
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

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]

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

b. Outline the development of axons in immature neurons. [2]

e. State **one** activity controlled by the medulla oblongata. [1]

b. State the function of the bones in the middle ear. [1]

c. Explain the role of the hair cells in the cochlea. [3]

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]
-

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

Outline innate and learned behaviour.

- 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]
-

Outline the effects of cocaine at synapses in the brain.

- 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]

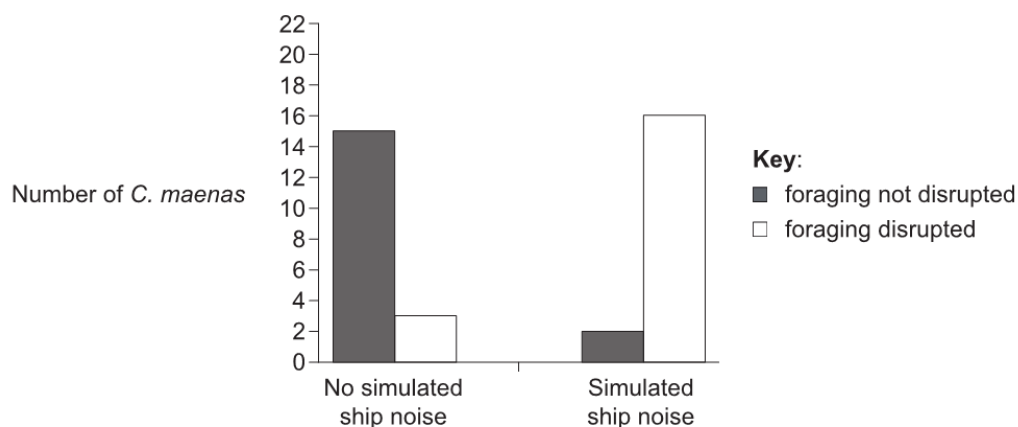
- c. Outline **one** way in which synchronized oestrus in female lions increases the chances of survival and reproduction of offspring. [2]

- d. Outline **one** way in which neurons can be altered by memory and learning. [2]
-

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

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

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]

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

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

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

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

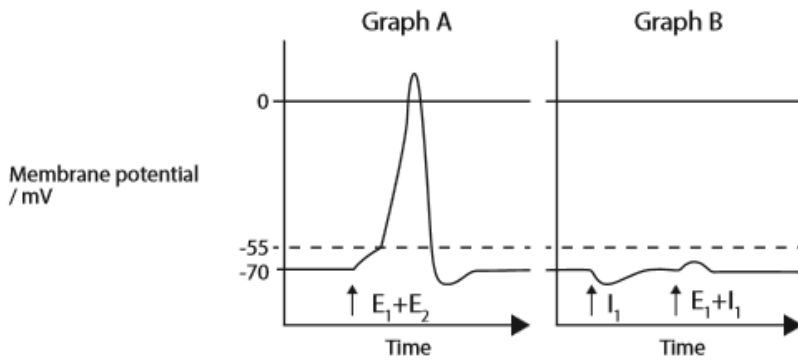
[3]

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

[1]

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

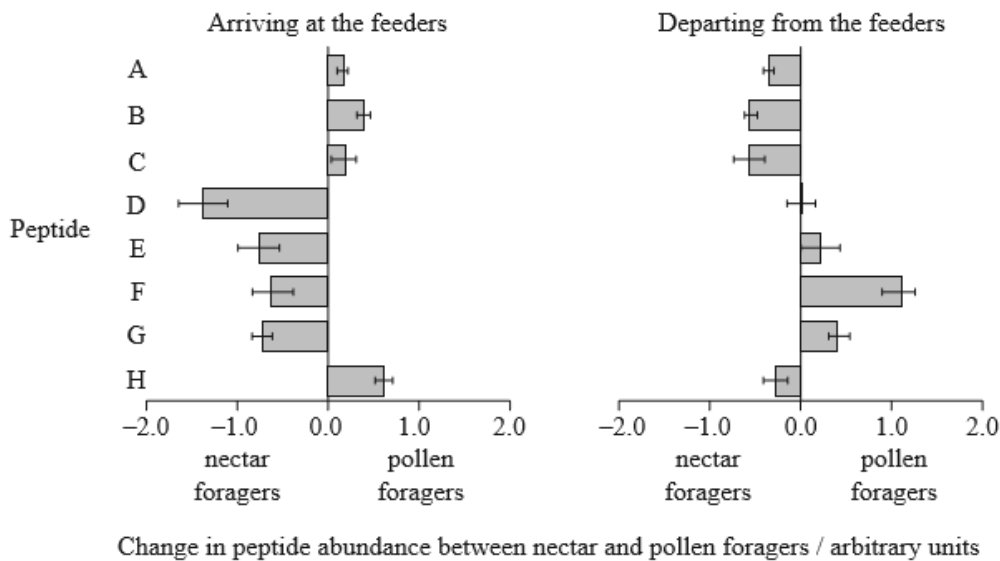
The graphs compare the changes in membrane potential that result from a combination of stimuli. Graph A shows two excitatory post-synaptic potentials (E_1 and E_2) acting on a neuron. Graph B shows one excitatory (E_1) and one inhibitory (I_1) post-synaptic potential, both acting on a neuron.



[Source: © International Baccalaureate Organization 2016]

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

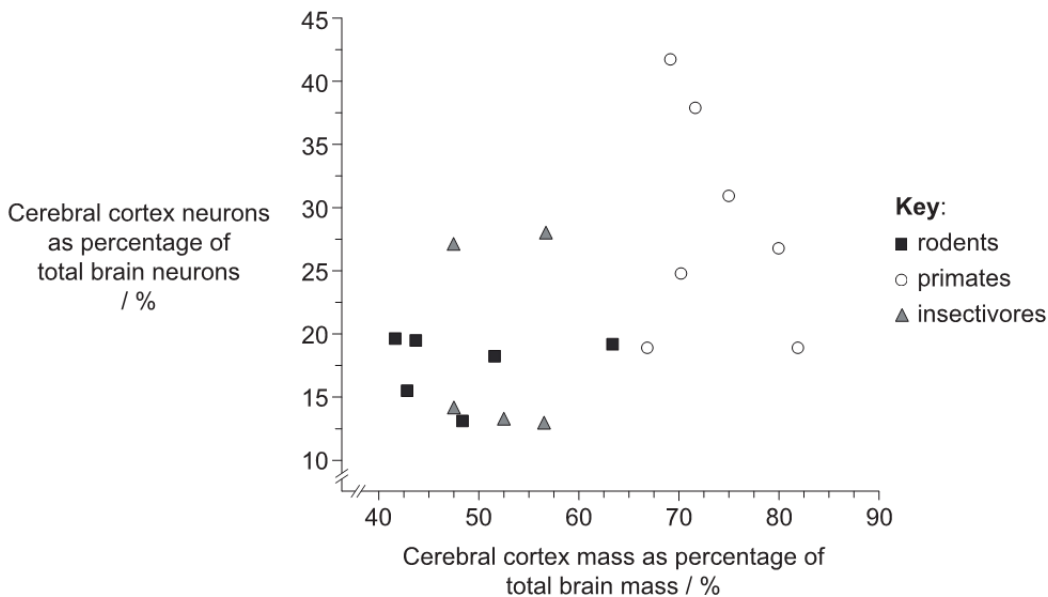
In order to investigate the hypothesis that honeybees (*Apis mellifera*) have an instinct to forage for either nectar or pollen, but not both, researchers installed different feeders containing either nectar alone or pollen alone. They collected four different groups of honeybees (those arriving at the 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.



[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]

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.



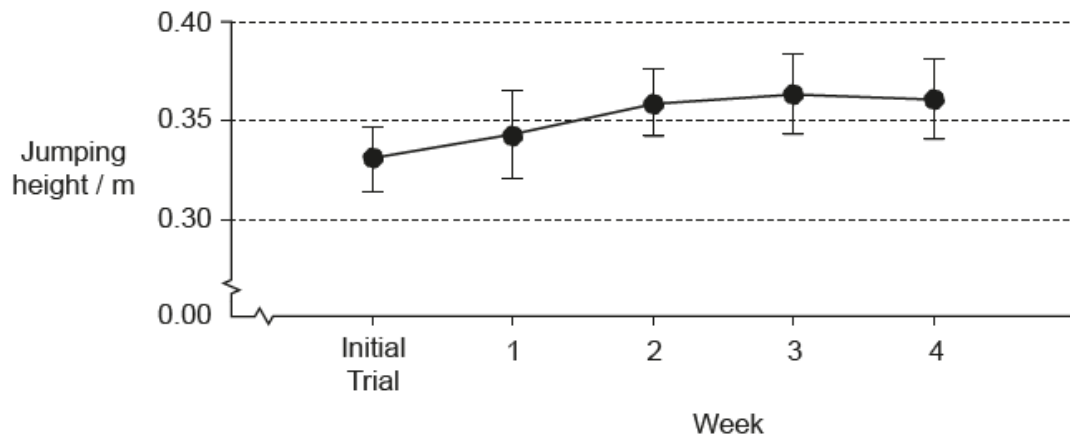
[Source: S Herculano-Houzel (2009) *Frontiers in Human Neuroscience*, 3, p 31, Frontiers Research Foundation <http://journal.frontiersin.org/article/10.3389/neuro.09.031.2009/full>]

- 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]

Explain the effects of cocaine in terms of its action at synapses in the brain and its social consequences.

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

- 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]

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

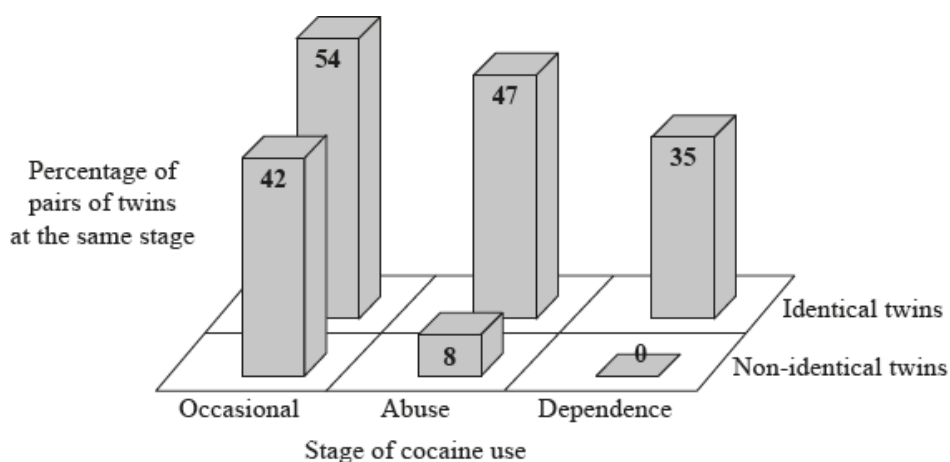
Excitatory drug:

Inhibitory drug:

Explain how sound is perceived by the ear.

