
HL Paper 3

- b. Outline how the human brain can reorganize itself following a stroke. [1]
- c.i. State the area of the human brain that may have been damaged when the following symptom is present: [1]
- A lack of muscle control on the left side of the body
- c.ii. State the area of the human brain that may have been damaged when the following [1]
- symptom is present.
- Difficulty in swallowing

Markscheme

- b. activities/functions spread across the brain
- OR**
- activities/functions taken over by other areas of the brain
- c.i. right motor cortex
- OR**
- right **cerebral** hemisphere
- c.ii. medulla «oblongata»

Examiners report

- b. [N/A]
- c.i. [N/A]
- c.ii. [N/A]

-
- b. List **two** stimuli and the receptors that detect them. [2]
- c. Outline how pain is perceived and the role of endorphins in this process. [3]

Markscheme

- b. a. pressure/movement/sound (detected by) mechanoreceptors;
- b. chemicals (detected by) chemoreceptors;
- c. temperature (detected by) thermoreceptors;
- d. light (detected by) photoreceptors;

- e. pain (detected by) nociceptors;
- f. stretch/orientation/movement (detected by) proprioceptors;
- c. a. impulses passed from pain receptors to sensory areas;
- b. of the cerebral cortex where pain is perceived / feelings of pain in the areas of the cerebral cortex;
- c. endorphins act as painkillers;
- d. which block transmission of impulses at the synapses involved in pain transmission;

Examiners report

- b. A large majority could list stimuli and receptors, but a significant number gave very general answers, for example sound in ears.
- c. Weaker candidates were more likely to describe the pain withdrawal reflex rather than how pain is perceived. In (c) most candidates earned at least one mark outlining how pain is perceived. The most common response was that endorphins act as painkillers.

Explain **two** methods that scientists have used to determine the different functions of the brain.

Markscheme

first method: [3]

- a. name of first method *eg: lesion studies*
- b. how the first method works *eg: carry out an autopsy*
- c. what can be learned from the first method *eg: relate the position of the lesion to observed changes in behaviour*

second method: [3]

- d. name of second method *eg: fMRI*
- e. how the second method works *eg: inject dye into blood **OR** active parts of the brain have dyed blood flowing to them*
- f. what can be learned from the second method *eg: known stimulus activates specific region of the brain that is detected*

Allow other verifiable methods.

Examiners report

[N/A]

-
- b. Outline the development of axons in immature neurons. [2]
 - e. State **one** activity controlled by the medulla oblongata. [1]

Markscheme

- b. a. axon grows from an «immature» neuron
- b. chemical stimuli trigger the growth/direction of axon
- c. only one axon develops per neuron
- d. some axons extend beyond neural tube to reach other parts of body
- e. gut muscles / heart rate/cardiac centre / vasomotor / breathing/ventilation rate / reflex centre of vomiting/coughing/sneezing/swallowing

Examiners report

- b. [N/A]
- e. [N/A]

- b. State the function of the bones in the middle ear. [1]
- c. Explain the role of the hair cells in the cochlea. [3]

Markscheme

- b. amplify/transmit the sound/vibrations
- c. a. hair cells located within the organ of Corti

OR

hair cells are mechanoreceptors

- b. hairs/cilia of hair cells move/vibrate with the movement of the liquid/fluid in the cochlea
- c. amount of movement is proportional to the amplitude/loudness of the sound
- d. frequency/wavelength/pitch distinguished by different hair cells/according to position of hair cells/length of hairs/cilia
- e. hair cells transmit impulses to auditory nerve/brain

Examiners report

- b. [N/A]
- c. [N/A]

- a. Approximately 350 000 people worldwide have received cochlear implants. Outline the use of cochlear implants in patients with hearing problems. [3]
- b. State the part of the ear that is responsible for detecting movement of the head. [1]
- c. Describe the role of bipolar cells in the eye. [3]

Markscheme

- a. a. microphone outside the ear pick up sounds
 - b. sound waves converted to electronic/digital signals
 - c. electronic impulses sent to electrode in cochlea
 - d. «electrode» directly stimulates auditory nerve
 - e. signals «generated by implant» sent to brain which recognizes signals as sound
- b. semicircular canals
- c. a. transmit the signals from the photoreceptors «rods and cones» to the ganglion cells
 - b. groups of/more than one rod cell synapse with one bipolar cell
 - c. one cone cell synapses with one bipolar cell
 - d. once light is absorbed bipolar cell depolarizes
 - e. activates/depolarizes a ganglion cell

Examiners report

- a. [N/A]
- b. [N/A]
- c. [N/A]

-
- a. Outline the neural control of the process of swallowing. [3]
 - b. Describe an example of learned behaviour. [3]

Markscheme

- a. a. «usually» autonomic reflex
 - b. «usually» involuntary/automatic

OR

not controlled consciously

 - c. coordinated by medulla «oblongata»
 - d. can be voluntary/consciously controlled «by cerebral cortex»
- b. a. learned behaviour is behaviour that is taught or received through experience

Allow other definition.

 - b. named organism

eg: Chimpanzees.

Allow human, people, etc, providing it is explicitly written.

 - c. named/description of behaviour

eg: Sticks used to spear juicy grubs.

eg: learning a language.

Examiners report

a. [N/A]

b. [N/A]

Outline innate and learned behaviour.

Markscheme

innate behaviour : [3 max]

a. inherited «from parents»/controlled by genes

b. develops independently of environment

OR

not modified by experience/learning

c. species specific/shared by all members of species

d. developed by natural selection/increases chance of survival/reproduction

e. valid example of innate behaviour

Only mark the first example if more provided

learned behaviour : [3 max]

f. develops as a result of experience/environmental stimulus

g. is a process of gaining new knowledge or skills

h. not inherited «from parents»

OR

not controlled by genes

i. may or may not increase chance of survival and reproduction

j. valid example of learned behaviour

Only mark the first example if more provided

[Max 6 Marks]

Examiners report

[N/A]

a. Define the term *stimulus*.

[1]

b (i) Outline the functions of the following parts of the brain.

[1]

Medulla oblongata:

b (ii) Outline the functions of the following parts of the brain.

[1]

Hypothalamus:

c. Explain the effects of psychoactive drugs on synaptic transmission. [3]

d. Outline how endorphins act as painkillers. [2]

Markscheme

a. stimulus is a change in the (internal/external) environment that can be detected

b (i) *medulla oblongata*: controls autonomic functions of the body such as heart rate/blood pressure/ventilation/swallowing/vomiting/digestion/cranial reflexes

b (ii) *hypothalamus*: links nervous and endocrine systems/produces hormones secreted by posterior pituitary/controls hormonal secretion by pituitary/maintains homeostasis such as control of body temperature/hunger/thirst/fatigue/circadian cycles

c. psychoactive drugs may increase or decrease transmission (to the post-synaptic membrane);

may increase the release/delay the breakdown/interfere with storage/uptake/reabsorption of neurotransmitters;

may mimic the action of neurotransmitters;

inhibitory drugs may reduce the effect of excitatory neurotransmitters/increase the effect/release of inhibitory neurotransmitters;

inhibitory drugs can hyperpolarize the post-synaptic neuron;

d. endorphins released by pituitary gland (during stress, injury or exercise);

endorphins block transmission of impulses at synapses involved in pain perception;

bind to receptors in the membrane neurons (involved in) sending pain signal;

block release of neurotransmitters;

Examiners report

a. Candidates were not able to give a concise definition that was complete. The definition of stimulus is given in the syllabus.

b (i) Outlining the functions of the two parts of the brain was done fairly well by many candidates who were able to get the two marks.

b (ii) Outlining the functions of the two parts of the brain was done fairly well by many candidates who were able to get the two marks.

c. As noted on the G2 forms, candidates were not sure what to include in their explanations of the effects of psychoactive drugs on synaptic transmission. The more able candidates were able to bring in different ways drugs could either increase or decrease synaptic transmission.

d. This section on how endorphins act as painkillers was very poorly done by most. It seemed that endorphins had not specifically been studied.

Outline the effects of cocaine at synapses in the brain.

Markscheme

excitatory (psychoactive) drug;

effect at synapses in brain that use dopamine as transmitter;

inhibits receptors / binds to membrane proteins that pump dopamine / inhibits reuptake of dopamine;

causes build-up of dopamine in synaptic cleft/synapse;

causes continuous transmission at these synapses;

Examiners report

Most candidates could outline the effects of cocaine on synapses in the brain in (c), but many answers contained inaccuracies concerning the neurons involved, the neurotransmitter and the effect on membrane receptors; there was no provision for marks about the behavioural aspects of cocaine use.

-
- a. With respect to Pavlov's experiments with dogs, distinguish between the conditioned and unconditioned stimulus. [3]
- b. The bird known as the blackcap (*Sylvia atricapilla*) traditionally migrates from its summer breeding grounds in Central Europe to Spain and Portugal for the winter. State **two** adaptive advantages of bird migration. [2]
- c. Outline **one** way in which synchronized oestrus in female lions increases the chances of survival and reproduction of offspring. [2]
- d. Outline **one** way in which neurons can be altered by memory and learning. [2]

Markscheme

- a. Unconditioned stimulus triggers a response automatically/innately
- Sight/smell of food «naturally» triggers salivation in dogs
- Conditioned stimulus is a previously neutral stimulus «eg: sound of bell» that becomes associated with the unconditioned stimulus «and is learned»
- Triggers a conditioned response, salivation with sound before food
- Award [2 max] if no reference to Pavlov's investigation.*
- b. Food is more abundant
- Temperature is more tolerable
- More suitable habitat
- c. **Alternative 1**
- Females have their cubs/are lactating at same time
- Can suckle/care for each other's cubs while others hunt

Cubs are more likely to survive when they are raised in a nursery rather than by a solitary mother

Alternative 2

A group of male cubs, of same age, leave the pride at the same time

So can compete for dominance of another pride more effectively

- d. Involve changes in neurons caused by slow-acting neurotransmitters

Neurons make new connections/increase number of synapses

«Short-term» memory depends on change in strength of existing neuronal connections

Long-term potentiation «LTP» is a lasting increase in strength of synaptic transmission

More receptors added to enhance synaptic transmission

Examiners report

- a. This question was surprisingly poorly attempted considering that Pavlovian conditioning is not new to the syllabus. Although many candidates were able to achieve one or 2 marks, very few were able to score 3. Candidates tended to confuse stimulus and response and did not focus on conditioned and unconditioned stimuli.
- b. Most were able to score at least one and many 2 marks for two advantages of bird migration during winter.
- c. Many were also able to score 2 marks for this question on synchronized oestrus in lions.
- d. This question on how neurons can be altered by memory and learning was the one with the weakest candidate answers in this option. Many were confused as to how this was different from question 4(b). Seldom was more than one mark awarded and then for increase in number of synapses.

General anesthetics act on the neurotransmitters in neuron synapses. Explain the effect of anesthetics on patients and how they affect synaptic transmission.

Markscheme

- a. patient loses awareness/does not feel pain/analgesia
- b. interfere/block neural/synaptic transmission between «areas of» sensory perception and the CNS
OR
block «sensory» neural pathways to the brain that detect pain
- c. increase presynaptic inhibition
OR
block receptors on the presynaptic membrane
- d. increase release of inhibitory neurotransmitters
OR
prevent release of excitatory neurotransmitters
- e. inhibit binding of neurotransmitters «to receptors» on postsynaptic membrane
- f. decrease «likelihood of» depolarization of the postsynaptic neuron
OR
hyperpolarize the postsynaptic neuron

- g. prevent propagation of action potential on the postsynaptic neuron
- h. vital physiological functions/breathing/maintenance of blood pressure continue to function
- i. the effects are reversible
- j. anesthetics mimic effect/stimulate release of endorphins «which are natural painkillers»/OWTTE

Examiners report

[N/A]

Discuss the concept of brain death and the use of the pupil reflex in testing for brain death.

Markscheme

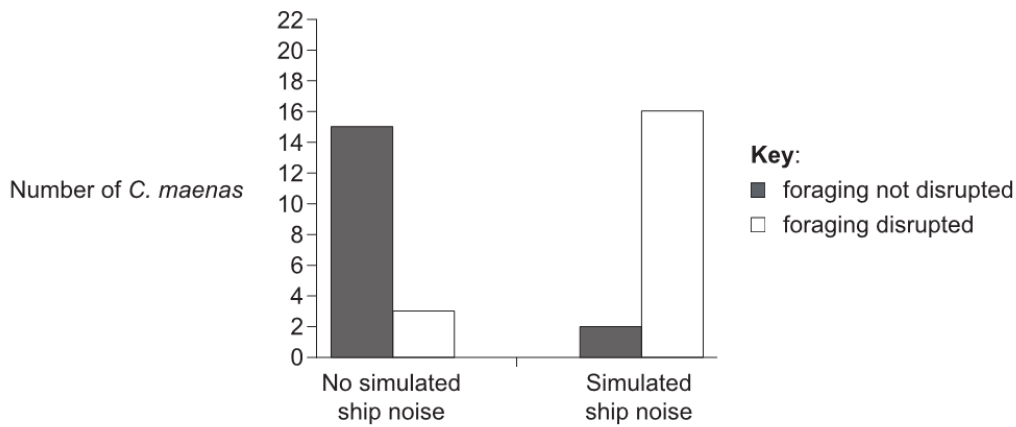
- whole brain death is brain stem and cerebrum;
- failure of pupil to respond to light indicates brain stem death;
- without brain stem function, life cannot continue;
- cerebrum involves higher order brain function;
- non-functioning cerebrum with functioning brain stem is vegetative state;
- some would argue this is the death of the person;
- though brain stem function alone may be able to maintain homeostasis;

Examiners report

This was by far the most poorly answered question in the paper.

Although many candidates could describe the pupil reflex, the details of brain death, the role played by the brain stem and the cerebrum were not known. The application of the pupil reflex to establish whole brain death, brain stem damage or cerebrum damage was not known. No candidate gained over two marks here and only very general answers were seen.

Noise from ships has the capacity to disrupt the foraging behaviour of shore crabs (*Carcinus maenas*). In this study, *C. maenas* were collected from Newquay Harbour in the UK and held for a maximum of 48 hours in salt-water tanks located at a neighbouring aquarium. The graph shows the effect of simulated ship noise on the time spent foraging for food by *C. maenas*.



[Source: Republished with permission of Elsevier Science and Technology Journals, from 'Noise negatively affects foraging and antipredator behaviour in shore crabs', Matthew A. Wale, Stephen D. Simpson, Andrew N. Radford, Animal Behaviour 86, 2013; permission conveyed through Copyright Clearance Center, Inc]

- a. State the effect of simulated ship noise on foraging behaviour. [1]
- b. Predict the consequences on *C. maenas* of increasing noise related to human activity. [3]

Markscheme

a. foraging behaviour disrupted more «in the presence of simulated ship noise»

b. a. affects searching for food/foraging/selecting optimum prey

b. increased risk of starvation/less food «for survival»

c. cause migration/relocation/moving to other foraging area

d. individuals less distracted by noise will survive

OWTTE

OR

leads to natural selection

e. decline in population

[Max 3 Marks]

Examiners report

a. [N/A]

b. [N/A]

Explain how the ear converts sound waves in the air to the nerve impulses sent to the brain.

Markscheme

- a. sound waves cause the eardrum to vibrate;
- b. the eardrum transmits these vibrations to the bones (of the middle ear);
- c. the bones (ossicles) amplify the vibrations;
- d. the bones cause movement / vibration of the oval window;
- e. (the oval window) causes movement of the fluid in the inner ear/cochlea:
- f. causes movement of the hairs (of hair cells);
- g. triggers action potential/nerve impulse;
- h. transmitted to brain by the auditory nerve;
- i. round window equalizes pressure in the inner ear;

Examiners report

The majority of candidates obviously used information from previous examination papers instead of focusing on the actual question, but were nevertheless successful. There was a wide range of answers in terms of clarity, but most candidates showed good knowledge of the processes occurring in the ear, simply lacking clear details such as the use of vibrations instead of sound, or the movement of hairs (not the hair cells themselves) in the cochlea as well as the formation of the nerve impulse.

Discuss the causes of addiction, including genetic predisposition, social factors and dopamine secretion.

Markscheme

social and genetic: [3 max]

genetic:

- a. genetic link found for (cocaine) addiction;
- b. difficult to prove / multifactorial;

social:

- c. alcohol/other drug problems among family members;
- d. poor school performance;
- e. poverty / family conflicts / chaos / stress;
- f. having friends who drink/use other drugs;
- g. not fitting in socially / being excluded because of race/ability/ethnicity/gender/age/sexual orientation / other factors;

dopamine and addiction: [3 max]

- h. substances with addictive potential stimulate the release of dopamine;
- i. dopamine is a chemical in the brain that is associated with reward and pleasure;
- j. substance use brings a flood of dopamine, which alters the chemistry of the brain;

Examiners report

Generally question 3 was well-answered, although some candidates only wrote about cocaine and its effects, and weaker candidates discussed the effects of addiction rather than causes.

Discuss the evolution of altruistic behaviour using **one** non-human example.

Markscheme

organism expends time/energy in caring for other (unrelated) members of the same species;

put themselves at risk or disadvantage for the good of other members of the species / actions that increase another individual's number of offspring at cost to one's own reproduction;

valid example; (e.g. *primates / vampire bats / male turkeys or other birds such as Florida jays / mole rats*)

Do not accept parental care.

description of altruistic behaviour of the example given;

might expect natural selection to be against behaviour that reduces chances of survival and reproduction;

close kin share alleles;

(adaptive significance is to) increase frequency of alleles shared in common;

(provides genetic advantages in kin by) promoting survival and reproduction within species;

altruistic behaviour towards non-relatives may allow selection of alleles responsible for the behaviour to be perpetuated;

some argue no true altruism as organism benefits either directly or indirectly in the future;

Award [5 max] if no valid non-human example given.

Examiners report

Many answers did not relate the evolution of altruistic behaviour with the genetic aspect. Very few answers made reference to the alleles. The specific behavioural aspects of vampire bats, mole rats and honey bees especially were well known but often failed to expand further.

a. Explain the role of the neurons used in the pain withdrawal reflex.

[3]

c. State **one** effect of tetrahydrocannabinol (THC) on brain function.

[1]

Markscheme

a. sensory neurons receive information from receptors;

transmit nervous impulses to the central nervous system;

relay neurons in the central nervous system transmit the information from sensory neurons to motor neurons;

motor neurons send impulse to effector;

c. inhibition of nervous impulses / binding to cannabinoid receptors / blocking of release of excitatory neurotransmitter

Examiners report

- a. The majority of candidates used correct terminology in describing the transmission of a nervous impulse involved in a withdrawal reflex.
 - c. Many wrote that tetrahydrocannabinol (THC) had an inhibitory effect at the level of receptors; this was largely well answered.
-

Explain how colour in the environment is detected by the eyes and relayed to the brain in humans.

Markscheme

Detected by the cones

OR

Cones are photoreceptors

They are located in the retina/concentrated in the fovea

Three types of cones that absorb different wavelengths of «visible» light

Cones absorb light passing impulse to bipolar cell

Bipolar cells connected to ganglion cells

There is one to one connection of cones to bipolar cells

OR

One to one connection of bipolar cells to ganglion cells

Relayed to the optic nerve

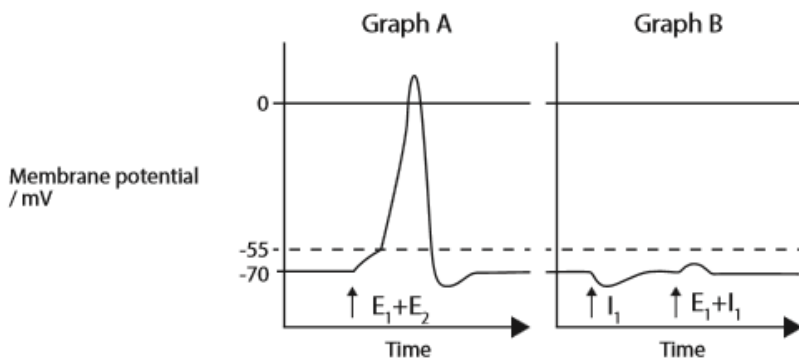
Right field of vision «of both eyes» is sent to the left part of the brain (*Vice versa*)

Information is passed to the visual cortex/occipital lobe

Examiners report

This question on colour detection was similar to ones that have appeared on past papers and candidates seemed very well prepared for it, with a good number of candidates receiving full marks. Weaker candidates tended to include irrelevant material, such as information on rods, but they were able to get marks for knowing the sequence of transmission of the impulse from the cones to the brain. Few mentioned wavelengths of light.

