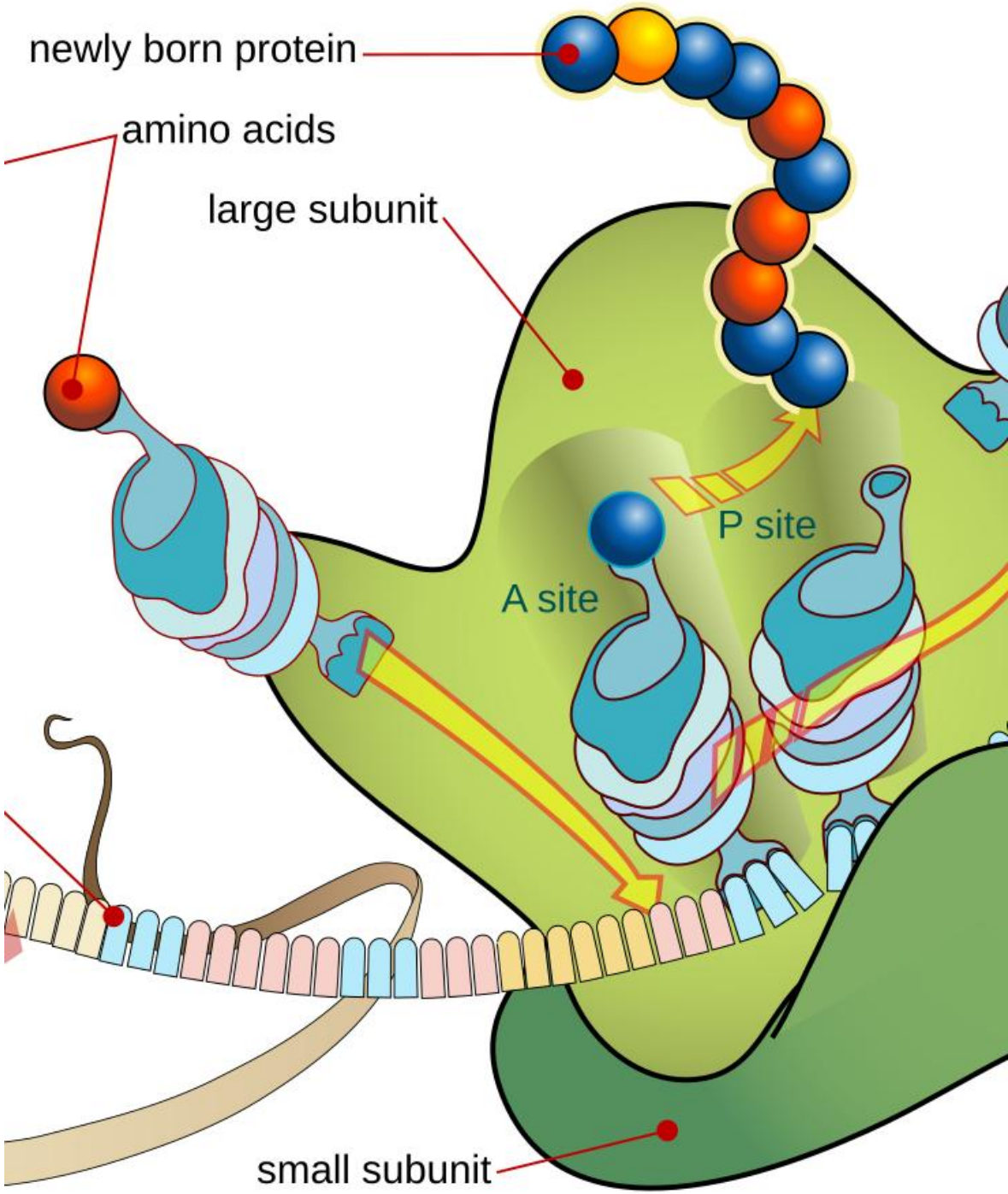
DP Biology – D1.2 (HL extension)

Inside protein synthesis

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

HL statements D1.2.12–19. Textbook pp. 625–636.
Image: a ribosome translating mRNA. LadyofHats, public domain.



