A

International Biology Olympiad – Hong Kong Contest 2019

國際生物奧林匹克 – 香港區比賽 2019

Co-organised by 合辦

Education Bureau
The Government of the Hong Kong Special Administrative Region
香港特別行政區政府教育局

The Hong Kong Academy for Gifted Education
香港資優教育學苑

Commissioned to 協辦

The Hong Kong University of Science and Technology

香港科技大學

20 October, 2019

2019 年 10 月 20 日

Rules and Regulations 競賽規則

1. The paper consists of 50 multiple-choice questions in bilingual versions. There are Version A and Version B of the question book, each consisting identical content, only in different question number sequence. Contestants should have the same version of multiple-choice answer sheet and question book.
   全卷共有 50 題多項選擇題，所有題目中英對照。題目簿分為 A 及 B 兩個版本，題目內容相同，惟題號順序有異，參賽者會獲發相同版本的選擇題答題紙與題目簿。

2. The Contest is a 2-hour written test.
   比賽時限為兩小時。

3. On the multiple-choice answer sheet, please write and fill in the 8-digit Contestant Number, English Name, and School Number.
   在選擇題答題紙上，請填上你的 8 位數字參賽者號碼、英文姓名、及學校名稱。

4. After you have made the choice in answering a multiple choice question, fill the corresponding circle on the multiple-choice answer sheet fully using a HB pencil. Any answers written on the question book are not considered.
   選定選擇題的答案後，請將選擇題答題紙上相應的圓圈用 HB 鉛筆完全塗黑。任何寫在問題簿上的答案將不獲考慮。

5. The questions have been translated from English into Chinese. If there is any inconsistency or ambiguity between the English version and the Chinese version, the English version shall prevail.
   中文版題目為英文版譯本，如中、英文兩個版本有任何抵觸或不相符之處，應以英文版本為準。

Q1 – 2. If a squirrel finds a patch of nuts on a piece of grassland, it has two options: it either eats them there or carries them one by one to a safe place, e.g., a tree nearby, before consuming them. The squirrel saves time and energy by eating the nuts on the grassland because it does not have to travel back and forth between the grassland and the tree. Eating under a tree, however, reduces the chance the squirrel is attacked by a predator. Therefore, there is a trade-off between feeding in safety and obtaining high energy intake rates.

1. Based on the above information, which of the following predictions is correct with regard to the distance between the nuts and the tree?

A. The distance between the nuts and the tree is irrelevant to the feeding options.
B. The squirrel has a higher tendency to eat the nuts on the grassland if the nuts are further away from the tree.
C. The squirrel has a higher tendency to eat the nuts on the grassland if the nuts are closer to the tree.
D. The squirrel has a higher tendency to eat the nuts under the trees if they are living in an island without predators.

2. Based on the above information, which of the following predictions is correct with regard to the size of the nuts? (Hint: The larger the nut, the longer is the time required for the squirrel to crack the nut and eat it.)

A. The size of the nuts is irrelevant to the feeding options.
B. The squirrel has a higher tendency to eat the nuts under a tree if the nuts are larger.
C. The squirrel has a higher tendency to eat the nuts under a tree if the nuts are smaller.
D. The information provided is insufficient to judge which prediction is correct.

3. Males of the grasshopper Ligurotettix coquilletti feed on the leaves of creosote bushes and set up mating territories on the bushes. They produce a loud clicking sound to attract females. An experiment was set up with two creosote bushes similar in size and shape. A calling male was placed on one of the bushes and the other bush was left empty. The number of males aggregate on the bushes at 12 and 36 hours later is shown in Figure 1. In another study, females exhibit a strong preference for bushes with multiple calling males.

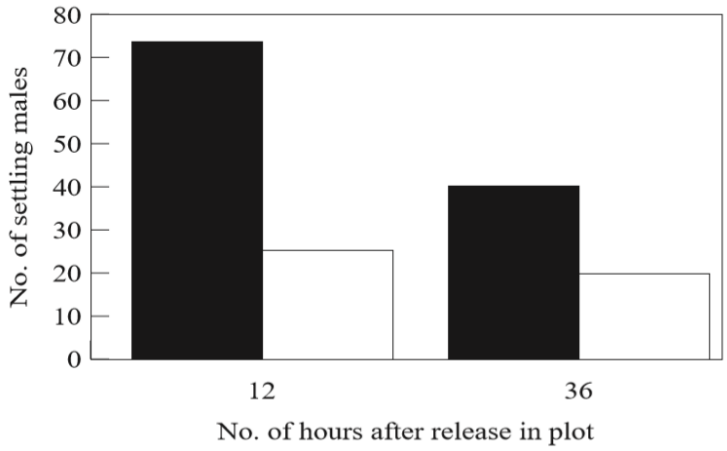


Figure: Number of settling males observed on bush with a calling male (black bars) and bush without calling male (white bars) 12 hrs and 36 hrs after release in plot. (Muller KL (1998) Animal Behaviour, 1998, 56, 479–485.)

Which of the following statement(s) is/are NOT a reasonable explanation of the above results?

(1) There are more males aggregated on the bush with a calling male than the bush without a calling male. It is because more males can attract more females

(2) Number of males on the bush with a calling male decreased with time because of aggressive territorial interactions among males on the bushes

(3) Females are attracted to bush with more males because they enjoy a larger mate choices and thus higher reproductive success

A. (1) only
B. (1) and (2) only
C. (2) and (3) only
D. All of the above

4. Some animal species' sex determination is not based on the presence of a Y chromosome. Females have two X chromosomes and males have one. Meiosis in males can produce 0X or 1X gametes. However, meiosis in female can produce gametes of 0X, 1X or 2X chromosomes. Which of the following is/are the cause of 2X gamete produced by the female?

(1) Two X chromosomes do not separate in meiosis I in the germ cells
(2) Two chromatids of a X chromosome do not separate in meiosis II in the germ cells
(3) Two chromatids of a X chromosome do not separate during mitosis in gamete precursor cells

A. (1) only
B. (1) and (2)
C. (2) and (3)
D. All of the above

5. You are studying cancer formation in mice and a genetic regulatory process was identified. Presence of nutrients would inhibit the expression of Gene 1. When nutrients are at low levels, gene 1 is active and its product can inhibit the activities of gene 2. When gene 2 is active, it will promote uncontrolled cell division and thus cause cancer.

You isolate a mutant strain of mice with a mutation at gene 1. These mutant mice develop cancer as young adults. Which of the following statement(s) is/are correct?

(1) The mutation at gene 1 is a dominant mutation
(2) When gene 2 of this mutant mice is eliminated, the mice would not develop cancer
(3) If there is no nutrient provided to the mutant mice, it would not develop cancer

A. (1) only
B. (2) only
C. (1) and (2) only
D. (1) and (3) only

6. In a lab experiment with a diploid plant species, you cross a purebred wrinkled, yellow-seeded plant with a purebred round, green-seeded plant. Round shape is recessive to wrinkled seed, and yellow color is recessive to green color. The two genes are not linked. When the F1 generation plants are crossed with each other, which of the following numbers are most likely to the result of this cross.

A. 22 round, yellow; 26 round, green; 28 wrinkled, yellow, 24 wrinkled, green
B. 90 round, yellow; 32 round, green; 30 wrinkled, yellow, 9 wrinkled, green
C. 11 round, yellow; 26 round, green; 27 wrinkled, yellow, 87 wrinkled, green
D. 64 round, yellow; 26 round, green; 27 wrinkled, yellow, 27 wrinkled, green

7. Lactase expression normally diminishes from 2 years of age. At around 12 years of age, most people stop producing lactase and they become lactose intolerant. They cannot comfortably digest dairy products that contain lactose. However, some people continue to express lactase in adulthood – lactase persistent. It is linked to a dominant mutation of the lactase gene.

Which of the following statement(s) is/are correct?

(1) A lactase persistent person can be homozygous or heterozygous
(2) The mutation leading to lactase persistence deletes one nucleotide in the coding region of the lactase gene
(3) The mutation leading to lactase persistence replaces one nucleotide with another in the regulatory region of the lactase gene, leading to a functional regulatory protein for the expression of lactase gene

A. (1) only
B. (2) only
C. (1) and (2) only
D. (1) and (3) only

8. Mean life span is often positively correlated with the mean body weight of an animal. Parrots are a group of birds with exceptionally long life compared to the other birds of the same weight, and they have high cognitive function too. Gene T showed strongest selective pressure in these long living birds. Ectopic expression of Gene T in rodent increases life span by as much as 40%, but there is no observable change to the cognitive function. Base on the information given, which of the following statement(s) concerning Gene T in rodents is/are correct?

(1) Gene T is sufficient to extend life span
(2) Gene T is necessary to extend life span
(3) Gene T is insufficient to increase cognitive function
(4) Gene T is unnecessary to increase cognitive function
(5) Gene T's role on life span and cognitive function is not concluded

A. (1) and (3)
B. (1) and (5)
C. (2) and (3)
D. (2) and (4)

9. There are 3 distinctive plumage variations of cockatiel. True-breeding of grey crosses with true-breeding of yellow yield 100% pearl. When pearl crosses with pearl yield 25% grey, 25% yellow and 50% pearl. Regarding the top of head, no bald spot is dominant to the presence of a bald spot in Mendelian fashion.

Cross 1: A female yellow cockatiel with a bald spot x a male of unknown phenotype yield

25% yellow with bald spot

25% yellow with no bald spot

25% pearl with bald spot

25% pearl with no bald spot

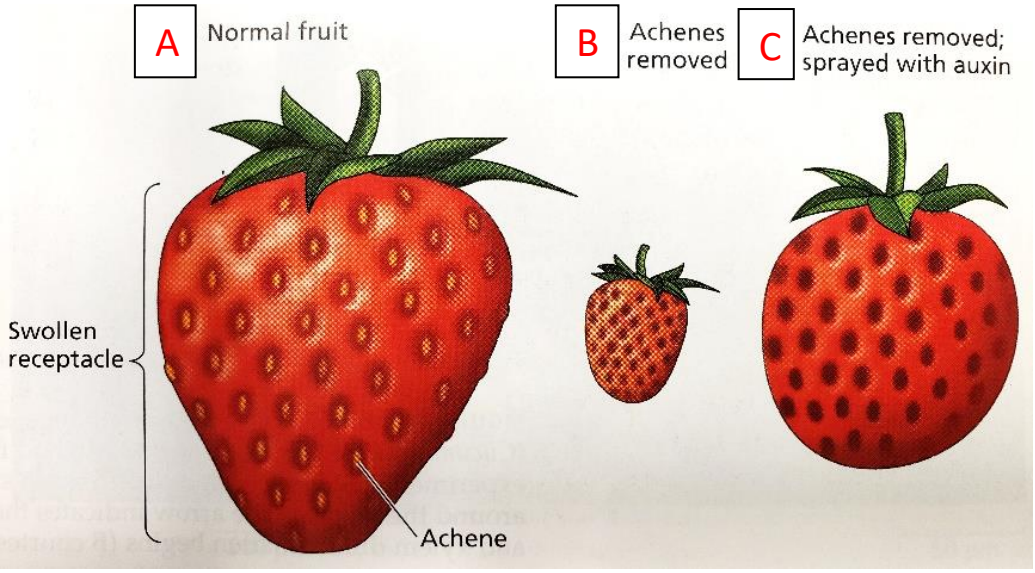
Determine the genotypes of both parents in cross 1.

Gene symbols:

Y = yellow; G = grey; B = dominant allele in baldness; b = recessive allele in baldness

A. YGBb x YYBB
B. YGbb x YGBb
C. YYBb x GGbb
D. YYbb x YGBb

10. In strawberry, the achenes are actually the true fruits. The fleshy tissue is a swollen receptacle whose enlargement is regulated by plant hormones. In the figure below, a normal strawberry (A), a strawberry with achenes removed (B), and a strawberry with achenes removed and then sprayed with auxins are shown.



(Adapted from "Plant Physiology 4th edition" by Taiz and Zeiger 2006, Sinauer Associates, Inc., Fig. 19.39, p.500)

With reference to the figure above, which of the following statement(s) is/are correct?

(1) A swollen receptacle produces auxin which is required for achene formation

(2) Achenes produce auxin which is required for receptacle enlargement

(3) Auxin alone can replace the role of achene in receptacle enlargement completely

A. (1) only

B. (2) only

C. (2) and (3) only

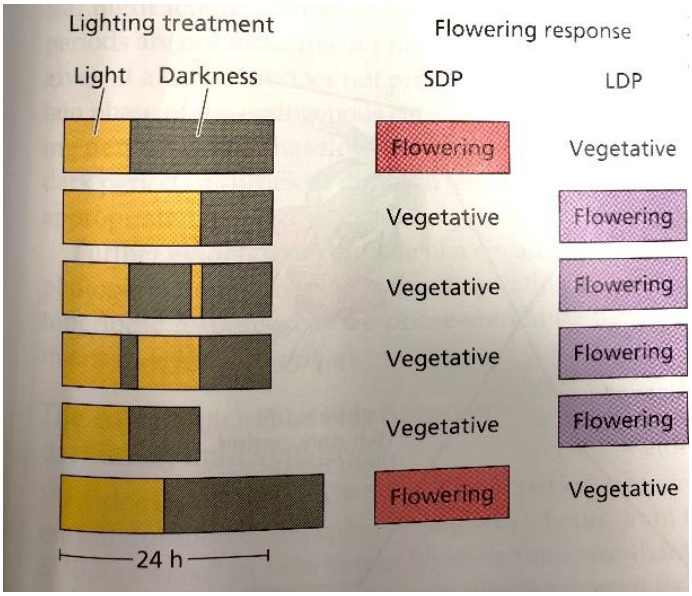
D. All of the above

11. In photosynthesis, carbon dioxide is converted to carbohydrates in plants using light as the energy source. For most plants, carbon dioxide is collected during daytime when sunlight is available. Interestingly, plants growing in the desert collect carbon dioxide during the night instead. Which of the following statement(s) about desert plants is/are likely to be true?

(1) Desert plants have evolved to synthesize carbohydrates in the dark
(2) Carbon dioxide collected at night is stored until daytime for carbohydrate synthesis
(3) Carbon dioxide is not collected during daytime to avoid dehydration

A. (1) only
B. (2) only
C. (3) only
D. (2) and (3) only

12. Flowering is controlled by light and dark cycle. The two main photoperiodic response categories are short-day plants (SDP) and light-day plants (LDP). The effects of different light/dark treatments on flowering of SDP and FDP are shown below.



(Adapted from "Plant Physiology 4th edition" by Taiz and Zeiger 2006, Sinauer Associates, Inc., Fig. 25.19B, p.651)

Based on the results, what is the most critical factor for flowering in both SDP and LDP?

A. Length of light period
B. Length of dark period
C. Length of light + dark periods
D. Number of light period in 24 h

Q13 – 14. Below is a phylogeny and divergence time estimates for 15 butterfly species. The phylogeny is constructed using 224 conserved, single copy genes. Error bars on nodes indicate the 95% confidence interval for divergence time estimates. Bootstrap support values for nodes are given when <100.

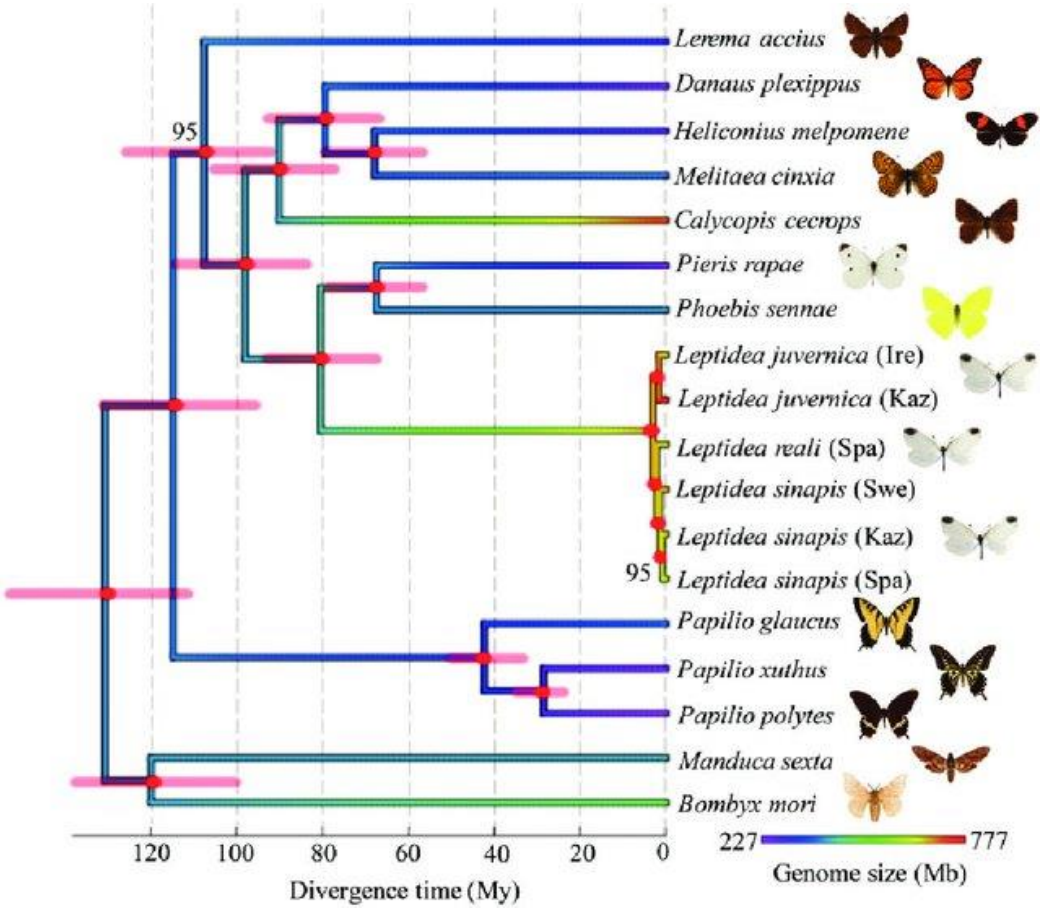


Figure from Backstrom et al (2017) Rapid increase in genome size as a consequence of transposable element hyperactivity in wood-white (Leptidea) butterflies. Genome Biology and Evolution, 9: 2491–2505.

