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AUSTRALIAN SCIENCE INNOVATIONS

School ID

Australian Science Olympiads

2018 AUSTRALIAN SCIENCE OLYMPIAD EXAM

BIOLOGY

TO BE COMPLETED BY THE STUDENT. USE CAPITAL LETTERS.

Student Name: ……..…..……

Home Address: ..……..……..

……..... **Post Code:** ……...

Telephone: (…….) …… **Mobile:** …….

E-Mail: …..……... **Date of Birth:** ……/……/..……

□ **Male** □ **Female** **Year 10** □ **Year 11** □ **Other:** …….

Name of School: ……..……..**State:** ……...

To be eligible for selection for the Australian Science Olympiad Summer School, students must be an Australian citizen.

The Australian Olympiad teams in Biology, Chemistry, Earth and Environmental Science and Physics will be selected from students participating in the Science Summer School.

Please note - students in Year 12 in 2018 are not eligible to attend the 2019 Australian Science Olympiad Summer School.

□ **I am an Australian public high school student and would like to be considered for the Australian Science Olympiad Summer School Scholarship.**

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AUSTRALIAN SCIENCE INNOVATIONS

Australian Science Olympiads

2018 AUSTRALIAN SCIENCE OLYMPIAD EXAM

BIOLOGY

Time Allowed

Reading Time: 10 minutes

Examination Time: 120 minutes

INSTRUCTIONS

- ***Attempt all questions in ALL sections of this paper.***
- **Permitted materials: non-programmable, non-graphical calculator, pens, pencils, erasers and a ruler.**
- **Answer all questions on the MULTIPLE CHOICE ANSWER SHEET PROVIDED. Use a pencil.**
- **Marks will not be deducted for incorrect answers.**

MARKS

- **1 mark for each question**
- **Total marks for the paper 75 marks**

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SECTION A
USE THE ANSWER SHEET PROVIDED

1. The ability of organisms and cells to maintain a stable internal environment is:

    a. Protein synthesis

    b. Digestion

    c. Positive feedback

    d. Homeostasis

2. The structure in plant cells that carries out photosynthesis is the:

    a. Cell membrane

    b. Chloroplast

    c. Ribosome

    d. Nucleus

3. Cells must be small in size in order to function. If a cell were too large:

    a. The cell would decay

    b. Diffusion could not take place efficiently

    c. The cell would lyse

    d. Diffusion would occur at a faster rate

4. The diameter of most animal cells ranges from:

    a. 1.0 to 10 µm

    b. 0.01 to 0.1 µm

    c. 10 to 100 µm

    d. 100 to 1000 µm

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5. Which of the pH values listed below represents the strongest base?

   a. 7

   b. 10

   c. 13

   d. 15

6. Evolutionary changes involve the production of new:

   a. individuals

   b. communities

   c. species

   d. trophic levels

7. When an early embryo divides into two separate embryos, these give rise to:

   a. Non identical, dizygotic twins

   b. Identical, monozygotic twins

   c. Non identical, monozygotic twins

   d. Identical, dizygotic twins

8. The virus which is responsible for AIDS is known as:

   a. HBV

   b. HIV

   c. HCV

   d. HPV

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9. The removal of pollutants or toxic wastes from the environment with the help of living organisms is best described as:

   a. defenestration

   b. bioremediation

   c. detoxification

   d. disease control

10. What is the predominant protein in the human body, by mass?

   a. Actin

   b. Tubulin

   c. Collagen

   d. Elastin

11. After vigorous exercise, changes occur in muscle tissue. Compared with 'at rest' conditions what will the change be?

	Glycogen	**ATP**	**Lactate**	**pH**
a	decreased	decreased	increased	decreased
b	decreased	increased	increased	increased
c	decreased	decreased	decreased	decreased
d	decreased	increased	increased	decreased

12. The proportion of adenine bases in a sample of DNA was found to be 12%. Which of the following statements is true? The proportion of:

   a. guanine bases in the sample is 12%

   b. uracil bases in the sample is 88%

   c. thymine bases in the sample is 12%

   d. cytosine bases in the sample is 12%

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13. Genetic adaptation is most accurately described as

a. a process by which an individual organism gradually changes itself to suit its environment.

b. a change in allele frequencies in a population as a result of changing environmental conditions

c. the emergence of new forms as a result of mutations in the genetic material

d. a change in the genotype of an individual organism as a result of selection pressures

14. The release of water vapour from the leaves of trees is called

a. Evaporation

b. Precipitation

c. Condensation

d. Transpiration

15. Sea anemones contain a venom that is used to sting and paralyse prey. The clownfish contains an enzyme in its scales that makes it immune to the venom. This allows the clownfish to freely live amongst the fronds of the sea anemone without being harmed, protected from their natural predators. In return, clownfish protect anemones from predation by butterfly fish, which can eat anemones. What type of relationship is this an example of?

a. Predator-prey

b. Mutualism

c. Commensalism

d. Parasitism

16. Which of the following is an abiotic factor in an ecosystem?

a. Bird

b. Tree

c. Rock

d. Deer

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17. The amount of energy that passes from one trophic level to the next in a food chain is approximately:

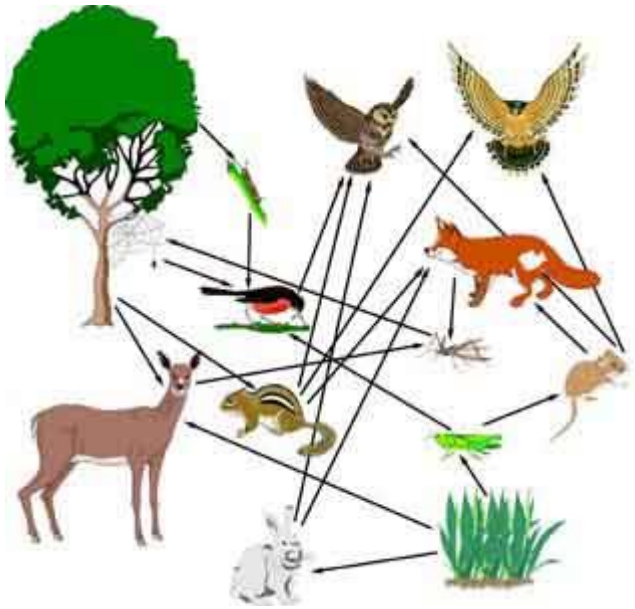
    a. 5%

    b. 10%

    c. 15%

    d. 20%

18. In the terrestrial food web below, what would be the effect of a farmer introducing a rat poison into the ecosystem that is toxic to rats and mice?



    a. The population of foxes would decrease

    b. The population of grasshoppers would decrease

    c. The population of hawks would increase

    d. The population of rabbits would decrease

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19. Which of the following statements is true about matter and energy in biological systems?

a. Matter is not recycled; energy is recycled

b. Matter is recycled; energy is not recycled

c. Both matter and energy are recycled

d. Neither matter nor energy are recycled

20. The intertidal zone is the area:

a. between low and high tide

b. beyond the continental shelf

c. between the subtidal zone and the continental shelf

d. above the high tide line

21. When subunits called monomers are bonded together, they form larger molecules called polymers. Proteins are polymers. What is the monomer that makes up proteins?

