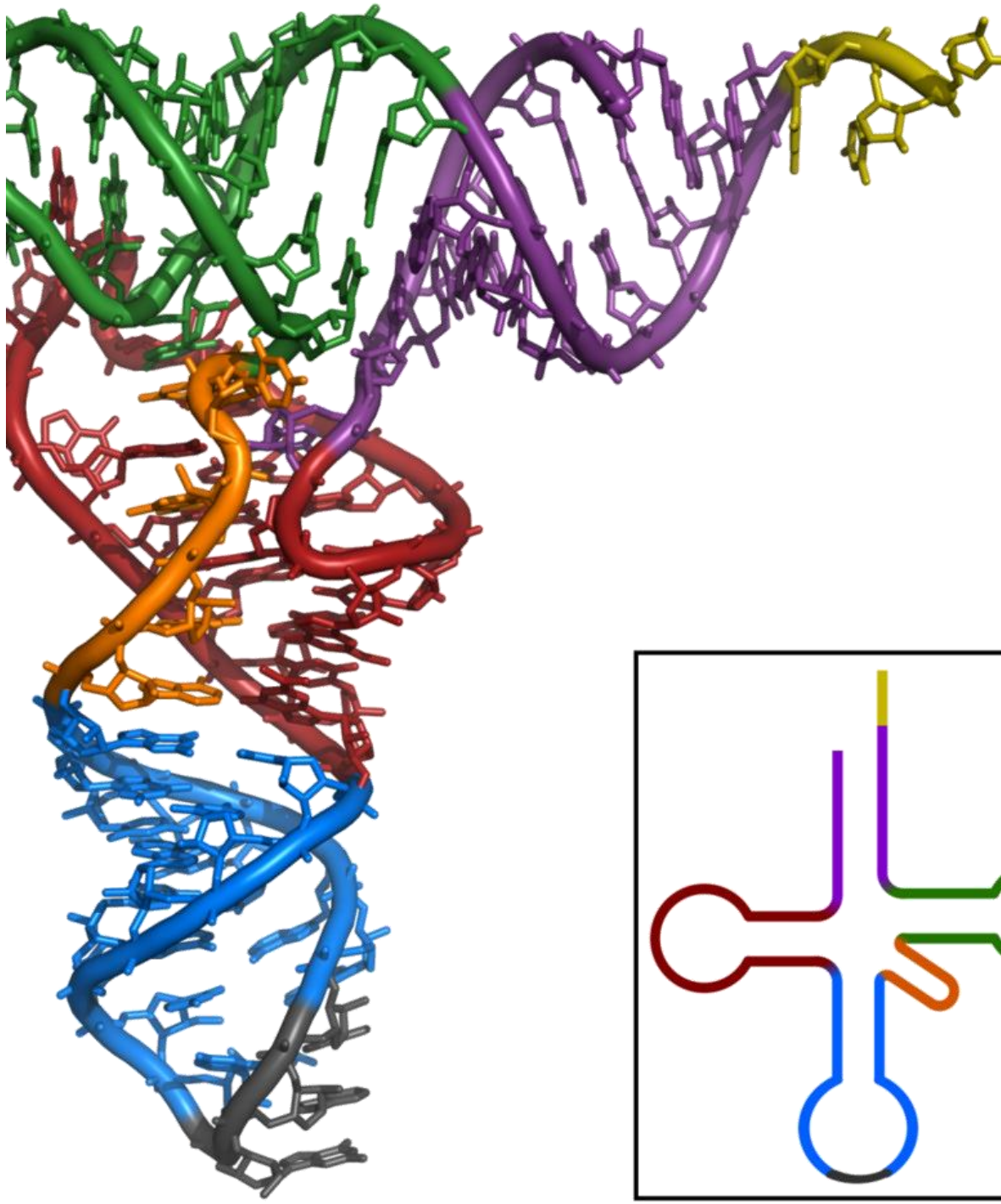
DP Biology – D1.2

Protein synthesis

- How does a cell turn a DNA base sequence into a chain of amino acids?
- What keeps protein synthesis reliable?