The graphs compare the changes in membrane potential that result from a combination of stimuli. Graph A shows two excitatory post-synaptic potentials (E_1 and E_2) acting on a neuron. Graph B shows one excitatory (E_1) and one inhibitory (I_1) post-synaptic potential, both acting on a neuron.



[Source: © International Baccalaureate Organization 2016]

With respect to the graphs, explain what is meant by summation.

Markscheme

More than one presynaptic neuron can form a synapse with the same postsynaptic neuron

Summation involves combining the effects of «excitatory and inhibitory» neurotransmitters/potentials

OR

action potentials form depending on the balance of signals of excitatory and inhibitory signals

E_1 and E_2 /two excitatory potentials/effects are added

« E_1 and E_2 /two excitatory potentials» depolarizes membrane

«Membrane potential» goes above threshold

OR

Generate action potential

Effect of inhibitory neurotransmitter/potential/ I_1 cancels effect of excitatory neurotransmitter/ E_1

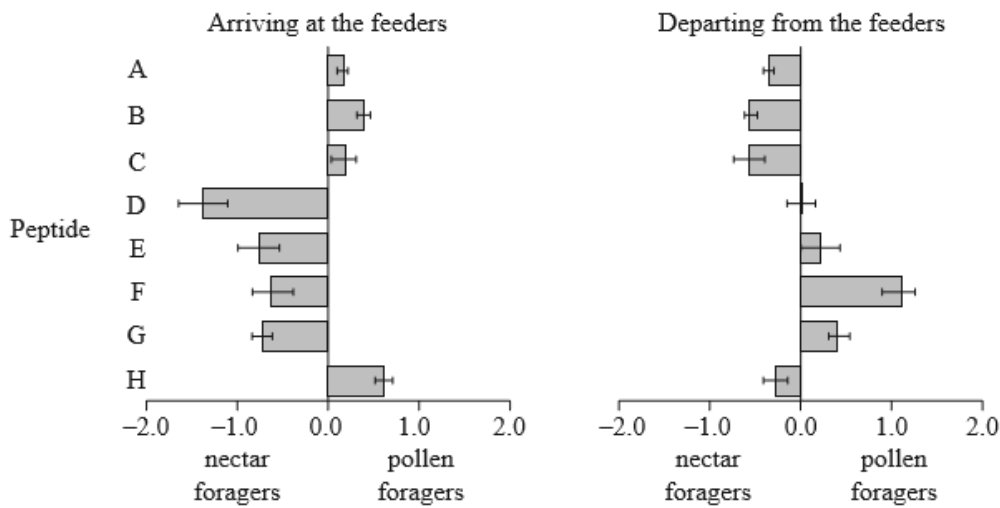
OR

Effect of inhibitory neurotransmitter/potential/ I_1 prevents threshold being reached when E_1 applied

Examiners report

This question was quite discriminating with one or 2 marks awarded to many candidates. Although summation appeared to be fairly well understood, candidates struggled to express themselves clearly. Many struggled to explain summation using the graphs provided so only the better candidates received 3 marks.

In order to investigate the hypothesis that honeybees (*Apis mellifera*) have an instinct to forage for either nectar or pollen, but not both, researchers installed different feeders containing either nectar alone or pollen alone. They collected four different groups of honeybees (those arriving at the nectar feeders, arriving at the pollen feeders, departing from the nectar feeders and departing from the pollen feeders) and measured the abundance of eight peptides in their brains. The relative difference of these brain peptides was then calculated by subtracting the abundance in nectar foragers from the abundance in pollen foragers and is shown by the bars on the graphs below.



Change in peptide abundance between nectar and pollen foragers / arbitrary units

[Source: 'Quantitative peptidomics reveal brain peptide signatures of behaviour'. Axel Brockmann, Suresh P. Annangudi, Timothy A. Richmond, Seth A. Ament, Fang Xie, Bruce R. Southey, Sandra R. Rodriguez-Zas, Gene E. Robinson and Jonathan V. Sweedler (2009) *PNAS*, 106 (7), pp. 2383–2388.]

- Identify which peptide shows the greatest difference between pollen foragers and nectar foragers departing from the feeders. [1]
- Distinguish between the difference in abundance of peptides in nectar and pollen foragers arriving at the feeders. [2]
- Evaluate the hypothesis that honeybees have an instinct to forage for **either** nectar **or** pollen, but not both. [2]
- Discuss how this type of foraging behaviour could optimize food intake. [2]

Markscheme

- (peptide) F
- (peptides) A, B, C and H more abundant in pollen foragers;
(peptides) D, E, F and G more abundant in nectar foragers;
greater abundance (differences) for nectar foragers;
A and C showed little difference;
Do not accept numerical statements only.
- (arguments supporting the hypothesis)
each group of foragers is always associated with the same group of peptides;
trends inverse between nectar (foragers) and pollen (foragers)/arriving and departing / *OWTTE*;
error bars on the graph show that the differences are likely to be significant;

(arguments not supporting the hypothesis)
no data about nectar/pollen actually collected / sample size;
there is no evidence of causation/that the peptide in the brain is determining the type of foraging itself;

- d. (predisposition/instinct/natural selection) ensures that both pollen and nectar will be collected;
- allows the bees to collect whichever food source is in abundance at the time / increases food collection efficiency;
- both pollen and nectar are diet requirements;
- this behaviour is part of division of labour/specialization;

Examiners report

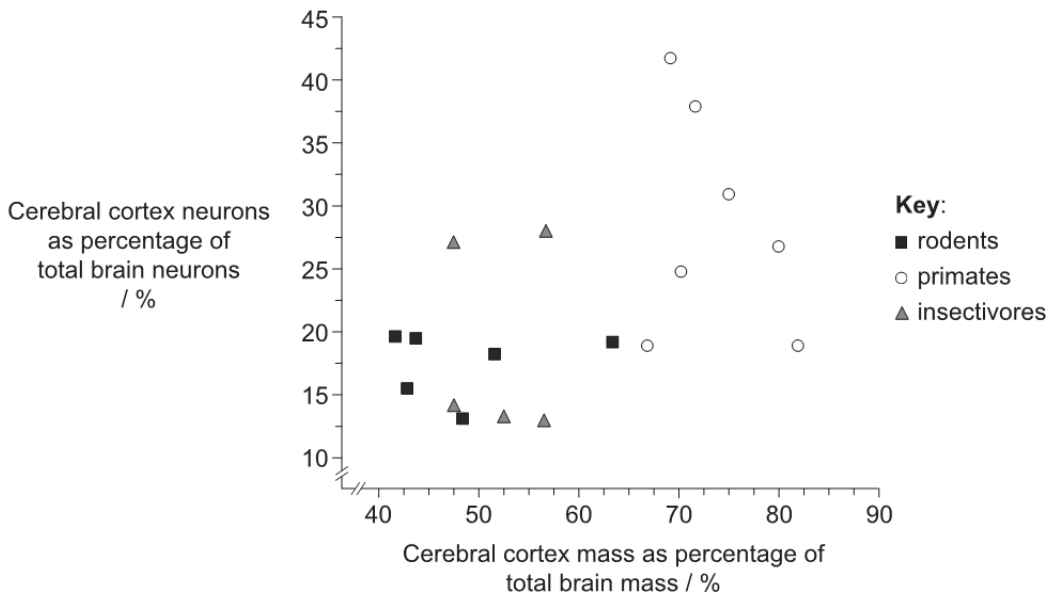
- a . Many candidates really did not seem to understand the underlying theory relating brain peptides to foraging strategy in bees and this question separated candidates who analysed data as a set and those that searched for details and lost the general picture. Whereas almost all candidates could identify the correct peptide in part (a).
- b. Many candidates really did not seem to understand the underlying theory relating brain peptides to foraging strategy in bees and this question separated candidates who analysed data as a set and those that searched for details and lost the general picture.

Most of them could distinguish the two groups in (b).
- c. Many candidates really did not seem to understand the underlying theory relating brain peptides to foraging strategy in bees and this question separated candidates who analysed data as a set and those that searched for details and lost the general picture.

Many candidates had difficulty evaluating the hypothesis although they could see the inversion of trends in (c).
- d. Many candidates really did not seem to understand the underlying theory relating brain peptides to foraging strategy in bees and this question separated candidates who analysed data as a set and those that searched for details and lost the general picture.

They frequently restated the question in the wording of their answer for (d), but many nevertheless gained the mark about increasing food collection efficiency.

The graph shows the correlation between the cerebral cortex mass and the number of neurons in the cerebral cortex of three groups of mammals (rodents, primates and insectivores). Each point indicates the mean number from different research studies for the species.



- a.i. State which group has the lowest percentage of cerebral cortex mass. [1]
- a.ii. Suggest advantages of the cerebral cortex containing a high percentage of the brain's neurons. [2]
- b. Suggest a role for the cerebral cortex in rodents such as rats and mice. [1]
- c. Explain how the cerebral cortex in humans differs from other mammals. [3]

Markscheme

a.i. rodents

a.ii.a. more neurons means more synapses/connections

- b. higher cognitive ability
- c. capacity for information processing increased

OWTTE

[Max 2 Marks]

b. a. sensory function

- b. information processing
- c. memory/learning
- d. motor function

Do not accept "language"

[Max 1 Mark]

c. a. parts/lobes/proportions more highly developed in humans «than in other animals»

- b. folding/wrinkles/sulci/gyri
- c. increases surface area
- d. larger mass of cerebral cortex «relative to body mass»
- e. enables higher order functions

Do not accept answers that only refer to the "brain" in general instead of the "cortex"

[Max 3 Marks]

Examiners report

- a.i. [N/A]
a.ii. [N/A]
b. [N/A]
c. [N/A]

Markscheme

excitatory (psychoactive) drug;

cocaine attaches to dopamine pumps/transporters (on presynaptic membrane);

blocks uptake/recycling / causes dopamine to persist in the synaptic cleft;

amplifies synaptic transmission / causes constant stimulation of postsynaptic neuron;

causes euphoria/feelings of happiness/pleasurable effects;

causes feelings of great energy/alertness/talkativeness;

addictive / causes addiction;

changes in personality / problems with family/friends/work;

crimes to pay for cost of drug/crime associated with the production/distribution;

Examiners report

Some concerns were expressed by teachers about this question. The IB Biology programme stipulates that the effects of cocaine on synapses in the brain and on mood and behaviour should be studied. An Aim 8 suggestion is to look also at the wider consequences for society. A maximum of two marks was awarded for these consequences and even when candidates did not include them, they were able to find six other relevant points if they were well prepared. There was some misinformation about the precise reasons for cocaine causing accumulation of dopamine in synapses, with candidates suggesting that secretion of dopamine increasing rather than reabsorption into the pre-synaptic neuron being prevented.

Explain, using examples, the neurological effects of inhibitory psychoactive drugs.

Markscheme

a. examples are benzodiazepines / THC / cannabis / alcohol

b. block / decrease synaptic transmission

c. causing less transfer of information to the brain / decreasing brain activity

d. benzodiazepines increase effect of GABA

e. GABA is an inhibitory neurotransmitter

f. Increase permeability of neural membrane to chloride ions/hyperpolarizes the neuron

g. alcohol enhances effect of GABA

h. «alcohol» also decreases activity of glutamate, an excitatory neurotransmitter

i. THC/cannabis can block cannabinoid receptors

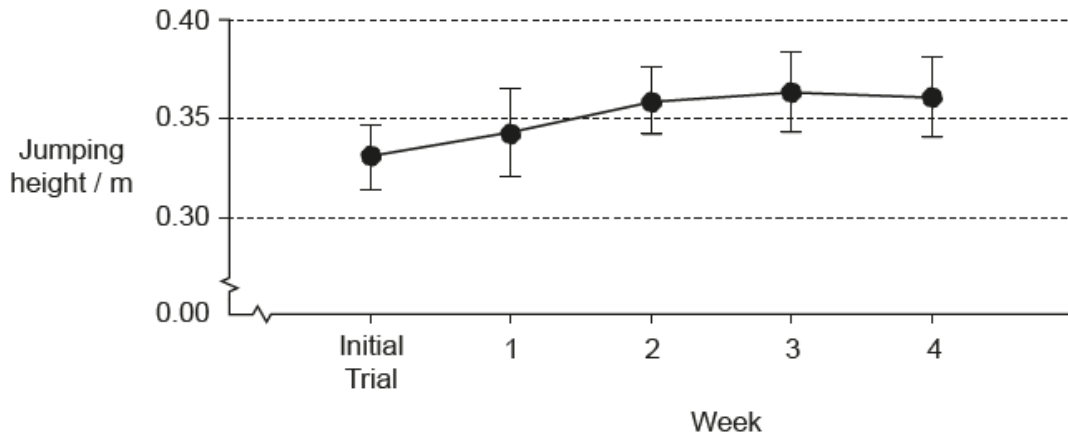
j. «THC» inhibits release of neurotransmitters that excite postsynaptic neurons/membranes

k. use of psychoactive drugs can lead to dependence/addiction / alter dopamine levels

Examiners report

[N/A]

- a. A study examined the effects of four weeks of intensive training in athletes on vertical jumping performance and neuromuscular learning. The graph shows the results for jumping height. [2]



[Source: Tine Alkjaer, Jacob Meyland, Peter C. Raffalt, Jesper Lundbye-Jensen and Erik B. Simonsen (2013) Neuromuscular adaptations to 4 weeks of intensive drop jump training in well-trained athletes. *Physiological Reports*, Volume 1, Issue 5, 2013, e00099, doi: 10.1002/phy2.99.]

- Outline the effect of training on jumping performance.
- b. List the different types of neurons involved in a reflex arc. [2]
- c. Predict whether an animal such as a laboratory rat could be encouraged to learn a new behaviour pattern. [2]
- d. Using an example, describe how innate behaviour may increase the chances of survival of a species. [3]

Markscheme

- a. a. jumping performance shows an improvement «during the first two/three weeks»

OR

no/little improvement as error bars all overlap

b. «during the period of this investigation» it reaches a plateau

c. the investigation was over a short time and is not conclusive of the effects of training over a longer period

- b. a. sensory/afferent neuron

b. motor/efferent neuron

c. relay neuron/interneuron

Two correct for [1]

Three correct for [2]

- c. a. operant conditioning/classical conditioning/trial and error experiences

- b. behaviour could be modified by positive/negative reinforcement
- c. animal makes an association between a particular behaviour and a consequence

Accept reward/punishment and/or examples such as food/electric shock.

- d. a. innate behaviour inherited/develops independently of environment

OR

Changes in innate behaviour depend on change in frequency of alleles that cause the behaviour ✓

- b. example of an innate behaviour ✓
- c. description of the behaviour ✓
- d. outcomes affecting survival

eg

b. synchronized oestrus in female lions

c. female lions can share responsibilities / females can suckle each other's cubs allowing some mothers to hunt

d. cubs are more likely to survive when they are raised in a group «nursery» rather than by a solitary mother /group of male cubs can leave pride together helping each other

Examiners report

- a. [N/A]
- b. [N/A]
- c. [N/A]
- d. [N/A]

Cocaine is considered an excitatory drug. State **one** other example of an excitatory drug and **one** example of an inhibitory drug.

Excitatory drug:

Inhibitory drug:

Markscheme

Excitatory drug: amphetamines/nicotine/caffeine;

Inhibitory drug: alcohol/benzodiazepines/THC;

(no brand names accepted, do not accept marijuana / heroin/other opiates)

Examiners report

Many were able to get both marks for this as examples of these types of drugs are clearly stated in the syllabus. However, others used brand names or street names which did not earn any credit.

Explain how sound is perceived by the ear.

Markscheme

eardrum moved by sound waves;

eardrum/tympanic membrane causes movement of the malleus/bones of the middle ear/ossicles;

bones of the middle ear/malleus, incus and stapes/hammer, anvil and stirrup amplify/magnify movement;

bones of the middle ear/stapes push on the oval window;

causing movement of fluid/vibration within the cochlea/inner ear;

hair cells are mechanoreceptors;

which release a chemical neurotransmitter when stimulated;

sounds/vibrations are transformed into nerve impulses/action potentials;

carried by auditory nerve to brain;

round window releases pressure so fluid in cochlea can vibrate;

Examiners report

Many candidates were able to get 5 or 6 marks for this section on the ear. This seemed well taught.

Discuss the concept of brain death and how it can be diagnosed.

Markscheme

it is a legal/medical definition of death;

some cases of coma are irreversible / some cases of coma may recover;

damage in the medulla (oblongata) is generally permanent;

doctors have to diagnose damage to decide treatment;

use tests of brain stem function to decide whether to preserve patient's life / without brain stem function life cannot continue;

test pupil reflex / shine light into eye;

if pupils do not constrict with light this suggests brain death;

more than one test used to diagnose brain death;

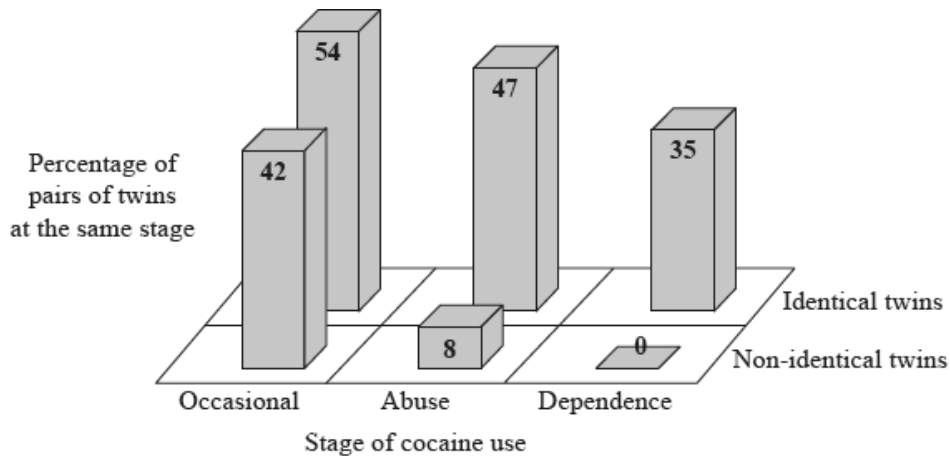
no response to pain or cranial reflexes;

legal/ethical definition needed for organ donation / long term use of life-support machines may be inappropriate / bioethical considerations;

Examiners report

Many candidates were able to get two marks for correctly describing the pupil reflex and its role in determining brain death. However, they were seldom able to obtain more than that as detail was lacking.

A study was conducted into the influence of genetic factors on occasional cocaine use, abuse and dependency. Pairs of female twins were interviewed to determine if either or both of them had used cocaine at all and also whether they had become abusers of cocaine or dependent upon it. Abuse was diagnosed if cocaine was having harmful consequences on the life of the person and dependence by signs that the person would suffer withdrawal symptoms without it. For each of these three stages of cocaine use, concordance rates were calculated for both identical and non-identical twins. The concordance rate is how many pairs of twins are both at a particular stage, expressed as a percentage of the total number of pairs in which either or both are at that stage. The bar chart shows the results.



