

IB BIOLOGY · D1.2

Protein synthesis

Notes to fill in alongside the guide. Each numbered block matches a chapter of the guide, and of the lesson slides. Write in the gaps, answer the cues, annotate the figures, and sum up each section in your own words.

BY THE END YOU CAN

- ☐ Explain how RNA polymerase uses one strand of a gene as a template, pairing U in the RNA with A on the template D1.2.1, D1.2.2
- ☐ Explain why a template can be read for a lifetime without changing, and why transcription is where a gene is switched on or off D1.2.3, D1.2.4
- ☐ Describe what mRNA, the two ribosome subunits and tRNA each do in translation D1.2.5, D1.2.6
- ☐ Pair a codon with its anticodon, and explain how pairing brings the right amino acid D1.2.7
- ☐ Explain why the code uses threes and what degenerate and universal mean, and use a codon table to deduce a polypeptide D1.2.8, D1.2.9
- ☐ Describe how the ribosome moves one codon at a time, joining each amino acid to the chain with a peptide bond D1.2.10
- ☐ Explain how one base change in the haemoglobin gene causes sickle cell anaemia D1.2.11
- ☐ Explain what 5' to 3' means for transcription and for translation D1.2.12
- ☐ Explain how transcription factors start transcription at a promoter, and name four kinds of DNA that code for no polypeptide D1.2.13, D1.2.14
- ☐ Describe how pre-mRNA is capped, tailed and spliced, and how alternative splicing makes several polypeptides from one gene D1.2.15, D1.2.16
- ☐ Describe how translation starts, and what the A, P and E sites do D1.2.17
- ☐ Explain how pre-proinsulin becomes insulin, and why proteasomes keep breaking proteins down D1.2.18, D1.2.19

01 Copying a gene into RNA

D1.2.1 D1.2.2

CUES

Predict: A gene's template strand reads T A C C T G. Which RNA does RNA polymerase make from it?

What is meant by gene?

What is meant by transcription?

What is meant by messenger RNA?

NOTES

- 1 A _____ is a stretch of DNA whose base sequence codes for a polypeptide.
- 2 Making RNA with a DNA template is _____, and the RNA that carries a gene's message to the ribosomes is _____ (mRNA).
- 3 One enzyme does the whole job. _____ binds at the start of a gene and parts the two DNA strands over a short stretch (it needs no helicase: that enzyme unzips DNA when the whole molecule is copied, in D1.1).
- 4 Free RNA nucleotides pair with the exposed bases of one strand only, the _____.

What is meant by RNA polymerase?

What is meant by template strand?

What is meant by coding strand?

What is meant by complementary base pairing?

What is meant by uracil?

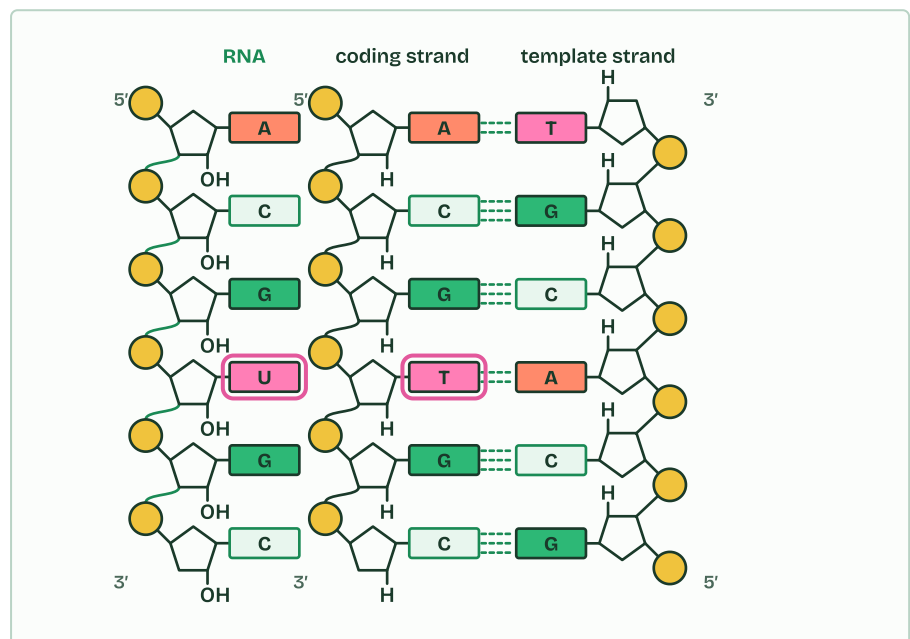
What is meant by hydrogen bonds?

- 5 The other strand is the _____, because the RNA ends up with its sequence.
- 6 _____ chooses every RNA base.
- 7 A on the template takes _____ (U), T takes A, C takes G and G takes C. The pairs are held by _____: weak enough to form and break as the enzyme passes, but specific, because only the right base fits.
- 8 The RNA is complementary to the template, and has the same sequence as the _____, with U where DNA has T.

Your own notes

ANNOTATE THE FIGURE

Number the 5 steps on the figure and note what happens at each.



REMEMBER IT

Which base pairs with which in transcription

A Apples	U Under	C Cars	G Garage
A _____	U _____	C _____	G _____

SPOT THE MISTAKE

What do students often get wrong about transcription? Write the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 01 in two or three sentences of your own.

CUES

Predict: A nerve cell in your brain is 60 years old and has never divided. Its genes have been transcribed all that time. What has happened to their base sequences?

What is meant by somatic cells?

What is meant by conserved?

What is meant by genome?

What is meant by gene expression?

What is meant by switched on?

What is meant by switched off?

