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Some questions may have been altered or removed compared to the version of this paper used during the competition period.

Answers are not provided at this time.

Students are not expected to have memorised all the facts assessed, or be familiar with all the topics presented. Their biological intuition and problem solving is being assessed.

British Biology Olympiad 2022

This was split into 2 papers of 45 minutes each.

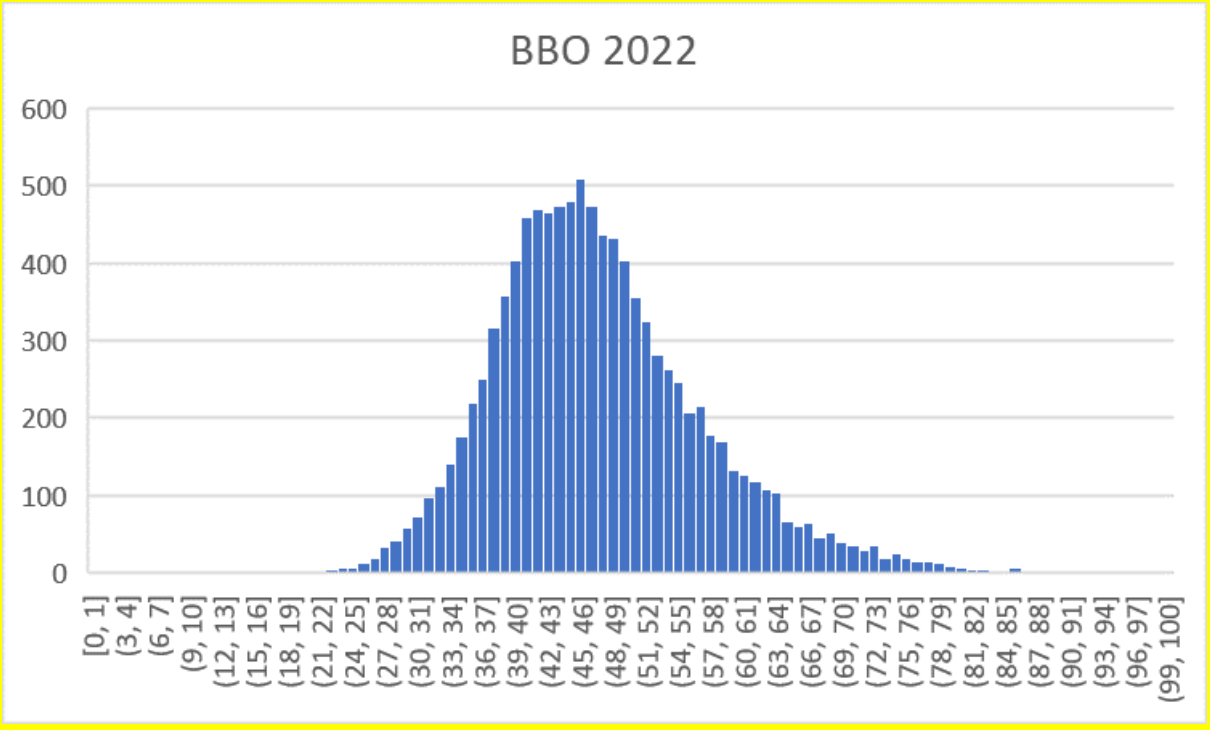
You may use a calculator.

It is recommended that you have pen and paper to hand for rough work.

No marks are subtracted for incorrect answers.

Some questions have more than one answer you need to choose. For some questions, you need to put the answers in the correct order.

Award	**Percentage score**	**Percentage of students who took part in the British Biology Olympiad 2022**
Gold	63.63%	5%
Silver	56.53%	10%
Bronze	50.87%	15%
Highly Commended	47.30%	15%
Commended	44.27%	15%



British Biology Olympiad 2022 Paper 1

Duration: 45 minutes
Total marks: 89

Question 1

Part 1 of 2
Chemical forces cause proteins to fold into their functional shapes via several stages.

Part 2 of 2
Which structural level of a protein is unaffected by hydrogen bonding?

1 mark
Choose ONE
a) Primary

b) Secondary

c) Tertiary

d) Quaternary

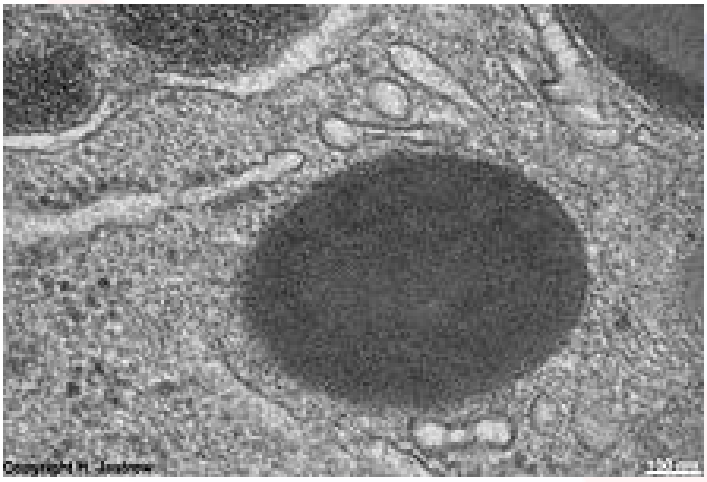
e) All levels are affected.

f) No levels are affected.

Question 2

Part 1 of 2

Lysosomes are membrane bound organelles which contain digestive enzymes.Which cell type would be best for studying lysosomes?



Human lysosome within cell

Part 2 of 2

Select the most appropriate answer

1 mark

Choose ONE

a) Fast-twitch muscle cell

b) Neuron

c) Bacterial cell

d) Phagocytic white blood cell

Question 3

Part 1 of 1

Which of the following are passive / facilitated (energetically favourable) processes in cells?

2 marks

Choose as many as appropriate

a) The establishment of a concentration gradient

b) Osmosis

c) Diffusion

d) The hydrolysis of ATP

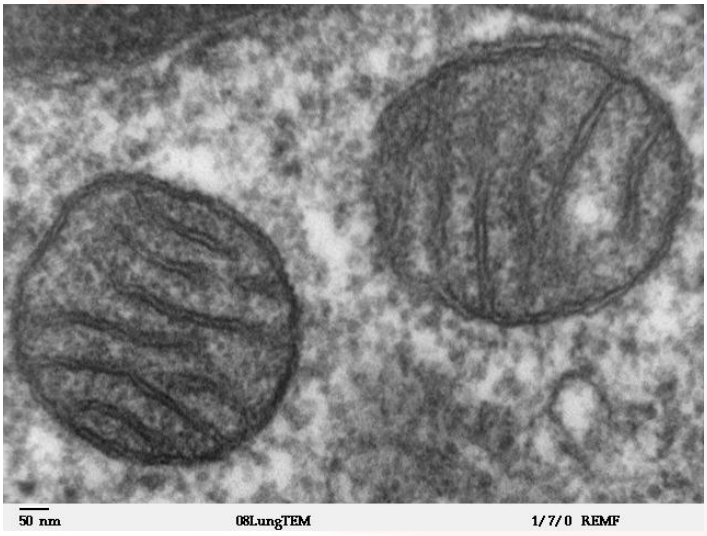
e) Synthesising a protein

f) Nucleotide polymerisation

Question 4

Part 1 of 2

Mitochondria have very crenated (creased) inner membranes, and the thylakoid membranes of chloroplasts are also highly folded and stacked.



Transmission electron microscope image credit Louisa Howard

Part 2 of 2

Why are the membranes of mitochondria and chloroplasts folded?

1 mark

Choose ONE

a) To maximise the amount of membrane for protons and electrons to diffuse through.

b) To increase the concentration gradient of protons.

c) To maximise the amount membrane-bound of respiratory / photosynthetic proteins which can fit in the cell.

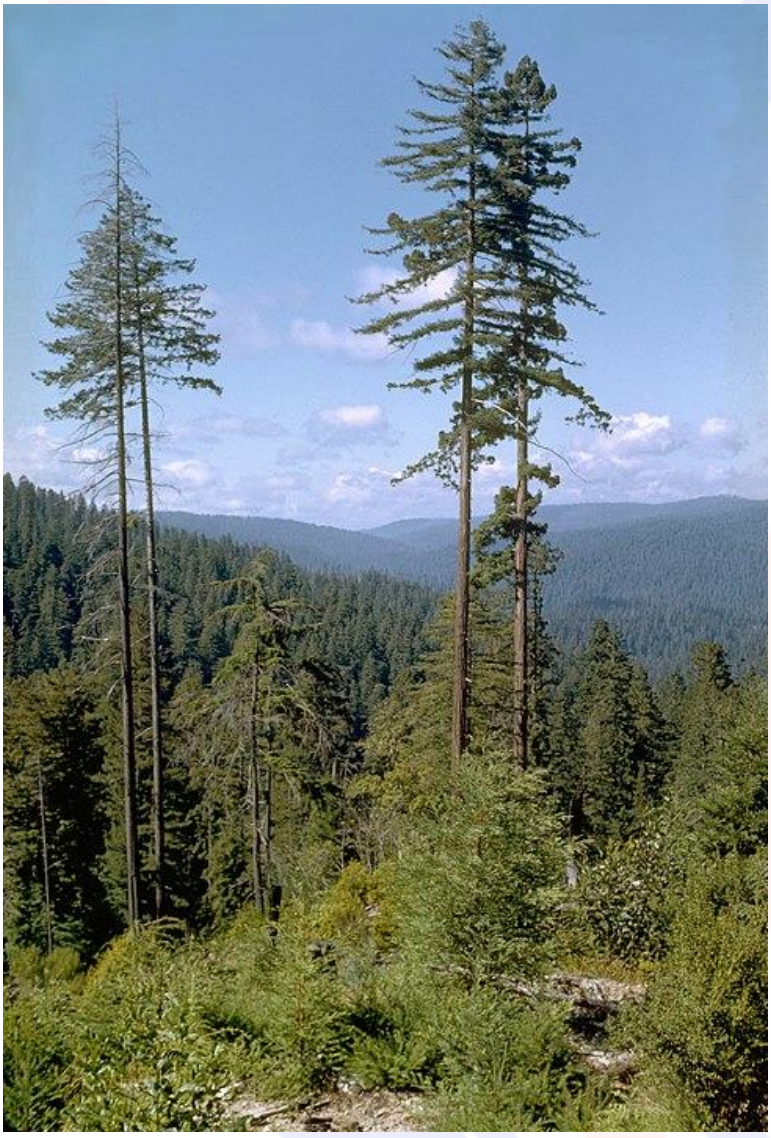
d) To increase the amount of light absorbed by the membranes.

e) To maximise the amount of protons / electrons which can be stored by the membranes.

