

Protein synthesis

Three one-hour lesson plans, and three more at higher level

Three one-hour lessons cover the standard level statements and three more the higher level ones (the guide gives D1.2 three hours at SL and three more at HL). The plan follows the chapters, so a class can read the guide for homework and use the lesson for the activities, the films and the protein factory. Every figure plays on a projector: step through it with the arrow keys and stop on each caption.

LESSON	COVERS	FOCUS	CHAPTERS
1 Copying a gene	D1.2.1 to D1.2.4	Transcription by RNA polymerase, complementary pairing, a template that never changes and genes switched on or off	1, 2
2 Codons and the code	D1.2.5 to D1.2.9	mRNA, ribosomes and tRNA; codons and anticodons; why the code is in threes; reading the table	3, 4, 5
3 Building the chain, and one base wrong	D1.2.10, D1.2.11	Elongation one codon at a time, peptide bonds, and how one substitution causes sickle cell anaemia	6, 7
4 Direction, promoters and non-coding DNA HL	D1.2.12 to D1.2.14	The direction of transcription and translation, transcription factors at the promoter, and DNA that codes for no polypeptide	8, 9
5 Processing and starting translation HL	D1.2.15 to D1.2.17	Caps, tails and splicing, one gene giving several polypeptides, and how translation starts	10, 11
6 Finishing, recycling, and the whole factory HL	D1.2.18, D1.2.19	Pre-proinsulin to insulin, proteasomes and a working proteome, then the whole process in the protein factory	12

The guide, for the class to read and play: biologybybradford.com/guides/ib-biology-d1-2-protein-synthesis

Copying a gene

60 minutes • D1.2.1 to D1.2.4 • Chapters 1, 2

Transcription by RNA polymerase, complementary pairing, a template that never changes and genes switched on or off

BY THE END, STUDENTS 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

TIMING

0-6	6 min	Do now: The kitchen	
6-18	12 min	Transcription step by step	
18-28	10 min	One gene, read again	
28-40	12 min	Stepping stones	
40-52	12 min	Improve this answer	
52-60	8 min	Exit	
	60 min	One lesson	

STARTER

- 6 min** **Do now: The kitchen**
- Students match eight kitchen cards to eight cell cards (activity 1 below), then spend one minute on where the comparison breaks.

ON THE BOARD, FROM THE GUIDE

Open the guide on the projector at each chapter (the links work in this PDF). Every figure plays from its own buttons, and the lesson's slides have the same figures, step by step, in the order of this plan.

01 Copying a gene into RNA

CHAPTER 01 IN THE SLIDES

Step through the figure (5 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. A gene: two strands of DNA, held by **hydrogen bonds**.
2. **RNA polymerase** parts the strands.
3. RNA nucleotides pair with the **template strand**: U opposite A.
4. The enzyme joins them into a strand and moves on; the DNA closes behind it.
5. The RNA has the **coding strand's** sequence, with U in place of T.

Predict box: A gene's template strand reads T A C C T G. Which RNA does RNA polymerase make from it? Hands up or mini whiteboards first.

Answer B: A U G G A C

Remember it: Apples Under Cars Garage (A on the template, U in the RNA, C on the template, G on the template).

02 Read for a lifetime, read when needed

CHAPTER 02 IN THE SLIDES

Switch the figure through Pancreatic beta cell, Developing red blood cell and Skin cell, and have the class say what will change before each.

Play the animation, One gene, copied. It loops; pause it on each moment below and ask what is happening (in the lesson slides it is a video).

1. RNA polymerase unzips a short stretch of the gene: the hydrogen bonds holding its bases together give way.
2. Free RNA nucleotides pair with the template by complementary base pairing, U opposite A.
3. Behind the enzyme the RNA peels off and the DNA closes up again.
4. The RNA has the coding strand's sequence, with U in place of T. The template has not changed.

Predict box: 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? Hands up or mini whiteboards first.

Answer C: Read many times, and still the same

THE LESSON

12

min

Transcription step by step

Chapter 1's figure on the board, step by step, with students drawing each step on mini whiteboards. Then chapter 1's predict box by vote, and Apples Under umbrellas.

10

min

One gene, read again

The transcription film, One gene, copied, after chapter 2. Then chapter 2's switch figure: why does the beta cell copy the insulin gene and the skin cell not? Finish with chapter 2's predict box, the 60-year-old nerve cell.

