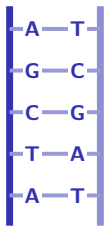
Nucleic Acids & Protein Synthesis

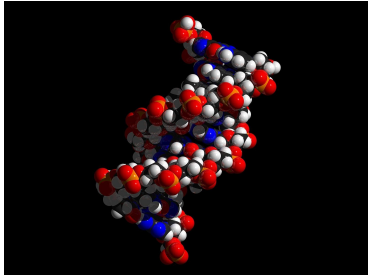
A-Level Biology ▪ Topic 6

A-Level Biology



What we will cover

1. Nucleotides & bases
2. DNA structure
3. DNA replication
4. The genetic code
5. Transcription & translation
6. Mutations



the DNA double helix

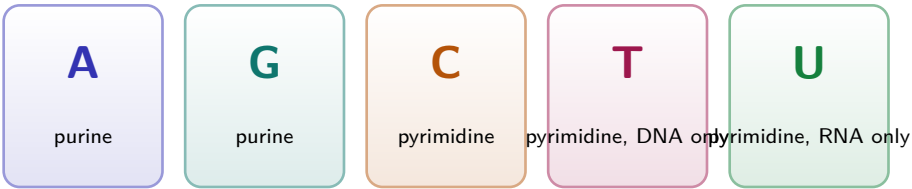
1 Nucleotides and DNA

Nucleotides

A **nucleotide** 核苷酸 has three parts: a pentose sugar, a phosphate, and a nitrogenous base. DNA uses deoxyribose; RNA uses ribose. Nucleotides join by

phosphodiester 磷酸二酯 bonds between the $5'$ phosphate of one and the $3'$ OH of the next.

The five bases



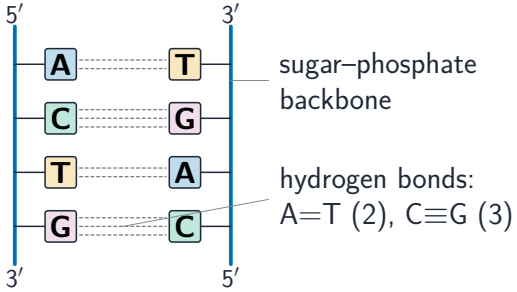
A pairs with T (or U in RNA); G pairs with C. Two H-bonds vs three.

DNA structure

Two **antiparallel** 反平行 strands twist into a **double helix** 双螺旋.

> **Complementary base pairing** 碱基互补配对: A–T by 2 hydrogen bonds, C–G by 3 – joined along a **phosphodiester** 磷酸二酯键 backbone.

DNA structure, in detail



the two strands run in opposite directions (antiparallel)

Two **antiparallel** 反平行 strands twist into a **double helix** 双螺旋.

The double helix, and the strands of replication

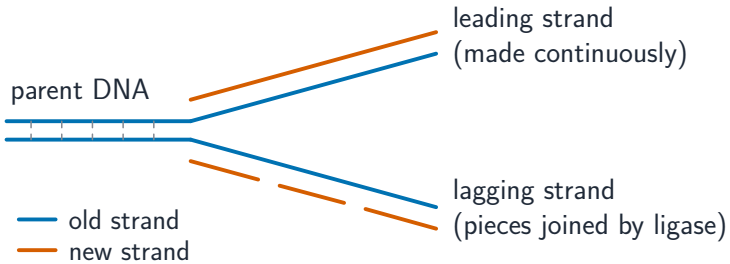
the shape	the flat ladder is twisted into a **double helix** 双螺旋 – a space-filling model shows the real form
the bases	**adenine** 腺嘌呤, **thymine** 胸腺嘧啶, **cytosine** 胞嘧啶, **guanine** 鸟嘌呤 – A pairs with T, C with G
purines 嘌呤 **and pyrimidines**	a large base always pairs with a small one, which keeps the helix a constant width
the leading strand	built continuously toward the unwinding point
the lagging strand 后随链	built in short pieces working away from it; **DNA ligase** 连接酶 joins them
why two ways	DNA polymerase can only build in one direction, and the two strands are antiparallel

The lagging strand exists because of the enzyme's one-way constraint, not because the two strands differ chemically. That is the explanation the mark scheme wants.

