

COMPETITOR #: \_\_\_\_\_



## **15<sup>th</sup> International Biology Olympiad**

**Brisbane, 2004**

### **THEORY EXAMINATION # 1**

**Total time available: 2½ hours (150 minutes)**

**Total points available: ~80**

## GENERAL INSTRUCTIONS

Please check that you have the appropriate examination papers and answer sheets.

It is recommended that you manage your time in proportion to the points allotted for each question.

### IMPORTANT

Use the answer sheets provided to record your answers.

Ensure your name and three digit code number is written on the top of each page of the answers.

Using the pencil provided, fill in the appropriate circle on the answer sheet.

Unless otherwise indicated, there is only **ONE** correct answer for each question.

Part marks are given and no marks are deducted for incorrect answers.

Good luck.

Questions 1-5. **A young family recently bought a Golden Retriever puppy as a pet. They took delivery of the dog at 8 weeks of age after the pup had been weaned and vaccinated.**

Question 1). Following birth, how did the pup find its way to its mother's teat to suckle?

(1 point)

- A. Using tactile cues
- B. Using visual cues
- C. Using auditory cues
- D. Using olfactory cues
- E. Using taste cues

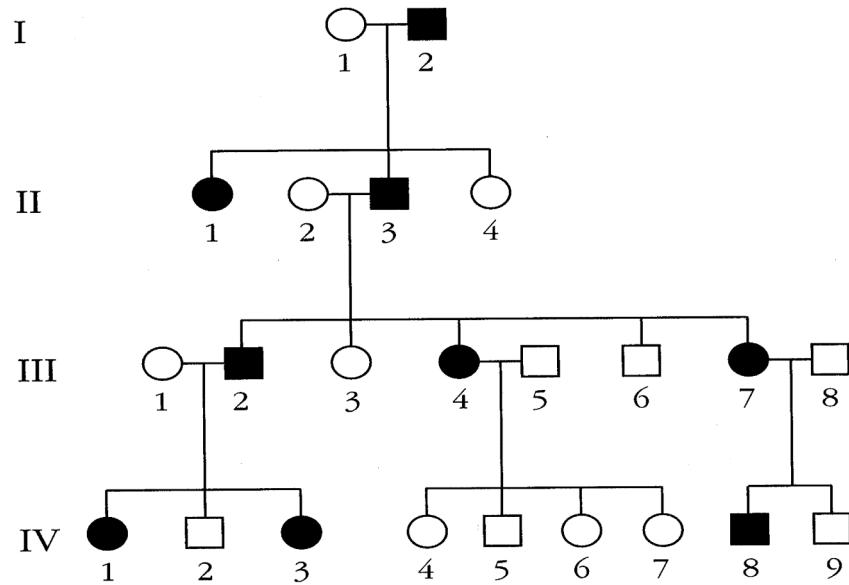
Question 2). Puppies are vaccinated against a range of pathogenic micro-organisms. Which host immune responses are stimulated to provide protection? (1 point)

- A. Inflammatory immune responses
- B. Adaptive immune responses
- C. Hypersensitivity immune responses
- D. Innate immune responses
- E. Cytokine immune responses

Question 3). Training the dog to obey commands (such as walk, sit, stay) involves modulating which behavioural pattern? (1 point)

- A. Imprinting
- B. Conditioning
- C. Mimicry
- D. Habituation
- E. Sensitization

Question 4). The Golden Retriever breed is an inbred line of dogs. The pedigree below is for a rare, but relatively mild, hereditary disorder of the skin.



1. How is the disorder inherited? (1 point)

- A. Autosomal, recessive
- B. Autosomal, dominant
- C. Sex-linked, recessive
- D. Sex-linked, dominant

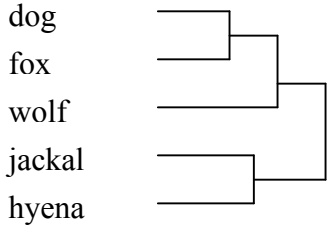
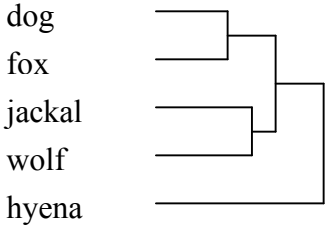
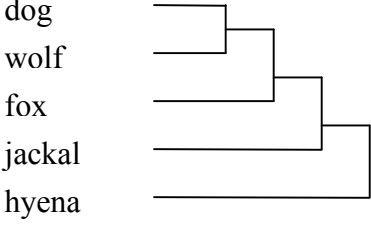
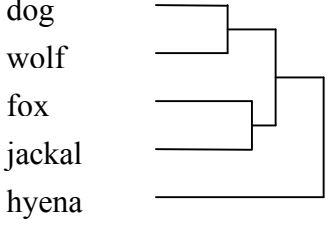
2. If  $D$  = dominant and  $d$  = recessive, what is the genotype of individual III-5 in the pedigree given above? (1 point)

- A. —  $DD$
- B. —  $Dd$
- C. —  $dd$

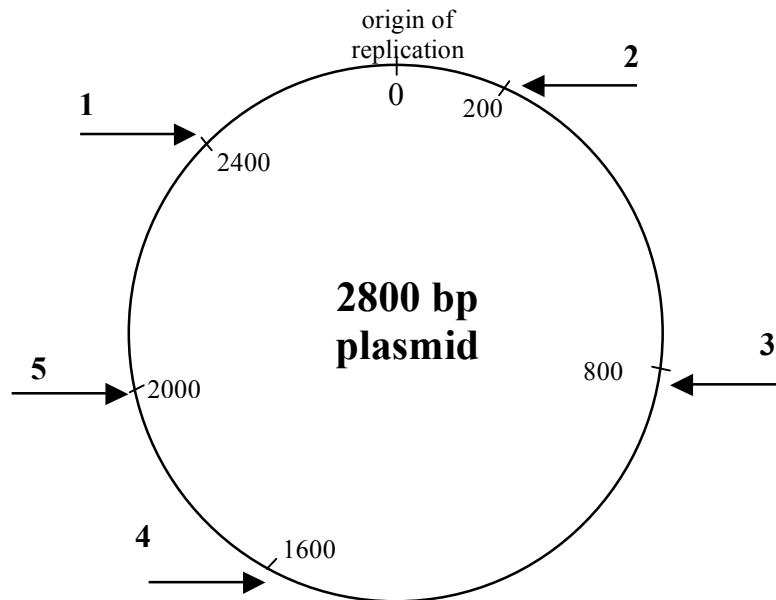
Question 5). Dogs, foxes, jackals, wolves and hyenas were all scored for the presence (+) or absence (-) of seven phenotypic characters (I-VII). The results are shown in the following Table.

Character	I	II	III	IV	V	VI	VII
Dog	+	+	+	+	+	+	+
Fox	-	+	+	-	+	+	-
Jackal	+	-	+	-	+	-	-
Wolf	+	+	+	-	+	+	+
Hyena	-	-	-	+	-	-	-

Which phenogram indicates the phylogenetic relationships between these five animal groups based on the data given? (1 point).

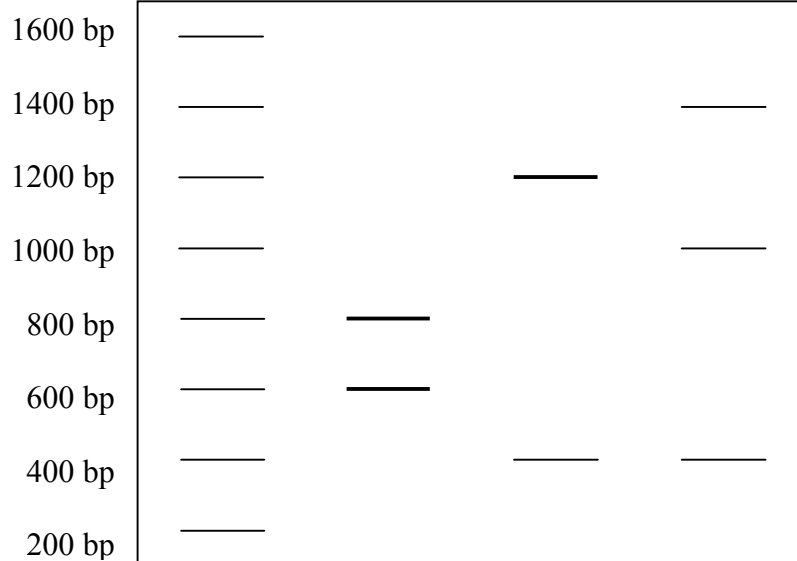
<p>A.</p> 	<p>B.</p> 
<p>C.</p> 	<p>D.</p> 

Questions 6-10. A 2800 bp plasmid was cut by restriction enzymes in three separate reactions: one reaction using *Bam*HI and *Hind*III; one using *Bam*HI and *Eco*RI; and one using *Hind*III and *Eco*RI. The restriction fragments were separated on an electrophoretic gel.



**B**

Size Markers	<i>Bam</i> HI + <i>Hind</i> III	<i>Bam</i> HI + <i>Eco</i> RI	<i>Hind</i> III + <i>Eco</i> RI
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**A**

**C**

**D**

Question 6). Which of the following statements is FALSE? (1 point)

- A. Plasmids do not possess protein coats
- B. Plasmids are circular double-stranded DNA molecules
- C. Plasmids can be incorporated into the host cell's chromosome
- D. Plasmid genes are required for bacterial survival and/or reproduction
- E. Plasmids are generally beneficial to their host cells

Question 7). Which of the restriction sites on the plasmid map (numbered 1-5) correspond to the restriction enzymes A, B or C. (2 points)

Restriction enzyme
A. <i>Bam</i> HI
B. <i>Eco</i> RI
C. <i>Hind</i> III

Site	Answer [A/B/C]
1	
2	
3	
4	
5	

Question 8). The four sides of the electrophoretic gel are labelled A, B, C and D. Which represents the cathode ? (1 point)

- A. A
- B. B
- C. C
- D. D
- E. not possible to determine

Question 9). The restriction enzyme *EcoRI* cuts double-stranded DNA as follows:



Which of the following fragments could bind to an *EcoRI* restriction cut site? (1 point)

(A)

(B)

(C)

(D)

.. CG

AATTCG ..

.. TGAATT

GT ..

.. GCAATT

GC ..

.. AC

TTAACA ..

Question 10). How do single plasmids come to acquire multiple genes for antibiotic resistance?

(1 point)

- A. Transposition
- B. Conjugation
- C. Transcription
- D. Transformation
- E. Transduction

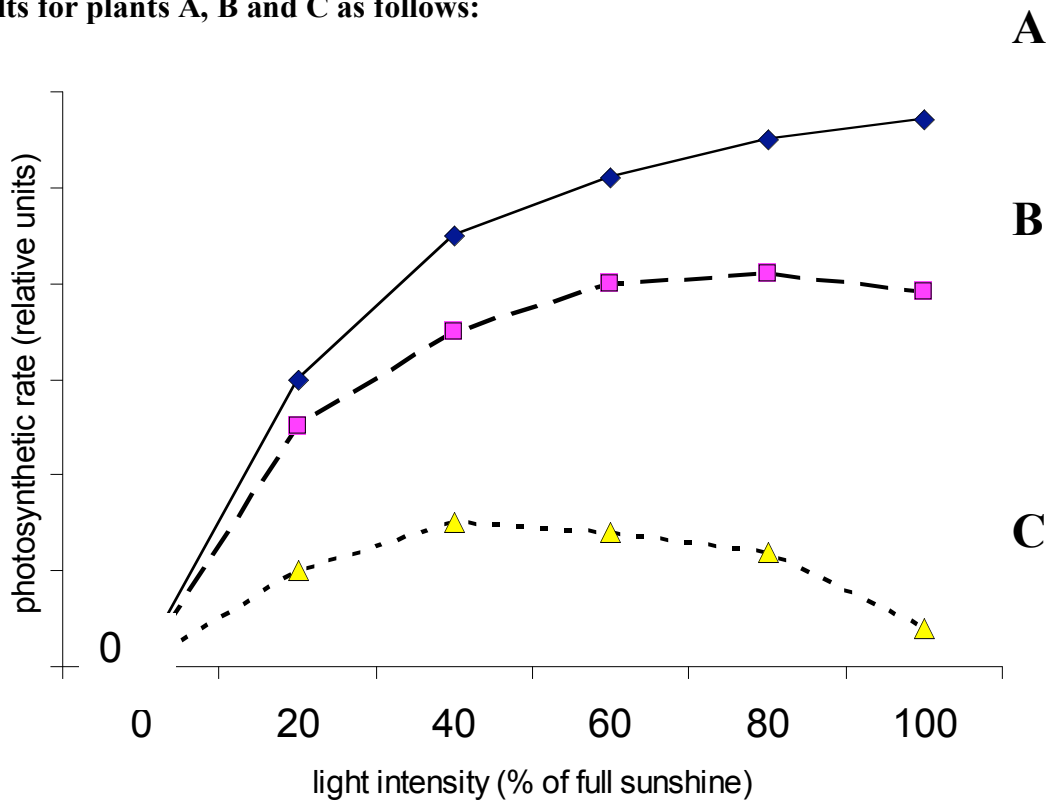


Question 11-15. A researcher placed ten individuals of each of three different types of plants at ten different light intensities, ranging from zero to full sunshine, for several days. The atmosphere was normal air, the temperature was 32°C and the plants were well watered.