Question 5

Part 1 of 2

The tallest trees, such as giant redwoods, are particularly sensitive to climate change, and many are already dying.



Hyperion, national parks service

Part 2 of 2

Why are very tall trees vulnerable?

1 mark

Choose ONE

a) They already require more carbon dioxide to grow very tall

b) They are already more exposed to the heat of the sun

c) Their highest leaves are already normally water-stressed and they cannot withstand drought

d) They are already more likely to be attacked by pests

e) Oxygen levels are insufficient for respiration at the tree top

Question 6

Part 1 of 1

Ribosomes are responsible for deciphering the genetic code.How do ribosomes ensure the correct amino acids are added to a growing polypeptide (protein)?

1 mark

Choose ONE

a) Ribosomes only add amino acids which have similar chemical properties to the rest of the polypeptide

b) Ribosomes select amino acids based on the secondary structure of the polypeptide

c) Ribosomes only add amino acids if there is proper base-pairing between RNA molecules

d) Ribosomes only add amino acids which bind to the mRNA

e) Ribosomes select amino acids based on the secondary structure of mRNA

Question 7

Part 1 of 1

Skeletal muscle can contract and relax much quicker than smooth muscle (which lines the gut *etc*).Which of these could increase the speed of muscle contraction (i.e. are limiting factors on muscle contraction).

4 marks

Choose as many as appropriate

a) Increasing the temperature of the muscle to 37 degrees Celsius

b) Increasing the number of sodium ion channels causing action potentials

c) Increasing the number of mitochondria

d) Increasing the rate of anaerobic glycolysis

e) Increasing the number of calcium ion channels

f) Mutations causing myosin to form and break cross-bridges more quickly

g) Increasing the amount of actin

Question 8

Part 1 of 2

If heart rate increases 4-fold, and stroke volume increases 1.5-fold, how many fold does cardiac output increase?*Type a number to one decimal place*

1 mark

Write something below

_____

Part 2 of 2

If cardiac output is 5 l/min, how much blood flows through the pulmonary artery?*Type a whole number in terms of l/min. E.g. '4' is acceptable*

1 mark

Write something below

_____

Question 9

Part 1 of 1

Assign these descriptions to the correct blood vessel.

3 marks

Groups

Arteries

Venules

Pulmonary veins

Arterioles

Put into the groups above

a) Very muscular

b) Carry oxygenated blood at low pressure

c) Very elastic

d) Control blood supply to tissues

e) Thin-walled

Question 10

Part 1 of 3
Endosymbiosis is the leading evolutionary theory for the origin of eukaryotic cells. Endosymbiosis states that the ancestors of eukaryotic cells could engulf other cells to establish a symbiotic relationship, which eventually became permanent.

Part 2 of 3
Which of the following statements about endosymbiosis are true?

2 marks
Mark the following as TRUE or FALSE
a) Chloroplasts have a double membrane due to endosymbiosis.

TRUE FALSE
b) Bacteria are ancestors of chloroplasts and mitochondria.

TRUE FALSE
c) Bacteria lost their chlorophyll gene during endosymbiosis.

TRUE FALSE
d) The flagella of some eukaryotic cells are derived from Bacteria.

TRUE FALSE
e) Plant cell ancestors acquired chloroplasts before mitochondria.

TRUE FALSE

Part 3 of 3
Sort these organelles into whether most scientists believe they arose from endosymbiosis or not.

4 marks
Groups
Endosymbiosis

Other origin

Put into the groups above
a) Cell nucleus

b) Vacuole

c) Plant plastids

d) Lysosomes

e) Mitochondria

f) Ribosomes

Question 11

Part 1 of 2
Some groups of life are defined by universal characteristics. For example, *all* mammals can produce milk, but *only* higher mammals give birth to live young.

Part 2 of 2
Assign these groups, which start broad and become narrow, universal characteristics which **all** organisms within that group and subsequent groups share.

4 marks
Groups
All life on Earth

Eukaryotes

Plants

Dicot plants

Put into the groups above
a) Two seed-leaves

b) Plastids(e.g. chloroplasts)

c) Cell membrane

d) Mitochondria

e) Flowers

f) Triplet code

g) Nucleus

Question 12

Part 1 of 2

An action potential in nerve cells is triggered when the potential across its membrane reaches a threshold which causes sodium ion channels to open rapidly.

Part 2 of 2

Which of these may cause an action potential?

3 marks

Choose as many as appropriate

a) Increased number of sodium/potassium ATPase pumps at the membrane

b) Increased number of potassium ion channels at the membrane

c) Increased number of leaky sodium ion channels at the membrane

d) Poison blocking channels allowing chloride ions into the membrane

Question 13

Part 1 of 2

In most organisms, in some cells, mitosis occurs without cytokinesis. This may result in...

2 marks
Choose ONE

a) cells with more than one nucleus.

b) cells that are unusually small.

c) cells lacking nuclei.

d) cell cycles lacking an S phase.

Part 2 of 2

What may happen if cytokinesis occurs without mitosis?

2 marks
Choose ONE

a) Cells with more than one nucleus.

b) Cells lacking nuclei.

c) Cells that are unusually large.

Question 14

Part 1 of 8
The DNA content of a diploid (2n) cell in the G1 phase of the cell cycle is *x*.

Part 2 of 8
The DNA content of the same cell at the start of meiosis I will be

1 mark
Choose ONE
a) 0.25*x*

b) 0.5*x*

c) *x*

d) 2*x*

Part 3 of 8
The DNA content at the start of meiosis II will be

1 mark
Choose ONE
a) 0.25*x*

b) 0.5*x*

c) *x*

d) 2*x*

Part 4 of 8
The DNA content at the end of meiosis II will be

1 mark
Choose ONE
a) 0.25*x*

b) 0.5*x*

c) *x*

d) 2*x*

Part 5 of 8
In the oocyte of a young female, a crossover (chiasma) between homologous arms of chromosome 7 occurs 60 million base pairs from one tip.A second chiasma occurs 45 million base pairs from the tip.



Pair of chromosomes with chiasmata

Part 6 of 8

How many base pairs are exchanged between the chromosomes?*Type you answer to the nearest million. E.g. type '30' for 30 million*

2 marks

Write something below

Part 7 of 8

In the same oocyte, a third crossover then forms 10 million bases from the tip.

Part 8 of 8

Now how many base pairs are exchanged between the chromosomes in total?*Type you answer to the nearest million. E.g. type '30' for 30 million*

2 marks

Write something below

Question 15

Part 1 of 6
A population contains 50 rats. 29 are black rats and 21 are white. Coat colour is controlled by a single gene, and the black allele is dominant.



White Rat (Rattus norvegicus) - Flickr Tambako The Jaguar CC BY-ND 2.0

Part 2 of 6
Calculate the frequency of the recessive (white) allele. Give your answer to two decimal places.

2 marks
Write something below

Part 3 of 6
Calculate the number of heterozygous rats (to the nearest whole number).

2 marks
Write something below

Part 4 of 6
How do you expect this allele frequency to change in the next generation in the absence of selection?

1 mark
Choose ONE
a) Higher

b) Lower

c) No change

d) Impossible to tell

Part 5 of 6
In actual fact, when the researchers came back after twenty generations, they found that all of the rats were black.

Part 6 of 6
What should the researchers conclude?

2 marks
Choose ONE
a) Natural selection most probably favours the black allele.

b) The alleles have equal fitness and genetic drift most probably fixed the black allele by chance.

c) The environment most probably changed, which changed the activity of the alleles so both produce black rats.

d) Further study is needed to tell which of these three explanations are most probable.

e) None of these explanations is likely.

Question 16

Part 1 of 9
This question explores primary production in an ecosystem.

Part 2 of 9
Which organisms capture energy into an ecosystem (i.e. are the primary producers)?

2 marks
Choose as many as appropriate
a) Photoautotrophs

b) Chemoautotrophs

c) Heterotrophs

d) Detritovores

e) Omnivores

f) Saprotrophs

Part 3 of 9
Plants are a primary producer and capture energy from the sun into the ecosystem. The photosynthetic equation contains: * $C_6H_{12}O_6$* CO_2* H_2O* O_2

Part 4 of 9
Which chemical is the electron donor (is oxidised)?

