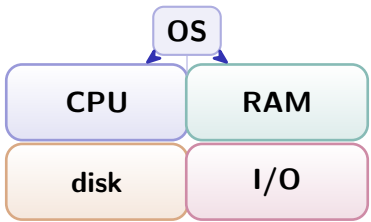
System Software

A-Level Computer Science ▪ Topic 16

A-Level Computer Science



What we will cover

1. How an OS shares resources
2. Processes, scheduling, memory
3. Interpreters and compilers
4. BNF, syntax diagrams, RPN
5. Recap

1 Sharing resources

The OS shares four scarce things

Many programs compete for CPU time, memory, disk and I/O. The OS shares them fairly so the machine stays responsive.

multi-tasking 多任务

switch the CPU quickly so several programs *seem* to run at once

paging 分页

give each process memory; use disk when RAM runs out

spooling 假脱机

queue print jobs on disk so the CPU never waits

caching 高速缓存

keep recently-used disk data in RAM

The user interface hides the hardware

The user sees windows, menus and folders – not addresses or sectors. One click on an icon makes the OS find the program, allocate memory, load it and start it.

CLI
powerful, scriptable

GUI
easier to learn

> Most systems offer both. The interface is an abstraction, not a different OS.

2 Processes

A process is a program in execution

Its code, current state, memory and open files. The **scheduler** 调度器 chooses which ready process runs next, and for how long.

round robin
each process gets a fixed **time slice** 时间片, then the back of the queue

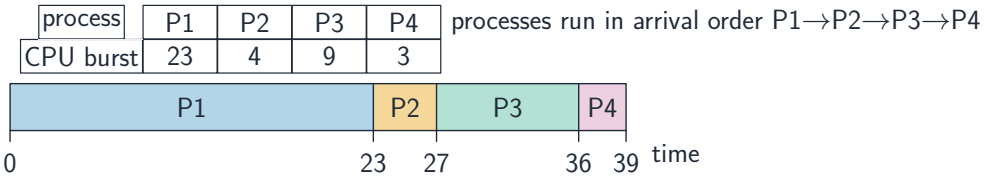
FCFS
first-come, first-served – simple, can stall behind a long job

SJF / SRT
shortest job, or shortest remaining time

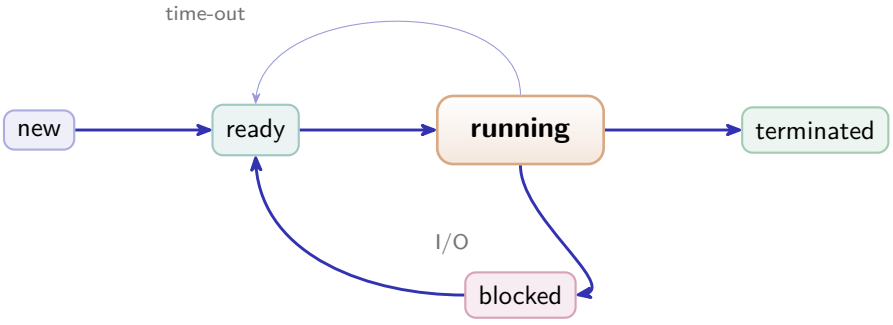
priority
urgent work first; risk of starvation

First come, first served

Simple and fair in arrival order, but one long job delays everything behind it.



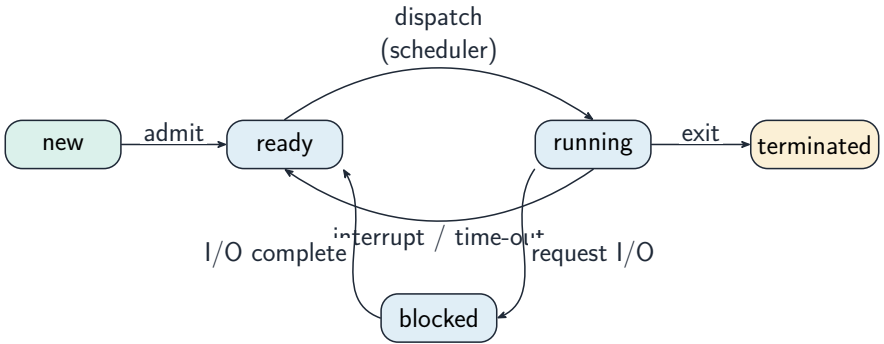
Process states



Time slice ends: running → ready. I/O requested: running → blocked. I/O done: blocked → ready.