The three plant types were:

- a C<sub>3</sub> plant adapted to growth in full sunshine (a “sun plant”)
- a C<sub>3</sub> plant that can only grow in low-light environments (a “shade plant”)
- a C<sub>4</sub> plant which, like most C<sub>4</sub> plants, is adapted to growth in full sunshine

The researcher then measured the photosynthetic rate of a leaf of each plant, and plotted the results for plants A, B and C as follows:



In the following questions, A, B or C refers to curves A, B or C above or the plants corresponding to these curves.

Question 11). Which type of plants gave results A, B and C? (1 point)

1. C <sub>3</sub> sun plant
2. C <sub>3</sub> shade plant
3. C <sub>4</sub> plant

Answer [A/B/C]

Question 12). Which result (A, B or C) would be obtained for the following? (1 point)

1. wheat, rice, oats, barley, peas and beans
2. plant that usually has the thinnest leaves
3. plant with highest water use efficiency
4. plant that preferentially invests nitrogen (N) into the manufacture of thylakoid proteins and chlorophyll, rather than enzymes of CO <sub>2</sub> fixation
5. plant with some chloroplasts lacking Rubisco (“Rubisco” = ribulose biphosphate carboxylase/oxygenase)

Answer [A/B/C]

Question 13). Curve C shows that photosynthesis by this plant decreases as the light intensity is increased from 60% to 100% of full sunshine. Why? (1 point)

- A. It lacks chlorophyll a
- B. It does not close its stomates when water stressed, and therefore becomes dehydrated under high light
- C. It has insufficient Rubisco to make use of high light, and reactive oxygen species consequently accumulate and damage membranes
- D. High light stimulates its mitochondrial (dark) respiration, consequently it respire more CO<sub>2</sub> at night than it photosynthetically fixes by day
- E. Its chloroplasts migrate to the sides of the leaf cells, making the leaves transparent and unable to absorb light for photosynthesis

Question 14). Leaves from the three plants exposed to 60% of full sunshine would undertake photosynthesis faster if provided with extra light (L) or extra carbon dioxide (D)?

(1 point)

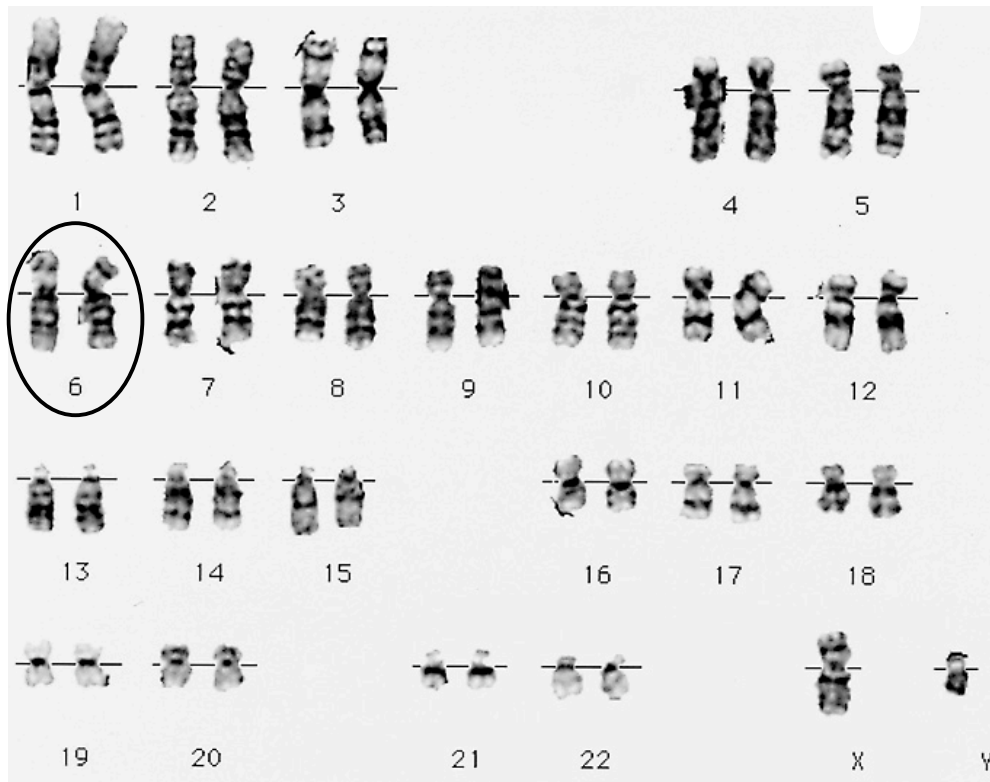
1. Plant A
2. Plant B
3. Plant C

Answer [L/D]

Question 15). Photorespiration occurs in a plant's chloroplasts when the  $O_2$  concentration is much greater than the  $CO_2$  concentration. In this case,  $O_2$  instead of  $CO_2$  is incorporated by Rubisco in the Calvin cycle. Rubisco's substrate, which is normally linked to  $CO_2$ , is which of the following: (1 point)

- A. 3-phosphoglycerate
- B. glycolate 2-phosphate
- C. glycerate 1,3-bisphosphate
- D. 3-phosphoglyceraldehyde
- E. ribulose 1,5-bisphosphate

Questions 16-20. **Karyotypes represent a display of the chromosomes present in eukaryotic cells. The following diagram shows a normal human male karyotype.**



Question 16). Karyotyping is routinely performed on cells that are undergoing which process?

(1 point)

- A. Prophase in meiosis
- B. Anaphase in mitosis
- C. Metaphase in mitosis
- D. Telophase in mitosis
- E. Interphase

Question 17). How many autosomes are shown in the picture? (1 point)

- A. 22
- B. 23
- C. 44
- D. 46
- E. 2

Question 18). What are the structures circled at position 6 in the diagram called?...

(1 point)

- A. two sister chromatids
- B. an homologous pair of chromosomes
- C. a chromosome
- D. interphase chromosomes
- E. RNA

Question 19). Which answer gives the correct responses to the blanks in the following statement?

“Human chromosomes are typically divided into two arms by their ‘.....’ . On human chromosome maps, the long arm is referred to as ‘.....’, while the short arm is called ‘.....’.”

(1 point)

- A. telomere; p; q
- B. centrosome; q; p
- C. centriole; L; S
- D. centrosome; l; s
- E. centromere; q; p

Question 20). The technology that produced the karyotype shown in the diagram has been largely superseded and replaced by which of the following? (1 point)

- A. light microscopy together with colour photography
- B. fluorescent in situ hybridizing (FISH) DNA probes called chromosome paints
- C. electron microscopy and colour lithograph techniques
- D. the polymerase chain reaction
- E. RNA silencing using short interfering RNAs (siRNA)

Questions 21-25. **A new volcanic island forms in the middle of an ocean. A fringing reef forms as marine currents bring eggs and larvae allowing different species to colonize. Other factors, such as predation, competition and diseases, are then responsible for extinctions of some reef species.**

Question 21). On average, the reef is colonized each century by ten new species of coral but 10% become extinct each century. How long will it take for the reef fauna to include at least 50 different species of coral? (1 point)

- A. 300 years
- B. 450 years
- C. 500 years
- D. 800 years
- E. 1200 years

Question 22). A major change in the direction of marine currents prevents the reef from being colonized by any new species. Assuming the extinction rate remains the same at 10% per century, how long will it take for the biodiversity of the reef to be lowered from 50 coral species to 30 species? (1 point)

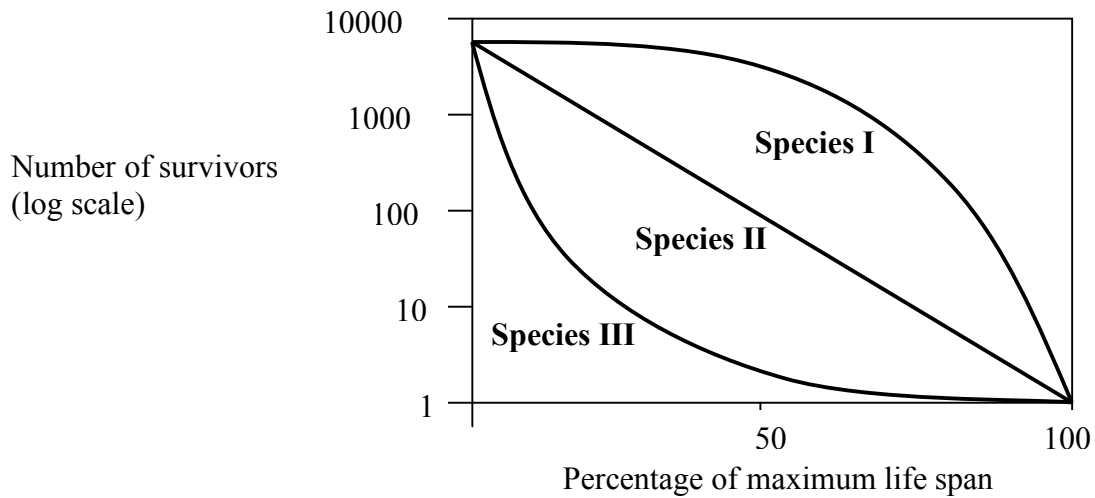
- A. 300 years
- B. 450 years
- C. 500 years
- D. 800 years
- E. 1200 years

Question 23). A marine biologist, wanting to calculate the number of fish (N) that lived on the reef, captured a sample of individuals (numbering S1), tagged them and released them. One month later, he collected another sample (numbering S2) and found several marked individuals amongst them (numbering S3). Which formula can be used to calculate N? (1 point)

- A.  $N = (S2 \times S3) / S1$
- B.  $N = (S1 \times S2 \times S3)$
- C.  $N = (S1 \times S3) / S2$
- D.  $N = (S1 \times S2) / S3$
- E.  $N = (S2 + S1) / S3$



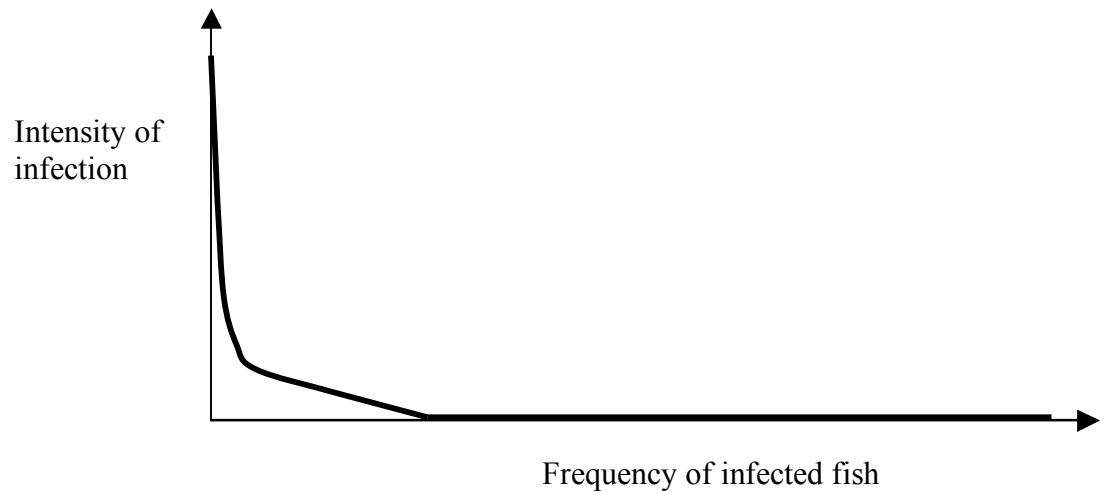
Question 24). Three species of reef organisms exhibit the following survivorship curves:



Which of the following statements is INCORRECT? (1 point)

- A. Juveniles of species III have a higher mortality than those of species I
- B. Death rates in species II are more uniform than those in species I
- C. It is likely that fecundity in species II is lower than that of species III
- D. Adults of species II have longer life expectancy than those of species III
- E. High adult mortality in species I is likely to be offset by high fecundity

Question 25). Fish caught on the reef were found to be infected with gill parasites. The intensities of infection were plotted against their frequency, as follows:

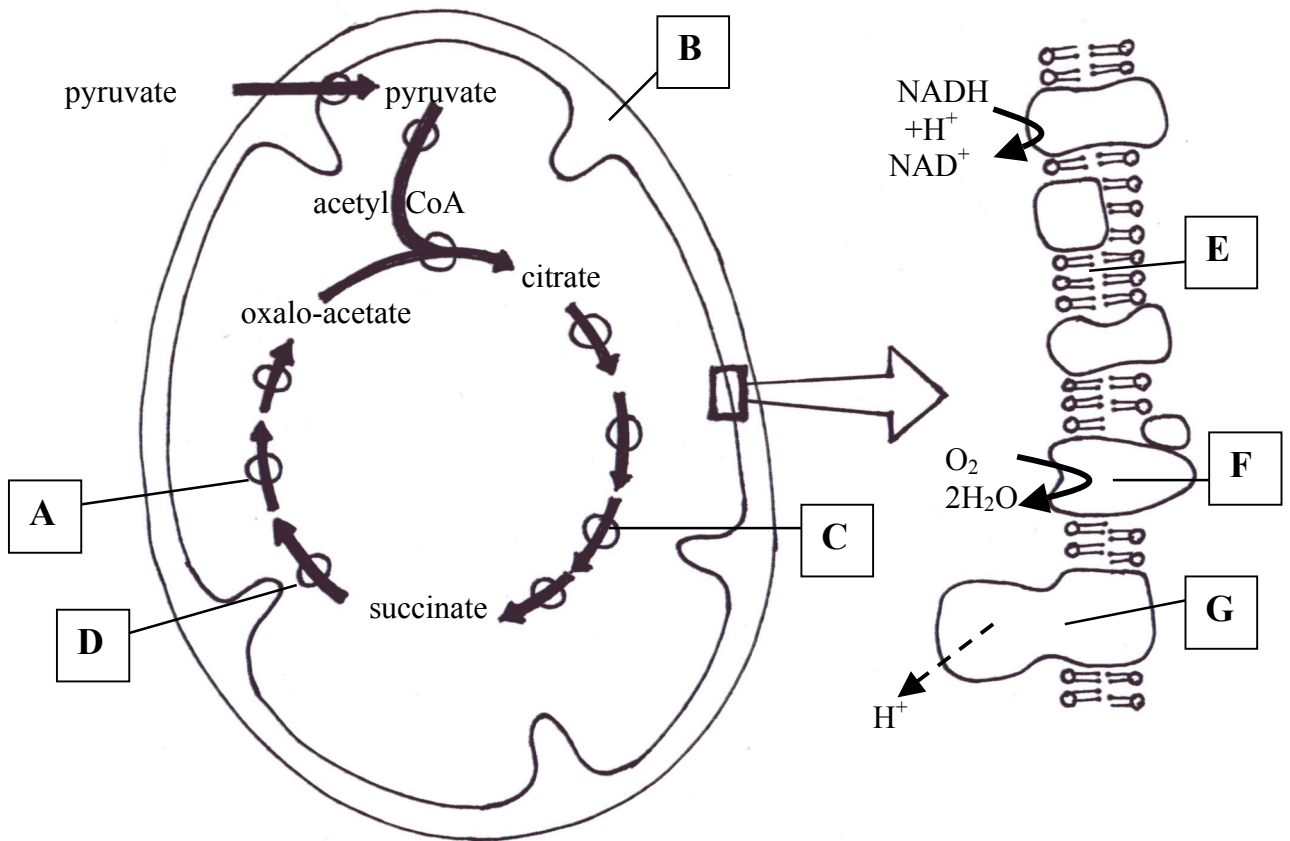


Which statement can be correctly inferred from these results? (1 point)

- A. Parasites accumulate in older hosts
- B. A few hosts contain most parasites
- C. Young hosts acquire most parasites
- D. Parasite dispersion depends on host distribution
- E. Most hosts contain a few parasites

Questions 26-30. **Early in the evolution of life on Earth, certain primitive photosynthetic cells acquired the ability to split water resulting in the accumulation of oxygen in the atmosphere. Other cells made use of oxygen by combining it with other molecules and harnessing the energy released.**

Question 26). The diagrams below depict a mitochondrion (left) showing some of the biochemistry that occurs in the matrix (O = enzyme) and a magnified view of the inner membrane (right) showing some of the multi-protein complexes within it.



Match the labelled components A to G with the following items: (2 points)

1. Protein complex that manufactures most of the ATP for which respiration is famous
2. Protein that releases CO<sub>2</sub>
3. Hydrogen ions (H<sup>+</sup>) moved during electron transport accumulate here, causing the pH to be at least 1 unit lower than in the matrix
4. Protein that contains copper as a cofactor
5. Protein that synthesises malate
6. Ubiquinone could be found performing its task here
7. Protein that reduces FAD to FADH<sub>2</sub>

1	2	3	4	5	6	7

Question 27). Consider the metabolic cycle of eight reactions (Krebs cycle/citric acid cycle) shown within the diagram of the mitochondrion (cycling from citrate to succinate to oxaloacetate). Which of the following statements is correct? (1 point)

- A. The cycle occurs in the intermembrane space of mitochondria
- B. The cycle is a central part of lactic-acid fermentation
- C. The cycle would cease to operate in the absence of NAD<sup>+</sup>
- D. The cycle directly generates most of a heterotrophic cell's ATP
- E. The cycle is responsible for the generation of oxygen

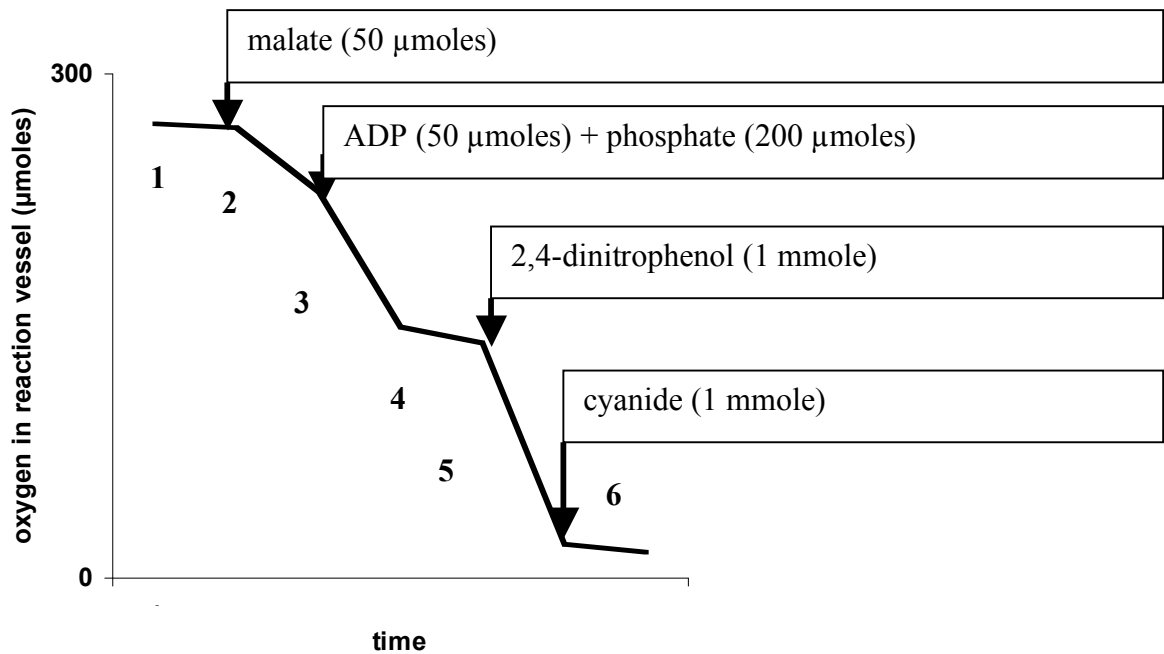
Question 28). Acetyl-CoA is formed in mitochondria during respiration. It is also made in other parts of cells, including the cytosol and plastids in plant cells. It is the main molecule used for the biosynthesis of which combination of the following? (1 point)

1. The aromatic amino acids tryptophan, tyrosine and phenylalanine
  2. Steroids
  3. The chitin in fungal cell walls and insect exoskeletons
  4. The hydrophobic tail of ubiquinone
  5. The purine bases of DNA and RNA
  6. Fatty acids
  7. Gibberellin plant hormones
- 
- A. 1, 5
  - B. 2, 4, 6, 7
  - C. 2, 3, 7
  - D. 1, 4, 7
  - E. 2, 3, 5, 6, 7

Question 29). Which combination of statements is correct for aerobic respiration? (1 point)

1.  $\text{H}_2\text{O}$  is a reducer
  2.  $\text{CO}_2$  is an oxidant
  3.  $\text{O}_2$  is an electron acceptor
  4.  $\text{H}_2\text{O}$  is an electron donor for organic substances
  5.  $\text{H}_2\text{O}$  is one of the end products
  6. Photophosphorylation occurs
  7. Oxidative phosphorylation occurs
  8. Substrate level phosphorylation occurs
- 
- A. 1, 2, 8
  - B. 2, 3, 4, 7
  - C. 3, 5, 7, 8
  - D. 1, 4, 7, 8
  - E. 2, 3, 5, 6, 7

Question 30). A student obtained a preparation of isolated mitochondria from a liver and studied respiration by continuously following the O<sub>2</sub> uptake of a 1 mL suspension of mitochondria in a reaction vessel. Additions were made to the suspension as shown. The following trace was obtained:



The student offers various conclusions for the rates of O<sub>2</sub> uptake shown at positions 1-6.

Select either conclusion A or B as correct for each numbered position: (1 point):

1.     A. The mitochondria were damaged and were no longer able to respire
- B. Almost no carbohydrate substrate was available for respiration

2.
  - A. Malate acted as a carbohydrate substrate for respiration
  - B. Malate combined directly with O<sub>2</sub>, removing the O<sub>2</sub> from solution
  
3.
  - A. Respiration by the mitochondria was coupled to ATP synthesis
  - B. Inorganic phosphate (Pi) stimulated the activity of Krebs cycle enzymes
  
4.
  - A. ADP slowly inactivated Krebs cycle enzymes
  - B. The supply of ADP was depleted
  
5.
  - A. 2,4-dinitrophenol causes H<sup>+</sup> ions to leak across the mitochondrial membrane
  - B. 2,4-dinitrophenol is better than malate as a natural substrate for respiration
  
6.
  - A. Cyanide (CN<sup>-</sup>) inhibits the terminal oxidase of respiration
  - B. Cyanide can substitute for O<sub>2</sub> in respiratory electron transport, generating HCN instead of H<sub>2</sub>O



Questions 31-35. **Most higher animals have cardiovascular systems that transport blood and fluids to body tissues.**

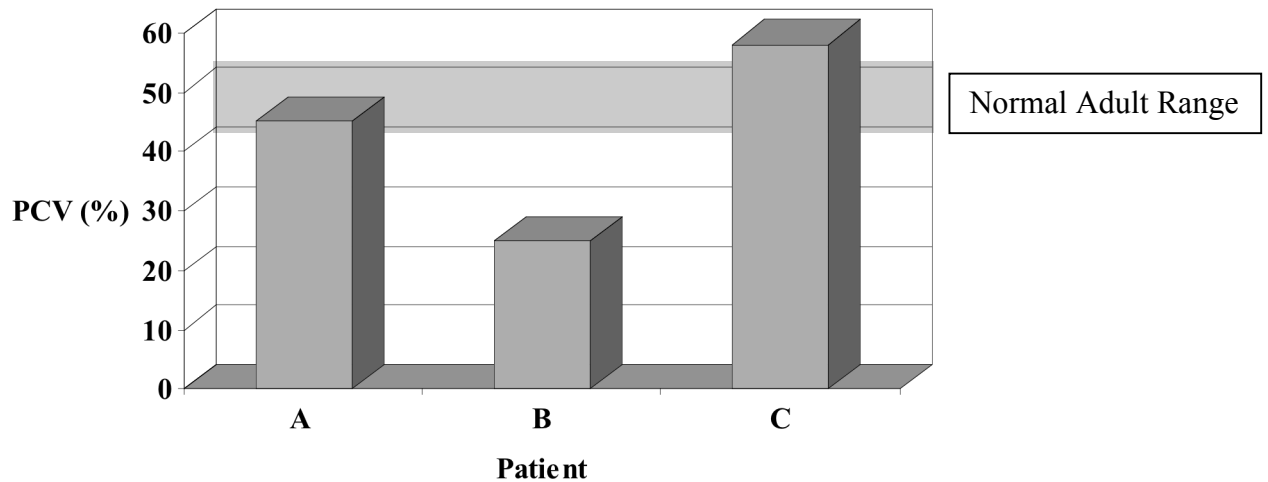
Question 31). Vertebrate whole blood consists of plasma and suspended cells or fragments. The following statements relate to the composition of a normal blood sample.