1 mark
Choose ONE
a) $C_6H_{12}O_6$

b) CO_2

c) H_2O

d) O_2

Part 5 of 9
Which chemical stores the solar energy?

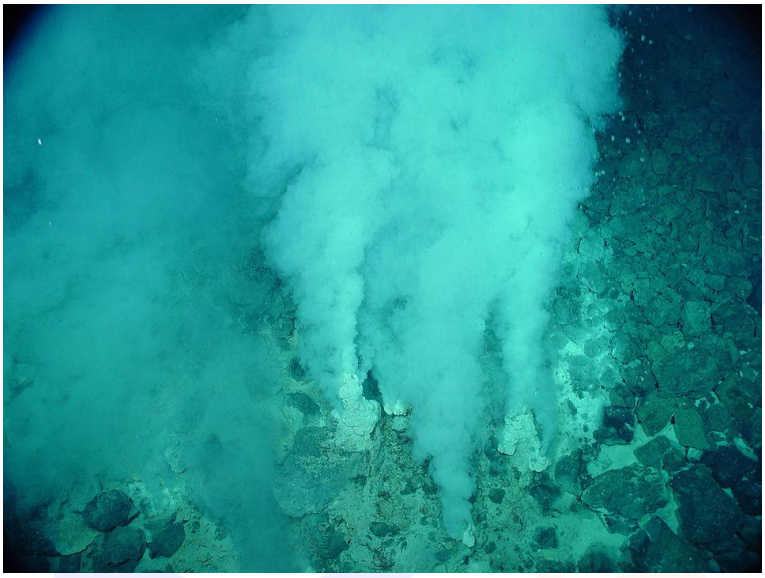
1 mark
Choose ONE
a) $C_6H_{12}O_6$

b) CO_2

c) H_2O

d) O_2

Part 6 of 9
Sunlight does not reach deep into the ocean. There are bacteria which can harvest chemical energy from volcanic vents. The chemicals involved in this reaction are: * $C_6H_{12}O_6$* CO_2* H_2O* H_2S* SIn this reaction, sulphur (S) is a product.



Bacterial matts around hydrothermal vent, credit NOAA

Part 7 of 9

Which chemical is the electron donor (is oxidised)?

1 mark

Choose ONE

a) $C_6H_{12}O_6$

b) CO_2

c) H_2O

d) H_2S

e) S

Part 8 of 9

How many elemental sulphur atoms (S) are generated per $C_6H_{12}O_6$?

2 marks

Write something below

Part 9 of 9

For **both** photosynthesis and chemical driven energy capture, are these statements *true* or *false*.

2 marks

Mark the following as TRUE or FALSE

a) When energy is stored, oxygen is produced

TRUE FALSE

b) When energy is stored, CO2 is used up

TRUE FALSE

c) The energy is stored in a reduced chemical

TRUE FALSE

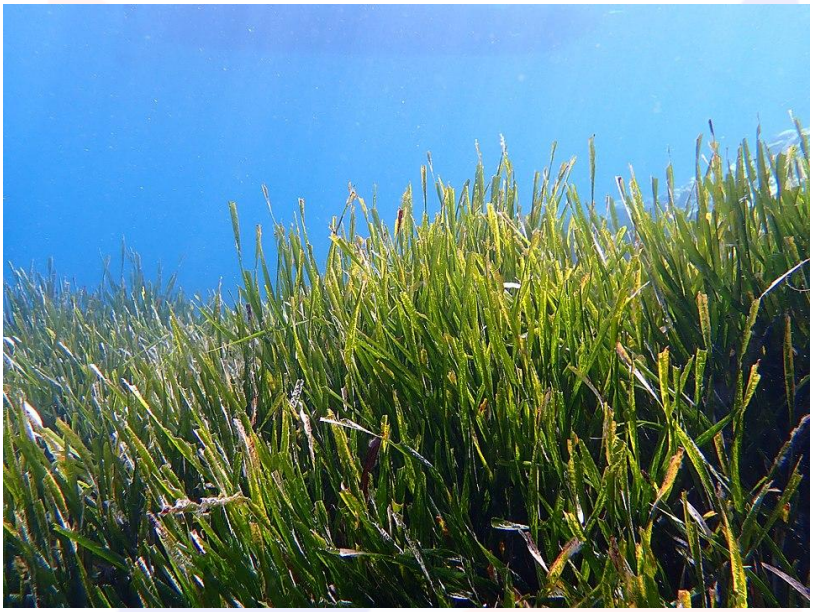
d) There is more energy in the products of the reaction than the reagents

TRUE FALSE

Question 17

Part 1 of 3

Scientists recently discovered seagrasses culture specific bacteria within their roots which are able to fix nitrogen gas from the air into biomolecules which the grass can use.



Neptune's seagrass, credit Frédéric Ducarme

Part 2 of 3

Which types of biologically important chemical bonds does nitrogen form?

3 marks

Choose as many as appropriate

a) Glycosidic bonds (sugars)

b) Peptide bonds (proteins)

c) Ester bonds (fats)

d) Base-pairing (nucleic acids)

e) Phosphodiester bonds (nucleic acids)

Part 3 of 3

What other nutrients will seagrass need to source from the **external environment** to grow?

3 marks

Choose as many as appropriate

a) Fresh water (non-salty)

b) Organic carbon (such as sugar or fat)

c) Protein

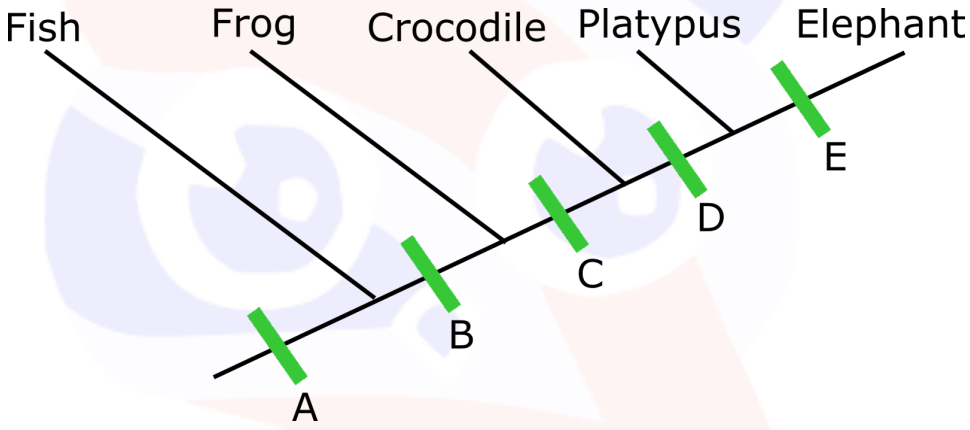
d) Soluble phosphate containing compounds

e) Soluble magnesium containing compounds

Question 18

Part 1 of 7

Monophyletic groups can be defined using evolutionary trees, based on which characteristics they share. Below, a simplified evolutionary tree of animals is shown with marked evolutionary events (A-E).The evolutionary events are:* **I** Formation of four legs* **II** Formation of milk-producing mammary glands* **III** Giving birth to live young* **IV** Formation of eggs with amniotic sacks* **V** Formation of vertebrae



Cladogram of animal evolution

Part 2 of 7

Sort the events I-V into order.*Put the first event (A) at the top, and the latest event (E) at the bottom.*

4 marks

Put into the correct order

a) III

b) IV

c) V

d) I

e) II

Part 3 of 7

The tree can be used to work out when the last common ancestor of pairs of animals lived. For example, the last common ancestor of frogs and elephants lived at point B.For each pair of animals below, state which point marks when the last common ancestor may have lived.

Part 4 of 7

Frogs and crocodiles

1 mark

Choose ONE

a) A

b) B

c) C

d) D

e) E

Part 5 of 7
Birds and elephants

1 mark
Choose ONE
a) A

b) B

c) C

d) D

e) E

Part 6 of 7
Whales and cows

1 mark
Choose ONE
a) A

b) B

c) C

d) D

e) E

Part 7 of 7
Insects and fish

1 mark
Choose ONE
a) A

b) B

c) C

d) D

e) E

Question 19

Part 1 of 4

Many flowers which appear uniform in colour to humans, show dark and light patterns when viewed in the ultra-violet spectrum.Usually the dark region is the centre of the flower. These dark areas tend to be larger in flowers growing in regions closer to the equator.



Dandelion in normal light (left) and ultraviolet (right) (Flickr tsaiproject CC BY 2.0)

Part 2 of 4

2 marks

Mark the following as TRUE or FALSE

a) The darker regions of flowers absorb UV radiation and may act as sun protection.

TRUE FALSE

b) Many insect pollinators have good vision in the UV region of light, thus the dark region helps attract the pollinators by acting as nectar guide.

TRUE FALSE

c) The larger dark area of flowers growing near the equator compensates for the reduced number of pollinating insects near the equator.

TRUE FALSE

d) Larger dark regions are less accurate as nectar guides.

TRUE FALSE

Part 3 of 4

Many tropical flowers are pollinated by birds or bats rather than insects.

Part 4 of 4

Match the feature of the flower to its most likely pollinator.

3 marks

Groups

Insects

Birds

Bats

Birds and bats

Put into the groups above

a) Large, strong flowers

b) Nectar is found at the base of long tube

c) Large white / pale petals

d) Produce very large amounts of nectar

e) Flowers turnto face sun

f) Flowers generate warmth to attract pollinators

Question 20

Part 1 of 3

What makes plants green?

