Polypeptide synthesis

**Key learning area – science**

**Course –** biology

**Module –** Module 5 – Heredity

**Topic – Polypeptide synthesis**

**Resource type – YouTube videos, website, activities, problem-solving questions**

## Lesson content

This lesson explains the process for polypeptide synthesis, compares the molecules involved in transcription and translation, and investigates the importance of mRNA and tRNA.

### Inquiry questions

1. How are polypeptides synthesised?
2. Why are mRNA and tRNA important in transcription and translation?

### Polypeptide synthesis

DNA is the genetic code which contains the instructions for every physical feature and physiological function of an organism. Transcription produces mRNA molecules from DNA (genes), while translation results in polypeptides being produced from the mRNA.

Watch [Protein Synthesis](https://www.youtube.com/watch?v=2zAGAmTkZNY) (duration 4:54) to learn about how DNA is read and used to produce the polypeptides.

For extra information, use the following resources:

* [Protein synthesis Amoeba sisters](https://www.youtube.com/watch?v=oefAI2x2CQM) (duration 8:46)
* [Protein synthesis BBC Bitesize](https://www.bbc.co.uk/bitesize/guides/z3mbqhv/revision/6)

#### Video quiz

1. What is a polypeptide?

1. Which molecule transcribes the information found in DNA?

1. Which base replaces thymine on mRNA and tRNA?

1. Which organelle translates mRNA?

1. What type of bond joins the amino acids in a polypeptide chain?

1. What is the difference between a polypeptide and a protein?

#### Activity

1. Complete the steps involved in polypeptide synthesis.
   1. **Transcription**

Step 1 –

Step 2 –

Step 3 –

* 1. **Translation**

Part a – The mRNA attaches to a ribosome which begins to read the mRNA codons, beginning with a start codon.

Part b –

Part c –

Part d –

Part e –

1. Complete the table below to compare DNA and RNA.

|  |  |  |  |
| --- | --- | --- | --- |
| Molecule | DNA | mRNA | tRNA |
| Labelled diagram |  |  |  |
| Bases |  |  |  |
| Number of strands |  |  |  |
| Name of base triplets |  |  |  |
| Amino acid attached? |  |  |  |
| Location in the cell |  |  |  |
| Function |  |  |  |

1. Considering the location, structure and function of DNA, mRNA and tRNA in the cell, assess the importance of mRNA and tRNA in the production of polypeptides.

1. Explain the function of the enzyme RNA polymerase during transcription.

1. Use the [mRNA and amino acid table](https://commons.wikimedia.org/wiki/File:Amino_Acid_Codon_Table.svg) to complete the sequences below. Remember that mRNA codons determine amino acids.
   1. DNA – T-A-C-T-G-A-C-G-C-G-T-A-T-A-C-T-G-A-C-T
   2. mRNA –
   3. tRNA –
   4. Amino acid sequence –

### Problem-solving question

Read the stimuli:

* Sickle cell anaemia is a genetic disease caused by a single substitution mutation in the haemoglobin-Beta gene. This gene codes for the production of haemoglobin, a protein that carries oxygen around the body in red blood cells. This mutation produces a polypeptide chain in which the amino acid glutamic acid is replaced with the amino acid valine, resulting in distortion in the shape of the red blood cell.
* [Effects of the mutation at the DNA level and mutation at the protein level](https://evolution.berkeley.edu/evolibrary/article/mutations_06#:~:text=Sickle%20cell%20anemia%20is%20a,cell%20gene%20have%20the%20disease.)
* Normal red blood cells are round and biconcave in shape, allowing them the flexibility to move easily through narrow blood vessels. Mutated haemoglobin molecules, however, adhere to one another to form rod-like chains, and change the shape of red blood cells to become sickle-shaped and stiff. These sickle-shaped red blood cells clump together to block blood vessels and disrupt blood flow to organs and tissues.
* Symptoms of sickle cell anaemia include pain, inflammation of hands and feet, fatigue, shortness of breath and jaundice.

Using the information provided in the stimulus and your understanding of polypeptide synthesis, outline how a mutation to the haemoglobin-Beta gene results in a significant change in protein structure of haemoglobin.

## Suggested answers

### Video quiz

1. A chain of amino acids
2. mRNA
3. Uracil
4. Ribosome
5. Peptide bond
6. Proteins and polypeptides are both composed of amino acids. Polypeptides are chains of single amino acids, however proteins are made up of one or more polypeptides joined together and packaged into shapes specific to their function.

### Activities

1. **Transcription**:

Step 1 – RNA polymerase unzips the length of DNA containing the required gene.

Step 2 –RNA polymerase uses one strand of DNA (called the sense strand or non-coding strand) to construct a mRNA molecule that is complimentary to the sense strand using free mRNA nucleotides within the nucleus.

Step 3 – mRNA moves out of the nucleus into the cytoplasm

**Translation**:

Part a – The mRNA attaches to a ribosome which begins to read the mRNA codons, beginning with a start codon.