Objectives for each class

Class	Statements	By the end of the class, you can...
1	D1.2.12–14	Explain the direction of transcription and translation, how transcription starts, and what non-coding DNA does
2	D1.2.15–16	Explain how eukaryotic mRNA is modified, and how alternative splicing gives different proteins
3	D1.2.17	Explain how translation starts and the roles of the A, P and E sites
4	D1.2.18–19	Explain how polypeptides are modified, using insulin, and how proteasomes recycle proteins

Direction in transcription and translation

D1.2.12

	Transcription	Translation
Enzyme or machine	RNA polymerase	Ribosome
Reads	The template DNA strand, 3′ to 5′	The mRNA, 5′ to 3′
Builds	RNA, 5′ to 3′	A polypeptide, from its amine (N) end to its carboxyl (C) end
Why this way	New nucleotides join to the 3′ -OH	The start codon is near the 5′ end

Key idea

Both processes run in a fixed direction, so the same base sequence always gives the same amino acid sequence.

Starting transcription at the promoter

D1.2.13

General transcription factors bind the promoter, just before the gene → **RNA polymerase joins them, forming an initiation complex** → Activators bound to enhancers can loop round and help → RNA polymerase separates the strands and starts making RNA

Transcription factors

Proteins that bind specific base sequences. Without the right factors, RNA polymerase cannot bind the promoter, so the gene is not transcribed. Different cells have different factors.

Common mistake

RNA polymerase is not a transcription factor. The factors help it bind.

DNA that does not code for polypeptides

D1.2.14

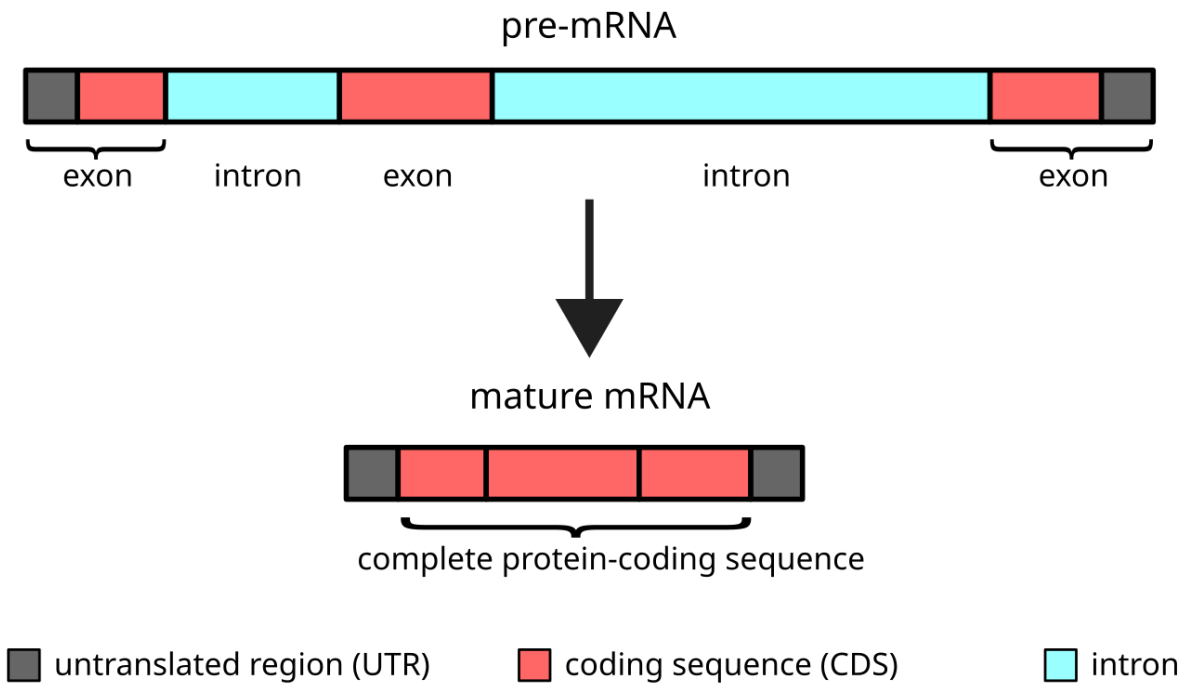
Sequence	Role
Regulators of gene expression	Promoters, enhancers and silencers, where transcription factors bind
Introns	Within genes; removed from mRNA before translation
Telomeres	Repeats at chromosome ends that protect genes from being lost during replication
Genes for rRNA and tRNA	Transcribed but not translated; the RNA itself is the product

Scale

Only about 1.5% of the human genome codes for protein. Much of the rest has roles, or is repeated sequence used in DNA profiling.

