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Level 2 Biology, 2015

91159 Demonstrate understanding of gene expression

9.30 a.m. Monday 16 November 2015
Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of gene expression.	Demonstrate in-depth understanding of gene expression.	Demonstrate comprehensive understanding of gene expression.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

If you need more space for any answer, use the page(s) provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–11 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

TOTAL 22

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QUESTION ONE: MAKING PROTEINS

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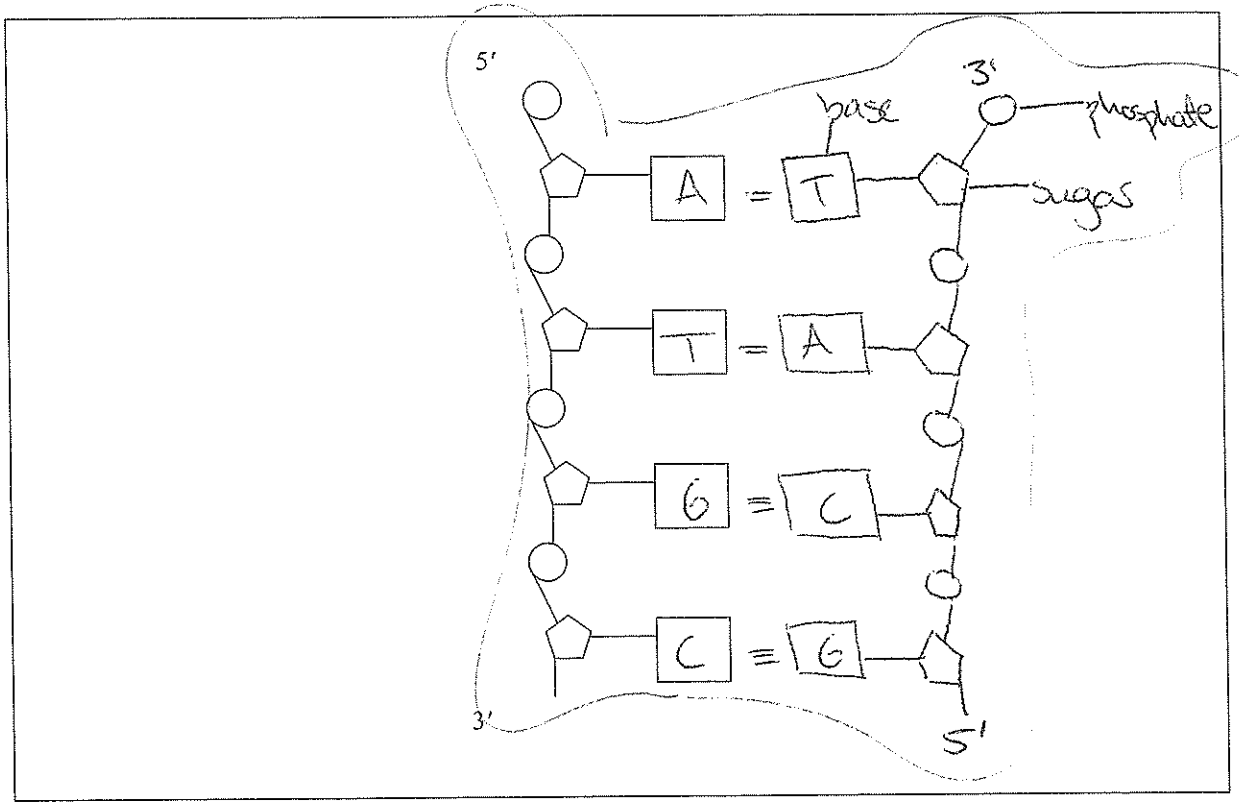
(a) The structure of DNA is made up of nitrogen bases, deoxyribose sugars, and phosphates.

Draw the corresponding **anti-parallel** complementary strand in the box below.

In your answer:

- fill in the template strand containing the bases adenine (A), thymine (T), guanine (G), cytosine (C)
- draw the corresponding **anti-parallel** complementary strand
- draw and label the sugars
- draw and label the phosphates.



(b) Protein synthesis is the process of making proteins. Triplets, codons, and anti-codons are important components in the process.

Discuss the relationship between triplets, codons, and anti-codons, and how they interact to form a protein.

In your answer include:

- a description of a triplet, codon, and anti-codon
- an explanation of what a start codon and a stop codon are
- a discussion of how triplets, codons, and anti-codons interact during transcription and translation to form a protein.

You may use diagrams in your answer.

