IB BIOLOGY | D1.2 | SL AND HL

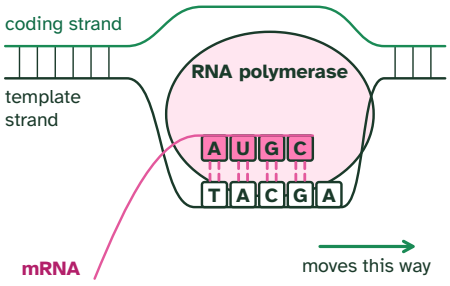
REVISION ON TWO PAGES

From gene to *protein*

What to know, what to draw and what to say. Nothing else.

THE ONE IDEA

A gene's base sequence is copied into mRNA, then read three bases at a time to set the order of amino acids in a polypeptide.



Draw it like this. RNA polymerase parts the strands; each RNA base pairs with the template, held by hydrogen bonds (dashed).

D1.2.1, D1.2.2 START HERE

Transcription: a gene copied into RNA

- Transcription is the **synthesis of RNA** on the DNA **template strand**.
- **RNA polymerase** does the whole job: it **parts the two DNA strands** and **joins each new nucleotide** to the last with a covalent bond.
- **Complementary base pairing** chooses every base: A on the template takes **uracil (U)**, T takes A, C takes G, G takes C.
- The pairs are held by **hydrogen bonds**: weak enough to break as the enzyme passes, specific enough to copy exactly. The RNA matches the coding strand, with U for T.

TEMPLATE BASE, RNA BASE

Apples Under Cars Garage

A Adenine pairs with U	**U** Uracil replaces T in RNA	**C** Cytosine pairs with G	**G** Guanine pairs with C

D1.2.3 and 4

Read for a *lifetime*

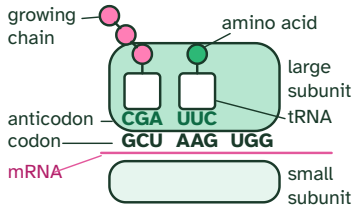
- Reading a template opens its hydrogen bonds for a moment; the **base sequence does not change**, so one gene gives many identical mRNAs.
- **Somatic cells that never divide** (most nerve cells of the outer brain) must **conserve their sequences** for life.
- **Not all genes are expressed** at once: transcription is where a gene is **switched on or off**.

Beta cell pancreas	Transcribes the insulin gene.
Skin cell same genes	Does not transcribe it.

D1.2.5 to 7

Translation: three RNAs

- The **base sequence of mRNA** sets the **amino acid sequence** of a polypeptide, at a ribosome.
- mRNA binds the **small subunit**; the **large subunit holds two tRNAs** at once.
- Each tRNA carries one amino acid and an **anticodon** that pairs with an mRNA **codon** by hydrogen bonds (A with U, C with G).



D1.2.8

A code written in *threes*

- **Why three:** four bases read singly give 4 meanings, in pairs 16: too few for 20 amino acids. Triplets give 64.
- **Degenerate**: most amino acids have **more than one codon**, but no codon means two.
- **Universal**: almost every organism reads **each codon as the same amino acid**.
- **AUG** is the start codon (methionine); **UAA, UAG, UGA** are stops.

4	16	64
one base	two bases	three bases

D1.2.9, D1.2.10 ELONGATION

One codon at a *time*

- **Skill:** deduce a polypeptide from mRNA with the codon table (it is given). Start at AUG, read in threes, end at a stop.

MRNA	AUG	GCU	AAG	UGG	UAA
chain	Met	Ala	Lys	Trp	stop

STEP 1	STEP 2	STEP 3
Bind A tRNA pairs with the next codon.	**Bond** A **peptide bond** joins its amino acid to the chain.	**Move** The ribosome moves **one codon**; the empty tRNA leaves.

- At a **stop codon** no tRNA pairs: the chain is released.

D1.2.11

One base, one *amino acid*

- **Sickle cell:** haemoglobin beta gene, codon 6: **GAG to GUG**, so **Glu to Val**.
- Non-polar Val replaces charged Glu, so at low oxygen haemoglobin forms **stiff fibres** that sickle red cells.

codon	5	6	7
normal	CCU	GAG	GAG
	Pro	Glu	Glu
sickle	CCU	GUG	GAG
	Pro	Val	Glu

A BASE SUBSTITUTION GIVES

Same, Swapped, Stopped

S Silent the same amino acid	**S** Missense a different amino acid	**S** Nonsense a stop: chain ends early

From the *promoter* to a working protein

D1.2.12 HIGHER LEVEL

Five prime to *three prime*

- A strand has a **5′ end** (phosphate on carbon 5′) and a **3′ end** (free OH on carbon 3′).
- **5′ to 3′ transcription**: each nucleotide joins the **3′ end** of the RNA; the template is read 3′ to 5′.
- **5′ to 3′ translation**: the ribosome moves from the 5′ end of the mRNA towards the 3′ end.
- The coding strand runs the same way as the mRNA, so written 5′ to 3′ their sequences match (U for T).

