edexcel

INTERNATIONAL GCSE

Biology (2017)

TOPIC GUIDE:
Protein synthesis: transcription and translation

Pearson Edexcel International GCSE in Science

Pearson

Introduction to the teaching of protein synthesis

Specification

In the 2011 International GCSE Biology specification, the specification points relating to chromosomes, genes and DNA are stated in the following way:

Students will be assessed on their ability to:

> *3.13 understand that the nucleus of a cell contains chromosomes on which genes are located*
>
> *3.14 understand that a gene is a section of a molecule of DNA and that a gene codes for a specific protein*
>
> *3.15 describe a DNA molecule as two strands coiled to form a double helix, the strands being linked by a series of paired bases: adenine (A) with thymine (T), and cytosine (C) with guanine (G)*

In the revised 2017 Edexcel International GCSE specification, this section is set out in the following way:

Students should:

> *3.14 understand that the genome is the entire DNA of an organism and that a gene is a section of a molecule of DNA that codes for a specific protein*
>
> *3.15 understand that the nucleus of a cell contains chromosomes on which genes are located*
>
> ***3.16B describe a DNA molecule as two strands coiled to form a double helix, the strands being linked by a series of paired bases: adenine (A) with thymine (T), and cytosine (C) with guanine (G)***
>
> ***3.17B understand that an RNA molecule is single stranded and contains uracil (U) instead of thymine (T)***
>
> ***3.18B describe the stages of protein synthesis including transcription and translation, including the role of mRNA, ribosomes, tRNA, codons and anticodons***

Summary of the changes

- Specification points 3.14 and 3.15 remain largely the same, except for the introduction of the idea of the genome being the entire DNA of an organism.
- Point 3.16 is now specific to Biology International GCSE and not the Science (Double Award) specification – hence being in bold type and with a specification reference ending with a ‘B’.
- Points 3.17 and 3.18 are completely new to the specification and assessed only as part of Biology International GCSE and not the Science (Double Award) specification.

Why make these changes?

The old specification was successful at linking together the concepts of chromosomes and genes, and underpinning this with DNA being the chemical molecule involved. However, it was restricted to the processes that occur in the nucleus only. Teaching this section gave the learners an incomplete understanding of the role of DNA, which is integral to protein synthesis – a process that takes place in the cytoplasm, rather than the nucleus. Additionally, there was no mention of the importance of RNA as a second nucleic acid. Biology teachers often mentioned that the teaching of these concepts resulted in learners putting these concepts 'into a box' with no other concepts to link to.

The revised specification has addressed these shortcomings with the inclusion of specification points 3.17 and 3.18. Students who study Biology at a higher level (GCE A Level, IB or International A level Biology) will now have excellent foundations on which to build the more challenging material in these courses.

Some ideas for teaching the topic of protein synthesis

Introductory ideas

Students can find this topic difficult to visualise as the processes are occurring at a nuclear and cytoplasmic level. Making these processes as visual as possible helps the learning process.

It is always a good idea to start with the familiar – for example, revision of cell structure with an emphasis on the nucleus. There are some superb images, for example:

https://fthmb.tqn.com/in0Axy5bzHQmzv_f1-NV2DC364U=/768x0/filters:no_upscale()/Nucleus-58a34aad3df78c4758d64d1c.jpg

The following is an outstanding resource published by The Wellcome Trust – it is now out of print but can still be downloaded. It gives lots of fun facts which students enjoy:

https://bigpictureeducation.com/sites/default/files/bp_files/the%20cell/wtdv030920~2.pdf

It is important to remind students regularly about the relationship between the sizes of the various organelles – misconceptions often develop because students are given erroneous ideas about sizes, particularly the nucleus.

The image below gives a good idea of the link between the nucleus, chromosomes and the DNA molecule:

http://www.bbc.co.uk/staticarchive/678f62dce35d0fc7ef2333d6d3bfbf53744374ff.jpg

Most textbooks also give excellent diagrammatic representations. One of these can be found on p227 of the new Bradfield and Potter International GCSE Biology textbook.

In order for students to think about knowledge acquisition, it is an excellent diversion to discuss the people and processes involved in the discovery of DNA: Watson, Crick, Franklin and Wilkins. This reinforces the idea in students that science is a collaborative enterprise – no-one owns scientific discovery or ideas. This discussion also puts the 1950s in a societal context by emphasizing the role of women in science at the time.

DNA and RNA structure

Once nuclear structure has been well revised and the links have been made between the various nuclear components, DNA structure can be considered. One good method for introducing the structure in a visual way is to use the following model. Although it seems quite basic, it serves its purpose very well.

Building this model requires:

- two retort stands
- string to represent the sugar-phosphate backbones
- pegs of four different colours to represent the four different bases (nucleotides)
- blu-tac to show the hydrogen bonds between the nitrogenous bases.

Using this model, it is possible to show the structure of nucleotides and DNA. It is then easy to modify the model in order to represent the process of DNA replication by creating new strands highlighting complementary base pairing. (This would require two more retort stands and more pegs!)

This model can also be adapted to show the structure of RNA, using a peg of a fifth colour to show the change from thymine to uracil in this nucleic acid. Remember too that RNA is single-stranded; shorter strands can be made and the single-stranded nature can be highlighted.