12

min

Stepping stones

Six prompts build an explanation of transcription (activity below). Pairs say it aloud, then swap roles.

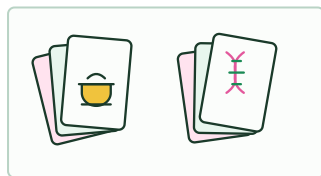
12

min

Improve this answer

A weak answer to "Outline how mRNA is made from a gene (5 marks)", marked and rewritten (activity below).

ACTIVITIES

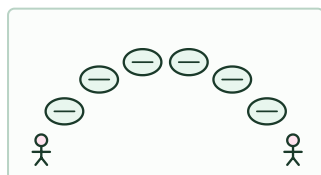


CARD MATCH

The kitchen

Eight kitchen cards (the recipe book, one recipe, the photocopier, the photocopy, the cook, the kitchen hands, the ingredients, the dish) to match with eight cell cards (the genome, a gene, RNA polymerase, mRNA, the ribosome, tRNAs, amino acids, the polypeptide). Then ask: where does it break? Push for these. A photocopy is identical, but mRNA pairs with the template and so matches the coding strand. A cook reads the whole recipe, but a ribosome reads three letters at a time. Recipes are not switched on and off.

Needs: two sets of cards for each pair, printed.

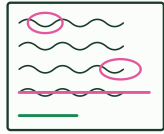


TALK

Stepping stones

Six stones on the floor or the board, each a prompt that starts a sentence: "RNA polymerase binds...", "It separates...", "Free RNA nucleotides...", "U pairs with...", "The enzyme joins...", "Behind it...". A student crosses the stones saying each sentence in full while a partner checks against chapter 1's captions, then they swap. Then do it again with the first words only.

Needs: six cards or six chalk circles.



WRITING

Improve this answer

This weak answer goes on the board: "Transcription makes RNA. The enzyme unzips the DNA and bases pair up, A with T and C with G. The RNA is a copy of the DNA. It then leaves." Students underline what earns credit and mark what is vague or wrong (A pairs with U in RNA; which strand; the enzyme's name; a copy of which strand; where), then write a 5-mark version. No markscheme is shown: the class builds the points from [chapter 1](#).

Needs: the answer on the board or printed.

PLENARY

8

min

Exit

"Why can the same gene be read for 80 years without changing?" and "Where is a gene switched on or off?" One sentence each.

WHAT STUDENTS GET WRONG

Helicase unwinds DNA for transcription. RNA polymerase does it in transcription; helicase is replication's.

The mRNA is a copy of the template strand. It is complementary to the template and matches the coding strand, with U for T.

A pairs with T in transcription. A on the template pairs with U in the RNA.

Transcription uses up the gene. The template is read, not changed, and can be read again.

Different cells have different genes. Same genes, different ones transcribed.

STRETCH AND SUPPORT

Support: cut the figures' captions into cards to put in order, use the dotted key terms as a glossary, and give a codon table with the reading path printed on it (row, column, line).

Support: use the mnemonics (Apples Under umbrellas; Same, Swapped, Stopped) as starters.

IN THE GUIDE

- 1 [Copying a gene into RNA](#)
- 2 [Read for a lifetime, read when needed](#)
- All [The whole guide, with the figures that play](#)
- PPTX [This lesson's slides, in the order of this plan](#)

PRACTISE AND REVISE

BUILD FOR YOUR CLASS

- [Tarsia puzzle](#), [dominoes](#) and [picture reveal](#) on D1.2, built from its key terms and ready to print
- A [pub quiz](#) with rounds on D1.2, to present or run with no projector
- An [escape room](#) built from the [question bank](#) on D1.2

ALREADY ON THE SITE FOR D1.2

- Quiz: [Protein Synthesis \(HL\)](#)
- Quiz: [Protein Synthesis](#)
- Revision map: [D1.2 Protein synthesis](#), to fill in
- Exam questions: [D1.2 in the exam maker](#), a paper with its markscheme

CARD SETS ON SPLYCR

Open a set to host it as a class game, or make a copy to edit.

- [D1.2 Protein Synthesis \(SL\)](#)
- [D1.2 Protein Synthesis \(HL\)](#)

EXAM PRACTICE

Check yourself

Set it for homework: a fresh paper of exam-bank questions on D1.2 at standard level each time, marked as students go and saved to their Exam practice when they are signed in.