a. Amino acid

b. Peptide

c. Nucleotide

d. DNA

22. During photosynthesis, plants convert carbon dioxide and water to sugar and oxygen. In this reaction, sugar and oxygen are the:

a. Enzymes

b. Products

c. Reactants

d. Byproducts

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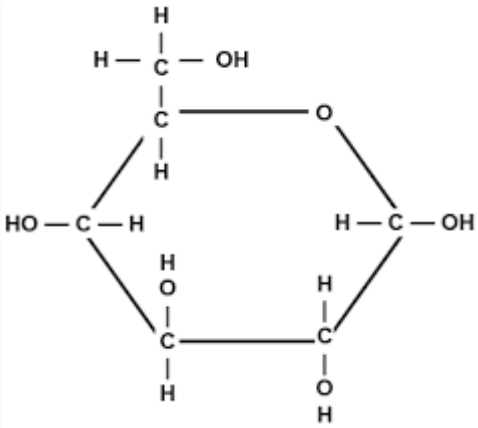
23. The molecule below is a:



a. Lipid

b. Carbohydrate

c. Protein

d. Nucleic acid

24. If a man of 70 kg weight ingests 40 g alcohol, the alcohol level in his blood will rise one part per thousand. About 1 g alcohol is eliminated per hour and 10 kg of body weight. A 70 kg man was involved in a traffic accident and ran from the scene. He was found 2.5 hours after the accident and a blood sample was taken. It contained 0.5 parts per thousand of alcohol. Assuming he did not ingest any alcohol during the intervening period, how much alcohol did his blood contain at the time of the accident?

a. 1.10 parts per thousand

b. 0.95 parts per thousand

c. 0.80 parts per thousand

d. 0.65 parts per thousand

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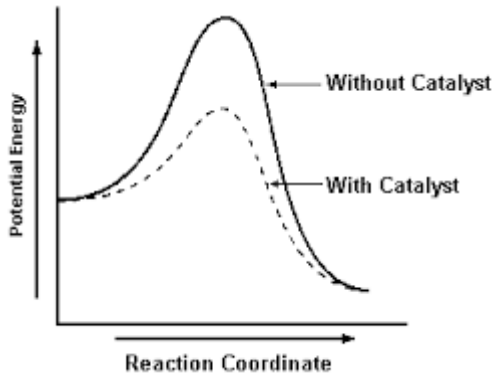
25. The graph below shows a catalysed reaction vs an uncatalysed reaction. Which of the following statements is true of catalysts?



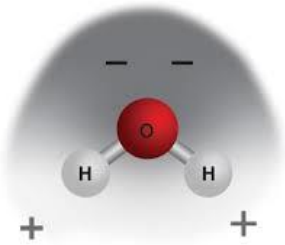
a. The catalyst lowers the energy needed for the reaction to proceed

b. The catalyst is consumed by the reaction, lowering the activation energy

c. The catalyst reduces the total energy produced by the reaction

d. Reactions never proceed without a catalyst

26. The diagram below shows a water molecule. What do the charges on either end of the molecule indicate about the molecule?



a. Water is a nonpolar molecule

b. Water is a polar molecule

c. Water is an ionic compound

d. Water is an ion

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27. What structure is found in plant cells but not in animal cells?

a. Nucleus

b. Vesicle

c. Vacuole

d. Cellulose

28. What term describes the diffusion of water through a semipermeable membrane down a concentration gradient?

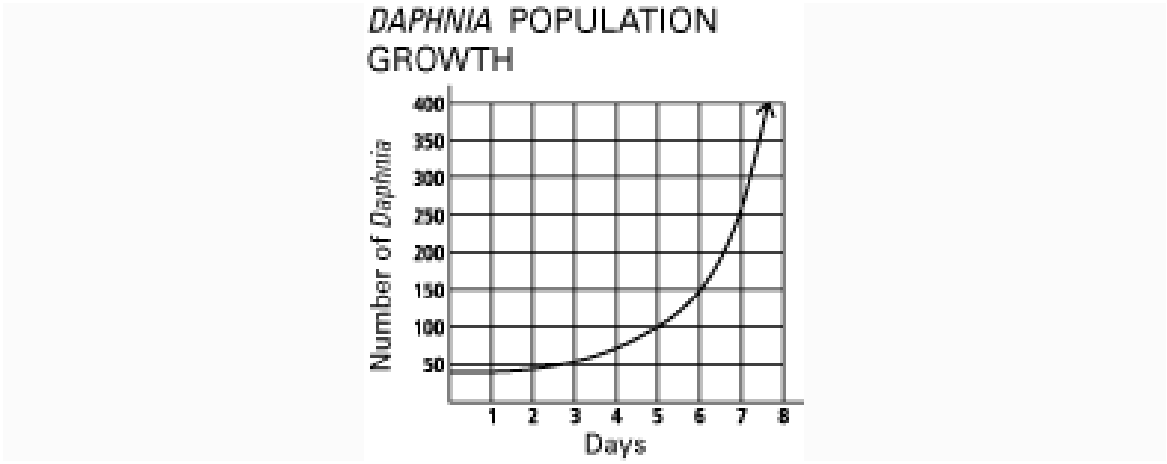
a. Osmotic pressure

b. Diffusion

c. Osmosis

d. Fluid diffusion

29. Which type of population growth is exhibited by the Daphnia population shown in the graph?



a. Arithmetic growth

b. Exponential growth

c. Density-dependent growth

d. Limited growth

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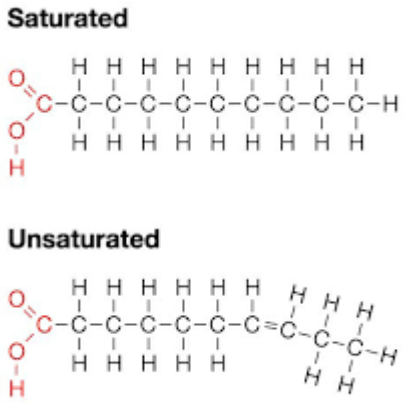
30. How is a saturated fatty acid different from an unsaturated fatty acid?



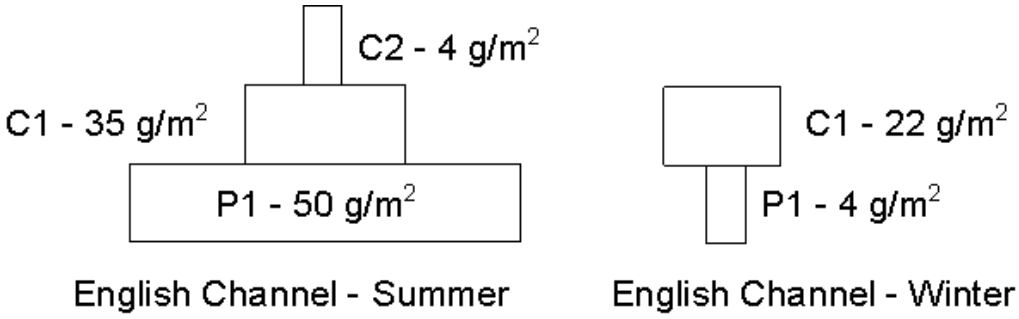
a. Saturated fatty acids contain at least one carbon-carbon double bond

b. Saturated fatty acids are found only in oils

c. Carbons in saturated fatty acids are bonded together only with covalent bonds

d. Saturated fatty acids contain only single bonds between carbons

31. The diagram below shows the seasonal changes in the pyramid of biomass in the English Channel.



In winter the pyramid of biomass is inverted because:

a. The primary production decreases dramatically and results in a die-off of zooplankton.

b. The primary production decreases and as the producers are rapidly consumed by the zooplankton they never develop a large population size.

c. The primary production remains the same all year but the cold means that the zooplankton and secondary consumers migrate elsewhere.

d. The primary production is increased but the phytoplankton have a shorter turnover time in winter.