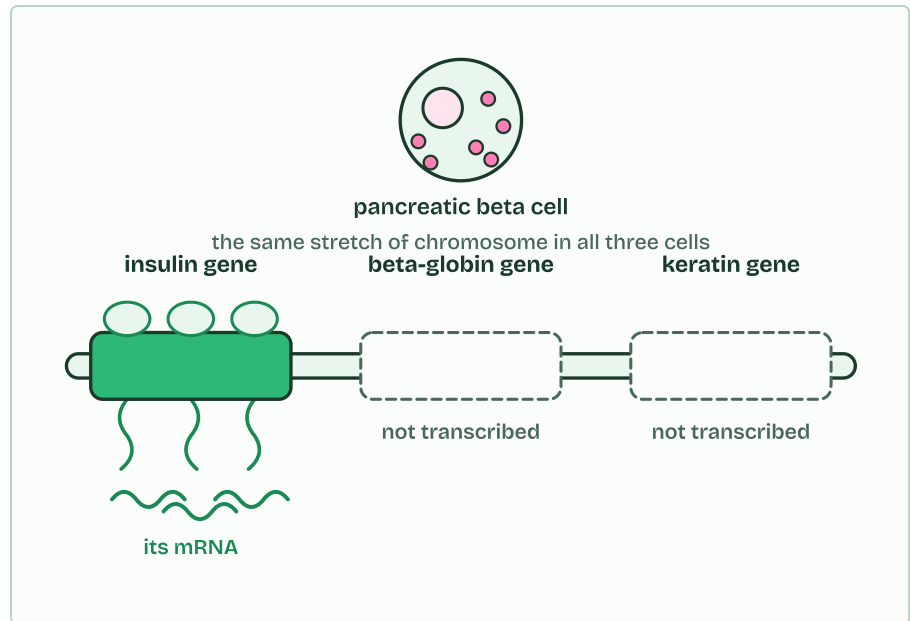
NOTES

- 1 That matters most in _____ that never divide again.
- 2 Their base sequences must be _____: held without change for the whole life of the cell.
- 3 Every somatic cell of one person has the same _____, yet no cell uses all of its genes.
- 4 That is _____, and it has two main steps: transcription copies the gene into mRNA, and translation (chapter 3) uses the mRNA to build a polypeptide.
- 5 A gene that is being transcribed is _____, and one that is not is _____.
- 6 Not all genes are expressed in a cell at one time, and transcription is where a gene is _____ or off.

Your own notes

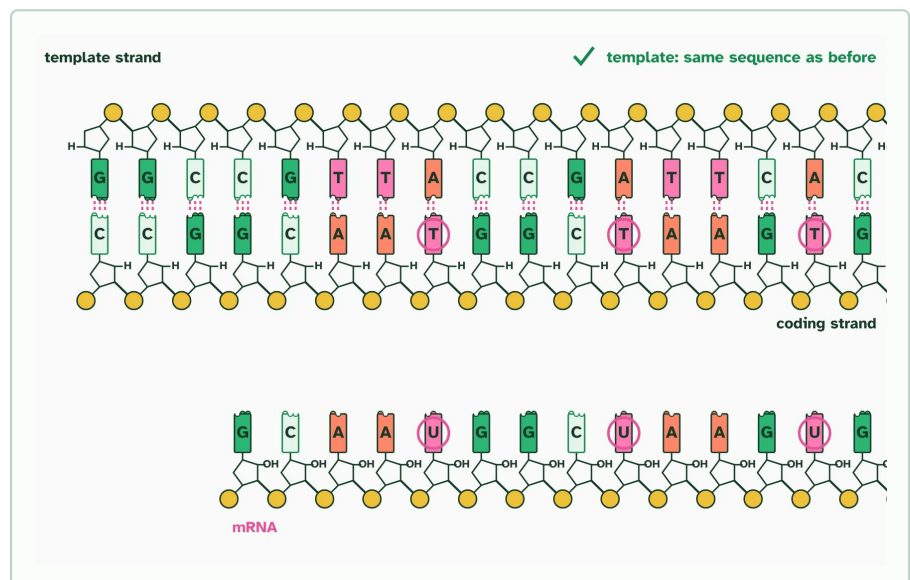
ANNOTATE THE FIGURE

The figure shows it as Pancreatic beta cell, Developing red blood cell and Skin cell. Note what changes each time.



ANNOTATE THE FIGURE

Annotate this still from the animation (One gene, copied): what is happening, and why?



SPOT THE MISTAKE

What do students often get wrong about stable templates, gene expression?
Write the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 02 in two or three sentences of your own.

03 Three kinds of RNA build a protein

D1.2.5 D1.2.6

CUES

Predict: The large subunit holds two tRNAs at the same moment. Why two, and not one?

What is meant by translation?

What is meant by polypeptide?

What is meant by amino acids?

What is meant by ribosomes?

What is meant by ribosomal RNA (rRNA)?

What is meant by small subunit?

What is meant by large subunit?

What is meant by transfer RNA (tRNA)?

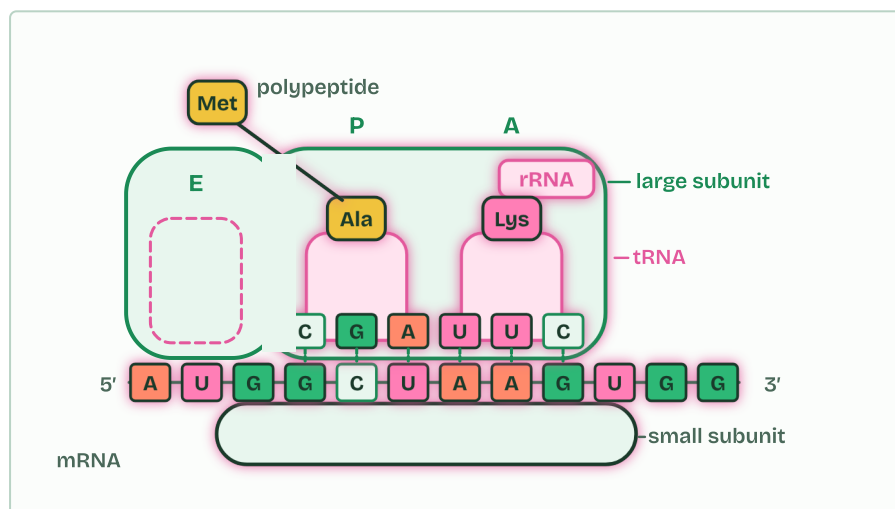
NOTES

- _____ makes a _____ whose order of _____ is set by the base sequence of an mRNA.
- It happens at _____, some free in the cytoplasm and some on the rough endoplasmic reticulum.
- A ribosome is made of _____ and protein, in two parts.
- The mRNA binds to the _____.
- The _____ can hold two tRNAs at once, side by side, and it joins their amino acids (the rRNA is what speeds up that joining).
- _____ molecules are short, single strands of RNA that fold back on themselves into a compact shape.
- mRNA binds to the _____ of the ribosome.
- Two tRNAs can bind at the same time, in the _____.