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



Codons and the code

60 minutes • D1.2.5 to D1.2.9 • Chapters 3, 4, 5

mRNA, ribosomes and tRNA; codons and anticodons; why the code is in threes; reading the table

BY THE END, STUDENTS CAN

- ☐ 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

TIMING

0-6	6 min	Do now	
6-16	10 min	A ribosome at work	
16-26	10 min	Dock the tRNA	
26-40	14 min	Why three, and the table	
40-54	14 min	Codon cipher	
54-60	6 min	Exit	
	60 min	One lesson	

STARTER

- 6 min** **Do now**
- "Four letters, twenty words. How long must each word be?" on mini whiteboards, then transcribe a six-base template from lesson 1 as a warm-up.

ON THE BOARD, FROM THE GUIDE

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03 Three kinds of RNA build a protein

CHAPTER 03 IN THE SLIDES

Tap the parts of the figure in turn: Small subunit, mRNA, Large subunit, rRNA, tRNA, Amino acid and Polypeptide.

Predict box: The large subunit holds two tRNAs at the same moment. Why two, and not one? Hands up or mini whiteboards first.

Answer B: So one amino acid can be joined to the next

04 Codon meets anticodon

CHAPTER 04 IN THE SLIDES

Switch the figure through Three codons, a rack of tRNAs, One tRNA docked and Each codon has found its tRNA, and have the class say what will change before each.

Predict box: A codon reads U G G. Which anticodon pairs with it? Hands up or mini whiteboards first.

Answer A: A C C

05 A code written in threes

CHAPTER 05 IN THE SLIDES

Slide the figure through Bases in each codon 1, Bases in each codon 2 and Bases in each codon 3, and have the class say what will change before each.

Step through the figure (3 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. The **genetic code**: 64 codons, read from the first base to the third.
2. Find the **first** base, then the **second**, then the **third**: GCU is alanine.
3. The **wheel** holds the same code, read from the centre out.

Predict box: Why can the code not use pairs of bases for each amino acid? Hands up or mini whiteboards first.

Answer C: Pairs give only 16 codons for 20 amino acids

THE LESSON

10

min

A ribosome at work

Chapter 3's explore figure on the board, with students tapping the parts in pairs. Then chapter 3's predict box.

10

min

Dock the tRNA

Chapter 4's figure, one student at the board, then chapter 4's predict box (UGG).

14

min

Why three, and the table

Chapter 5's first predict box, then figure 5.1's slider. Then the codon tool, The genetic code: find the amino acid with six codons and the ones with one, and define degenerate and universal from what the class found. Its Practise with the chart drill sets rounds of ten for homework, and Share this round gives the whole class the same ten questions.

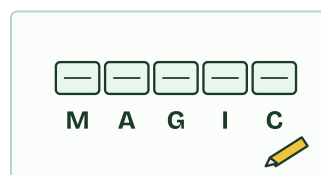
14

min

Codon cipher

Pairs decode and write messages with the codon table (activity below).

ACTIVITIES



PUZZLE

Codon cipher

Pairs decode mRNA messages whose amino acids' one-letter codes spell words (print the table with one-letter codes: the codon tool, The genetic code, shows three-letter names). Every message starts with the start codon, so every word begins with M: AUG GCU GGU AUU UGU UAA reads Met-Ala-Gly-Ile-Cys, M A G I C. Words can use only the letters A, C, D, E, F, G, H, I, K, L, M, N, P, Q, R, S, T, V, W and Y, and each message ends with a stop codon. Then each pair writes a message for another pair as a coding strand (harder: as a template strand). The teacher's key: check each message with the codon tool's converter.

Needs: the codon tool or printed tables, and paper.

PLENARY

6

min

Exit

Chapter 5's second predict box: deduce the chain, using the table.

WHAT STUDENTS GET WRONG

tRNA carries the codon. Codons are on mRNA; anticodons are on tRNA.

Anticodons contain T. tRNA is RNA: U.

Degenerate means a codon can code for two amino acids. It means an amino acid can have several codons.

The stop codon is an amino acid. It codes for none and ends the chain.

Reading the anticodons or the template in the codon table. The table is of mRNA codons.

STRETCH AND SUPPORT

Support: cut the figures' captions into cards to put in order, use the dotted key terms as a glossary, and give a codon table with the reading path printed on it (row, column, line).