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32. In a stable ecosystem, which of the following limits the number of trophic levels?

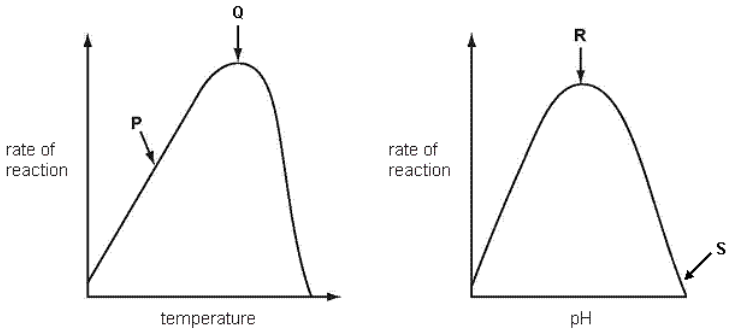
a. biomass.

b. the number of primary producers.

c. availability of nutrients.

d. energy.

33. The graphs below show the effects of temperature and pH on enzyme activity. Which statement about the enzyme activity is correct?



a. at P, hydrogen bonds are formed between enzyme and substrate.

b. at Q, the kinetic energy of enzyme and substrate is highest.

c. at R, peptide bonds in the enzyme begin to break.

d. at S, the substrate is completely denatured.

34. During which of the following stages of the cell cycle does DNA replication occur?

a. interphase.

b. prophase.

c. metaphase.

d. mitosis.

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Questions 35 – 38 relate to the following information.

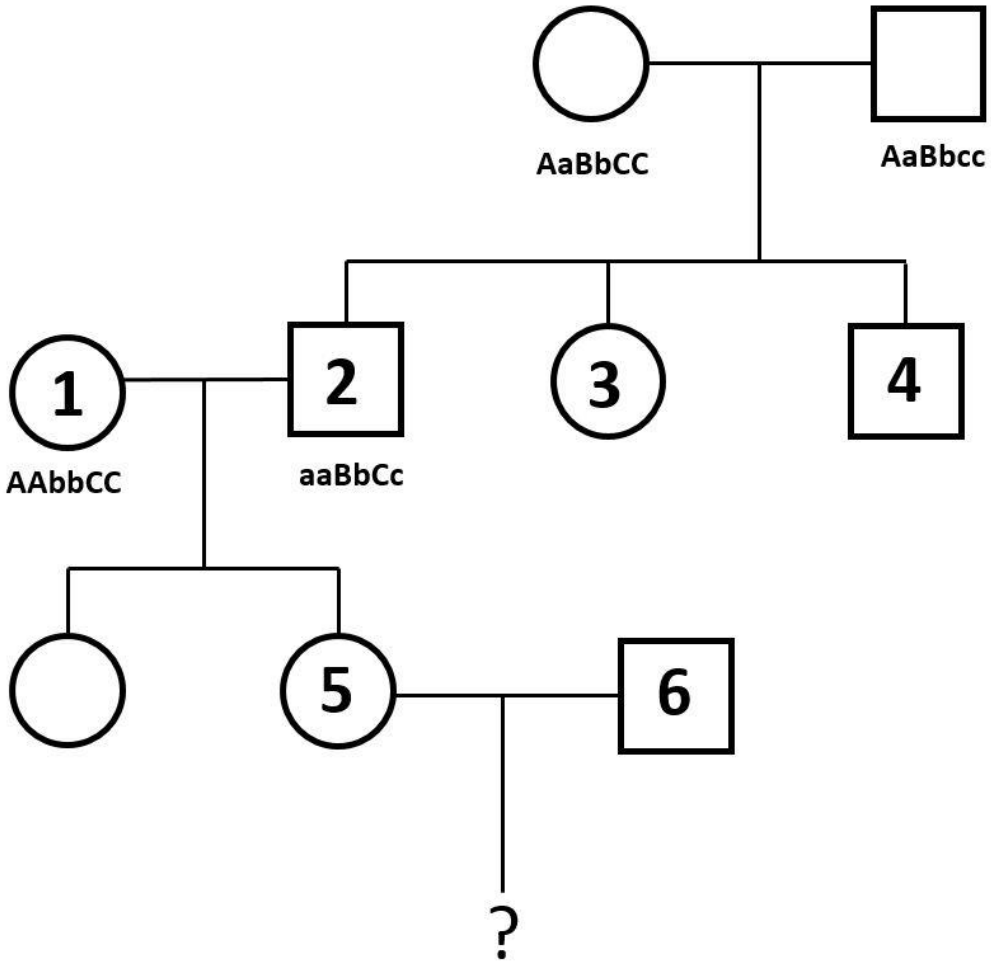
Skin colour is determined by the expression of pigments. Pigment expression is encoded by three gene loci, each with two alleles, which are inherited from an individual's parents. 'A', 'B', and 'C', represent equivalent alleles that code for a darker pigment at each loci respectively, and 'a', 'b', and 'c', are the corresponding alleles for a lighter pigment.

Consequently, every individual has a skin colour genotype consisting of a string of six letters, e.g., AaBBCc, AABbCc, aabbCC and skin colour can be determined by looking at the individual's combination of dark and light pigment alleles. In this way, an individual with genotype AaBBcc will have the same skin colour as an individual with AaBbCc.

35. Identify the genotypes for the following: lightest and darkest skin tones (in that order).

	Lightest tone	Darkest tone
a	AABBCC	aabbcc
b	AaBBcc	AabbCC
c	aabbcc	AABBCC
d	AAbbcc	aabbCC

A pedigree for skin tone has been constructed below with some genotypes identified.



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36. It is known that individuals 3 and 4 have the same skin tone but different genotypes. Which of the following options identifies the two genotypes of individuals 3 and 4?

    a. AabbCc and aaBbCc

    b. AabbCc and AabbCc

    c. Aabbcc and aaBbCc

    d. AabbCc and aaBbCc

37. If individual 1 and individual 2 have offspring, how many different genotypes are possible?

    a. Four genotypes

    b. Three genotypes

    c. Six genotypes

    d. Eight genotypes

38. It is known that individual 5 has genotype AabbCc and individual 6 has genotype aabbcc. What is the probability that the offspring of individual 5 and individual 6 will have the same skin tone as their father?

    a. 0% chance

    b. 25% chance

    c. 50% chance

    d. 66% chance

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Questions 39 – 41 relate to the following information.

Graves' disease is an autoimmune disease that results in the overproduction of thyroid hormones T3 (tri-iodothyronine) and T4 (thyroxine). This results in a form of hyperthyroidism.

The pathway controlling production of thyroid hormones involves the release of Thyrotropin-Releasing Hormone (TRH) from the hypothalamus, which in turn stimulates the release of Thyroid Stimulating Hormone (TSH) from the anterior pituitary gland. TSH acts on the thyroid to release T3 and T4. The pathway is regulated by negative feedback from thyroid hormones.

Negative feedback is a key regulatory mechanism for physiological function in living organisms, wherein the response or output of a system to a stimulus results in an action that decreases the strength of that stimulus.

An example of negative feedback is the release of insulin in response to high blood glucose levels. Insulin acts on muscle and liver cells and induces them to increase uptake of glucose, thereby decreasing blood glucose levels back to normal.