Your own notes

ANNOTATE THE FIGURE

Label each part and say what it does: small subunit, mRNA, large subunit, rRNA, tRNA, amino acid, polypeptide.



SPOT THE MISTAKE

What do students often get wrong about translation? Write the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 03 in two or three sentences of your own.

04 Codon meets anticodon

D1.2.7

CUES

Predict: A codon reads U G G.
Which anticodon pairs with it?

What is meant by codon?

What is meant by anticodon?

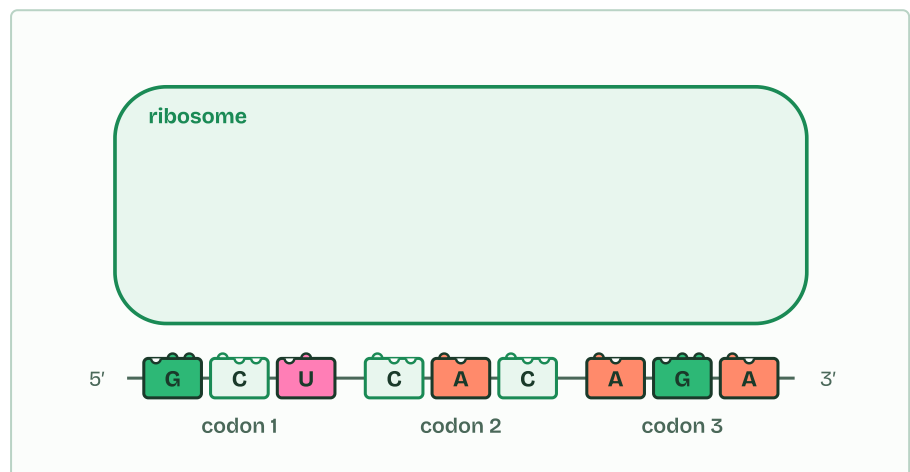
NOTES

- 1 Each group of three is a _____.
- 2 A tRNA carries a matching group of three exposed bases at one end, its _____, and one particular amino acid at the other end.
- 3 A codon sits on mRNA, an _____ on tRNA.

Your own notes

ANNOTATE THE FIGURE

The figure shows it as Three codons, a rack of tRNAs, One tRNA docked and Each codon has found its tRNA. Note what changes each time.



SPOT THE MISTAKE

What do students often get wrong about codons and anticodons? Write the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 04 in two or three sentences of your own.

05 A code written in threes

D1.2.8 D1.2.9

CUES

Predict: Why can the code not use pairs of bases for each amino acid?

What is meant by genetic code?

What is meant by triplet code?

What is meant by stop codons?

What is meant by start codon?

What is meant by degenerate?

What is meant by universal?

What is meant by reading frame?

NOTES

- 1 The _____ says which amino acid each codon stands for.
- 2 So the code is a _____.
- 3 The other three, UAA, UAG and UGA, are _____: they code for nothing and end the chain.
- 4 AUG codes for methionine and is also the _____, where translation begins.
- 5 With 61 codons for 20 amino acids, most amino acids have more than one codon, so the code is _____: leucine, serine and arginine have six each, methionine and tryptophan only one.
- 6 The code is also _____: almost every living thing reads each codon as the same amino acid, from bacteria to people.

Your own notes

ANNOTATE THE FIGURE

The figure shows it at bases in each codon 1, in each codon 2 and in each codon 3. Note what changes each time.

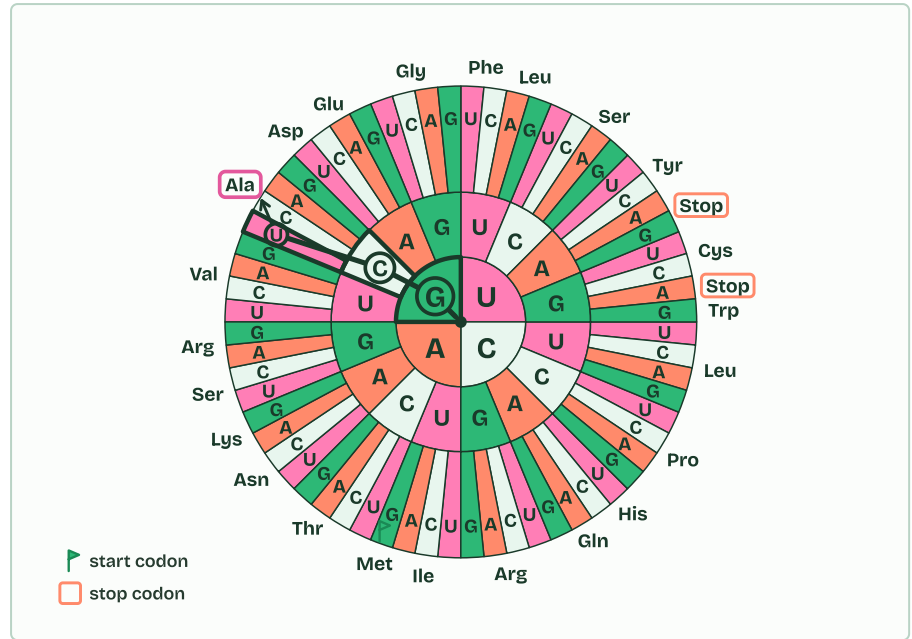
20 amino acids

each small block is one base:

A C G U

ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each: 1 genetic code; 2 first, second, third; 3 wheel.



SUMMARY

Sum up section 05 in two or three sentences of your own.

CUES

Predict: A polypeptide is 150 amino acids long. How many codons did the ribosome read to make it, counting the codon that ended it?

What is meant by elongation?

What is meant by peptide bond?

What is meant by condensation?