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

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]

- a. Identify which stage of cocaine use shows the least percentage difference between identical twins and non-identical twins. [1]
- b. Compare the results for identical twins and non-identical twins. [3]
- c. 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]

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

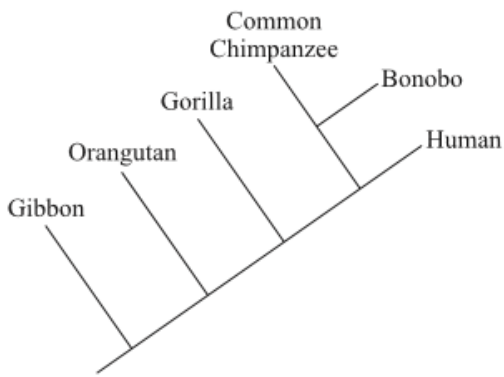
b. State **one** excitatory and **one** inhibitory psychoactive drug. [2]

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]

The diagram below is a cladogram.



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

(i) Cerebellum

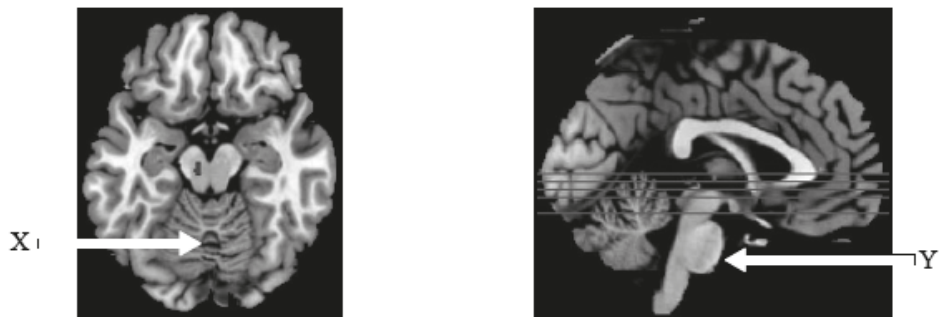
(ii) Hypothalamus

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]

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]

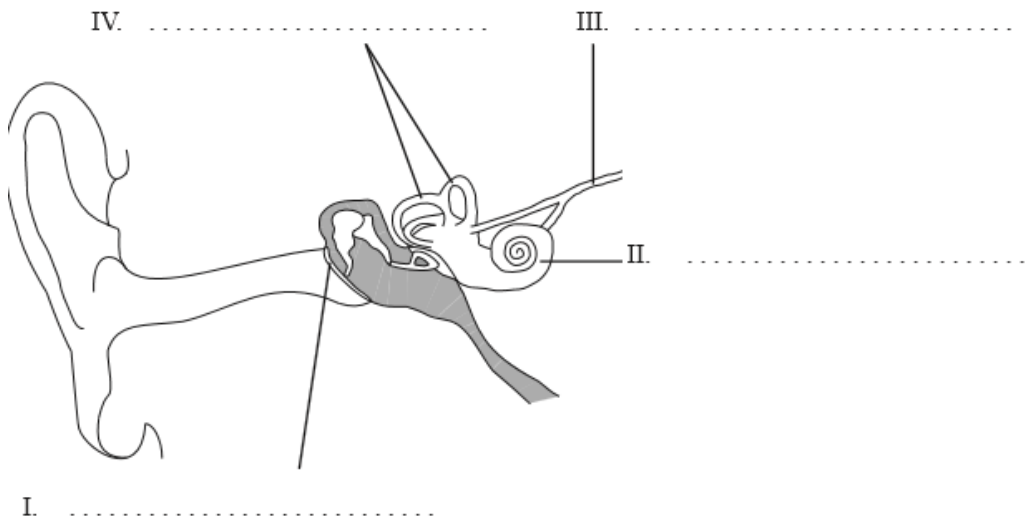
Characteristic	Rod cells	Cone cells
Location		
Light intensity detected		
Connection to optic nerve		

a. Distinguish between innate and learned behaviour. [1]

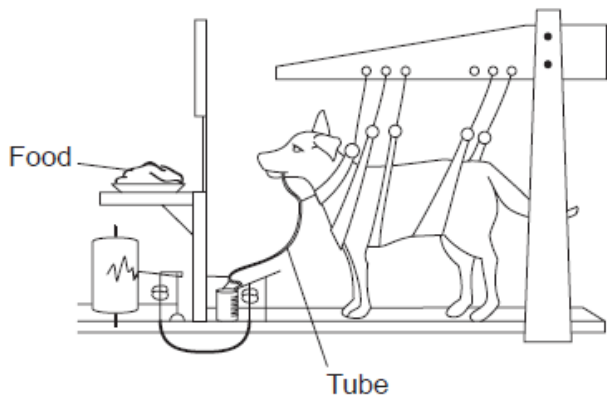
c. Distinguish between analogous and homologous structures. [2]

Analogous structures	Homologous structures

Label the diagram of the ear.



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

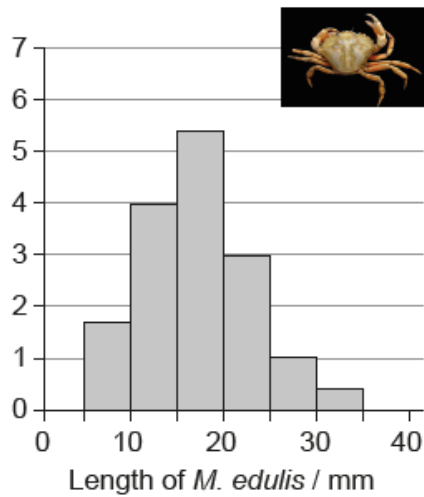


[Source: adapted from <http://animalbehaviour.net>]

- 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]

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.

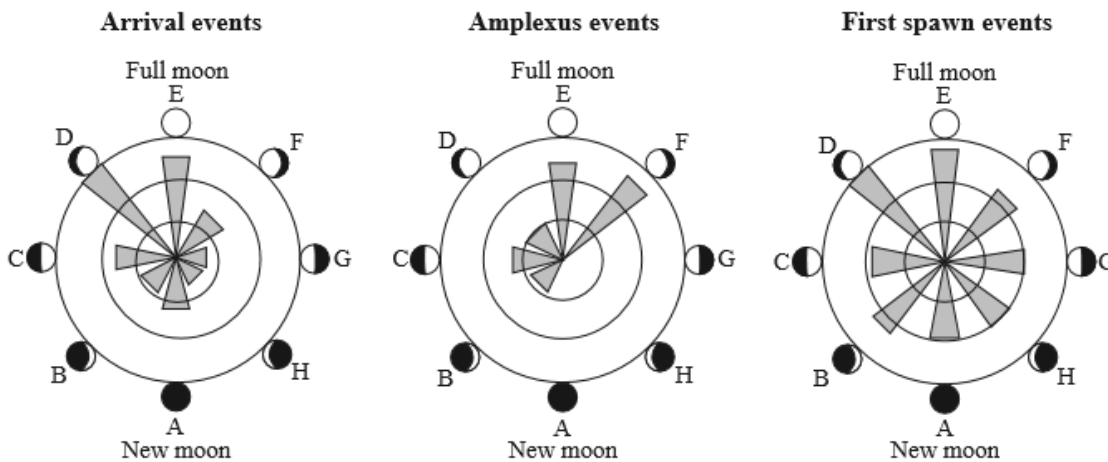
Mean number of *M. edulis* eaten per day



[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]

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

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.

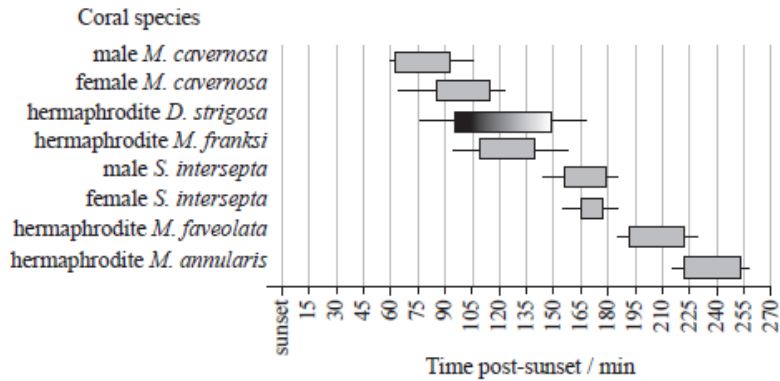


[Reprinted from *Animal Behaviour*, vol. 78 (2), Rachel A. Grant, Elizabeth A. Chadwick and Tim Halliday, 'The lunar cycle: a cue for amphibian reproductive phenology?', pp 349–357, ©2008 . With permission from Elsevier.]