Although a number of disorders may result in hyperthyroidism, Graves' disease is a common cause. Major symptoms include hand tremors, weight loss, and an enlarged thyroid.

39. What is the function of the thyroid hormones T3 and T4?

a. Act to regulate the body's metabolic rate

b. Act to maintain blood pressure by causing the kidney to retain fluid and by constricting blood vessels

c. Stimulates release of thyroxine and tri-iodothyronine from the thyroid gland

d. Act as inhibitory hormones that prevent release of other hormones such as Growth hormone

40. In Graves' disease, the body produces an antibody called TSI that mimics the action of TSH. Which of the below statements is correct?

a. TSI binds to many TSH at once, causing them to accumulate and prevent movement around the body

b. TSI binds to the TSH receptor and mimics the action of TSH on the thyroid gland

c. TSI binds with thyroxine and tri-iodothyronine to prevent them from entering the bloodstream, hence inducing hormone re-uptake and breakdown by the thyroid gland

d. TSI binds to TRH receptors, preventing TSH from being released

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41. What would the level of TSH in the body be compared to that of an individual without Graves' disease?

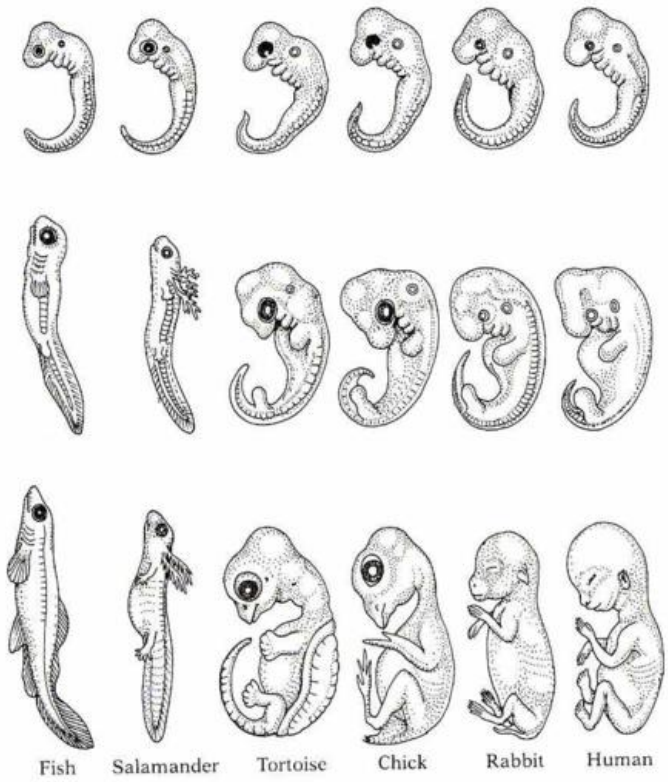
a. Lower, as a result of lowered TRH levels

b. The same, as TSH is not involved

c. Higher, as a result of lowered TRH levels

d. Higher, as a result of a desensitized thyroid gland

42. The diagram below shows several different embryos at different stages of development.



How do the embryos provide evidence for evolution?

a. The embryos have different tail lengths

b. Different adults evolve from the embryos

c. The embryos have similar looking structures

d. Divergent evolution results in common embryo characteristics

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Questions 43 – 47 relate to the following information.

Animal behaviour is shaped by 3 main influences: acquisition of food, predator avoidance, and mate choice. In theory, forming social groups allows individuals to balance the need for predator detection with the ability to find food.

You develop a set-up (shown below) to test this hypothesis. A subject fish is given the choice to swim towards two other fish. The fish are of the same species and are healthy. A camera records their speed of movement.

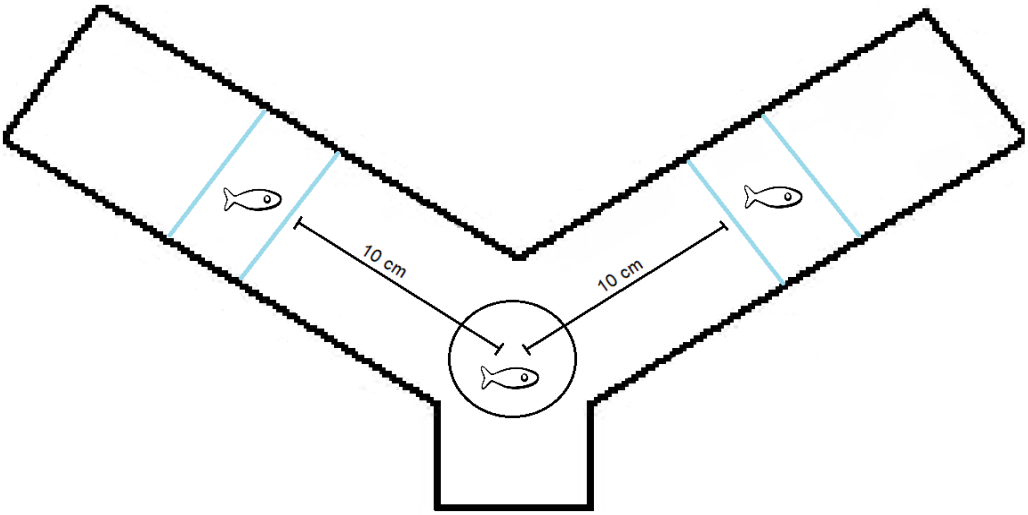

Figure 1: Experimental set-up. The experimental fish was placed in a plastic cylinder (r = 4 cm) an equal distance away from 2 test fish enclosed in individual glass tanks (12x10x4 cm). The cylinder surrounding the experimental fish was raised after an accommodation interval (5 min) allowing the experimental fish to move freely within the inner portion of the maze.

43. If the fish are trying to find individuals to group with and together balance their needs of predator avoidance and foraging ability, which result would you expect?

    a. The experimental fish will move towards the less active test fish

    b. The experimental fish will move towards the more active test fish

    c. The experimental fish will show no preference for either test fish

    d. None of the above

44. Which is the independent variable in your experimental set-up?

    a. The accommodation interval

    b. The activity of the experimental fish

    c. The experimental fish choice of swim direction

    d. The activity of the experimental fish

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45. Which aspect of your procedure would NOT increase validity and reliability?

a. Monitoring tank pH

b. Conducting all trials in a single session

c. Using different experimental fish after 6 trials

d. Selecting a sufficient separation distance to clearly demonstrate that the experimental fish has made a choice

After conducting your experiment and collecting the data, you produce the following figure:

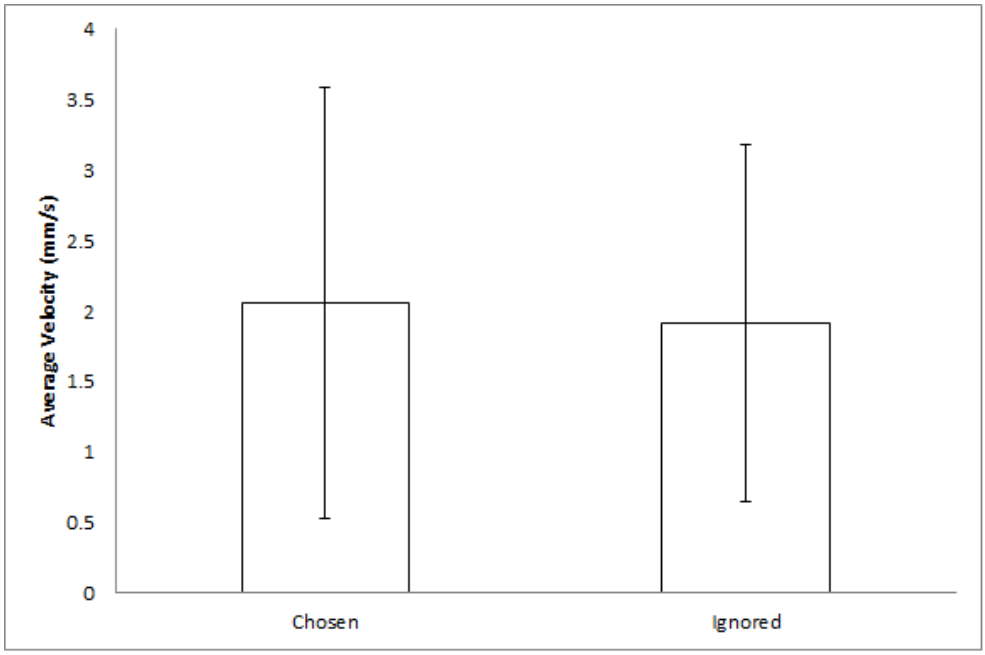

Figure 2: Average velocity of chosen and ignored individuals, with error bars calculated from the standard deviation of each sample; p-value= 0.36

46. What is the biggest problem with this figure?

a. No x-axis label

b. Overlapping error bars

c. It is a bar graph, and scientific standard is always a line graph

d. The y-axis does not represent the dependent variable

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47. What conclusion can be drawn from this experiment?

a. The experimental fish showed a slight preference for more active test fish

b. The experimental fish showed a preference for less active test fish

c. The experimental fish showed no preference between test fish

d. The experimental fish did not move significantly from where it was placed during the 5 minute accommodation interval

Questions 48 to 52 relate to the following information.

On an expedition around the world, scientists collected venom from a number of snake species. They also gathered data on mortality from snake bites of each species.

The snakes observed were the southern United States copperhead with a mortality percentage of less than 1%, the western diamondback rattlesnake with 5-15% mortality, the eastern coral snake with 5-20% mortality, the king cobra with greater than 40% mortality, the Indian krait with 77% mortality, the European viper with 1-5% mortality, the bushmaster with usually 100% mortality, the fer-de-lance with 10-20% mortality, the black-necked cobra with 11-40% mortality, and the puff adder with 11-40% mortality.

48. What does the term mortality relate to?

a. Death of the prey or victim

b. Illness of the prey or victim

c. Disease of the prey or victim

d. Health of the prey, victim and snake

49. How many snakes were observed?

a. 5

b. 7

c. 10

d. 12

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50. Which snake venom has the highest mortality rate?

a. king cobra
b. indian krait
c. european viper
d. bushmaster

51. Which two snakes have the same mortality percentage?

a. copperhead and european viper
b. black-necked cobra and puff adder
c. western diamondback rattlesnake and eastern coral snake
d. fer-de-lance and eastern coral snake

52. From the information recorded, which snake venom is most quick to take effect?

a. bushmaster
b. copperhead
c. western diamondback rattlesnake
d. this cannot be determined

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Examine the data found in Table 1 and answer Questions 53 – 55

Table 1: Growth of eight plants in a three week period

	Amount of Light per day (hours)	Amount of Water per day	Height Week 1 (cm)	Height Week 2 (cm)	Height Week 3 (cm)
Plant 1	0	¼ cup	0	0	0
Plant 2	0	1 cup	0	0	0
Plant 3	4	¼ cup	1	3	6
Plant 4	4	1 cup	0.5	1	1.5
Plant 5	8	¼ cup	1.5	4	8
Plant 6	8	1 cup	1	3	6
Plant 7	16	¼ cup	1	2	3
Plant 8	16	1 cup	1.5	5	10

53. In this plant growth experiment, what were the two variables tested?

a. Amount of light per day and height

b. Amount of water per day and plant number

c. Plant number and height

d. Amount of light per day and amount of water per day

54. Which plant had the greatest growth when measured in Week 2?

a. Plant 3

b. Plant 5

c. Plant 6

d. Plant 8

55. Which protocol provided the best growth conditions?

a. 8 hours of light per day and 1 cup of water

b. 4 hours of light per day and ¼ cup of water

c. 8 hours of light per day and ¼ cup of water

d. 16 hours of light per day and 1 cup of water

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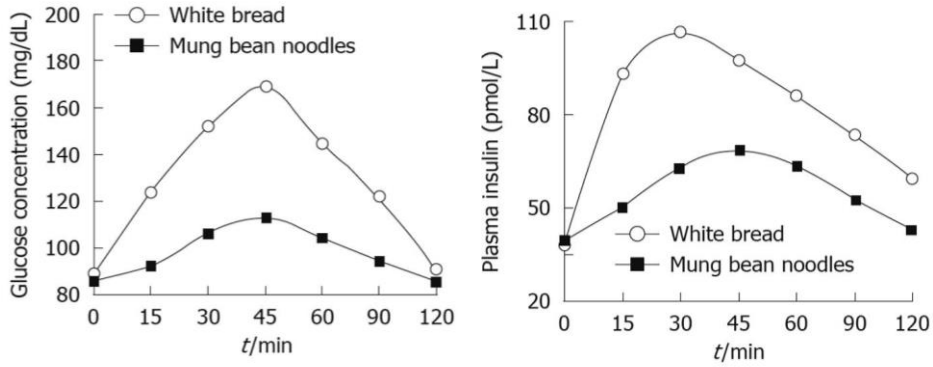
Questions 56 – 60 relate to the following information.

The glycaemic index (GI) measures the rise in blood sugar levels caused by a measured quantity of a particular food. The GI is a useful nutritional concept because it measures how rapidly carbohydrates are absorbed in the human body by measuring the increase in blood glucose concentration, thereby also giving an indication of expected insulin elevations.

A rapid increase in blood sugar levels indicates that a food has a high glycaemic index. Blood glucose levels are measured by sampling a tiny pin-prick of blood using a device especially calibrated to detect glucose levels.

The following graphs show the body's typical responses to ingestion of equal amounts of two different foods.



Source: Baishideng Publishing Group Co

56. Carbohydrates are <u>not</u>:

a. one of the four basic macromolecules of life

b. polymers made up of monomers called monosaccharides

c. polymers made up of simple sugars such as glucose and fructose

d. polymers that include glycogen, starch and insulin

57. The graph shows that mung bean noodles have a:

a. lower GI than white bread

b. higher GI than white bread

c. lighter weight than white bread

d. quicker digestion rate than white bread

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58. Which of the following foods would have the highest GI per gram?