1 mark

Choose ONE

a) Diffraction of light through thylakoid membranes

b) Refraction of light in the epidermis

c) Chemicals in the phloem fluid

d) Chlorophyll

e) Melanin

Part 2 of 3

Sunlight contains different colours. Which visible colour is **least** useful for photosynthesis?



D-Kuru/Wikimedia Commons

1 mark

Choose ONE

a) Blue

b) Green

c) Yellow

d) Red

e) All visible colours are equally useful

f) No visible colours are useful

Part 3 of 3

Blue light travels further through water than other colours, but any colour light travels less well through water than air.When deep aquatic plants are brought to the surface, what colour are they expected to appear to us compared to mostly green land plants.

1 mark

Choose ONE

a) Darker blue

b) Darker red

c) Lighter green

d) Lighter blue

e) Lighter red

Question 21

Part 1 of 3

No living insects are larger than about 70 g.However, the largest fossil insects are estimated to have weighed 450 g.Scientists have found it is impossible to breed insects larger than about 70 g, except when special manipulations are made.*Note: all insects live on land. The largest and smallest insects can fly*



Elephant beetle

Part 2 of 3

Using this information, select the most likely limiting factor for insect size.

1 mark

Choose ONE

a) **A** Insect exoskeletons cannot support larger bodies

b) **B** There is insufficient food for larger insects

c) **C** There is currently insufficient genetic diversity to select on to make larger insects

d) **D** Insect respiratory systems (trachea; air-filled tubes) cannot currently deliver sufficient oxygen to cells far from the surface

e) **E** Insect circulatory systems (fluid filled sacks) cannot deliver sufficient nutrients to cells far from their heart

Part 3 of 3

Match the potential limiting factor to the special manipulation which would overcome it.

3 marks

Groups

A

B

C

D

E

Put into the groups above

a) Microgravity /space-station

b) High-oxygenchambers

c) Remove wings,limit movement

d) Hand feed

e) Gene-editing

Question 22

Part 1 of 7

Tristerix (*Tristerix aphyllus*) is a plant of the mistletoe family. Tristerix seeds are eaten by Mockingbirds (*Mimidae*), and are deposited on the hedgehog cactus (*Echinopsis chiloensis*) in their faeces. Tristerix seeds germinate to produce a long mobile appendage. At night, the cactus opens its stomata to exchange gasses, and Tristerix enters through them, then grows inside.A year later, tristerix punches through the cactus and produces flowers and their nectar is drunk by the Glowing Puffleg hummingbird (*Eriocnemis vestita*).



The flowers of Tristerix (Tristerix aphyllus) being pollinated by a hummingbird, Chile. © BBC Studios

Part 2 of 7

Which symbiotic relationship do Tristerix (*Tristerix aphyllus*) and Mockingbirds (*Mimidae*) have?

1 mark
Choose ONE
a) Parasitic

b) Commensalist (neutral)

c) Mutualist

d) Predatory

Part 3 of 7

Which symbiotic relationship do Tristerix (*Tristerix aphyllus*) and Glowing Pufflegs (*Eriocnemis vestita*) have?

1 mark
Choose ONE
a) Parasitic

b) Commensalist (neutral)

c) Mutualist

d) Predatory

Part 4 of 7

Which symbiotic relationship does Tristerix (*Tristerix aphyllus*) and hedgehog cacti (*Echinopsis chiloensis*) have?

1 mark

Choose ONE

a) Parasitic

b) Commensalist (neutral)

c) Mutualist

d) Predatory

Part 5 of 7

Scientists do not know how Tristerix finds open stomata.

Part 6 of 7

Hypothesise which types of **tropism** Tristerix seeds may use to enter cacti?

3 marks

Choose as many as appropriate

a) Gravitropism

b) Chemotropism

c) Thigmotropism

d) Phototropism

e) Hydrotropism (hygrotropism)

Part 7 of 7

Most plant stomata are open during the day time. Why does Tristerix only enter stomata at night?

1 mark

Choose ONE

a) The tristerix manipulates the cactus to open stomata during the night.

b) To reduce water loss, the cactus stomata only open at night.

c) The cactus keeps stomata open at night to keep cool.

d) Tristerix only grows at night.

British Biology Olympiad 2022 Paper 2

Duration: 45 minutes
Total marks: 95

Question 1

Part 1 of 10

Flower colour is a common trait bred for by gardeners. A flower breeding company wanted a **pure breeding white flower**. The breeders start with a collection of clematis plants. Most have purple flowers. *For this question, assume the purple/white colouring is controlled by a single gene.*



Purple clematis flower

Part 2 of 10

How could you find your first white clematis flower?

3 marks

Choose as many as appropriate

a) Cross the purple clematis with a white flowering pea (a distant species)

b) Mutagenise the seed of a purple clematis with x-rays

c) Search collections for clematis which already have white flowers

d) Grow the plants on very acidic soil

e) Grow purple clematis in high light to bleach away the colour

f) Search the wild for a clematis which has white flowers

Part 3 of 10

The breeders succeeded in finding a white clematis!



White clematis

Part 4 of 10

However, when the clematis was selfed (bred with itself) some of its progeny had white flowers but others had purple. Roughly, 3/4 of the progeny had white flowers and 1/4 were purple.

Part 5 of 10

For the white flower allele, the parent clematis was...

1 mark
Choose ONE
a) homozygous.

b) heterozygous.

Part 6 of 10

The white colour is...

1 mark
Choose ONE
a) recessive.

b) dominant.

Part 7 of 10

What proportion of the white flowering progeny are expected to be homozygous for the white allele?*Give a number to two decimal places*

2 marks
Write something below

Part 8 of 10

How could you identify homozygous white flowers?

2 marks

Choose as many as appropriate

a) Choosing the tallest plants

b) Choosing the whitest flowers

c) Checking the flower colour of the progeny

d) Sequencing the genomes of the white flowers

e) Crossing the white flowers with a purple flower and checking the flower colour of the progeny

Part 9 of 10

The breeders found a plant which was true breeding (homozygous) for the white colour. However, when the breeders sold the seed to farmers, there was a big problem. The seeds germinated, but most of the plants died before they flowered!

Part 10 of 10

What are likely causes of this?

2 marks

Choose as many as appropriate

a) The purple pigment of the flower was also a plant defence compound

b) The white flowers attracted herbivores

c) The purple pigment of the flower is essential for plant growth

Question 2

Part 1 of 5

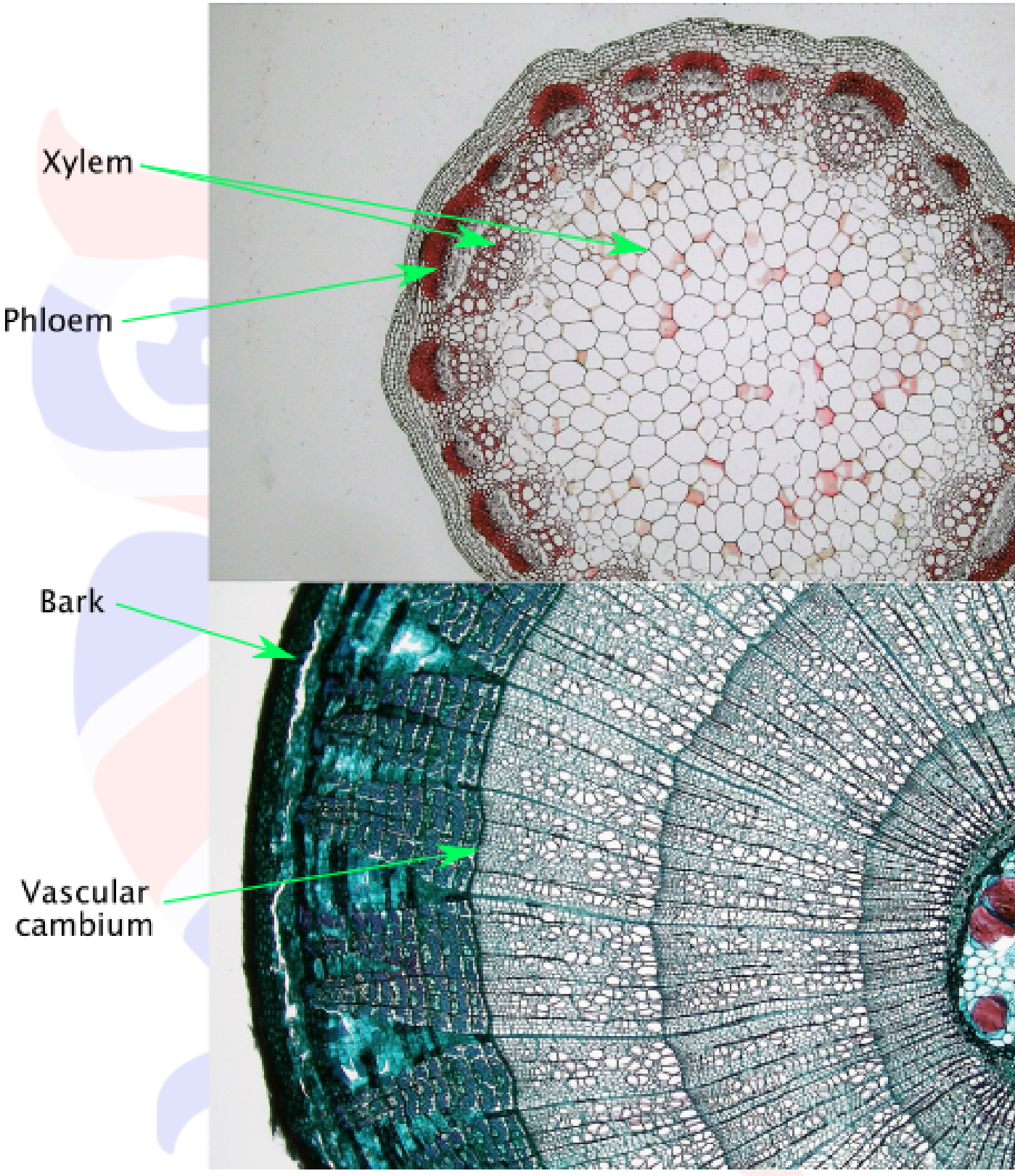
"Girdling" is the process of removing outer tissues around the branch or trunk of a woody plant.