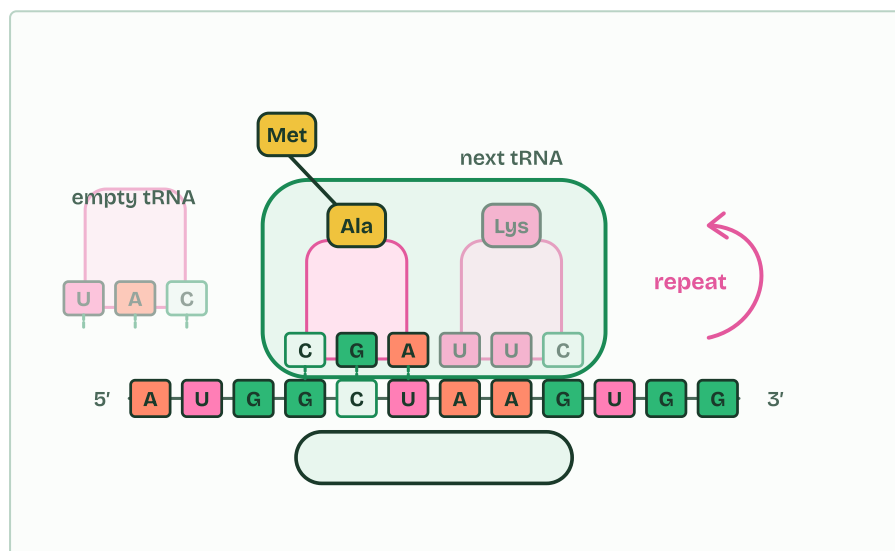
NOTES

- 1 Once translation has started, the polypeptide grows by a cycle that repeats for every codon. This is _____, and it is the part of translation this chapter follows. How translation starts is chapter 11.
- 2 The ribosome joins the chain to that amino acid with a _____. This is a _____ reaction, so a molecule of water is released, and the chain now hangs from the newest tRNA.
- 3 The next tRNA _____ with the open codon.
- 4 A _____ joins the chain to its amino acid.
- 5 The ribosome _____ one codon along.
- 6 The empty tRNA _____. Repeat.

Your own notes

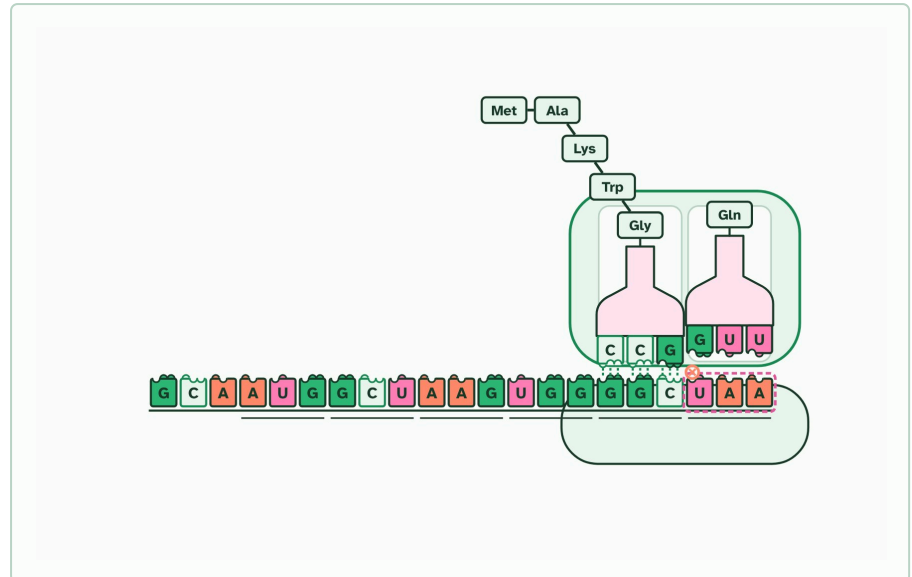
ANNOTATE THE FIGURE

Number the 4 steps on the figure and note what happens at each: 1 pairs; 2 peptide bond; 3 moves; 4 leaves.



ANNOTATE THE FIGURE

Annotate this still from the animation (One codon at a time): what is happening, and why?



SPOT THE MISTAKE

What do students often get wrong about elongation? Write the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 06 in two or three sentences of your own.

CUES

Predict: In a gene, one base changes so that an mRNA codon GAA becomes GAG. What happens to the polypeptide?

What is meant by mutation?

What is meant by point mutation?

What is meant by base substitution?

What is meant by silent?

What is meant by missense?

What is meant by nonsense?

What is meant by haemoglobin?

What is meant by sickle cell anaemia?

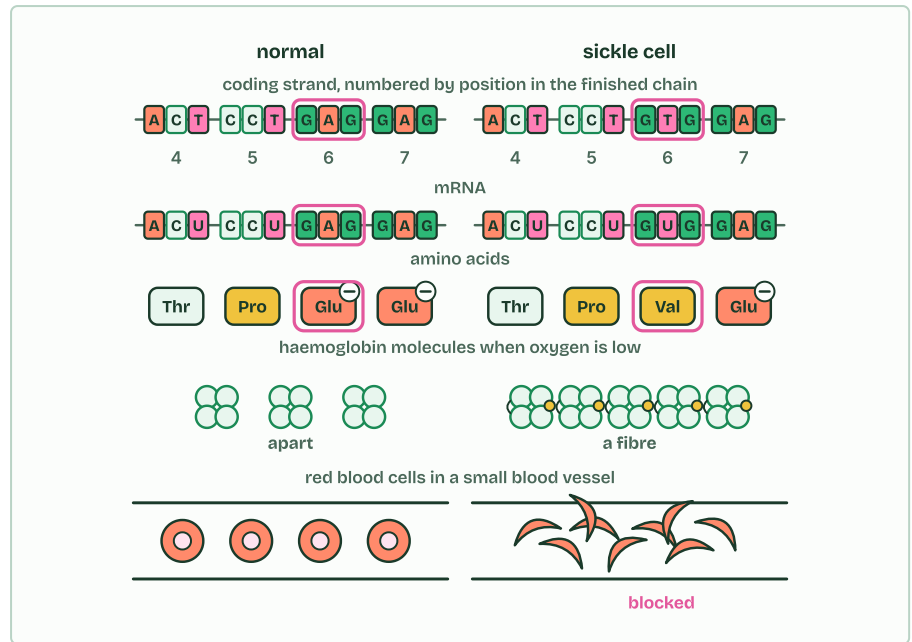
NOTES

- 1 A _____ is a change in the base sequence of a gene.
- 2 A _____ changes one base, and the commonest kind is a _____: one base swapped for another, which changes one codon.
- 3 If it stands for the same amino acid, the mutation is _____, which the code's degeneracy allows.
- 4 If it stands for a different amino acid, it is _____.
- 5 If it is a stop codon, it is _____, and the chain ends early, usually too short to work.
- 6 Sickle cell anaemia is the guide's example of a point mutation that changes a protein. _____ carries oxygen in red blood cells.
- 7 The sickled cells block small blood vessels, which causes pain and damage to organs, and they are destroyed early, so the person has too few red blood cells, which is _____.