- 1) Red cells get their colour from the waste CO<sub>2</sub> carried by haemoglobin
- 2) Erythrocytes are the most abundant cell type in blood
- 3) Platelets contain a nucleus and DNA
- 4) Haemoglobin is composed of two polypeptide chains
- 5) Gamma-globulin is a key protein in plasma
- 6) All adult blood cells originate in the bone marrow

Which one of the following combinations contains only true statements? (1 point)

- A. 3, 4, 5
- B. 2, 5, 6
- C. 1, 2, 3, 5, 6
- D. 4, 5, 6
- E. 2, 4, 6

Question 32). The haematocrit (or packed cell volume, PCV) is the proportion of the total blood volume occupied by blood cells. The normal haematocrit range for adult males is 40-50%. The graph below shows the haematocrit results for three patients A, B and C.



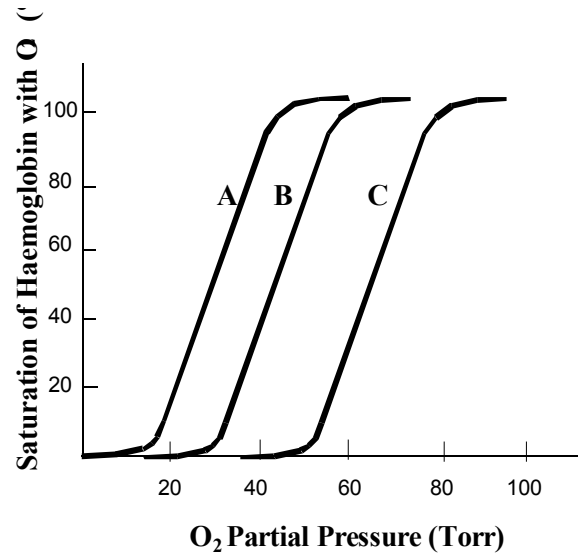
Which patient could a doctor correctly diagnose as suffering from the following conditions?

(use D to indicate none) (1 point)

1. Dehydration
2. Anaemia
3. Decreased albumin levels
4. No apparent health problems

Answer [A/B/C/D]

Question 33). The amount of oxygen carried in the blood is dependent on the amount of respiratory pigment (such as haemoglobin) and the partial pressure of oxygen. For a fixed concentration of haemoglobin, the greater the partial pressure of oxygen the greater the percent saturation of haemoglobin.



Which of the following combinations represents the oxygen equilibrium curves shown above for conditions A, B and C, in order? [\*Exercise blood is blood collected after a period of extreme exercise.] (1 point)

- A. normal blood, foetal blood, exercise blood\*
- B. foetal blood, exercise blood\*, normal blood
- C. foetal blood, normal blood, exercise blood\*
- D. exercise blood\*, foetal blood, normal blood
- E. exercise blood\*, normal blood, foetal blood

Question 34). A major role for blood clotting is to help repair damaged blood vessels and tissue wounds. Which factors are important in this process? (1 point)

- A. erythrocytes, thrombin, fibrin, gamma globulin
- B. monocytes, gamma globulin, thrombin, erythrocytes
- C. lymphocytes, erythrocytes, fibrin, platelets
- D. platelets, thrombin, erythrocytes, fibrin
- E. fibrin, thrombin, platelets, gamma globulin

Question 35). Various abnormal conditions may arise in the cardiovascular system, including:

- A) Cholesterol plaque deposits in arteries
- B) Overproduction of red blood cells in the bone marrow
- C) Single nucleotide mutation in the coding region of the haemoglobin gene
- D) High blood pressure
- E) Uncontrolled proliferation of progenitor blood cells
- F) Reduction in haemoglobin synthesis

Which of these abnormalities cause the following blood disorders? (1 point)

	Answer [A/B/C/D/E/F]
1. Sickle cell anaemia	
2. Hypertension	
3. Atherosclerosis	
4. Beta-thalassemia	
5. Leukaemia	
6. Polycythemia	

Questions 36-38. **Reproduction has many features that vary within the plant kingdom.**

Question 36). Which of the following statements concerning reproduction is true?

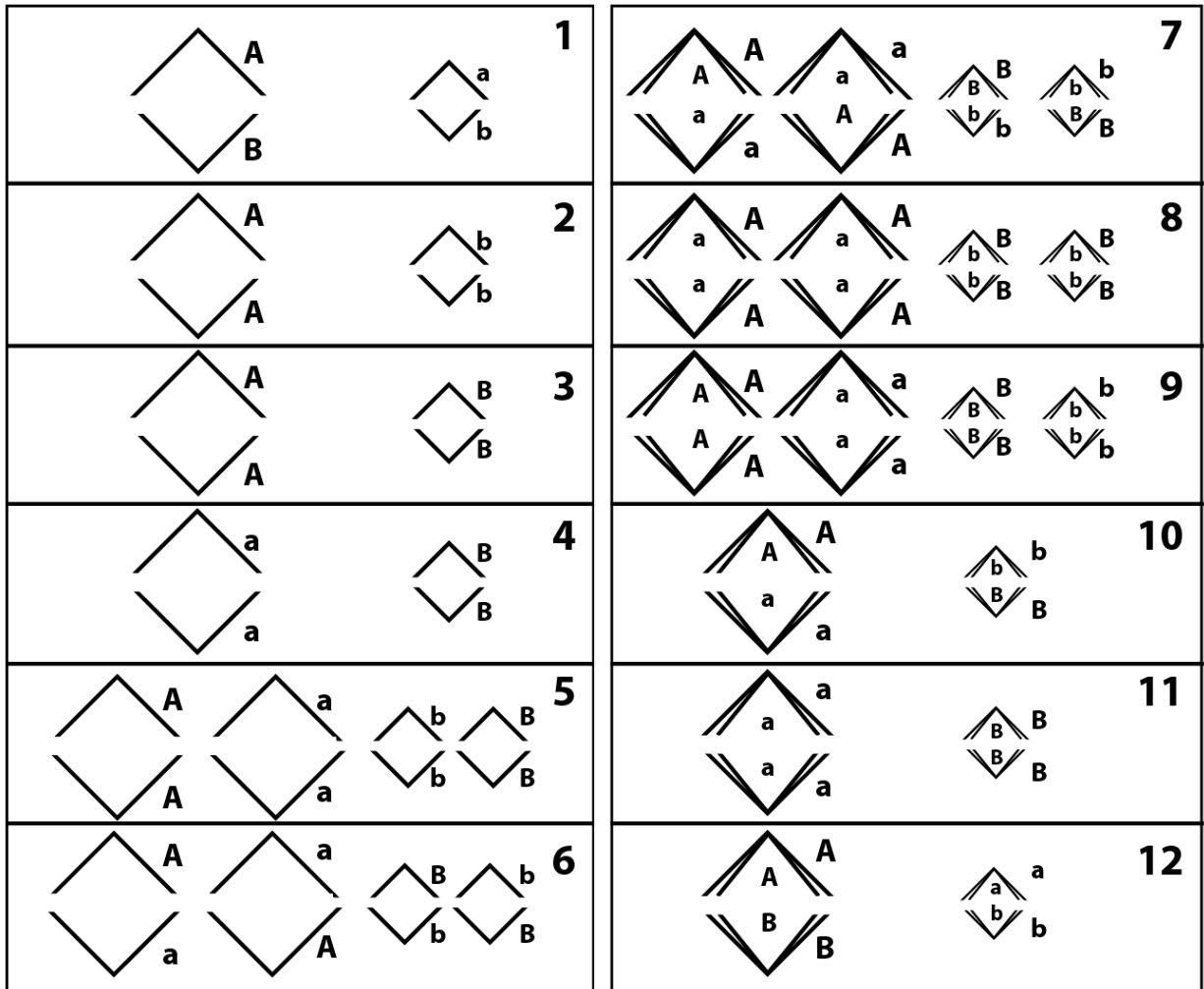
(1 point)

- A. Haploid organisms (i.e. organisms whose cells have only one of each chromosome) do not exist; the only cells that are haploid are gametes (ova and sperm)
- B. It is theoretically and practically impossible for an organism to reproduce without meiosis
- C. Sexual reproduction always involves the production of sperm and ova by separate male and female individuals
- D. All cells of all eukaryotic organisms (even fungi) contain a single nucleus (either haploid or diploid)
- E. Sexual reproduction without meiosis is not possible

Question 37). Which of the following is a principal difference between gymnosperms and angiosperms? (1 point)

- A. Gymnosperms produce flagellated sperm that swim in water whereas angiosperms produce sperm enclosed in pollen
- B. Gymnosperms lack seeds whereas angiosperms have seeds
- C. In gymnosperms, the ovule develops into a seed whereas in angiosperms the ovary develops into a seed
- D. Gymnosperms lack ovaries that develop into fruits whereas angiosperms have ovaries that develop into fruits
- E. Gymnosperms produce scaly dry fruit whereas angiosperms produce soft juicy fruit

Question 38). Plant reproduction was studied in *Haplopappus gracilis* which is diploid and has only two pairs of chromosomes, one long pair and one short pair ( $2n = 4$ ). The diagrams below represent anaphases of individual cells in meiosis or mitosis in a plant that is genetically a double heterozygote (Aa Bb) for alleles of two genes, one gene on the long chromosome and the other on the short chromosome. Single lines represent chromatids, and the points of the V's represent centromeres.

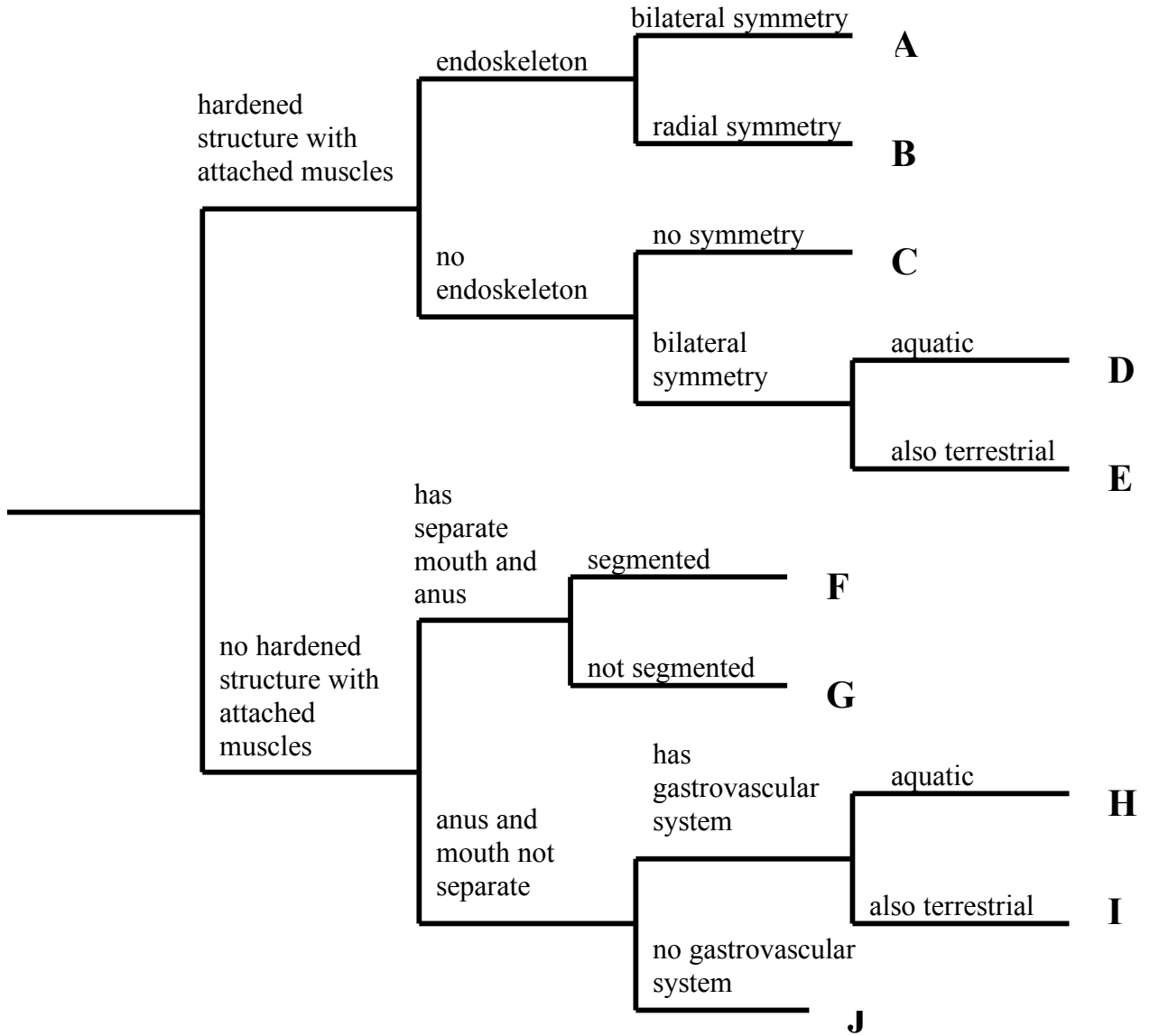


In each case, indicate if the diagram represents a cell in: (3 points)

meiosis I (= A)      meiosis II (= B)      mitosis (= C)      or an impossible situation (= D)

1	2	3	4	5	6	7	8	9	10	11	12

Questions 39-42). A dichotomous key was constructed for ten groups of animals based on seven characters.