Stretch: the code would work with fewer stop codons, or with more. Why might three stops, and degeneracy in the third base, make the code tolerant of mistakes? (Silent changes: the guiding question on reliability.)

IN THE GUIDE

3 [Three kinds of RNA build a protein](#)

4 [Codon meets anticodon](#)

5 [A code written in threes](#)

A11 [The whole guide, with the figures that play](#)

PPTX [This lesson's slides, in the order of this plan](#)

EXAM PRACTICE

Check yourself

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



PRACTISE AND REVISE

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ALREADY ON THE SITE FOR D1.2

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CARD SETS ON SPLYCR

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- [D1.2 Protein Synthesis \(SL\)](#)
- [D1.2 Protein Synthesis \(HL\)](#)

Building the chain, and one base wrong

60 minutes • D1.2.10, D1.2.11 • Chapters 6, 7

Elongation one codon at a time, peptide bonds, and how one substitution causes sickle cell anaemia

BY THE END, STUDENTS CAN

- ☐ 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

TIMING

0-6	6 min	Do now: Translation in order	
6-16	10 min	The elongation cycle	
16-28	12 min	Paper ribosome	
28-40	12 min	One base, one amino acid	
40-52	12 min	The protein factory	
52-60	8 min	Exit	
	60 min	One lesson	

STARTER

6
min

Do now: Translation in order

Eight cards put in the order a message meets them (activity below).

ON THE BOARD, FROM THE GUIDE

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06 One codon at a time

CHAPTER 06 IN THE SLIDES

Step through the figure (4 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. The next tRNA **pairs** with the open codon.
2. A **peptide bond** joins the chain to its amino acid.
3. The ribosome **moves** one codon along.
4. The empty tRNA **leaves**. Repeat.

Play the animation, One codon at a time. It loops; pause it on each moment below and ask what is happening (in the lesson slides it is a video).

1. A tRNA whose anticodon pairs with the codon brings the right amino acid.
2. A peptide bond joins the chain to the new amino acid.
3. The ribosome moves along one codon, and the empty tRNA leaves to collect another amino acid.
4. At a stop codon no tRNA fits, and the polypeptide is released.

Predict box: A polypeptide is 150 amino acids long. How many codons did the ribosome read to make it, counting the codon that ended it? Hands up or mini whiteboards first.

Answer B: 151

Step through the figure (5 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. One base differs in the gene for haemoglobin's beta chain.
2. So one **codon** in the mRNA differs.
3. So one **amino acid** differs: **valine** for glutamic acid.
4. The non-polar valine makes the molecules stick into **fibres**.
5. Fibres bend the cells into sickles that block small vessels.

Step through the figure (2 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. The gene is transcribed and translated: Its 23 amino acids are joined by 22 peptide bonds: one of 20^{23} (about 8×10^{29}) possible chains this long. A ribosome makes the chain one amino acid at a time, and it starts to fold as it comes out.
2. It folds into a shape of its own, held by **weak bonds** between its side chains.

Step through the figure (4 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. Which strand will you copy?
2. Pick the base that pairs: RNA has U, not T.
3. Which tRNA's anticodon pairs with this codon?
4. One base differs. What does it do to the protein?

Predict box: In a gene, one base changes so that an mRNA codon GAA becomes GAG. What happens to the polypeptide? Hands up or mini whiteboards first.

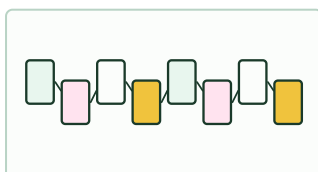
Answer C: No change: GAG also codes for Glu

Remember it: Same Swapped Stopped (Silent, Missense, Nonsense).

THE LESSON

10 min	The elongation cycle Chapter 6's step-through, then the ribosome film, One codon at a time, then chapter 6's predict box (151 codons).
12 min	Paper ribosome Groups slide the paper ribosome along a paper mRNA, ending on the model's limits (activity below).
12 min	One base, one amino acid Chapter 7's predict box (GAA to GAG) first, then figure 7.1, Fold a protein (make the sickle cell change, fold both and make a second copy of each) and Same, Swapped, Stopped. Then Sort the substitutions.
12 min	The protein factory In pairs, on a device each: rounds 1, 3 and 4 (round 2 and round 5 for homework).