13. Based on the above phylogeny, which statement is false?

A. *Papillo xuthus* is the sister species (closest relative) of *Papillo glaucus*

B. The genus *Leptidea* is monophyletic (all having a common ancestor)

C. *Manduca sexta* diverged earlier than *Melitaea cinxia*

D. *Bombyx mori* and *Lerema accius* share a common ancestor

14. How can the divergence time between species be calculated?

A. DNA changes in a relatively clocklike manner

B. The mutation rate is the same across all species

C. We have fossil evidence of all living species

D. Mutations almost never occur

Q15 – 16. DNA is highly repetitive. The graph below illustrates the relationship between genome size and repeated DNA content in the same 15 butterfly species.

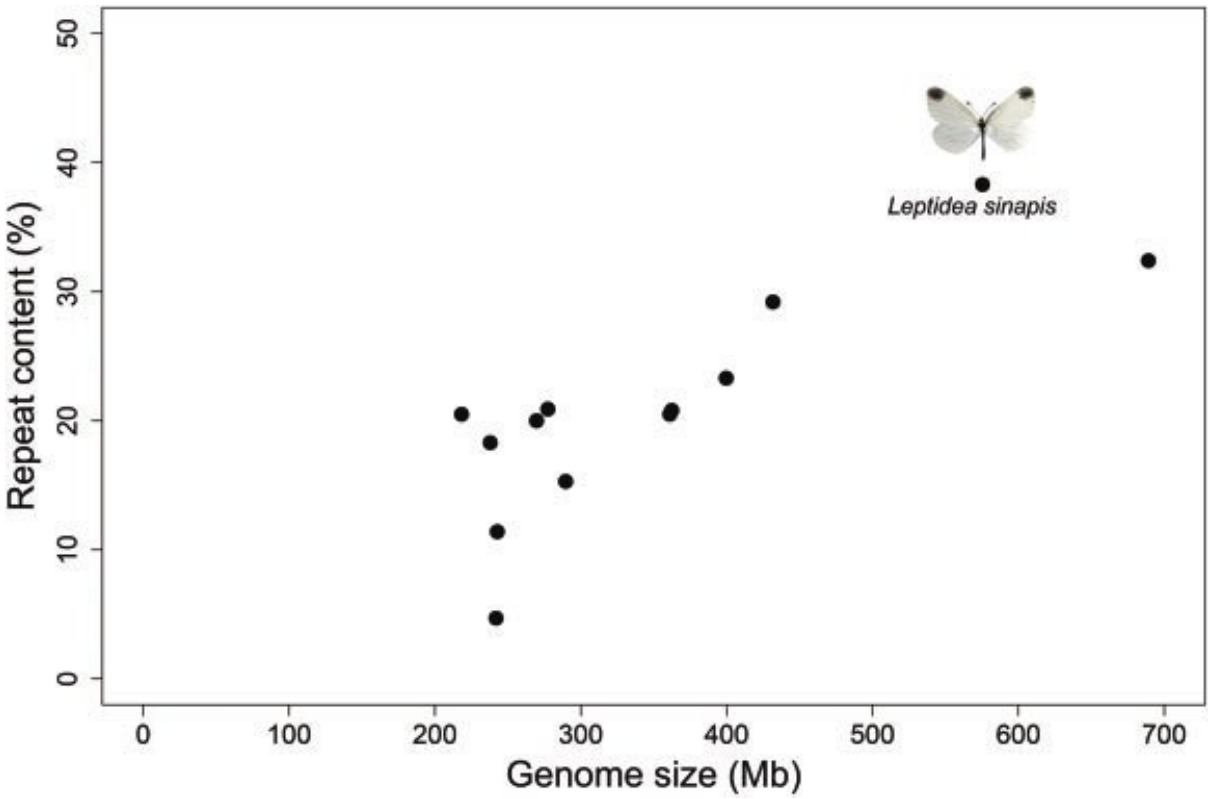


Figure from Backstrom *et al* (2017) Rapid increase in genome size as a consequence of transposable element hyperactivity in wood-white (Leptidea) butterflies. Genome Biology and Evolution, 9: 2491–2505.

15. What is the relationship between genome size and repeat content as shown in the graph?

A. Cannot determine

B. No relationship

C. Positive correlation

D. Negative correlation

16. When comparing two species with different genome size, the species with the larger genome size tends to have

(1) more DNA

(2) more genes

(3) larger nuclei

A. (1) only

B. (2) only

C. (1) and (3) only

D. All of the above

Q17 – 19. A student dissects a clam and finds a jelly-like structure. He wants to know if the structure contains some enzymes that can digest starch. The jelly-like structure is crushed inside a mortar with cool seawater. The extract solution is then mixed with starch solution in 10 cavities of a spotting tile. For every two minutes, a drop of iodine solution is added to one cavity and the colour is recorded (B = blue black; R = red/ brown; C = clear/ yellow):

Time (min)	0	2	4	6	8	10	12	14	16	18
Jelly-like structure + starch	B	B	B	R	R	R	R	C	C	C

17. Which of the following is important in giving valid results of the experiment?

(1) The volume of extract solution is the same in each cavity

(2) The volume of starch solution is the same in each cavity

(3) The volume of iodine solution added to each cavity is the same

A. (1) only

B. (1) and (2) only

C. (2) and (3) only

D. All of the above

18. Which of the following conclusion(s) can be made based on the results?

(1) The jelly structure contains starch digesting substances

(2) The digestion of starch was completed within 12-14 minutes

(3) The activity of the substances in the jelly structure is highest in cool seawater

A. (1) only

B. (1) and (2) only

C. (2) and (3) only

D. All of the above

19. Another student repeats the experiment with another clam. Below are the results:

Time (min)	0	2	4	6	8	10	12	14	16	18
Jelly-like structure + starch	B	B	B	B	B	B	B	R	R	R

Which of the following statement(s) is/are the appropriate explanations of the differences between the results of the first and second experiments?

(1) The jelly structure of the second clam contains higher amount of starch digesting substances

(2) More seawater was added for extraction in the second experiment

(3) Less starch solution was added in the second experiment

A. (1) only

B. (2) only

C. (1) and (2) only

D. All of the above

20. EPO is a hormone synthesized in the kidney, which is responsible for stimulating red blood cell production. EPO production is regulated by oxygen levels through a transcription factor HIF in the kidney cells. EPO can be used to treat severe anemia. Some athletes illegally take EPO to enhance their performance.

According to the above passage, which of the following pathways is correct?

A. low oxygen level→ more EPO →more HIF → more RBC
B. low oxygen level → more HIF → more EPO → more RBC
C. high oxygen level → less EPO → less HIF → less RBC
D. high oxygen level → more HIF → less EPO → less RBC

21. Which of the following is/are the likely consequence(s) of taking external EPO to enhance performance by athletes?

(1) The blood has greater oxygen carrying capacity
(2) There is iron deficiency in blood
(3) The blood becomes more viscous and clot more easily
(4) The vital capacity of the athletes will increase

A. (1) only
B. (1) and (2) only
C. (1), (3) and (4) only
D. (1), (2) and (3) only

Q22 – 23. A 28-year-old female runner died in the Boston Marathon in 2002 from hyponatremic encephalopathy - brain damages caused by low sodium concentration in blood. Her brain swelled due to excessive water entry.

In human body, the blood osmolarity is maintained by a hormone called anti-diuretic hormone (ADH), which increases water reabsorption at kidney and produces hypertonic urine. ADH secretion is found higher in the days close to ovulation of woman.

22. Which of the following is/are the likely explanation(s) for the female marathon runner to develop hyponatremic encephalopathy?

(1) She was close to her mid-menstrual cycle and had higher levels of ADH
(2) She drank too much water
(3) The weather is too hot
(4) She had eaten too much salt

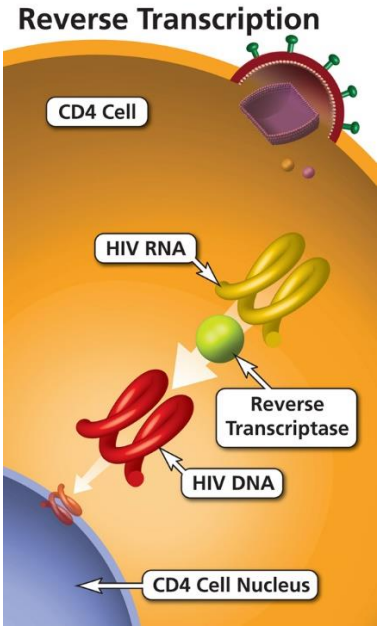
A. (1) only
B. (1) and (2) only
C. (1), (2) and (3) only
D. All of the above

23. Why does a low sodium concentration in blood lead to excessive entry of water into brain?

(1) The osmolarity of blood is lower than that of the brain cells, causing osmotic intake of water
(2) More sodium ions diffuse from brain cells into blood
(3) Low blood osmolarity decreases ADH secretion

A. (1) only
B. (1) and (2) only
C. (1) and (3) only
D. All of the above

Q24 – 26. Human immune deficiency virus (HIV) is responsible for over 2 million deaths each year worldwide. HIV is a RNA virus that undergoes reverse transcription from RNA to DNA inside the infected CD4+ T cells.



The current approach to treat HIV infections includes 3-4 antiretroviral drugs. These drugs have two different actions. One type of drugs mimics nucleic acids and terminate DNA chain elongation during reverse transcription. Another type of drugs binds to a non-active site of the reverse transcriptase that interferes with transcription.

As a student set up an experiment examining three anti-retroviral drugs (drugs A, B, and C). He cultured recombinant CD4+ T cells (one of the major targets of HIV) and infect them with HIV. He then added into the cultures one of the three antiretroviral drugs (A, B, C) and one plain culture as control. After 24 hours, he measured the levels of viral RNA and reverse transcriptase activity and compared them with the control group. The results are shown below:

	Viral RNA concentration (as compared with the control group)	Reverse transcriptase activity (as compared with the control group)
Drug A	Reduce	No change
Drug B	Reduce	No change
Drug C	Reduce	Reduce

24. What is/are the mechanism(s) of the action of the three drugs as inferred from the results?

(1) Drug A mimics the nucleotide

(2) Drug B inactivates the reverse transcriptase

(3) Drug C inactivates the reverse transcriptase

A. (1) only

B. (1) and (2) only

C. (1) and (3) only

D. All of the above

25. If one of the drug mimics the nucleotide adenine to terminate the addition of further nucleotides to the nascent DNA strand, with which base of the viral RNA would the drug pair with in reverse transcription?

A. Thymine

B. Guanine

C. Uracil

D. Cytosine

26. Given the results of the experiment, what is/are the difference(s) between drug A and drug C in their actions on reverse transcriptase?

(1) Drug A will compete with the substrate(nucleotides) to bind to the active sites of reverse transcriptase, but drug C will not

(2) Drug C will alter the shape of the active site of reverse transcriptase, but drug A will not

(3) Drug C will denature reverse transcriptase, but drug A will not

A. (1) only

B. (1) and (2) only

C. (1) and (3) only

D. All of the above

27. Rods and cones are two distinct cell types in the retina. Rods are mainly responsible for vision at dim light, while cones are for colour vision. The figure below shows the distribution of rods and cones across the yellow spot and blind spot (optic disc).

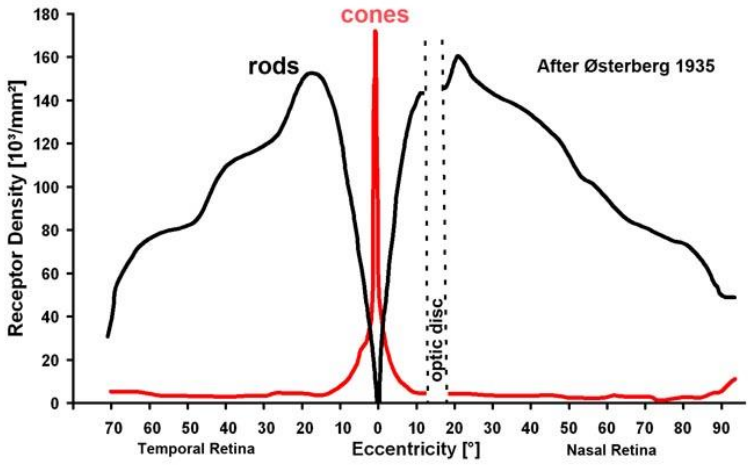


Fig. 20. Graph to show rod and cone densities along the horizontal meridian.

Yellow spot

Which of the following can be correctly inferred from the figure?

(1) In dim light, we see less clear at the centre than at the periphery

(2) We see nothing when light falls on optic disc

(3) The most colourful vision is at the centre of our visual field in day time

A. (1) only

B. (1) and (2) only

C. (2) and (3) only

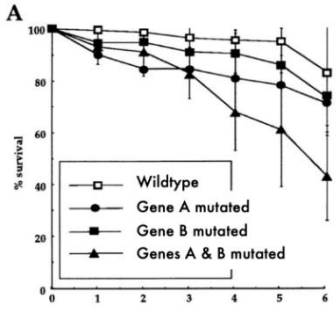
D. All of the above

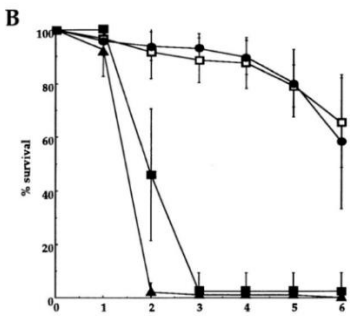
28. An experiment was conducted to investigate the survival rate of fruit flies after fungal and bacterial infections. Fruit flies were subject to one of the following three treatments:

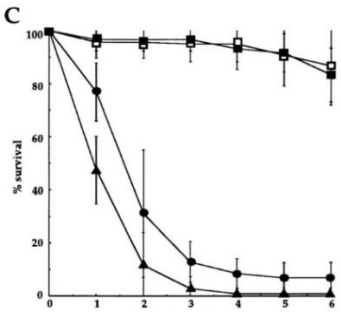
- prickled at the abdomen with a clean needle (Figure A)
- prickled with a needle dipped into a concentrated solution of spores of the fungus *Aspergillus fumigatus* (Figure B)
- prickled with a needle dipped into a concentrated solution of the bacteria *Escherichia coli* (Figure C)

Four types of fruit flies were investigated: wildtype flies, flies with mutations in Gene A, flies with mutations in Gene B and flies with mutations in both Genes A and B. The survival rate of these insects was followed over a 6-day period at 29° C.

(Adapted from Lemaitre, B., Nicolas, E., Michaut, L., Reichhart, J. M., & Hoffmann, J. A. (1996). The dorsoventral regulatory gene cassette spätzle/Toll/cactus controls the potent antifungal response in Drosophila adults. Cell, 86(6), 973-983.)







Which of the following statement(s) is/are consistent with the data above?

(1) Gene A is essential for the survival of fruit flies after both bacterial and fungal infection
(2) Gene A is essential for the survival of fruit flies after bacterial infections
(3) Survival after fungal or bacterial infection requires the activities of both genes A and B in fruit flies
(4) Fungal infection is more deadly to fruit flies than bacterial infection

A. (1) and (2) only
B. (2) and (4) only
C. (3) and (4) only
D. (1), (2) and (4) only

29. The following figure is from one of the earliest studies on the effect of radioactive irradiation on cells. The element used in this experiment is 226-Radium, which produces alpha irradiation. In a tissue culture of chick choroid, the number of cells undergoing mitosis was counted before, during and after exposure to radium.

(Adapted from Canti, R. G. (1929). Biological effects of radium irradiation. Acta radiologica, 10(4), 320-331).