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A triplet is a section of three adjacent nucleotides (sugar, phosphate, base) on the DNA. These triplets match the codons on the mRNA (messenger RNA). A codon is a section three adjacent nucleotides (on the tRNA (transfer RNA)) which make up the mRNA. Anti-codons match these codons according to the complementary base-pairing rules. Triplets, codons and anti-codons are all involved in the transcription and translation in protein synthesis. Transcription is the process where the genetic information stored in DNA (through its sequence of bases and triplets) is transcribed on to a strand of mRNA which then carries it to the cytoplasm and ribosomes. This is so that the original DNA does not get damaged leaving the nucleus. Transcription begins when a specific nucleotide sequence on the DNA strand (start triplet) causes the enzyme RNA polymerase to attach to the DNA molecule. RNA polymerase breaks the weak hydrogen bonds between the bases holding the DNA double helix together, therefore, causing it to unwind and exposing the bases. It also organises the mRNA so that ~~it~~ lies opposite to the DNA. Free nucleotides from the nucleus are matched to the exposed nucleotides on the DNA based on the complementary base-pairing rules where adenine always pairs with thymine and cytosine with guanine. However, when RNA polymerase transcribes the DNA, uracil binds to adenine rather than the thymine which is found in DNA. Only small parts of the DNA are exposed at a time and the helix closes once the RNA polymerase has moved on. Transcription forms a single mRNA strand which has many groups of three bases (called codons)

There is more space for your answer to this question on the following page.

that code for specific amino acids. RNA polymerase continues to move along the DNA strand until it reaches a terminator nucleotide sequence (stop codon) where it then releases the mRNA polymer and detaches it from the DNA. The mRNA then leaves the nucleus via a nuclear pore and enters the ribosomes in the cytoplasm to be translated. Translation is the process where the genetic code carried by the mRNA is decoded to produce the specific sequence of amino acids in a polypeptide chain/protein. This is so that the protein can be used for important cellular functions, e.g. to make an enzyme. Translation occurs in the ribosomes which are found near the nucleus on the rough endoplasmic reticulum or free in the cytoplasm of the cell. The mRNA acts as a template and enters a ribosome by threading through it and coming out to where the tRNA can lie opposite it. The tRNA lies next to the mRNA based on the complementary codon-anti codon base pairing rules. It is a clover-shaped molecule with a "tail end" to which an amino acid is attached and a "closed end" with an anti codon. Amino acids found in the cytoplasm attach to the tRNA according to the three bases (anti codon) at the end of each tRNA molecule. A start codon initiates translation and fills the first side of the ribosome. The tRNA then "picks up" the amino acid that its anti-codon codes for and temporarily pairs with the bases on the mRNA. The ribosome slides down the mRNA, "reading" the codons on it. Peptide bonds form between the amino acids that have been brought to the mRNA by the tRNA. This continues until a stop codon is reached which then terminates translation and releases the polypeptide chain from the ribosome. This long chain then folds into a three-dimensional structure to become a functional protein.

QUESTION TWO: METABOLIC PATHWAYS

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In 1941 biologists George Beadle and Edward Tatum exposed the bread mould *Neurospora crassa* to radiation. The mutated moulds lost their ability to produce an amino acid (arginine), and this slowed or stopped their growth. However, they found when they provided the mould with the amino acid arginine, growth was restored. They concluded that a gene mutation inactivates an enzyme needed to synthesise the amino acid in a metabolic pathway.

(a) Describe what a gene mutation is.

A ~~gene~~ mutation is a permanent change in the base sequence of DNA which can alter the amino acid sequence of the protein encoded by the gene. Mutations can be caused by exposure to mutagens such as radiation, chemicals, viruses or diet.

(b) The biologists carried out further experiments and found three mutations prevented the amino acid arginine from being made.

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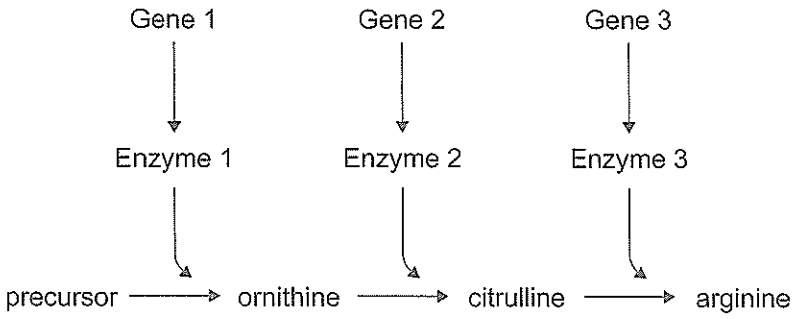
Using the *Neurospora crassa* metabolic pathway below, discuss why there are three mutations that can occur for the amino acid arginine not to be produced.

In your answer:

- explain what a metabolic pathway is
- discuss why a mutation to any one of the genes can result in arginine not being produced
- discuss why the biologists concluded 'One Gene Codes for One Protein'.