Having made strands of RNA, it is important to highlight the triplet code. The ‘bonds’ can be split in the middle and the code discussed. Students need to understand that each group of three bases on the template strand codes for an amino acid – here the linkage becomes really important. Students will often say “each triplet codes for the production of an amino acid” – when referring to animal cells, this is an error easily made.

It may be useful to discuss with students the reason for the code being a triplet code. Students can try to write out the different combinations that can be made using four different bases (A, C, G and U):

- if one base at a time is read, there will be only 4 combinations (and hence a maximum of 4 amino acids)
- if two bases at a time are read, there will be 4^2 or 16 combinations (and hence a maximum of 16 amino acids)
- if three bases at a time are read, there will be 4^3 or 64 combinations (and hence a maximum of 64 amino acids)

If students are told that there are 20 amino acids that the body must manufacture then they can see why a triplet code is needed. They can also see that it is possible that:

(a) a number of different combinations of bases code for the same amino acid (this idea will be useful when considering why mutations are rare)
(b) some combinations of bases do not code for an amino acid.

tRNA

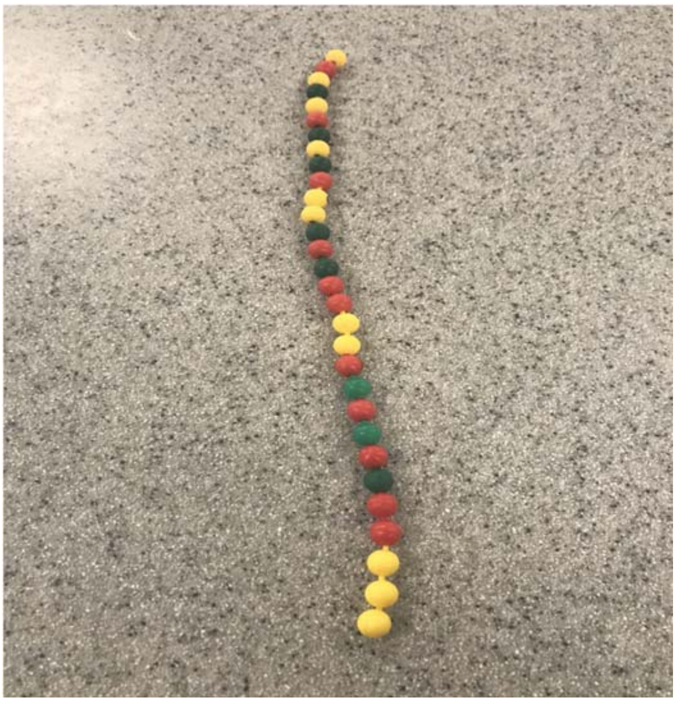
The peg model can also be used to show the process of transcription. One of the DNA strands can be used as the template strand on which to create an mRNA molecule: this gives another opportunity to highlight complementary base pairing, as well as showing the differences between DNA and RNA.

To illustrate the structure of a tRNA molecule, pipe cleaners and plasticine can be used as shown in the picture below. It is easy to show the anti-codon by using plasticine and an amino acid using blu-tac. At this point, there is a good opportunity to consider linkage between different areas of the specification. Students can be reminded where amino acids come from and why it is important to have amino acids available in the cytoplasm.

Transcription

A balloon can be used to represent a ribosome (but students should be warned that this does not show the relationship between the sizes of organelles accurately) and the mRNA strand created using the DNA model can be shown to be moving out of the nucleus to the ribosome. In this way the link between codons and anti-codons could be highlighted. By using beads of different colours to represent amino acids, these can then be linked together to form a polypeptide chain.

By varying the colours of the beads it is possible to show, if the triplet code varies, how the resulting polypeptide chain also varies.



DNA mutation

Finally, the original DNA model can be used to show the effect of a gene mutation. This can be done in the following way:

- An incorrect peg can be inserted when DNA replication is occurring and, if the error is carried forward in the template strand, an incorrect bead then becomes part of the final polypeptide strand. This may have an effect on the final protein.
    - This is also a good point to talk briefly about degeneracy of the code, referring back to the 64 combinations of bases that code for 20 amino acids, especially with the more able students.
    - Discussing mutations at this stage can also lead into a brief discussion about evolution.

- An additional peg is inserted during DNA replication – this changes the triplet code and students are able to see that the entire base sequence shifts and the eventual polypeptide chain is significantly altered.
- One of the required pegs during DNA replication is omitted – once again the significant effect can be seen on the final polypeptide chain due to the incorrect reading of the triplet code.
    - Insertions and deletions illustrate how the code works and can be linked to these specification statements:
      3.35B understand how a change in DNA can affect the phenotype by altering the sequence of amino acids in a protein
      3.36B understand how most genetic mutations have no effect on the phenotype, some have a small effect and rarely do they have a significant effect

- The pegs during DNA replication can be inverted – similar to a substitution mutation.

ESL learners

This is a section of work which is terminology laden and many of the terms are completely new to the students. For an ESL learner these terms are likely to be extremely challenging. It is therefore advisable that students do a detailed glossary for this section of work with the definitions; many of these words are regularly assessed as part of final examinations.

A note for teachers

Note that this Guide is intended to support teachers of International GCSE Biology and provides subject coverage beyond the demands of the specification.