The state diagram

Ready, running, blocked – and only the scheduler moves a process between ready and running.



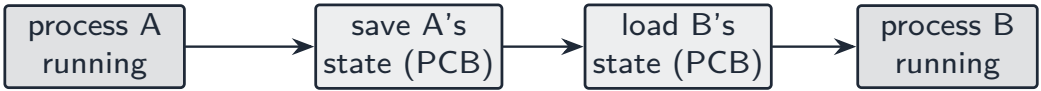
PCB and context switch

For each process the OS keeps a **process control block** 进程控制块 (PCB): saved program counter, registers, state, memory info. A **context switch** 上下文切换 saves one PCB and loads another. A small cost, paid on every switch.

The **kernel** 内核 is the interrupt handler: a device or the timer raises an interrupt, the running process is saved, and the right routine runs.

Isolated processes talk via **IPC** 进程间通信: **pipes** 管道, **shared memory** 共享内存, message passing.

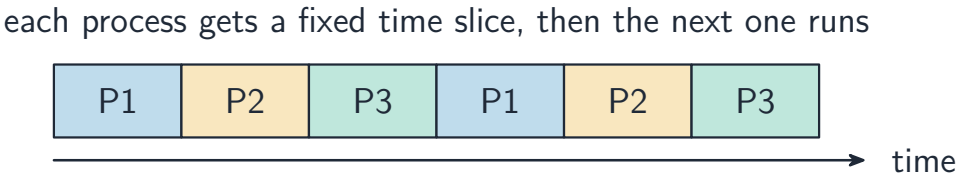
Process control block and context switch



A context switch saves one process's state and loads another's

Round robin

Each process gets a fixed **time slice** 时间片; when it expires the scheduler switches to the next.



Virtual memory, paging, thrashing

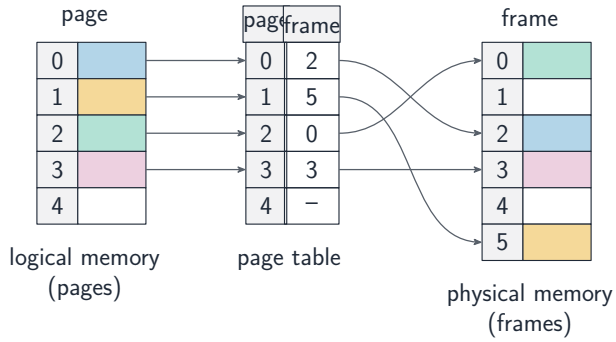
Each process gets its own **virtual address space** 虚拟地址空间, mapped onto physical memory.

- **pages** 页 ↔ **frames** 页框 of the same size
- a page table stores the mapping
- a **page fault** 缺页 loads the page from the **swap file** 交换文件

> **Thrashing** 抖动 is when the OS spends most of its time swapping pages instead of running programs – too little RAM for the working set.

Segmentation 分段 splits memory into variable-sized logical chunks (code, stack, heap), each with its own permissions.