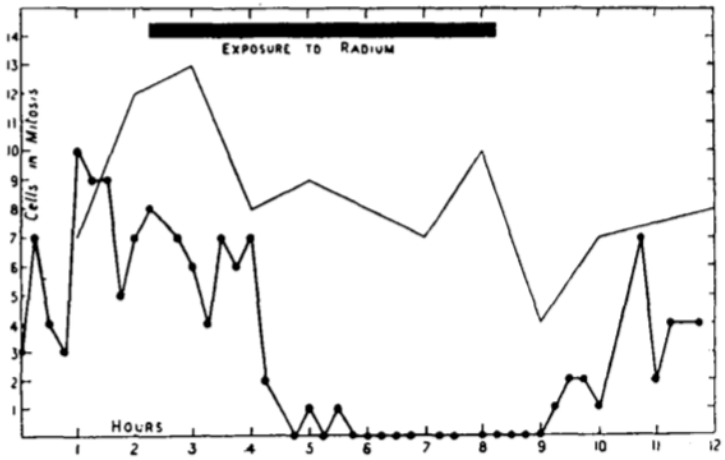


Fig. I. Graph showing the cessation and the return of mitosis in a tissue culture of chick choroid irradiated with 100 mg. of radium element filtered with 0.5 mm. of platinum at a distance of 1.4 cm. The thin line superposed shows the number of cells in mitosis in an unirradiated culture of the same age.

Which of the following statement(s) is/are consistent with the data above?

(1) Radium irradiation kills all the cells at hour 6

(2) The effect of radium irradiation on mitosis is highest after 2 hours of exposure

(3) Some cells can recover from the effect of radium irradiation

A. (1) only

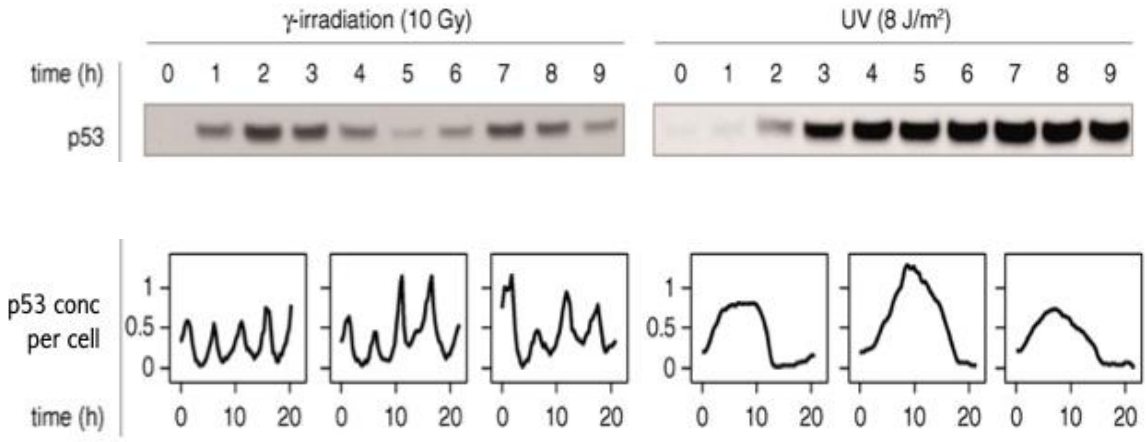
B. (3) only

C. (2) and (3) only

D. All of the above

30. p53 is a protein that can suppress tumour cells. It is produced in response to cellular stress. The following figure shows the concentration p53 in human breast cancer cells after exposure to gamma or UV irradiation. The intensity of the bands in the figure represents the relative concentration of the protein at the specified time point.

(Adapted from Purvis, J. E., Karhohs, K. W., Mock, C., Batchelor, E., Loewer, A., & Lahav, G. (2012). p53 dynamics control cell fate. Science, 336(6087), 1440-1444).



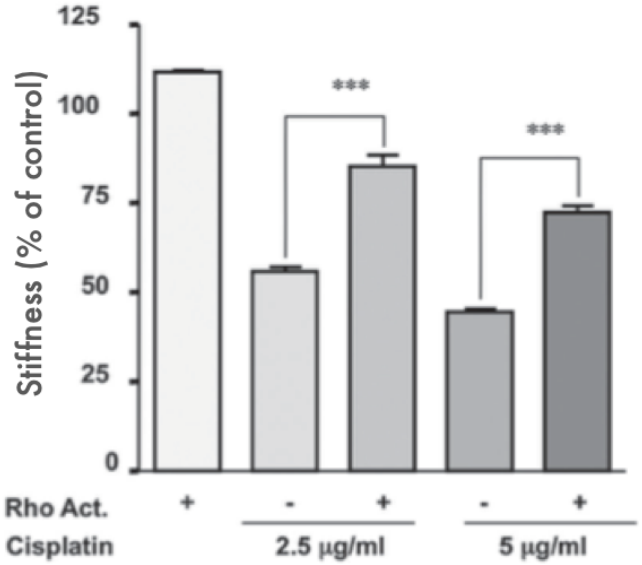
Which of the following statement(s) is/are consistent with the data above?

(1) UV irradiation can activate a more sustained, higher levels of p53 than gamma irradiation in breast cancer cells
(2) After gamma irradiation, the amount of p53 protein oscillates every 6-7 hours
(3) p53 protein is not detectable in unirradiated human breast cancer cells

A. (1) and (3) only
B. (1) and (2) only
C. (2) and (3) only
D. All of the above

31. The following figure shows the effect of the activation of the gene Rho and the chemotherapy drug Cisplatin on the stiffness of human ovarian cancer cells (how hard the cells are).

(Adapted from Sharma, S., Santiskulvong, C., Rao, J., Gimzewski, J. K., & Dorigo, O. (2014). The role of Rho GTPase in cell stiffness and cisplatin resistance in ovarian cancer cells. Integrative Biology, 6(6), 611-617).



Which of the following statement(s) is/are consistent with the data above?

(1) Cisplatin makes ovarian cancer cells softer

(2) Rho gene makes ovarian cancer cells softer

(3) The effect of cisplatin is not dependent on the activation of gene Rho

(4) Doubling the concentration of cisplatin does not greatly increase its effect

A. (1) only

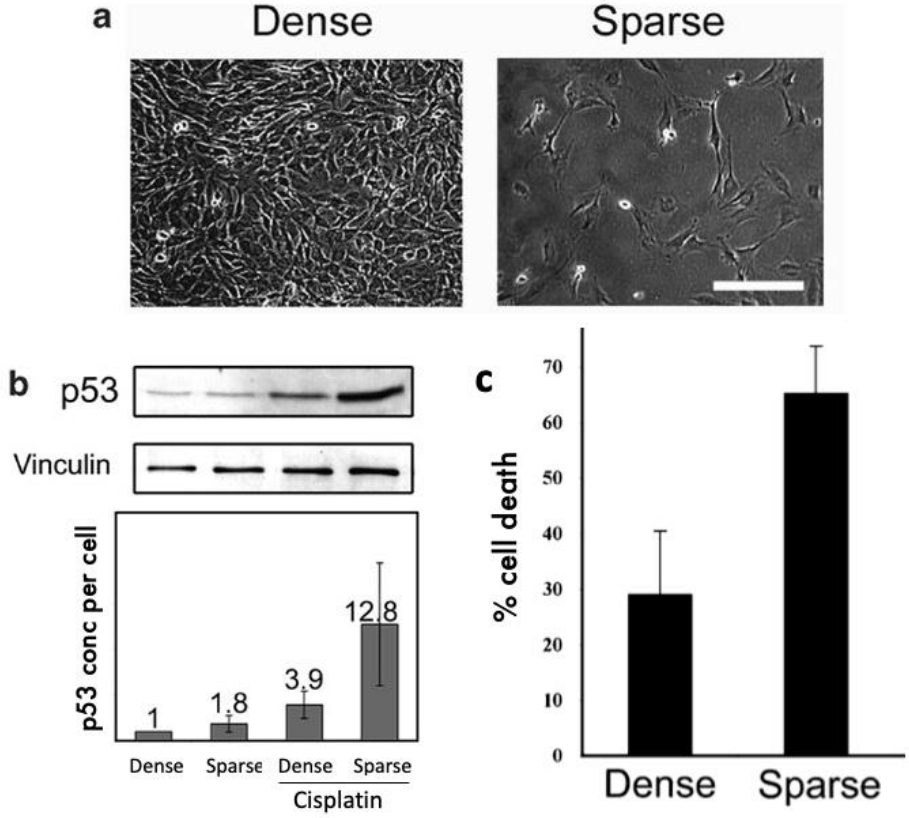
B. (2) only

C. (1) and (4) only

D. (1), (3) and (4) only

32. The following figures show two flasks of mouse fibroblast cells with different cell density (dense and sparse, Fig a). The expression of p53, a protein that can suppress tumour cells, in cells in these two flasks was measured. The measurement was repeated after the cells were treated with a chemotherapy drug called Cisplatin (Fig b). The number of dead cells in each flask after Cisplatin treatment was also measured (Fig c).

(Adapted from Bar, J., Cohen-Noyman, E., Geiger, B., & Oren, M. (2004). Attenuation of the p53 response to DNA damage by high cell density. Oncogene, 23(12), 2128).



Which of the following statement(s) is/are consistent with the data above?

(1) The concentration of p53 protein in mouse fibroblast cells is induced by Cisplatin

(2) The concentration of p53 protein is correlated with Cisplatin-induced cell death

(3) The effect of cisplatin on concentration of p53 is much greater in higher cell density

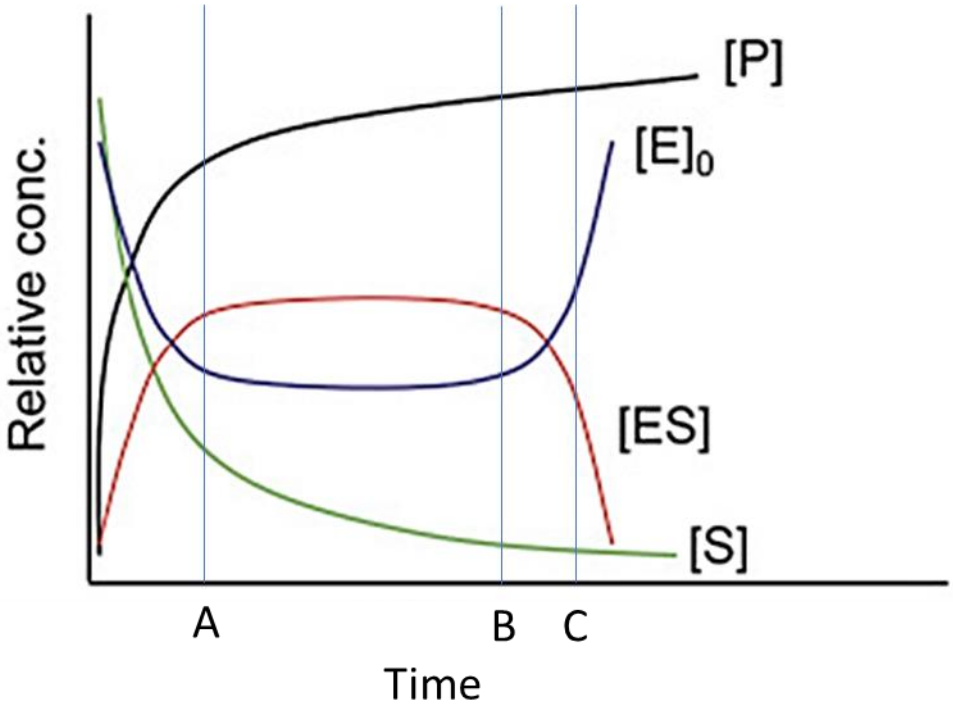
A. (1) only

B. (1) and (2) only

C. (2) and (3) only

D. All of the above

33. The graph below illustrates the change in concentrations of product ([P]), free enzyme ([E]0), enzyme-substrate complex ([ES]), and substrate ([S]) in an enzymatic reaction.



Indicate which of the following is/are correct?

(1) At time point A, rate of product production is limited by the concentration of enzyme

(2) The rate of product production before time point A depends on the amount of activation energy required for the reaction to happen

(3) If additional substrate is added at time point C, the lines of product ([P]), free enzyme ([E]0), and enzyme-substrate complex ([ES]) would all go upward

(4) The length of time for [ES] to remain level (between time point A and B) depends on the initial concentration of substrate

A. (1) only
B. (2) and (3) only
C. (1), (2) and (4) only
D. All of the above

34. Glycolysis is a fundamental cellular process involved in the generation of energy for supporting cellular activities. During glycolysis, some of the energy stored in the six-carbon sugar molecule is used to drive the synthesis of ATP from ADP. In addition, NADH is generated from NAD+ in glycolysis.

Indicate which of the following is/are correct?

(1) Glycolysis can proceed in the absence of oxygen

(2) Glycolytic reactions include an oxidative reaction

(3) Regeneration of NAD+ from NADH is essential for the continuation of glycolysis

A. (1) only
B. (1) and (2) only
C. (2) and (3) only
D. All of the above

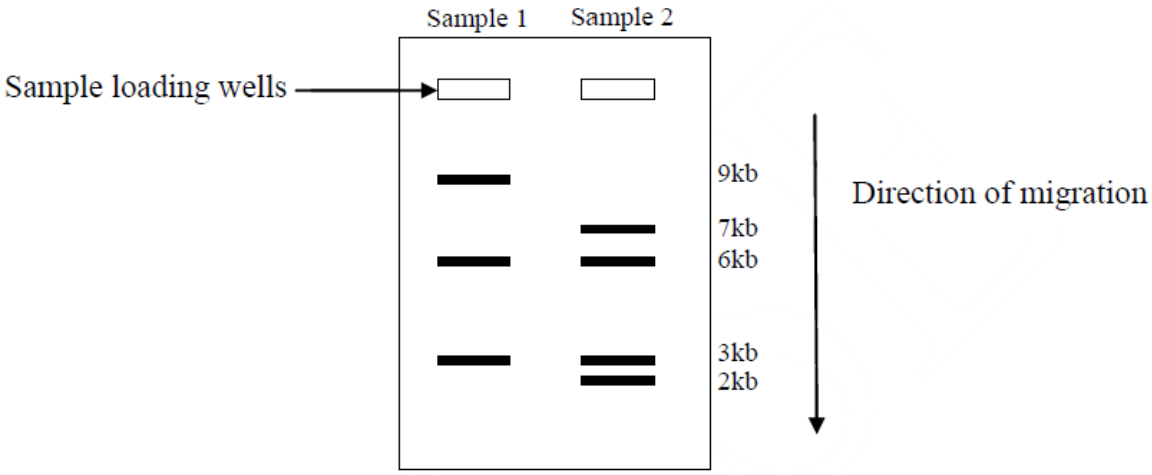
35. The Ames test is a useful mutagenicity test used to assess the carcinogenic potential of chemical compounds. In this method, a histidine-dependent Salmonella strain is used. These bacterial strains can grow only if the medium contains the amino acid histidine because some of the genes responsible for the synthesis of histidine have mutated. The bacterial cells were treated with the compound to be tested in the rat liver extract. After incubation, the bacteria were spread on an agar plate that did not contain histidine. Plates were kept at 37 °C for 2 days, and bacterial colonies appearing on them were counted. A control setup was made using bacteria not treated with a compound.

Indicate which of the following is/are correct?

(1) None or very few colonies should appear in the control plates
(2) When many bacterial colonies appear on the plates after the treatment of a compound, it indicates that this compound has 'corrected' the mutated genes of the bacteria so that they regain the ability to synthesize histidine
(3) Compounds proven to be mutagenic by the Ames test must be carcinogenic to humans

A. (1) only
B. (1) and (2) only
C. (2) and (3) only
D. All of the above

36. Restriction endonucleases are enzymes which cut DNA at specific sequences. Two samples of DNA (sample 1 and sample 2) that have the same DNA sequence and length (18 kb) were cut using three different restriction enzymes simultaneously. Each DNA sample has one recognition sequence for each of the three enzymes. When the digested samples were run on an agarose gel, the following pattern was obtained.



Indicate which of the following is/are correct?

(1) Sample 2 was contaminated by other DNA

(2) Sample 1 was circular DNA while sample 2 was linear DNA

(3) The 9 kb DNA fragments of sample 1 consisted of the 7 kb and 2 kb fragments of sample 2

(4) Sample 2 had a higher concentration of DNA than sample 1

A. (1) only

B. (2) and (3) only

C. (1), (2) and (4) only

D. All of the above

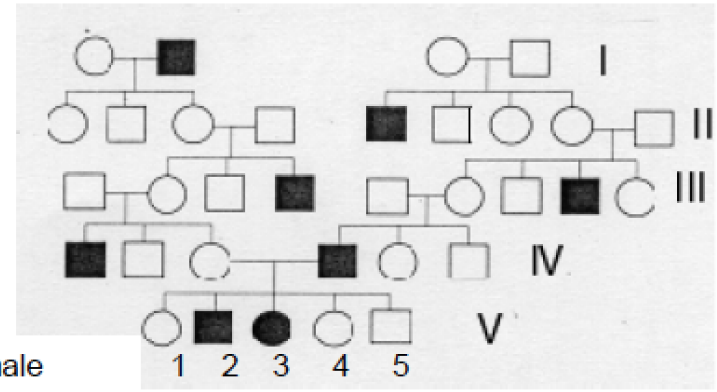
37. DNA replication can be studied using radioactive nucleotides. The cells undergo first mitosis in the presence of radioactive nucleotides and then the second mitosis in non-radioactive nucleotides. The photograph below shows the chromosomes of the cells after two cycles of mitosis. The dark regions indicate radioactivity.

Indicate which of the following is/are correct?