a. steak

b. mung bean noodles

c. olive oil

d. egg white

59. The insulin response curve shown above demonstrates that:

a. insulin responses are not affected by the GI of food types

b. insulin levels are higher in white bread than in mung bean noodles

c. insulin is released in response to blood glucose levels

d. insulin is less effective when foods have low GI

60. Response curves such as those shown above are useful for measuring all of the following except:

a. The uptake of fats into the blood stream

b. The amount of glucose in each liver cell

c. How quickly oral medicines are absorbed from the digestive system

d. Rates of alcohol elimination

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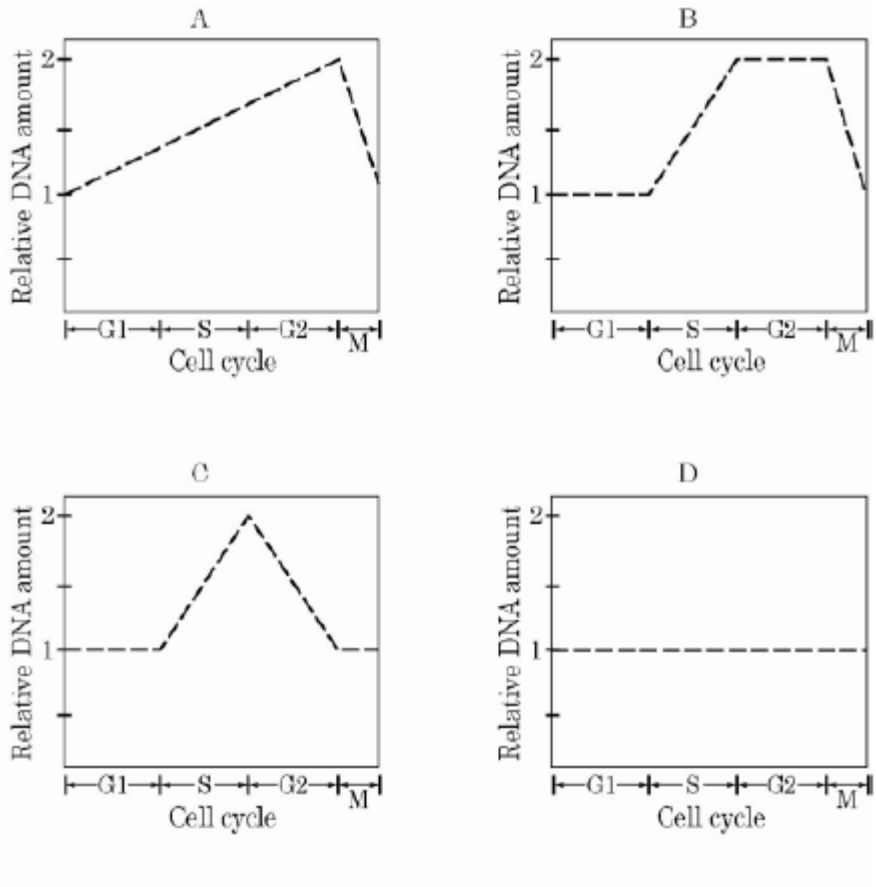
61. Which one of the following graphs shows the relative change in the amount of mitochondrial DNA of a cell undergoing mitosis?



Correct answer is A for question 61

62. If a segment of an mRNA molecule has the sequence 5' GUACCGAUCG 3', which of the following could have been the template DNA molecule?

a. 5' GCUAGCCAUG 3'

b. 5' GUACCGAUCG 3'

c. 5' CATGGCTAGC 3'

d. 5' CGATCGGTAC 3'

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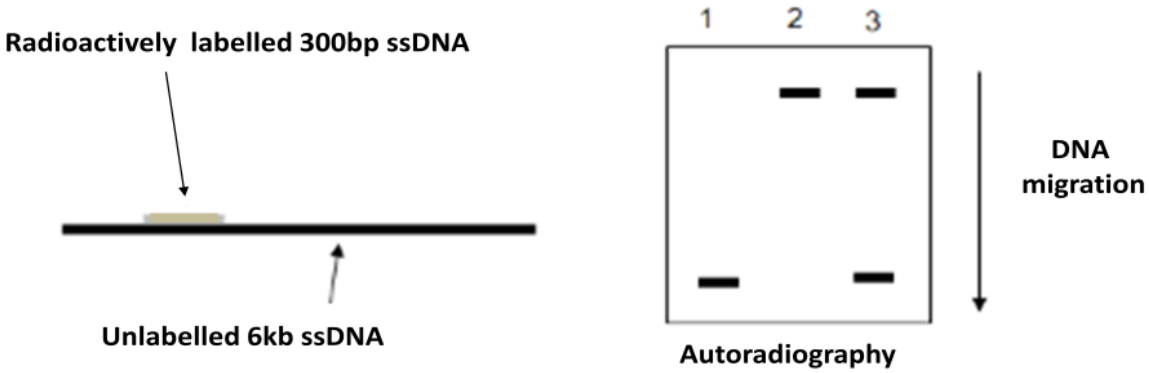
63. DNA helicase, a key enzyme in DNA replication, separates double-stranded DNA into single-stranded DNA (ssDNA). The following describes an experiment exploring the characteristics of this enzyme.

A linear 6 kb ssDNA was annealed with a short (300 bp) complementary ssDNA that is labeled with radioactive nucleotides (***a***). The annealed DNA was then treated in one of three ways: with DNA helicase, boiling without helicase, or boiled helicase. Treated DNA samples were electrophoresed on agarose gel. The gel in ***b*** shows the DNA bands that could be detected in the gel by autoradiography. (It is assumed that adequate ATP was provided during the treatment of DNA helicase).



(a) **(b)**

Which of the following explanations is correct?

a. The band appearing in the top part of the gel is the 6.3 kb ssDNA only.

b. The band appearing in the lower part of the gel is the labelled 300 bp DNA.

c. If the annealed DNA is treated only with DNA helicase and the reaction is complete, the band pattern looks like the lane 3 in ***b.***

d. If the annealed DNA is treated only with boiled helicase, the band pattern will look like lane 1 in ***b***.

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64. Self-incompatibility (SI) in flowering plants is the most common mechanism of preventing self-pollination and is mediated by a single S locus with multiple alleles. In gametophytic self-incompatibility (GSI), incompatibility of pollen is determined by the haploid pollen genotype at the S locus. In sporophytic self-incompatibility (SSI), incompatibility is determined by the diploid S genotype of the pollen-receiving plant.

The table below shows the SI type and pollen/style S-gene genotypes of two plants crossed for fertilization. (The style of a flowering plant receives pollen grains for fertilization.)

Which of these crosses (I, II, III, and IV) will result in successful fertilizations?

	SI type	Expressed genotype	
		Pollen of plant 1	Style of plant 2
I	GSI	S_1 or S_2	$S_2\,S_3$
II	GSI	S_2 or S_3	$S_2\,S_3$
III	SSI	S_1 or S_2	$S_1\,S_3$
IV	SSI	S_1 or S_2	$S_3\,S_4$

a. I and III

b. I and IV

c. II and III

d. II and IV

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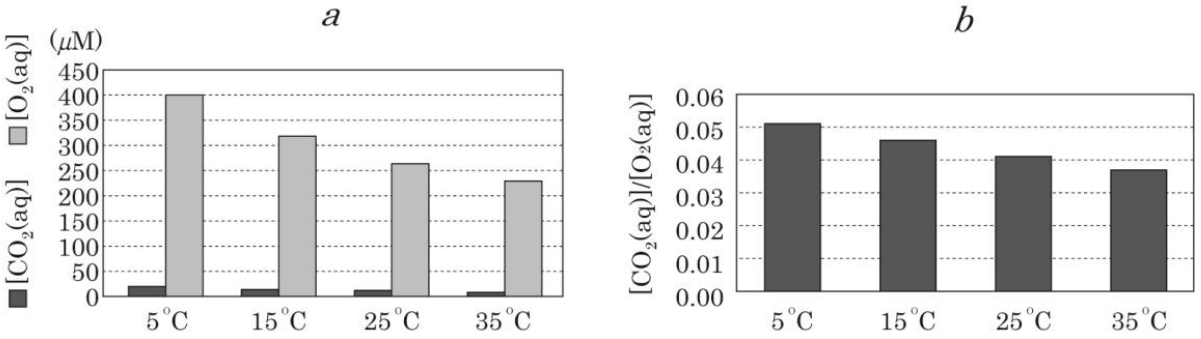
65. Rubisco is an enzyme crucial for carbon fixation in plants. In addition to a predominant carboxylation reaction, the enzyme also catalyses an oxidation reaction.