Girdled Birch Tree - Flickr Dave Bonta CC BY-NC-ND 2.0

Part 2 of 5

Girdling can be shallow or deep. * Shallow girdling removes tissues to the vascular cambium. * Deep girdling removes even more tissue.The top image below shows the cross section of a small plant stem, which you may be familiar with. * The phloem carries sugars* The xylem carries waterThe bottom image shows the cross section of a larger woody stem, which contains the same tissues. Work out which tissues are the xylem and phloem.



Berkshire Community College Bioscience Image Library

Part 3 of 5

What will happen if a **branch** of a grape vine is girdled?*Tick all the correct statements.*

3 marks

Mark the following as TRUE or FALSE

a) If the girdling is shallow, it will not have any effect on the plant

TRUE FALSE

b) If the girdling is shallow, the grapes on the branch will be sweeter

TRUE FALSE

c) If the girdling is deep, the leaves on the branch will wilt

TRUE FALSE

d) If the girdling is deep, the branch will die

TRUE FALSE

e) If the girdling is deep, the plant will die

TRUE FALSE

Part 4 of 5

What will happen if a **trunk** of a grape vine is girdled?*Tick all the correct statements.*

2 marks

Mark the following as TRUE or FALSE

a) If the girdling is shallow, it will not have any effect on the plant

TRUE FALSE

b) If the girdling is deep, the leaves will wilt

TRUE FALSE

c) If the girdling is deep, the plant will die

TRUE FALSE

d) If the girdling is shallow, the roots will not grow

TRUE FALSE

Part 5 of 5

The xylem vessels have thick, strong walls. Why?

1 mark

Choose ONE

a) The xylem is under high pressure.

b) The xylem is under high tension.

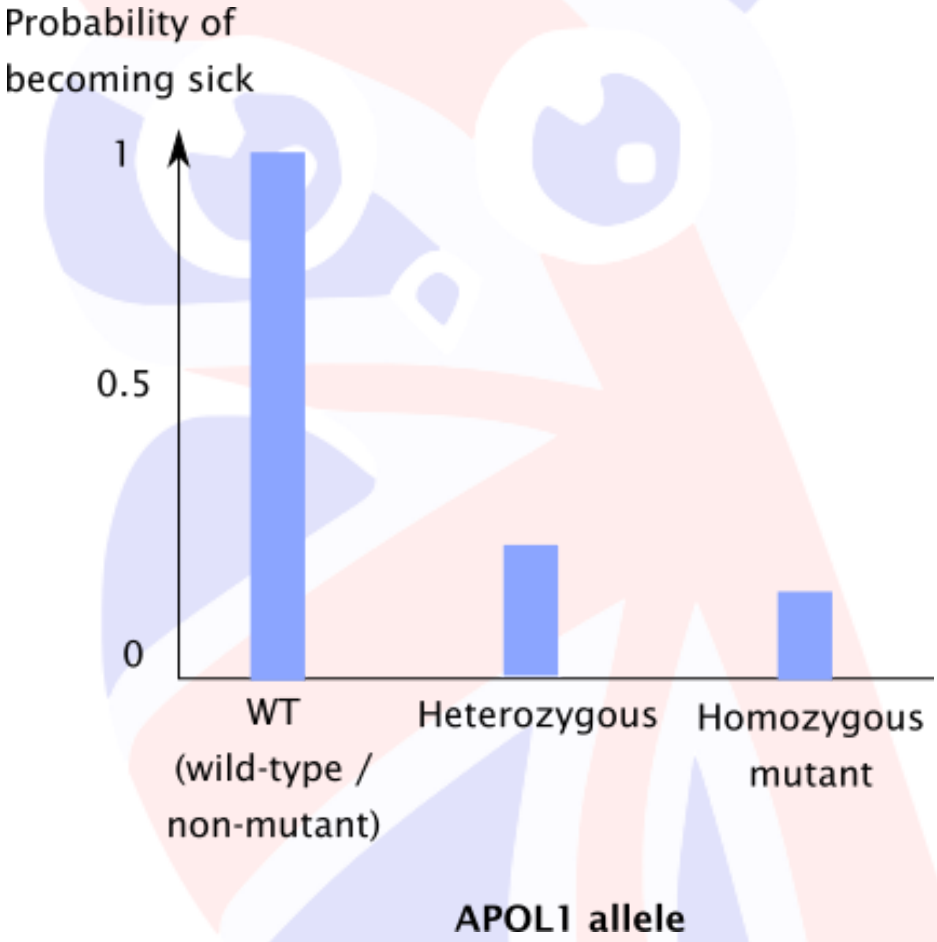
c) The xylem must be protected from herbivores.

d) To resist the movement of water into the xylem by osmosis.

Question 3

Part 1 of 5

Trypanosomes are single-celled parasites found across Africa. Almost all people are naturally immune to *Trypanosoma brucei brucei* due to a protein in our blood called APOL1 which lyses the cells. However, many people are vulnerable to *Trypanosoma brucei gambiense*.In some African populations, about 60% of people are found to be genetically resistant to *T. gambiense*.To investigate why, scientists measured the likelihood of people with different APOL1 alleles becoming sick with *T. gambiense* after they get infected.



Graph

Part 2 of 5

Which of these is correct?

1 mark

Choose ONE

a) The mutation increases the risk of disease

b) The mutation is recessive

c) The mutation is dominant

d) Risk of disease is determined by alleles of a different gene

Part 3 of 5

Calculate the frequency of the mutant APOL1 alleles in the african population.*Give your answer as a decimal to two decimal places*

3 marks
Write something below
_____

Part 4 of 5
The same African populations are found to have high rates of severe kidney disease.Scientists have discovered that homozygous carriers of APOL1 mutations have a high risk of kidney disease, whereas heterozygotes do not.

Part 5 of 5
Mark the following as *true* or *false*

1 mark
Mark the following as TRUE or FALSE
a) The frequency of the mutant allele is probably increasing in Africans over time.

TRUE FALSE
b) Natural selection is acting to maintain an equilibrium of wild-type and mutant APOL1 alleles in Africa.

TRUE FALSE
c) If a drug to treat *T. gambiense* is widely available, the frequency of mutant alleles will increase.

TRUE FALSE
d) If a drug to treat the kidney disease is widely available, the frequency of mutant alleles will increase.

TRUE FALSE
e) The frequency of the mutant allele is likely to be higher in Europeans than Africans.

TRUE FALSE

Question 4

Part 1 of 4

Ancient Mesopotamians used creatures called Kungas as the first beasts of burden. Kungas were said to be docile and strong like donkeys, but tall and fast like horses. Only recently, scientists discovered what Kungas were by genetic sequencing of equine remains found in tombs.Kungas are a hybrid of female donkeys (*Equus africanus*) crossed with male Tibetan asses (*Equus hemionus*). They were bred specially by ancient people and were very valuable.



Depiction of an equid, thought to be the kunga. Detail from the War panel of the 3rd millennium BC 'Standard of Ur' mosaic, in the British Museum - Agricolae, Wikimedia, CC BY-SA 3.0

Part 2 of 4

What are some possible reasons why Kungas have to be artificially bred?

3 marks

Choose as many as appropriate

a) The parent species have incompatible genetic codes

b) The parent species are not sexually attracted to one another

c) The parent species live far apart

d) Kungas are badly adapted in the wild, so die

Part 3 of 4

Kungas were said to be sterile.Why might this be?

2 marks

Choose as many as appropriate

a) Kungas are all the same sex

b) Historians are mistaken and Kungas probably were not sterile

c) The parent species may have different numbers of chromosomes

d) There may be some genes in the parent species which are lethal to Kungas if homozygous

Part 4 of 4

What are possible reasons that the sex of the Kunga's parent species matters?

4 marks

Choose as many as appropriate

a) The Kunga requires one X chromosome from each species

b) The Kunga requires one Y chromosome from each species

c) The hormones of the developing Kunga and its mother must interact correctly

d) The autosomes (non-sex chromosomes) that the Kunga inherits depends on the sex of each parent

e) Each sex of each parent species may leave different epigenetic imprints which alter gene expression in the Kunga

f) The Kunga may need mitochondrial genes found only in *Equus africanus*

g) The Kunga may need mitochondrial genes found only in *Equus hemionus*

Question 5

Part 1 of 6

A researcher is working on a DNA plasmid. The plasmid contains 5000 nucleotides (5 kBp).The plasmid has restriction (cut) sites for nuclease enzymes *EcoRI* and *BamHI*. The plasmid contains 2 *EcoRI* sites and ***x*** *BamHI* sites. Both enzymes are used by the researcher to cut the plasmid. The researcher observed 3 bands when the product was run on an agarose gel.