SL statements D1.2.1–11. Textbook pp. 615–624.
Image: model of a transfer RNA molecule. Yikrazuul, CC BY-SA 3.0.



Objectives for each class

Class	Statements	By the end of the class, you can...
1	D1.2.1–4	Describe transcription, and explain why DNA templates stay stable and how transcription controls gene expression
2	D1.2.5–7	Outline translation, and what mRNA, ribosomes and tRNA each do
3	D1.2.8–9	Explain the features of the genetic code, and use a table of codons
4	D1.2.10–11	Describe elongation, and explain how a point mutation changes a protein

Overview of this chapter

Part	Statements	What it covers
Transcription	D1.2.1–4	From DNA to RNA, and switching genes on and off
Translation	D1.2.5–7	From mRNA to polypeptide
The genetic code	D1.2.8–9	Codons, and how to read the table
Building the chain	D1.2.10	The ribosome moves and peptide bonds form
When bases change	D1.2.11	Sickle cell anaemia

From gene to protein

D1.2.1



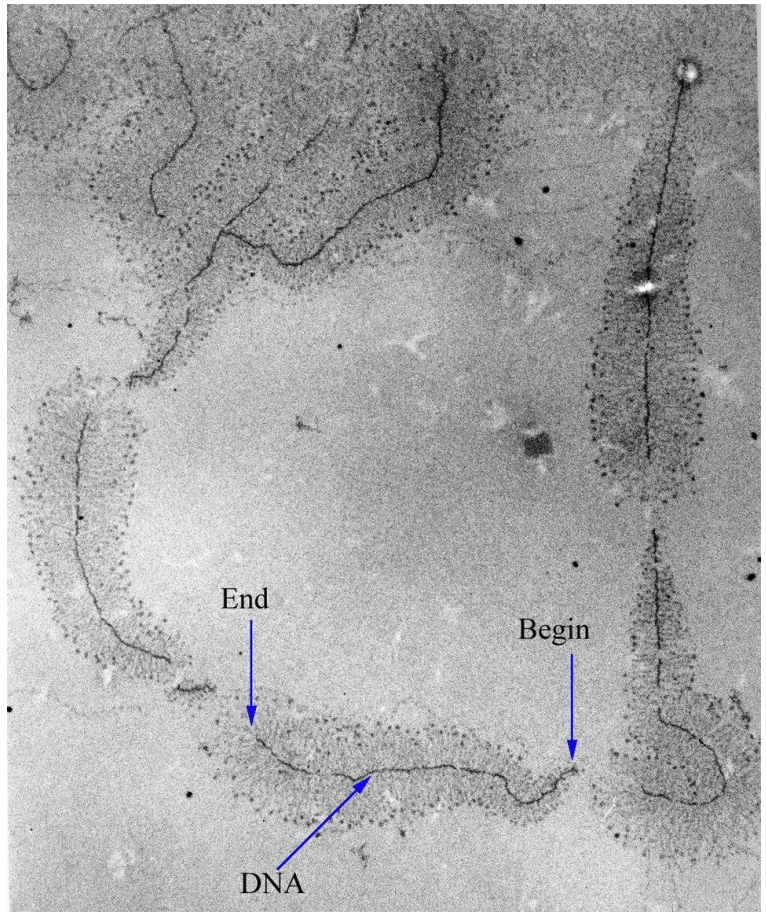
- The base sequence of a gene codes for the amino acid sequence of a polypeptide
- **Transcription** makes RNA, using DNA as a template
- **Translation** uses the base sequence of mRNA to build a polypeptide
- Proteins often determine the observable characteristics of an organism

Common mistake

Do not swap the two words. Transcription keeps the language of bases. Translation changes it, from bases into amino acids.