- 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]

- d. The lunar cycle could affect the timing of breeding. Suggest, with a reason, **one** other environmental variable which could affect the timing. [2]

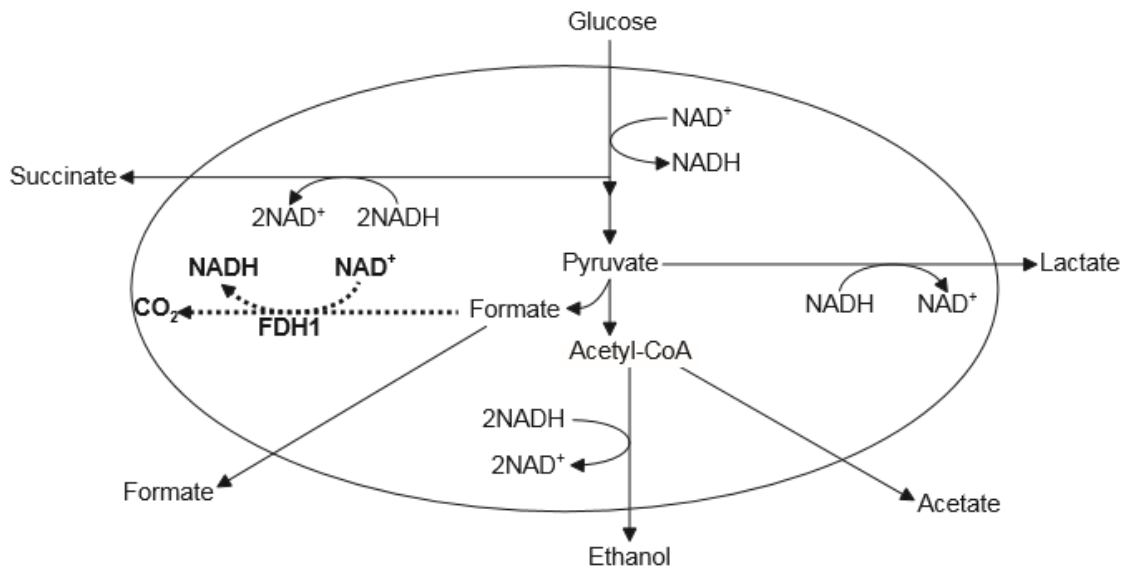
Corals can be male, female or hermaphrodite (both male and female) and the release of their gametes is called spawning. Data was collected to study the spawning behaviour in the Gulf of Mexico of three genera of coral: *Montastraea*, *Stephanocoenia* and *Diploria*. The spawning behaviour is expressed 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.]

- b. Suggest why it may be advantageous for each species of coral to spawn within a tight time frame. [1]
- c. Discuss the significance of different spawning windows for different species. [2]
- d. Scientists hypothesized that the release of the male gamete triggers a chemical signal for females to release their eggs. Discuss this hypothesis. [2]
- e. 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]
- f. Define the term *innate behaviour*. [1]

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.

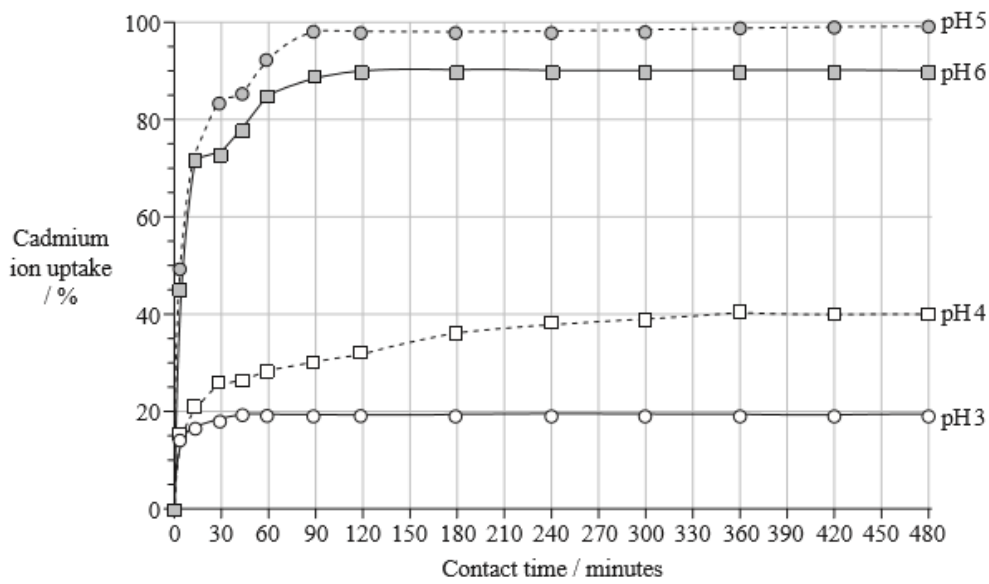


[Source: Ka-Yiu San, E. D. Butcher Professor of Bioengineering, Professor of Chemical Engineering, Rice University.]

- 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]

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]

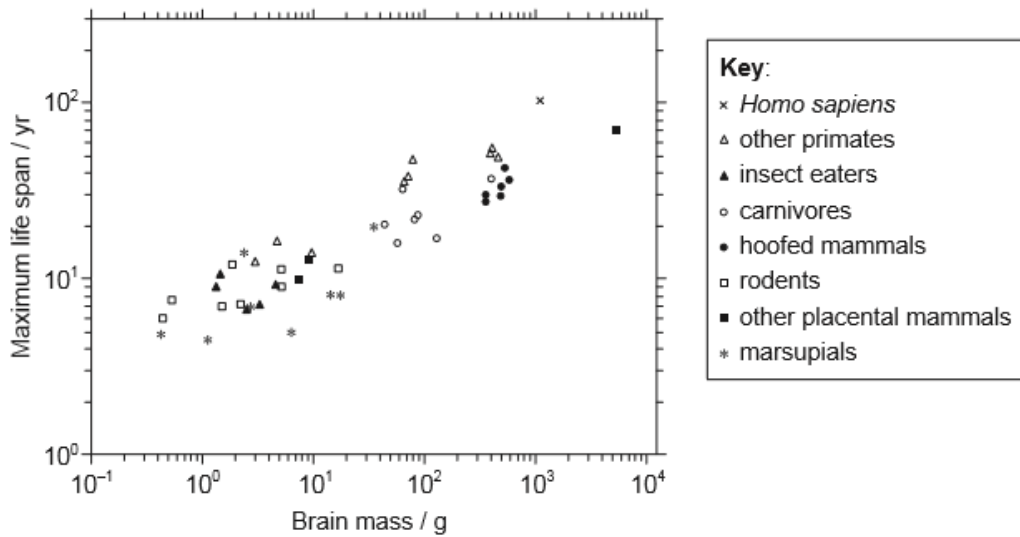
- a. Describe the cadmium ion uptake by *A. fumigatus* at pH 6. [2]

- 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]

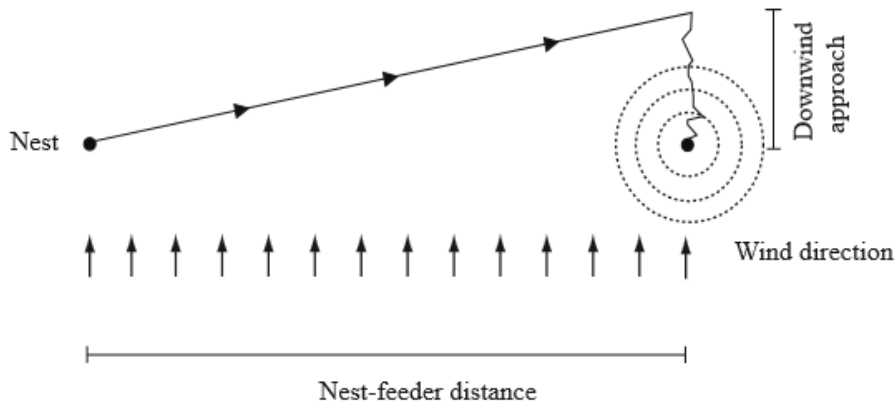
The evolution of increased body size in mammals has been accompanied by an increase in life span. Another variable that could affect life span is brain size. Data was analysed from 47 mammalian species.



[Source: Hofman, M. A. (1993), Encephalization and the evolution of longevity in mammals. *Journal of Evolutionary Biology*, 6: 209–227. doi: 10.1046/j.1420-9101.1993.6020209.x]

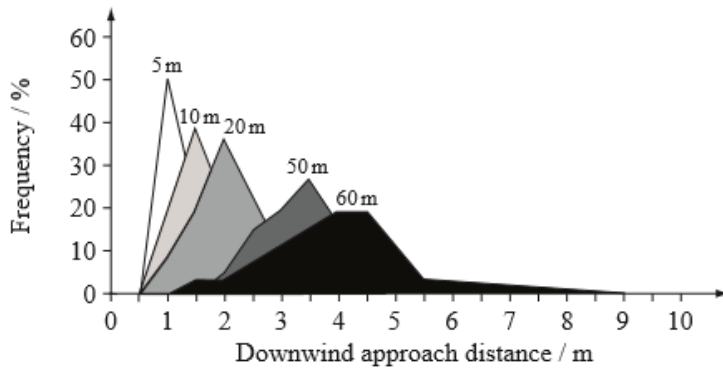
- a. State the relationship between brain mass and maximum life span. [1]
- b. Identify the group with the widest range of brain mass. [1]
- c. Compare the brain mass and life span of primates and marsupials. [3]
- d. Discuss how a larger brain size and longer life span might have contributed to the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

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.

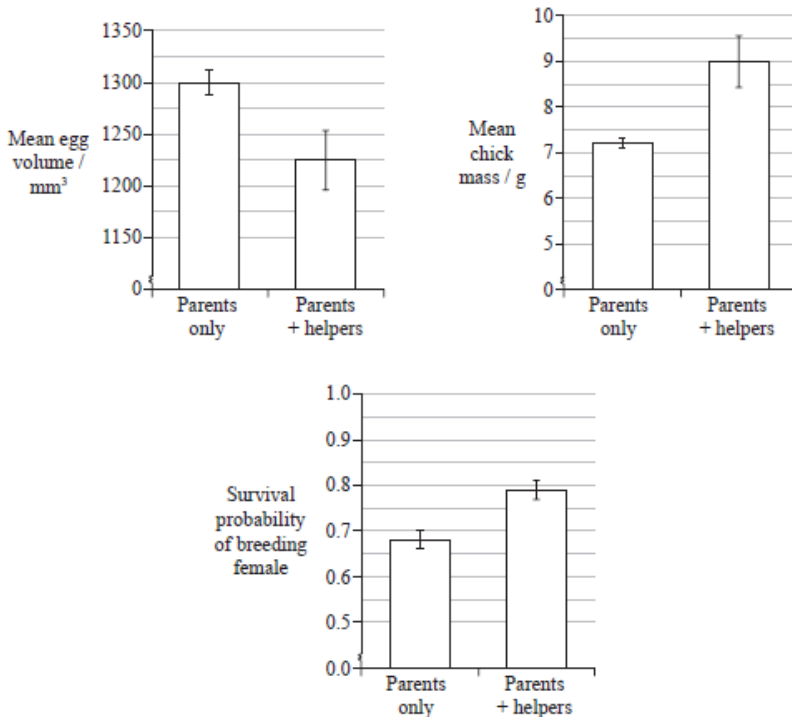


[Source: adapted from H Wolf and R Wehner, (2005), *Journal of Experimental Biology*, 208, pages 4223–4230]

- 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]

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.