ACTIVITIES

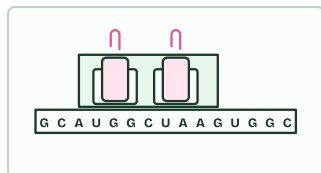


CARD SORT

Translation in order

Eight cards to put in the order a message meets them: mRNA, ribosome, codon, anticodon, tRNA, amino acid, peptide bond, polypeptide. Then one sentence linking each pair of neighbours.

Needs: sets of cards.



MODEL

Paper ribosome

A long mRNA strip (the demonstration gene of chapters 1 to 7, printed in codons), a ribosome card with two windows cut in it, and tRNA cards with the anticodon at the foot and an amino acid on a paper clip at the top. Groups slide the ribosome one codon at a time, dock the tRNA, move the paper clips onto the newest one, and send the empty tRNA back. Then ask what the model leaves out, and what it gets wrong: it has no energy, nothing forces the right tRNA to arrive, real bonds are chemical, and a ribosome is made of RNA and protein.

Needs: printed strips and cards, scissors, paper clips.

GAME

The protein factory

One device per pair. The standard level rounds are for lesson 3 and the higher level rounds for lesson 6; its record downloads as a CSV for a class comparison.

Needs: one device per pair.

PLENARY

8
min

Exit

A short written question on translation or elongation from the D1.2 exam maker (in Practise and revise), marked in pairs against its markscheme.

WHAT STUDENTS GET WRONG

Amino acids in the chain are held by hydrogen bonds.

Peptide bonds; the hydrogen bonds are codon to anticodon.

Every mutation changes the protein. Silent substitutions do not.

Sickle cell haemoglobin cannot carry oxygen. It carries it; the harm is the fibres, the cell shape and the cells' short life.

STRETCH AND SUPPORT

Support: cut the figures' captions into cards to put in order, use the dotted key terms as a glossary, and give a codon table with the reading path printed on it (row, column, line).

Support: use the mnemonics (Apples Under umbrellas; Same, Swapped, Stopped) as starters.

Stretch: Reading Frame, a codon game whose last round adds insertions and deletions, a look ahead to D1.3.

Stretch: in the factory's round 5, find a single base change in the demonstration gene for each of Same, Swapped and Stopped, and explain why changes to the third base are most often silent.

IN THE GUIDE

- 6** [One codon at a time](#)
- 7** [One base, one amino acid](#)
- A11** [The whole guide, with the figures that play](#)
- PPTX** [This lesson's slides, in the order of this plan](#)

PRACTISE AND REVISE

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- Revision map: [D1.2 Protein synthesis](#), to fill in
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- [D1.2 Protein Synthesis \(HL\)](#)

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Direction, promoters and non-coding DNA HL

60 minutes • D1.2.12 to D1.2.14 • Chapters 8, 9

The direction of transcription and translation, transcription factors at the promoter, and DNA that codes for no polypeptide

BY THE END, STUDENTS CAN

- ☐ 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

TIMING

0-6	6 min	Do now	
6-16	10 min	Which way it runs	
16-34	18 min	Gene expression simulation	
34-42	8 min	Switch the gene on	
42-54	12 min	What is in a genome?	
54-60	6 min	Exit	
60 min		One lesson	

STARTER

- 6 min** **Do now**
 Chapter 8's predict box (3'-TACAAGCGT-5') on mini whiteboards.

ON THE BOARD, FROM THE GUIDE

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08 Five prime to three prime, both times

CHAPTER 08 IN THE SLIDES

Step through the figure (4 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. The polymerase reads the **template 3' to 5'**.
2. Each new nucleotide joins the RNA's **3' end**.
3. Nothing can join at the 5' end.
4. The ribosome reads the mRNA **5' to 3'** too.

Predict box: A template strand reads 3'-TACAAGCGT-5'. Written 5' to 3', what is the mRNA? Hands up or mini whiteboards first.

Answer B: 5'-AUGUUCGCA-3'

09 Where a gene starts, and DNA that codes for nothing

CHAPTER 09 IN THE SLIDES

Switch the figure through Absent and Present, and have the class say what will change before each.

Tap the parts of the figure in turn: Telomere, tRNA gene, Regulatory sequence, Promoter, Exon, Intron, Exon, Intron, Exon, rRNA gene and Telomere.