[Source: adapted from P Zickler, (1999), *NIDA Notes*, 14, number 4]

- Identify which stage of cocaine use shows the least percentage difference between identical twins and non-identical twins. [1]
- Compare the results for identical twins and non-identical twins. [3]
- Analyse the data to find whether it supports the hypothesis that genetic factors cause some people to have a much higher chance of cocaine dependence than others. [3]

Markscheme

- occasional
- both (identical and non-identical twins) show lower percentages going from occasional to abuse to dependence;
at every stage, the percentage is higher for identical twins;
non-identical twins percentage drops to zero for dependence (but identical twins does not);
difference is similar for both groups between abuse and dependence;
sharper decrease between occasional and abuse for non-identical twins/OWTTE;

Do not accept answers stating numerical values only

- c. hypothesis supported as identical twins are more likely to behave the same for abuse and dependence than non-identical twins;
identical twins have the same genotype / OWTTE;
hypothesis not supported as environment is the major factor for trying cocaine;
not known if similar results may be due to similar environment;
not enough data for valid statistical analysis/OWTTE;

Examiners report

- a. Most identified 'occasional' as the stage showing the least difference between the two types of twins. The comparison of results was a bit more difficult, although most gained some marks; many did not understand that these were concordance rates rather than percentages of use. Some candidates stated numerical values only instead of stating the relationship between values in their comparisons, gaining no mark. The analysis was sometimes laborious, but most could see the differences between the two types of twins as a supporting evidence for genetic factors; statements about evidence for environmental factors were scarce.
- b. Most identified 'occasional' as the stage showing the least difference between the two types of twins. The comparison of results was a bit more difficult, although most gained some marks; many did not understand that these were concordance rates rather than percentages of use. Some candidates stated numerical values only instead of stating the relationship between values in their comparisons, gaining no mark. The analysis was sometimes laborious, but most could see the differences between the two types of twins as a supporting evidence for genetic factors; statements about evidence for environmental factors were scarce.
- c. Most identified 'occasional' as the stage showing the least difference between the two types of twins. The comparison of results was a bit more difficult, although most gained some marks; many did not understand that these were concordance rates rather than percentages of use. Some candidates stated numerical values only instead of stating the relationship between values in their comparisons, gaining no mark. The analysis was sometimes laborious, but most could see the differences between the two types of twins as a supporting evidence for genetic factors; statements about evidence for environmental factors were scarce.

Explain how the structures of the human ear allow for sound perception.

Markscheme

- eardrum/tympanic membrane vibrates with sound (waves);
- movements of eardrum/tympanic membrane amplified by bones of middle ear/stapes;
- bones are malleus/hammer, incus/anvil, stapes/stirrup;
- movement transmitted to oval window;
- creates pressure waves in the liquid within cochlea;

- waves travel up to/dissipate at round window;
- hairs in cochlea vibrate according to movement (of liquid/waves);
- different frequencies detected by different hair cells (on different parts of membrane);
- movement of hairs cause action potential/depolarization/hyperpolarization of hair cells;
- cause nerve impulses to be transmitted through auditory nerve;

Examiners report

The majority of candidates scored very well for this question, although some answers could have been clearer.

- b. State **one** excitatory and **one** inhibitory psychoactive drug. [2]
 - Excitatory:
 - Inhibitory:
- c. Describe, using **one** specific example of an animal, how the process of learning can improve its chances of survival and reproduction. [2]

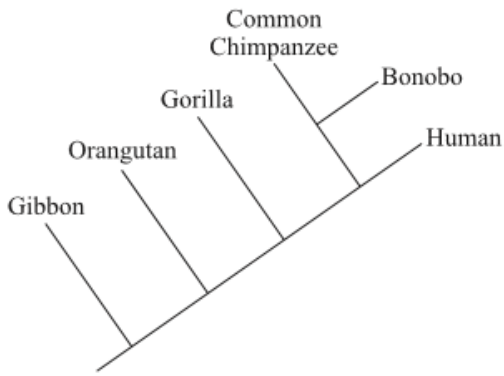
Markscheme

- b. a. *excitatory*: nicotine / cocaine / amphetamines / other drugs;
- b. *inhibitory*: benzodiazepines / alcohol / THC / other drugs;
- c. a. named animal;
- b. description of learned action allowing a more flexible response that improves health/survival/reproduction;
- eg:*
 - a. chimpanzees;
 - b. poking sticks in the wood increases chances to get more food/termites/insects;
 - a. blue jays;
 - b. avoidance of certain bad taste / poisonous insects prevents them from being sick/poisoned;
 - a. hedgehogs;
 - b. running across roads instead of rolling up when vehicles approach more likely prevents them from being killed;
- Accept any other verifiable examples.*

Examiners report

- b. The vast majority stated the psychoactive drugs correctly.
- c. Most candidates provided correct examples and descriptions of learned behaviour, although some names (i.e. bird) and/or its importance were too vague; some also confused innate and learned behaviour.

The diagram below is a cladogram.



a. State a function of each of the following parts of the human brain. [2]

(i) Cerebellum

(ii) Hypothalamus

b (i) Identify the **two** most closely related organisms. [1]

b (ii) Identify the species to which the Bonobo is most distantly related. [1]

c. Describe **one** type of barrier that may exist between gene pools. [3]

Markscheme

a. (i) (coordinates) unconscious motor functions/balance and movement

(ii) (maintains) homeostasis/thermoregulation/appetite/thirst / coordinates endocrine systems / secretes hormones/regulating factors

b (i) (common) chimpanzee and bonobo

b (ii) gibbon

c. named barrier;

description of its action;

results in terms of gene pools;

e.g.:

behavioural barrier;

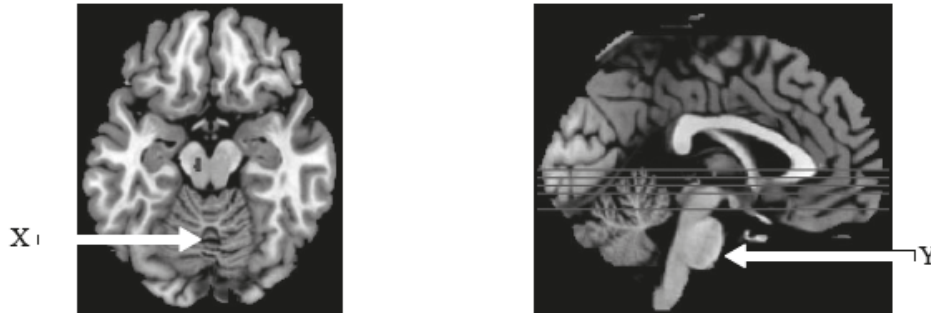
different populations mate at different times of year thus preventing interbreeding;

allele frequencies become different in the two gene pools/separates gene pools / sympatric speciation;

Examiners report

- a. The vast majority of candidates provided correct answers.
- b (i) This part presented a cladogram of larger primates and the two subparts were interpreted correctly by the vast majority of candidates.
- b (ii) This part presented a cladogram of larger primates and the two subparts were interpreted correctly by the vast majority of candidates.
- c. This part required candidates to name a barrier that may exist between gene pools and describe its action and the results in terms of gene pools. Mixed results were obtained here, although many candidates gained all the marks. Some candidates confused between types of barrier and types of evolution (e.g. geographic vs allopatric), were vague about its action and could not relate to gene pools.

The following images identify brain activity associated with a specific function.



[Source: SfN Article: Gambling Severity Predicts Midbrain Response to Near-Miss Outcomes, Henry W. Chase and Luke Clark, Articles – Behavioral/Systems/Cognitive | *The Journal of Neuroscience*, 5 May 2010, 30(18): 6180–6187; doi:10.1523/JNEUROSCI.5758-09.2010]

- a. Label the indicated areas on the images. [1]

X:

Y:

- b. State the diagnostic tool used for functional analysis in the images. [1]

- c. Using the table below, distinguish between *rod cells* and *cone cells*. [3]

Characteristic	Rod cells	Cone cells
Location		
Light intensity detected		
Connection to optic nerve		

Markscheme

- a. X: cerebellum;
Y: medulla oblongata; } (both needed)

Accept pons/brain stem in place of medulla oblongata

- b. functional magnetic resonance imaging / fMRI

Accept EMRI.

c.

<i>characteristic</i>	<i>rod cells</i>	<i>cone cells</i>
<i>location</i>	(all along the) retina	in fovea;
<i>light intensity detected</i>	dim	bright;
<i>connection to optic nerve</i>	group of rod cells to single nerve fibre	single cone to single nerve fibre;

Award [1] for each correct row.

Examiners report

- a. Many candidates labelled the two brain areas correctly, but others provided one or two incorrect answers; the majority identified Y as either the *medulla oblongata* or the pons and gained the mark, providing that their answer to X was correct. Most had fMRI, but some missed the 'f' and did not gain the mark. Most gained marks for the rods and cones, but some marks were not awarded because of imprecise or too vague answers; some candidates answered about colour vision instead of intensity of light. Answers for controlling experiments involving human behaviour were very diverse, but some gained marks for mentioning variations between humans and/or ethics.
- b. Many candidates labelled the two brain areas correctly, but others provided one or two incorrect answers; the majority identified Y as either the *medulla oblongata* or the pons and gained the mark, providing that their answer to X was correct. Most had fMRI, but some missed the 'f' and did not gain the mark. Most gained marks for the rods and cones, but some marks were not awarded because of imprecise or too vague answers; some candidates answered about colour vision instead of intensity of light. Answers for controlling experiments involving human behaviour were very diverse, but some gained marks for mentioning variations between humans and/or ethics.
- c. Many candidates labelled the two brain areas correctly, but others provided one or two incorrect answers; the majority identified Y as either the *medulla oblongata* or the pons and gained the mark, providing that their answer to X was correct. Most had fMRI, but some missed the 'f' and did not gain the mark. Most gained marks for the rods and cones, but some marks were not awarded because of imprecise or too vague answers; some candidates answered about colour vision instead of intensity of light. Answers for controlling experiments involving human behaviour were very diverse, but some gained marks for mentioning variations between humans and/or ethics.

- a. Distinguish between innate and learned behaviour.

[1]

- c. Distinguish between analogous and homologous structures.

[2]

Analogous structures	Homologous structures

Markscheme

- a. innate behaviour is independent of experience/environmental conditions/inherited
while learned behaviour is influenced by experience/environment / *OWTTE*

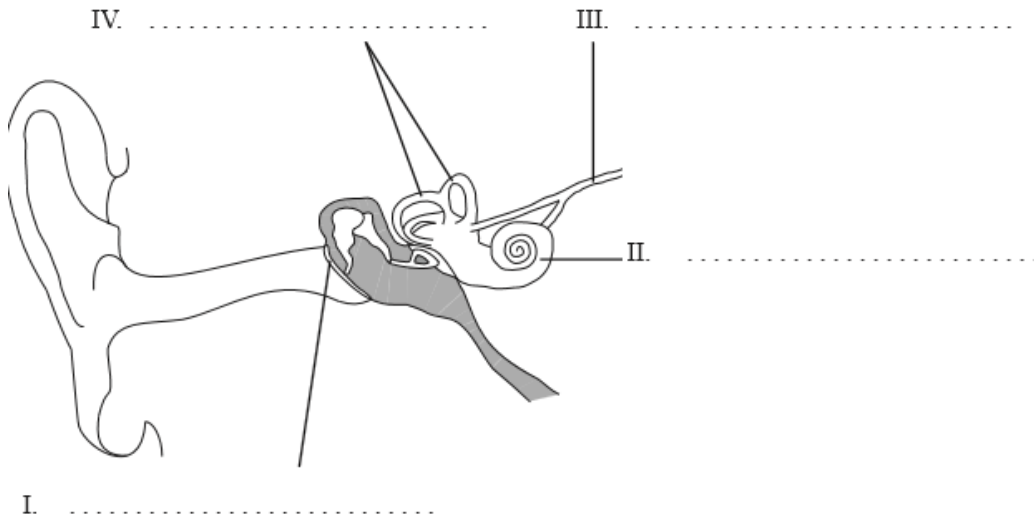
c.

<i>Analogous structures</i>	<i>Homologous structures</i>
same function	(same or) different function;
differ in (fundamental) structure	similar in (fundamental) structure;
not common ancestry/convergent evolution	common ancestry/divergent evolution;

Examiners report

- a. Many gave vague answers to this section and did not make reference to the role of the environment or experience in distinguishing between the two types of behaviour. Candidates should not describe "learned" behaviour as that which we learn.
- c. The table was given so that candidates could easily distinguish between analogous and homologous structures clearly but some still did not compare like points.

Label the diagram of the ear.



Markscheme

I eardrum / tympanic membrane

II cochlea

III auditory/vestibulocochlear nerve

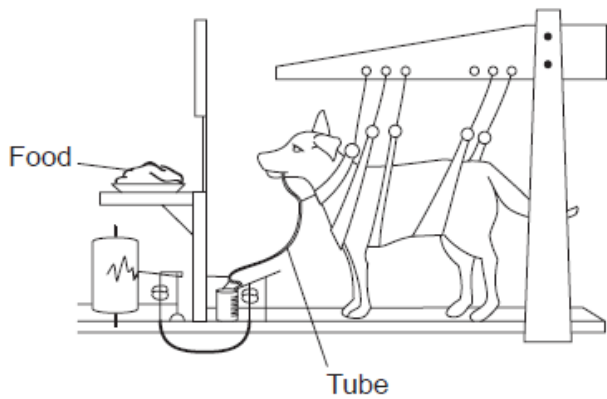
IV semicircular canals

Award [1] for every two correct.

Examiners report

Candidates did surprisingly poorly on this simple task of naming the structures of the ear. Structure IV was often incorrectly named. It was unclear why so many indicated that these were the bones of the middle ear as this is indicated in E.2.6.

The diagram shows the procedure used by Pavlov during his experiment on dogs.



[Source: adapted from <http://animalbehaviour.net>]

a(i).State the type of stimulus provided by the sight and smell of the food.

[1]

a(ii)State the function of the tube.

[1]

b. State **two** effects presynaptic neurons could have on postsynaptic transmission.

[1]

Markscheme

a(i),unconditioned (stimulus)

a(ii)to collect the saliva (for measurement of volume)

b. excitation and inhibition

Examiners report

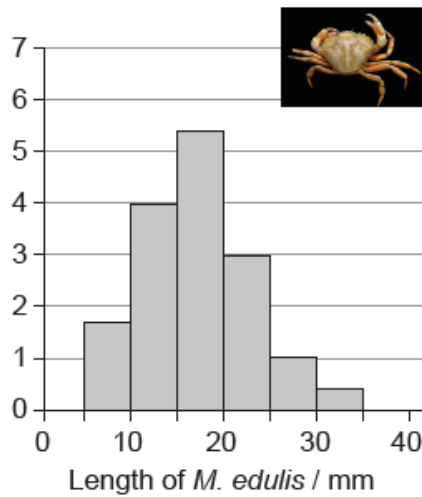
a(i).The majority of candidates did well in the first part of this question.

a(ii)The majority of candidates did well in the first part of this question.

b. [N/A]

The shore crab (*Carcinus maenas*) preys on mussels (*Mytilus edulis*). *M. edulis* vary in size. The frequency distribution of the numbers of each length of *M. edulis* eaten by a population of *C. maenas* per day is shown in the graph.

Mean number of *M. edulis* eaten per day



[Source: adapted from C Ameyaw-Akumfi and RN Hughes, (1987), *Marine Ecology Progress Series*, **38**, pages 213–216
Photo: https://en.wikipedia.org/wiki/Carcinus_maenas#/media/File:Carcinus_maenas.jpg]

- a. State the most common length of *M. edulis* eaten by the *C. maenas* population. [1]
- b. Suggest reasons for the length you stated in (a) being the most common length of *M. edulis* that *C. maenas* eat. [3]

Markscheme

a. 17.5 mm **OR** 15 mm to 20 mm

b. a. larger mussels too much effort to open *OWTTE*

OR

best ratio between effort and energy return

b. smaller mussels means more individuals have to be eaten for the same return on effort

c. greater time/predator exposure spent during foraging to obtain required daily energy

d. it «may be» the most common size available

OR

«correct mussel» size favoured by natural selection

e. the claws are best adapted to prey on mussels of this size

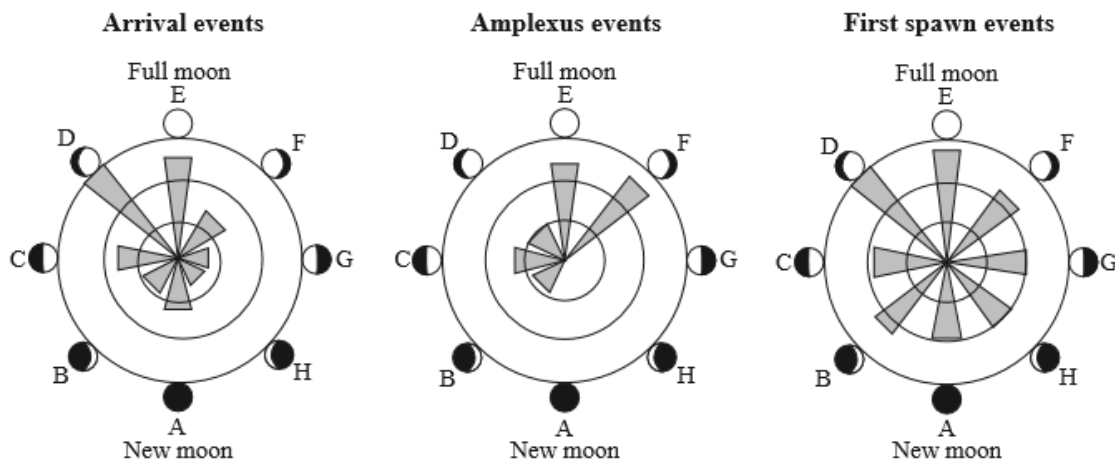
Examiners report

a. [N/A]

b. [N/A]

Each spring, the breeding season for various species of toads begins with a mass arrival of females at ponds and lakes. Males arrive later and actively compete for the females. Amplexus (mating embrace) and spawning (depositing eggs in water) then follow. Many environmental variables affect the timing of breeding. The hypothesis that periodicity in reproductive behaviour reflects periodicity in the lunar cycle was tested over several breeding

seasons at sites in Wales (UK) and Italy. The lengths of the shaded bars indicate the relative frequencies of the events.



[Reprinted from *Animal Behaviour*, vol. 78 (2), Rachel A. Grant, Elizabeth A. Chadwick and Tim Halliday, 'The lunar cycle: a cue for amphibian reproductive phenology?', pp 349–357, ©2008 . With permission from Elsevier.]

- Identify which reproductive event is least influenced by the lunar cycle. [1]
- Compare the data for arrival events with amplexus events. [2]
- Deduce the relationship between arrival events and amplexus events in moon phases D to F. [1]
- The lunar cycle could affect the timing of breeding. Suggest, with a reason, **one** other environmental variable which could affect the timing. [2]

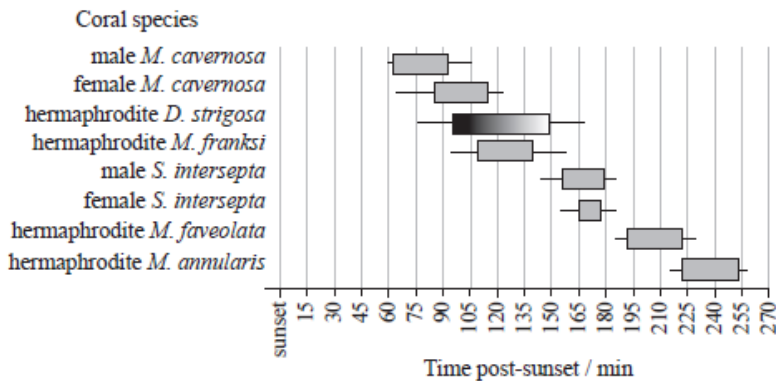
Markscheme

- first spawn/spawning
- frequency at full moon/E about the same;
both arrival (event) and amplexus (event) have low/similar frequencies in B and C;
highest frequency for arrival (event) in D whereas highest frequency for amplexus (event) in F;
always some arrivals but amplexus (event) only in B to F / no amplexus (event) in G/H/A;
- mass arrival (events) at phases D and E is followed by large amplexus (events) at phases E and F;
full moon/lunar cycle seems to influence timing of both events (in sequence) / *OWTTE*;
- example of environmental condition;
reason for the example;
e.g.:
rainfall;
necessary to maintain pond levels to enable the toads to spawn;
temperature / season / daylength;
affects metabolism / survival of offspring;

Examiners report

- Three circular graphs relating toad reproduction events with moon phases were presented as data. A certain number of candidates read the amplexus events as being the least influenced by the lunar cycle instead of the first spawn events in part (a); it is difficult to know if this was due to a misinterpretation of the graph or a misreading of the negative question.
- Candidates usually presented good data comparisons in part (b).
- but kept comparing data in part (c) where they were expected to find a causality relationship between arrival and amplexus; many provided incorrect answers such as "inversely proportional", trying to find a mathematical relationship.
- For part (d), most candidates provided a valid environmental variable, but some of the reasons were either vague or irrelevant (e.g. food, affecting red deer reproduction when the data was about toads).

Corals can be male, female or hermaphrodite (both male and female) and the release of their gametes is called spawning. Data was collected to study the spawning behaviour in the Gulf of Mexico of three genera of coral: *Montastraea*, *Stephanocoenia* and *Diploria*. The spawning behaviour is expressed in minutes post-sunset. Peak spawning windows are shown as grey bars and the range as black bars.