Question 39). Which groups (A-J) are represented by numbers 1 to 10? (2 points)

Group	Letter
1. Annelida (annelids)	
2. Arthropoda (crustaceans)	
3. Cnidaria (jelly fish)	
4. Echinodermata (starfish)	
5. Mollusca (bivalves)	
6. Mollusca (gastropods)	
7. Chordata (chordates)	
8. Nematoda (roundworms)	
9. Platyhelminthes (flatworms)	
10. Porifera (sponges)	

Question 40). Animal body plans vary in the organization of their tissue layers and body cavities. They may be diploblastic (D) or triploblastic (T). They may be acoelomate (A), pseudocoelomate (P) or coelomate (C). Indicate the character states for the following animals: (1 point)

		tissue layers [D/T]	body cavities [A/P/C]
1.	Platyhelminthes (flatworms)		
2.	Annelida (segmented worms)		
3.	Nematoda (roundworms)		



Question 41). Differences in embryological development allow the differentiation of animals into protostomes and deuterostomes based on cleavage patterns (radial = R; spiral = S), cell fate (indeterminate = I, determinate = D) and the development of the mouth of the embryo (arising from blastopore = B, arising at opposite end to blastopore = O). Which are the correct character states for deuterostomes? (1 point)

- A. S, D, O
- B. S, D, B
- C. S, I, O
- D. S, I, B
- E. R, D, O
- F. R, D, B
- G. R, I, O
- H. R, I, B

Question 42). Insects may have simple or complex development cycles.

- A. They may hatch from eggs looking like small adults.
- B. They may undergo gradual changes (incomplete metamorphosis)
- C. They may undergo profound changes (complete metamorphosis).

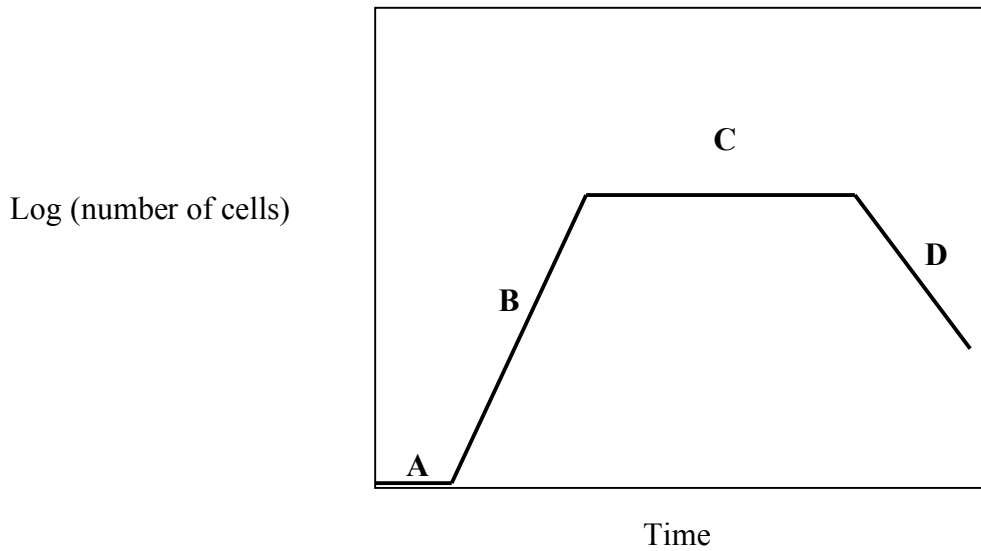
Which developmental cycles do the following insects undergo ? (1 point)

1. Flies
2. Wingless insects
3. Fleas
4. Lice

Answer [A/B/C]

Questions 43-47. **Bacteria are prokaryotic micro-organisms that grow under a variety of environmental conditions.**

Question 43). Bacterial growth under laboratory conditions at a particular temperature can be represented as the log number of viable cells plotted against time of incubation.



Match the four stages labelled A to D on the graph with the following growth phases. Note: one phase is not shown and should be entered as “E”. (1 point)

<b>Growth Phase</b>
1. exponential (log) growth phase
2. death phase
3. transition phase
4. stationary phase
5. lag phase

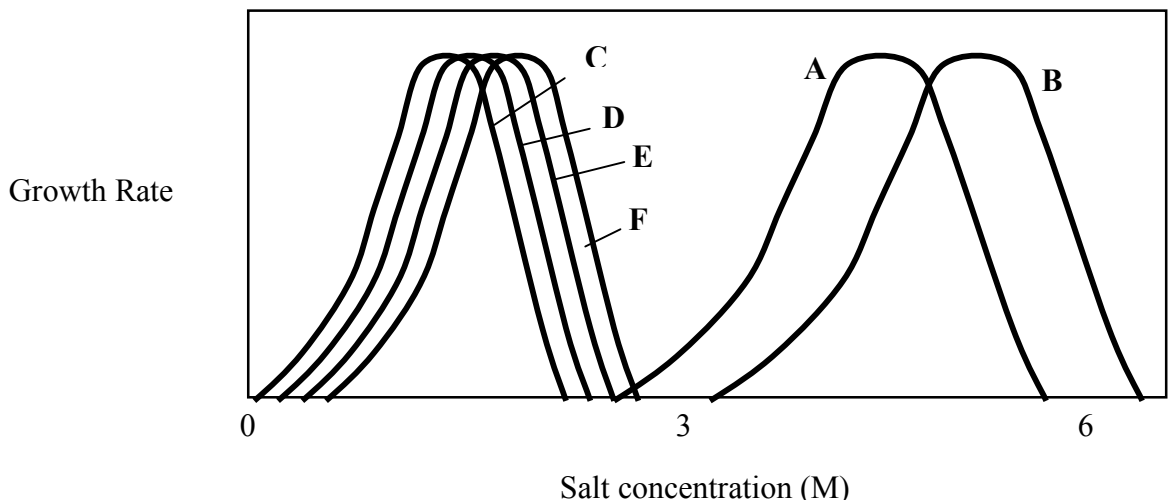
<b>Answer</b>
[A/B/C/D/E]

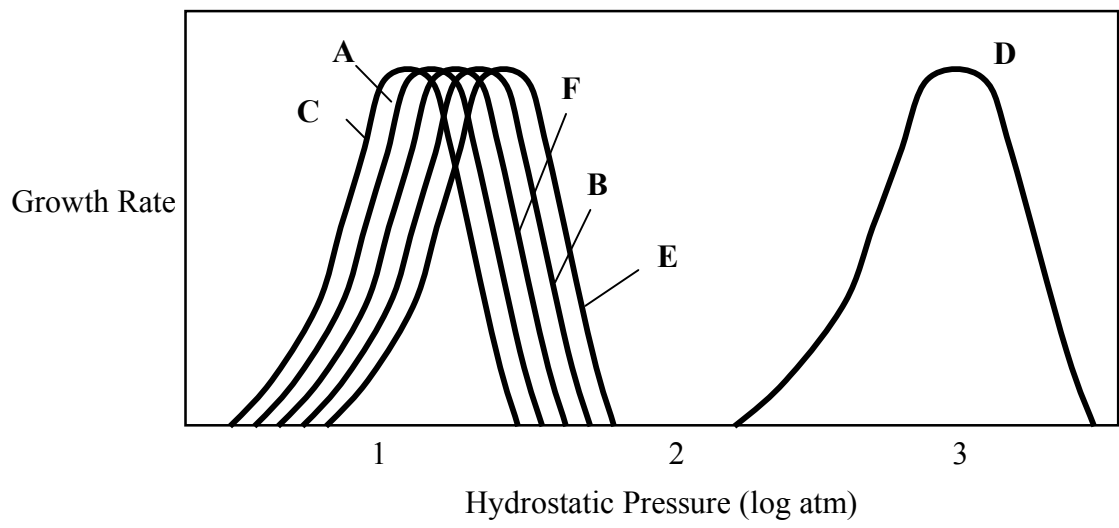
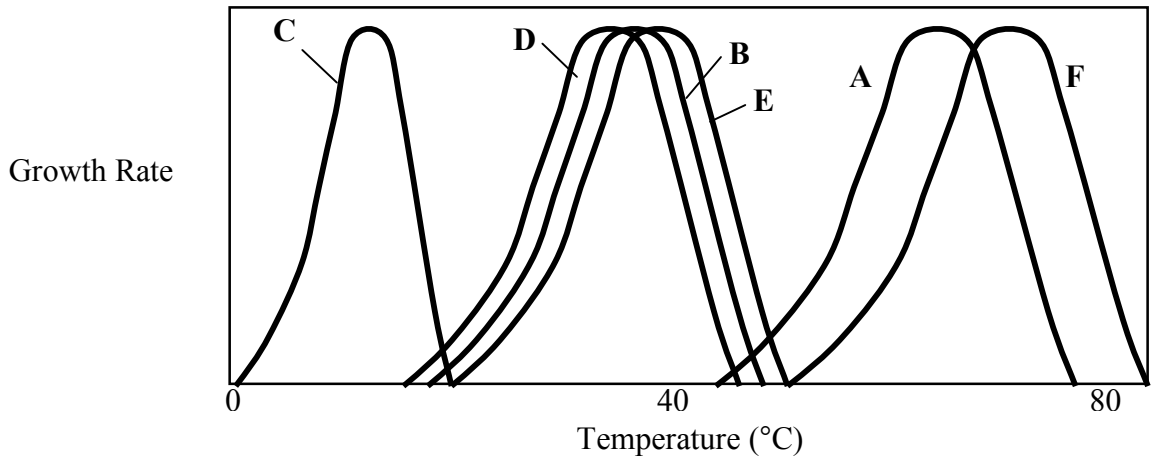
Question 44). Most known bacteria grow in the temperature range of 30 - 40°C, but thermophiles are able to survive at temperatures of up to 80°C. Indicate which of the following are reasons for the survival of thermophiles by answering Yes or No. (1 point)

1. large size
2. small size
3. cell membrane composition
4. accelerated cell repair mechanisms
5. protein thermostability

Answer
[Yes/No]

Question 45). Most bacteria (mesophiles) do not tolerate extreme conditions, whereas extremophiles can survive in environments of high salt, high pressure or extreme temperature (as shown in the following three graphs).



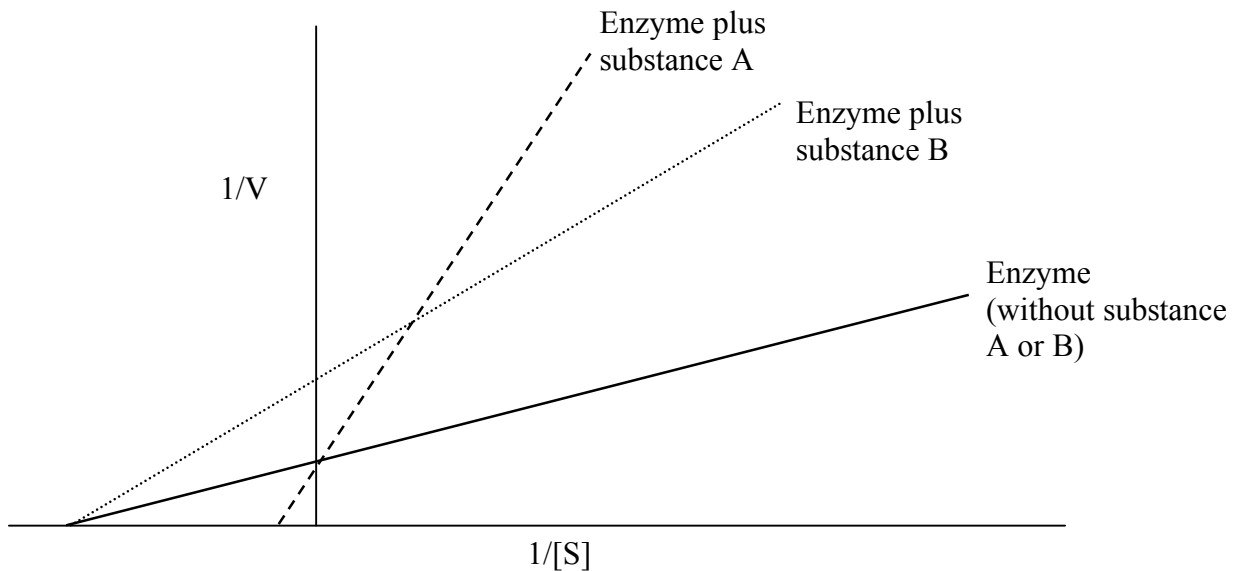


Match the growth characteristics labelled A to F with the following types of bacteria. (1 point).