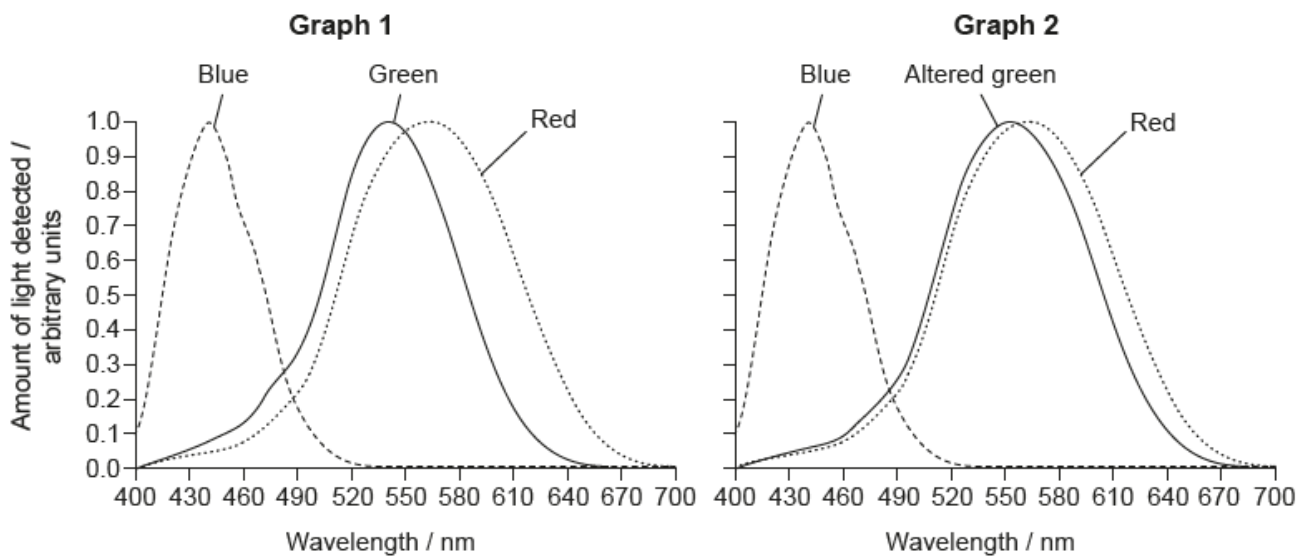
The bar charts below show the effect of the presence of helpers on mean egg volume, mean mass of six-day-old chicks and the probability of survival of the breeding females until the next breeding season.



[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]

- 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]

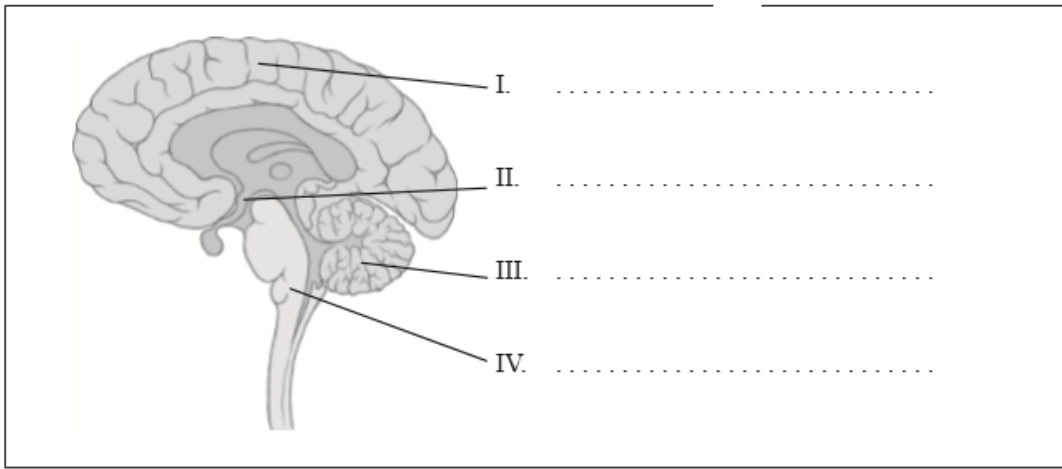


[Source: © International Baccalaureate Organization 2017]

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]

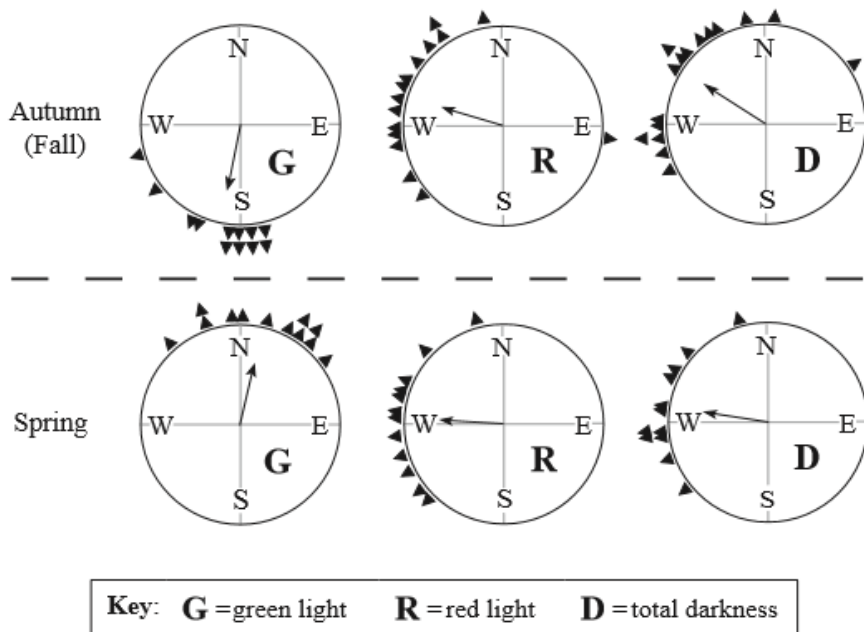
- a. Identify the parts of the brain indicated on the diagram below. [2]



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]

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>]

a. Identify the season and light conditions which result in the strongest northerly direction flown by the robins.

[1]

Season:

Light conditions:

b. Distinguish between the effect of red light and green light on the behaviour of the robins in spring and autumn (fall).

[2]

c. 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]

d. Using the data in the diagram, deduce with a reason, whether European robins migrate during the daytime or at night.

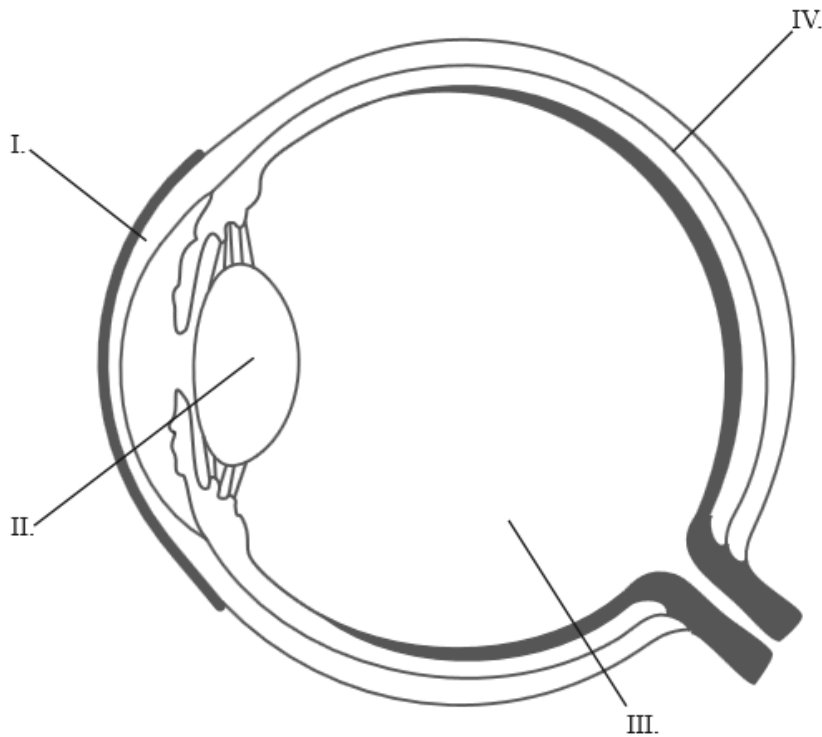
[2]

e. Scientists anesthetized the beaks of some robins in order to deactivate the magnetoreceptors. Predict how this would affect their orientation in red light.

[1]

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

[2]



I.

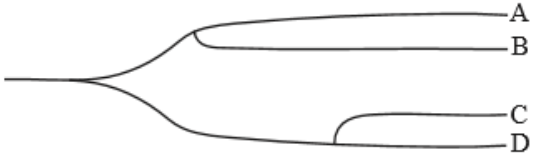
II.

III.

IV.