[Adapted from P. D. Vize, J. A. Embesi, M. Nickell, D. P. Brown and D. K. Hagman (2005) "Tight temporal consistency of coral mass spawning at the Flower Garden Banks, Gulf of Mexico, from 1997–2003." *Gulf of Mexico Science*, 1, pp. 107–114. © 2005 by the Marine Environmental Sciences Consortium of Alabama. Used with permission.]

- Suggest why it may be advantageous for each species of coral to spawn within a tight time frame. [1]
- Discuss the significance of different spawning windows for different species. [2]
- Scientists hypothesized that the release of the male gamete triggers a chemical signal for females to release their eggs. Discuss this hypothesis. [2]
- The spawning window of *D. strigosa* is shown as a shaded gradient indicating a strong bias towards spawning in the early portion of the window. Suggest a reason for the spawning behaviour of *D. strigosa*. [1]
- Define the term *innate behaviour*. [1]

Markscheme

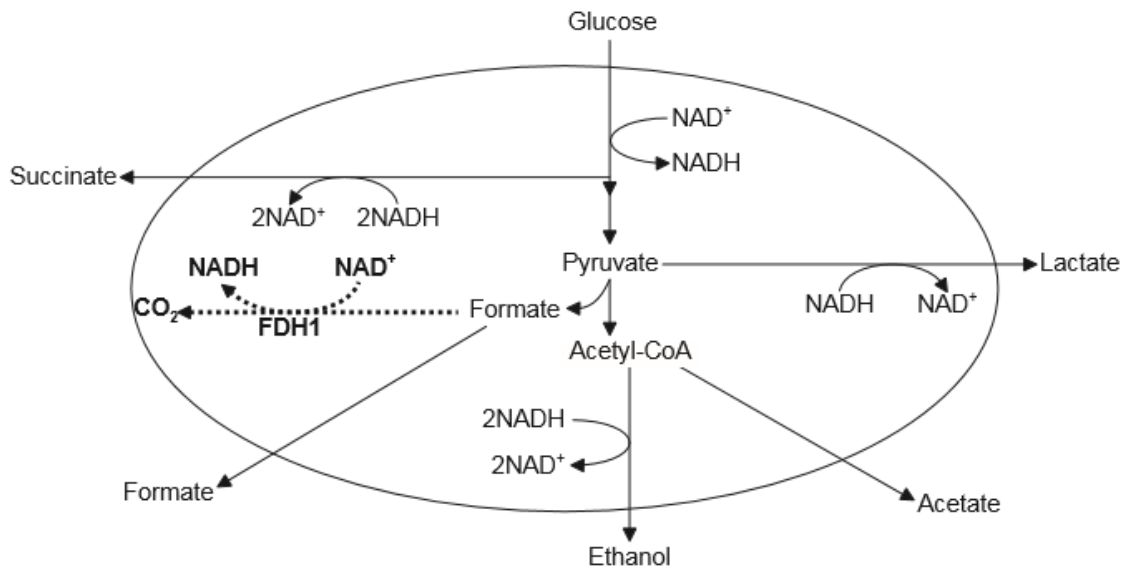
- b. to increase the possibilities of fertilization
- c. a. to avoid interspecific/cross-fertilization;
 - b. cross-fertilization usually not successful/non-productive;
 - c. some overlap of species spawning occurs so temporal separation is not completely successful;
 - d. example of overlap (e.g. *D. strigosa* overlaps with *M. cavernosa*/*M. franksi*);
- d. a. females always spawned after males suggesting hypothesis correct;
 - b. for example in *M. cavernosa* or *S. intercepta*;
 - c. difficult to tell for hermaphrodites;
 - d. chemical analysis of water should be undertaken after males spawned / other chemical signals / further evidence required to support cause and effect;
- e. a. the spawning of *D. strigosa* is influenced by male *M. cavernosa*;
 - b. the spawning of *D. strigosa* is influenced by the release of *M. franksi*;
 - c. *D. strigosa* spawning diminishes due to the appearance (spawning) of *M. franksi*;
 - d. light intensity determined;
- f. innate behaviour develops independently of the environmental context / not learned/ stereotyped / inherited / genetic pre-disposition

Do not accept instinct.

Examiners report

- b. Some candidates had a hard time recognizing the importance of the timing of spawning to fertilization in part (b).
- c. Some candidates had a hard time recognizing the importance of the timing of spawning to fertilization in part (b), or to avoiding cross-breeding in part (c) and instead related it to the presence of predators.
- d. In part (d), many candidates discussed the hypothesis, not in relationship to the data but rather to the potential causes of a possible chemical signal.
- e. Most candidates performed well in the data analysis with (e) being the best discriminator of the better candidates.
- f. [N/A]

Succinate is industrially produced by continuous fermentation. It is used as a raw material in the production of flavour enhancers, drugs and industrial chemicals. One method of increasing the production of succinate is to genetically modify *E. coli* to express high levels of formate dehydrogenase (FDH1). This results in the production of higher concentrations of NADH. The engineered pathway is shown as a bold dotted line in the image.



[Source: Ka-Yiu San, E. D. Butcher Professor of Bioengineering, Professor of Chemical Engineering, Rice University.]

- Using the diagram, suggest a reason for high concentrations of NADH favouring the production of succinate. [1]
- Predict **one** metabolite other than succinate that will be produced in greater amounts if the amount of NADH available is increased. [1]
- Outline the process of continuous culture fermentation. [2]
- Outline **one** reason this process, to increase the production of succinate, represents pathway engineering. [1]

Markscheme

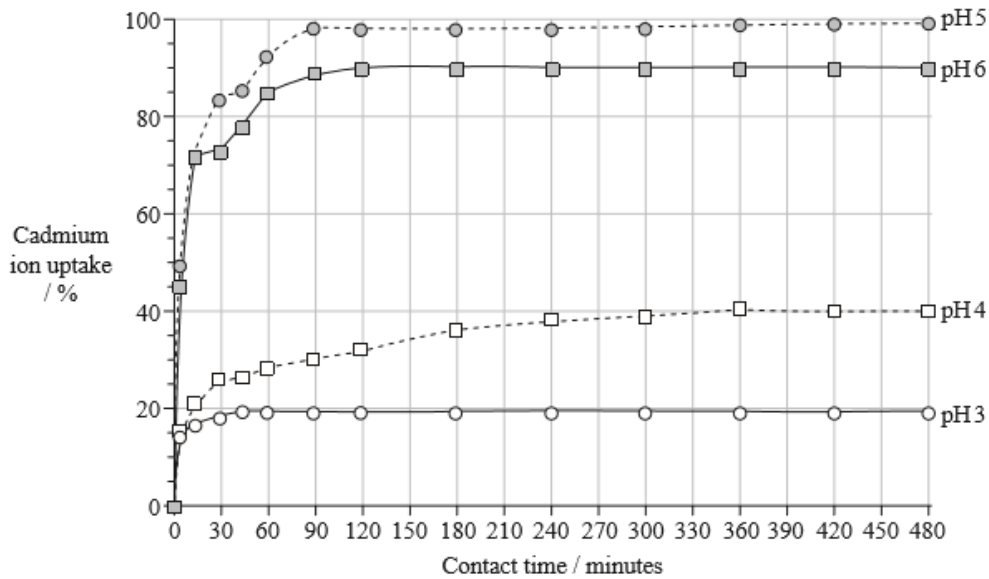
- NADH is required as a reducing agent/electron donor/hydrogen donor/co-enzyme/limiting factor for the production of succinate
High levels of FDH1 produce greater quantities of NADH which is required for conversion of glucose «via intermediates» to succinate
- Lactate/ethanol
CO₂ «favoured by high FDH1 levels»
- Raw materials are supplied in continuous amounts
Products/wastes are continuously extracted
Conditions are monitored/regulated to keep variables at a steady state
- Genetic processes/rate limiting chemicals/regulatory processes are being optimized

Examiners report

- This was fairly well answered with many able to achieve the mark, usually for noting that NADH was a reducing agent or electron donor.
- This was an easy question with almost all candidates able to predict one metabolite using the diagram.
- The process of continuous culture fermentation seemed to be familiar to all candidates selecting this option with many scoring the 2 marks.
- This was discriminating as many found it difficult to clearly show why the given process represented pathway engineering.

Removal of toxic heavy metals from industrial waste water is essential in order to control environmental pollution. Industrial waste water near Yanbu City, Saudi Arabia was found to contain 19 species of microorganisms that could tolerate heavy metals. The accumulation of cadmium ions in the most common of these microorganisms, *Aspergillus fumigatus*, was investigated.

The graph below shows the effect of pH on the ability of *A. fumigatus* to absorb cadmium ions from an aqueous solution.



[Source: adapted from S Al-Garni, et al., (2009), *African Journal of Biotechnology*, 8(17), pages 4163–4172]

- a. Describe the cadmium ion uptake by *A. fumigatus* at pH 6. [2]
- b. Calculate the difference in cadmium ion uptake between pH 4 and pH 5 at 60 minutes. [1]
%
- c. Discuss the use of *A. fumigatus* for the removal of cadmium ions in polluted waters. [2]
- d. The investigation found that both living and dead *A. fumigatus* cells were able to absorb cadmium ions. Suggest an advantage of using dead *A. fumigatus* cells. [1]

Markscheme

- a. rapid initial uptake (to approximately 75 % uptake);
 rate of uptake slows and plateaus (at approximately 85 % uptake after 90 minutes);
 only 90 % of cadmium ions absorbed (however long the contact time) / reaches maximum at 120 min;
- b. 64 (%) (allow responses in the range of 62 to 66 %)

c. can remove almost 100 %/98 % cadmium ions at pH 5 therefore very efficient;

A. fumigatus able to remove cadmium ions at pH values tested;

removal of cadmium ions more efficient at higher pH/weak acid;

strongly acidic/very low pH may inhibit/reduce uptake of cadmium ions by *A. fumigatus*;

pollution causing acidification of water may make removal more difficult;

A. fumigatus common therefore may be convenient/easy to use / OWTTE;

cadmium is not actually removed as it may pass along food chains / be released when *A. fumigatus* dies / unknown impact on environment;

d. easier to store/collect/transport dead/dried material;

prevents overgrowth of *A. fumigatus*;

reduce BOD and allow other organisms to use more resources/live in water;

Examiners report

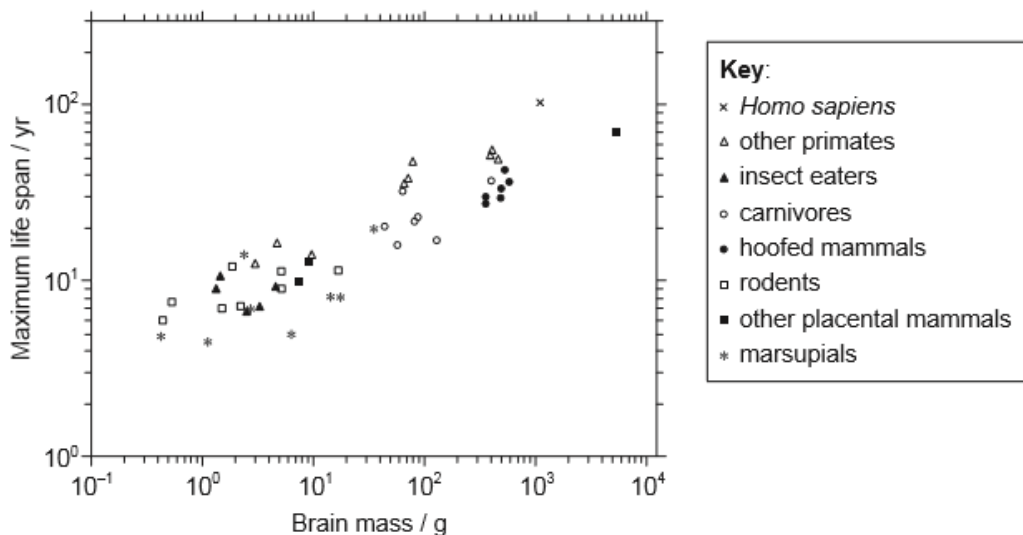
a. Well answered in general.

b. Well answered in general although many candidates failed to calculate the difference in cadmium ion uptake.

c. Little use of the data available. Only 2 of the mark scheme choices seen in answers.

d. Mostly well answered.

The evolution of increased body size in mammals has been accompanied by an increase in life span. Another variable that could affect life span is brain size. Data was analysed from 47 mammalian species.



- a. State the relationship between brain mass and maximum life span. [1]
- b. Identify the group with the widest range of brain mass. [1]
- c. Compare the brain mass and life span of primates and marsupials. [3]
- d. Discuss how a larger brain size and longer life span might have contributed to the evolution of these species. [2]

Markscheme

- a. as brain mass increases life span increases / positive/direct relationship/correlation
- b. other placental mammals

c.

	<i>primates</i>	<i>marsupials</i>
a.	larger range of brain mass	(smaller);
b.	(generally) greater brain mass	(generally less);
c.	larger range of life span	(smaller);
d.	(generally) with greater life span	(generally with lesser life span);
e.	both with positive relationship between brain mass and life span;	
f.	both overlap (with the primates higher);	

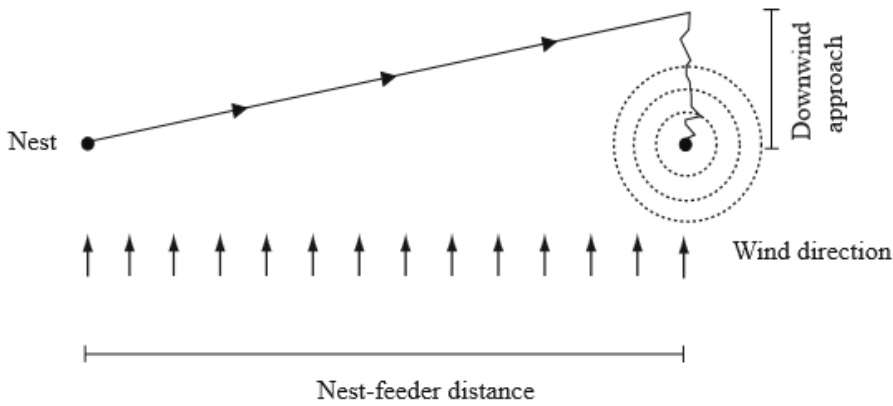
Do not accept answers stating only numerical values without comparative wording.

- d. a. larger brain size allows for higher intelligence/better cognition/more complex brain functions;
- b. more efficient food finding / escape from predators;
- c. longer life span favours parental care / survival for more reproduction;
- d. (these advantages) favour natural selection which leads to evolution;

Examiners report

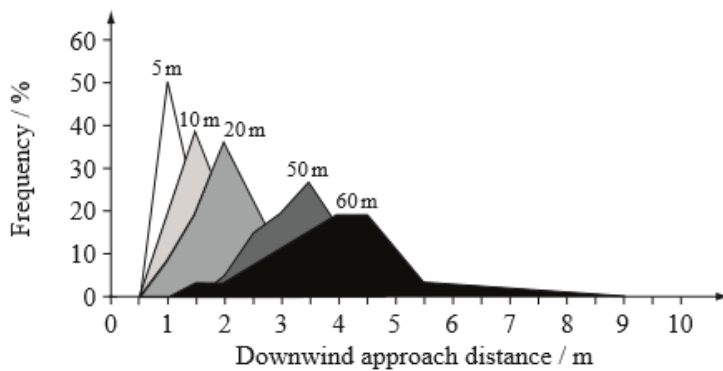
- a. The majority of candidates could state the relationship between brain mass and maximum life span and could identify the group with the widest range of brain mass.
- b. The majority of candidates could state the relationship between brain mass and maximum life span and could identify the group with the widest range of brain mass.
- c. Whereas some candidates could quickly establish all the key elements for the comparison, others provided incomplete complex answers.
- d. Many discussed brain mass and life span in terms of human evolution instead of using the data about all species on the graph.

Desert ants (*Cataglyphis fortis*) use odour to help find their food. When a constant wind is blowing, the ants do not approach food directly. Instead, they walk downwind of the food source and then, when they detect the odour of the food, they follow the odour trail upwind until they reach the food, as shown in the figure below.



[Source: adapted from H Wolf and R Wehner, (2005), *Journal of Experimental Biology*, 208, pages 4223–4230]

To investigate this behaviour pattern, feeders were established at distances of 5 m to 60 m away from the nest. Each feeder consisted of a Petri dish filled with biscuit crumbs. The graph below shows the distribution of downwind approach distances for each different nest-feeder distance.



[Source: adapted from H Wolf and R Wehner, (2005), *Journal of Experimental Biology*, 208, pages 4223–4230]

- Outline the relationship between the downwind approach distance and the nest-feeder distance. [1]
- Compare the results observed when the feeders were located at 5 m with the feeders at 60 m. [3]
- Suggest **one** possible source of uncertainties or errors in these experiments. [1]
- Deduce, with a reason, what type of behaviour pattern is shown by the ants in the experiment. [2]

Markscheme

- downwind approach distance increases with increasing nest-feeder distances / the closer the feeder to the nest the shorter the downwind approach distance / direct/positive relationship
- feeder at 5 m has smaller downwind approach distances than feeder at 60 m / *vice versa*;
feeder at 5 m has peak frequency at 50 % whereas at 60 m peak/plateau at 20 %;
narrower range of approach distances for 5 m while wider range of approach distances for 60 m;
feeder at 5 m has peak approach distance at 1 m downwind while feeder at 60 m has peak/plateau 4 m – 4.5 m;

- c. difficulty handling ants / size of ants;
variation of wind;
other odours;
path of trail not easy to measure accurately;
Accept any other reasonable suggestions.

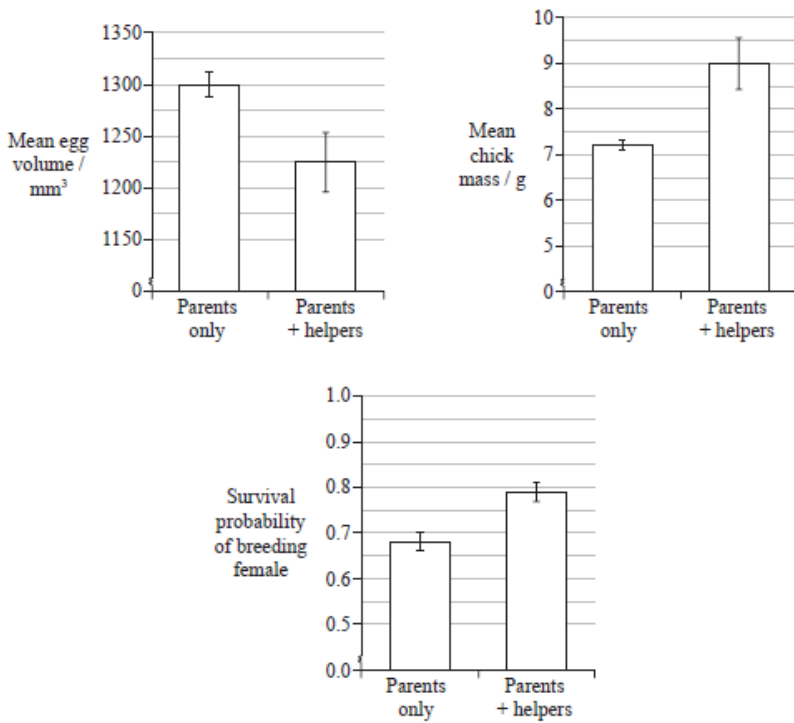
- d. *EITHER*
innate behaviour / taxis;
because all walking at same angle to constant wind / all turn and follow odour trail when they detect smell;
OR
learned behaviour;
because of repetition/training / following other ants;

Examiners report

- a. Almost all candidates were correctly able to identify the relationship between the downwind approach distance and the nest-feeder distance.
 - b. Many were also able to get 2 or 3 marks for this section.
 - c. The most common suggestion given was variation in the wind.
 - d. Many found this section on the type of behaviour more difficult but both innate and learned were accepted if the candidate was able to support their choice with a good reason.
-

Cooperative breeding in birds occurs when more than two birds of the same species help to rear the young from one nest. For the Australian superb fairy-wren (*Malurus cyaneus*), mature non-breeding birds help to protect and rear the young, although they are not parents of any of them.