(1) The results show that DNA replication is semi-conservative
(2) If DNA replication were conservative, only half of the chromosomes would show radioactivity
(3) The sections indicated by the arrows in the photograph are the result of crossing over

A. (1) only
B. (1) and (2) only
C. (2) and (3) only
D. All of the above

Q38 – 39. The chart below shows the pedigree of a trait with 100% penetrance. Penetrance is the proportion of individuals with an allele who express the trait of that allele.



○ : unaffected female
● : affected female
□ : unaffected male
■ : affected male

38. Indicate which of the following is/are correct?

(1) This trait must not be Y-linked
(2) The genotype of the mother of V3 is heterozygous carrier
(3) If individual V2 marries a homozygous normal person, the probability that their first child will be a carrier is 50%

A. (1) only
B. (1) and (2) only
C. (2) and (3) only
D. All of the above

39. Indicate which of the following is/are correct?

(1) Change in an individual over time is evolution

(2) If no variation is present in a population, evolution can still occur

(3) Genetic drift is a mechanism of evolution

(4) Evolution results in perfect species

A. (1) and (4) only

B. (2) only

C. (3) only

D. (2) and (3) only

40. In a butterfly species, the wing colour is determined by a locus with three alleles: C (black wings) > cg (grey wings) > c (white wings). In a survey of a large population living in Area 1 (Population 1), the following allelic frequencies were obtained: C=0.5, cg=0.4, and c=0.1. A small group of butterflies flies to Area 2 and starts a new population (Population 2). After several generations, a large randomly mating population has the following phenotypic frequencies: black wings (0.0), grey wings (0.75), and white wings (0.25).

Indicate which of the following is/are correct?

(1) In population 1, if the butterflies continue to mate randomly, the frequency of black-winged individuals will be 0.25

(2) If population 1 consists of 6,500 butterflies, the number of individuals with grey wings will be 1,560

(3) The change in allelic frequencies in Population 2, as compared to population 1, is an example of the bottleneck effect

A. (2) only
B. (1) and (2) only
C. (2) and (3) only
D. All of the above

41. The feather of domestic fowl, hen- or cock-feather, is controlled by a gene with two alleles, H (hen) and h (cock). The combination of different alleles in the female and male fowl and their phenotype are shown in the table below. However, when the male fowl with hh is castrated (removal of testes), its feather becomes hen-like.

Genotype	Phenotype	
	Female	Male
HH	Hen-feather	Hen-feather
Hh	Hen-feather	Hen-feather
hh	Hen-feather	Cock-feather

Indicate which of the following is/are correct?

(1) Allele H is dominant over h

(2) Allele h expresses in male fowl but not in the females

(3) The expression of h is related to the male sex hormones of the male fowl

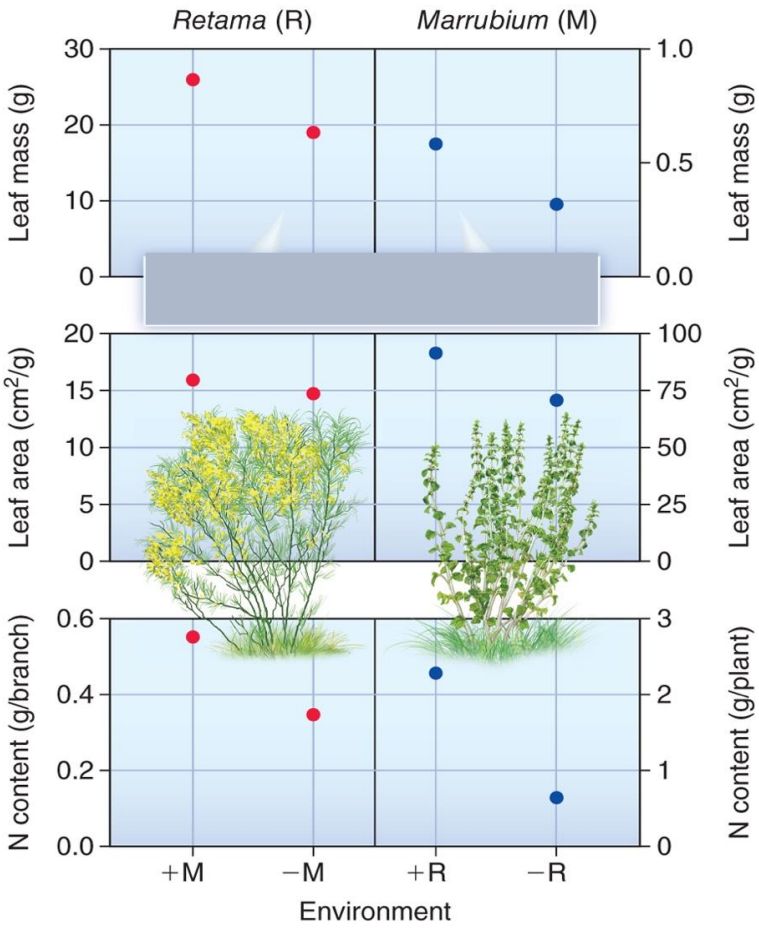
A. (2) only

B. (1) and (2) only

C. (2) and (3) only

D. All of the above

42. The following diagram shows the relationship between two plant species, R and M, in south-eastern Spain, which is a semi-arid region. R is a shrub while M is a herb growing underneath the canopy of R.



Indicate which of the following is/are correct?

(1) M benefits from the relationship more than R benefits
(2) To obtain the above data, two R plants, one is growing with M while another one is not, are compared
(3) When M is growing underneath R, the soil is likely to hold more water and has faster litter decomposition

A. (1) only
B. (1) and (3) only
C. (2) and (3) only
D. All of the above

43. Cattle egrets usually feed with cows. The table below shows the feeding efficiency of the egret with and without cow.

	With cow	alone
Number of steps made by egret/capture of prey	13.7	76.5
Captures of prey/minute	2.0	0.6

From Grubb, T. (1976).

Indicate which of the following is/are correct?

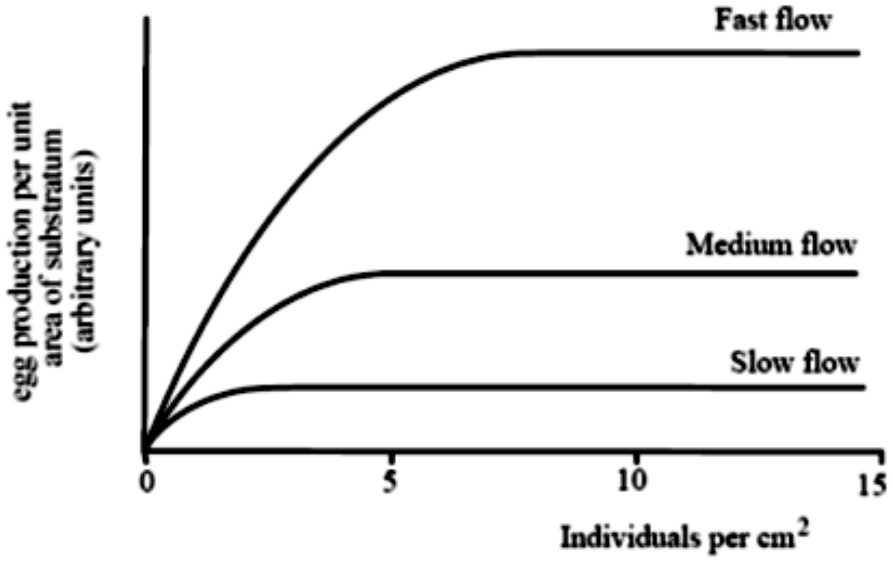
(1) When feeding with cows, the egret captures more prey within a period of time than when feeding alone

(2) When feeding alone, the egret needs to use more energy to obtain the same number of prey

(3) The efficiency ratio (number of steps per capture per minute) with cow is about 20 times greater than that without cow

A. (1) only
B. (3) only
C. (2) and (3) only
D. All of the above

44. The graph below shows egg production at different population densities of the barnacle (Semibalanus balanoides) at three rates of water flow.



Indicate which of the following is/are correct?

(1) The higher the population density, the more eggs are produced

(2) The effect of water flow on egg production is independent of the population density

(3) Faster water flow can increase egg production

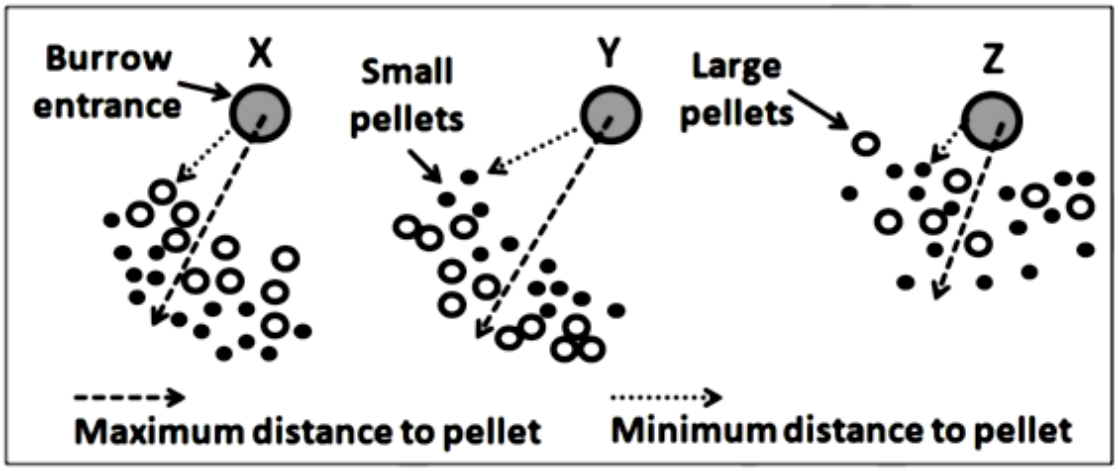
A. (1) only

B. (3) only

C. (2) and (3) only

D. All of the above

45. After fiddler crabs take up nutrients from the sediment, they give out small sand balls (pellets) around their burrows. Three male crabs, X, Y and Z, deposit pellets in different patterns as shown below. A study was conducted to test the hypothesis that the patterns of pellets are related to the mating success of the male crab by showing a crab's strength. Crab Y was observed to mate most frequently.



Indicate which of the following is/are correct?

(1) The observation is consistent with the hypothesis
(2) According to the hypothesis, it is predicted that crab Z will attract least females
(3) Further studies with more crabs may give more support to the hypothesis, but the hypothesis can never be proved to be absolutely true

A. (1) only
B. (2) only
C. (2) and (3) only
D. All of the above

46. An experiment studied the development of poison in a species of poisonous fish. The eggs and sperm were harvested from a wild population and in vitro fertilization carried out. The resulting embryos were then hatched and grown in an indoor tank containing artificial seawater. It was found that the fish never became poisonous.

In a later experiment, young fish grown in this tank were divided into two groups and placed in separate tanks in a bay where they were exposed to real seawater. Tank A had a horizontal net that prevented the fish from reaching the sea bottom, while Tank B had no horizontal net. Subsequently, no poison was detected from the fish cultured in Tank A, but poison was found in fish from Tank B.

Indicate which of the following is/are correct?

(1) Development of poison in the fish requires natural seawater
(2) The poison of the fish comes from the bottom of the sea
(3) Development of poison in the fish is wholly controlled by genes

A. (1) only
B. (2) only
C. (2) and (3) only
D. All of the above

Q47 – 48. There are two theories about how water is transported in plants: root pressure and cohesion-tension theory. Root pressure is the positive pressure built up by active transport of salts and sugar into xylem vessels at root, which pushes the xylem water upward. Cohesion-tension theory explains the ascent of water in xylem by transpiration pull, a pulling force created by transpiration at leaves.

47. Which of the following can be considered evidence objecting to root pressure as the ONLY mechanism of water transport in plants?

(1) Root pressure is not found in all plants. For tall trees, the pressure found are not strong enough to push the water up to the tree top
(2) Root pressure is absent or reduced when the plant is actively transpiring, e.g. dry and sunny days
(3) Water can still rise upward in the absence of root
(4) Water comes out at cut surface of stem – exudation

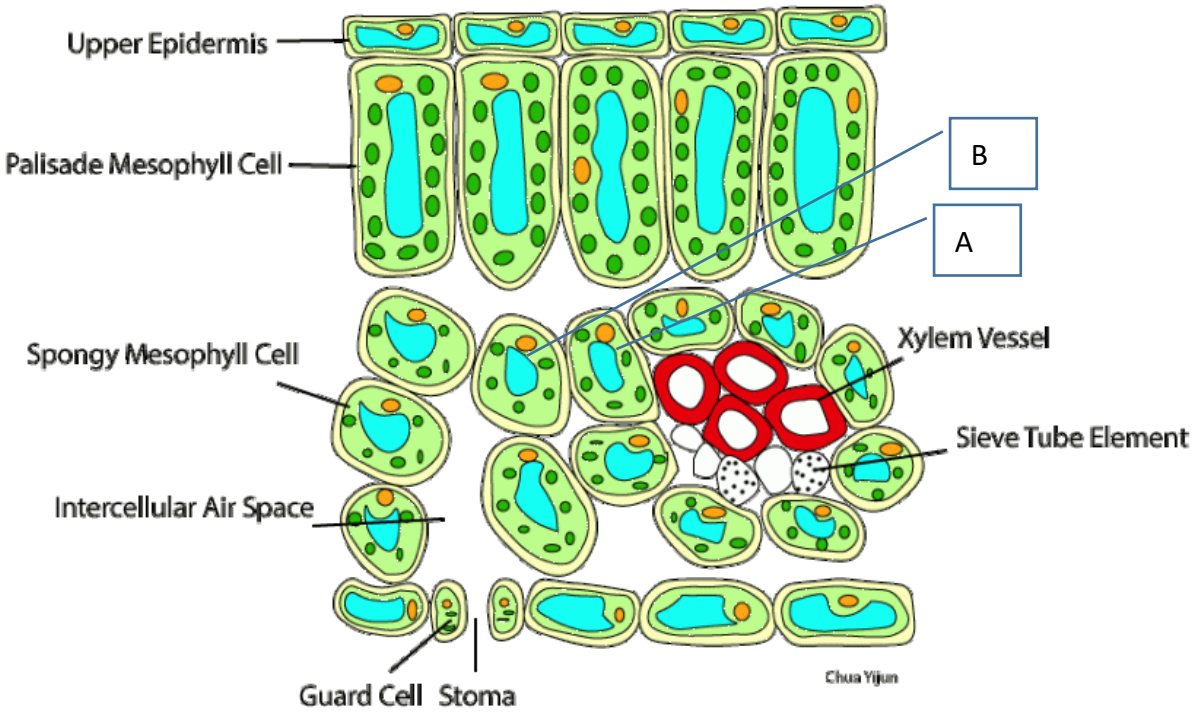
A. (1) and (2) only
B. (1), (2) and (3) only
C. (1), (3) and (4) only
D. All of the above

48. Which of the following can be considered evidence supporting the cohesion-tension theory?

(1) Rate of water transport in plants is closely in line with the rate of transpiration
(2) The tension found inside xylem is strong enough to pull water up to the top of the tallest trees
(3) Tree trunks contract during the day and expand at night (hint: the diameter of the xylem vessels will change with the pressure inside)

A. (1) only
B. (1) and (2) only
C. (2) and (3) only
D. All of the above

49. Below is a section of a leaf.



https://biologyform4secondaryschoolofmalaysia.wordpress.com/2017/12/04/density-of-chloroplast-in-palisade-mesophyll-cell/

According to the cohesion-tension theory, which of the following can be predicted?

(1) Water potential of xylem vessels is lower than that of cell B

(2) Water potential of cell A is higher than that of cell B

(3) A continual evaporation of water at the surface of the mesophyll cells

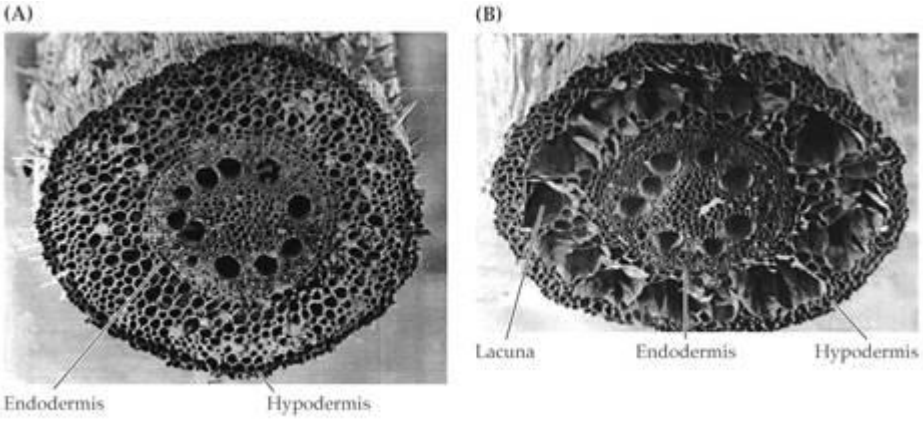
A. (1) only

B. (1) and (2) only

C. (2) and (3) only

D. All of the above

50. The photomicrographs below show the transverse sections of maize roots kept under (A) normal condition and (B) under 72 hours of flooding. Lacuna are created by death of the cortical cells (between endodermis and hypodermis) to form columnar intracellular spaces in the submerged roots.