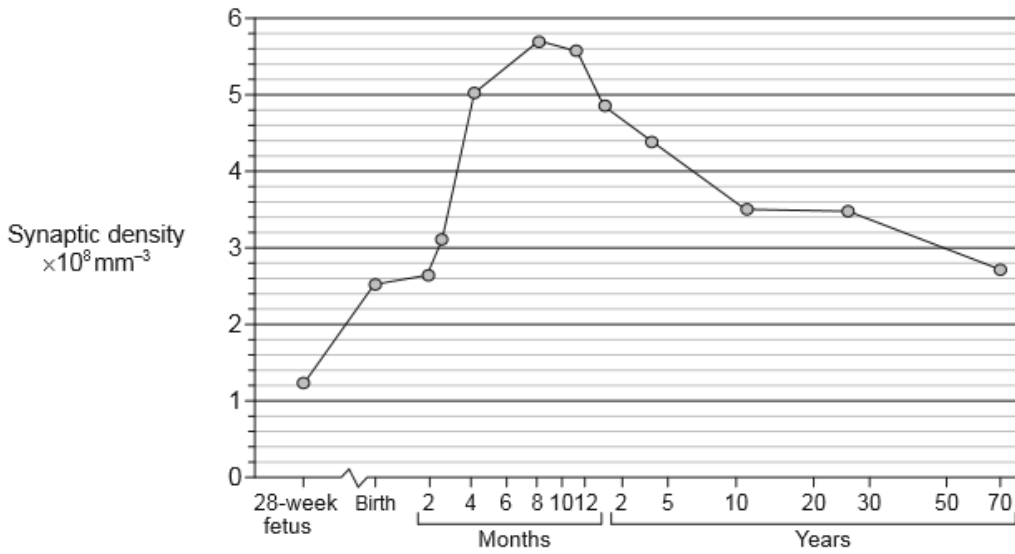
b. Outline the evidence provided by DNA for the common ancestry of living organisms. [2]

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]

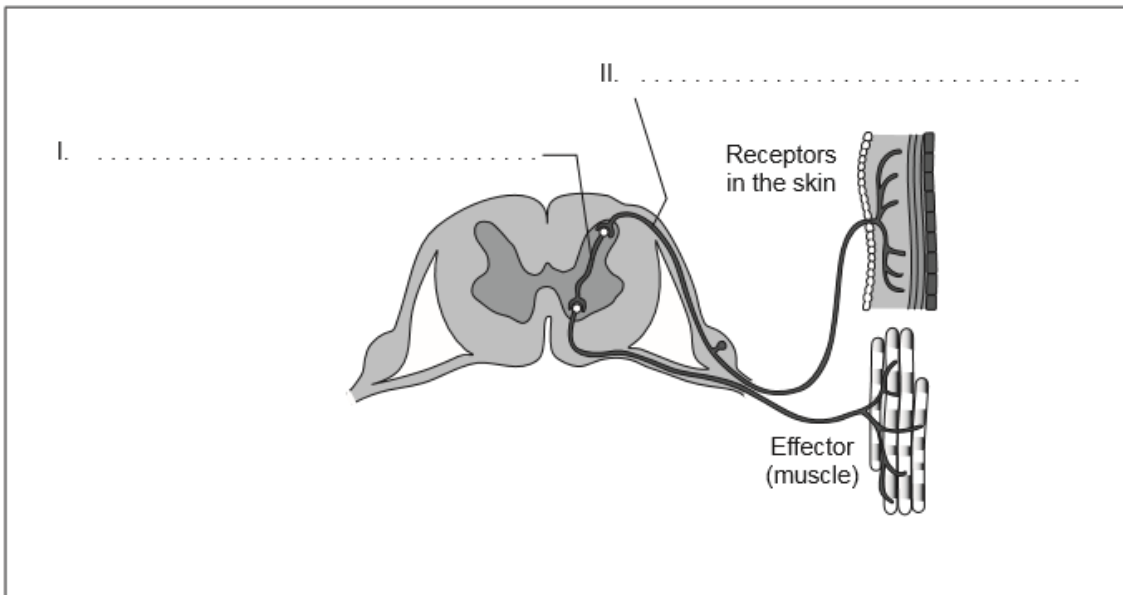


d. Suggest **two** reasons for using cladograms for the classification of organisms. [2]

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.



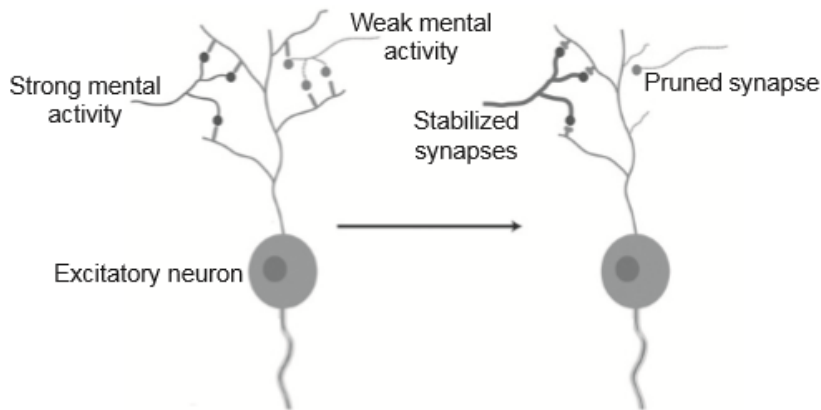
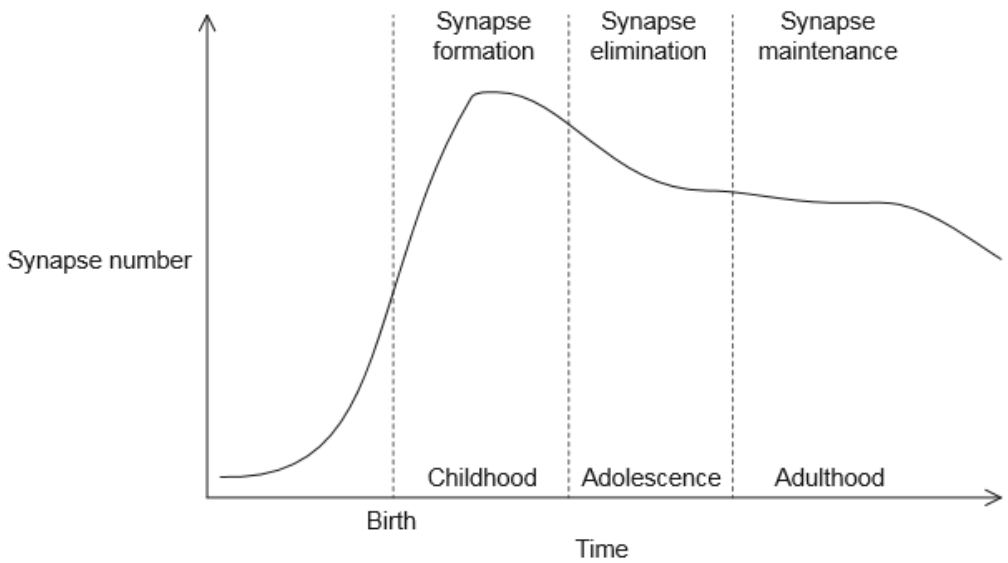
[Source: Reprinted from *Brain Research*, 163 (2), Peter R. Huttenlocher, "Synaptic density in human frontal cortex – Developmental changes and effects of aging", pp. 195–205 © 1979, published by Elsevier. Used with permission.]



[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). [2]
- 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]

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.

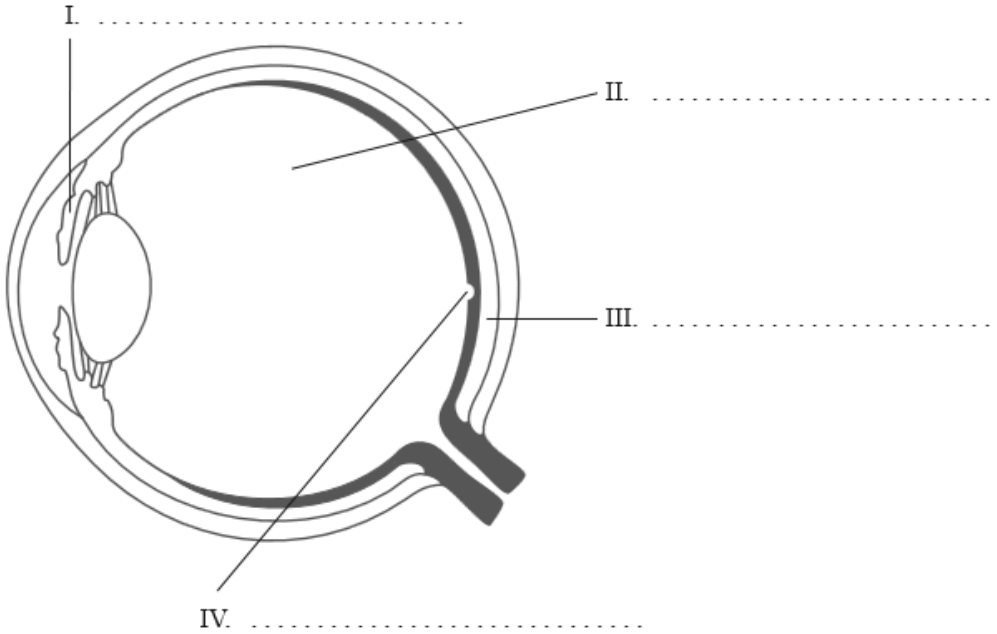


[Source: adapted from Doll, C. A. and Broadie, K. (2014), Impaired activity-dependent neural circuit assembly and refinement in autism spectrum disorder genetic models. *Frontiers in Cellular Neuroscience* 8: 30. doi: 10.3389/fncel.2014.00030. Copyright © 2014 Doll and Broadie.]

- a. State what happens to unused neurons. [1]
- b. Predict how mental activity might delay the onset of Alzheimer's disease. [2]

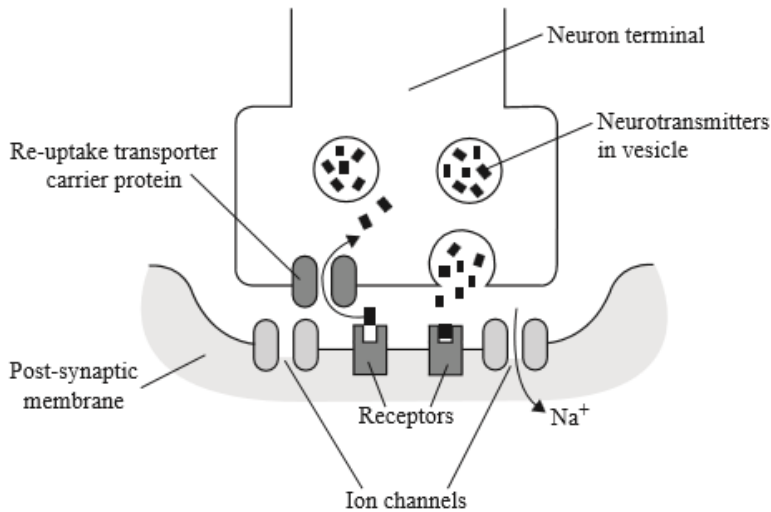
- c. Autism appears early in life and affects how a person communicates and relates to others. There is evidence that autism could be caused by a surplus of synapses. Using all of the information provided, suggest **two** possible causes of a surplus of synapses in people with autism. [2]

- a. Label the following diagram of the eye. [2]