The bar charts below show the effect of the presence of helpers on mean egg volume, mean mass of six-day-old chicks and the probability of survival of the breeding females until the next breeding season.



[Source: From A F Russell, et al., (2007), *Science*, 317, pages 941-944. Reprinted with permission from AAAS.]

- a(i). State the effect of the presence of the helpers on mean chick mass. [1]
- b. Calculate the percentage decrease in mean egg volume found in the presence of helpers as compared to the parents only. Show your working. [2]
- c. With reference to the data, suggest why the activity of the helper affects the probability of survival of the breeding female until the next breeding season. [2]
- d. Cooperative breeding is an altruistic behaviour. Outline the evolution of altruistic behaviour. [2]

Markscheme

a(i). (mean) chick mass increases in presence of helpers

- b. $\frac{1300-1225}{1300} \times 100\%$ or other correct calculation;
5.8%;
Accept the correct answer if it is not rounded up to 5.8% or if it is rounded up to 6%.

c. with helper, smaller egg volume;

less resources from mother to produce egg/rear young;

more resources toward survival of mother;

d. (altruistic) behaviour is inherited;

adaptations/behaviours that help the colony survive at expense of individual;

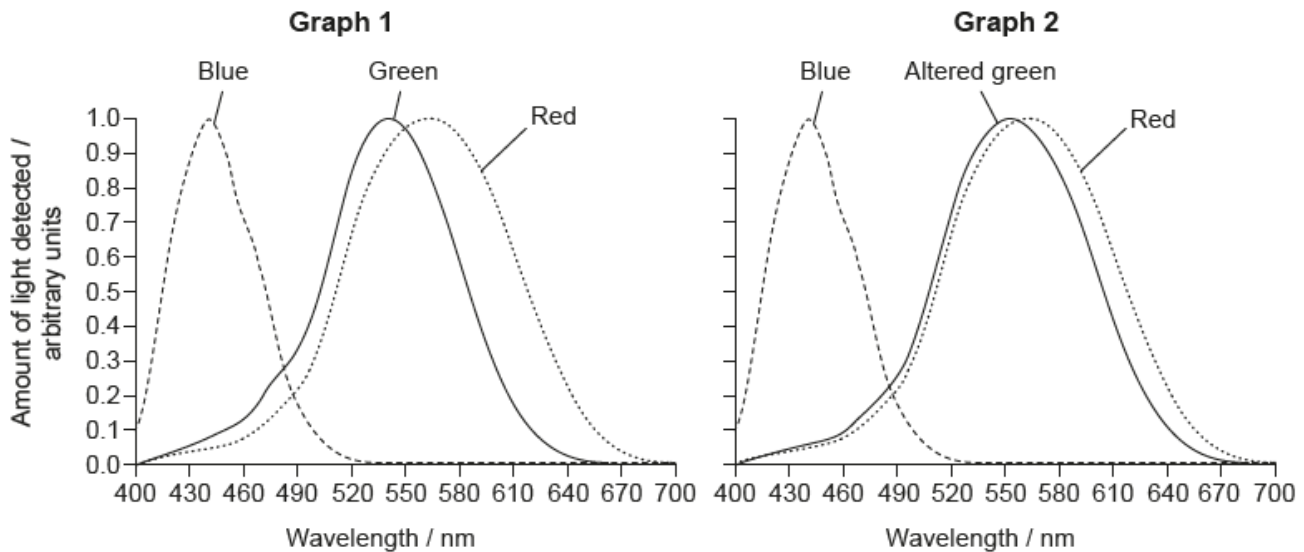
selected for (natural selection);

will be more likely to be passed on;

Examiners report

- a(i). Most candidates correctly identified an increase in the mean mass of the chicks in the presence of the helpers.
- b. Many candidates correctly stated the percentage decrease in mean egg volume. Some were reluctant to round up to one decimal point. A few used an alternative method for this calculation.
- c. No candidate used all the data. That is, no candidate used the smaller mean egg volume to explain that this may mean that the breeding female would be using less resources as the egg volume was smaller. Many incorrectly wrote of helpers protecting the breeding female from predators- as this did not use the data in any way. Marks were awarded if data was used, and most did suggest that with the helper the female may use less energy and that this may increase survival.
- d. Very few candidates applied the theory of natural selection here. Although many did correctly state the meaning of altruistic behaviour, which was the starting point leading towards the idea of selection pressure.

- a. Graph 1 shows the range of light wavelengths detected by the three types of cone cells in normal colour vision. Graph 2 shows the range of light wavelengths detected by a person with one form of colour blindness. Each line shows a different type of cone cell. [2]



[Source: © International Baccalaureate Organization 2017]

Deduce, with a reason, the difference in colour perception between people with normal colour vision and those with this type of colour blindness.

- b. Explain how sounds of different wavelengths are distinguished by the ear. [3]

Markscheme

a. *difference in colour perception:*

a. cannot distinguish red and green

reason:

b. green and red cones detect very similar wavelengths

OR

peak of altered green shifts to the right

OR

range of altered green wider «than normal green»

b. a. «movement of eardrum and ossicles» causes vibration of cochlear fluid

b. hair cells in different position «along the basal membrane» have hair/cilia of different length *OWTTE*

c. different hair/cilia vibrate at different wavelengths

d. «different hair cells send different» nerve signals in the auditory nerve

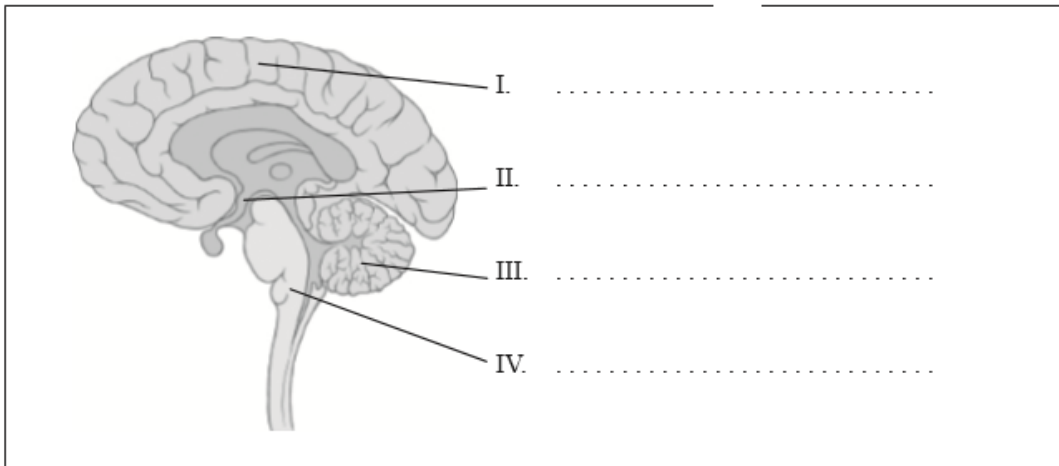
Examiners report

a. [N/A]

b. [N/A]

a. Identify the parts of the brain indicated on the diagram below.

[2]



Patrick J. Lynch, medical illustrator; C. Carl Jaffe, MD, cardiologist

b. Outline the unconscious control of the heart rate.

[3]

c. Describe different aspects of the processing of visual stimuli.

[3]

Markscheme

a. I. cerebral hemisphere / cerebrum;

II. hypothalamus;

III. cerebellum;

IV. medulla oblongata;

Award [1] for any two of the above.

b. heart can contract without nervous stimulation/myogenic contractions;

SA node is pacemaker/generates heart beat/initiates each cardiac cycle;

epinephrine/adrenalin speeds up the heart rate;

autonomic/sympathetic and parasympathetic nervous system control;

sympathetic speeds up heart rate;

parasympathetic/vagus nerve slows heart rate (back to normal/resting rate);

c. edge enhancement is greater perception at edges of light/dark areas;

caused by processing in two types of ganglion cell in retina;

contralateral is processing left field of view in right side of brain / *vice versa*;

cross over between left and right sides in the optic chiasma;

convergence is combining impulses from groups of (rod/cone) cells;

done by bipolar cells in retina;

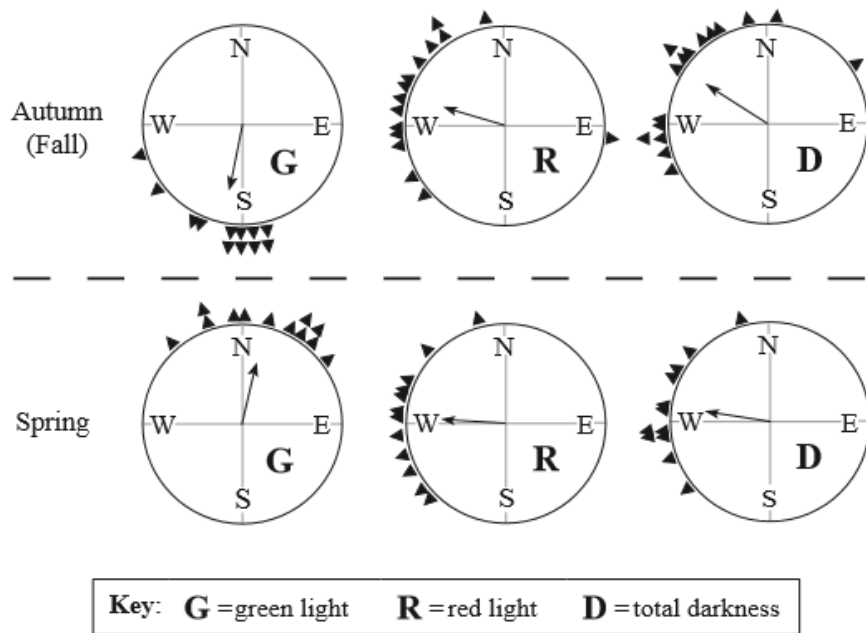
Examiners report

a. Part (a) was straightforward for well prepared candidates.

b. In part (b) candidates were expected to base their answer on assessment statement E5.4 and outline the roles of the sympathetic and parasympathetic nervous systems. Some candidates failed to distinguish between the control of the heart rate by these parts of the autonomic nervous system and the stimulation of the heart beat by the sino-atrial node.

c. Part (c) was answered in great detail by the best prepared candidates, who described edge enhancement, contralateral processing and convergence. There was some misunderstanding of contralateral processing, with candidates suggesting that all stimuli perceived by an eye are processed by the opposite side of the brain, rather than each side of the brain processing stimuli from the same half of the visual field in both eyes.

European robins (*Erithacus rubecula*) migrate South in the autumn (fall) and North in the spring. They orient their direction of flight using the local magnetic field, which they detect through magnetoreceptors in the upper beak. The orientation of the birds in a captive environment was studied in spring and autumn, which are the times of year when the birds normally migrate. The response of the birds to green light, red light and total darkness was investigated. Triangles on the edge of circles indicate the mean direction flown by individual birds while the arrows indicate the overall mean direction of flight.



[Source: R. Wiltschko et al. (2008), "Light-dependent magnetoreception: orientation behaviour of migratory birds under dim red light", *The Journal of Experimental Biology*, 211 (20), 3344–3350: Figure 4. Reprinted with permission, jeb.biologists.org. <http://jeb.biologists.org/content/211/20/3344.long>]

- Identify the season and light conditions which result in the strongest northerly direction flown by the robins. [1]

Season:

Light conditions:
- Distinguish between the effect of red light and green light on the behaviour of the robins in spring and autumn (fall). [2]
- Based on the results of these experiments, suggest **one** possible conclusion that could be drawn regarding the effect of red light on the behaviour of robins. [1]
- Using the data in the diagram, deduce with a reason, whether European robins migrate during the daytime or at night. [2]
- Scientists anesthetized the beaks of some robins in order to deactivate the magnetoreceptors. Predict how this would affect their orientation in red light. [1]

Markscheme

- spring, green light
Both required for [1].
- in green light birds migrate North in spring but South in autumn;
 - in red light birds orientate (North) West in both autumn and spring;

- c. a. in red light birds do not migrate in the normal pattern/direction;
 - b. red light disorientates the birds/interferes with the functioning of magnetoreceptors;
 - c. red light has (almost) the same effect as total darkness / birds do not see in red light;
- d. a. during daytime;
 - b. direction of migration is not normal/wrong orientation in darkness;
- e. a. no effect;
 - b. may become (even) more random;

Examiners report

- a. This option was very popular and candidates tended to score well on it.

Almost all candidates read the diagrams correctly for the 1 mark.
 - b. This option was very popular and candidates tended to score well on it.

Most candidates were able to correctly distinguish between the effects of red and green light on robin behaviour.
 - c. This option was very popular and candidates tended to score well on it.

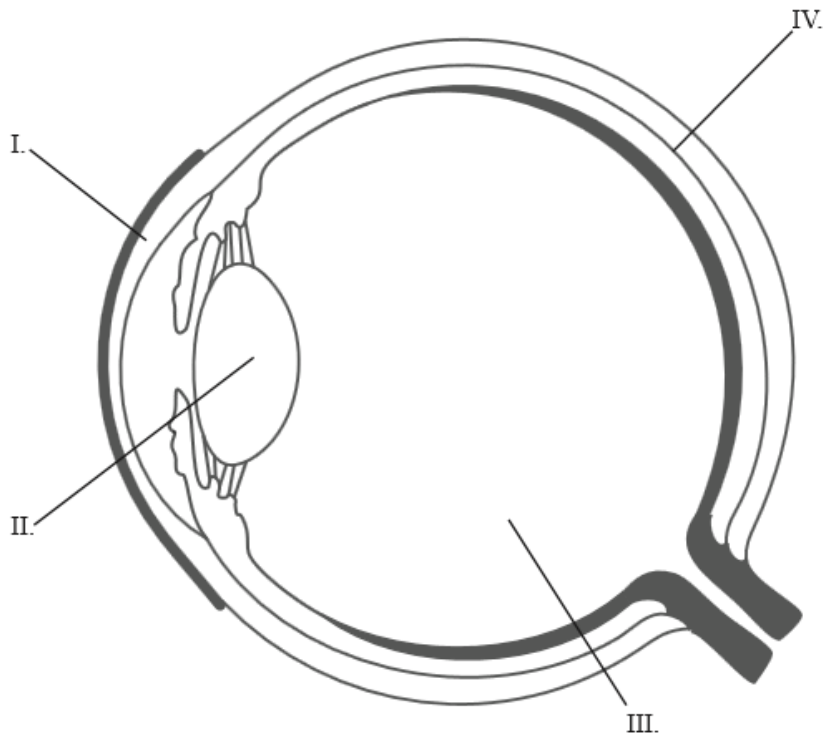
Many candidates repeated their response to section (b) in this question and did not get the 1 mark.
 - d. This option was very popular and candidates tended to score well on it.

Almost all correctly deduced that the robins migrated in daylight but only some could clearly explain why for the second mark.
 - e. This option was very popular and candidates tended to score well on it.

Most candidates were able to get at the 1 mark for this.
-

- a. The diagram below represents the human eye. State the names of structures I, II, III and IV.

[2]



I.

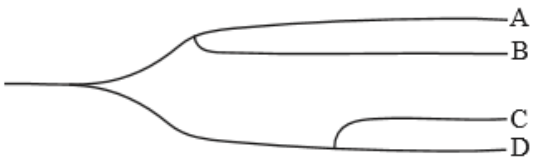
II.

III.

IV.

b. Outline the evidence provided by DNA for the common ancestry of living organisms. [2]

c. The cladogram below shows the classification of species A to D. Deduce how similar species A is to species B, C and D. [2]



d. Suggest **two** reasons for using cladograms for the classification of organisms. [2]

Markscheme

a. I. cornea;

II. lens;

III. vitreous humour;

IV. choroid; (Accept sclera as line is on the border between these two)

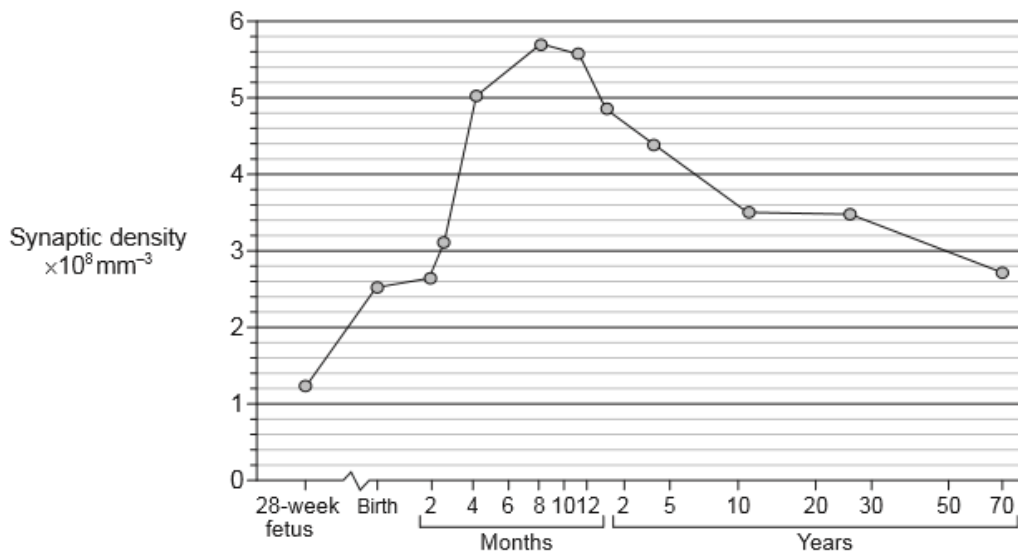
Two correct for [1] and four correct for [2].

- b. all living organisms use DNA as genetic/hereditary material;
genetic code is (almost) universal;
idea that mutations accumulate gradually in DNA;
- c. A is most similar to B;
A is equally similar to C and D;
A is least similar to both C and D;
- d. methods used to prepare cladograms use a different approach from traditional classification/taxonomy;
show ancestral relationships;
reflect how recently two groups shared a common ancestry;
cladograms are (objective/accurate because they are usually) based on molecular differences;
they should be considered as a good complement to traditional classification;

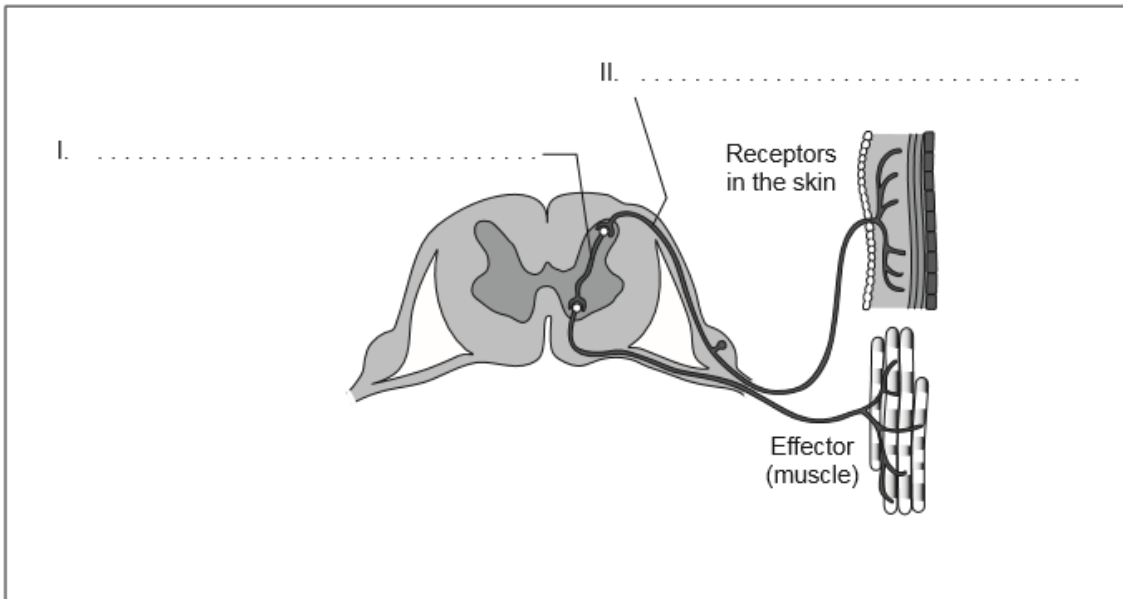
Examiners report

- a. Candidates did surprisingly poorly on this simple task of naming the structures of the eye. The label line for IV was on the border of the choroids and the sclera, and thus either one was accepted as correct.
- b. This was poorly done. Some correctly indicated that DNA was the genetic or hereditary material for all living organisms and that the genetic code is universal. Many wrote about pentadactyl limbs, DNA being made of 20 amino acids or about chimps and humans which did not get marks.
- c. Many candidates correctly interpreted the cladogram, deducing that A and B were most similar. Some were able to get a second point.
- d. Many were able to get one mark for indicating that cladograms showed ancestral/evolutionary relationships but only a few got the second mark for another reason for using cladograms.