For an aquatic plant, the frequency of the oxidation reaction depends on the relative concentrations of the reagents CO_2 and O_2 in the aquatic solution, which in turn are coupled to temperature. The figures show the absolute (*a*) and relative (*b*) concentrations of CO_2 and O_2 dissolved in water that is at equilibrium with the atmosphere.



Choose the most correct statement.

a. The frequency of the oxidation reaction decreases with increasing temperature.

b. In water at equilibrium with the atmosphere, the relative concentration change with temperature of CO_2 is larger than that of O_2.

c. Rubisco has a higher affinity for O_2 than for CO_2.

d. At a temperature of 90°C, Rubisco catalyzes only one of the above two reactions in vascular plants.

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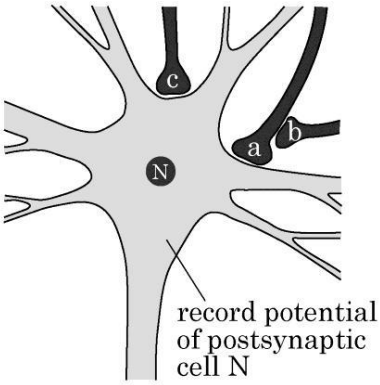
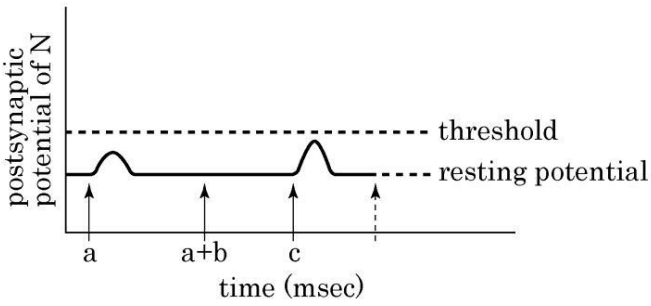
66. As shown in the left-hand picture below, neuron (N) receives signals directly from two separate nerve terminals (a and c). Nerve terminal (b) is synaptically connected to nerve terminal (a). The right-hand graph shows various postsynaptic potentials recorded in neuron (N) caused by input signals from the three presynaptic terminals.





Which of the following statements about the signal transmissions at these synapses are correct?

I. Action potentials would be generated in neuron (N) if nerve terminals (a) and (c) were stimulated simultaneously.
II. The neurotransmitter released from nerve terminal (b) is inhibitory.
III. When nerve terminal (b) is stimulated alone, an inhibitory postsynaptic potential (IPSP) would be recorded in neuron (N).
IV. When nerve terminals (b) and (c) are stimulated simultaneously, the excitatory postsynaptic potential (EPSP) recorded in neuron (N) is smaller compared to when only nerve terminal (c) is stimulated.

a. Only I and II

b. Only I and IV

c. Only I, II and III

d. Only III and IV

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67. The table below shows the results of experimental tests on skin graft rejection between two different mouse strains. (Assume strains [A] and [B] are genetically identical except for the MHC loci.)

Exp.	Skin donor mouse	Skin recipient mouse	Skin rejection	
			6~8 d	10~13 d
I	[A]	[A]	did not occur	did not occur
II	[A]	[B]	did not occur	occurred weakly
III	[A]	[B] mouse which had previously received strain [A] skin	occurred strongly	
IV	[A]	[B] mouse which has received lymphocytes from a strain-[A]-skin-grafted [B] mouse	occurred strongly	

Which of the following statements is **not** correct?

a. Graft rejection is considered to be the result of immune responses.

b. MHC genes are mainly responsible for the graft rejection.

c. If strain [B] skin is grafted onto mouse [A], the result would be the same as the result of Exp. II.

d. If strain [A] skin is grafted onto an offspring from a mating between [A] and [B] mice (e.g. F1, [A] x [B], the result would be the same as that of Exp. III.

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68. Eusocial honeybees have a specific system of sex determination. Females are diploid (2n) and develop from fertilized eggs; males are haploid (n) and develop from unfertilized eggs. Assuming that the queen copulated with a single male, which of the following is/are most likely true for this social group?

I. The males have mothers but not fathers.
II. A female should foster her brothers to increase her inclusive fitness rather than trying to increase her direct reproduction.
III. It is advantageous to females' (workers') fitness if the queen produces sons and daughters in equal proportions.
IV. A female should remove the eggs of other females (workers) from the nest to increase her fitness.

a. Only I and II

b. Only I and III

c. Only I and IV

d. Only III and IV

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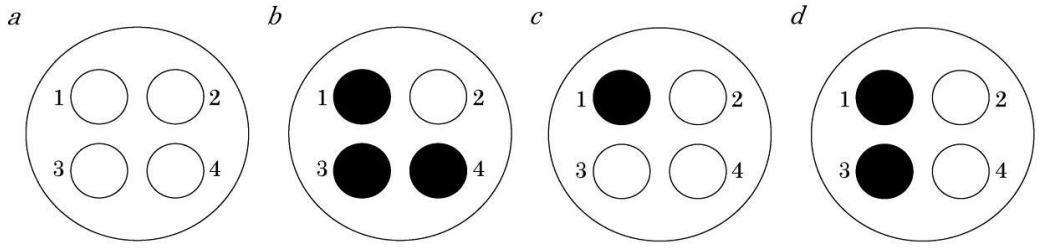
69. Four mutant strains of bacteria (1 to 4) all require substance S to grow. Each strain is blocked at one step in the S-biosynthesis pathway. Four plates were prepared with minimal medium and a trace of substance S, to allow a small amount of growth of mutant cells.

On plate *a*, mutant cells of strain 1 were spread over entire surface of the agar to form a thin lawn of bacteria. On plate *b*, the lawn was composed of mutant cells of strain 2, and so on. On each plate, cells of each of the four mutant types were inoculated over the lawn, as indicated in the figure by the circles.

Dark circles indicate excellent growth. A strain blocked at a later step in the S substance metabolic pathway accumulates intermediates that can 'feed' a strain blocked at an earlier step.