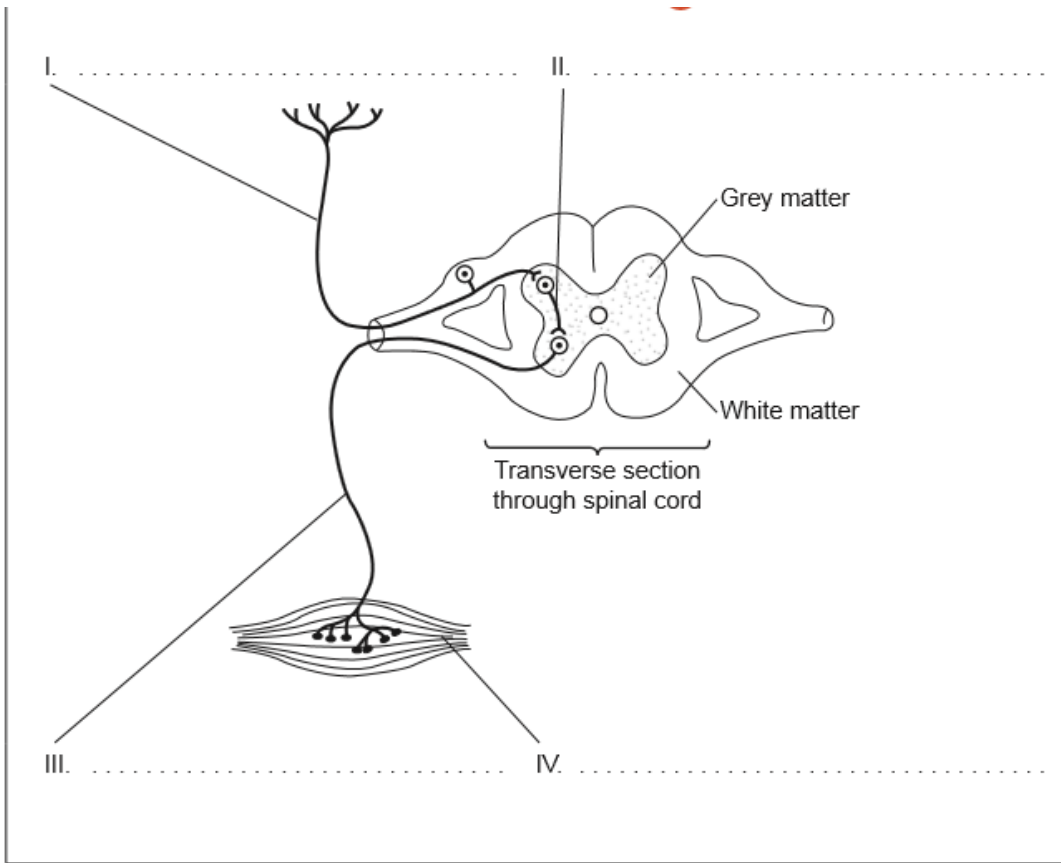
- b. Outline how the pupil reflex can be used to indicate brain death. [2]

- c. The diagram below shows a synapse where the neurotransmitter is dopamine and some of the processes that take place during nerve transmission. [3]

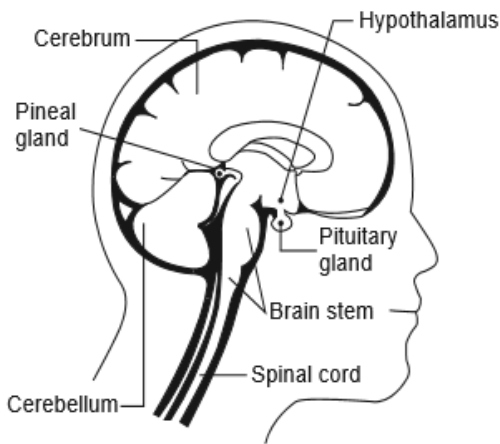


[Source: Diagram reprinted with permission from the Faculty of Health, Birmingham City University, UK]

Explain the effect of cocaine on neurotransmission at a synapse.



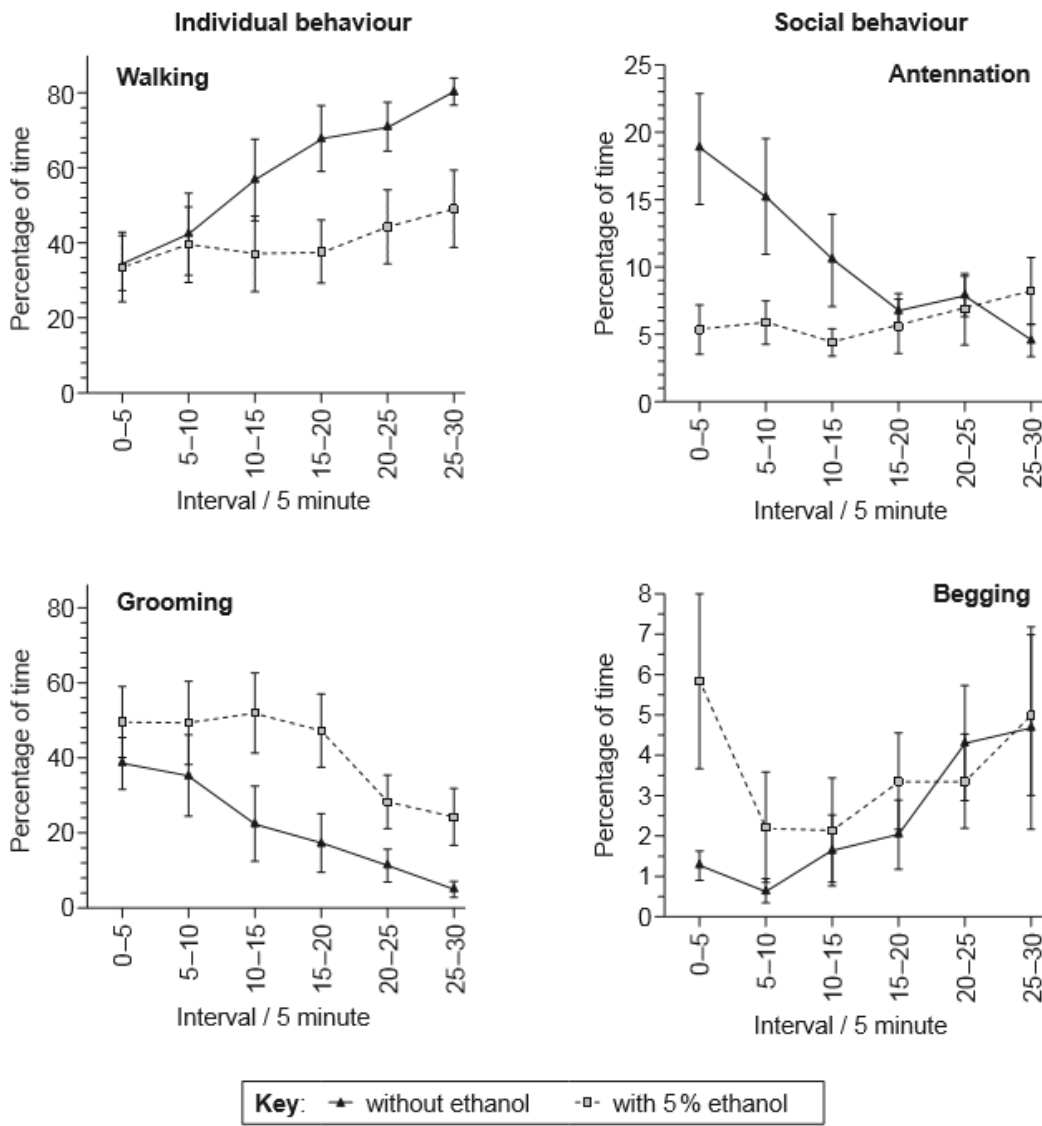
[Source: © International Baccalaureate Organization 2015]



[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]
- c (ii) Outline control of heart rate by the medulla oblongata. [2]

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.



[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)]

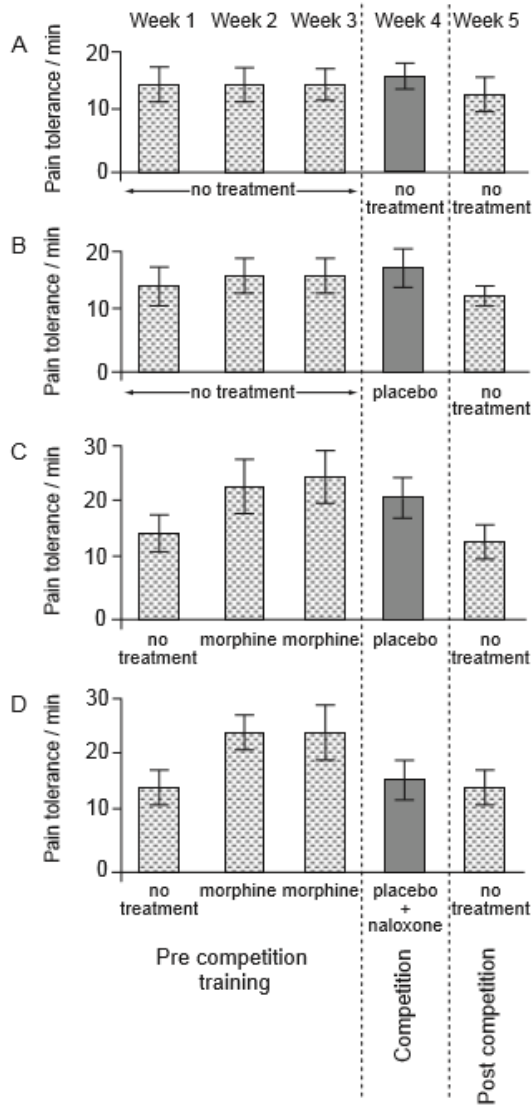
- State the percentage of time the honey bees engaged in begging during the first five minute interval. [1]

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]

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.