Type of bacterium
1. Barophile
2. Mesophile only
3. Thermophile only
4. Halophile only
5. Psychrophile
6. Thermophile, halophile

Answer
[A/B/C/D/E/F]

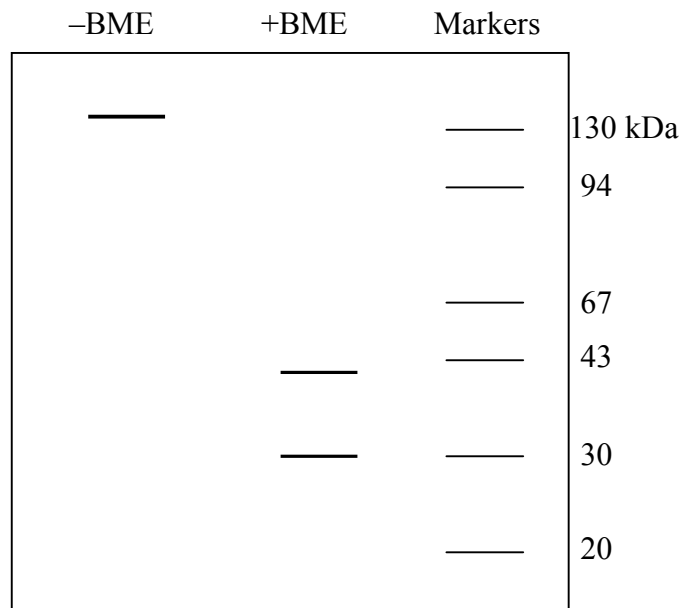
Question 46). A Lineweaver-Burk (double reciprocal) plot is shown below depicting the activity of a bacterial enzyme alone and in the presence of two different substances, A and B. The y-intercept of each line represents  $1/V_{MAX}$  for the enzyme under the different conditions.



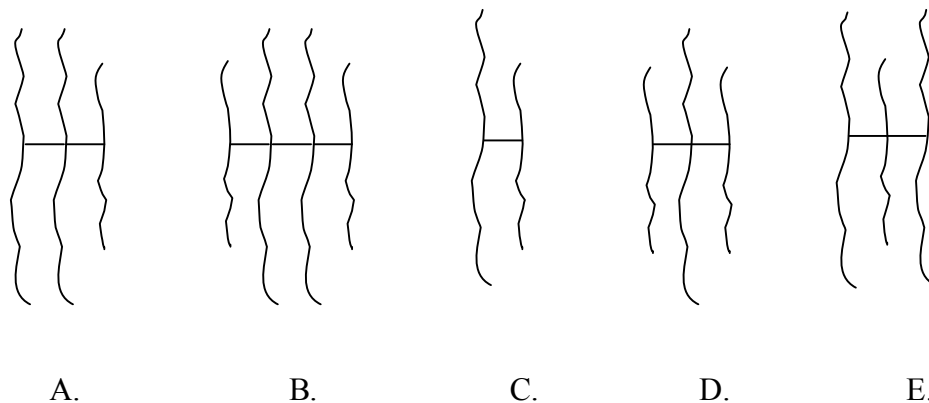
Which of the following statements about this enzyme is correct with regard to the Lineweaver-Burk plot shown above? (1 point)

- A. Substance A is a non-competitive inhibitor while substance B is a competitive inhibitor
- B. Substance A is a competitive inhibitor while substance B is a non-competitive inhibitor
- C. Substance A is a stimulatory cofactor while substance B is a competitive inhibitor
- D. Substance B is a stimulatory cofactor while substance A is a competitive inhibitor
- E. Both substance A and substance B are stimulatory cofactors

Question 47). One way bacterial proteins can maintain stability under extreme conditions is through disulfide bond bridges between cysteine amino acids. The results below are from an analysis of a bacterial protein using the reducing agent  $\beta$ -mercaptoethanol (BME), which reduces disulfide bonds. The polypeptide products were separated on the basis of molecular mass by SDS-polyacrylamide gel electrophoresis. Markers = proteins of known molecular mass (in kDa).



Based on these results, which of the following diagrams best represents the polypeptide structure of the native bacterial protein? (Note: “—” represents a disulfide bond) (1 point)



Questions 48-52. **Lipids are vital to cell structure and metabolism; yet fats have a notorious reputation as being bad for your health.**

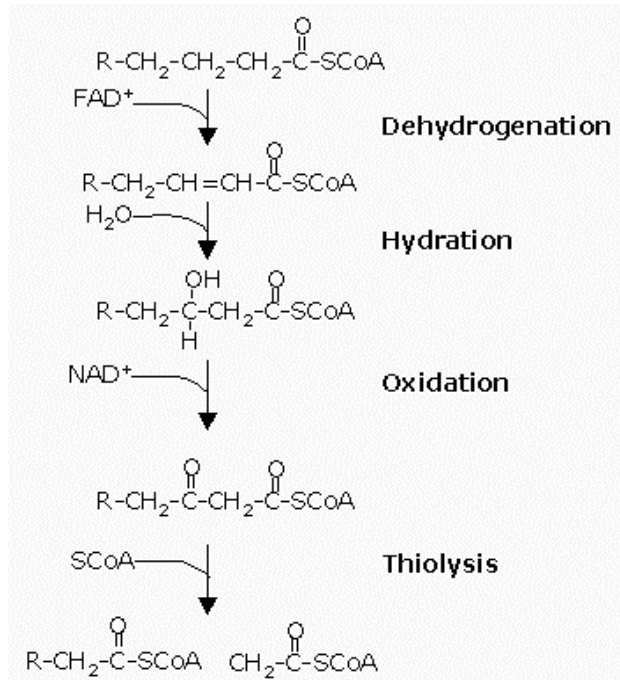
Questions 48). Which one of the following possible causes of the development of obesity is INCORRECT? (1 point)

- A. Sedentary lifestyle
- B. Abnormal hypothalamus function
- C. Environmental factors
- D. Increased thyroid hormone levels
- E. High caloric intake

Question 49). Which statement regarding the hormonal control of fat deposition in adipose tissue is correct? (1 point)

- A. Insulin promotes the formation of triacylglycerol in adipose tissue
- B. Insulin promotes the formation of cholesterol in adipose tissue
- C. Adrenaline (epinephrine) promotes the formation of triacylglycerol in adipose tissue
- D. Adrenaline (epinephrine) promotes the formation of cholesterol in adipose tissue
- E. Glucagon promotes the formation of triacylglycerol in adipose tissue
- F. Glucagon promotes the formation of cholesterol in adipose tissue

Question 50). Mitochondria are the primary site in cells for the metabolism of long-chain fatty acids, and use a process called  $\beta$ -oxidation. One cycle of  $\beta$ -oxidation of a fatty acid, which has been prior activated to a coenzyme A (CoA) ester, is shown below:

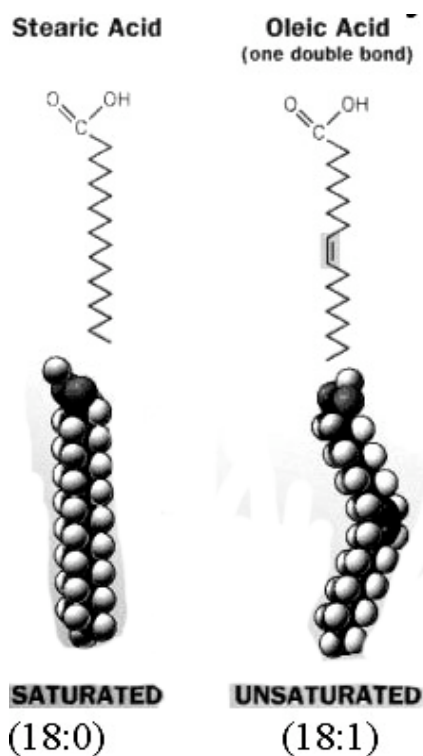


Based on this diagram, how many cycles of the pathway would be needed for complete  $\beta$ -oxidation of stearic acid (C18:0)? (1 point)

- A. 3
- B. 6
- C. 8
- D. 9
- E. 16
- F. 18



Question 51). The melting temperature of a fat-containing substance is dependent on the degree of unsaturation of the constituent fatty acid chains – unsaturated fatty acids reduce the regular packing together of fatty acids. Examples of two common 18-carbon fatty acids, stearic and oleic, with different degree of unsaturation, are shown below in diagrammatic form:



Which one of the following substances would you expect to have the highest ratio of unsaturated/saturated fatty acids? (1 point)

- A. butter
- B. vegetable oil
- C. margarine
- D. peanut paste
- E. cake of soap

Question 52). In humans, many lipids, including cholesterol, are carried in the blood in large spherical-shaped lipid-protein complexes called lipoproteins. Their structure reflects the hydrophilic, hydrophobic or other functional properties of the constituent molecules. Given the major components of lipoproteins below, predict whether they would be in the core (C) or surface (S) layer of lipoproteins. (1 point)

1. Proteins involved in tissue receptor binding
2. Cholesterol
3. Cholesterol ester (cholesterol esterified to a fatty acid)
4. Phospholipid
5. Triacylglycerol

Answer C or S

Questions 53-57. **Photosynthesis occurs in plants when their chloroplasts capture light energy and convert it to chemical energy stored in sugar and other organic molecules.**

Question 53). From several parts of pea plants that had been either kept in light for 12 hours or in the dark for 12 hours, mRNA was extracted and used in Northern blots with five different gene probes. The results are shown below.

Probe	Leaf		Stem		Root		Tendril	
	light	dark	light	dark	light	dark	light	dark
1	++++	+	-	-	-	-	++	+++
2	+++	+++	++	+	+	-	+++	+++
3	+++	+	+++	+	+	+	++	+++
4	++++	+	+	-	-	-	+++	+
5	+++	+++	++	++	+	+	+++	+++

Which result best indicates that the Rubisco small subunit gene was used as a probe? (1 point)

- A. 1.
- B. 2.
- C. 3.
- D. 4.
- E. 5.

Question 54). The main types of plants are C<sub>3</sub> plants, C<sub>4</sub> plants and CAM plants (CAM stands for Crassulacean Acid Metabolism). Match the ten items listed in the left-hand column with the ten corresponding items in the right-hand column. (2 points)

1. CAM plants at night
2. CAM plants during dry hot days
3. plastoquinone
4. CO <sub>2</sub> compensation point
5. cellulose
6. linoleic acid and galactose
7. photorespiration
8. flavonoids
9. oils
10. starch

A. amylose and amylopectin
B. unbranched glucose polymer
C. CO <sub>2</sub> fixation followed by malate accumulation in large vacuoles
D. components of thylakoid membranes' polar lipids
E. UV filters and animal attractants
F. CO <sub>2</sub> evolved when two glycines are converted to one serine
G. stored in organelle with a surrounding membrane of a monolayer of polar lipids
H. electron transporting molecule
I. photosynthesis proceeds despite closed stomates
J. respiration + photorespiration = photosynthesis

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

Question 55). ~~Plants, directly or indirectly, supply all of humanity's food. Match the crops listed in the left hand column with the name of the plant organ forming most or all of the material actually consumed (listed in the right hand column): (1 point)~~

1. <del>broccoli</del>
2. <del>ginger</del>
3. <del>Brussels sprout</del>
4. <del>pumpkin</del>
5. <del>celery</del>
6. <del>carrot</del>
7. <del>potato</del>
8. <del>strawberry</del>
9. <del>onion</del>
10. <del>kohl rabi</del>

A. <del>axillary bud</del>
B. <del>stem</del>
C. <del>modified stem (tuber)</del>
D. <del>receptacle</del>
E. <del>leaves</del>
F. <del>modified stem (rhizome)</del>
G. <del>fruit</del>
H. <del>inflorescence</del>
I. <del>petioles</del>
J. <del>root</del>

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

Question 56). The accumulation of salt in soil is a major limitation to agriculture. What is the primary cause of the inability of non-halophyte (i.e. salt-sensitive) plants to grow in soils of high salt concentration? (1 point)