(Adapted from "Biochemistry & Molecular Biology of Plants" by Buchanan, Gruissem, and Jones 2000, American Society of Plant Biologists, Fig. 22.18, p.1179)

Which of the following functions of lacuna formation in maize root after flooding is likely to be true?

A. To enhance the absorption of water to aerial structure
B. To protect submerged roots from pathogen attack
C. To facilitate oxygen transport from aerial structure to submerged roots
D. To make the root float in water

====End of the Contest====

題 1－2. 假設松鼠在草地找到堅果，牠有兩個選擇：牠可以在草地把堅果吃掉，或將堅果一個一個帶到安全地方，例如附近的大樹，然後進食。松鼠在草地上進食可以節省時間和能量，因為牠不需要在草地和大樹間來回走動。不過松鼠在大樹下進食可以減少被捕食者襲擊的機會。所以牠在安全進食和獲取最多能量之間需權衡取捨。

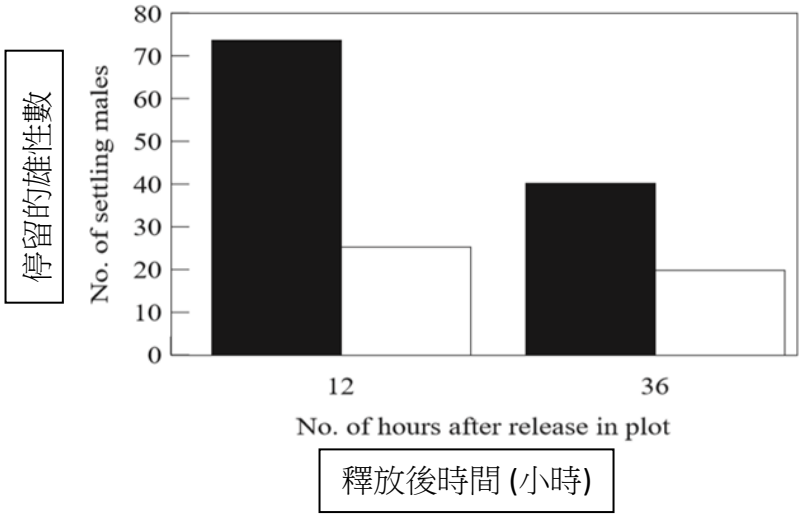
1. 按以上資料，以下哪項就堅果和大樹之間距離的預測是正確？

A. 堅果和大樹間的距離跟進食方式的選擇是沒有關係的
B. 若堅果遠離大樹，松鼠更大機會在草地進食堅果
C. 若堅果接近大樹，松鼠更大機會在草地進食堅果
D. 若松鼠居住的島嶼沒有捕食者，牠們更大機會在大樹下進食堅果

2. 按以上資料，以下哪項就堅果體積的預測是正確？(提示：堅果越大，需要越多時間打開堅果來進食。)

A. 堅果的體積跟進食方式的選擇是沒有關係的
B. 若堅果體積大，松鼠有更大機會在大樹下進食堅果
C. 若堅果體積小，松鼠有更大機會在大樹下進食堅果
D. 所提供資料不足以判斷哪項預測是正確

3. 雄性草蜢 (*Ligurotettix coquilletti*) 進食木焦油灌木葉片並在灌木上建立交配領土。它們會製造響亮和短而尖的聲音去吸引雌性。實驗使用兩棵體積形狀相若的木焦油灌木，一隻求偶中的雄性被放到其中一棵灌木上，而另一棵則留空。下圖一顯示 12 和 36 小時後雄性在灌木上聚集的數量。另一個實驗則顯示雌性對有多隻求偶中雄性的灌木有强烈偏好。



圖：在釋放草蜢 12 和 36 小時後，在有求偶中雄性的灌木上 (黑柱) 和沒有求偶中雄性的灌木上 (白柱) 停留的雄性數量。 (Muller KL (1998) Animal Behaviour, 1998, 56, 479 – 485.)

以下哪一/些句子不是以上實驗結果的合理解釋？

(1) 有求偶中雄性的灌木比沒有求偶中雄性的灌木上有更多雄性聚集，因為越多雄性可以吸引越多雌性

(2) 灌木上雄性的數量隨時間減少，因為雄性間有具侵略性的領土互動行為

(3) 雌性被有更多雄性的灌木吸引，因為它們可以有更多的配偶可供選擇，所以有更高的成功交配率

A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

4. 有些動物的性別不是取決於是否有 Y 染色體的存在。雌性有兩條 X 染色體而雄性只有一條。雄性進行減數分裂可製造 0X 或 1X 的配子。可是，雌性進行減數分裂可製造 0X，1X 或 2X 的配子。以下哪項是導致雌性製造 2X 配子的原因？

(1) 兩條 X 染色體沒有在生殖细胞的減數分裂 I 中分離
(2) 兩條 X 染色單體沒有在生殖细胞的減數分裂 II 中分離
(3) 兩條 X 染色單體沒有在配子前身細胞的有絲分裂 中分離

A. 只有 (1)
B. 只有 (1) 和 (2)
C. 只有 (2) 和 (3)
D. 以上皆是

5. 你正在研究小鼠如何形成癌症，並發現一個基因控制過程。營養充裕會抑制基因 1 的表達。當營養量處於低水平，基因 1 變得活躍而其產物可抑制基因 2 的活動。當基因 2 變得活躍，它會促使不受控的細胞分裂，因而產生癌症。

你分離出一個基因 1 變異的小鼠品種。這些小鼠剛成年就患上癌症。 以下哪項是正確的？

(1) 基因 1 的變異是顯性的
(2) 當這些小鼠的基因 2 被移走，這些小鼠不會患癌
(3) 如果沒有提供營養給這些小鼠，這些小鼠不會患癌

A. 只有 (1)
B. 只有 (2)
C. 只有 (1) 和 (2)
D. 只有 (1) 和 (3)

6. 在一個利用二倍體植物的實驗中，你將純種的皺皮，黃色種子的植物跟純種的圓形，綠色種子的植物交配。相對皺皮，圓形是隱性。相對綠色，黃色是隱性。兩個基因沒有連鎖性。當 F1 代的植物互相交配，以下哪組交配結果數字是最大機會的？

A. 22 圓形，黃色；26 圓形，綠色；28 皺皮，黃色；24 皺皮，綠色
B. 90 圓形，黃色；32 圓形，綠色；30 皺皮，黃色；9 皺皮，綠色
C. 11 圓形，黃色；26 圓形，綠色；27 皺皮，黃色；87 皺皮，綠色
D. 64 圓形，黃色；26 圓形，綠色；27 皺皮，黃色；27 皺皮，綠色

7. 一般人從兩歲開始體內會減少製造乳糖酶。到大概 12 歲，大部分人會停止製造乳糖酶而出現乳糖不耐症。他們不能夠有效地消化含乳糖的奶類製品。但有些成年人仍會持續地製造乳糖酶，形成乳糖酶續存性 。這是由於乳糖酶顯性基因的變異。

以下哪項是正確的？

(1) 有乳糖酶續存性的人可以是純合子或雜合子
(2) 乳糖酶續存性基因的變異是從乳糖酶的基因編碼區移除一粒核苷酸
(3) 乳糖酶續存性基因的變異是從乳糖酶的基因調控序列換一粒核苷酸，導致調控蛋白使乳糖酶基因功能能表達

A. 只有 (1)
B. 只有 (2)
C. 只有 (1) 和 (2)
D. 只有 (1) 和 (3)

8. 動物的平均壽命一般跟其平均體重成正比。鸚鵡比其他相同體重的鳥類有更長的壽命，且有很高的認知功能。基因 T 在這些長壽鳥類中顯示出最強的選擇壓力。在嚙齒動物中將基因 T 異位表達，可延長壽命達 40%，但認知功能上沒有明顯的改變。按以上資料，以下哪項關於嚙齒動物上基因 T 是正確的？

(1) 基因 T 已足夠去延長壽命
(2) 基因 T 是必須以延長壽命
(3) 基因 T 是不足夠去增加認知功能
(4) 基因 T 不是必須以增加認知功能
(5) 基因 T 對壽命和認知功能上的作用不能用作總結

A. (1) 和 (3)
B. (1) 和 (5)
C. (2) 和 (3)
D. (2) 和 (4)

9. 一種小形鸚鵡有 3 種獨特的羽毛變化。純種灰色跟純種黃色交配得出 100% 珍珠色。珍珠色跟珍珠色交配會得出 25%灰色，25%黃色和 50%珍珠色。至於頭頂，按孟德爾遺傳學沒有禿頭相對禿頭是顯性基因。

交配 1：黃色禿頭的雌性 x 未知表現型的雄性 得出

25% 黃色禿頭

25% 黃色沒有禿頭

25% 珍珠色禿頭

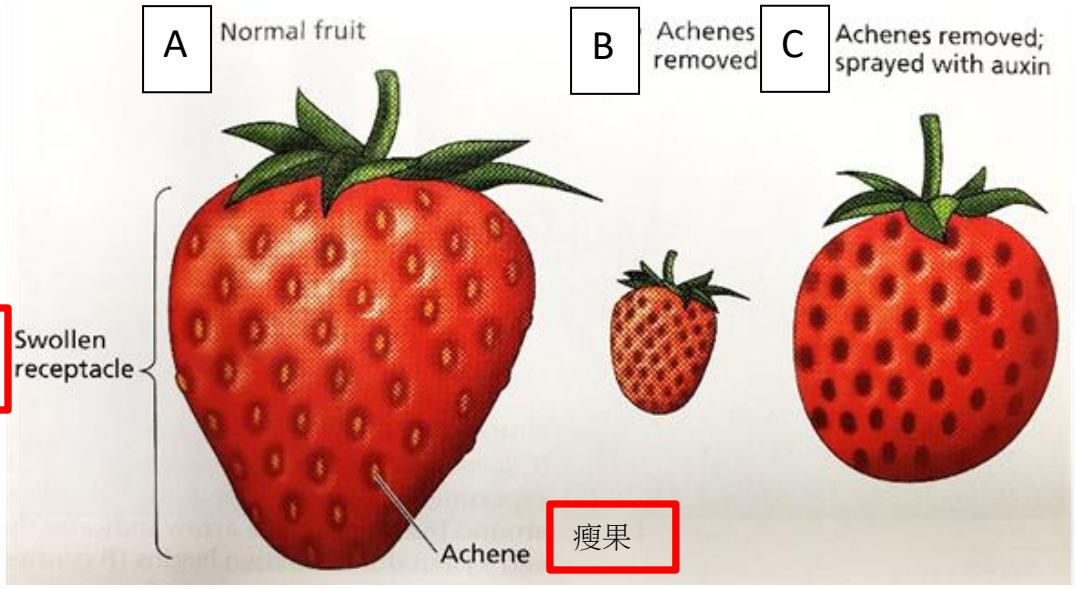
25% 珍珠色沒有禿頭

找出交配 1 中父母的基因型。

基因符號：Y = 黃色；G = 灰色；B = 禿頭的顯性等位基因；
b = 禿頭的隱性等位基因

A. YGBb x YYBB
B. YGbb x YGBb
C. YYBb x GGbb
D. YYbb x YGBb

10. 草莓的瘦果其實是真果。果肉組織是膨脹的花托，花托的增大是由植物激素控制。下圖是一棵正常的草莓 (A)，一棵瘦果被移除的草莓 (B) 和一棵瘦果被移除後再噴灑生長素的草莓 (C)。



(取自 ” Plant Physiology” 第四版，by Taiz and Zeiger 2006, Sinauer Associates, Inc., Fig. 19.39, p.500)

根據上圖，以下哪項是正確？

(1) 瘦果的形成需要膨脹花托所製造的生長素。

(2) 花托的增大需要瘦果所製造的生長素。

(3) 單生長素便可以完全取代瘦果以增大花托

A. 只有 (1)

B. 只有 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

11. 光合作用中，植物利用光作為能量將二氧化碳轉化為碳水化合物。大部分植物在日間有陽光時收集二氧化碳， 有趣的是沙漠植物是在晚上收集二氧化碳。以下哪項關於沙漠植物是真實的？

(1) 沙漠植物進化成在黑暗中製造碳水化合物

(2) 晚上收集的二氧化碳會被儲存直至日間以製造碳水化合物

(3) 二氧化碳不在日間收集去防止脫水

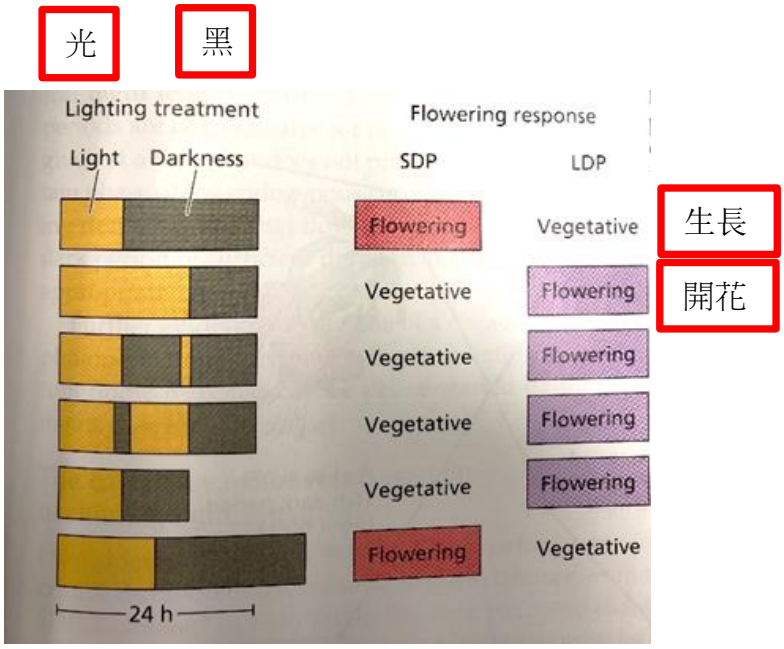
A. 只有 (1)

B. 只有 (2)

C. 只有 (3)

D. 只有 (2) 和 (3)

12. 開花受光暗循環所控制。兩種主要光週期反應的類別是短日照植物(SDP) 和長日照植物 (LDP)。以下顯示不同的光暗處理對 SDP 和 LDP 的開花的影響。

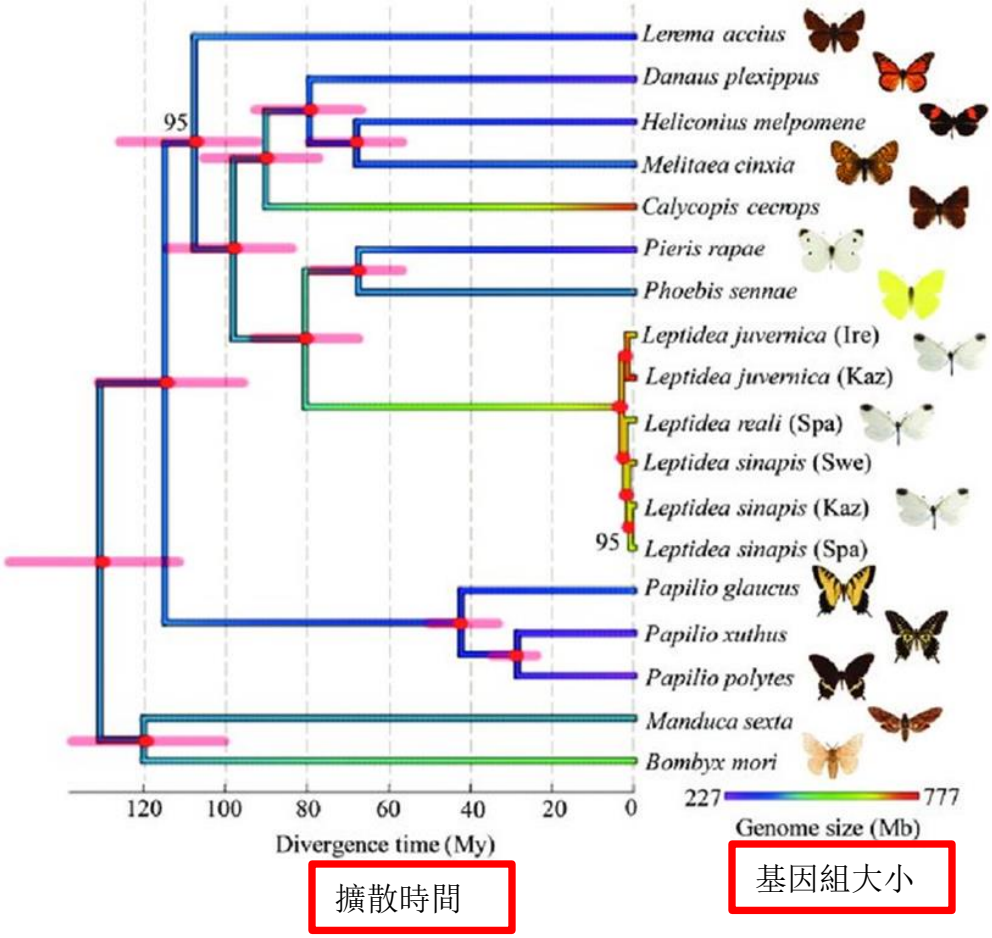


(取自 “Plant Physiology” 第四版 by Taiz and Zeiger 2006, Sinauer Associates, Inc., Fig. 25.19B, p.651)

按實驗結果，甚麼是 SDP 和 LDP 開花的最關鍵條件？

A. 光照的長度
B. 黑暗的長度
C. 光照 + 黑暗的長度
D. 24 小時內光照的次數

題 13 – 14. 以下是 15 種蝴蝶的發展史和擴散時間。發展史使用 224 個保守的，單拷貝的基因來建構。節點上的誤差線表示估計擴散時間的 95%信賴區間。拔靴帶(Bootstrap) 支援節點的數值<100。



圖取自 Backstrom et al (2017) 轉座子的高度活躍令小粉蝶屬 (Leptidea) 的基因組迅速擴大。Genome Biology and Evolution, 9: 2491 – 2505.