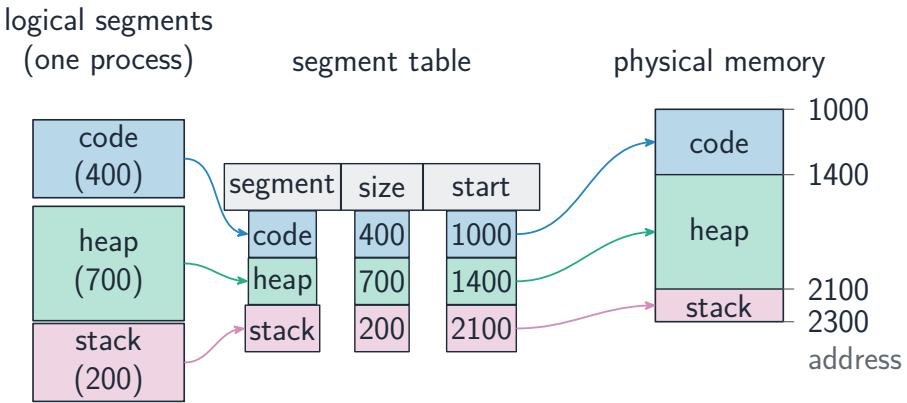
Virtual memory, paging, segmentation



Paging maps each page of logical memory to a frame of physical memory

Paging and segmentation

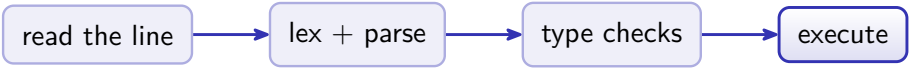
Paging splits memory into equal **pages** 页; segmentation splits it into logical, unequal **segments** 段.



3 Translation

How an interpreter runs a program

An **interpreter** 解释器 translates and runs the source at the same time.



- errors are reported immediately; it usually stops
- no executable is produced – translation is redone every run
- slower, but fast development feedback and portable

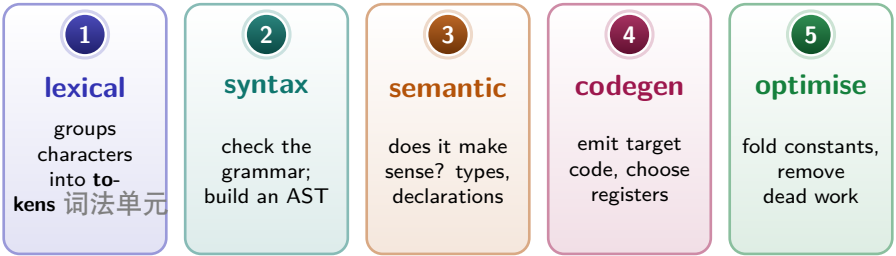
Two more jobs the OS does, and how a compiler reads code

Interrupt handling	**Interrupt handling** 中断处理: a device raises a signal, the CPU saves state, runs the handler, and resumes – so no polling loop is needed.
Inter-process communication	**Inter-process communication** 进程间通信: pipes, shared memory and message queues let separate processes exchange data under the OS's control.
Lexical analysis	**Lexical analysis** 词法分析 splits the source into tokens and strips comments and whitespace.
Syntax analysis	**Syntax analysis (parsing)** 语法分析 builds an **abstract syntax tree** 抽象语法树 from those tokens – and reports a **syntax error** 语法错误 when they fit no rule.
Then	**Code optimisation** 代码优化 improves the intermediate form, and code generation emits machine code or **bytecode** 字节码.

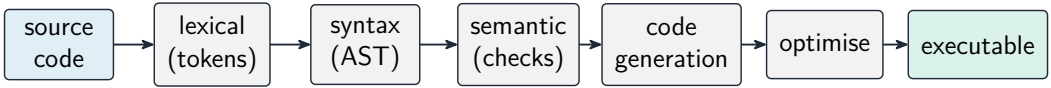
A syntax error is caught before anything runs; a logic error is not caught at all. The compiler can only check the grammar.

Five stages of compilation

A **compiler** 编译器 turns source into **machine code** 机器码.



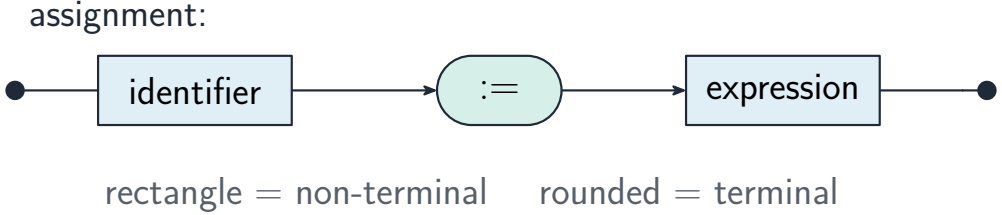
Five stages of compilation, in detail



The phases of compilation, from source code to an optimised executable

Syntax, as a diagram

A syntax diagram says the same as BNF: follow any path through it and you get a valid construct.