Your own notes

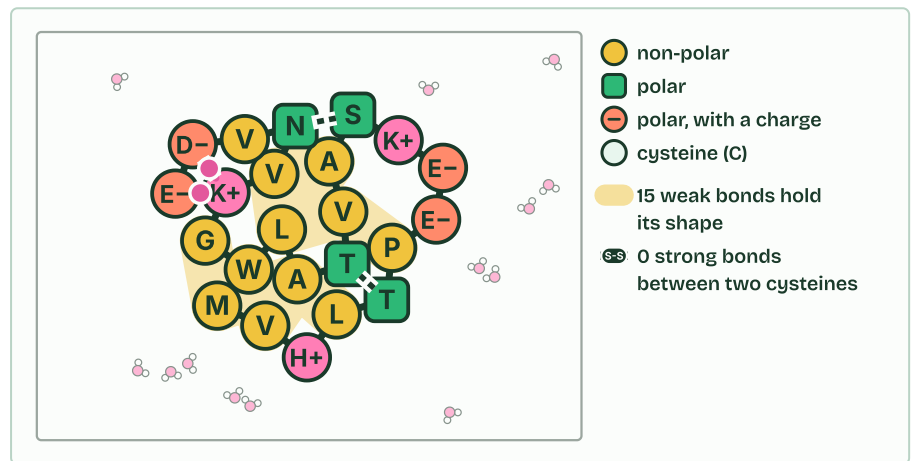
ANNOTATE THE FIGURE

Number the 5 steps on the figure and note what happens at each.



ANNOTATE THE FIGURE

Number the 2 steps on the figure and note what happens at each.



ANNOTATE THE FIGURE

Number the 4 steps on the figure and note what happens at each.

Clinic sample
Two alleles of one gene

	start	1	2	3	4	5	6	7	8
	normal								

A
T
G
G
T
G
C
A
T
C
T
G
A
C
T
G
A
G
G
A
G
A
A
G

A
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T
G
C
A
T
C
T
G
A
C
T
G
T
G
G
A
G
A
A
G

normal, amino acid 6

?

sickle cell, amino acid 6

?

REMEMBER IT

What a substitution can do

S Same	S Swapped	S Stopped
S	S	S

SPOT THE MISTAKE

What do students often get wrong about mutations that change protein structure? Write the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 07 in two or three sentences of your own.

08 Five prime to three prime, both times

D1.2.12 HL

CUES

Predict: A template strand reads 3'-TACAAGCGT-5'. Written 5' to 3', what is the mRNA?

What is meant by 5' end?

What is meant by 3' end?

What is meant by 5' to 3'?

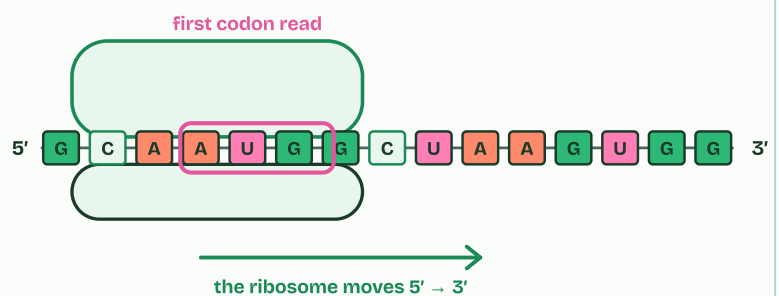
NOTES

- 1 A strand has a _____, where the last nucleotide has a phosphate on its carbon 5', and a _____, where the last nucleotide has a free OH on its carbon 3'.
- 2 _____ transcription means that RNA polymerase joins the 5' phosphate of each incoming RNA nucleotide to the 3' OH at the end of the growing RNA (the sugar is ribose, because this is RNA).
- 3 The polymerase reads the _____.
- 4 Each new nucleotide joins the RNA's _____.
- 5 The ribosome reads the mRNA _____ too.

Your own notes

ANNOTATE THE FIGURE

Number the 4 steps on the figure and note what happens at each.



SPOT THE MISTAKE

What do students often get wrong about directionality? Write the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 08 in two or three sentences of your own.

CUES

Predict: A gene for a tRNA is transcribed in every cell, but its RNA is never translated. Is it coding or non-coding DNA?

What is meant by promoter?

What is meant by transcription factors?

What is meant by non-coding sequences?

What is meant by regulators of gene expression?

What is meant by introns?

What is meant by telomeres?

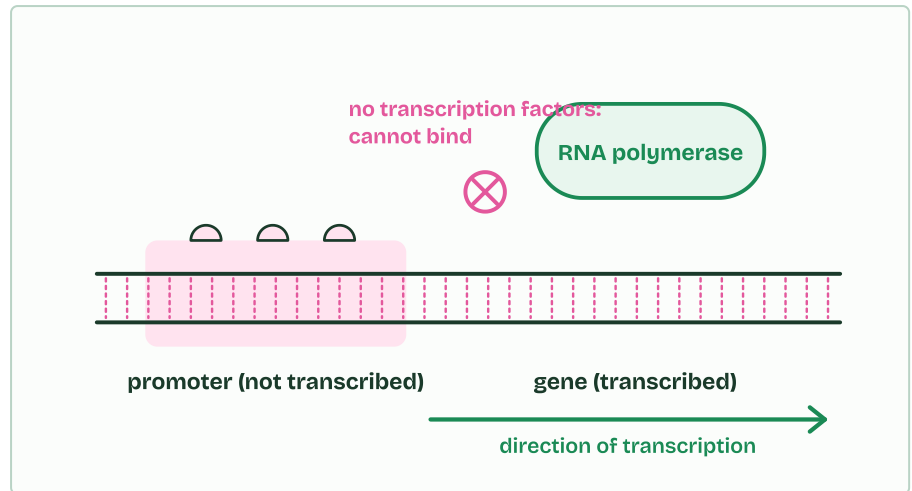
NOTES

- 1 The _____ is a stretch of DNA just before the part of a gene that is transcribed.
- 2 It is where transcription starts. _____ are proteins that attach to the promoter, and RNA polymerase can bind and start only when the right ones are in place (you do not have to name any).
- 3 _____ are stretches of DNA that code for no polypeptide.
- 4 _____: promoters, and other sequences where factors bind;
- 5 _____: stretches inside a gene that are transcribed but cut out of the RNA (chapter 10);
- 6 _____: repeats of a short sequence (TTAGGG in humans) at each end of a chromosome, which protect the genes near the ends when the DNA is copied;