13. 按以上發展史，哪項是不正確？

A. *Papillo xuthus* 是 *Papillo glaucus* 的姐妹種 (最近親屬)

B. 小粉蝶屬是單系群 (全部來自共同的祖先)

C. *Manduca sexta* 較 *Melitaea cinxia* 早分離出來

D. *Bombyx mori* 和 *Lerema accius* 有共同祖先

14. 物種間的擴散時間是怎樣計算出來？

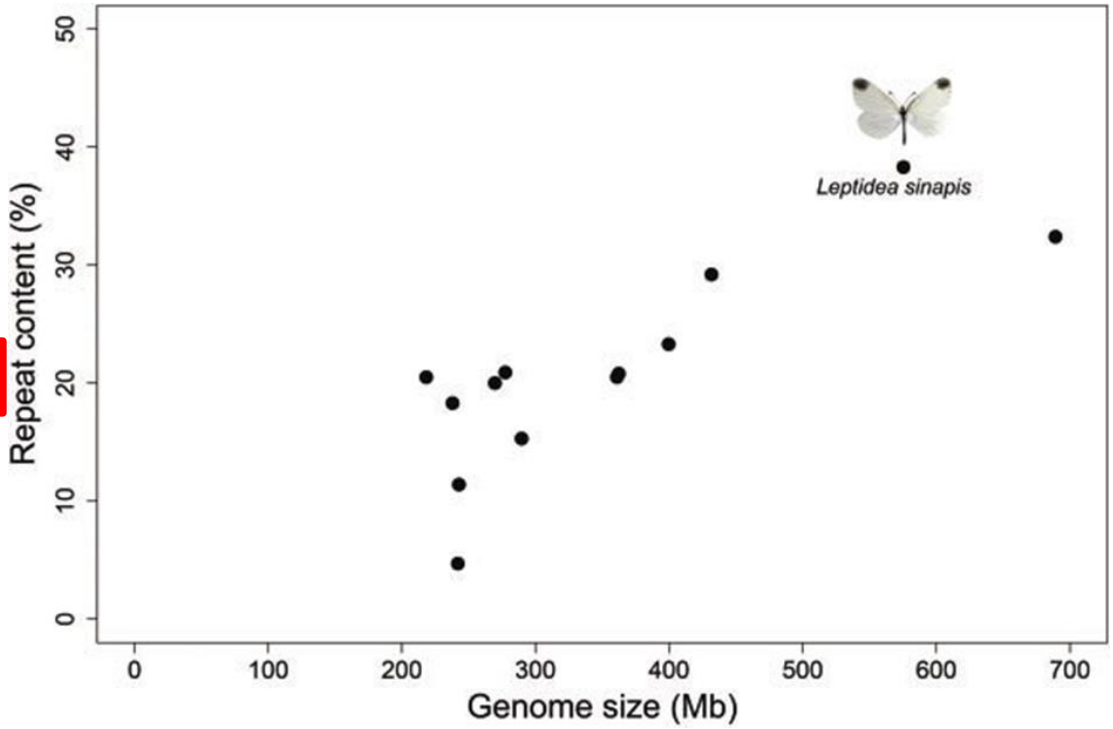
A. DNA 的改變是相對有規律的

B. 所有物種有相同的基因變異速率

C. 我們擁有所有活體物種的化石證據

D. 變異幾乎不會發生

題 15 – 16. 脫氧核醣核酸是高度重複的。以下圖表展示 15 種蝴蝶的基因組的大小(Genome size)和脫氧核醣核酸的重複量(Repeat content)之間的關係。



重複量

基因組大小

圖取自 Backstrom *et al* (2017) Rapid increase in genome size as a consequence of transposable element hyperactivity in wood-white (Leptidea) butterflies. Genome Biology and Evolution, 9: 2491 – 2505.

15. 圖表顯示基因組的大小和重複量之間有甚麼關係？

A. 不能確定
B. 沒有關係
C. 正比
D. 反比

16. 當比較兩個擁有不同大小基因組的物種，較大基因組的物種傾向有_____

(1) 更多 DNA

(2) 更多基因

(3) 更大的細胞核

A. 只有 (1)

B. 只有 (2)

C. 只有 (1) 和 (3)

D. 以上皆是

題 17 – 19. 一個學生解剖一隻蚌並找到一個嗜喱狀構造。他想知道該構造有沒有可消化澱粉的酶。用研缽和冷凍海水將嗜喱狀構造搗爛，然後將提取液和澱粉溶液在 10 個點滴瓷板的洞內混合。每兩分鐘將一滴碘溶液加到一個洞內並記錄其顏色。

(B = 藍黑色；R = 紅色/啡色；C = 透明/黃色)

時間 (分鐘)	0	2	4	6	8	10	12	14	16	18
嗜喱狀構 造+ 澱粉	B	B	B	R	R	R	R	C	C	C

17. 以下哪項對得出有效實驗結果是重要的？

(1) 每個洞內提取液的量是相同的

(2) 每個洞內澱粉溶液的量是相同的

(3) 加到每個洞內碘液的量是相同的

A. 只有 1

B. 只有 1 和 2

C. 只有 2 和 3

D. 以上皆是

18. 按實驗結果可以得出以下哪個結論？

(1) 啫喱狀構造有可以消化澱粉的物質

(2) 澱粉可以在 12-14 分鐘內消化完

(3) 啫喱狀構造物質在冷凍海水內有最高的活性

A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

19. 另一個學生用另外一個蚌重複實驗，以下是其結果：

時間 (分鐘)	0	2	4	6	8	10	12	14	16	18
啫喱狀構造 + 澱粉	B	B	B	B	B	B	B	R	R	R

以下哪項是第一個和第二個實驗不同結果的合理解釋？

(1) 第二隻蚌的啫喱狀結構含有更大量消化澱粉的物質

(2) 第二個實驗使用更多海水去作提取

(3) 第二個實驗加入更少的澱粉溶液

A. 只有 (1)

B. 只有 (2)

C. 只有 (1) 和 (2)

D. 以上皆是

20. EPO 是一種由腎臟製造的激素，負責刺激紅血球的製造。透過腎臟轉錄因子 HIF，氧濃度會控制 EPO 的產生。EPO 可用於治療嚴重貧血。有些運動員非法進食 EPO 從而提升表現。

按以上段落，以下哪行動步驟是正確？

A. 低氧水平→ 更多 EPO → 更多 HIF→更多紅血球
B. 低氧水平→ 更多 HIF → 更多 EPO→更多紅血球
C. 高氧水平→ 更少 EPO → 更少 HIF→更少紅血球
D. 高氧水平→ 更多 HIF → 更少 EPO→更少紅血球

21. 以下哪項是運動員進食外來 EPO 去提升表現的最可能的後果？

(1) 血液有更高的載氧量
(2) 血液鐵質缺乏
(3) 血液會變得更黏稠和更容易凝結
(4) 運動員的肺活量會增加

A. 只有 (1)
B. 只有 (1) 和 (2)
C. 只有 (1), (3) 和 (4)
D. 只有 (1), (2) 和 (3)

題 22 – 23. 一個 28 歲女運動員在 2002 年波士頓馬拉松死於低血鈉症腦病 – 血液的鈉濃度過低造成腦部損壞。她的腦部因太多水份進入而脹大。

人體內的血液滲透壓是靠一種叫抗利尿激素 (ADH)來維持，它會增加水份在腎臟的重吸收，並製造高滲壓的尿液。女性近排卵期會分泌更多 ADH。

22. 以下哪項是該女馬拉松跑手發生低血鈉症腦病的最可能的原因？

(1) 她接近月經週期的中段，並有更高水平的 ADH

(2) 她喝太多水

(3) 天氣太熱

(4) 她進食了太多鹽份

A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (1), (2) 和 (3)

D. 以上皆是

23. 為什麼血液的鈉濃度過低會導致太多水份進入腦部？

(1) 血液滲透壓比腦細胞的低，導致水份滲透攝入

(2) 更多鈉離子從腦細胞擴散到血液

(3) 低血液滲透壓降低 ADH 分泌

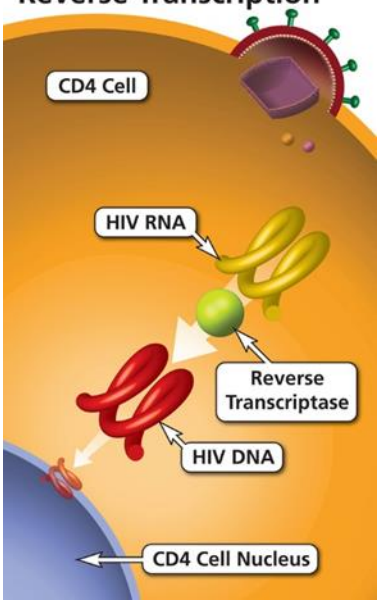
A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (1) 和 (3)

D. 以上皆是

題 24 – 26. 人類免疫缺乏病毒 (HIV) 每年引致全球二百萬人死亡。HIV 是一種 RNA 病毒，會在受感染的 CD4+ T 細胞內將 RNA 反轉錄成 DNA。



逆轉錄

逆轉錄酶

CD4 細胞

現時治療 HIV 的方法包含 3-4 種抗逆轉錄病毒藥物。這些藥物有兩個功能。一種藥物是模仿核酸，從而終止反轉錄時 DNA 鏈的延長。另一種藥物是跟反轉錄酶的不活性部位結合去阻礙反轉錄。

有一個學生進行一個實驗測試三種抗逆轉錄病毒藥物 (藥物 A, B, 和 C)。他培養基因重組 CD4+ T 細胞 (其中一個 HIV 的主要目標)，並讓細胞感染 HIV。之後他將三種抗逆轉錄病毒藥物 (A, B, C) 分別加到細胞中，沒有藥物的細胞是對照組。24 小時後，他量度病毒 RNA 的量和反轉錄酶的活性，並與對照組比較。

	病毒 RNA 濃度 (跟對照組比較)	反轉錄酶的活性 (跟對照組比較)
藥物 A	減少	沒有改變
藥物 B	減少	沒有改變
藥物 C	減少	減少

24. 按結果，三種藥物的作用機制是甚麼？

(1) 藥物 A 模仿核酸

(2) 藥物 B 使反轉錄酶不活躍

(3) 藥物 C 使反轉錄酶不活躍

A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (1) 和 (3)

D. 以上皆是

25. 假設一種藥物模仿核酸腺嘌呤去終止更多核酸被加到初期的 DNA 鏈。反轉錄時，它會跟病毒 RNA 的哪個鹼基配對？

A. 胸腺嘧啶

B. 鳥嘌呤

C. 尿嘧啶

D. 胞嘧啶

26. 按實驗結果，藥物 A 和藥物 C 對反轉錄酶的影響有甚麼分別？

(1) 藥物 A 會跟基質(核酸)競爭反轉錄酶的活性部位，藥物 C 不會

(2) 藥物 C 會改變反轉錄酶活性部位的形狀，藥物 A 不會

(3) 藥物 C 會令反轉錄酶變性，藥物 A 不會

A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (1) 和 (3)

D. 以上皆是

27. 桿細胞 (rods) 和視錐細胞 (cones) 是視網膜上的兩種不同細胞。視桿細胞主要負責光線微弱時的視力，而視錐細胞負責顏色視覺。下圖顯示視桿細胞和視錐細胞橫跨黃斑和盲點(視盤 optic disc)的分佈。

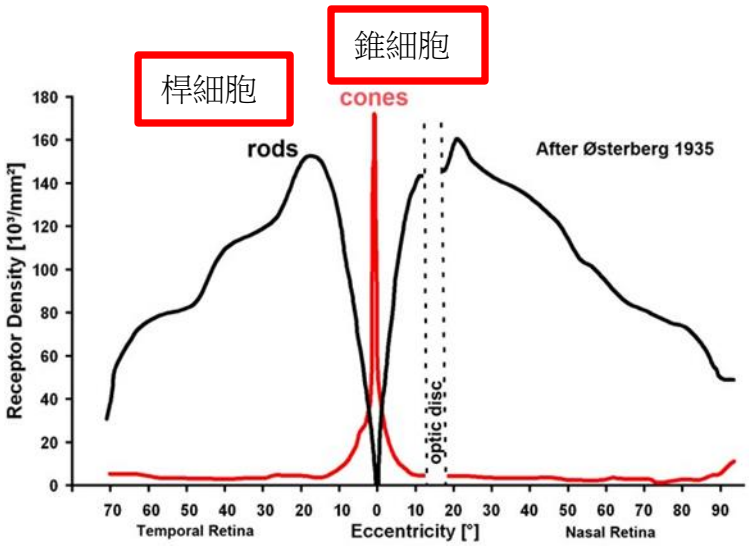


Fig. 20. Graph to show rod and cone densities along the horizontal meridian.

黃斑

以下哪項可從上圖作正確推斷？

(1) 光線微弱時，我們從中間比旁邊看得不清楚。

(2) 當光線落在視盤上我們甚麼也看不見。

(3) 日間時在視野中間的顏色視覺是最豐富的。

A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (2) 和 (3)

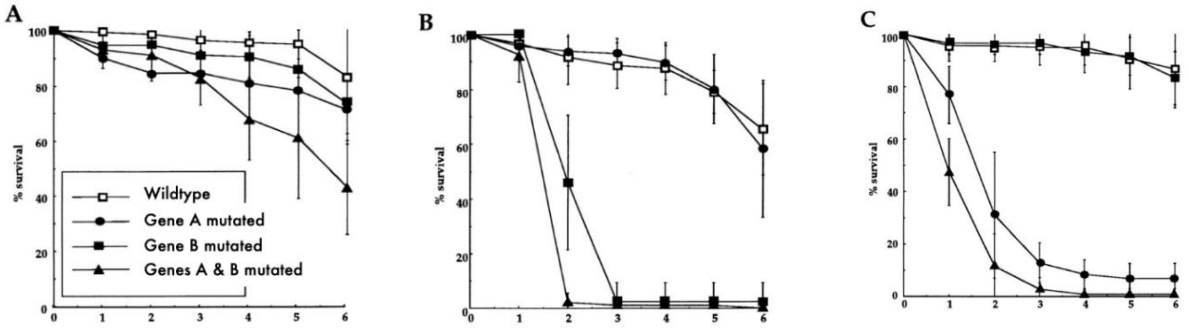
D. 以上皆是

28. 一個實驗研究果蠅受真菌和細菌感染後的生存率。果蠅會接受以下其中一個處理：

- 被乾淨的針刺其腹部(圖 A)
- 被蘸過真菌 Aspergillus fumigatus 胞子濃縮液的針刺 (圖 B)
- 被蘸過細菌 Escherichia coli 濃縮液的針刺 (圖 C)

有四種果蠅用作研究：野生型果蠅，基因 A 變異的果蠅，基因 B 變異的果蠅，和基因 A 和 B 變異的果蠅。果蠅在攝氏 29 度下 6 天內的生存率會被追蹤。

(取自 Lemaitre, B., Nicolas, E., Michaut, L., Reichhart, J. M., & Hoffmann, J. A. (1996). The dorsoventral regulatory gene cassette spätzle/Toll/cactus controls the potent antifungal response in Drosophila adults. Cell, 86(6), 973-983.)



哪項與以上資料吻合？

(1) 基因 A 對果蠅受真菌和細菌感染後生存是必要的

(2) 基因 A 對果蠅受細菌感染後生存是必要的

(3) 果蠅受真菌和細菌感染後生存需要有基因 A 和基因 B 的活性

(4) 果蠅受真菌感染比細菌感染更致命

A. 只有 (1) 和 (2)

B. 只有 (2) 和 (4)

C. 只有 (3) 和 (4)

D. 只有 (1), (2) 和 (4)

29. 下圖來自其中一個最早期放射性輻射對細胞的影響的研究。這個實驗所使用的原素是鐳 226，會產生阿爾法輻射。在雞脈絡膜組織培養中，數算實驗進行前，期間，和之後有絲分裂的細胞數量。

(取自 Canti, R. G. (1929). Biological effects of radium irradiation. Acta radiologica, 10(4), 320-331)

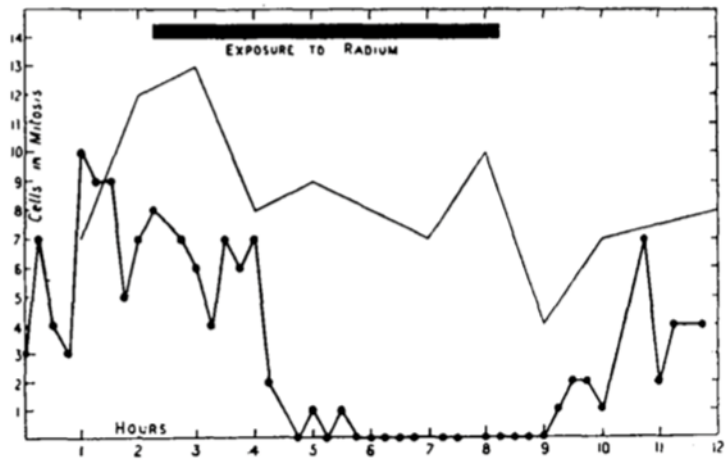


Fig. I. Graph showing the cessation and the return of mitosis in a tissue culture of chick choroid irradiated with 100 mg. of radium element filtered with 0.5 mm. of platinum at a distance of 1.4 cm. The thin line superposed shows the number of cells in mitosis in an unirradiated culture of the same age.