DNA replication

Replication is **semi-conservative** 半保留复制 – each new molecule keeps one old strand.

- **DNA polymerase** 聚合酶 adds nucleotides $5' \rightarrow 3'$
- **leading strand** 前导链 continuous; **lagging strand** 后随链 in pieces, joined by **ligase** 连接酶



2 The genetic code

The genetic code

gene 基因 → polypeptide

triplet 三联体 = 3 bases

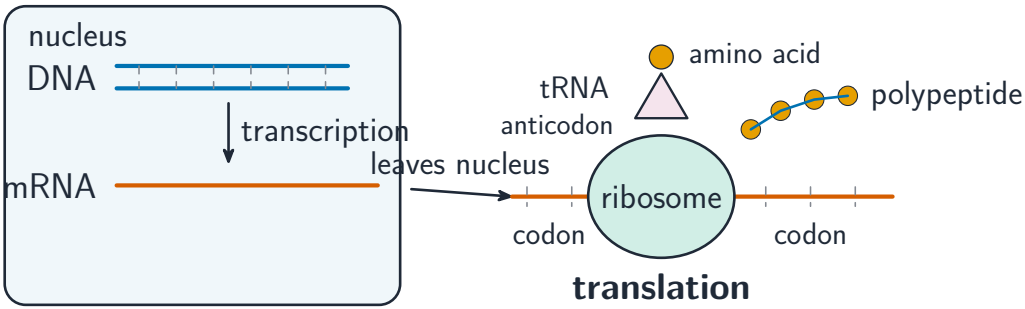
universal 通用

64 triplets, 20 amino acids ⇒ most amino acids have more than one triplet

RNA 核糖核酸 is a single strand with the sugar **ribose** 核糖, and uses **uracil** 尿嘧啶 in place of thymine.

Transcription and translation

- **transcription** 转录 – DNA → **mRNA** 信使 RNA in the nucleus
- **translation** 翻译 – the ribosome reads **codons** 密码子; **tRNA** 转运 RNA **anticodons** 反密码子 bring amino acids

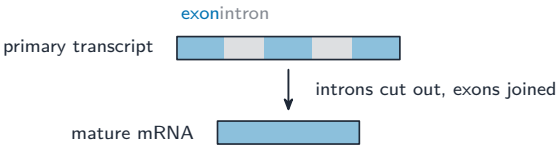


Which strand is copied, and what happens next

the template strand 模板链	the strand of DNA that is copied
the non-transcribed strand 非转录链	its partner – and its base sequence matches the mRNA, with U for T
the primary transcript 初级转录本	the first RNA made, still containing introns
splicing	introns are cut out and exons joined, giving mature mRNA
translation	ribosomes read codons; tRNA brings the matching amino acid; **peptide bonds 肽键** join them
the energy 能量	ATP is needed at several steps – transcription, tRNA loading, and each peptide bond

Name which strand is the template. Reading the wrong one gives a sequence that is complementary to the right answer, and scores nothing.

Splicing

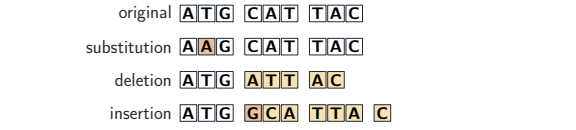


In eukaryotes the first transcript has coding **exons** 外显子 and non-coding **introns** 内含子.

> **Splicing** 剪接 cuts out the introns and joins the exons to make the finished mRNA.