D1.2.13, D1.2.14 HIGHER LEVEL

The *promoter*, and non-coding DNA

- The **promoter**, just before a gene, is not transcribed. **Transcription factors** bind it; only then can RNA polymerase bind and start.

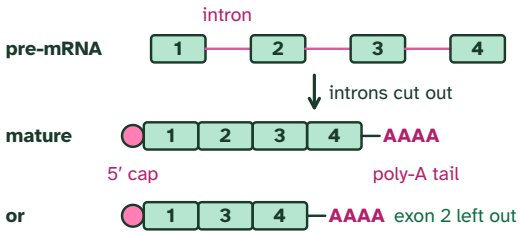
NON-CODING	CODES FOR NO POLYPEPTIDE
Regulators	Promoters, and other sites factors bind.
Introns	Transcribed, then cut out of the RNA.
Telomeres	Repeats that protect the chromosome ends.
rRNA, tRNA genes	Transcribed, never translated.

D1.2.15, D1.2.16 HIGHER LEVEL

Capped, *cut* and tailed

- In eukaryotes, **pre-mRNA** becomes **mature mRNA** in the nucleus.
- **Splicing: introns are removed** and the **exons joined**.
- A **5′ cap** and a **3′ poly-A tail stabilise** the mRNA.
- **Alternative splicing**: other combinations of exons let **one gene code for several polypeptides**.

In, Exit: introns stay in the nucleus; exons exit in the mRNA.



D1.2.17 HIGHER LEVEL

Starting the *chain*

- **Small subunit:** binds the **5′ end**, slides to AUG.
- **Initiator tRNA** (UAC, Met) pairs; **large subunit** joins.
- Initiator sits in P; a second tRNA binds at A.

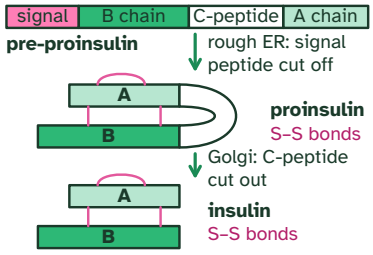
THREE TRNA SITES — *Arrive, Pass, Exit*

A **A site** a tRNA arrives	**P** **P site** holds the chain	**E** **E site** empty tRNA exits

D1.2.18, D1.2.19 HIGHER LEVEL

Finished, then *recycled*

- Many polypeptides must be **modified before they work**.
- **Insulin:** the **signal peptide** is cut off, then the **C-peptide**.
- **Proteasomes** break down tagged proteins for reuse: a proteome needs **constant breakdown and synthesis**.



WATCH OUT

Six mistakes that *cost marks*

- ✕ **RNA polymerase parts the DNA, not helicase.** One enzyme does it all.
- ✕ **mRNA is complementary to the template.** It matches the coding strand, U for T.
- ✕ **Codons are on mRNA, anticodons on tRNA.** DNA has neither.
- ✕ **Degenerate: several codons, one amino acid.** Never the reverse.
- ✕ **Peptide bonds join amino acids.** Hydrogen bonds hold codon to anticodon.
- ✕ **Introns leave the RNA, not the gene.** The DNA keeps them.

COVER THE SHEET

Can you *answer these?*

1. Outline the roles of RNA polymerase.
2. Explain how two cells with the same genes differ.
3. Describe the roles of mRNA, ribosomes and tRNA.
4. Explain why the genetic code is a triplet code.
5. Describe one step of elongation.
6. Explain how sickle cell anaemia arises.
7. Explain 5′ to 3′ transcription. HL
8. State four kinds of non-coding DNA. HL
9. Distinguish pre-mRNA from mature mRNA. HL
10. Describe the roles of the A, P and E sites. HL
11. Outline how pre-proinsulin becomes insulin. HL

IN THE EXAM

Given DNA? Write the mRNA first (template A gives U), then **start at AUG and read in threes**. Name each bond: "peptide" or "hydrogen".

GO FURTHER

Animated figures, a dry lab and a marked Check are in the full guide online.