What is the order of genes (1~4) in the metabolic pathway for synthesis of substance S?

a. $1 \rightarrow 3 \rightarrow 4 \rightarrow 2$

b. $2 \rightarrow 4 \rightarrow 3 \rightarrow 1$

c. $1 \rightarrow 2 \rightarrow 4 \rightarrow 3$

d. $3 \rightarrow 4 \rightarrow 2 \rightarrow 1$

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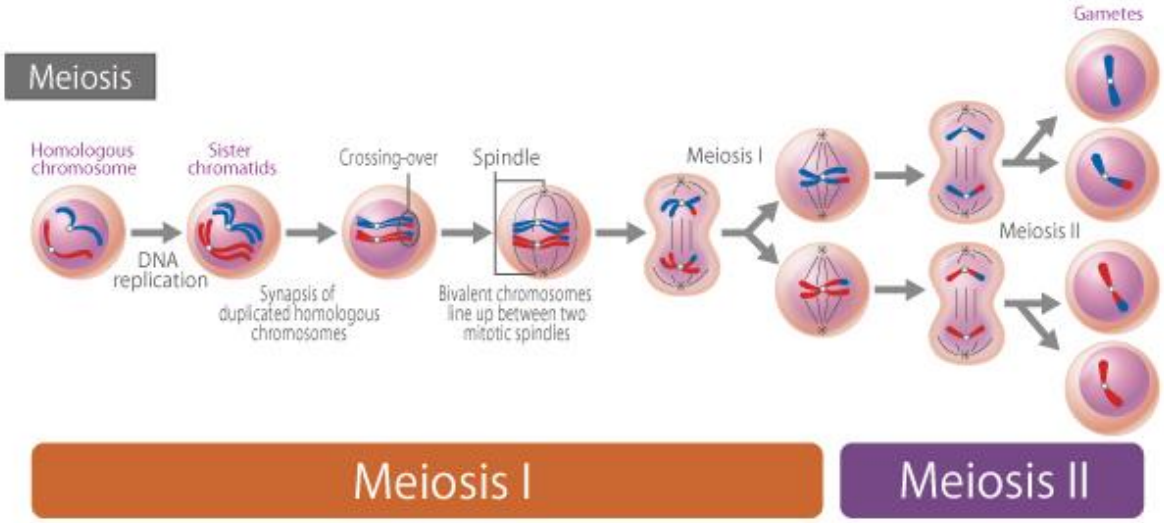
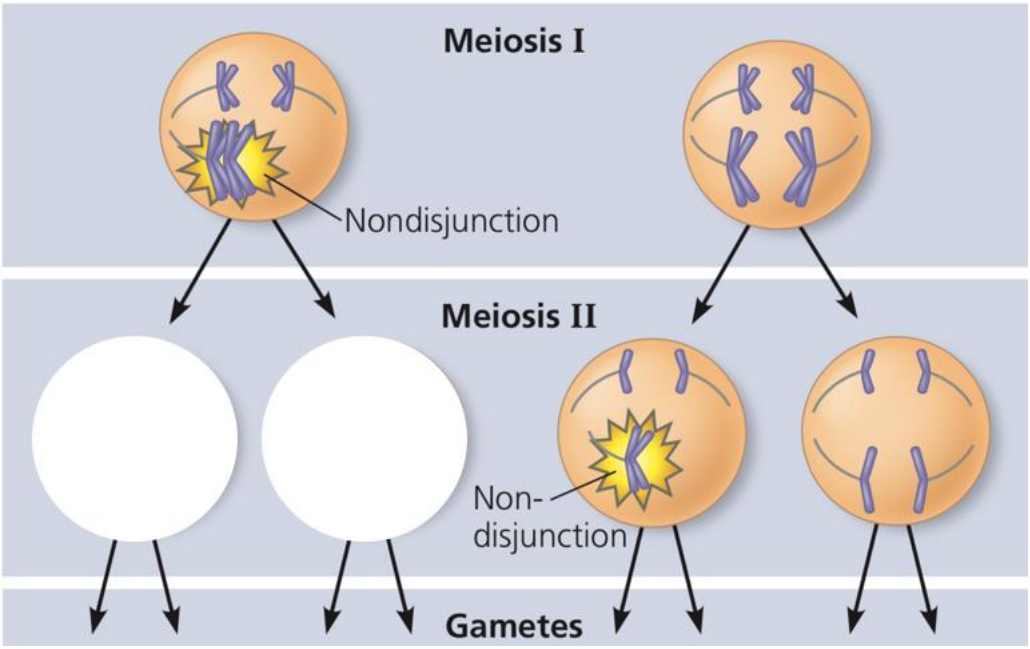
70. Aneuploidy is the presence of an abnormal number of chromosomes in a cell, for example humans having 45 or 47 chromosomes instead of the usual 46. This is caused by non-disjunction, where sister chromatids fail to separate at the centromere in anaphase of either meiosis I or II. Below is a simplified flowchart of meiosis and an incomplete diagram of non-disjunction.



Source: http://csls-text3.c.u-tokyo.ac.jp/images/fig/fig18_03.jpg



Source: Campbell Biology

Identify the TRUE statement:

a. Non-disjunction in meiosis I leads to four abnormal gametes.
b. Non-disjunction in meiosis II leads to three abnormal, and one normal gamete.
c. Down syndrome (having an extra chromosome 21) is not caused by aneuploidy.
d. Non-disjunction in meiosis II leads to two gametes each with one extra chromosome, and two gametes each with one fewer chromosome than usual.

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71. The surface area and average depth of a certain body of water are 45457625 km^2 and 2682m respectively. The volume of water is closest to:

a. 2×10^{-11} GL

b. 1×10^{16} GL

c. 4×10^{9} GL

d. 1×10^{11} GL

72. Identify the TRUE statement:

a. There is a selective disadvantage to retaining vestigial structures.

b. Prolific use of antibiotics directly causes bacteria to mutate and become antibiotic resistant.

c. Unrelated species may evolve similar adaptations.

d. Crossing over and recombination in meiosis creates new genes.

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Questions 73 to 75 relate to the following information:

Osmotic pressure is the pressure that must be applied to a pure solvent to prevent osmosis into a given solution, when the solution is separated from the pure solvent by a semipermeable membrane. Water moves from a region of low osmotic pressure to high osmotic pressure. The osmotic pressure (π) generated by a dissolved solute is proportional to the concentration of that solute, and may be approximated by the Van't Hoff formula:

$$\pi = i\, M_{solute}\, R\, T$$

where:

π is the osmotic pressure in mmHg
M_{solute} is the molar concentration of the solute (mol/L or M)
R = 62.36 L mmHg K^{-1} mol^{-1} (a constant)
T is the absolute temperature in Kelvin (equivalent to 273 + T °C)
i is the dimensionless Van't Hoff index, the ratio between the concentration of particles produced when the substance is dissolved, and the concentration of a substance as calculated from its molar mass. The Van't Hoff index for $CaCl_2$, assuming full dissociation in water, would be 3.

An experiment is set up as shown below. The two compartments are separated by a semipermeable membrane, and the temperature is 23 °C.

Compartment A Pure water	Compartment B 2M NaCl solution

73. Calculate the minimum pressure that would need to be externally applied in order to prevent osmosis in either direction. Furthermore, identify the compartment to which this pressure should be applied. Assume complete dissociation of NaCl.

a. 7.38×10^4 mmHg to compartment A

b. 7.38×10^4 mmHg to compartment B

c. 3.69×10^4 mmHg to compartment A

d. 3.69×10^4 mmHg to compartment B

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74. Someone replaced the pure water originally in compartment A with 2.7M glucose ($C_6H_{12}O_6$) solution. The solution in compartment B and the temperature remain unchanged. In which direction will osmosis occur?

a. From compartment B to A

b. From compartment A to B

c. There will be no osmosis

d. Unable to be determined

75. Assume all the information in question 74 still holds true. Now calculate the minimum pressure that would need to be externally applied in order to prevent osmosis in either direction. Furthermore, identify the compartment to which this pressure should be applied.

a. 4.98×10^4 mmHg to compartment A

b. 2.40×10^4 mmHg to compartment B

c. 1.12×10^6 mmHg to compartment B

d. 1.20×10^6 mmHg to compartment A

END OF EXAM

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Integrity of Competition

If there is evidence of collusion or other academic dishonesty, students will be disqualified. Markers' decisions are final.

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