Your own notes

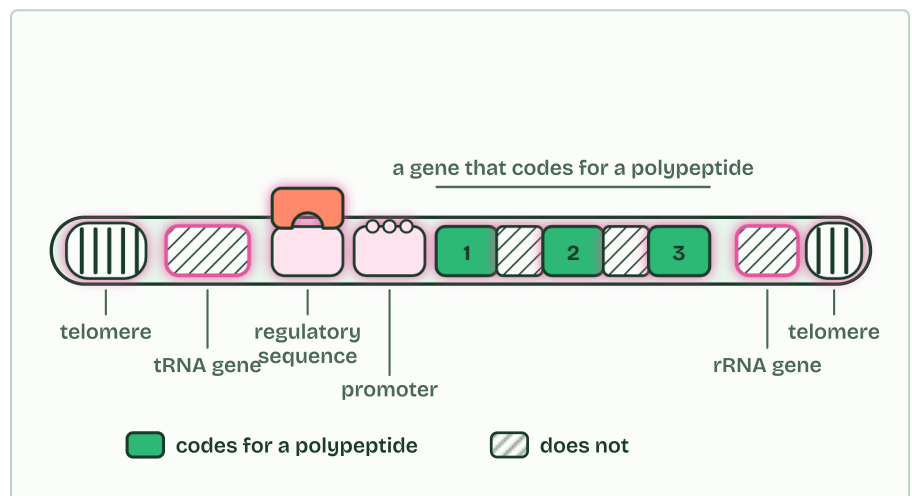
ANNOTATE THE FIGURE

The figure shows it as Absent and Present. Note what changes each time.



ANNOTATE THE FIGURE

Label each part and say what it does: telomere, tRNA gene, regulatory sequence, promoter, exon, intron, exon, intron, exon, rRNA gene, telomere.



SPOT THE MISTAKE

What do students often get wrong about promoters and non-coding DNA?
Write the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 09 in two or three sentences of your own.

10 Capped, cut and tailed

D1.2.15 HL D1.2.16 HL

CUES

Predict: A gene has four exons. Exons 1 and 4 are always kept, and exons 2 and 3 can each be kept or left out. How many different mature mRNAs can it make?

What is meant by pre-mRNA?

What is meant by post-transcriptional modification?

What is meant by mature mRNA?

What is meant by splicing?

What is meant by exons?

What is meant by 5' cap?

What is meant by poly-A tail?

What is meant by alternative splicing?

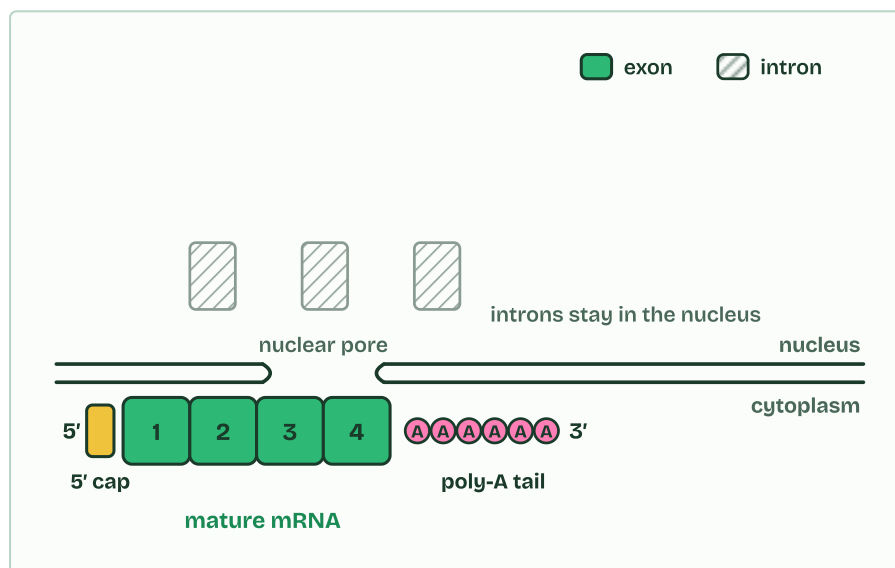
NOTES

- 1 In a eukaryotic cell, the RNA that RNA polymerase makes from a protein-coding gene is _____.
- 2 It is changed in the nucleus before it leaves, a stage called _____, and the result is _____.
- 3 In _____, the introns are cut out and the _____ joined end to end, so the mature mRNA carries only sequence that codes for the polypeptide.
- 4 A _____, a modified guanine nucleotide, is added to the 5' end, and a _____, a long run of adenine nucleotides (often about 200), to the 3' end.
- 5 _____: in many genes, which exons are kept can vary.

Your own notes

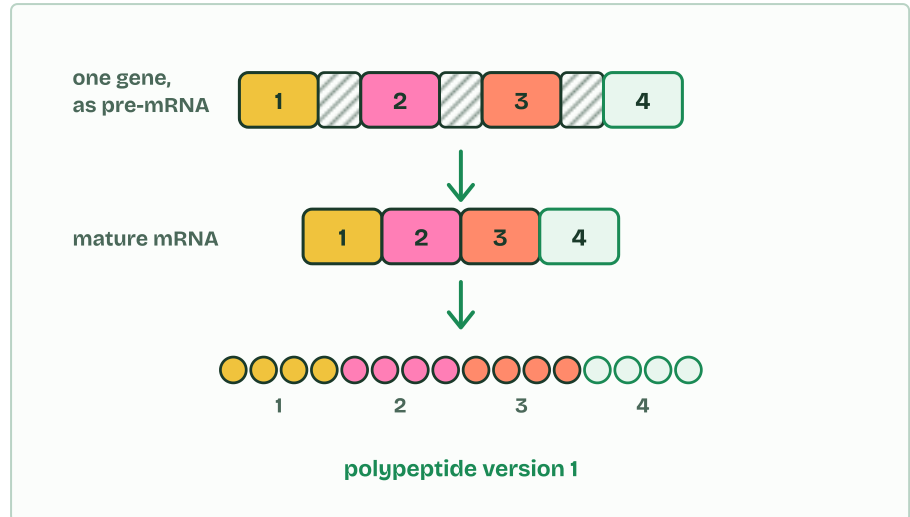
ANNOTATE THE FIGURE

Number the 5 steps on the figure and note what happens at each.



