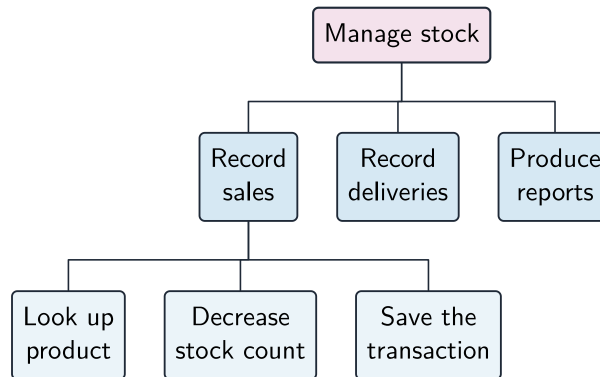
A **procedure (function)** 过程 is a named, reusable block of code. **Calling** it runs its code with the **arguments** you supply, and it may **return** a value:

```
sum ← Add(3, 4)       // call, passing 3 and 4
```

Procedures let you use code without knowing its inner workings –**procedural abstraction** 过程抽象.

Developing Procedures

You **define** a procedure with a name, **parameters** (inputs), and a body, and optionally `RETURN` a result:



Decomposing a program into procedures and sub-procedures

```
PROCEDURE Add(a, b)
{
    RETURN(a + b)
}
```

Writing your own procedures reduces repetition, breaks a big problem into named pieces, and makes programs readable and easier to test –the essence of **abstraction** 抽象.

Libraries

A **library** 库 is a collection of ready-made procedures that others can reuse. An **API** (Application Program Interface) 应用程序接口 documents what each procedure does, its parameters, and its result –so you can use it without seeing its code. Libraries save time and let you build on existing, tested work.

Random Values

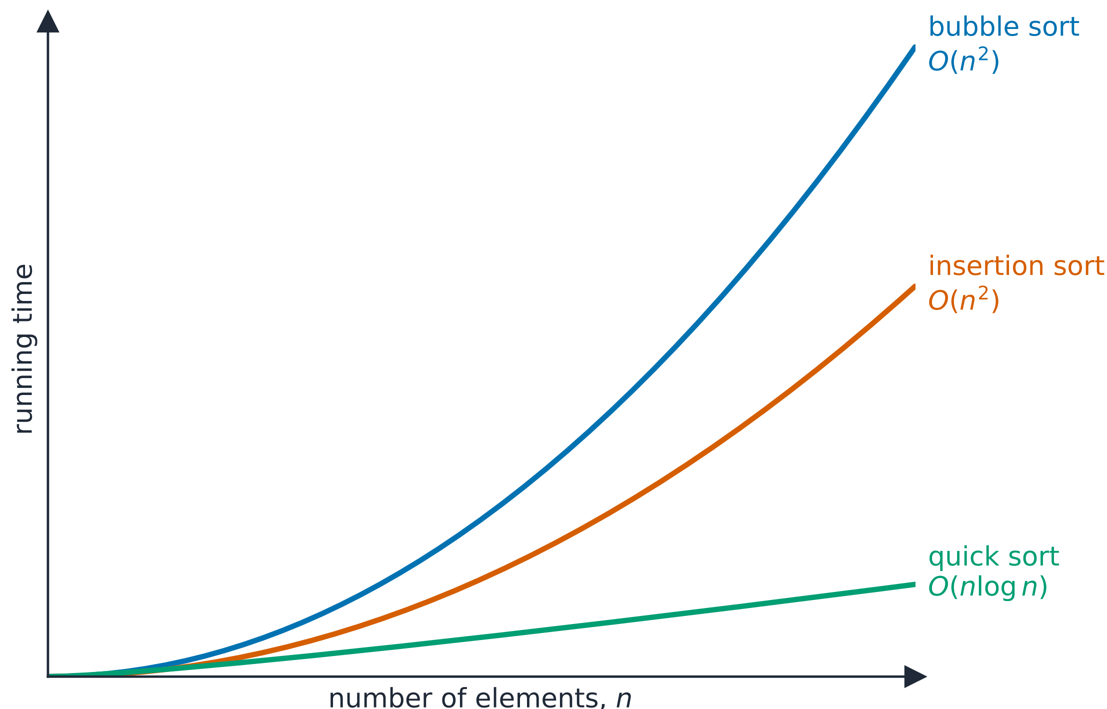
`RANDOM(a, b)` returns a random integer from `a` to `b` (inclusive), letting a program produce **unpredictable** results –for games, sampling, or simulations. Each call may give a different value, so a program using randomness behaves differently each run.

Simulations

A **simulation** 模拟 is a program that models a real-world process to study it safely and cheaply. Simulations **simplify** reality (they leave out detail) and often use **randomness** to imitate chance events. They let you test scenarios that would be too costly, slow, or dangerous in real life –but their results are only as good as their assumptions.

Algorithmic Efficiency

Efficiency 效率 is how much time (or memory) an algorithm needs as its input grows. A **reasonable-time** algorithm's work grows like a polynomial of the input size (e.g. linear or quadratic); an **unreasonable-time** algorithm grows far faster (e.g. doubling with each added item), becoming impractical for large inputs. A faster algorithm can make a previously impossible problem solvable. Sometimes an exact answer takes too long, so a **heuristic** 启发式–an approach that finds a good-enough answer quickly –is used instead.



How the running time of an algorithm grows with the input size n

Undecidable Problems

Some problems are **undecidable** 不可判定: no algorithm can solve **every** case of them with a correct yes/no answer. This is a fundamental limit of computing –not a matter of needing a faster computer, but a proof that no such algorithm can exist.

Exam skill: be able to determine a code segment's result by tracing it, compare two algorithms' efficiency (reasonable vs unreasonable time), and recognize procedural and data abstraction in a program.

Exam tips

- Know a variable is a named store for a value and trace how **assignment** updates it step by step.
- Read the AP **pseudocode** carefully —`a <- expression` assigns, and lists are **1-indexed** on the exam reference sheet.

- Distinguish a variable from a **list** (a collection accessed by index) and use list operations correctly.
- Evaluate expressions with the right precedence and boolean logic (`AND`, `OR`, `NOT`).
- Pick clear, meaningful variable names —the written tasks reward readable code.