Part b – tRNA molecules temporarily attach to the ribosome by matching their anti-codons with the complimentary mRNA codons. Peptide bonds are formed between the amino acids attached to the tRNA.

Part c – After each amino acid is joined by a peptide bond, the tRNA to which it was bound detaches from the ribosome. Amino acids continue to be added in this way until a stop codon is reached.

Part d –The polypeptide detaches and moves to the Golgi body to be packaged into a protein.

Part e – The mRNA breaks down into individual nucleotides which can be reused.

Table 1 Molecule, DNA, mRNA and tRNA

|  |  |  |  |
| --- | --- | --- | --- |
| Molecule | DNA | mRNA | tRNA |
| Labelled diagram | See diagrams at 2:27 of [Protein Synthesis](https://www.youtube.com/watch?v=2iaqE0xmsHI) (duration 4:54) |  |  |
| Bases | Adenine, thymine, guanine, cytosine | Adenine, uracil, guanine, cytosine | Adenine, uracil, guanine, cytosine |
| No. of strands | 2 | 1 | 1 |
| Name of base triplets |  | Codons | Anti-codons |
| Amino acid attached? | No | No | Yes |
| Location(s) in the cell | Nucleus | Nucleus, cytoplasm | Cytoplasm |
| Function | Contains all of the genetic information for the physical and physiological traits of an organism. | Carries information from DNA in the nucleus to the ribosomes in the cytoplasm. Formed as a complimentary strand to the DNA sequence of the gene required for a polypeptide. | Carries amino acids at one end determined by anticodons which are complimentary of mRNA codons at the other end. Bring amino acids to ribosomes in the correct sequence as coded for by mRNA codons so that peptide bonds can form and a polypeptide can be synthesised. |

1. In polypeptide synthesis, DNA remains within the nucleus, but ribosomes which synthesise polypeptides exist in the cytoplasm. mRNA is essential to carry the genetic code stored in DNA from the nucleus to the ribosome. The correct construction of mRNA, formed from complementary base pairs to the DNA sequence, is important to specify the correct tRNA carrying a specific amino acid to bind with the matching mRNA codon. This ensures that the right amino acids sequence of the resulting polypeptide chain and, hence, the correct protein to be created.

The role of tRNA is vitally important in ensuring that its anticodon specifies and binds to the correct amino acid. This will ensure that the resulting polypeptide chain will have the right amino acid sequence that allow the protein-folding process to occur correctly. If not, the protein will not have the correct shape, a feature that is critical in determining its function.

1. During transcription, RNA polymerase binds to DNA and unzips the length of DNA containing the gene required to synthesise a polypeptide. RNA polymerase then uses one strand of DNA (called the sense strand or non-coding strand) to construct a mRNA molecule that is complimentary to the sense strand using free mRNA nucleotides within the nucleus.
2. Amino acid sequence
   1. DNA – T A C T G A C G C G G T A T A C T G A C T
   2. mRNA – A U G A C U G C G C C A U A U G A C U G A
   3. tRNA –
   4. Amino acid sequence – START – Thr – Ala – Pro – Tyr – Asp - STOP

## Marking guidelines

### Problem-solving questions

**3 marks**:

* Outlines all steps in polypeptide synthesis in sequential order
* Relates mutation of haemoglobin-Beta gene to specific change in the haemoglobin protein

**2 marks**:

* Outlines some steps in polypeptide synthesis in sequential order
* Links mutation of haemoglobin-Beta gene to change in the haemoglobin protein

**1 mark**:

* Provides some relevant information

### Sample answer (3/3)

1. A substitution mutation occurs in the DNA sequence of the haemoglobin-Beta gene whereby the GAG triplet becomes GTG.

2. The mRNA strand, complimentary to the DNA sequence, produced during transcription is therefore incorrect.

3. The incorrect mRNA codon is complimentary to the incorrect tRNA, causing tRNA to deliver the amino acid valine to the ribosome instead of the amino acid glutamate during translation.

4. The incorrect amino acid sequence forms a dysfunctional polypeptide.

5. Incorrectly shaped haemoglobin proteins produced, resulting in sickle-cell shape are blood cells that are stiff and easily form blood clots.

### Sample answer (2/3)

1. There is a change in the DNA sequence of the haemoglobin-Beta gene.

2. The mRNA strand produced during transcription is incorrect.

3. At translation, tRNA to deliver the wrong amino acid to the ribosome.

4. The incorrect amino acid sequence forms a dysfunctional polypeptide.

5. Incorrectly shaped proteins produced.

### Sample answer (1/3)

1. The DNA sequence is changed.

2. The mRNA is wrong.

3. The wrong amino acid is added to the polypeptide.

5. The protein is different.

## Biology Stage 6 Syllabus outcome

**BIO12-12 –** Explains the structures of DNA and analyses the mechanisms of inheritance and how processes of reproduction ensure continuity of species

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