

A-Level Biology – Control and Gene Technology

A-Level Biology (Edexcel / AQA / OCR style) · Total marks: 36 · Answers on the last page

Covers nervous and hormonal control, homeostasis, gene expression and biotechnology. Answer in full sentences using correct biological terminology, as required for extended-response A-level questions.

Section A – Nervous and Hormonal Control

1. Describe the sequence of events at a synapse that results in transmission of a nerve impulse to the next neurone. [4]
2. Explain the role of negative feedback in maintaining a stable core body temperature, using one physiological response to a rise in temperature as an example. [3]
3. Distinguish between the roles of the sympathetic and parasympathetic nervous systems in controlling heart rate. [2]
4. Describe the pathway of a reflex arc from stimulus to response, naming the components involved. [4]

Section B – Gene Expression

5. Explain how the lac operon in *E. coli* is switched on in the presence of lactose and the absence of glucose. [4]
6. Explain what is meant by a totipotent stem cell and a pluripotent stem cell, giving one example source of each. [3]
7. Explain why differential gene expression, rather than differences in DNA base sequence, is responsible for cell differentiation in a multicellular organism. [3]

Section C – Biotechnology and Extended Application (Extended response)

8. Outline the steps involved in producing genetically modified bacteria that can produce human insulin, using restriction enzymes and a plasmid vector. [5]
9. A student carries out gel electrophoresis to separate DNA fragments produced by cutting a sample of DNA with a restriction enzyme. Explain how the fragments are separated and how their sizes can be determined. [3]
10. Explain the practical and ethical benefits of producing human insulin using genetically modified bacteria rather than extracting insulin from animal pancreases. [3]
11. Suggest one social or economic concern associated with the use of genetically modified organisms in agriculture. [2]

Answers

Check your working against these. If an answer does not match, try the question again before looking for the method.

1. An action potential arriving at the presynaptic knob causes voltage-gated Ca^{2+} channels to open, and Ca^{2+} ions diffuse into the presynaptic neurone; this triggers synaptic vesicles containing neurotransmitter to move to and fuse with the presynaptic membrane, releasing neurotransmitter into the synaptic cleft by exocytosis; the neurotransmitter diffuses across the cleft and binds to specific receptors on the postsynaptic membrane, opening ligand-gated Na^+ channels; Na^+ influx depolarises the postsynaptic membrane, generating a new action potential if threshold is reached; the neurotransmitter is then broken down or removed to prevent continuous stimulation.
2. In negative feedback, a change away from the set point is detected and triggers a response that counteracts the change, returning the system towards the set point. For example, when core temperature rises above the set point, the hypothalamus detects this and increases blood flow to the skin by vasodilation of arterioles, increasing heat loss by radiation from the skin surface (accept: increased sweating, increasing evaporative cooling), lowering core temperature back towards normal.
3. The sympathetic nervous system releases noradrenaline, which binds to receptors on the sinoatrial node (SAN) and increases heart rate (e.g. during exercise or the 'fight or flight' response). The parasympathetic nervous system releases acetylcholine, which binds to SAN receptors and decreases heart rate (e.g. at rest); together they provide antagonistic control of heart rate.
4. A stimulus (e.g. a hot object) is detected by a receptor (e.g. a thermoreceptor in the skin); a sensory neurone carries the nerve impulse to the central nervous system (spinal cord); within the spinal cord the sensory neurone synapses with a relay (intermediate) neurone, which synapses with a motor neurone; the motor neurone carries the impulse to an effector (a muscle, which contracts, or a gland, which secretes), producing a rapid, involuntary response without requiring conscious involvement of the brain, allowing a fast protective reaction.
5. In the absence of lactose, the lac repressor protein binds to the operator region, blocking RNA polymerase from transcribing the structural genes (*lacZ*, *lacY*, *lacA*). When lactose is present, a lactose derivative (allolactose) binds to the repressor protein, changing its shape so it can no longer bind to the operator; RNA polymerase can then bind to the promoter and transcribe the structural genes, producing enzymes such as β -galactosidase needed to metabolise lactose.
6. A totipotent stem cell can differentiate into any cell type, including extra-embryonic tissue such as the placenta; an example is a cell of the very early embryo (e.g. the zygote or cells from early cleavage divisions). A pluripotent stem cell can differentiate into almost any type of body cell but not extra-embryonic tissue; an example is an embryonic stem cell taken from the inner cell mass of a blastocyst.
7. Almost all nucleated body cells contain an identical copy of the organism's genome (produced by mitosis from the original zygote), so the DNA base sequence is the same in every cell. However, cells become structurally and functionally different because different genes are transcribed and translated (switched on) or not expressed (switched off) in different cell types, controlled by transcription factors and epigenetic mechanisms; this differential gene expression produces different proteins in different cell types, giving rise to their specialised structure and function even though the DNA sequence is unchanged.
8. The human insulin gene is obtained, for example by using reverse transcriptase to make complementary DNA (cDNA) from mature insulin mRNA. The gene and a bacterial plasmid vector are cut using the same restriction endonuclease enzyme, producing fragments with complementary

sticky ends. The insulin gene is inserted into the cut plasmid and joined using DNA ligase, forming a recombinant plasmid. The recombinant plasmid is inserted into bacterial cells by transformation (e.g. using heat shock with calcium chloride treatment). A marker gene, such as one for antibiotic resistance, is used to identify bacteria that have successfully taken up the recombinant plasmid. The transformed bacteria are then cultured (cloned) in a fermenter under controlled conditions, expressing the human insulin gene, and the insulin produced is extracted and purified.

9. DNA fragments, which are negatively charged due to their phosphate groups, are loaded into wells in an agarose gel, and an electric current is applied across the gel; the fragments migrate towards the positive electrode, with smaller fragments moving faster and further through the gel matrix than larger fragments, separating them according to size. Comparing the distance each fragment has migrated with a DNA ladder (a mixture of fragments of known size) run alongside the sample allows the size of the unknown fragments to be estimated.
10. Practical benefits: bacteria can be grown rapidly in large fermenters, producing large quantities of pure insulin cheaply, consistently and without relying on a limited supply of animal pancreases; because the insulin produced is identical to human insulin, there is a much lower risk of immune rejection or allergic reaction than with animal-derived insulin, which differs slightly in amino acid sequence. Ethical benefits: this method avoids the use and slaughter of animals to obtain insulin, addressing animal welfare concerns and making the insulin more acceptable to vegetarians or certain religious groups.
11. Any valid concern, for example: biotechnology companies may patent GM seeds, requiring farmers to purchase new seed every growing season rather than saving seed from their own crop, which can increase costs and reduce farmers' independence (accept other valid concerns, e.g. reduced biodiversity from growing GM monocultures, or public distrust limiting market acceptance of GM produce).

Need this topic taught, not just practised? Book a trial lesson at 50% off with Mr. Ahmad — online worldwide or in person in Dubai.

WhatsApp +971 55 373 5695 · mathandsciencetutor.com