A metabolic pathway is a series of biochemical reactions, catalysed by enzymes, whereby an initial molecule is modified in a step-by-step process to form the final product. Each step in a metabolic pathway is indirectly controlled by a different gene on the DNA, as that gene has the specific code for the enzyme needed to catalyse that step. The steps in a metabolic pathway are linked by their intermediate products, i.e. the products from one reaction become the reactants for the next reaction. Mutations that occur in any one of the genes involved in a metabolic pathway can result in a "faulty" enzyme. Enzymes are proteins that are folded into complex, specific shapes to allow only one type of molecule (the substrate) to fit into them. Therefore, the production of an enzyme is controlled by the transcription and translation of the protein, and, if an error occurs during one of these processes, causing a

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mutation and a non-functional protein, or the protein folds incorrectly after translation, the functioning of the enzyme will be severely affected. This can result in the final product not being produced as well as a build up of intermediate substances, both of which usually have a dramatic effect on the organism's phenotype. The production of arginine is controlled by a metabolic pathway. There are a number of possible ways in which arginine cannot be produced because the metabolic pathway has three points where different genes/enzymes are controlling the outcome. For example if 'Gene 1' on the DNA mutates to produce a non-functional protein, making a "faulty" enzyme that no longer works, then the precursor will not be converted to ornithine and arginine would not be produced, regardless of whether all the enzymes are fully functional. Another gene ('Gene 2') is needed in the second step of the metabolic pathway to convert ornithine into citrulline. If a mutation occurs during the production of the protein encoded by Gene 2 then Enzyme 2 will be "faulty" and therefore, unable to carry out its role because its active site (area where the substrate fits into it) will have a different shape and, will therefore, not allow ornithine to fit into it. This would also result in arginine not being produced, regardless of whether Enzymes 1 and 3 are both fully functional. Gene 3 is needed to produce Enzyme 3 therefore a mutation in this gene will result in another "faulty" enzyme which is unable to convert citrulline into arginine. In this case, arginine would not get produced, regardless of whether the other enzymes were fully functional.

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QUESTION THREE: ENVIRONMENT, GENOTYPE INTERACTIONS

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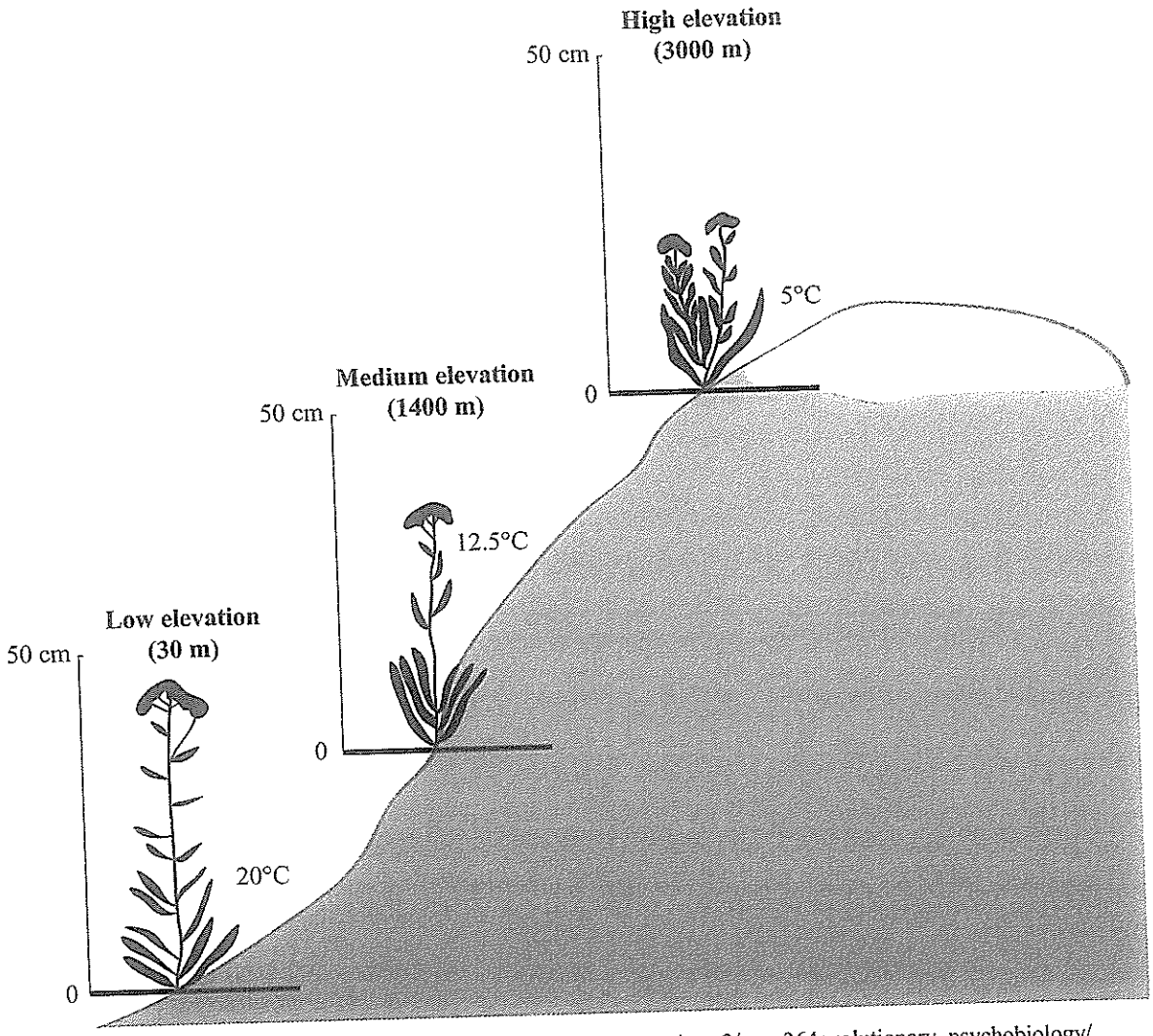
The common yarrow plant, *Achillea millefolium*, can be cut into several sections, and each section will grow asexually (reproduces without fertilisation or exchanging gametes) when put into soil. In an experiment, biologists cut one yarrow plant into three sections and planted each section at a different elevation to determine how phenotype is affected by the environment. See figure below.