Synaptic density is the number of synapses per unit volume. The graph shows the synaptic density for a 28-week-old fetus, and from birth to age 70.



[Source: Reprinted from *Brain Research*, 163 (2), Peter R. Huttenlocher, "Synaptic density in human frontal cortex – Developmental changes and effects of aging", pp. 195–205 © 1979, published by Elsevier. Used with permission.]



[Source: adapted from <http://image.tutorvista.com>]

- a. (i) Determine the age when synaptic density is highest. [4]
- (ii) Explain how synaptic density decreases after the age determined in (a)(i).
- b. Label the diagram of the reflex arc with the names of the neurons indicated. [2]
- c. Draw an arrow on the diagram of the reflex arc to show the direction of impulses. [1]

Markscheme

- a. (i) 8 months
- (ii) Neural pruning
OR
 loss of neurons
 Through apoptosis/programmed cell death

Loss of dendrites/axon branches/synapse elimination

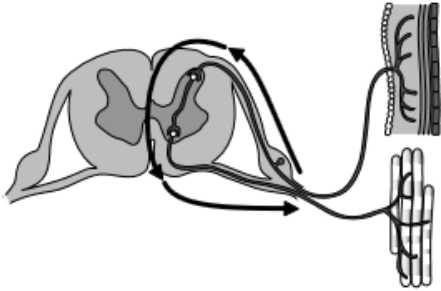
Due to lack of use

«In older age» damage to brain/strokes/chemical abuse

b. /: interneuron/relay neuron

//: sensory neuron

c. Arrow drawn on diagram to show correct direction of impulse



Arrow can also be a single loop through interneuron showing complete pathway or two arrows to and from interneuron.

Examiners report

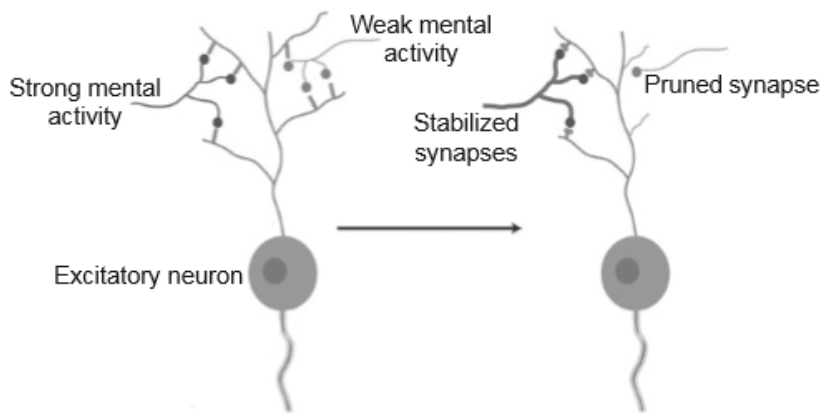
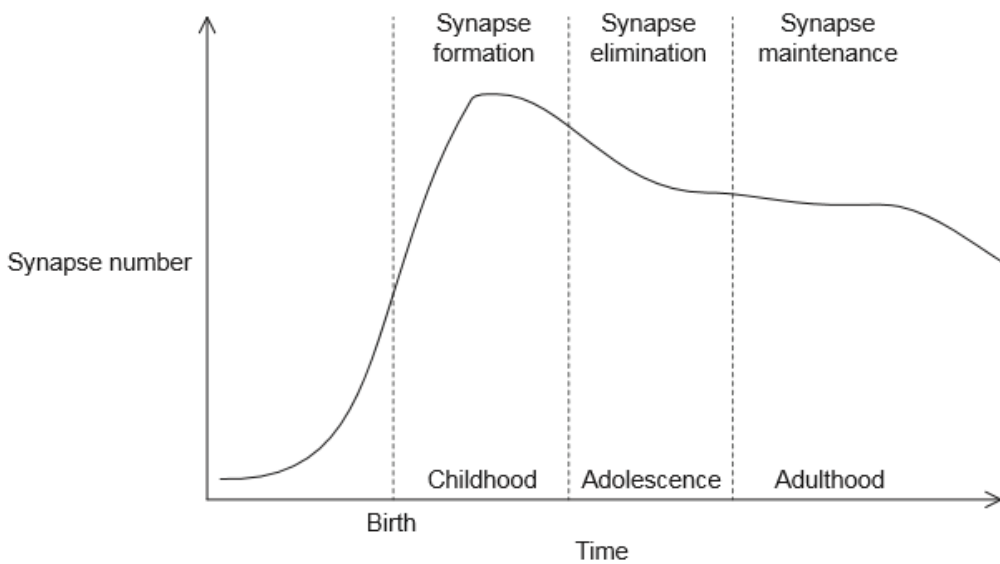
a. (i) Almost all were able to read the correct value off the graph and score one mark.

(ii) This question was poorly answered and one that seemed poorly understood. Many candidates did not 'explain' how synaptic density decreases (after 8 months) but instead described the graph. Some were able to get a mark for knowing that the neural pruning occurred and others that the change in density was due to lack of use but little other knowledge was apparent.

b. Most were able to correctly label the diagram and get two marks.

c. Some carelessly drew only half the pathway for the reflex arc and therefore did not score the mark for this question.

Defects in the formation of synapses could be the cause of neurological disorders such as Alzheimer's disease that affects the ability to think and remember clearly. It is more frequent in people older than 65 years of age. The graph shows the changes in synapse number over time. The diagram shows activity-related neural development.



[Source: adapted from Doll, C. A. and Broadie, K. (2014), Impaired activity-dependent neural circuit assembly and refinement in autism spectrum disorder genetic models. *Frontiers in Cellular Neuroscience* 8: 30. doi: 10.3389/fncel.2014.00030. Copyright © 2014 Doll and Broadie.]

- State what happens to unused neurons. [1]
- Predict how mental activity might delay the onset of Alzheimer's disease. [2]
- Autism appears early in life and affects how a person communicates and relates to others. There is evidence that autism could be caused by a surplus of synapses. Using all of the information provided, suggest **two** possible causes of a surplus of synapses in people with autism. [2]

Markscheme

- neuron pruning

OR

synapses removed

Do not accept "apoptosis".

- more synapses maintained with stimulation/mental activity/OWTTE
 - strong mental activity prevents «neuron» pruning

c. a. most synapses are formed during childhood/before birth

OR

first years of childhood most important for brain development

b. more synapses «than normal» may be formed «during childhood/before birth in autism»

c. «in autism» pruning of neurons does not occur «causing excess of synapses»

OR

normal synapse elimination does not remove extra synapses

Examiners report

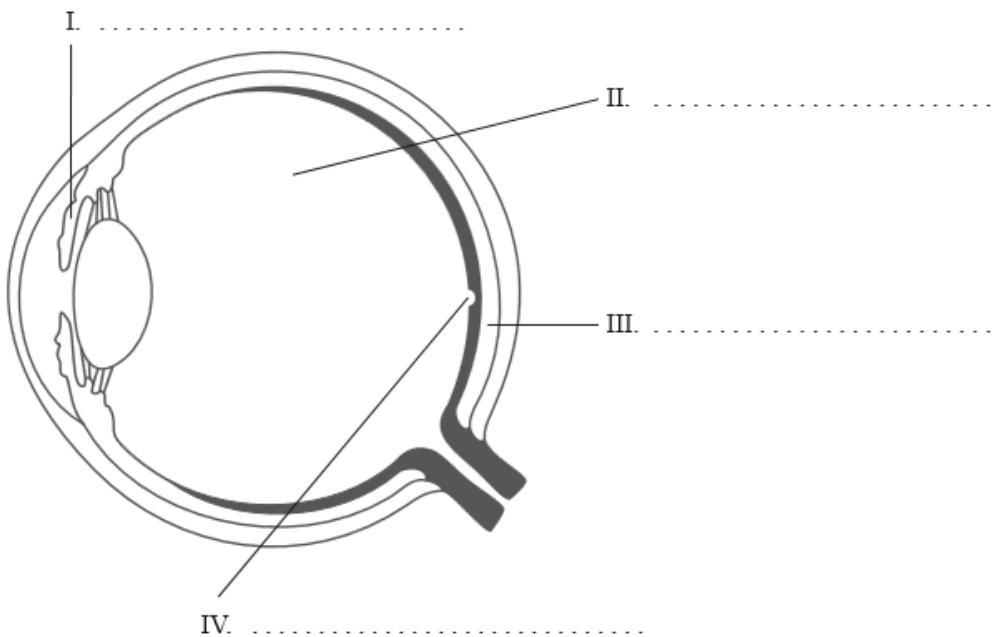
a. [N/A]

b. [N/A]

c. [N/A]

a. Label the following diagram of the eye.

[2]

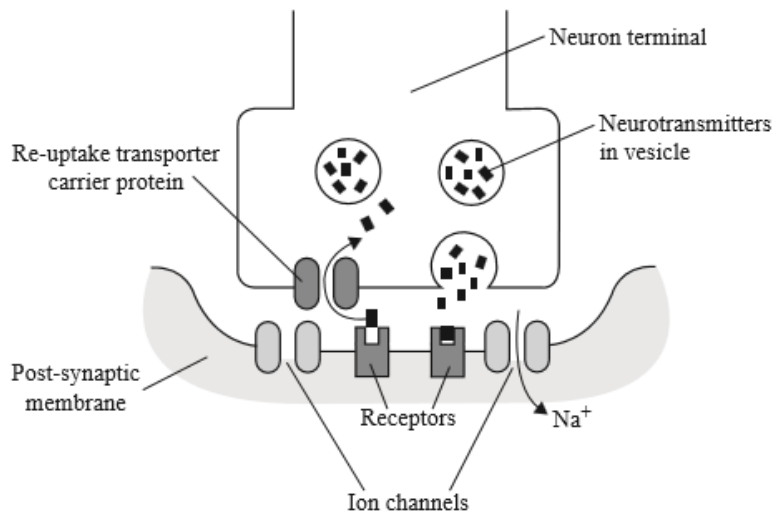


b. Outline how the pupil reflex can be used to indicate brain death.

[2]

c. The diagram below shows a synapse where the neurotransmitter is dopamine and some of the processes that take place during nerve transmission.

[3]



[Source: Diagram reprinted with permission from the Faculty of Health, Birmingham City University, UK]

Explain the effect of cocaine on neurotransmission at a synapse.

Markscheme

a. I iris

II vitreous humour

III choroid

IV fovea (*do not accept yellow spot*)

Award [1] for every two correct answers.

b. a. pupil normally constricts when light is shone on it;

b. light detected in the retina and impulse sent to brain;

c. lack of (motor) response indicates no brain processing taking place/brain death;

c. a. dopamine initiates depolarization of post-synaptic membrane;

b. cocaine binds to (transporter) carrier proteins/proteins in pre-synaptic membrane;

c. cocaine blocks reabsorption (of dopamine);

d. cocaine causes dopamine build up in synaptic cleft/space;

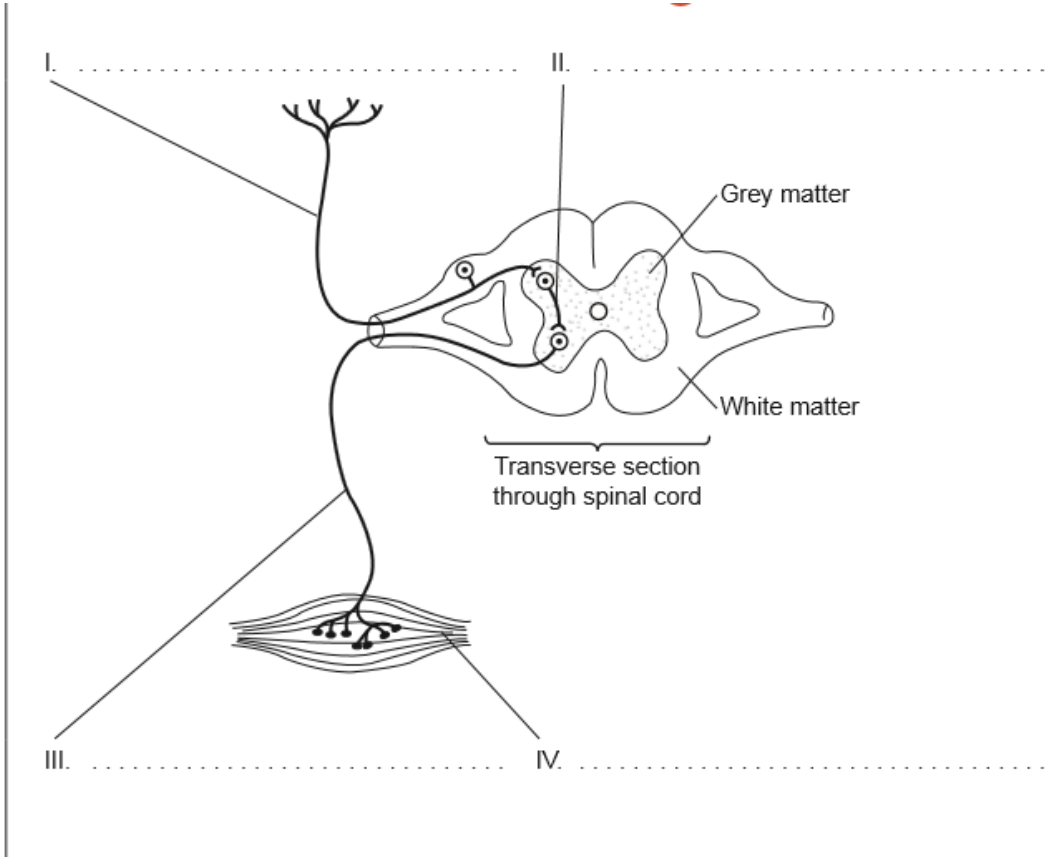
e. so stimulus continues/cocaine is excitatory;

Examiners report

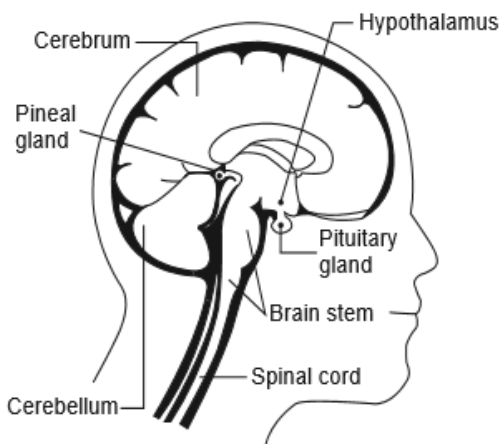
a. It was disappointing how many candidates could not label the diagram of the eye correctly.

b. Although many were able to get 1 mark for understanding that a lack of pupil response to light indicated no brain processing and therefore brain death, few were able to get a second mark. Many were using incorrect terminology to describe what happened to the pupil in response to light. A persistent misconception seemed to be that the pupil "detects" light and not the retina.

c. In general, candidates did poorly on this question with many only getting one mark. Many were incorrectly saying cocaine is a neurotransmitter or that it caused more dopamine to be produced rather than it caused dopamine build up in the synaptic cleft due the fact it blocks the reabsorption of dopamine. Many were relying on general 'street' knowledge rather than any biological information.



[Source: © International Baccalaureate Organization 2015]



[Source: © International Baccalaureate Organization 2015]

- a. Label the numbered parts of the reflex arc. [2]
- b. State the type of human sensory receptor that detects motion, gravity and stretch. [1]
- c (i) State the part of the brain responsible for coordination and balance, especially during athletic competition such as the Olympics. [1]

Markscheme

a. Award **[1]** for every two correct up to **[2 max]**.

I: sensory/afferent neuron;

II: interneuron/relay neuron;

III: motor/efferent neuron;

IV: effector/muscle;

b. mechanoreceptor

c (i) cerebellum

c (ii) (a) (autonomic nerve signals from medulla oblongata) can override pacemaker;

b. parasympathetic stimulation decreases heart rate;

c. parasympathetic/vagus nerve runs from the medulla oblongata to the heart;

d. sympathetic nerves from medulla (travel down spinal cord where) synapse with other nerves before going to heart;

Examiners report

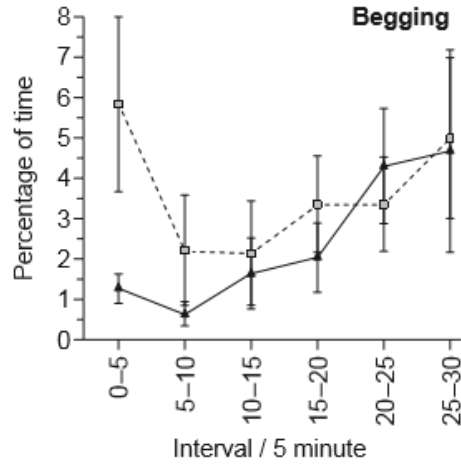
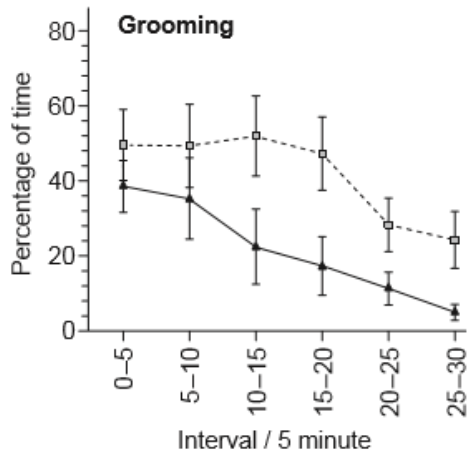
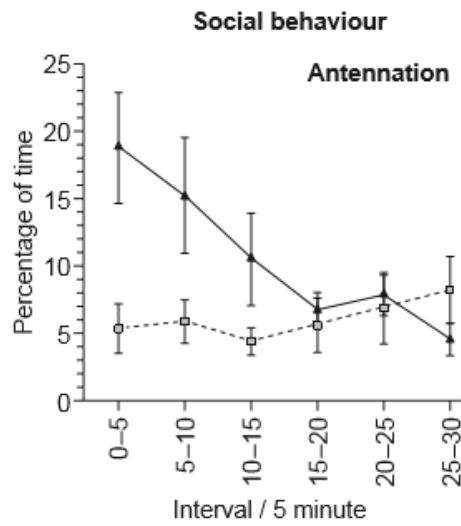
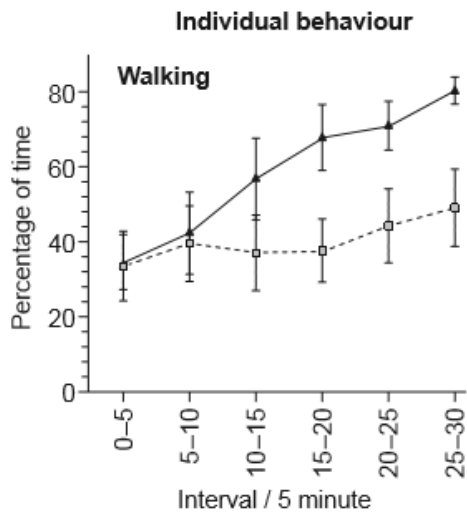
a. The majority of candidates were able to correctly label the reflex arc.

b. Almost all could name mechanoreceptors.

c (i) The majority correctly identified the cerebellum although occasionally cerebrum or brain stem was chosen, not earning a mark.

c (ii) Few candidates gained more than 1 mark and many did not score any. The role of the medulla oblongata in modifying the innate rhythm of the pacemaker was not understood. Parasympathetic control and the role of vagus nerve were not often mentioned. Candidates frequently talked about flight-or-fight responses and the role of adrenaline instead. Another misconception was that the medulla oblongata actually was initiating each heart beat rather than overriding the SAN. This section seemed to be poorly taught.