Transcription and RNA polymerase

D1.2.1



Genes being transcribed, seen with an electron microscope. CC BY-SA 3.0.

1. **RNA polymerase** binds to DNA at the start of a gene
2. It separates the two strands as it moves along
3. Only one strand, the **template strand**, is transcribed
4. RNA nucleotides pair with the exposed bases
5. RNA polymerase links them with **covalent bonds**
6. RNA separates from the DNA, and the double helix reforms

Key idea

One enzyme does all of this. Transcription does not need helicase or DNA polymerase.

Base pairing in transcription

D1.2.2

Strand	Base sequence
DNA non-template strand	A T G C C A G T
DNA template strand	T A C G G T C A
mRNA	A U G C C A G U

- **Hydrogen bonds** form between complementary bases
- In RNA, **adenine on the template pairs with uracil**, and there is no thymine
- mRNA therefore matches the non-template strand, with U in place of T

Activity

A non-template strand reads A G G T T C A G T. Write the template strand, then the mRNA.

Why DNA templates stay stable

D1.2.3

- Transcription copies a base sequence but **does not change the DNA**
- The same gene can be transcribed many times
- Some body cells, such as neurons, do not divide, so they keep the same DNA throughout life
- So their sequences must be conserved for many years

Key idea

DNA is a stable molecule. Its bases are protected inside the helix and held by hydrogen bonds, and its backbone is held by strong covalent bonds.

Link

Damage from radiation or chemicals can still change bases. Repair mechanisms fix most of this damage, and what remains is mutation (D1.3).

Transcription controls gene expression

D1.2.4

- **Gene expression** turns the information in a gene into an observable effect
- Not all genes in a cell are expressed at any given time
- Transcription is the first stage, so it is a key point for switching a gene on or off

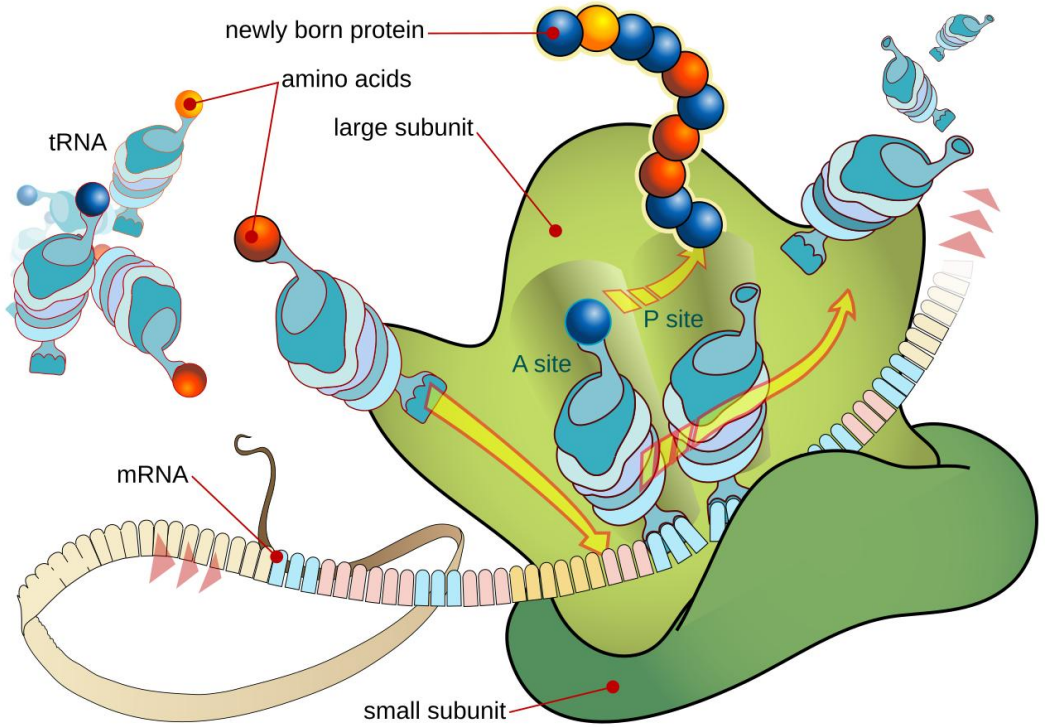
Cell	Gene for alcohol dehydrogenase	Gene for making a neurotransmitter
Liver cell	Switched on	Switched off
Nerve cell	Switched off	Switched on

Common mistake

Different cell types in one person have the same genes. They differ in which genes are being transcribed.