Processing mRNA in eukaryotes

D1.2.15



Pre-mRNA is spliced to mature mRNA. Mutundis, CC BY-SA 3.0.

Change	Purpose
Introns removed, exons spliced	Leaves only the coding sequence
5′ cap added	Protects the 5′ end; helps the ribosome bind
3′ poly-A tail added	Protects from breakdown; helps export

Where and why

Processing happens in the nucleus, before the mRNA leaves. Prokaryotes have no nucleus, no introns and no splicing, so to express a human gene in bacteria, an intron-free copy (made from mRNA) is used.

One gene, several proteins

D1.2.16



Troponin T

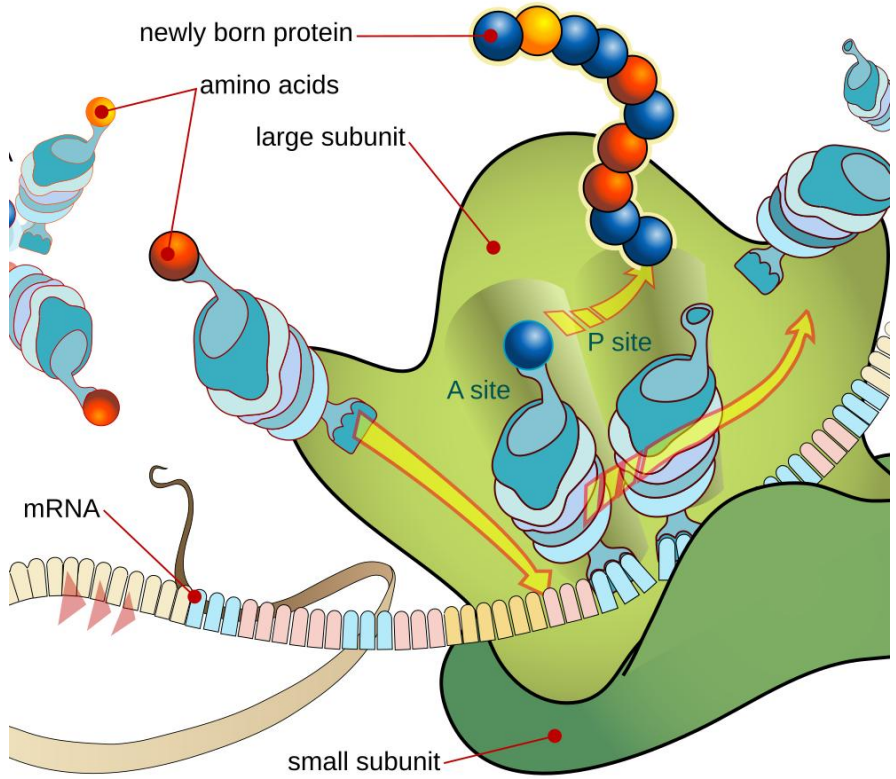
Heart muscle in the foetus and the adult use different exons of the troponin T gene, giving slightly different proteins (isoforms).

So

Alternative splicing includes or leaves out particular exons. About 20 000 human genes can give far more kinds of protein. The diagram is simplified: the real troponin T gene has many more exons.

Getting ready to translate

- Each amino acid is attached to a tRNA with the matching anticodon by a specific **tRNA-activating enzyme**, using ATP
- The **initiator tRNA** carries methionine and has the anticodon UAC
- The ribosome has a small and a large subunit
- The large subunit has three tRNA sites: **A** (arrival), **P** (peptide bond) and **E** (exit)



Ribosome with A and P sites. LadyofHats, public domain.