3 Mutations

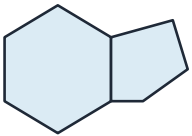
Gene mutations



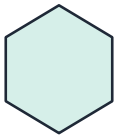
A **mutation** 突变 changes the base sequence:

- **substitution** 替换 – swaps one base (small effect)
- **deletion** 缺失 / **insertion** 插入 – shift every later triplet (a **frameshift** 移码)

Nucleotides – the building blocks



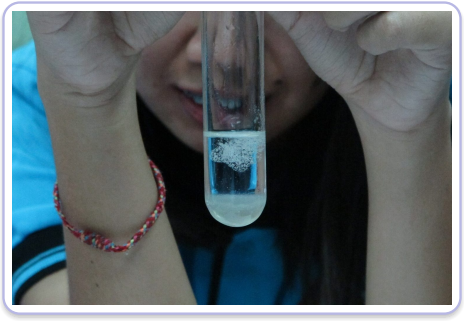
purine
double ring (A, G)



pyrimidine
single ring (C, T, U)

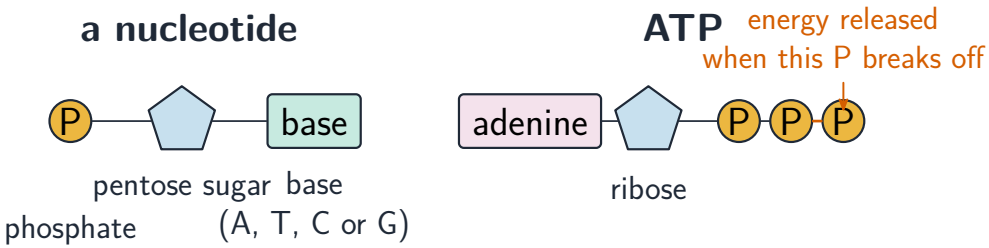
The two groups differ in shape: a purine is a double ring, a pyrimidine a single ring – which is why a purine always pairs with a pyrimidine

Nucleotides – the building blocks, continued



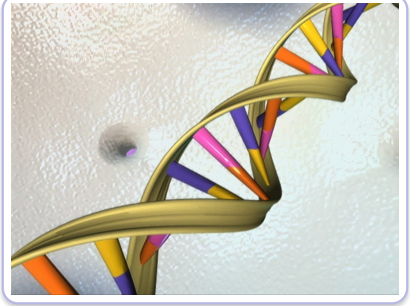
DNA extracted from cells appears as pale, stringy strands of these nucleotide polymers

Nucleotides – the building blocks, continued (2)



A nucleotide is a phosphate, a sugar and a base; ATP is a nucleotide with three phosphates

RNA



DNA double helix: RNA is a related nucleic acid that carries genetic information into protein synthesis

Exam tips

- DNA is **antiparallel**, held by hydrogen bonds (A=T two, C G three); replication is **semi-conservative** (each product keeps one old strand).
- State **where** and **what**: transcription (nucleus $\rightarrow$ mRNA), translation (ribosome, mRNA + tRNA $\rightarrow$ polypeptide).
- Describe the code with all four terms: **triplet, non-overlapping, degenerate, universal**.
- For a **gene mutation** (substitution, insertion, deletion) explain the effect on the protein – and why a substitution can be silent (degeneracy).

4 Recap

Worked example – transcribe and translate

A DNA template strand reads `TAC GGA TTT`. Give the mRNA and say how many amino acids result.

- mRNA is built complementary to the template, with U in place of T.
- `TAC` → `AUG`; `GGA` → `CCU`; `TTT` → `AAA`.
- mRNA: `AUG CCU AAA` – and AUG is always the start codon.
- 3 codons ⇒ 3 amino acids; each tRNA anticodon pairs with one codon.

A → U (never T) when transcribing. Codon is on the mRNA, anticodon on the tRNA, and the triplet on the DNA – do not mix the three names.

Topic 6 – key takeaways

1 Base pairing

A–T (2 bonds), C–G (3); antiparallel

2 Replication

semi-conservative; leading & lagging strands

3 Code

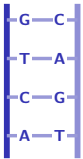
triplets; transcription then translation

4 Mutations

substitution vs frameshift (indel)

Check yourself

1. How many hydrogen bonds join C and G?
2. What does “semi-conservative” mean?
3. Where does translation take place?
4. Which mutation causes a frameshift?



Answers **1.** three **2.** each new molecule keeps one old strand **3.** at the ribosome **4.** deletion or insertion