以下哪項與以上資料吻合？

(1) 放射性輻射在第 6 小時殺死所有細胞

(2) 放射性輻射對有絲分裂的影響在第 2 小時最高

(3) 有些細胞可以從放射性輻射中恢復

A. 只有 (1)

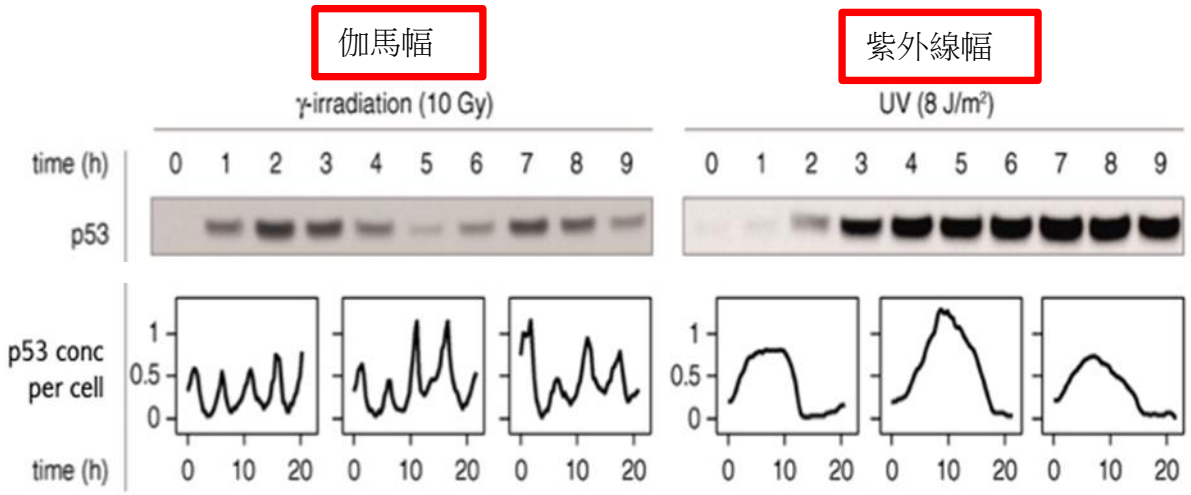
B. 只有 (3)

C. 只有 (2) 和 (3)

D. 以上皆是

30. p53 是可以抑制腫瘤細胞的蛋白質，它在細胞受壓力時被製造。下圖顯示 p53 在人類乳癌細胞暴露在伽馬或紫外線幅射後的濃度。圖中的譜帶強度代表該時間點的相應蛋白濃度。

(取自 Purvis, J. E., Karhohs, K. W., Mock, C., Batchelor, E., Loewer, A., & Lahav, G. (2012). p53 dynamics control cell fate. Science, 336(6087), 1440-1444).



以下哪項與以上資料吻合？

(1) 相對伽馬放射，紫外線放射可以在乳癌細胞活化更持久，更高水平的 p53

(2) 受伽馬放射後，p53 蛋白的量每 6-7 小時來回擺動

(3) p53 蛋白在沒有被放射的人類乳癌細胞探測不到

A. 只有 (1) 和 (3)

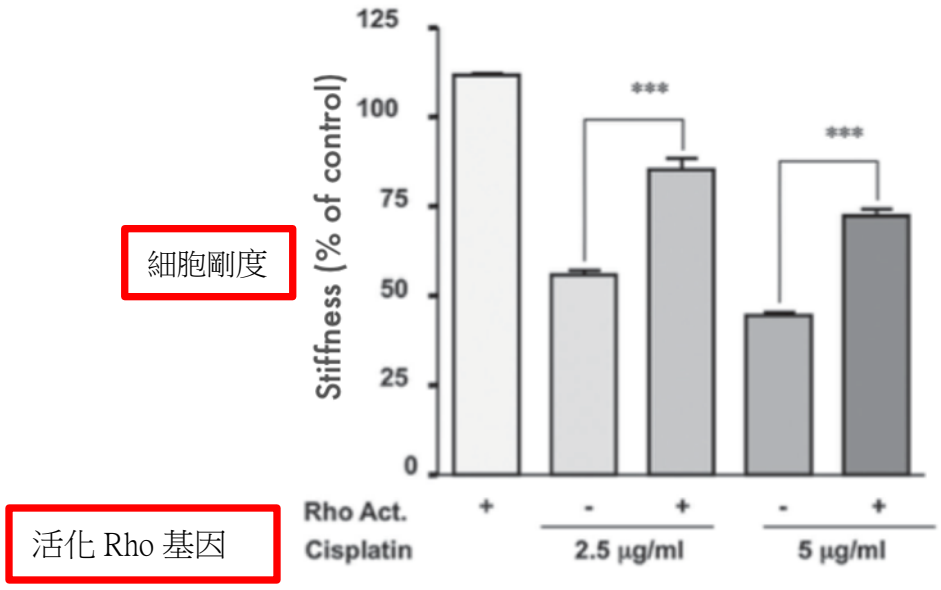
B. 只有 (1) 和 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

31. 下圖顯示活化 Rho 基因和化學療法藥物克莫 (Cisplatin) 對人類乳癌細胞剛度的功用。

(取自 Sharma, S., Santiskulvong, C., Rao, J., Gimzewski, J. K., & Dorigo, O. (2014). The role of Rho GTPase in cell stiffness and cisplatin resistance in ovarian cancer cells. Integrative Biology, 6(6), 611-617).



以下哪項與以上資料吻合？

(1) 克莫令人類乳癌細胞更柔軟

(2) Rho 基因令人類乳癌細胞更柔軟

(3) 克莫的功能不是取決於 Rho 基因的活化

(4) 克莫的加倍濃度不會大幅增加其效果

A. 只是 (1)

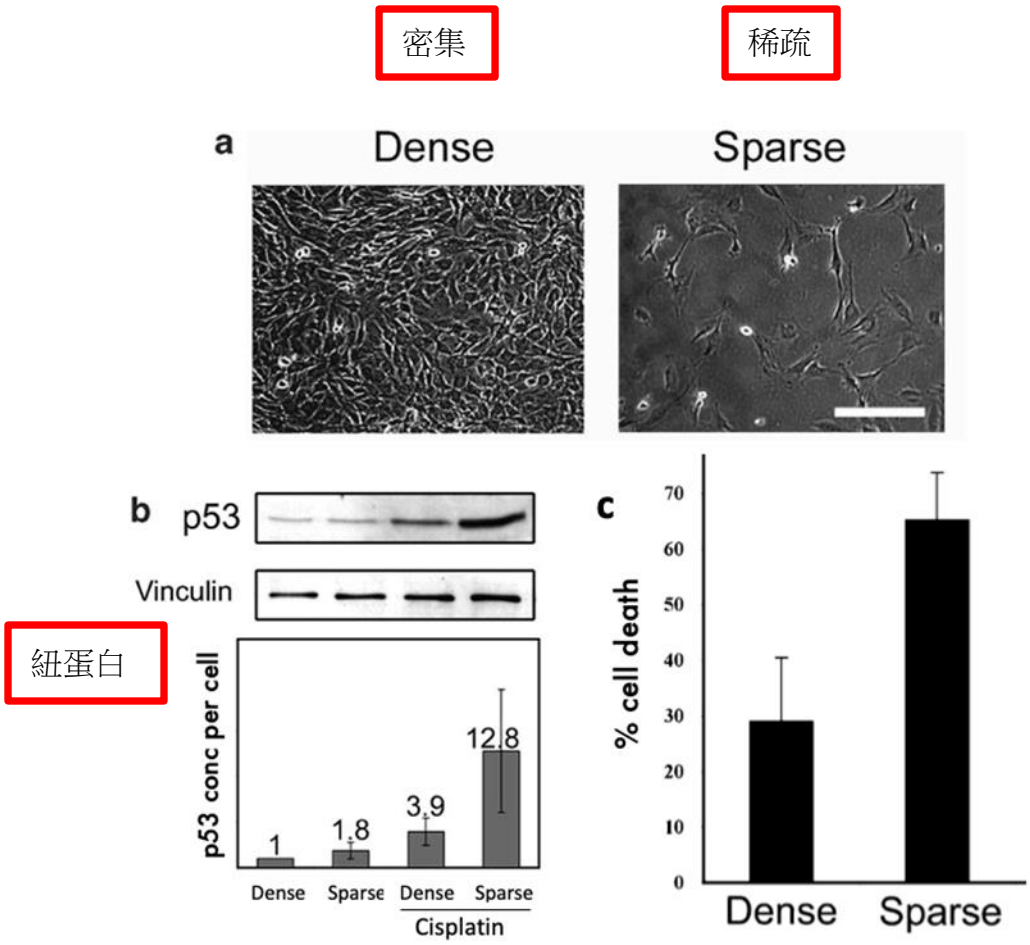
B. 只是 (2)

C. 只是 (1) 和 (4)

D. 只是 (1), (3) 和 (4)

32. 下圖顯示兩瓶不同細胞密度(密集和稀疏，圖 a)的小鼠纖維母細胞，p53 是抑制腫瘤細胞的蛋白質，它在細胞的作用會被量度。在使用化學療法藥物克莫後(圖 b) 會進行重複測量，每瓶死亡細胞的數量也會被量度 (圖 c)。

(取自 Bar, J., Cohen-Noyman, E., Geiger, B., & Oren, M. (2004). Attenuation of the p53 response to DNA damage by high cell density. Oncogene, 23(12), 2128).



以下哪項與以上資料吻合？

(1) 克莫可提高小鼠纖維母細胞 p53 蛋白的濃度

(2) p53 蛋白的濃度跟克莫引致細胞死亡有關聯

(3) 克莫在高細胞密度中對 p53 蛋的的濃度有更大作用

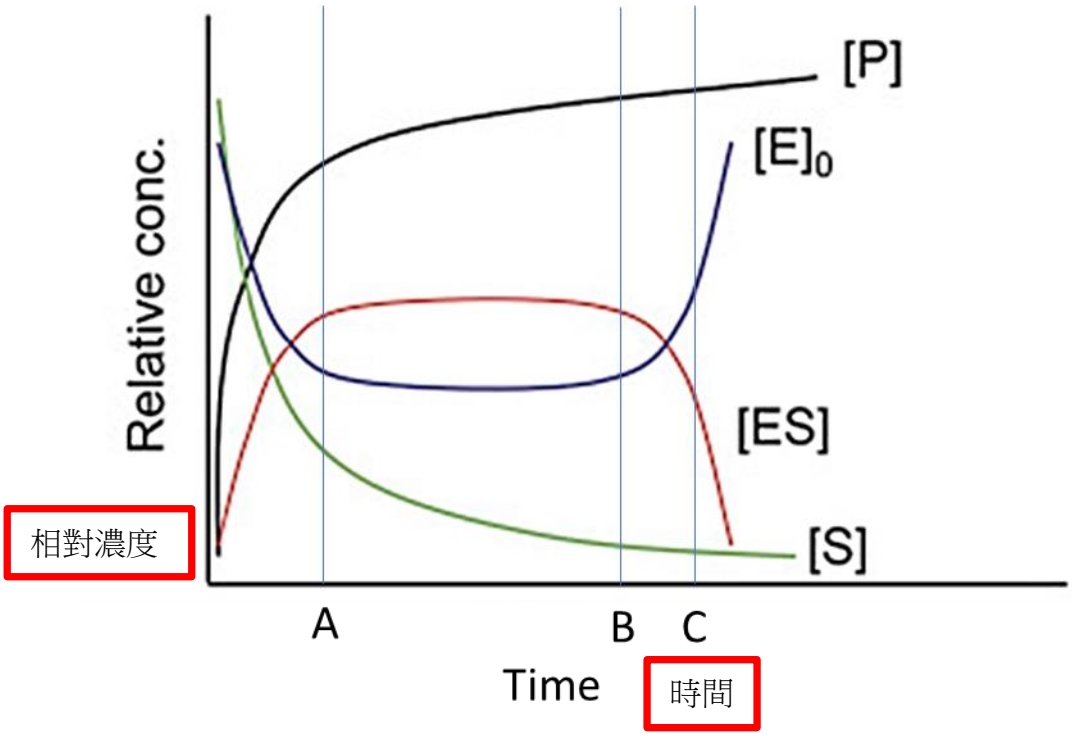
A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

33. 下圖顯示在一個酶促反應中，產物([P])、自由酶 ([E]0)、酶受質複合物 ([ES]) 和受質 ([S]) 濃度的改變。



以下哪項是正確？

(1) 在時間點 A，產物的製造受酶的濃度所限制

(2) 在時間點 A 之前，產物製造率是依賴反應所需的活化能

(3) 如果時間點 C 加入更多受質，產物([P])，自由酶 ([E]0)，酶受質複合物 ([ES])的線會全部往上走

(4) 酶受質複合物 ([ES])的量維持不變的時間長度 (點 A 和點 B 之間)依賴開始時受質的量

A. 只有 (1)

B. 只有 (2) 和 (3)

C. 只有 (1), (2) 和 (4)

D. 以上皆是

34. 糖酵解是細胞基礎過程以生產能量來支持細胞活動。糖酵解期間，含有 6 碳分子的糖類所儲存能量會被用作轉化 ADP 成 ATP。另外，NADH 也會在糖酵解時從 NAD+ 產生。

以下哪項是正確？

(1) 糖酵解可在缺氧下進行

(2) 糖酵解包含氧化作用

(3) 糖酵解持續發生，NAD+從 NADH 再生是必需的

A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

35. 艾美氏測試是有效的致突變性測試，可評估化學物品的致癌風險。這個方法會利用依賴組氨酸的沙門氏菌種。因為負責合成組氨酸的基因變異，這些菌種只可在有組氨酸的培養基中生長。這些細菌被化合物處理後準備在大鼠肝臟提取物中測試。細菌經繁殖後被播到沒有組氨酸的瓊脂平皿上。經過兩天在攝氏 37 度，細菌聚落的數量會被點算。沒有被化合物處理的細菌是用作對照組。

以下哪項是正確？

(1) 沒有或很少聚落在對照平皿上出現

(2) 受化合物處理過後，很多細菌聚落在平皿上出現，顯示這化合物能改正細菌的基因變異，所以它們可以重新製造組氨酸

(3) 一個被艾美氏測試證明為致突變性的化合物，必定是人類的致癌物

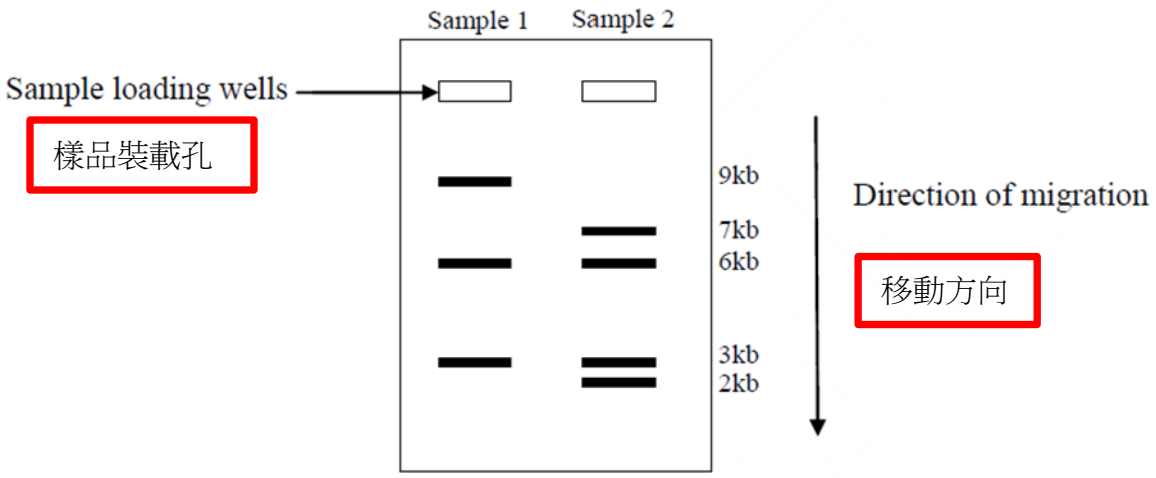
A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