4 Grammar and RPN

BNF – a grammar in text

Backus-Naur Form 巴科斯-诺尔范式 writes a **grammar** 文法 as production rules: `<digit> ::= 0 | 1 | …| 9`

```
<identifier> ::= <letter>
       | <identifier> <letter>
       | <identifier> <digit> < > are
```

non-terminals 非终结符; literals are **terminals** 终结符. Recursion expresses "any number of".

A **syntax diagram** 语法图 (railroad diagram) shows the same grammar graphically. The parser uses either to decide whether a program is valid.

Reverse Polish Notation needs no brackets

Infix: operator between operands, so you need brackets and precedence.
RPN 逆波兰表示法 (postfix): operator follows its operands.

Scan left to right with an operator **stack** 栈: output operands; pop higher-or-equal precedence operators before pushing; parentheses flush the stack.

Worked example – evaluate RPN

Evaluate $3\ 4\ 2\ *\ +$

Push each operand; on an operator, pop two, apply, push the result.

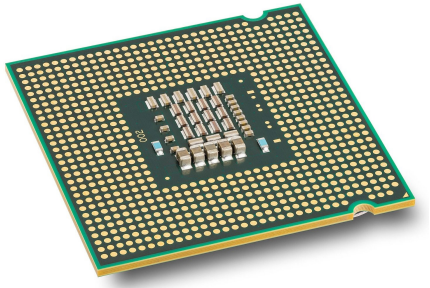
Token	Stack
3	3
4	3, 4
2	3, 4, 2
*	3, 8
+	11

$(A + B) \times (C - D)$

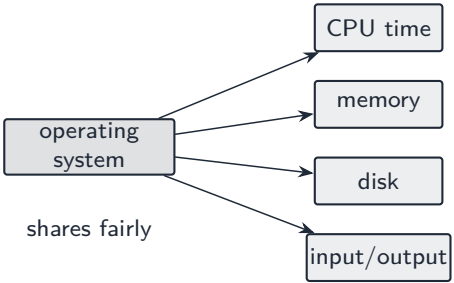
Convert: `A B + C D - ×`

Evaluate $(3 + 4) \times (5 - 2)$: push 3, 4; $+ \to 7$; push 5, 2; $- \to 3$; $\times \to 21$.

How an OS maximises use of resources



The processor is a key resource the OS shares between competing tasks



The OS shares the CPU, memory, disk and I/O between programs

The processor is a key resource the OS shares between competing tasks

What a scheduler is trading off

responsiveness	how quickly an interactive process gets a turn
throughput	how many processes complete per unit time
fairness	every process getting a share, and none starving
the trade-off	you cannot maximise all three – and each algorithm picks a different corner
first come, first served	maximum fairness by arrival, and terrible responsiveness behind a long job
round robin	good responsiveness; a short time slice costs throughput in context switching

Naming the trade-off is what turns a list of algorithms into an answer. Say which of the three a given algorithm sacrifices.

The OS also manages memory (RAM)

The OS also manages memory (RAM), deciding what to keep in it and what to page out to disk

Exam tips

- List the **stages of compilation** (lexical, syntax and semantic analysis, code generation, optimisation) and what each does.
- Explain **virtual memory and paging** (disk used as extra RAM) and its cost (disk thrashing).
- Evaluate **Reverse Polish Notation** with a stack – no brackets are needed.
- Use **BNF or a syntax diagram** to test whether a string is valid.

5 Recap

Topic 16 – key takeaways

1 OS

multi-task, page, spool, cache; PCB / context switch

2 Memory

virtual addresses, pages, faults, thrashing

3 Compile

lex, parse, semantic, generate, optimise

4 RPN

postfix; evaluate with an operand stack

Check yourself

1. Round-robin: what happens when a time slice ends?
2. What is thrashing?
3. Name the five compilation stages in order.
4. Evaluate $5\ 1\ 2\ +\ 4\ \times\ +$

Answers **1.** it goes to the back of the ready queue **2.** constant paging, little useful work **3.** lex, syntax, semantic, codegen, optimise **4.** $5 + (1 + 2) \times 4 = 17$