Translation: three types of molecule

D1.2.6



A ribosome translating mRNA. LadyofHats, public domain.

Molecule	Role
mRNA	Carries codons from the gene; binds to the small subunit
Ribosome	Holds mRNA and tRNA; forms peptide bonds
tRNA	Brings an amino acid; two can bind to the large subunit at once

D1.2.5

Translation makes a polypeptide from mRNA: the base sequence of mRNA decides the amino acid sequence.

Codons and anticodons

D1.2.7

	First	Second	Third
mRNA codon	A U G	G C A	U U U
tRNA anticodon	U A C	C G U	A A A
Amino acid	Methionine	Alanine	Phenylalanine

- A **codon** is three bases on mRNA; an **anticodon** is three bases on tRNA
- Complementary base pairing holds them together, using hydrogen bonds
- Each tRNA carries the amino acid that matches its anticodon

Key idea

This pairing is what links the language of bases with the language of amino acids, and it keeps translation reliable.

Features of the genetic code

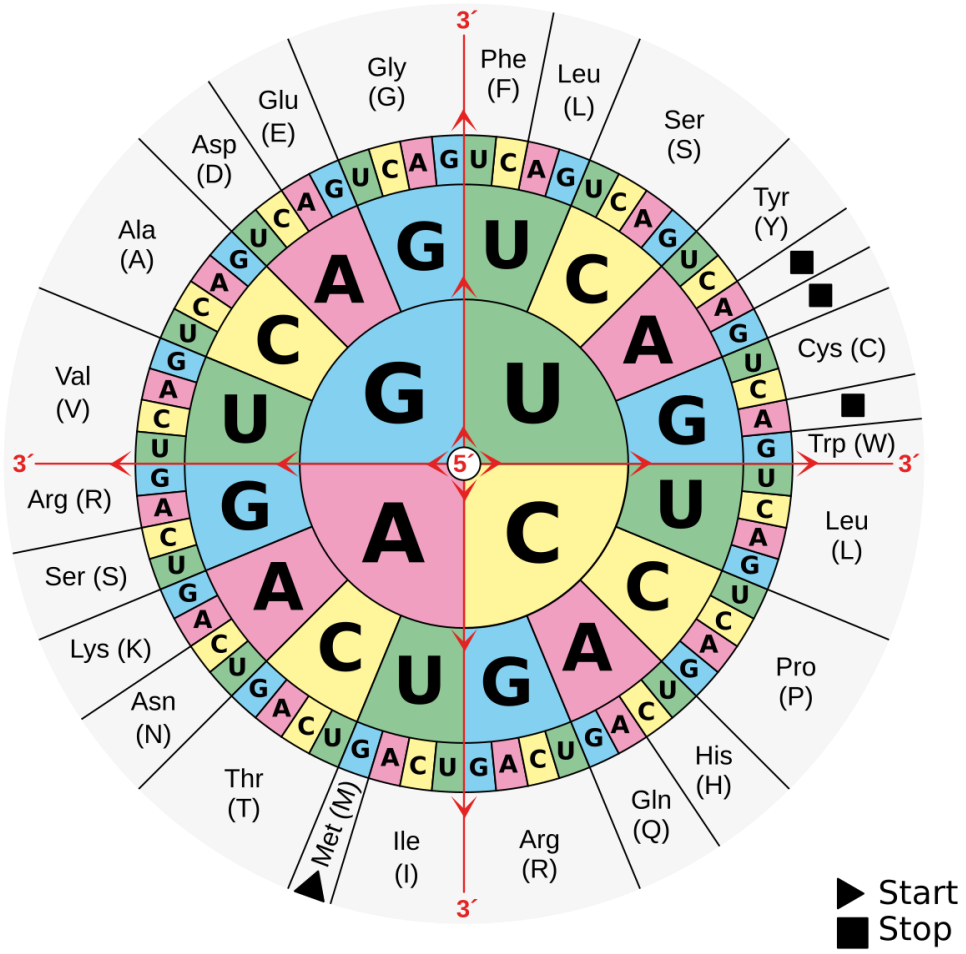
D1.2.8

Feature	What it means
Triplet	Three bases code for one amino acid. Two bases would give only 16 combinations, too few for 20 amino acids. Three give 64.
Degenerate	More than one codon can code for the same amino acid. GCU, GCC, GCA and GCG all give alanine.