***Achillea millefolium* growth response to different elevations**



Adapted from http://www.flyfishingdevon.co.uk/salmon/year3/psyc364evolutionary_psychobiology/psy364_genotype_phenotype/psy364_genotype_phenotype.htm

(a) Describe the difference between genotype and phenotype.

The genotype of an organism is the written form of their genetic make up whereas the phenotype is the physical representation of its genotype.

(b) Explain why the biologists used genetically identical cuttings, at the different elevations.

The biologists planted genetically identical cuttings at different elevations to ~~see~~ investigate the relationship between their phenotypes ~~and~~ (i.e. how tall they grew)

and the environmental conditions (~~exist~~) (i.e. temperature and wind). //

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(c) Analyse the results shown in the figure on the previous page.

In your answer include:

- an explanation of why plants may grow differently at different elevations
- a discussion of the interaction between temperature, genotype, and phenotype expression
- a discussion of environmental factors that would influence the yarrow plants' genetic expression.

The plants may grow differently at different elevations due to them being exposed to different environmental conditions. These conditions would include temperature and wind. The phenotype of the plants cannot always be predicted based on their genotypes as the environment can, obviously, have a huge effect on it. The phenotype can be affected by the environmental conditions that exist internally or externally without the genotype being altered in any way. Although all three plants have identical genotypes, they are each exposed to different environmental conditions. At lower temperatures (5°C) and high elevation (where the plant would be exposed to the most wind), the plant is very short. As the temperature increases (5°C to 12.5°C to 20°C), the height of the plants also increases. This indicates that warmer temperatures at a low elevation (and therefore least exposure to wind) are the ideal environmental conditions for the plants' genotypes to be expressed fully (i.e. their phenotype shows they are tall plants). The genotypes remain unchanged when exposed to different environmental conditions, therefore, this is not the case of "tall plant genotype" verses "short plant genotype." //

E7

Extra paper if required.
Write the question number(s) if applicable.

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QUESTION NUMBER

2. b) Therefore, a mutation to ~~one~~ any one of the genes involved in this metabolic pathway can result in arginine not being produced. The biologists have concluded that "One Gene Codes for One Protein" because each gene on a section of DNA has the code for a specific amino acid sequence for a protein. The base sequence of a gene determines the amino acid sequence of the final protein encoded by this one gene. M

Annotated Exemplar Template

Excellence exemplar for 91159 2015		Total score	22
Q	**Grade score**	**Annotation**	
1	E7	This student has shown clear understanding of the relationship between DNA and mRNA, triplets and codons, codons and anticodons. They have clear links between the stages in protein synthesis. In order to achieve E8 a clearer link between the mRNA and the ribosome would be required.	
2	E8	The student displays a thorough understanding of the links between DNA sequence to the order of amino acids coded for to produce a protein(in this case enzyme) of the right shape. They demonstrated sound understanding of a metabolic pathway and the link between one gene-one protein.	
3	E7	The student shows links between the data given for change of environmental factor to the expression of the genotype being different from the predicted phenotype. To achieve a higher grade they would need to have a link between the gene expression changes in the 3 plants.	