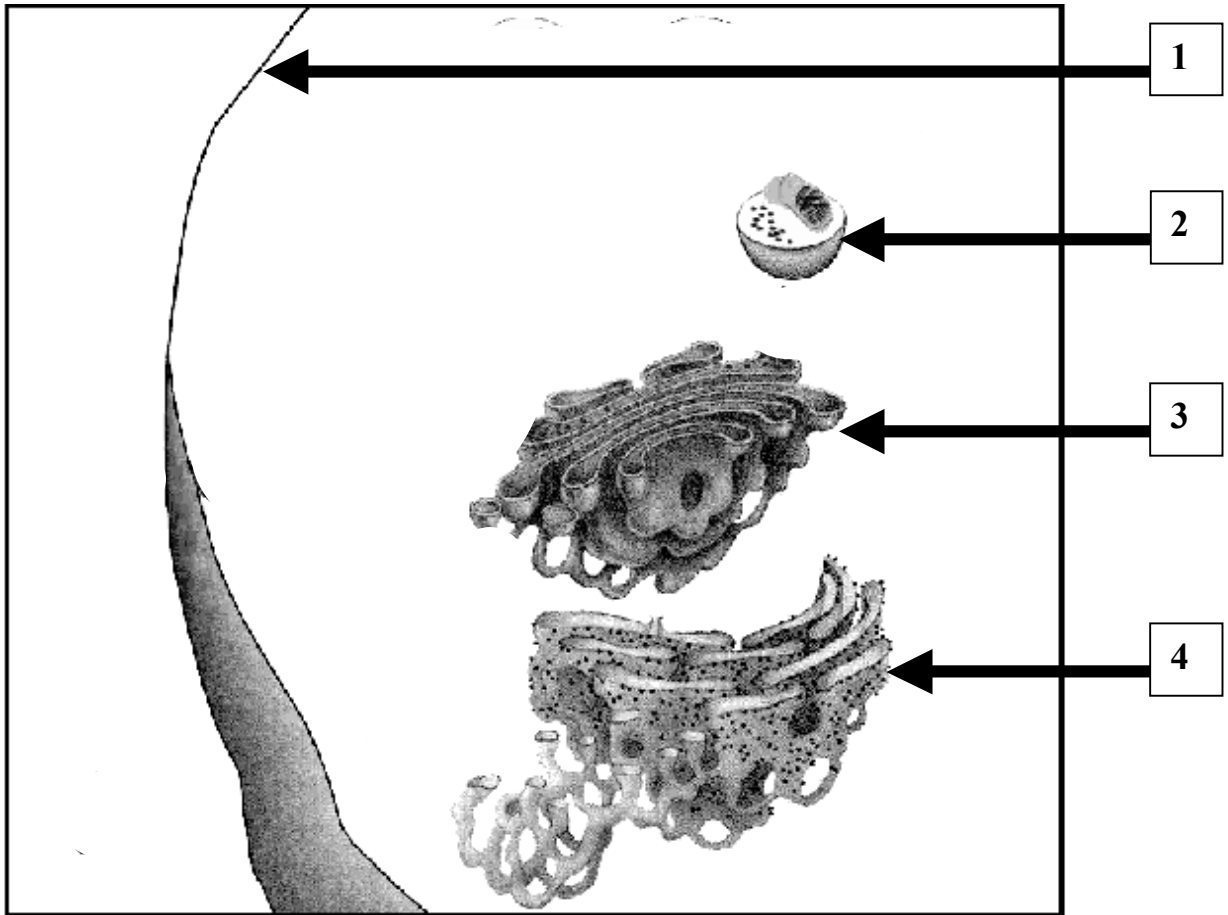
- A. Salt crystals form in the stomata and stop gas exchange
- B. Large quantities of  $\text{Na}^+$  and  $\text{Cl}^-$  enter the plant cells and poison them
- C. Salt accumulates in root cells and osmosis follows, causing the cells to burst
- D. The oxygen content of the soil is too low
- E. The water potential of the soil is too low

Question 57). Plants obtain from the soil various mineral nutrients with important physiological roles. Match each of the phrases in the right-hand column with one of the nutrients listed in the left-hand column. (2 points).

1. calcium	A. cation important in the development of stomatal guard cell turgor
2. nitrogen	B. the form of nitrogen usually available for uptake by plants in natural ecosystems
3. nitrate	C. required for the biosynthesis of the side chains of the amino acids cysteine and methionine
4. iodine	D. component of all amino acids, nucleotides and chlorophylls
5. phosphate	E. the "central" atom in a chlorophyll molecule
6. magnesium	F. allows for cell wall cross-linking through pectates
7. potassium	G. important component of DNA and RNA, but not of purine or pyrimidine bases
8. sulfate	H. most common metal ion in electron-transporting proteins
9. manganese	I. a principal function is in photosynthetic water-splitting
10. iron	J. it is not essential for plant growth

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

Questions 58-62. Eukaryotic cells contain many different organelles performing a variety of functions. The following diagram shows several organelles within a typical animal cell.



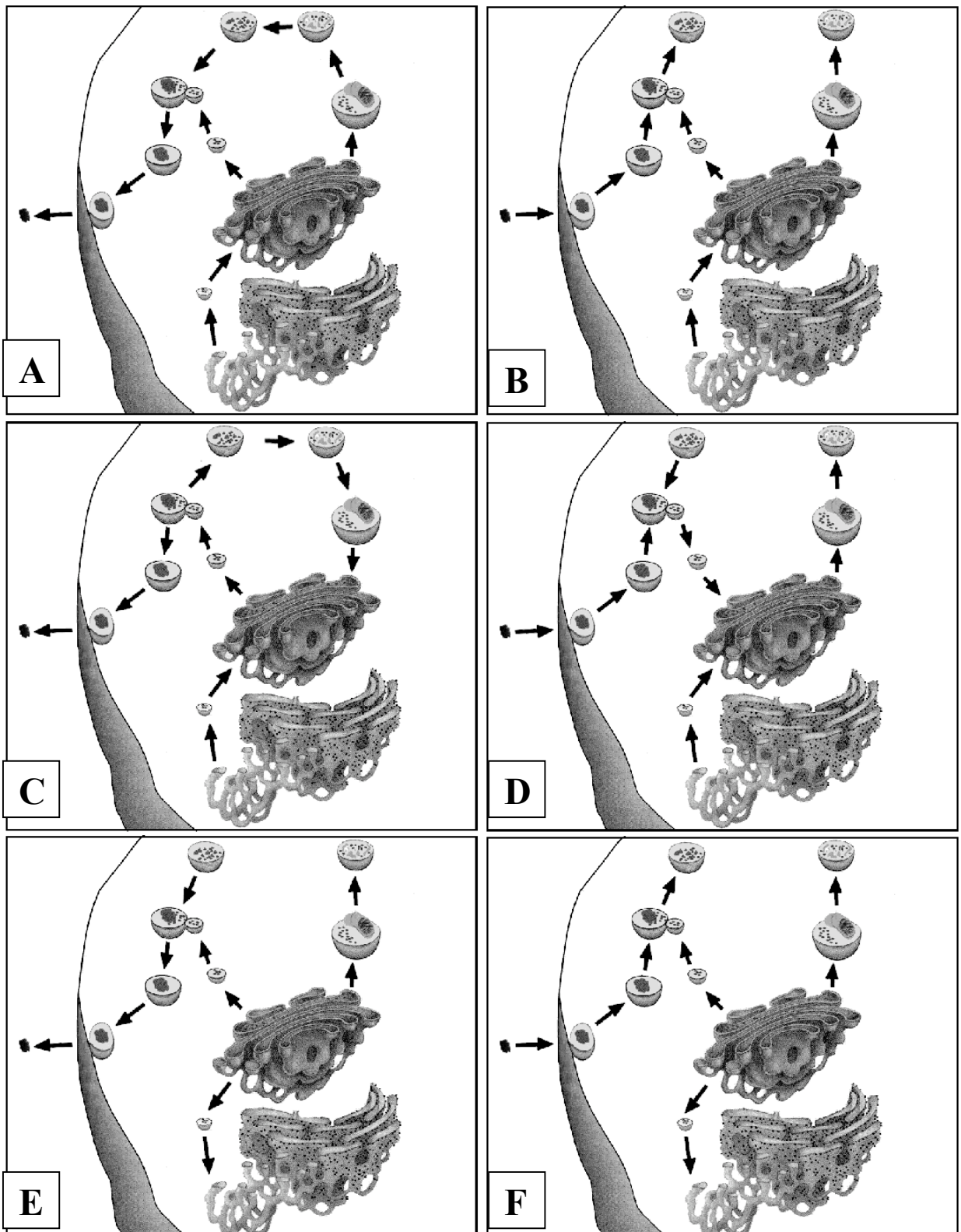
Question 58). Identify organelles 1-4 using names selected from the following list. (1 point)

- A. nucleus
- B. Golgi apparatus
- C. plasma membrane
- D. mitochondrion
- E. vesicle
- F. endoplasmic reticulum
- G. centrosome

1.	2.	3.	4.

Question 59). Which diagram shows the correct organelle interactions for phagocytosis?

(1 point)





Question 60). In multicellular eukaryotes, adjacent cells are connected to each other to form tissues and organs. Which of the following is NOT an example of an intercellular connection?

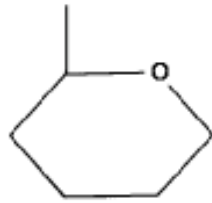
(1 point)

- A. tight junction
- B. plaque junction
- C. plasmodesma
- D. desmosome
- E. gap junction

Question 61). Organelles can be divided into functional groups. Which of the following functional groupings is correct? (1 point)

- A. nucleus, microfilaments and plasma membrane regulate cell architecture and movement
- B. endoplasmic reticulum, Golgi apparatus and mitochondria maintain membrane functionality and secretion
- C. nucleus, ribosomes and smooth endoplasmic reticulum process genetic information
- D. endoplasmic reticulum, transport vesicles and centrioles maintain membrane functionality and secretion
- E. microtubules, microfilaments and intermediate filaments regulate cell architecture and movement

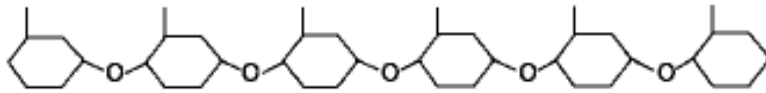
Question 62). Match the following diagrams to the chemicals listed. (1 point)



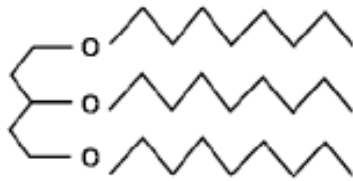
A



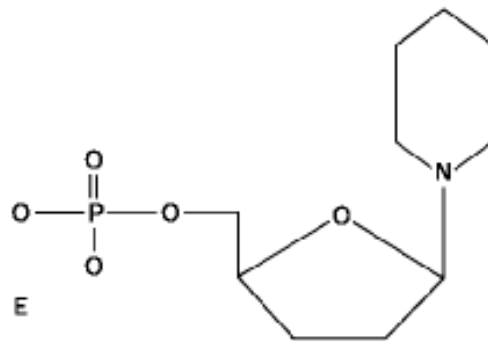
B



C



D

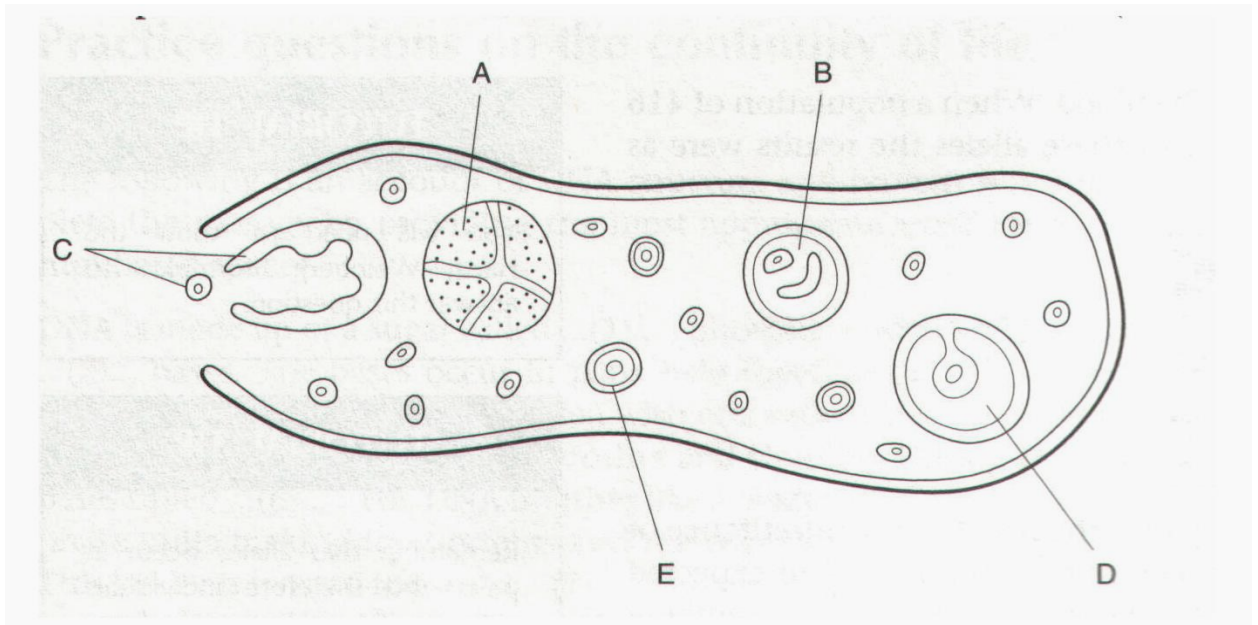


E

1. Lipid
2. Functional protein
3. Nucleotide
4. Polysaccharide
5. Monosaccharide

Answer [A/B/C/D/E]

Questions 63-67). The diagram below shows a section through a mammalian ovary.