Universal	Almost all organisms read the codons in the same way, which suggests a common ancestor.
Start and stop	AUG starts translation. Three codons mean stop.

Common mistake

Degenerate does not mean that one codon can give several amino acids. It works the other way round.

Reading a table of mRNA codons



Amino acids by mRNA codon, read from the centre outwards. Mouagip, public domain.

Worked example

mRNA	A U G | G C U | U G U | U A A
Polypeptide	Met – Ala – Cys – stop

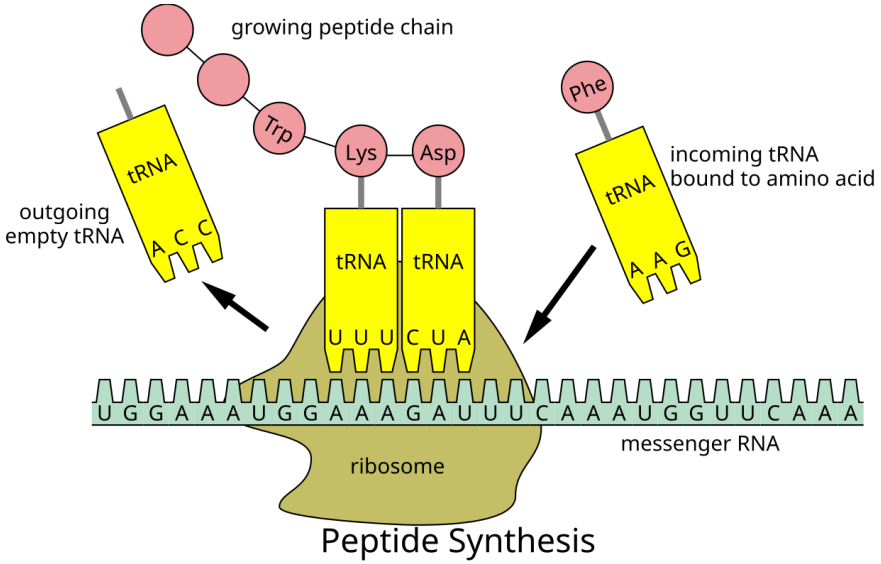
- Split the sequence into codons, starting at the first base
- Look up each one in turn
- The stop codon adds no amino acid

Activity

Deduce the amino acids for C A C G G G. Then deduce the template strand of DNA for the same mRNA.

Building the polypeptide

D1.2.10



Peptide synthesis. Boumphreyfr, vector by Glrx, CC BY-SA 3.0.

1. A tRNA with the matching anticodon binds to the next codon
2. A **peptide bond** links the growing chain to the new amino acid
3. The ribosome moves **one codon** along the mRNA
4. The empty tRNA leaves the ribosome
5. The cycle repeats, adding one amino acid each time

Exam note

Focus on this repeating cycle of elongation. You do not need the special events at the start and the end of translation at SL.