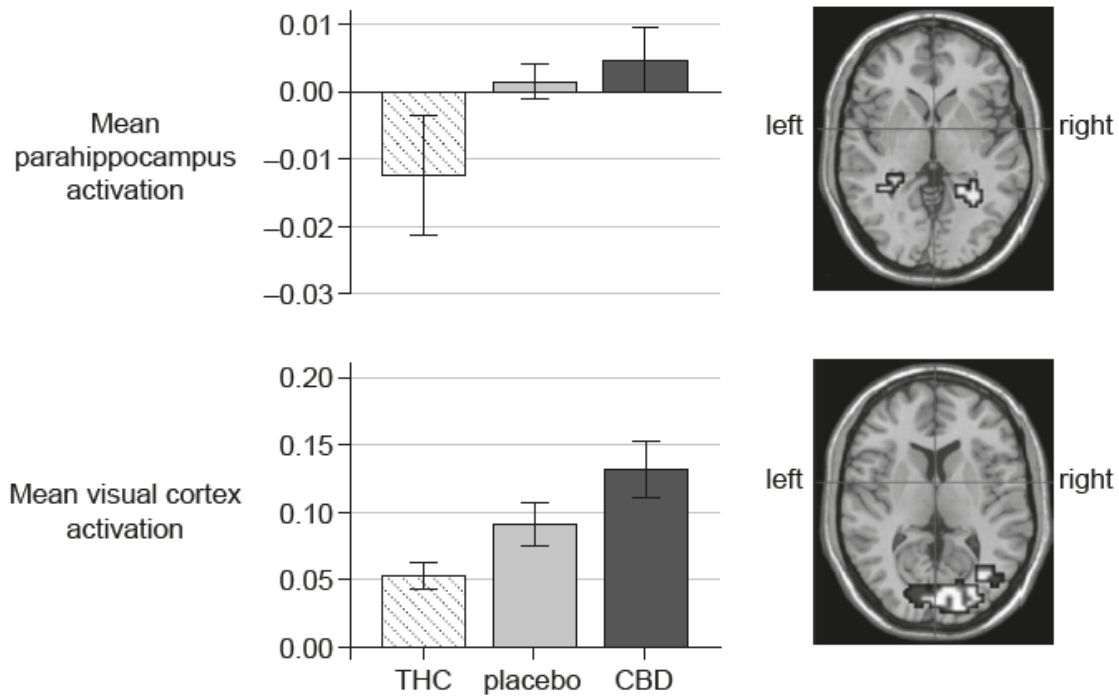
During pre-competition training, some teams received injections of morphine. During competition, no morphine was administered. However, some teams thought they were receiving morphine injections. Instead, they were injected with a placebo (a saline solution) or the placebo plus naloxone (an endorphin 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]
- Analyse the effect of the placebo as seen in the data. [2]
 - Suggest a reason for the reduced pain tolerance in team D during competition. [1]
- Analyse the data collected in the week following competition. [2]

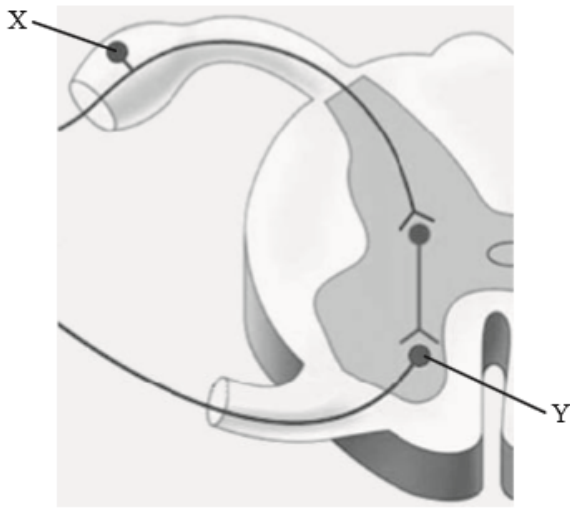
D-9-tetrahydrocannabinol (THC) and cannabidiol (CBD), the two main psychoactive ingredients of the *Cannabis sativa* plant, have distinct symptomatic and behavioural effects. Functional magnetic resonance imaging (fMRI) was used in healthy volunteers to examine their effects on the parahippocampus, an 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]

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

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]

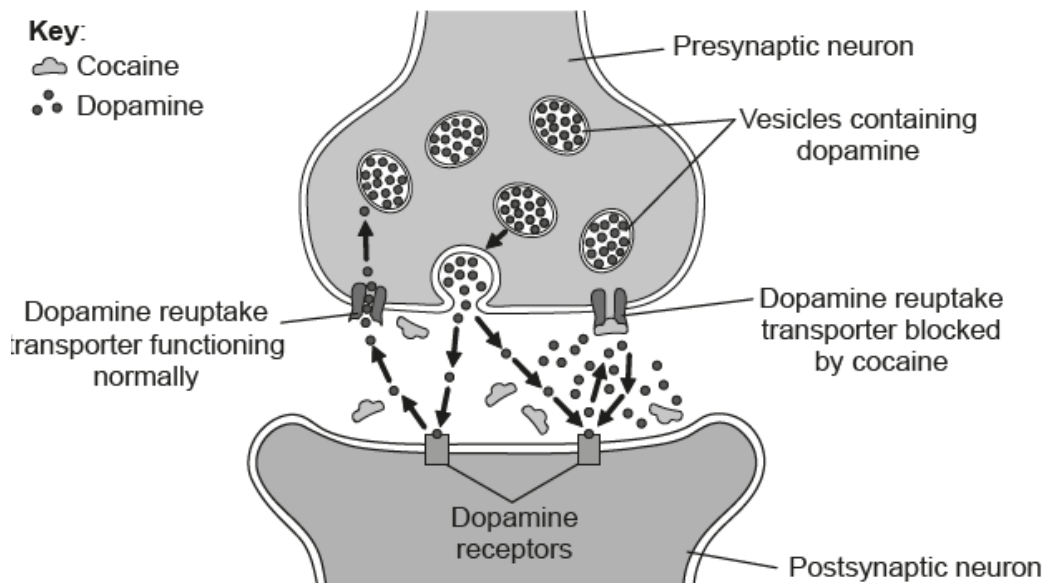
c. State whether the following psychoactive drugs are excitatory **or** inhibitory, using the table below.

[2]

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

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.

[2]

c. Outline the structure of a reflex arc.

[3]

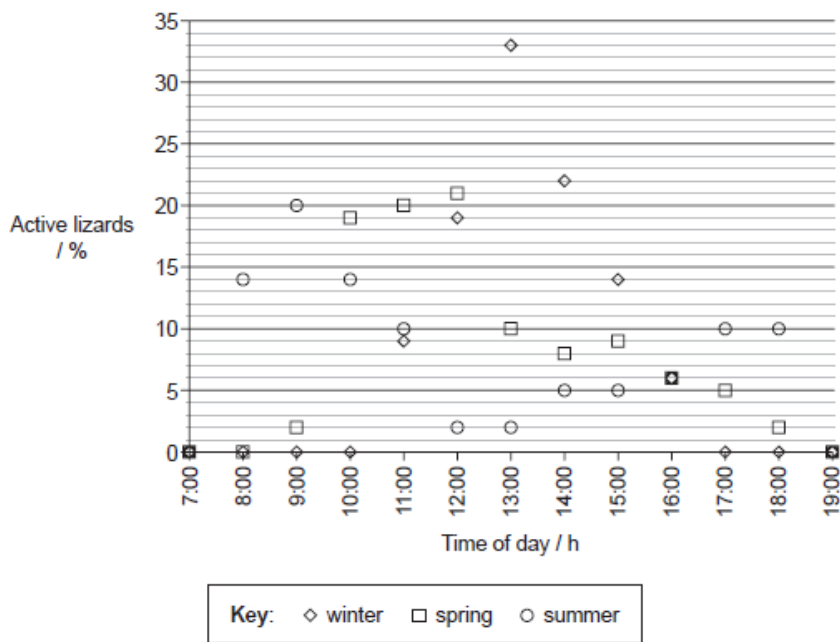
d. State the type of receptor that detects odours.

[1]

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.



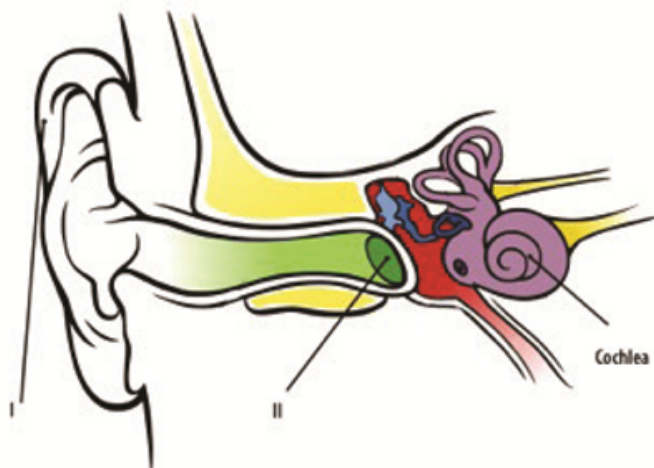
[Source: www.biodiversityexplorer.org]



[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]

The diagram shows the structure of the human ear.



[Source: © International Baccalaureate Organization 2013]

a (i) Label structures I and II

[1]

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.

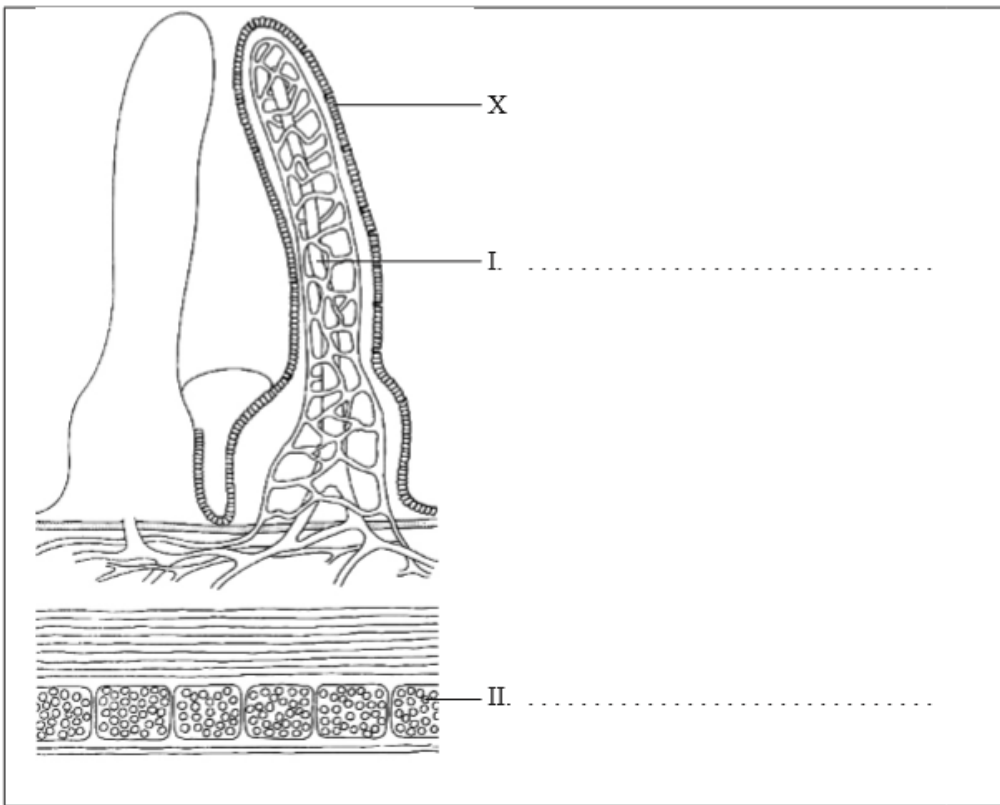
[2]