Honey bees (*Apis mellifera*) were fed with sucrose solution only or with low doses of ethanol in sucrose solution to examine how a slightly intoxicated state could affect their behaviour. Individual behaviour involves walking and grooming while social behaviour includes contact of antennae between bees to show recognition (antennation) and asking other bees for food when hungry (begging). The graphs show individual and social behaviour changes observed in successive five minute intervals two hours after honey bees were fed sucrose solution either with or without ethanol.



Key: ▲ without ethanol ◻ with 5% ethanol

[Source: Wright GA, Lillvis JL, Bray HJ, Mustard JA (2012) Physiological State Influences the Social Interactions of Two Honeybee Nest Mates. *PLoS ONE* 7(3): e32677. doi:10.1371/journal.pone.0032677. Figs 5 (A), (D), (E), (F)]

- State the percentage of time the honey bees engaged in begging during the first five minute interval. [1]
 Bees fed with ethanol:%
 Bees fed without ethanol:%
- Describe the trends in antennation for honey bees fed with ethanol and without ethanol. [2]
- Distinguish between the times spent walking and grooming for honey bees fed with ethanol and without ethanol. [2]
- Evaluate the hypothesis that ethanol affects the social behaviour of honey bees. [3]

Markscheme

a. bees fed with ethanol:

5.9 (%); (allow answers in the range of 5.8 (%) to 6.0 (%))

bees fed without ethanol:

1.3 (%); (allow answers in the range of 1.2 (%) to 1.4 (%))
 (both needed)

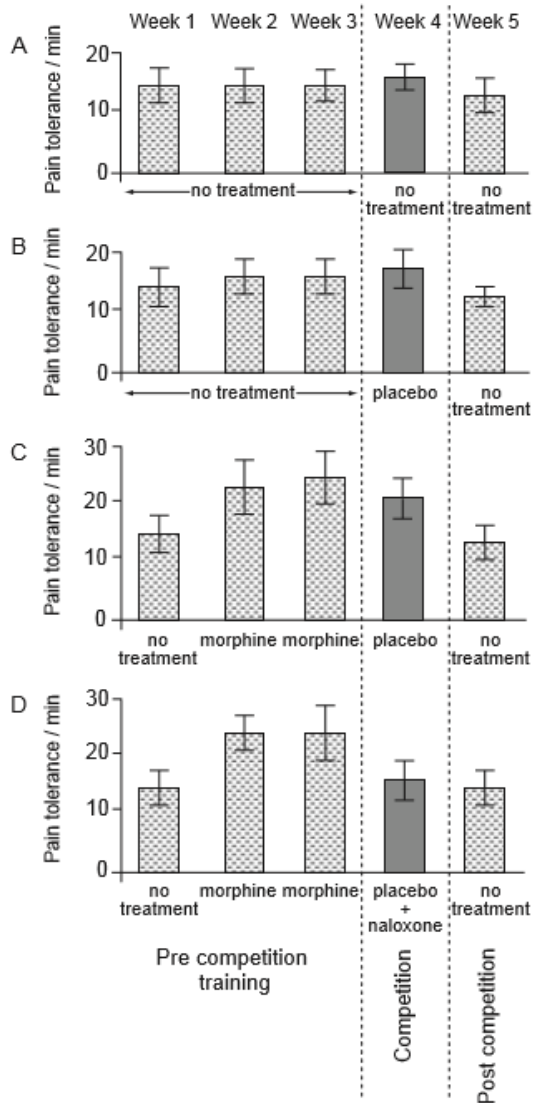
- b. a. without alcohol (antennation starts at a high level and) decreases with time;
- b. with alcohol, the value (starts low and) very slowly increases;
- c. the values of both groups become very similar with time;
- c. a. (time spent) walking is greater in bees without alcohol (than alcohol);
- b. (time spent) grooming is greater with alcohol (than without alcohol);
- c. the end point difference is greater in walking;
- d. (time spent) walking increases whereas grooming decreases for both groups of bees;
- d. a. (hypothesis is supported as) alcohol decreases antennation at the start of the experiment;
- b. (hypothesis is supported as) alcohol increases begging at the start;
- c. begging time is more variable/less significant differences with alcohol (so less clear than in antennation);
- d. (hypothesis is supported as) the effect of alcohol on social behaviors becomes less distinguishable over time (with the effect of sucrose) / OWTTE;

Examiners report

- a. The vast majority of candidates stated the percentages correctly, but there were some answers out of range and some others in which candidates inverted the values.
- b. Most described the trends in antennation correctly, but some only stated values without saying that they were decreasing or increasing or described minor changes for each interval without mentioning the general trend.
- c. Most described the trends in antennation correctly, but some only stated values without saying that they were decreasing or increasing or described minor changes for each interval without mentioning the general trend. Similar answers were presented for the differences between walking and grooming.
- d. The evaluation of the hypothesis was more difficult for many who failed to mention that the effect was more noticeable at the beginning of the observation period or did not read that the components of social behaviour were antennation and begging.

Regions of the brain that perceive pain also contain receptors for pain-killers, such as morphine (from poppy plants) or endorphins (produced in the brain). Teams of young men competed in pain-endurance tests by repeatedly squeezing hand-springs until reaching unbearable pain.

During pre-competition training, some teams received injections of morphine. During competition, no morphine was administered. However, some teams thought they were receiving morphine injections. Instead, they were injected with a placebo (a saline solution) or the placebo plus naloxone (an endorphin blocking drug) as shown in the following data.



[Source: Figure 2 (A–D). "Opioid-Mediated Placebo Responses Boost Pain Endurance and Physical Performance: Is It Doping in Sport Competitions?" Fabrizio Benedetti, Antonella Pollo, and Luana Colloca. *The Journal of Neuroscience*, 31 October 2007, 27(44): 11934–11939; doi:10.1523/JNEUROSCI.3330-07.2007]

- State the effect of morphine during pre-competition training for team C. [1]
- Identify which team showed the greatest tolerance to pain on competition day. [1]
- (i) Analyse the effect of the placebo as seen in the data. [2]
- (ii) Suggest a reason for the reduced pain tolerance in team D during competition. [1]
- Analyse the data collected in the week following competition. [2]

Markscheme

- increases tolerance to pain (when given in weeks 2 and 3)
- team C

- c (i) a. placebo has no effect in team B where morphine was not administered previously;
 - b. team B thought they were getting morphine but their performance was the same as team A;
 - c. placebo has a greater effect if morphine has been administered previously as in team C;
 - d. naloxone negates the (expected) effect of placebo (even if morphine administered previously) in team D;
 - e. error bars overlap so results may not be statistically significant/no difference;
- c (ii) a. naloxone (an endorphin blocking drug) blocks the receptors for endorphins / stops endorphins from acting as pain killers
- d. a. pain tolerance goes down in all groups / all have same level of pain tolerance;
 - b. morphine-like effect/morphine effect is temporary;
 - c. endorphins/naturally produced pain-killers levels/number of receptors for pain-killers decreases;
 - d. decrease in pain tolerance is evidence for motivation/determination during competition and training / lack of motivation when no competition;

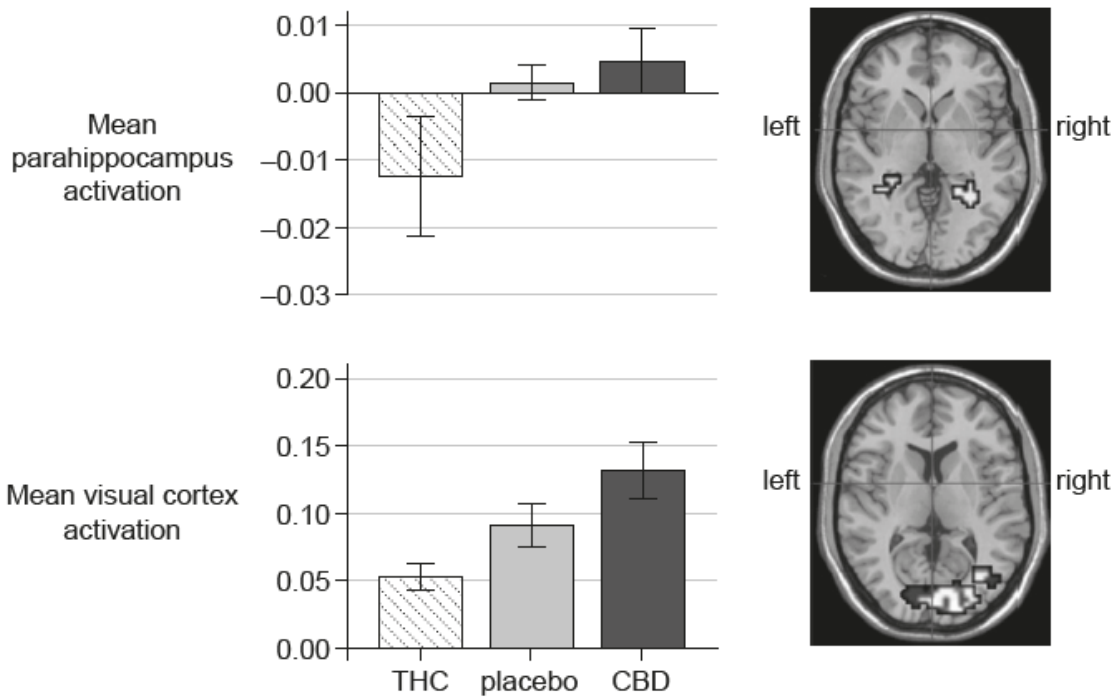
Examiners report

- a. (a) and (b) Almost all candidates were able to correctly answer both parts which involved directly identifying information from the data provided.

Very few did not score both points.
- b. (a) and (b) Almost all candidates were able to correctly answer both parts which involved directly identifying information from the data provided.

Very few did not score both points.
- c (i) Candidates did not do well on section (i) as they did not notice that Team A was not given a placebo. Most saw or invented effects of the placebo, with many thinking it was effective in all cases, when in fact the placebo did not have an effect.
- c (ii) For section (ii) many simply repeated what was already in the stem so did not gain the mark.
- d. A large number of candidates were able to gain 1 mark for seeing that pain tolerance went down in all groups during the week after competition but few were able to get a second mark.

D-9-tetrahydrocannabinol (THC) and cannabidiol (CBD), the two main psychoactive ingredients of the *Cannabis sativa* plant, have distinct symptomatic and behavioural effects. Functional magnetic resonance imaging (fMRI) was used in healthy volunteers to examine their effects on the parahippocampus, an area of the brain related to emotions and on the visual cortex. The effects are as shown.



[Source: adapted from S. Bhattacharyya et al. (2010), "Opposite effects of delta-9-tetrahydrocannabinol and cannabidiol on human brain function and psychopathology." *Neuropsychopharmacology*, 35:3, pages 764–774. Copyright © 2010 American College of Neuropsychopharmacology]

- a. Outline the benefits of using fMRI in this experiment. [2]
- b. Compare and contrast the effects of THC and CBD on the areas of the brain studied. [3]
- c. State the function of the visual cortex. [1]

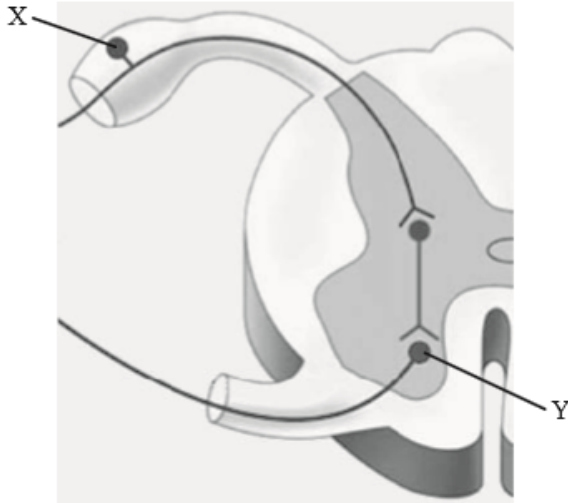
Markscheme

- a. a. «fMRI» allows imaging through magnetic resonance
- b. to measure the amount of activity/blood flow in different parts of the brain
- OR**
- to identify the parts of the brain that are activated
- c. non-invasive/indirect observation/real time observation
- b. a. THC causes a negative/inhibitory mean activation of parahippocampus whereas CBD causes a positive/excitatory one
- OR**
- THC and CBD cause opposite effects on parahippocampus
- b. both cause a positive/excitatory «mean activation» of the visual cortex
- c. «magnitude» of mean activation of both ingredients is minute on parahippocampus compared to visual cortex/OWTTE
- d. mean activation due to THC lower than CBD for both «parahippocampus and visual cortex»
- OR**
- mean activation due to THC lower than placebo whereas higher for CBD for both
- e. other valid comparison/contrast between the two drugs
- c. processing visual information/signals from the optic nerve/OWTTE

Examiners report

- a. [N/A]
- b. [N/A]
- c. [N/A]

The following diagram shows a section through the spinal cord.



[Source: CAMPBELL, NEIL A., REECE, JANE B., *BIOLOGY*, 7th edition. ©2005, p. 1013. Reprinted by permission of Pearson Education, Inc., Upper Saddle River, NJ.]

- a. Outline **one** function for each of the following parts of the brain.

[2]

Part of brain	Function
Cerebellum	
Medulla oblongata	

- b (i) Label cells X and Y.

[1]

X:

Y:

- b (ii) Outline the direction of nerve impulses through the cells labelled X and Y.

[1]

- b (iii) Define the term *reflex*.

[1]

- c. State whether the following psychoactive drugs are excitatory **or** inhibitory, using the table below.

[2]

Psychoactive drug	Excitatory <i>or</i> inhibitory
Alcohol	
Amphetamines	
Benzodiazepines	
Nicotine	

Markscheme

a.

<i>brain part</i>	<i>function</i>
<i>cerebellum</i>	unconscious movements / balance / coordination;
<i>medulla oblongata</i>	homeostatic activities / swallowing / digestion / vomiting / breathing / circulation;

b (i) X: (cell body of) sensory neuron;

Y: (cell body of) motor neuron;

(both needed)

b (ii) from the sensory neuron/X to the motor neuron/Y

b (iii) rapid and unconscious response (to a stimulus / of the nervous system)

c. Award **[1]** for every two correct responses.

<i>psychoactive drug</i>	<i>excitatory or inhibitory</i>
<i>alcohol</i>	inhibitory;
<i>amphetamines</i>	excitatory;
<i>benzodiazepines</i>	inhibitory;
<i>nicotine</i>	excitatory;

Examiners report

a. The majority of candidates could gain all the marks for this question based on factual recall but generally those who were not well prepared did not gain any marks.

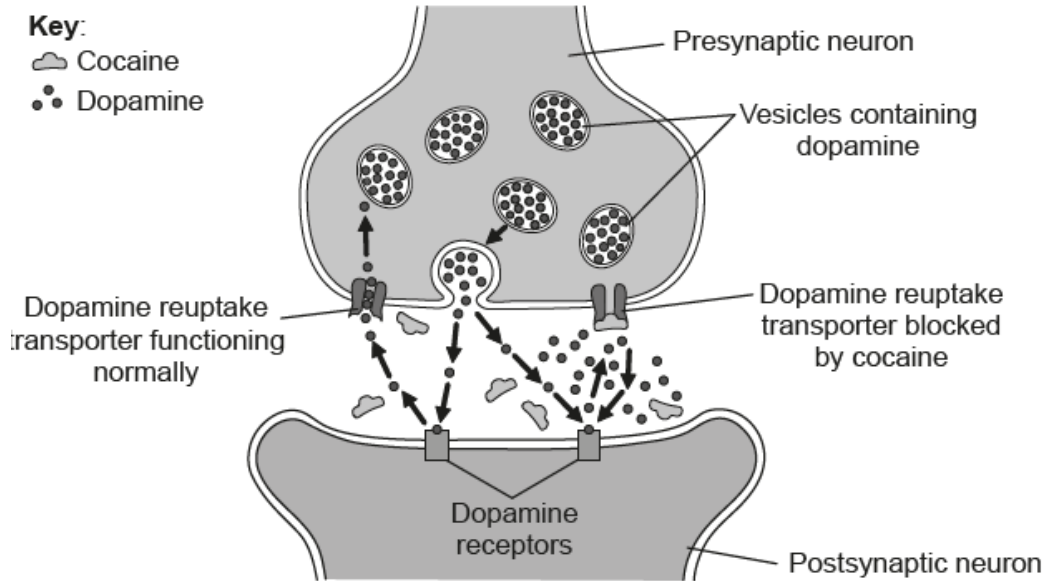
b (i) The majority of candidates could gain all the marks for this question based on factual recall but generally those who were not well prepared did not gain any marks.

b (ii) The majority of candidates could gain all the marks for this question based on factual recall but generally those who were not well prepared did not gain any marks.

- b. (iii) The majority of candidates could gain all the marks for this question based on factual recall but generally those who were not well prepared did not gain any marks. Some fell short at giving a complete definition for the term reflex, usually missing the word rapid.
- c. The majority of candidates could gain all the marks for this question based on factual recall but generally those who were not well prepared did not gain any marks.

- a. The diagram shows the mechanism of action of the psychoactive drug cocaine.

[2]



[Source: © International Baccalaureate Organization 2017]

Suggest how cocaine might influence the brain.

- b. Dopamine acts as a slow-acting neurotransmitter. Outline **one** function of slow-acting neurotransmitters.
- c. Outline the structure of a reflex arc.
- d. State the type of receptor that detects odours.

[2]

[3]

[1]

Markscheme

- a. a. «cocaine» is an excitatory drug *OWTTE*

OR

excitatory influence on the brain

b. increase the concentration/level of dopamine in the synapse *OWTTE*

c. prolonged effect/continuous stimulus of dopamine on the brain/postsynaptic neuron

d. addiction/dependence on high levels of dopamine for the same effect/addiction

- b. a. they contribute to memory/learning

b. they modulate fast synaptic transmission «in the brain»

c. by causing the release of secondary messengers in the postsynaptic neuron

c. a. receptor cell

b. sensory neuron passes stimulus

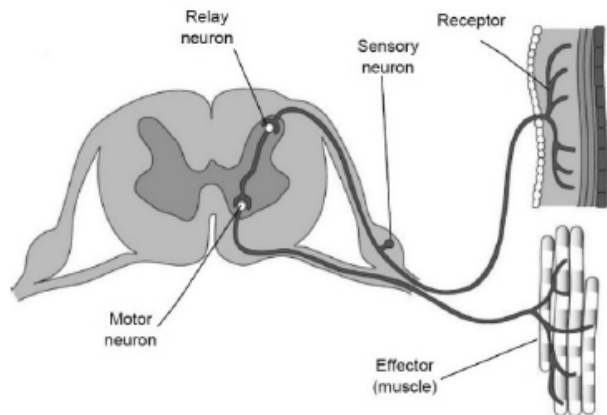
c. to interneuron/relay neuron

d. which transmit response to motor neuron

e. effector

Award marking points for a clearly annotated diagram.

eg:



d. olfactory «receptor»

OR

chemoreceptor

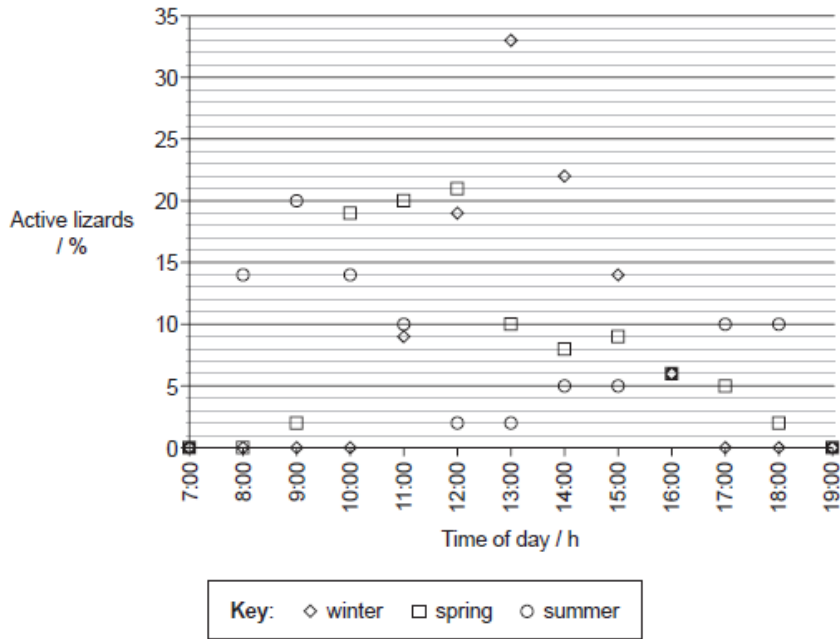
Examiners report

- a. [N/A]
- b. [N/A]
- c. [N/A]
- d. [N/A]

Lizards living in the Kalahari Desert of southern Africa are diurnal (active in daylight). Scientists studied this rhythmical behaviour during different seasons of the year. Observations were made of the number of lizards active each hour and this was recorded as a percentage of the total number of lizards that were active. The graph shows the results for the Southern Spiny Agama (*Agama hispida*) lizard. Between the hours of 19:00 and 7:00 the lizards were inactive.