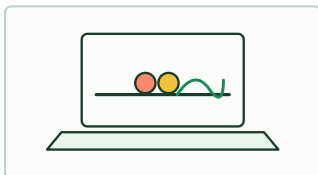
Predict box: A gene for a tRNA is transcribed in every cell, but its RNA is never translated. Is it coding or non-coding DNA? Hands up or mini whiteboards first.

Answer A: Non-coding: its RNA is the product

THE LESSON

- 10**
min **Which way it runs**
Chapter 8's figure. Students add 5' and 3' labels and two arrows to their lesson 1 drawing.
- 18**
min **Gene expression simulation**
Pairs work through the simulation and its questions (activity below).
- 8**
min **Switch the gene on**
Chapter 9's switch figure, then chapter 9's predict box (the tRNA gene).
- 12**
min **What is in a genome?**
Pairs estimate and shade a 100-square grid, then check it against chapter 9's chromosome figure (activity below).

ACTIVITIES

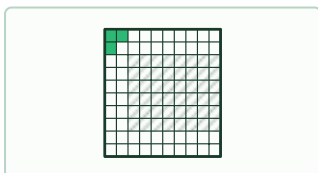


SIMULATION · HL

Gene expression simulation

The free [Gene Expression Essentials](#) simulation from PhET, with these questions. What must be on the regulatory region before RNA polymerase will transcribe the gene? What does a positive transcription factor do, and what does a negative one do? Why would a cell destroy its mRNA? Which slider on the mRNA screen changes the rate most? What does "affinity" mean here? Land on this: the regulatory region in the simulation stands for the promoter, and the factors decide whether a gene is read.

Needs: laptops or tablets (it runs in a browser).



DATA · HL

What is in a genome?

Pairs estimate, then shade, a 100-square grid for the human genome: protein-coding exons, introns, regulators, rRNA and tRNA genes, telomeres, and other. Then compare with the real figures: about 1 to 2% codes for protein ([chapter 9](#)), and introns make up roughly a quarter or more of the genome. The point is the size of the coding share, not exact numbers for the rest.

Needs: printed grids and coloured pencils.

PLENARY

- 6**
min **Exit**
"Name four kinds of non-coding DNA and say what each does."

WHAT STUDENTS GET WRONG

The ribosome reads 3' to 5'. 5' to 3'; it is the template that is read 3' to 5' in transcription.

The promoter is the TATA box, and it is transcribed. The promoter is a region, not transcribed; a TATA box is one sequence found in many.

Non-coding DNA is junk, or is never transcribed. It has jobs; introns and rRNA and tRNA genes are transcribed.

STRETCH AND SUPPORT

Support: play the factory's "Let the cell do it" on the board before pairs try a round.

IN THE GUIDE

- 8** [Five prime to three prime, both times](#)
- 9** [Where a gene starts, and DNA that codes for nothing](#)
- A11** [The whole guide, with the figures that play](#)
- PPTX** [This lesson's slides, in the order of this plan](#)

PRACTISE AND REVISE

BUILD FOR YOUR CLASS

- [Tarsia puzzle, dominoes and picture reveal](#) on D1.2, built from its key terms and ready to print
- A [pub quiz](#) with rounds on D1.2, to present or run with no projector
- An [escape room built from the question bank](#) on D1.2

ALREADY ON THE SITE FOR D1.2

- Quiz: [Protein Synthesis \(HL\)](#)
- Quiz: [Protein Synthesis](#)
- Revision map: [D1.2 Protein synthesis](#), to fill in
- Exam questions: [D1.2 in the exam maker](#), a paper with its markscheme

CARD SETS ON SPLYCR

- Open a set to host it as a class game, or make a copy to edit.
- [D1.2 Protein Synthesis \(SL\)](#)
 - [D1.2 Protein Synthesis \(HL\)](#)

EXAM PRACTICE

Check yourself

Set it for homework: a fresh paper of exam-bank questions on D1.2 at higher level each time, marked as students go and saved to their Exam practice when they are signed in.

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



Processing and starting translation HL

60 minutes • D1.2.15 to D1.2.17 • Chapters 10, 11

Caps, tails and splicing, one gene giving several polypeptides, and how translation starts

BY THE END, STUDENTS CAN

- ☐ 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

TIMING

0-6	6 min	Do now	
6-18	12 min	Capped, cut and tailed	
18-30	12 min	Paper splice	
30-42	12 min	Starting the chain	
42-54	12 min	Be the ribosome	
54-60	6 min	Exit	
	60 min	One lesson	

STARTER

6
min

Do now

"List what must happen to pre-mRNA before it leaves the nucleus, and why." Cold call, then the board.