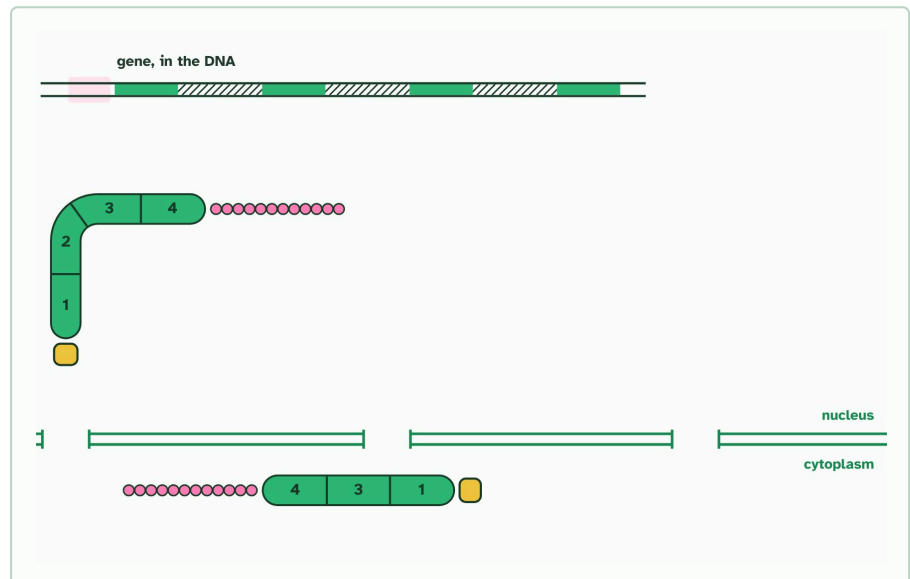
ANNOTATE THE FIGURE

The figure shows it as All four exons and Leave out exon 2. Note what changes each time.



ANNOTATE THE FIGURE

Annotate this still from the animation (From promoter to mature mRNA): what is happening, and why?



REMEMBER IT

Introns and exons

I In
I _____

E Exit
E _____

SPOT THE MISTAKE

What do students often get wrong about RNA processing and alternative splicing? Write the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 10 in two or three sentences of your own.

11 Starting the chain

D1.2.17 HL

CUES

Predict: The first peptide bond has just formed, joining methionine to the second amino acid. Before the ribosome moves, which site holds the tRNA carrying both amino acids?

What is meant by initiation?

What is meant by 5' terminal?

What is meant by initiator tRNA?

What is meant by a site?

What is meant by p site?

What is meant by e site?

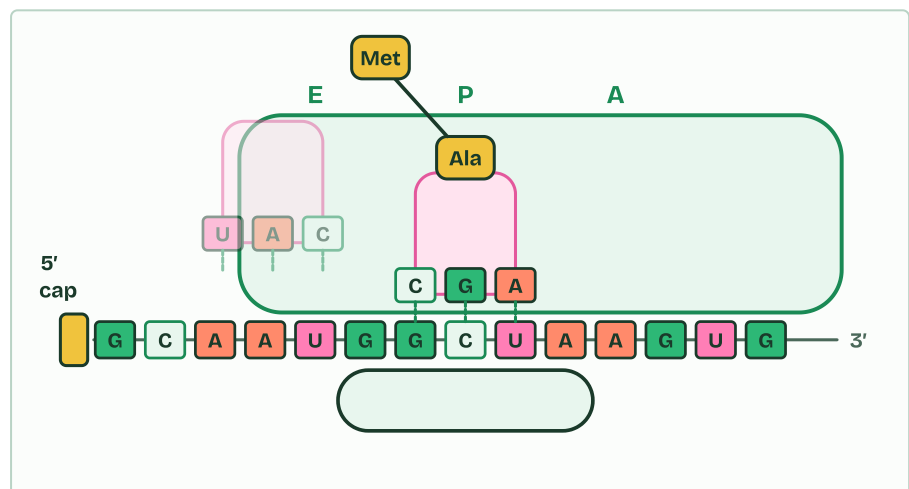
NOTES

- _____ is how translation starts.
- The _____ is where each new tRNA arrives with its amino acid.
- The _____ holds the tRNA carrying the growing chain, which is joined by a peptide bond to the amino acid in the A site.
- The _____ is where an empty tRNA goes when the ribosome moves one codon, and where it leaves from.
- the small subunit attaches to the mRNA at its _____, its 5' end (in eukaryotes the 5' cap helps);
- the _____, anticodon UAC, carrying methionine, pairs with AUG;
- the large subunit joins, so the ribosome is complete, with the _____ in the P site;
- another tRNA, matching the next codon, binds in the _____.

Your own notes

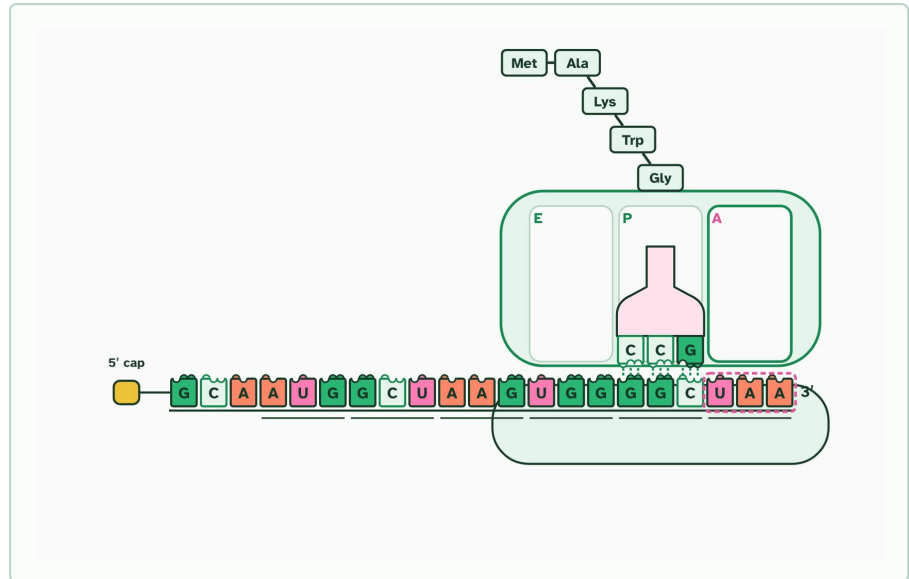
ANNOTATE THE FIGURE

Number the 6 steps on the figure and note what happens at each.