Part 2 of 6

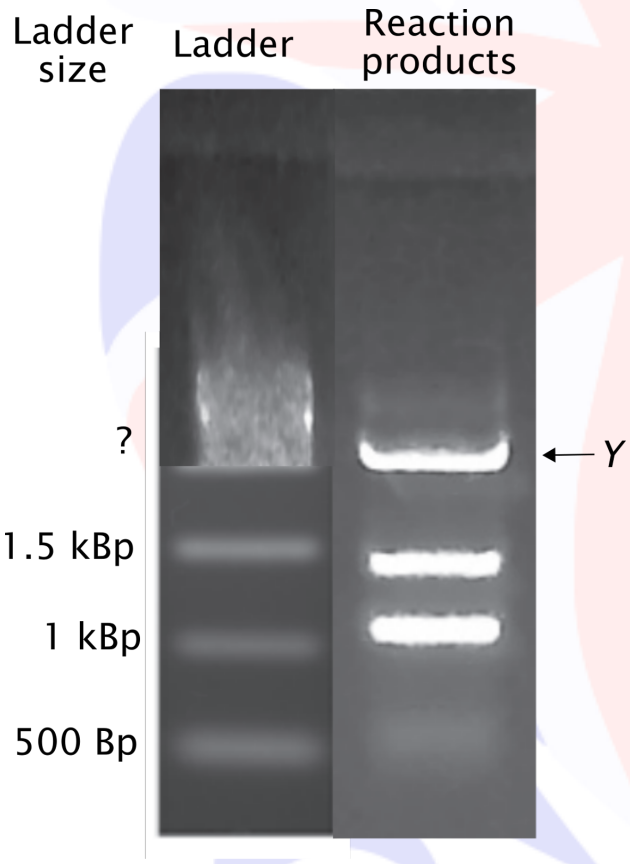
What is the value of ***x***? *Type a numeral. E.g. '5'*

1 mark

Write something below

Part 3 of 6

The researcher compared the size of the bands to a ladder of nucleic acids of known length, as shown in the image. However, there was a problem with the ladder, so the size of one band could not be measured directly.



Part 4 of 6

Determine the size of the unknown band (***y***) using the available information.*Type your answer in Bp. (I.e. 10 kBp or 100000 Bp are acceptable)*

2 marks

Write something below

Part 5 of 6

This researcher's experiment is similar to the process of 'DNA fingerprinting'.

Part 6 of 6

How does DNA fingerprinting distinguish between different people?

3 marks

Choose as many as appropriate

a) Mutations in some people may create or destroy cut sites

b) Mutations in some people may increase or decrease the distance between cut sites

c) Different people express different nuclease enzymes

d) Some people express more or less nuclease enzymes

e) Many sequences are tested to see differences between close relatives

Question 6

Part 1 of 12
The polymerase chain reaction (PCR) is a method invented to amplify nucleotide sequences.The technique works by:* Primers made of DNA bind (anneal) to the sequence to be amplified.* DNA polymerase extends the primers along the sequence.* The sequence is 'melted' so the new double strand sequence dissociates into single strands.* The process repeats.

Part 2 of 12
The reaction is primarily controlled by changing the temperature of the reaction in a machine called a *thermocycler*.This is because temperature controls the melting of the sequences.



G-STORM GS4 thermal cycler

Part 3 of 12
Rank the following steps by the temperature at which they take place.*Put the highest temperature step at the top, and the lowest temperature step at the bottom.*

2 marks
Put into the correct order
a) Melting the extended sequences

b) Extending the primers

c) Primer annealing to the sequences

Part 4 of 12
Different primers have different binding (annealing) temperatures depending on the energy it takes to overcome the base-pairing.

Part 5 of 12
Rank the following primers by the temperature at which they anneal.*Put the highest temperature primer at the top, and the lowest temperature primer at the bottom.*

2 marks

Put into the correct order
a) Short primer with lots of A/T bases.

b) A short primer with a sequence which does **not** match the target sequence very closely.

c) Long primer with lots of G/C bases.

d) Short primer with lots of G/C bases.

Part 6 of 12
PCR usually uses a *Taq* DNA polymerase. Taq polymerase was originally taken from a thermophilic (heat loving) bacterium that lives in hot springs.

Part 7 of 12
What are the reasons that Taq polymerase is suitable for PCR?

4 marks
Choose as many as appropriate
a) Nucleotides are universal, so Taq can replicate sequences from any organism.

b) High temperatures used for melting sequences denture Taq.

c) The amplification is quicker if it can take place at a higher temperature.

d) Bacterial polymerases are very error prone.

e) Taq polymerase can amplify mRNA.

Part 8 of 12
qPCR is used in diagnostic testing, and to detect the presence of sequences in the environment. In qPCR:* Primers which are *specific* to a sequence of interest are used to amplify the sequence.* A dye is included in the reaction which is fluorescent when it binds double-stranded DNA.* The amount of fluorescence is measured at the end of each thermocycle. Modern qPCR reactions can be extremely specific as they only detect the sequence the researcher chooses.They can also be extremely sensitive as they can amplify the sequence a billion fold.

Part 9 of 12
For each of these features, state whether they improve qPCR specificity or sensitivity, or do not directly impact specificity and sensitivity.*Think about qPCR, as described above, and not PCR in general*

4 marks
Groups
Improved specificity

Improved sensitivity

Not directly relevant

Put into the groups above
a) The amount of targetapproximately doublesevery thermocycle

b) Taq engineered to haveimproved 'proofreading'

c) 'Hot start' Taq (only works on primers binding at high temperatures)

d) The products of primer extension become targetsfor primer binding

e) Primers assessed againstdatabases of all genomes toidentify potential targets

Part 10 of 12

Which of these applications require very high specificity and sensitivity, as opposed to methods with normal sensitivity and specificity?

2 marks

Choose as many as appropriate

a) Detecting the presence of very endangered species from water / air samples taken from a habitat.

b) Diagnosing a common virus which has a high viral-load in infected people.

c) Diagnosing mutant DNA coming from tumor cells in blood samples.

d) Determining which organisms are male from cell samples.

Part 11 of 12

A qPCR test was carried out for some genetic material in two people.In **Sample A**, the measurements of fluorescence began increasing at the 18th cycle of heating and cooling.In **Sample B**, the measurements of fluorescence began increasing at the 16th cycle.

Part 12 of 12

Which of these are correct?

2 marks

Choose as many as appropriate

a) There was twice as much of the target material in one sample vs the other.

b) Sample B has more of the target material than sample A.

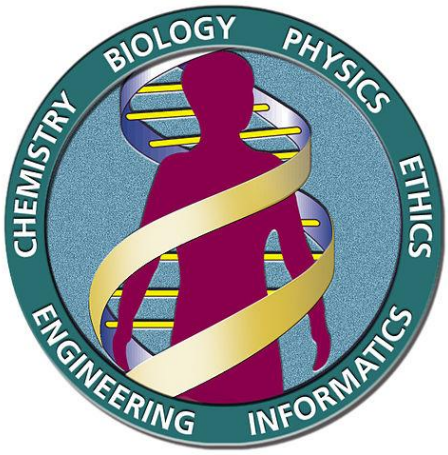
c) One person may have been heterozygous for the target allele, and the other homozygous.

d) The DNA extraction to prepare the samples may have been more efficient for person B than for person A.

Question 7

Part 1 of 13

When the human genome was first sequenced in 2003, scientists were very surprised to only identify about 20,000 genes.However, the human proteome contains 80,000 - 400,000 proteins.



Logo of the human genome project

Part 2 of 13

Why were so many fewer genes found than expected?

4 marks

Mark the following as TRUE or FALSE

a) The sequencing methods in 2003 missed large coding sections of the genome.

TRUE FALSE

b) There is somatic recombination within cells of our body to create a greater variety of proteins.

TRUE FALSE

c) Many genes undergo alternative splicing to generate a greater variety of proteins.

TRUE FALSE

d) Protein translation can start on different nucleotides (frame-shift) to generate different proteins.

TRUE FALSE

e) The bioinformatic tools at the time failed to annotate most of the genes.

TRUE FALSE

f) The human nucleus contains only 1/10th of DNA within the cell.

TRUE FALSE

g) Many proteins are chemically modified in various ways after translation.

TRUE FALSE

h) Most of the proteins in our cells are produced by microorganisms living in our guts.

TRUE FALSE

Part 3 of 13

The human genome project revealed that the haploid human genome contains 3.3 billion (3 300 000 000) nucleotides.The average length of a human protein is 480 amino acids.

Part 4 of 13
Using the information given in this question, calculate the proportion of the human genome which is protein coding (is transcribed to an exon).*Give your answer to two decimal places, as a percentage. E.g. 1.20, or 1.20% is acceptable*

3 marks
Write something below

Part 5 of 13
What is contained in the rest of the genome which is not protein coding?

3 marks
Choose as many as appropriate
a) DNA which folds into specific shapes to catalyse reactions like an enzyme.

b) Sequences which form centromeres and telomeres.

c) Much unused DNA is deleted from cells as they specialise (differentiate).

d) Much of the genome is remnants of viruses and parasitic sequences.

e) Sequences which help control the rate of transcription.

Part 6 of 13
The simplest organisms, such as some bacteria, tend to have very short genomes, whereas animals and plants have very large genomes. Moreover, a much greater proportion of bacterial genomes tends to be protein coding.

Part 7 of 13
What are sensible hypotheses to explain this observation?

3 marks
Mark the following as TRUE or FALSE
a) Bacterial genomes need to be replicated quicker.