ON THE BOARD, FROM THE GUIDE

Open the guide on the projector at each chapter (the links work in this PDF). Every figure plays from its own buttons, and the lesson's slides have the same figures, step by step, in the order of this plan.

10 Capped, cut and tailed

CHAPTER 10 IN THE SLIDES

Step through the figure (5 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. Pre-mRNA: **exons** and **introns**.
2. A **5' cap** is added.
3. A **poly-A tail** is added.
4. Introns are cut out and the exons **spliced** together.
5. Mature mRNA leaves the nucleus.

Switch the figure through All four exons and Leave out exon 2, and have the class say what will change before each.

Play the animation, From promoter to mature mRNA. It loops; pause it on each moment below and ask what is happening (in the lesson slides it is a video).

1. Transcription factors bind the promoter. Only then can RNA polymerase bind and begin.
2. The RNA grows 5' to 3': every new nucleotide joins its 3' end.
3. In a eukaryote the first RNA is pre-mRNA: exons, with introns between them.
4. A 5' cap and a poly-A tail are added. The introns are cut out and the exons spliced together.
5. Spliced another way, the same gene gives a different polypeptide.
6. Capped, tailed and spliced, the mature mRNA leaves the nucleus.

Predict box: 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? Hands up or mini whiteboards first.

Answer C: 4

Remember it: In Exit (Introns, Exons).

11 Starting the chain

CHAPTER 11 IN THE SLIDES

Step through the figure (6 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. The **small subunit** attaches at the mRNA's 5' end.
2. It moves to the **start codon**, AUG, where the **initiator tRNA** pairs.
3. The **large subunit** joins: the initiator tRNA is in the **P site**.
4. The next tRNA arrives in the **A site**.
5. A peptide bond joins the two amino acids.
6. The ribosome moves one codon; the empty tRNA leaves from the **E site**.

Play the animation, Start, then A, P and E. It loops; pause it on each moment below and ask what is happening (in the lesson slides it is a video).

1. The small subunit attaches to the mRNA at its 5' end.
2. It moves towards the 3' end until it reaches the start codon, AUG. The initiator tRNA pairs with it.
3. The large subunit joins. The initiator tRNA sits in the P site.
4. Another tRNA arrives in the A site. A peptide bond joins methionine to its amino acid.
5. The ribosome moves one codon. The empty tRNA leaves from the E site; the chain's tRNA is now in P.
6. At the stop codon the chain is released and the subunits come apart.

Predict box: 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? Hands up or mini whiteboards first.

Answer A: A site

Remember it: Arrive Pass Exit (A site, P site, E site).

THE LESSON

12 Capped, cut and tailed

min

Chapter 10's step-through, then the HL transcription film, From promoter to mature mRNA (try its Cap and tail switch). Then [chapter 10's](#) predict box (four exons) and Introns stay In, Exons Exit.

12 Paper splice

min

Students splice a paper pre-mRNA two ways and translate both (activity below).

12 Starting the chain

min

[Chapter 11's](#) predict box (which site holds the chain) first, then the step-through and the HL ribosome film, Start, then A, P and E, then Arrive, Pass, Exit.

12 Be the ribosome

min

A role play of initiation and elongation (activity below).

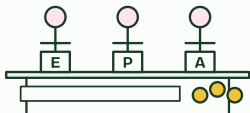


MODEL · HL

Paper splice

A paper pre-mRNA (the factory's split gene, printed in codons with exons and introns coloured), a paper cap and a tail. Students cut out the introns, tape the exons together, add the cap and the tail, then translate with the codon tool, The genetic code. Two groups splice differently (one leaves out exon 2) and compare their chains. Then leave intron 1 in and translate it: what happens?

Needs: printed strips, scissors and tape.



ROLE PLAY · HL

Be the ribosome

Three students stand as the E, P and A sites behind a bench, with an mRNA strip of codons on the bench (the demonstration gene with its leader). Others are tRNAs holding anticodon cards and an amino acid bead (or a coloured cube). The small subunit (one student with a card) starts at the 5' end and walks to AUG, the initiator tRNA steps into P, the large subunit (the three sites) arrives, tRNAs arrive at A, the chain of beads is passed from P to A, everyone shifts one codon, and the empty tRNA leaves from E. The class calls each move.