Question 63). What is the correct sequence in which the labelled structures develop? (1 point)

- A. A-B-D-C-E
- B. D-B-E-A-C
- C. B-D-C-E-A
- D. C-E-B-D-A
- E. E-B-D-C-A

~~Question 64). Hormonal changes during normal pregnancy are correctly described by which of the following statements? (1 point)~~

- ~~A. — Estriol (estrogen and progesterone metabolite) excretion is greatest just before ——— parturition~~
- ~~B. — Human chorionic gonadotropin secretion is greatest in the last 3 months~~
- ~~C. — Human chorionic somatomammotropin secretion is greatest in the first 3 months~~
- ~~D. — Oxytocin secretion is greatest in the middle 3 months~~
- ~~E. — Pregnanediol excretion is greatest in the first 3 months~~

Question 65). Which of the listed functions do these hormones play in breast development and lactation? (1 point)

Hormone	Function
1) Progesterone	A. Plays a background role in breast development
2) Estradiol	B. Stimulates development of alveolar components
3) Prolactin	C. Stimulates growth of ductal system
4) Oxytocin	D. Stimulates milk let-down
5) Insulin	E. No role

Question 66). Where does fertilization of the oocyte by sperm usually occur? (1 point)

- A. Vagina
- B. Cervix
- C. Uterus
- D. Fallopian tubule
- E. Ovary

Question 67). Which of the following act to block polyspermy in humans? (1 point)

- A. Fusion of egg and sperm
- B. Oocyte membrane depolarization
- C. Swelling of fertilized oocyte
- D. Release of cortical granules
- E. All of above

Questions 68-72. Antibodies are produced by B-lymphocytes when animals encounter foreign antigenic material. Different antibody isotypes are formed at different times after exposure; early transient responses are followed by more persistent responses. Antibodies formed soon after infection can be denatured in the laboratory by treatment with 2-mercapto-ethanol while those occurring later are unaffected. You are provided with six serum samples collected serially from one individual animal.

**Serum 1 - collected before immunization with *Brucella abortus***

**Serum 2 - collected 6 days after immunization with *Brucella abortus***

**Serum 3 - collected 42 days after immunization with *Brucella abortus***

**Serum 4 - Serum sample 2 treated with 2-mercapto-ethanol**

**Serum 5 - Serum sample 3 treated with 2-mercapto-ethanol**

**Serum 6 - collected 42 days after subsequent immunization with *Brucella melitensis***

**You test the sera against 2 antigens and obtain the following results:**

<b>Specimen</b>	<b><i>Brucella abortus</i> antigen</b>	<b><i>Brucella melitensis</i> antigen</b>
<b>Serum 1</b>	<b>negative (-)</b>	<b>negative (-)</b>
<b>Serum 2</b>	<b>positive (+)</b>	<b>negative (-)</b>
<b>Serum 3</b>	<b>positive (+)</b>	<b>negative (-)</b>
<b>Serum 4</b>	<b>negative (-)</b>	<b>negative (-)</b>
<b>Serum 5</b>	<b>positive (+)</b>	<b>negative (-)</b>
<b>Serum 6</b>	<b>positive (+)</b>	<b>positive (+)</b>

Question 68). Which of the following statements is true? (1 point)

- A. The animal has shown an immune response to neither *Brucella abortus* nor to *Brucella melitensis*
- B. No immune response resulted from the immunization with *Brucella melitensis*
- C. An immune response to the immunization with *Brucella abortus* has been proven by these tests
- D. The animal has been previously exposed to both *Brucella abortus* and to *Brucella melitensis*
- E. The animal has been previously exposed to either *Brucella abortus* or to *Brucella melitensis*

Question 69). Which of the following statements is true? (1 point)

- A. Serum 4 and serum 6 can be used to differentiate cultures of *Brucella abortus* from those of *Brucella melitensis*
- B. *Brucella abortus* and *Brucella melitensis* have been proven to be the same organism by these tests
- C. The sera tested have no specificity for either *Brucella abortus* or for *Brucella melitensis*
- D. IgG antibodies to both *Brucella abortus* and to *Brucella melitensis* are likely to be present in Serum 6
- E. No conclusions regarding the specificity of any antibodies can be made from the data

Question 70). Subsequent testing of the sera with cultures of *Yersinia enterocolitica* showed that sera 3, 5 and 6 gave positive (+) reactions. Which of the following statements is true? (1 point)

- A. These sera can be used as antisera for identifying *Yersinia enterocolitica* in culture
- B. *Yersinia enterocolitica* and *Brucella abortus* share antigenic determinants
- C. The sera tested have no specificity for either *Brucella abortus*, for *Brucella melitensis* or for *Yersinia enterocolitica*
- D. *Brucella abortus*, *Brucella melitensis* and *Yersinia enterocolitica* have been proven to be the same organism by these tests
- E. Antibodies specific to *Yersinia enterocolitica* have been shown to react in these tests

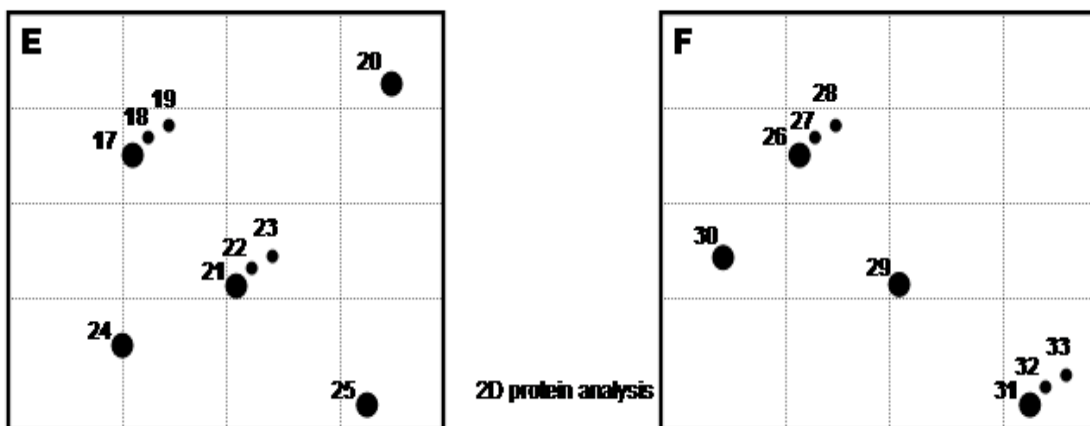
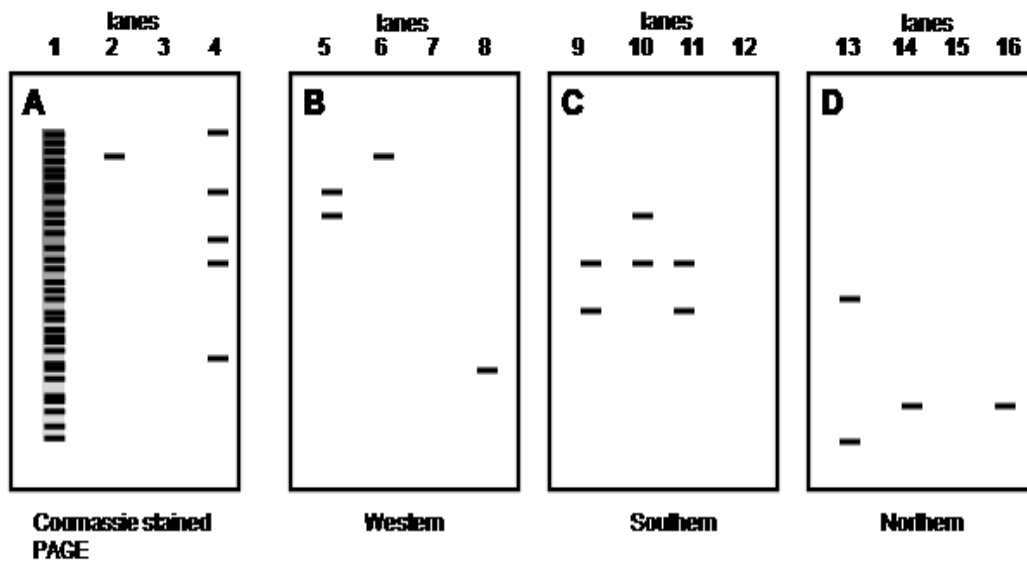
Question 71). Which of the following statements is true? (1 point)

- A. IgG antibodies to *Brucella abortus* have been demonstrated in Serum 2
- B. IgM antibodies to *Brucella melitensis* have been demonstrated in Serum 6
- C. IgM and IgG antibodies to *Brucella abortus* have been demonstrated in these tests
- D. IgM antibodies to both *Brucella abortus* and to *Brucella melitensis* have been demonstrated by these tests
- E. IgM antibodies to both *Brucella abortus* and to *Yersinia enterocolitica* have been demonstrated by these tests

Question 72). From the above reactions, which of the following could be assumed to contain IgM antibodies specific for *Brucella abortus*? (1 point)

- A. Serum 2 and Serum 3
- B. Serum 2 and Serum 4
- C. Serum 2 and Serum 5
- D. Serum 2 and Serum 1
- E. None of the above

Questions 73-77. In the following diagrams, you are given the results of six electrophoretic gel separations. Bands are shown in numbered lanes in polyacrylamide protein gels, Western blots, Southern blots and Northern blots and spots are numbered on two-dimensional protein gels. Use the information to answer the following questions.





Question 73). A research scientist had designed a probe that recognizes two distinct fragments of a gene when digested genomic DNA is examined. Which of the following would confirm that a section of DNA has been lost from this gene in the cells of a tumour compared to normal tissue? (1 point)

- A. When comparing lane 10 from the tumour and lane 11 from normal tissue
- B. When comparing lane 11 from the tumour and lane 10 from normal tissue
- C. There would be no change in the observed band pattern
- D. When comparing lane 14 from the tumour and lane 13 from normal tissue
- E. When comparing lane 14 from the tumour and lane 16 from normal tissue

Question 74). Which of the following would suggest that the cause of a patient suffering a metabolic disease is caused by changes in the post-translational modification of a protein involved in the metabolic pathway associated with the disease ? (1 point)

- A. Lane 5 from normal tissue with lane 6 from affected tissue
- B. Lane 8 from normal tissue with lane 6 from affected tissue
- C. Spots 21, 22 and 23 from normal tissue compared to spots 26, 27 and 28 from affected tissue
- D. Spots 31, 32 and 33 from normal tissue compared to spot 25 from affected tissue
- E. Spot 20 from normal tissue compared to spot 29 from affected tissue

Question 75). Which of the following best supports the hypothesis that the developmental change seen in two different tissues of an embryo is regulated by controlling transcription? (1 point)

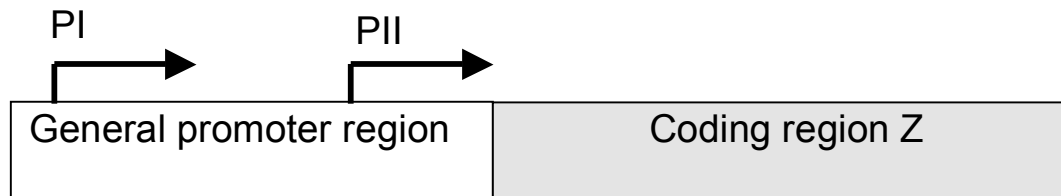
- A. Comparing lane 2 (brain) with lane 3 (limb bud)
- B. Comparing spots 21, 22 and 23 in brain to spot 29 in limb bud.
- C. Comparing lane 14 in brain and lane 15 in a limb bud
- D. Compare lane 8 (brain) with lane 6 (limb bud)
- E. Compare lane 11 (brain) with lane 12 (limb bud)

Question 76). Which lanes on panels A, B, C and D best represent the experiments in which cells have been transfected with a plasmid encoding a recombinant protein?

[First, the expressed RNA that had been transcribed from the plasmid was analysed by a specific nucleic acid probe. The expressed protein was then purified and visualized to confirm purity. Finally, the expressed protein was reacted with a specific antibody probe.] (1 point)

- A. 14, 2 and 6
- B. 1, 6 and 9
- C. 14, 2 and 8
- D. 13, 9 and 5
- E. 9, 8 and 2

Question 77). A gene “Z” has two promoters. One promoter (PI) is used when the cell is stimulated by a particular steroid hormone, while the second promoter (PII) is used when the steroid hormone is absent. The single mRNA from transcription using PII is much shorter than that of the single mRNA transcript generated when PI is used.



Assuming no degradation, which two lanes best represents the results of an experiment in which the RNA transcript from gene Z has been specifically probed with a nucleic acid specific to gene Z mRNA? [The source of the RNA for the blot comes from cells treated with the steroid hormone compared to RNA from untreated cells.] (1 point)

- A. Comparing lane 15 (steroid-treated cells) and lane 13 (untreated cells)
- B. Comparing lane 13 (steroid-treated cells) and lane 14 (untreated cells)
- C. Comparing lane 13 (steroid-treated cells) and lane 15 (untreated cells)
- D. Comparing lane 14 (steroid-treated cells) and lane 13 (untreated cells)
- E. None of the above

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END