Initiation and elongation

D1.2.17



Site	Role in each cycle of elongation
A	A tRNA carrying the next amino acid arrives and pairs with the codon
P	Holds the tRNA with the growing chain; the chain is moved onto the amino acid in the A site, forming a peptide bond
E	The empty tRNA leaves after the ribosome moves on one codon

Act out translation

D1.2.17

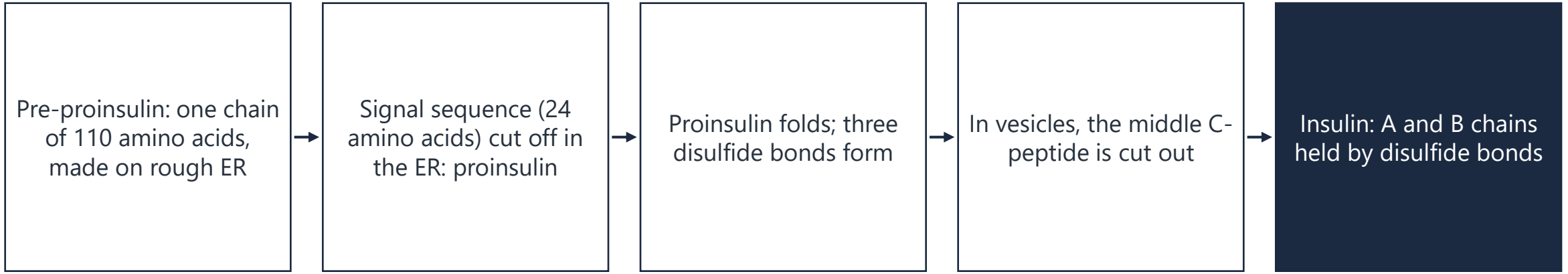
1. In groups, use cards for mRNA codons, tRNAs and amino acids, and three chairs for the A, P and E sites. Translate the sequence AUG GCU UUC GGA UAA.
2. **Explain** why translation stops at UAA.
3. **Predict** the effect of a mutation that changed AUG to AUC.

Check

After each step, say which site each tRNA is in. The growing chain is always attached to the tRNA in the P site.

From pre-proinsulin to insulin

D1.2.18

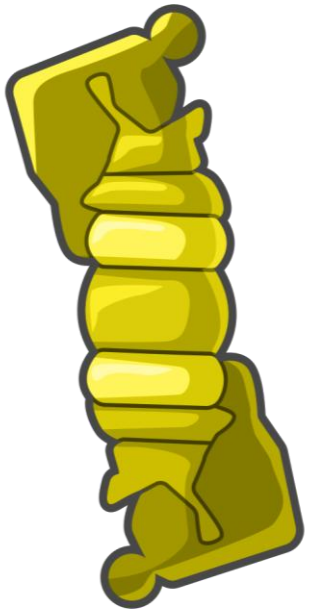


Other modifications

Many polypeptides are not active as made. They may be cut, folded into their tertiary structure, joined to other polypeptides (quaternary structure), or have sugars or phosphate groups added. Making insulin as an inactive precursor stops it acting inside the cell that makes it.

Recycling proteins: proteasomes

D1.2.19



- Proteins that are damaged, misfolded or no longer needed are tagged with a chain of **ubiquitin**
- A proteasome recognizes the tag, unfolds the protein and breaks it into short peptides
- The amino acids are recycled to make new proteins
- A working proteome needs constant breakdown as well as synthesis

A proteasome. NIAID, public domain.

Why break proteins down?

Some proteins, such as those that control the cell cycle, must be removed quickly at the right time. Damaged proteins could clump together and harm the cell.

Check that you can explain

1. The direction of transcription and translation
2. How transcription factors start transcription at the promoter
3. Four kinds of non-coding DNA
4. How mRNA is spliced, capped and given a poly-A tail
5. How alternative splicing gives troponin T variants
6. How translation starts, and the A, P and E sites
7. How pre-proinsulin becomes insulin
8. How proteasomes recycle amino acids

Exit activity: 5 minutes

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

1. State the roles of the A and P sites of a ribosome.
2. Outline two changes made to mRNA before it leaves the nucleus.
3. Explain why insulin is made as pre-proinsulin first.

Image credits

Ribosome mRNA translation en.svg – LadyofHats – Public domain

Pre-mRNA to mRNA MH.svg – Mutundis – CC BY-SA 3.0

Proteasome (NIH BioArt 667 – 758780).svg – Courtesy of NIAID Ryan Kissinger – Public domain

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