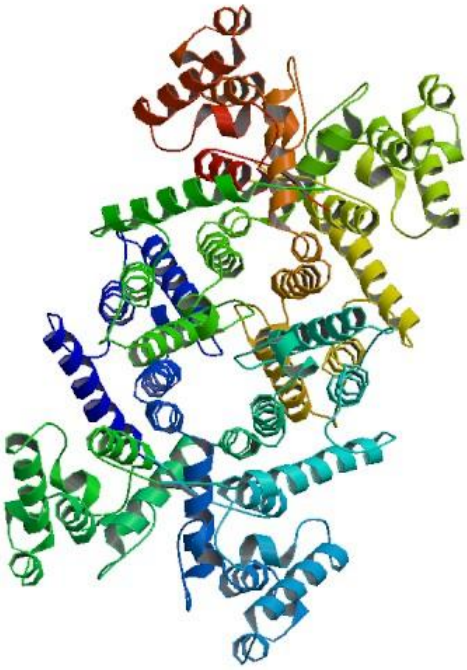
TRUE FALSE
b) Animals and plants need more complicated promoters and enhancers.

TRUE FALSE
c) Animals and plants produce a wider variety of proteins.

TRUE FALSE
d) Replicating the genome consumes a larger proportion of the energy of bacteria.

TRUE FALSE

Part 8 of 13
The largest human gene by far is *dystrophin*, which is mutated in muscular dystrophy. *Dystrophin* is approximately 2 200 000 bases long (including introns).Dystrophin is **not** the largest human protein, having 3 684 amino acids. Titin contains 34 350 amino acids.



Dystrophin structure

Part 9 of 13

Which of these is correct?

1 mark

Choose ONE

a) *Dystrophin* contains more exon sequence than *Titin*.

b) *Titin* contains more exon sequence than *Dystrophin*.

c) It is not possible to say which gene has more exon sequence.

d) Dystrophin is a heavier protein than titin.

Part 10 of 13

Human RNA polymerase II moves at an average speed of 3 200 bases per minute.Human DNA polymerase delta moves at an average speed of 2 000 bases per minute.

Part 11 of 13

Which of these is correct?

1 mark

Choose ONE

a) *Dystrophin* is **transcribed** quicker than *Titin*.

b) It is not possible to say which gene is **transcribed** quicker.

c) *Titin* is **replicated** quicker than *Dystrophin*.

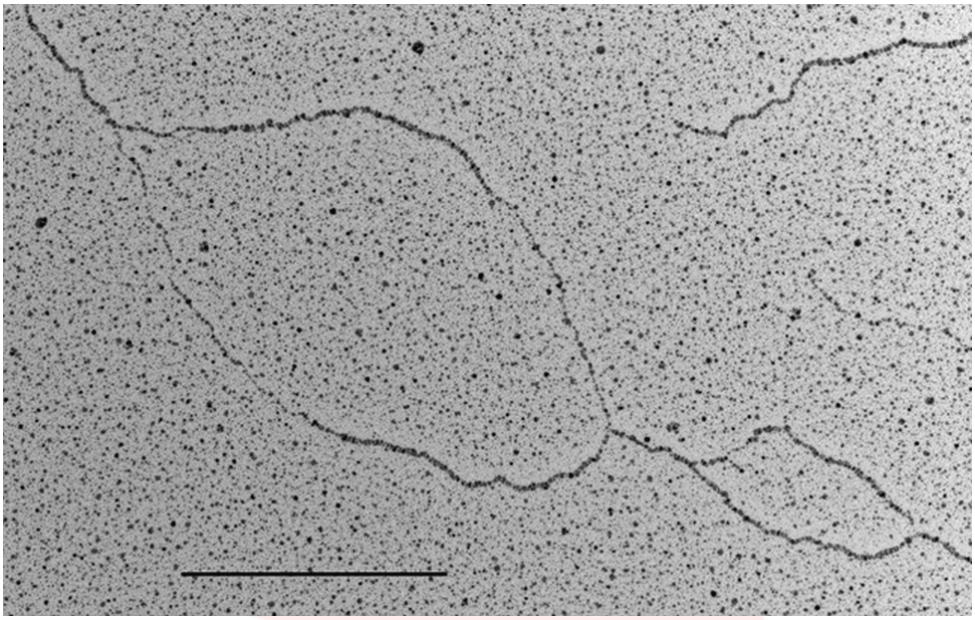
d) It is not possible to say which gene is **replicated** quicker.

e) Both genes are replicated quicker than they are transcribed.

Part 12 of 13

Human genome replication begins from 'initiation sites' which have special properties.Replication forks usually move in both directions along DNA, outwards from an

initiation site, and stop when they reach another fork moving towards them.In human cell cycles, S-phase takes 9 hours on average.



DNA being replicated

Part 13 of 13

Estimate the *minimum* number of replication initiation sites used in a human cell.*Give a number to the nearest whole number. E.g. 1197 would be acceptable.*

4 marks

Write something below

_____

Question 8

Part 1 of 5

The beaches of Northern Cyprus are home to two species of marine turtle: the loggerhead turtle (*Caretta caretta*) and the green turtle (*Chelonian mydas*). Both are endangered and protected species. Female loggerhead turtles visit the beach to lay eggs from late May every year.



Loggerhead sea turtle hatchlings make their way to the ocean

Part 2 of 5

A group of researchers tried to estimate how many loggerhead turtles visit the beach (A), and so used the mark-release-recapture method. In 2019, they marked and released 54 turtles. In 2020, they captured only 30 turtles and 12 of them were previously marked.

Part 3 of 5

How many turtles do the researchers estimate visit the beach (A) every year?

2 marks

Write something below

_____

Part 4 of 5

Unfortunately, quite a few things went wrong with this experiment!* The researchers captured turtles for two weeks in 2019, but for 2 months in 2020.* Marked turtles were much more likely to be eaten by predators.* The team accidentally counted some green turtles in 2020, but did not in 2019.* A neighbouring beach (B) was created January 2020, so some turtles did not return to beach (A).* The researchers found it easier to spot and count marked turtles than unmarked turtles.

Part 5 of 5

For each error, sort them into whether this will have no effect or cause and under- or over-estimate in loggerhead turtle numbers who visit the beach (A).

4 marks

Groups
No effect

Underestimate

Overestimate

Put into the groups above
a) Differing lengths of capture periods

b) Counting green turtles

c) Marked turtles are easier to find

d) Increased predation of marked turtles

e) Creation of beach B

Question 9

Part 1 of 10
* DNA polymerases and RNA polymerases do not require a high-energy co-factor (such as ATP) to function.* Ribosomes require GTP to function.* Glycogen synthase requires ATP to function.*ATP, GTP and UTP are approximately equal as energy sources.*

Part 2 of 10
Why do DNA / RNA polymerases not require an additional source of energy?

1 mark
Choose ONE
a) Nucleotide polymerisation is an exothermic reaction.

b) Nucleotide polymers have a lower free energy than free nucleotides.

c) Formation of phosphodiester bonds between free nucleotides is energetically favourable.

d) DNA/RNA polymerases cleave high energy phosphate bonds in their substrates which releases energy.

e) Base-pairing between nucleotides provides energy for polymer synthesis.

Part 3 of 10
In anaerobic glycolysis, 1 ATP is consumed to turn glucose into glucose-6-P. A second ATP is then consumed in the next step. In the final steps, 4 ATP are produced. Thus anaerobic glycolysis of glucose has a net yield of 2 (4 ATP produced - 2 ATP consumed).

Part 4 of 10
Addition of one glucose monomer to glycogen consumes 1 ATP molecule to phosphorylate glucose and then 1 UTP molecule to power glycogen synthase.Phosphorylated glucose (glucose-6-P) can be released from glycogen in an energetically favourable reaction which does not produce or consume ATP. Glucose-6-P can be turned back into glucose in a second energetically favourable reaction which does not produce or consume ATP.* Glucose-6-P can be released into the cytoplasm of muscle cells and used directly in glycolysis.* Only glucose can be released from liver cells into the blood, for use by muscle cells.

Part 5 of 10
What is the net energy yield when glucose from food is first stored as glycogen in **muscles**, then used in **anaerobic** respiration?*Give your answer as a number in terms of ATP molecules. E.g. '4' is acceptable.*

2 marks
Write something below

Part 6 of 10
What is the net ATP yield when glucose from food is first stored as glycogen in the **liver**, then used in **anaerobic** respiration?*Give your answer as a number, in terms of ATP molecules. E.g. '4' is acceptable.*

1 mark
Write something below

Part 7 of 10
What are the main purposes of glycogen stored in the liver?

2 marks

Choose as many as appropriate

a) As an energy source for anaerobically respiring muscles.

b) As an energy source for aerobic respiration.

c) To supply glucose to the brain between meals.

d) To balance the osmolarity (water potential) of blood.

Part 8 of 10

Protein synthesis requires at least 2 ATP to charge tRNA, 1 GTP to bind ribosomes, and 1/3 GTP to move a ribosome 1 base along an mRNA molecule.

Part 9 of 10

What is the minimum energy cost of synthesising a peptide bond?*Give your answer as a number, in terms of ATP molecules. E.g. '4' is acceptable.*

2 marks

Write something below

Part 10 of 10

Why don't our bodies use proteins to store excess energy?

2 marks

Choose as many as appropriate

a) Synthesising proteins consumes lots of energy, making them inefficient.

b) Proteins attract lots of water, increasing the weight of energy stores.