[Source: www.biodiversityexplorer.org]



[Source: adapted from RB Huey and EP Pianka, (1977), *Ecology*, 58(5), pages 1066–1075]

- a. State **one** time in spring when 5 % of the lizards were active. [1]
- b(i). Winter and summer weather conditions differ in the Kalahari Desert. Compare the results for summer and winter. [3]
- b(ii). Winter and summer weather conditions differ in the Kalahari Desert. Compare the results for summer and winter. [3]
- b(iii). The temperatures differ in summer and winter. Suggest **one** other possible reason why the lizard activity differs in summer and winter. [1]
- b(iv). The temperatures differ in summer and winter. Suggest **one** other possible reason why the lizard activity differs in summer and winter. [1]
- c. Outline **one** other example illustrating the adaptive value of a rhythmical behaviour pattern in a **named** animal. [3]

Markscheme

- a. 17:00

	summer	winter
a.	active for more hours	active for fewer hours;
b.	peak activity 9:00 / more active in the morning / OWTTE	peak activity at 13:00 / more active around mid-day / OWTTE;
c.	peak activity lower	peak activity higher;
d.	two peaks of activity	(only) one high peak;
e.	both have more inactive hours than active;	
f.	same level of activity at 16:00;	

A table format is not required.

	summer	winter
a.	active for more hours	active for fewer hours;
b.	peak activity 9:00 / more active in the morning / OWTTE	peak activity at 13:00 / more active around mid-day / OWTTE;
c.	peak activity lower	peak activity higher;
d.	two peaks of activity	(only) one high peak;
e.	both have more inactive hours than active;	
f.	same level of activity at 16:00;	

A table format is not required.

b(ii)a. change in behaviour/availability of their prey/food sources;

- b. change in presence of predators;
- c. protection from sun (in the middle of the day in summer);
- d. amount of daylight hours (is reduced in winter);

Do not accept answers related to temperature eg: cold blooded or poikilothermic.

b(ii)a. change in behaviour/availability of their prey/food sources;

- b. change in presence of predators;
- c. protection from sun (in the middle of the day in summer);
- d. amount of daylight hours (is reduced in winter);

Do not accept answers related to temperature eg: cold blooded or poikilothermic.

c. a. name of organism;

- b. rhythmical behaviour;
- c. adaptive value;

Accept common name eg: deer, bear but not category names eg: fish, bird.

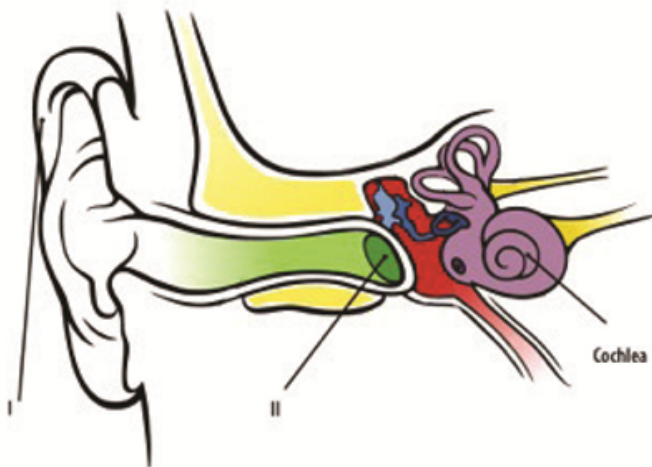
eg:

- a. coral;
- b. male and females release gametes into the sea at the same time;
- c. this increases the chances of fertilization;

Examiners report

- a. The majority of candidates did well on this question, although some had problems with clear, precise comparisons of data. Many candidates used examples of red deer mating in the fall, (grizzly) bears hibernating, or animals with nocturnal-diurnal behaviour as examples of rhythmical behaviour but some incorrectly used polar bears or, in a few cases, the waggle dance, completely misunderstanding the meaning of rhythm here.
- b(i).The majority of candidates did well on this question, although some had problems with clear, precise comparisons of data. Many candidates used examples of red deer mating in the fall, (grizzly) bears hibernating, or animals with nocturnal-diurnal behaviour as examples of rhythmical behaviour but some incorrectly used polar bears or, in a few cases, the waggle dance, completely misunderstanding the meaning of rhythm here.
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The diagram shows the structure of the human ear.



[Source: © International Baccalaureate Organization 2013]

I.

II.

a (ii) Outline how sounds are perceived in the cochlea, including the name of the cell type involved.

[1]

c. Identify a function of the parts of the brain by using numerals II to V to complete the chart. Hypothalamus has been completed for you.

[2]

Part of Brain		Function	
Hypothalamus	I		Memory centre
Medulla oblongata	II	I	Homeostasis
Cerebellum	III		Secretes hormones regulating body functions
Pituitary gland	IV		Coordinates balance
Cerebral hemispheres	V		Controls breathing

d. Discuss how the pupil reflex can be used as a test for brain death.

[2]

Markscheme

a (i): pinna;

II: ear drum / tympanic membrane; (both needed)

a (ii) cilia/hair/hair bundles of hair cells vibrate with (cochlear) liquid/fluid movement

	Part of Brain		Function
a.	hypothalamus	I	V memory centre
b.	medulla oblongata	II	I homeostasis
c.	cerebellum	III	IV secretes hormones regulating body functions
d.	pituitary gland	IV	III coordinates balance
e.	cerebral hemispheres	V	II controls breathing

Award [1] for any **two** correct responses.

d. a. pupil reflex is controlled by autonomic nervous system/brain/midbrain; (do not accept medulla)

b. light shone into the eye would normally cause pupil contraction;

c. no pupil reflex indicates that synapses are not functioning;

d. can indicate brain death but not necessarily / OWTTE;

Examiners report

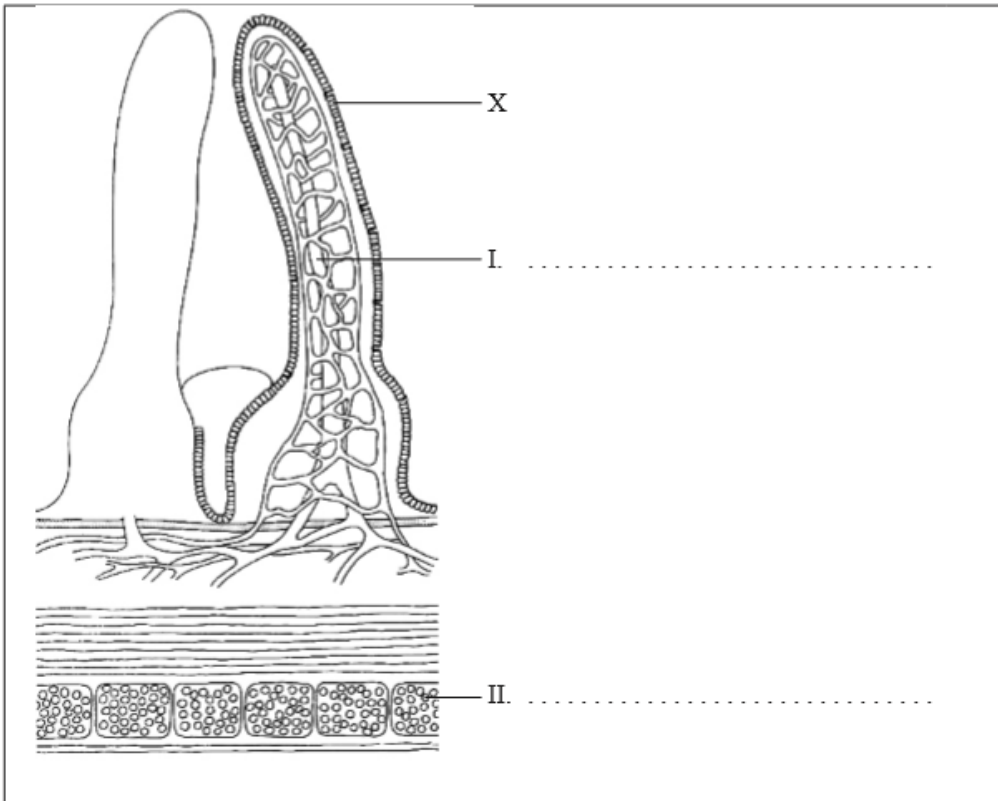
a (i) N/A

a (ii) Although most had an idea of the process of hearing, they were not very successful in 5a (ii) because they could not outline the roles for all three of cilia, hair cells and cochlear fluid.

c. [N/A]

d. Most candidates gained one mark for writing that the pupil constricts when a bright light is shone in the eyes, but didn't get much more; most ignored the mechanism or located it in the medulla oblongata, which is incorrect (the reflex pathway is located in the anterior part of the brain stem; although the medulla is the posterior part of the brain stem, the oversimplification of locating the pathway in the medulla, or stating that the autonomic nervous system is controlled by the medulla because other parts of the brain are not in the syllabus is incorrect); most missed the discussion element and confused probability and certainty of brain death.

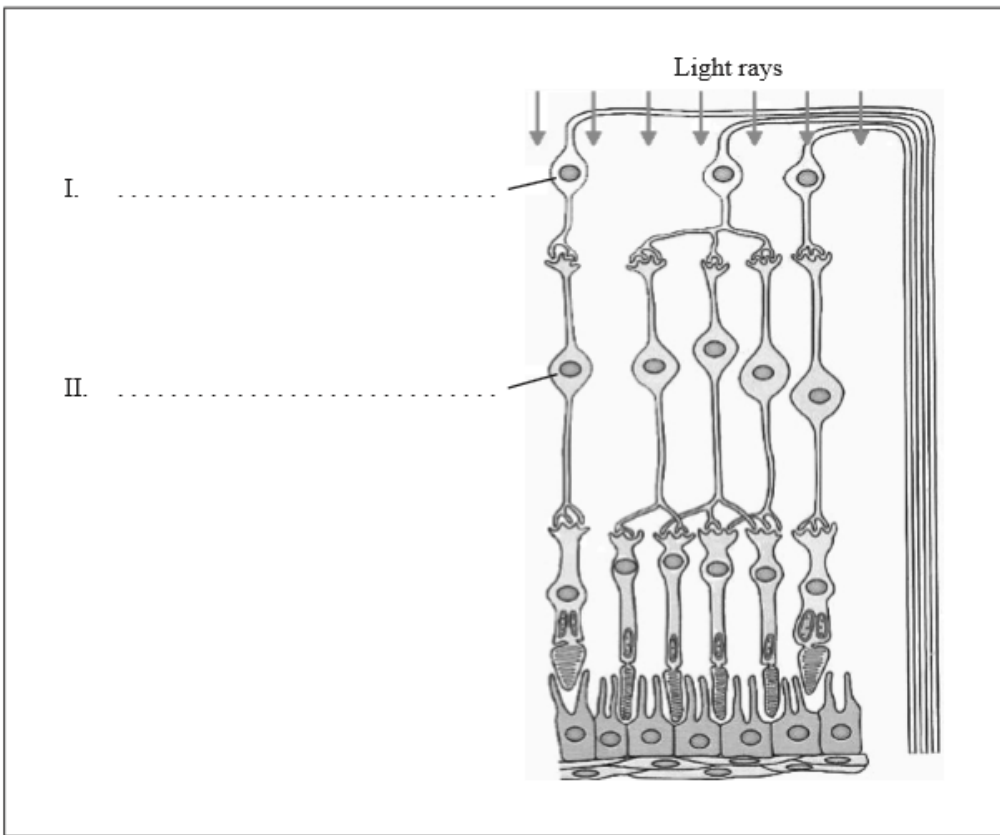
The diagram below shows a section through the ileum.



Roland Soper, Nigel P. O. Green, G. Wilfred Stout and Dennis J. Taylor, *Biological Science*, 1990, p. 316, Cambridge University Press. Used with permission.

a (i) The diagram below shows the structure of the retina. Label I and II.

[1]



C. J. Clegg, *Introduction to Advanced Biology*, 2000, p. 285. Reproduced by permission of Hodder Education.

a (i) Label I and II.

[1]

a (ii) Distinguish between rods and cones.

[2]

b. Outline the pupil reflex.

[2]

c. Discuss the use of the pupil reflex in testing for brain death.

[3]

Markscheme

a (i): ganglion cell

II: bipolar cell/neuron

(both needed)

a (ii): lacteal

II: longitudinal/smooth muscles / muscularis mucosa

(both needed)

a (ii)	<i>rods</i>	<i>cones</i>
	used in dim light	used in bright light;
	black and white vision / one type sensitive to all wavelengths of light	colour vision / three types sensitive to red, blue and green light;
	passage from group of rod cells to single bipolar neuron/nerve fibre in optic nerve	passage of impulse from single cone cell to a single bipolar neuron/nerve fibre;
	detect shape and movement	perception of fine detail;
	found all along the retina	found in fovea / concentrated in one region;

To award **[2 max]** responses need to be compared.

Responses do not need to be shown in a table format.

- b. rapid unconscious response to change in light intensity / controls amount of light entering eye to prevent damage to retina/to see in darkness; in bright light circular muscles in iris contract causing pupil to constrict / in dim light longitudinal/radial muscles in iris contract causing pupil dilation;
- constriction by parasympathetic NS / dilation by action of sympathetic NS;
- c. pupil reflex is a brain stem reflex / shows activity in the medulla oblongata;
- pupil reflex must be absent in brain death;
- pupil reflex is possible in coma victims where motor function is absent;
- pupil reflex alone not enough to diagnose brain death;
- other criteria include coma/absence of response to pain in all extremities/ absence of brain stem reflexes/lack of respiratory movements;
- some cases of coma irreversible / some cases may recover;
- doctors need to diagnose damage to decide treatment/long-term life support /organ donation;

Examiners report

a (i) Good answers.

a (i) Very few identified the muscle correctly. There was some complaint about the fact that what was tested was a longitudinal section of the villus instead of a transverse section as stated in the guide. The complaint is reasonable, nevertheless, the candidates should have known the order in which the muscle layers appear and could have inferred the answer to the question. As a matter of fact, the more able candidates answered this question correctly.

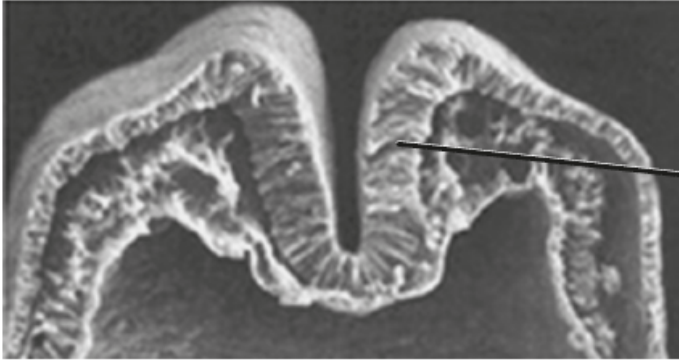
a (ii) Good answers.

b. Several answers described the pupil reflex arc/pathway which was sometimes sufficient to gain one mark.

c. Few answers related to coma victims, dismissing almost half of the possible marking points but leaving sufficient possibilities to score well. Many candidates considered that if no pupil reflex is present, brain death is sure. Some stated the role of brain stem. Vegetative state was confounded with brain death. Several candidates repeated part of the information given in the previous question.

The images show the early stages and completed outcome of the process of neurulation.

Early stages



I.

Completed outcome



II.

Structure X

Structure Y

[Source: adapted from www.slideshare.net]

a.i. Label the parts I and II on the images. [2]

a.ii. Structure Y will eventually elongate to form two structures. State the names of these two structures. [2]

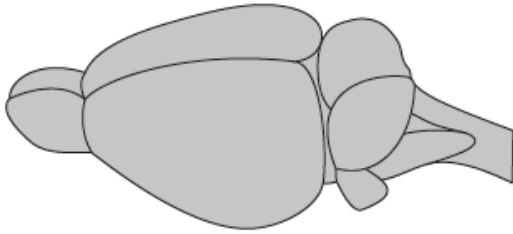
1.

2.

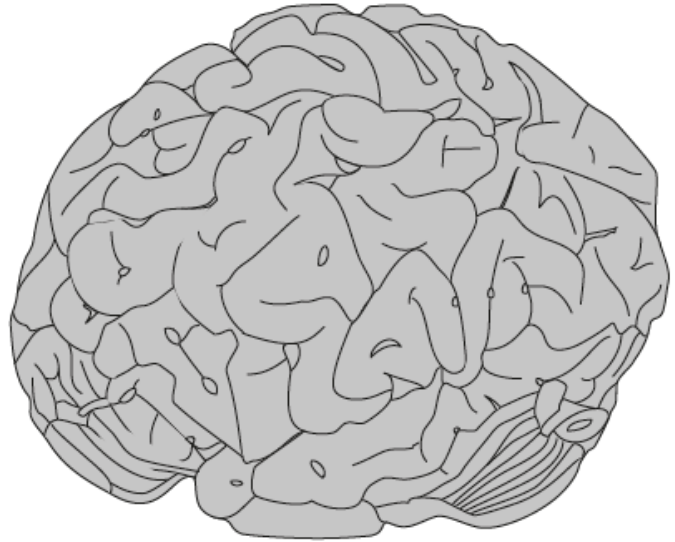
a.iii. State the condition that arises if the closure of structure X is incomplete during embryonic development. [1]

b. The diagrams show a rat brain and a human brain. They are not drawn to scale. [2]

Rat brain



Human brain



[Source: © International Baccalaureate Organization 2017]

Distinguish between the cerebral cortex of the human brain and of the rat brain.

Markscheme

a.i.a. /: neural groove/plate/fold

b. //: ectoderm

a.ii.a. brain

b. spinal cord

a.iii.spina bifida

b. a. human cortex larger than rat cortex

b. human cortex proportionally larger than other brain parts than rat cortex *OWTTE*

c. surface area «of cortex» larger for humans

d. more infolding of the surface of the cerebral cortex in humans

Examiners report

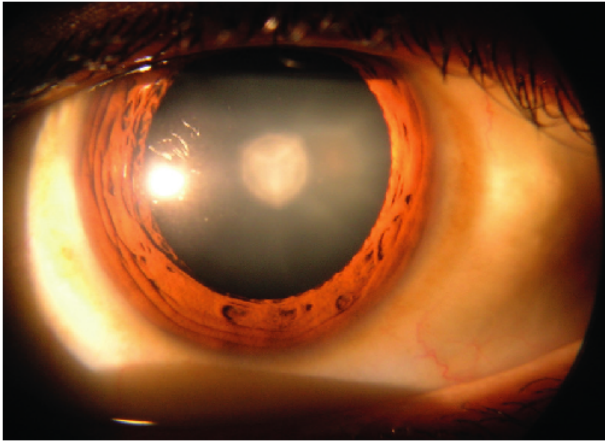
a.i. [N/A]

a.ii. [N/A]

a.iii. [N/A]

b. [N/A]

A cataract is a clouding of the lens in the eye, resulting in blurred vision.



[Source: Cataract in Human Eye, Rakesh Ahuja, MD (https://en.wikipedia.org/wiki/Cataract#/media/File:Cataract_in_human_eye.png)]

b. Explain the use of a local anesthetic during surgery to remove the cataract.

[2]

c. Describe red-green colour blindness.

[2]

Markscheme

b. a. reduction/elimination of pain

OR

to block sensory perception

b. blocks synaptic transmission between «sensory neurons and CNS»

OWTTE

c. allows patient to remain aware

d. prevent reflex causing blinking/eye movement

OWTTE

[Max 2 Marks]

c. a. sex/X-linked «genetic trait»

b. results from absent/defective cone cells

c. cannot distinguish between red and green

[Max 2 Marks]

Examiners report

b. [N/A]

c. [N/A]