Needs: a bench, a codon strip, anticodon cards and beads on string.

PLENARY

6

min

Exit

"Explain why translation must start from the 5' end of the mRNA", or the D1.2 exam maker's 4-mark question on the initiation of translation.

WHAT STUDENTS GET WRONG

Introns are cut out of the DNA. Out of the RNA.

The initiator tRNA binds the A site. The P site.

The large subunit binds first. The small subunit binds the mRNA first.

STRETCH AND SUPPORT

Stretch: how many mature mRNAs could a gene with six exons make if exons 2 to 5 are each optional? ($2^4 = 16$) Why might a cell want that?

Support: play the factory's "Let the cell do it" on the board before pairs try a round.

IN THE GUIDE

10 [Capped, cut and tailed](#)

11 [Starting the chain](#)

A11 [The whole guide, with the figures that play](#)

PPTX [This lesson's slides, in the order of this plan](#)

EXAM PRACTICE

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



PRACTISE AND REVISE

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CARD SETS ON SPLYCR

Open a set to host it as a class game, or make a copy to edit.

- [D1.2 Protein Synthesis \(SL\)](#)
- [D1.2 Protein Synthesis \(HL\)](#)

Finishing, recycling, and the whole factory HL

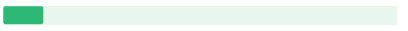
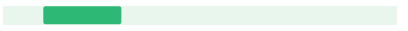
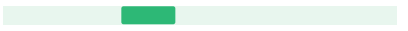
60 minutes • D1.2.18, D1.2.19 • Chapter 12

Pre-proinsulin to insulin, proteasomes and a working proteome, then the whole process in the protein factory

BY THE END, STUDENTS CAN

☐ Explain how pre-proinsulin becomes insulin, and why proteasomes keep breaking proteins down D1.2.18, D1.2.19

TIMING

0-6	6 min	Do now	
6-18	12 min	Pre-proinsulin to insulin	
18-26	8 min	Proteasomes	
26-42	16 min	The protein factory	
42-54	12 min	An extended question	
54-60	6 min	Exit	
	60 min	One lesson	

STARTER

6
min

Do now

"Is a polypeptide a protein?" A vote, then one reason each side.

ON THE BOARD, FROM THE GUIDE

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12 Finished, then recycled

CHAPTER 12 IN THE SLIDES

Step through the figure (5 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. Pre-proinsulin: a **signal peptide** sends it into the rough ER.
2. Stage 1: the signal peptide is cut off, leaving **proinsulin**.
3. Proinsulin folds and **disulfide bonds** form.
4. Stage 2: the **C-peptide** is cut out.
5. **Insulin**: two chains held by disulfide bonds.

Step through the figure (3 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. A tagged protein reaches a **proteasome**.
2. Its peptide bonds are **hydrolysed**.
3. The amino acids are used again to build new proteins.

Predict box: 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? Hands up or mini whiteboards first.

Answer B: 59

THE LESSON

12 min	Pre-proinsulin to insulin <u>Chapter 12's</u> step-through of the two stages, with its first predict box (59 amino acids).
8 min	Proteasomes <u>Chapter 12's</u> proteasome figure and its second predict box (is it wasteful?), then the proteome in one sentence.
16 min	The protein factory In pairs, the higher level orders: rounds 6 to 10.
12 min	An extended question A timed extended question on D1.2 from the exam maker (higher level), peer-marked against its markscheme.

ACTIVITIES

GAME

The protein factory

One device per pair. The standard level rounds are for lesson 3 and the higher level rounds for lesson 6; its record downloads as a CSV for a class comparison.

Needs: one device per pair.

PLENARY

6 min	Exit One sentence answering each guiding question.
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WHAT STUDENTS GET WRONG

Proteasomes only remove faulty proteins. They also clear proteins no longer needed, and the amino acids are reused.

Insulin is made as two separate chains. One chain, cut twice.

STRETCH AND SUPPORT

Stretch: why might cells make insulin as a longer chain and cut it, rather than as two chains? (One gene, and one folding step that lines the disulfide bonds up correctly.)

Stretch: the ribosome and the proteasome in the Molecule of the Month pages of PDB-101 (RCSB), to see the real shapes.

Support: play the factory's "Let the cell do it" on the board before pairs try a round.

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- 12** [Finished, then recycled](#)
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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.

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