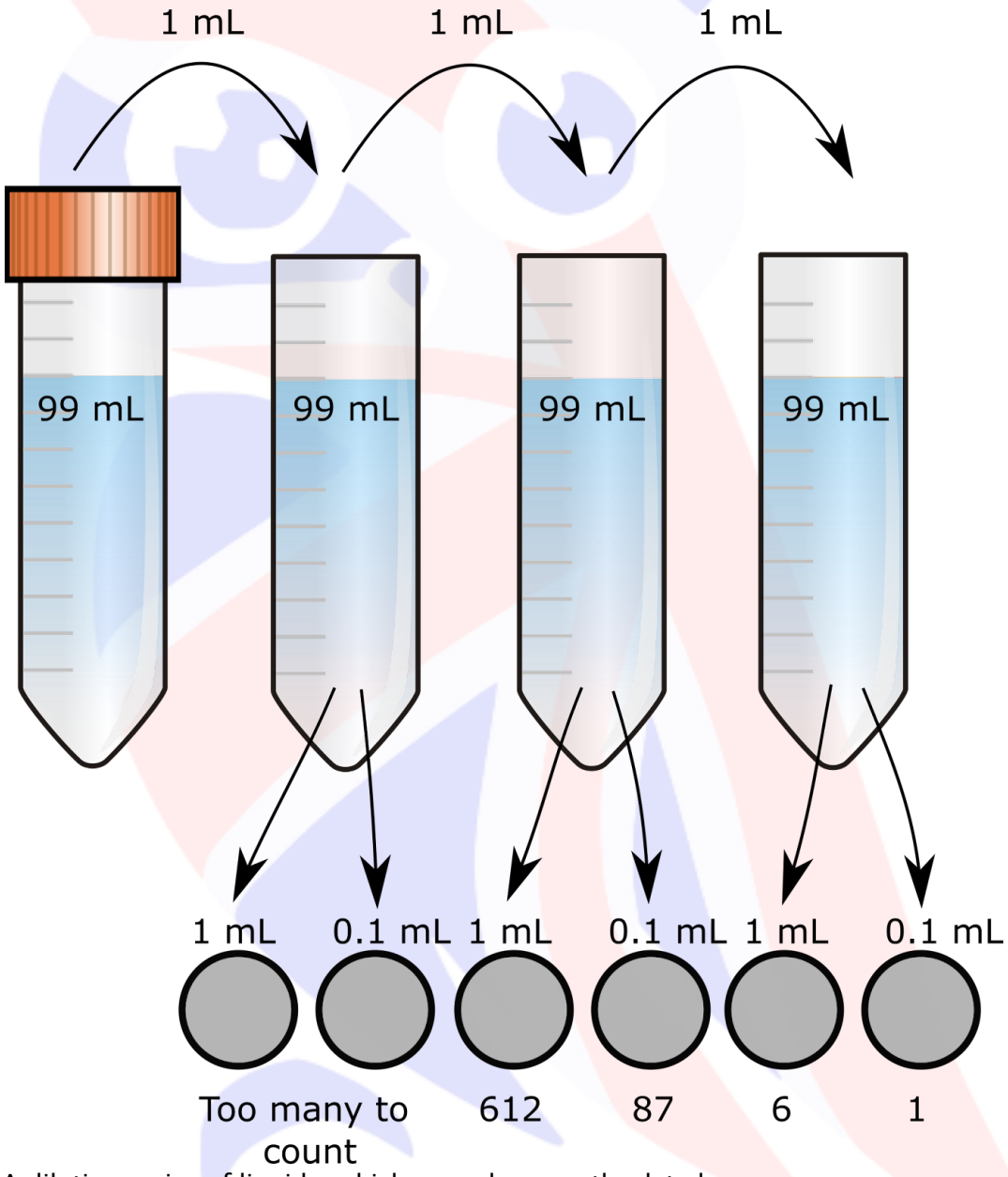
c) Respiration of peptides is energetically unfavourable.

d) We do not have enzymes which can respire amino acids.

Question 10

Part 1 of 7

A woman is suspected of having an *E. coli* infection. The hospital needs to work out how severe the infection is and which antibiotic to give the patient. * 2 mL of blood from the patient was diluted 98 mL of buffer solution. * 1 mL of this solution was then diluted into 99 mL of buffer. * This was repeated twice more. * For each dilution, 1 mL and 0.1 mL of solution was plated on an agar plate. After 24h, the number of bacterial colonies (colony forming units; CFU) were counted.CFU counts are only reliable between 5 and 250 CFU.



A dilution series of liquids, which are subsequently plated.

Part 2 of 7

Which CFU count should doctors use to calculate the severity of this infection?

1 mark

Choose ONE

a) Too many to count

b) 612

c) 87

d) 6

e) 1

Part 3 of 7

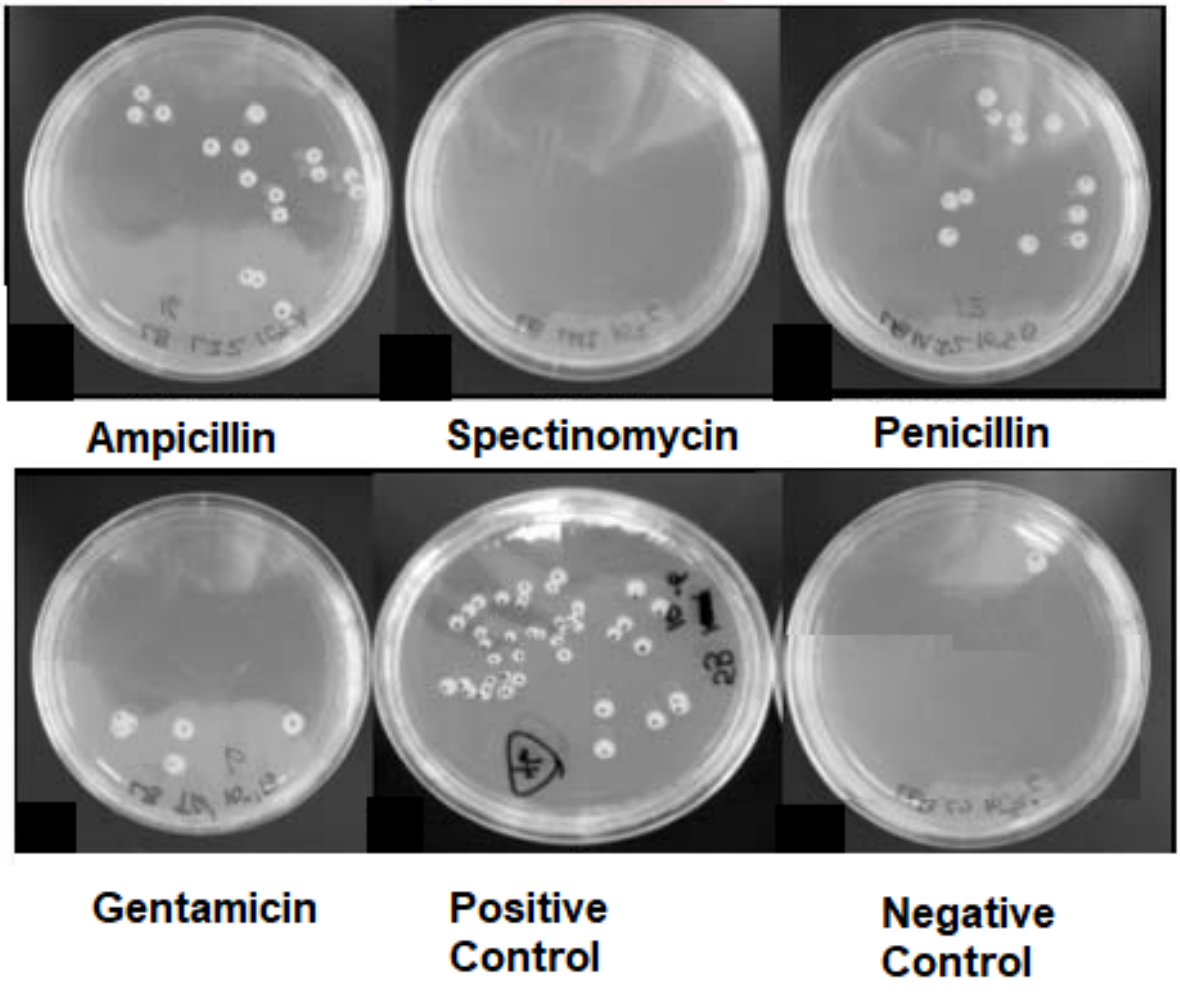
What is the number of CFU per mL of blood? *Give your answer to the nearest whole number? e.g. 123456789 is acceptable*

3 marks

Write something below

Part 4 of 7

The doctors thought this infection was severe enough to need antibiotics. However, many *E. coli* strains have antibiotic resistance. Therefore, some of the patients *E. coli* was streaked onto agar plates containing antibiotics, as shown below.



Part 5 of 7

Which antibiotic should the doctor prescribe?

1 mark

Choose ONE

a) Ampicillin

b) Spectinomycin

c) Penicillin

d) Gentamicin

e) All of them

Part 6 of 7

What causes **this patient's** bacteria to be resistant to the antibiotics?

1 mark

Choose ONE

a) In response to the antibiotic, her *E. coli* evolved a resistance gene

b) All *E. coli* are resistant to antibiotics by default

c) Her *E. coli* already had antibiotic resistance genes in its genome

Part 7 of 7

What should the negative control plate contain?

1 mark

Choose ONE

a) A mix of all the antibiotics

b) *E. coli* which are resistant to all antibiotics

c) No antibiotic

d) Agar which does not have all the nutrients *E. coli* needs

e) None of the patient's *E. coli*