Comparing transcription and translation

D1.2.10

	Transcription	Translation
Location	Nucleus in eukaryotes	Ribosomes in the cytoplasm or on rough ER
Reads	DNA template strand	mRNA codons
Product	RNA	Polypeptide
Key molecules	RNA polymerase, RNA nucleotides	mRNA, tRNA, ribosome, amino acids
Bond made in the product	Covalent bonds between nucleotides	Peptide bonds between amino acids

A point mutation changes a protein

D1.2.11

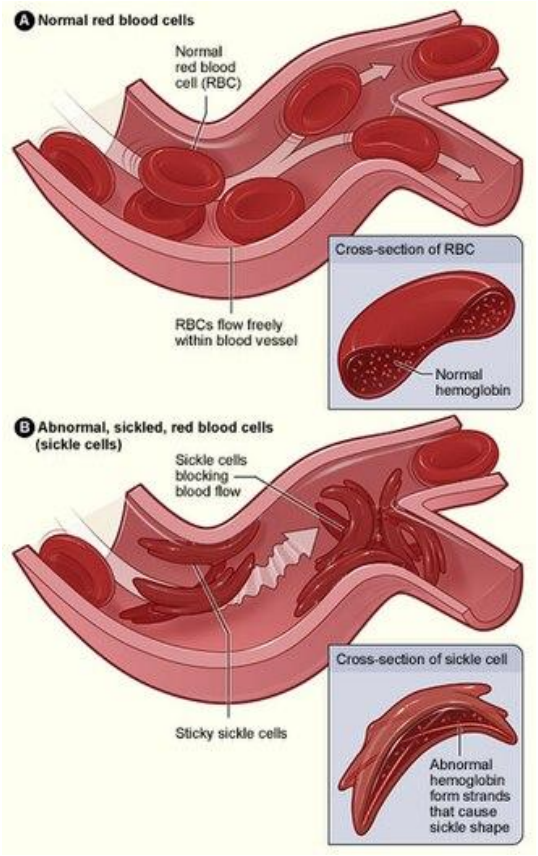
	Normal allele	Sickle cell allele
DNA non-template	G A G	G T G
mRNA codon	G A G	G U G
Amino acid	Glutamic acid	Valine

- One base in the gene for beta-globin, a subunit of haemoglobin, is substituted
- One amino acid changes in the polypeptide
- Valine is non-polar and glutamic acid is charged, so the protein behaves differently

Key idea

Protein structure depends on amino acid sequence. A change in a single base can therefore have a large effect on the whole organism.

Sickle cell anaemia



Normal and sickled cells. NHLBI, public domain.

- At low oxygen, the altered haemoglobin molecules stick together in long fibres
- Red blood cells become rigid and **sickle-shaped**
- Sickled cells can block small blood vessels, causing pain and organ damage
- These cells have a short life, which leads to **anaemia**

Link

This is why this allele is the standard example of a mutation. You will meet the gene again in D1.3 and D3.2.

Check that you can explain

1. What RNA polymerase does
2. How base pairing works in transcription
3. Why DNA templates stay stable
4. Why transcription controls expression
5. What mRNA, ribosomes and tRNA each do
6. Codons and anticodons
7. Why the code is triplet, degenerate and universal
8. How to use a table of codons
9. How a ribosome builds a polypeptide
10. How one base change causes sickle cell anaemia

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. A DNA template strand reads T A C G G A. Write the mRNA.
2. Give the anticodon that pairs with the codon G C A.
3. Explain what is meant by saying that the genetic code is degenerate.

Image credits

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Ribosome mRNA translation en.svg – LadyofHats – Public domain
Aminoacids table.svg – Mouagip – Public domain
Peptide syn.svg – Boumphreyfr vector conversion by Glrx – CC BY-SA 3.0
Sickle cell 01.jpg – The National Heart, Lung, and Blood Institute (NHLBI) – Public domain

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