ANNOTATE THE FIGURE

Annotate this still from the animation (Start, then A, P and E): what is happening, and why?



REMEMBER IT

The three sites

A Arrive	P Pass	E Exit
A _____	P _____	E _____

SPOT THE MISTAKE

What do students often get wrong about initiation of translation? Write the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 11 in two or three sentences of your own.

CUES

Predict: Insulin's two chains are 21 and 30 amino acids long, and pre-proinsulin is 110. How many amino acids are cut away in all?

What is meant by post-translational modification?

What is meant by pre-proinsulin?

What is meant by signal peptide?

What is meant by proinsulin?

What is meant by disulfide bonds?

What is meant by proteasome?

What is meant by proteome?

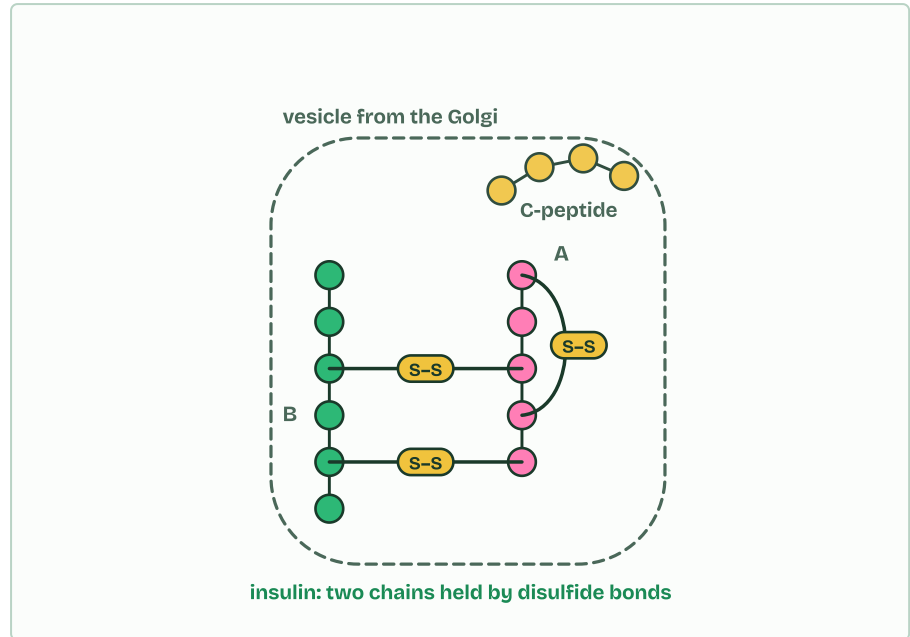
NOTES

- 1 They are modified first, which is called _____: they are cut, folded and bonded, or given extra groups such as sugars or phosphates.
- 2 It starts as _____, 110 amino acids long, which begins with a _____ of 24 amino acids.
- 3 In stage 1, in the rough ER, the signal peptide is cut off, leaving _____ (86 amino acids).
- 4 Proinsulin folds, and three _____ form: two join what will become the B chain to the A chain, and one lies within the A chain.
- 5 A _____ is a barrel-shaped complex of proteins, in the cytoplasm and the nucleus, that hydrolyses the peptide bonds of a protein into short pieces, which other enzymes then split into single amino acids for the cell to use again in building new proteins.
- 6 The _____ is all the proteins a cell makes.

Your own notes

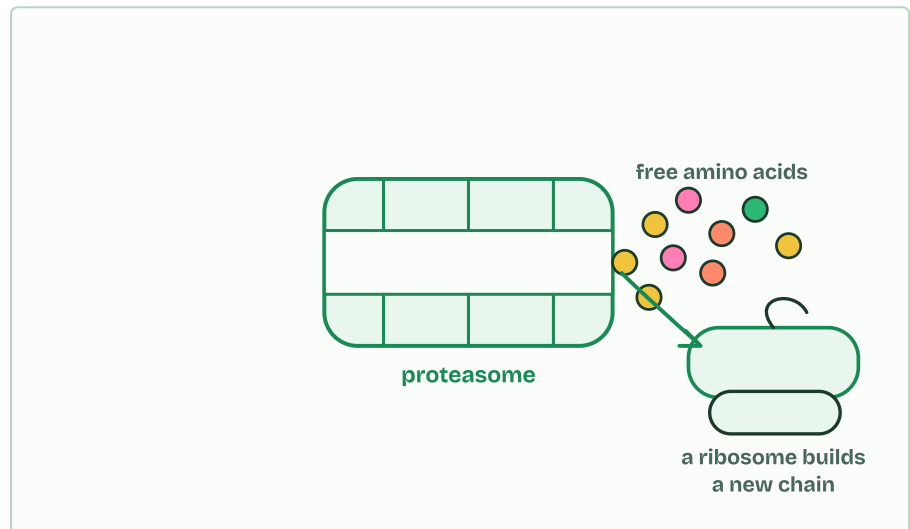
ANNOTATE THE FIGURE

Number the 5 steps on the figure and note what happens at each: 1 signal peptide; 2 proinsulin; 3 disulfide bonds; 4 C-peptide; 5 Insulin.



ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each.



SPOT THE MISTAKE

What do students often get wrong about modification and proteasomes?
Write the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 12 in two or three sentences of your own.



Check yourself

The check for this guide is online: a fresh paper of past-paper style questions from the exam bank on D1.2 each time, marked as you go, and saved to your Exam practice progress when you are signed in. Scan the code, or type the link.

biologybybradford.com/exam-maker/sit?topics=D1.2&level=HL&paper=quiz&marks=15&src=ep

How this was made. The course structure, the activities and the teaching choices come from my own classroom, my presentations and my years of teaching IB and AP Biology. I use Claude, an AI, to help write and build the interactive guides, lesson plans, slides and practice questions, and to draw the diagrams and code the interactives. I direct the work and review it against the IB and AP specifications before it goes live.