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]

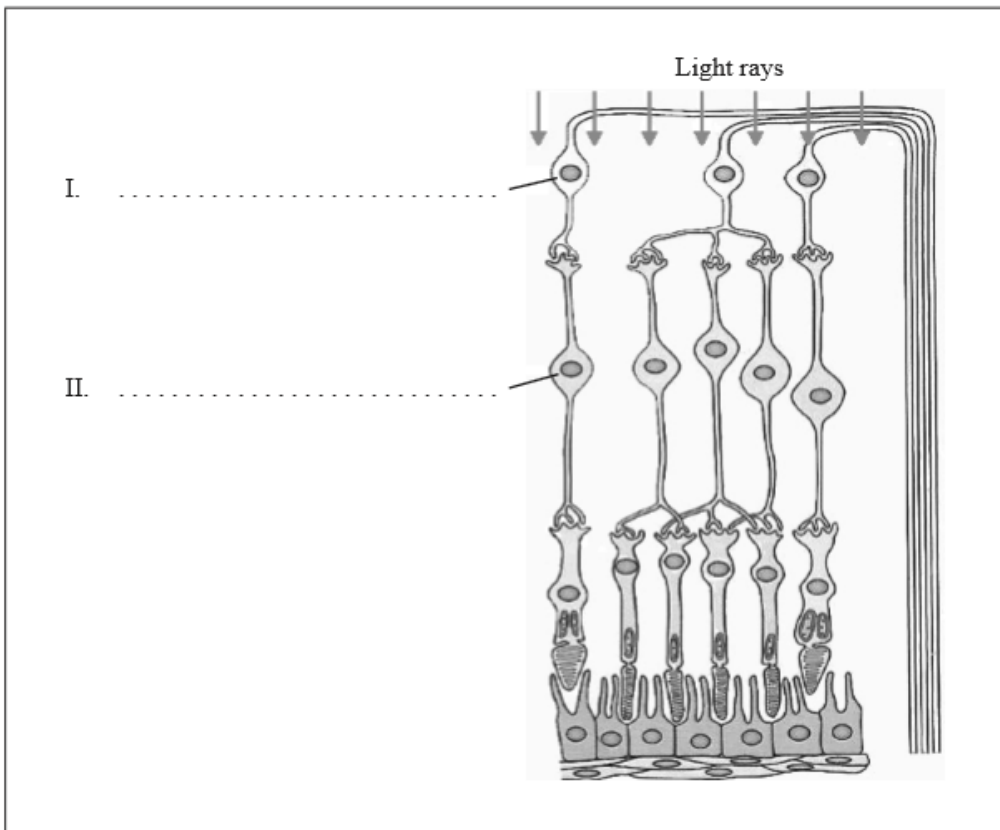
The diagram below shows a section through the ileum.



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]

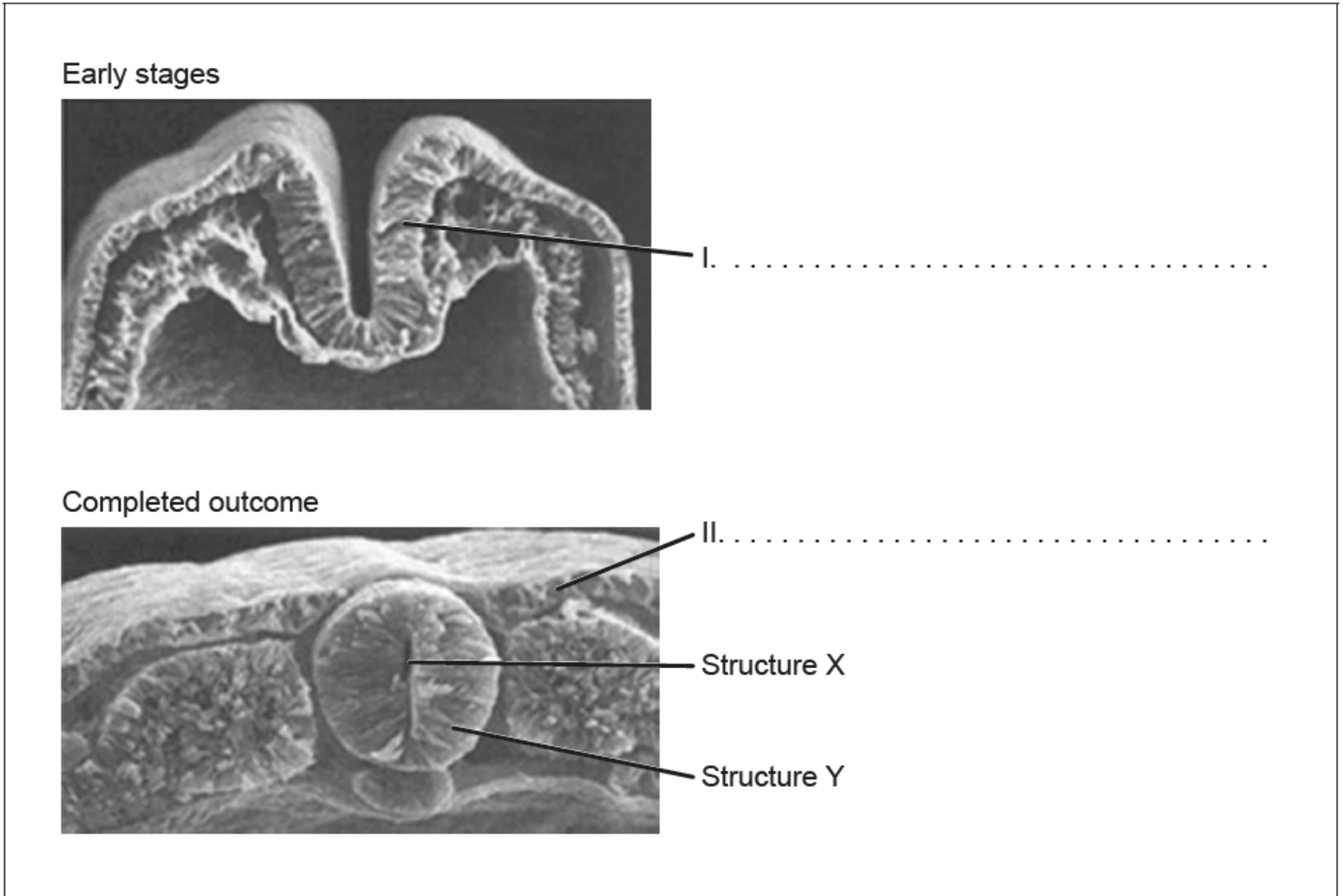
b. Outline the pupil reflex.

[2]

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

[3]

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



[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.

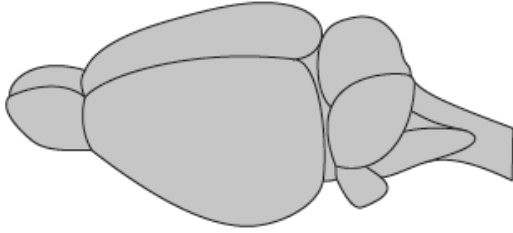
a.iii. State the condition that arises if the closure of structure X is incomplete during embryonic development.

[1]

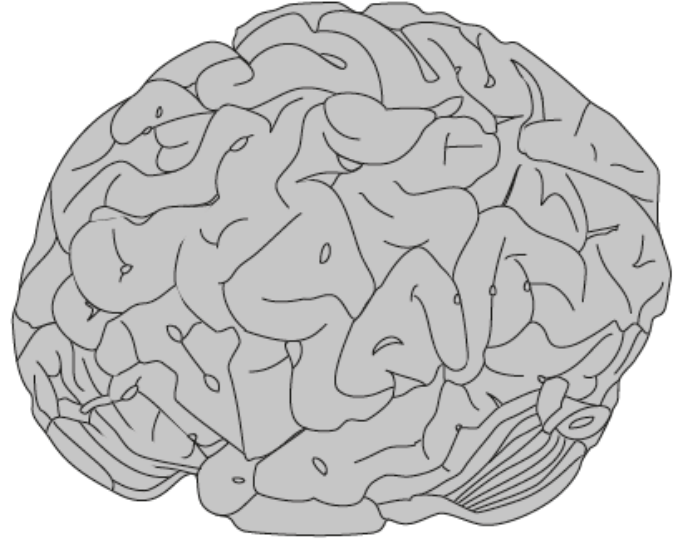
b. The diagrams show a rat brain and a human brain. They are not drawn to scale.

[2]

Rat brain



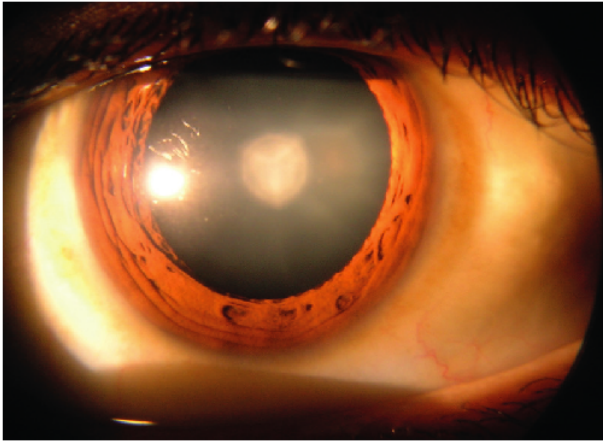
Human brain



[Source: © International Baccalaureate Organization 2017]

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

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]