36. 限制性核酸內切酶是一種在 DNA 特定序列切割的酶。兩個 DNA 的樣本 (樣本 1 和樣本 2) 有相同的 DNA 序列和長度 (18kb) 同時被 3 個限制性核酸內切酶切割。每一個 DNA 樣本都含有每一個限制性核酸內切酶的可識別序列。當已被消化的樣本在瓊脂糖凝膠上移動，可得到以下排列形式：



以下哪項是正確？

(1) 樣本 2 被其他 DNA 所污染

(2) 樣本 1 是環形的 DNA，樣本 2 是線性的 DNA

(3) 樣本 1 的 9kb DNA 小段包含樣本 2 的 7kb 和 2kb 小段

(4) 樣本 2 DNA 的濃度比樣本 1 高

A. 只有 (1)

B. 只有 (2) 和 (3)

C. 只有 (1), (2) 和 (4)

D. 以上皆是

37. 可用放射性的核甘酸來研究複製 DNA。細胞用放射性的核甘酸進行第一次有絲分裂，第二次有絲分裂則使用非放射性的核甘酸。 以下相片顯示進行兩次有絲分裂周期後的染色體。暗區表示放射性存在。

以下哪項是正確？

(1) 結果顯示 DNA 是半保留的複製

(2) 如果複製 DNA 是全保留的，只有一半染色體會出現放射性

(3) 相片箭咀所示部分是 染色體互換的結果

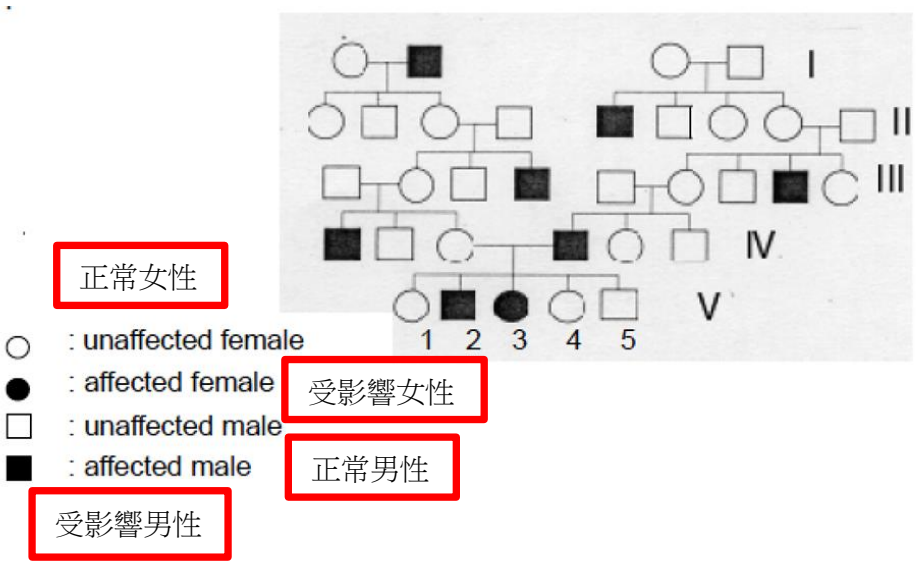
A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

38. 下圖顯示有 100%外顯率特徵的譜系。 外顯率是擁有該等位基因並表現其特徵的個體比例。



以下哪項是正確？

(1) 這特徵必定與 Y 染色體無關聯

(2) V3 母親的基因型是雜合子攜帶者

(3) V2 個體跟正常純合子結婚，他們第一個孩子是攜帶者的機會率是 50%

A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

39. 以下哪項關於進化是正確？

(1) 進化是一個個體隨著時間的改變

(2) 即使一個族群中的個體沒有差異，依然可以有進化

(3) 遺傳漂便是一個進化機制

(4) 進化產生完美物種

A. 只有 (1) 和 (4)

B. 只有 (2)

C. 只有 (3)

D. 只有 (2) 和 (3)

40. 一種蝴蝶翅膀的顏色取決於一個基因所在的三個等位基因。

C (黑色翅膀)>cg (灰色翅膀)>c(白色翅膀)。

一個按居住在範圍 1 的大族群的統計(族群 1)，得到以下等位基因型的出現頻率：C=0.5，cg=0.4，c=0.1。 一小群蝴蝶飛到範圍 2 並開始一個新族群(族群 2)，幾代之後，一個大的族群隨機交配後有以下表現型的頻率。 黑色翅膀(0.0)，灰色翅膀(0.75)，白色翅膀(0.25)。

以下哪項是正確？

(1) 在族群 1，如果蝴蝶繼續隨機交配，黑色翅膀的出現頻率會是 0.25

(2) 如果族群 1 有 6500 蝴蝶，灰翅膀的數量是 1560

(3) 跟族群 1 比較，族群 2 等位基因出現的頻率改變，是瓶頸效應的例子

A. 只有 (2)

B. 只有 (1) 和 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

41. 家禽的羽毛，例如母雞或公雞羽毛，是受一個基因的兩個等位基因控制，H(母雞)和 h(公雞)。在雌性和雄性家禽中同等位基因的組合和牠們的表現型在下圖顯示。 不過，當 hh 雄性家禽被閹割(移除睪丸)，羽毛會變成母雞羽毛。

基因型	表現型	
	雌性	雄性
HH	母雞羽毛	母雞羽毛
Hh	母雞羽毛	母雞羽毛
hh	母雞羽毛	公雞羽毛

以下哪一項是正確的？

(1) 等位基因 H 相對 h 是顯性

(2) 等位基因 h 在雄性禽鳥表現，但不在雌性禽鳥表現

(3) h 的表達與雄性禽鳥的雄激素有關

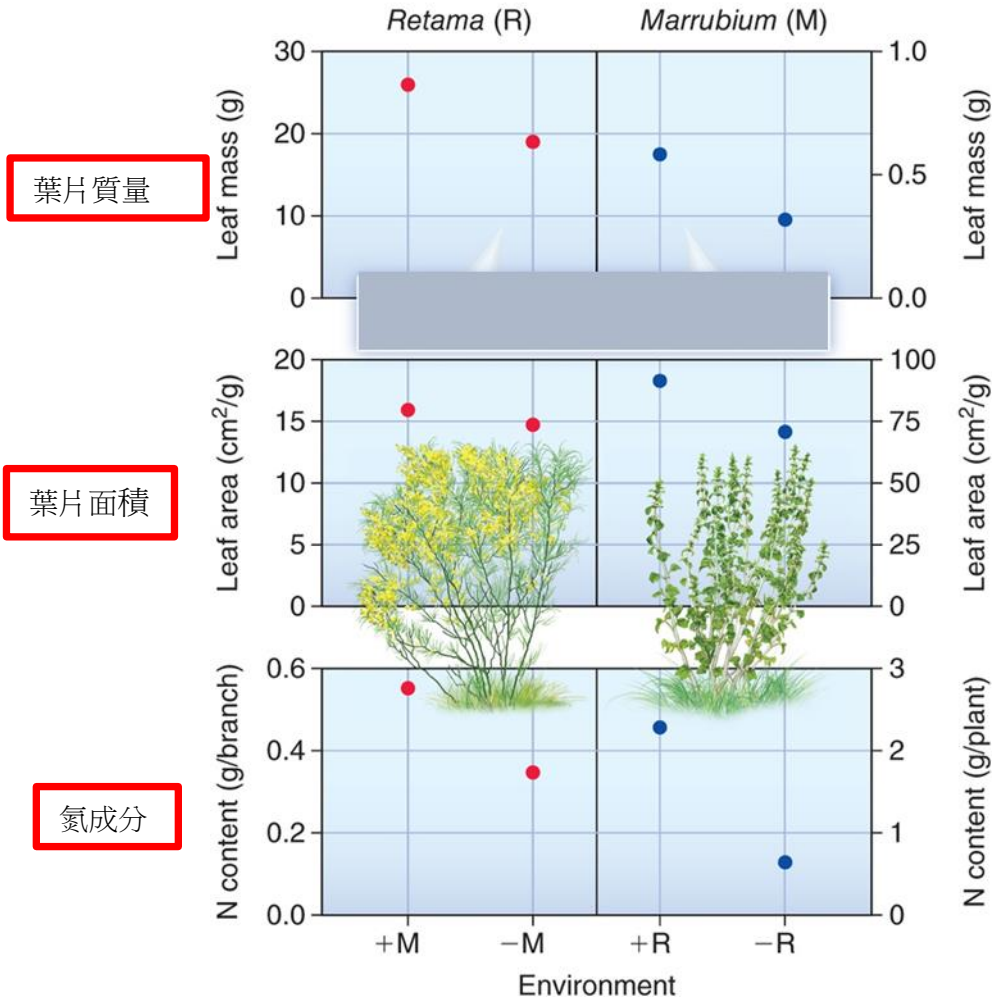
A. 只有(2)

B. 只有 (1) 和 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

42. 下圖顯示西班牙東南部兩個植物物種的關係，西班牙東南部是半乾旱地區。R 是灌木而 M 是 生長在 R 樹蔭下的草本植物。



葉片質量

葉片面積

氮成分

以下哪項是正確？

(1) 在從者關係中，M 比 R 得到更多利益

(2) 要得到以上數據需要比較兩棵 R，一顆跟 M 一起生表，一顆沒有。

(3) 當 M 在 R 下面生長，泥土會含有更多水分和有更快凋落物的降解

A. 只有 (1)

B. 只有 (1) 和 (3)

C. 只有 (2) 和 (3)

D. 以上皆是

43. 牛背鷺一般跟牛隻一起進食，下圖顯示在有牛和沒有牛鷺鳥的進食效率的情況。

	有牛	沒有牛
鷺鳥動作的數量 / 獵物的數量	13.7	76.5
獵物的數量 / 分鐘	2.0	0.6

From Grubb, T. (1976).

以下哪項是正確？

(1) 跟牛隻一起進食的鷺鳥比單獨進食可捉到更多獵物

(2) 單獨進食的鷺鳥要用更多能量去獲取相同數量的獵物

(3) 效率比例是每分鐘每獵物所需動作數量，有牛的效率比例是沒有牛的 20 倍

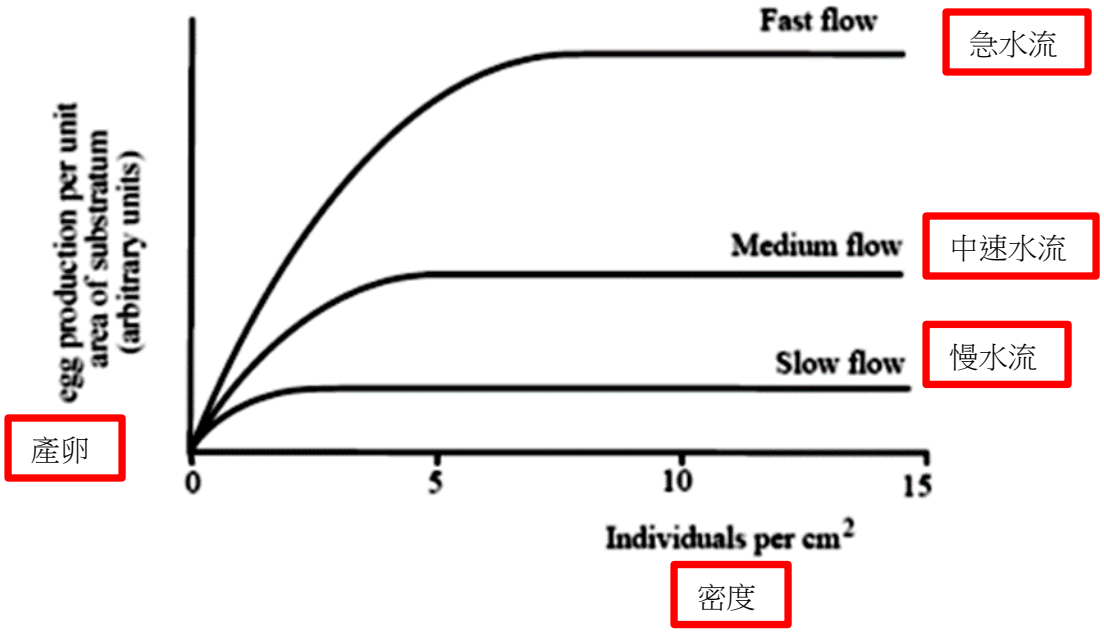
A. 只有 (1)

B. 只有 (3)

C. 只有 (2) 和 (3)

D. 以上皆是

44. 下圖顯示滕壺在不同族群密度和三種水流速度下的產卵情況。



以下哪項是正確？

(1) 族群密度越高，會產越多的卵

(2) 水流對產卵的影響與族群密度無關

(3) 速度快的水流可以增加產卵量

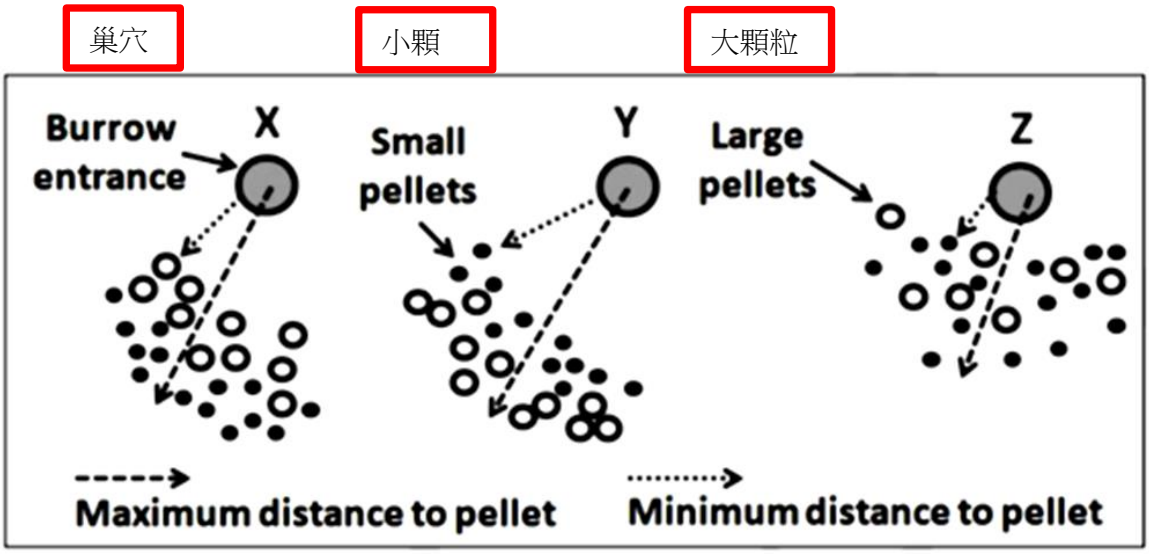
A. 只有 (1)

B. 只有 (3)

C. 只有 (2) 和 (3)

D. 以上皆是

45. 招潮蟹從沉降物得到營養後，他們會環繞巢穴放下小沙球(顆粒)。 按下圖，三隻雄性蟹 X ，Y 和 Z 以不同形式放下顆粒。 進行研究以測試一個假設：顆粒擺放形式跟雄性蟹透過顯示力量大小的交配成功率相關。 蟹 Y 被觀察到有更頻密的交配。



以下哪一項是正確的？

(1) 觀察結果跟假設一致

(2) 根據假設，可預測蟹 Z 吸引最少的雌性

(3) 用更多蟹所做的後續研究，可為假設提供更多支持，但假設是永遠不能被證實完全真確

A. 只有 (1)

B. 只有 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

46. 一個研究有毒魚種的毒性發展。 從野生族群收集卵子和精子並進行人工受精， 得出的胚胎在室內人工海水池孵化和成長，發現魚不會有毒性。

之後的實驗在這水次長大的幼魚 被分成兩組，分別安置在海灣的兩個水池， 暴露於真正的海水。水池 A 有一橫置的網防止魚接觸海底，水池 B 沒有橫置的網。然後水池 A 的魚沒有驗出毒素，但水池 B 的魚帶有毒素。

以下哪項是正確？

(1) 魚毒素的發展需要天然海水

(2) 魚的毒素來自海底

(3) 魚毒素的發展全部是由基因來

A. 只有 (1)

B. 只有 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

題 47 – 48. 有兩個關於水怎樣在植物中被轉運的理論，根壓力和內聚力-學說。 根壓力是將鹽和糖主動轉運到根部的木質導管來建立正壓力，向上推動木質導管的水份。內聚力學說可解釋木質導管的水份因蒸騰拉力而向上移動，拉力是建基於葉片上的蒸騰作用。

47. 以下哪項可証明來否決根壓力是水在植物中運輸的惟一機制？

(1) 根壓力不是在所有植物中找到，對於高樹，壓力强度不足以將水推到樹項

(2) 植物的蒸騰作用活躍時 (如在乾燥和晴朗日子)， 根壓力會減弱或會不存在

(3) 沒有根時，水仍然能夠向上移動

(4) 水在莖部切口溢出 -- 泌水作用

A. 只有 (1) 和 (2)

B. 只有 (1), (2) 和 (3)

C. 只有 (1), (3) 和 (4)

D. 以上皆是

48. 以下哪項可証明來支持內聚力學說？

(1) 植物轉運水的速率跟蒸騰作用的速率非常接近

(2) 木質導管內的張力可足夠將水份拉到最高的樹頂

(3) 樹幹在日間收縮和在晚間擴張 (提示：木質導管的直徑會隨內裡的壓力改變)

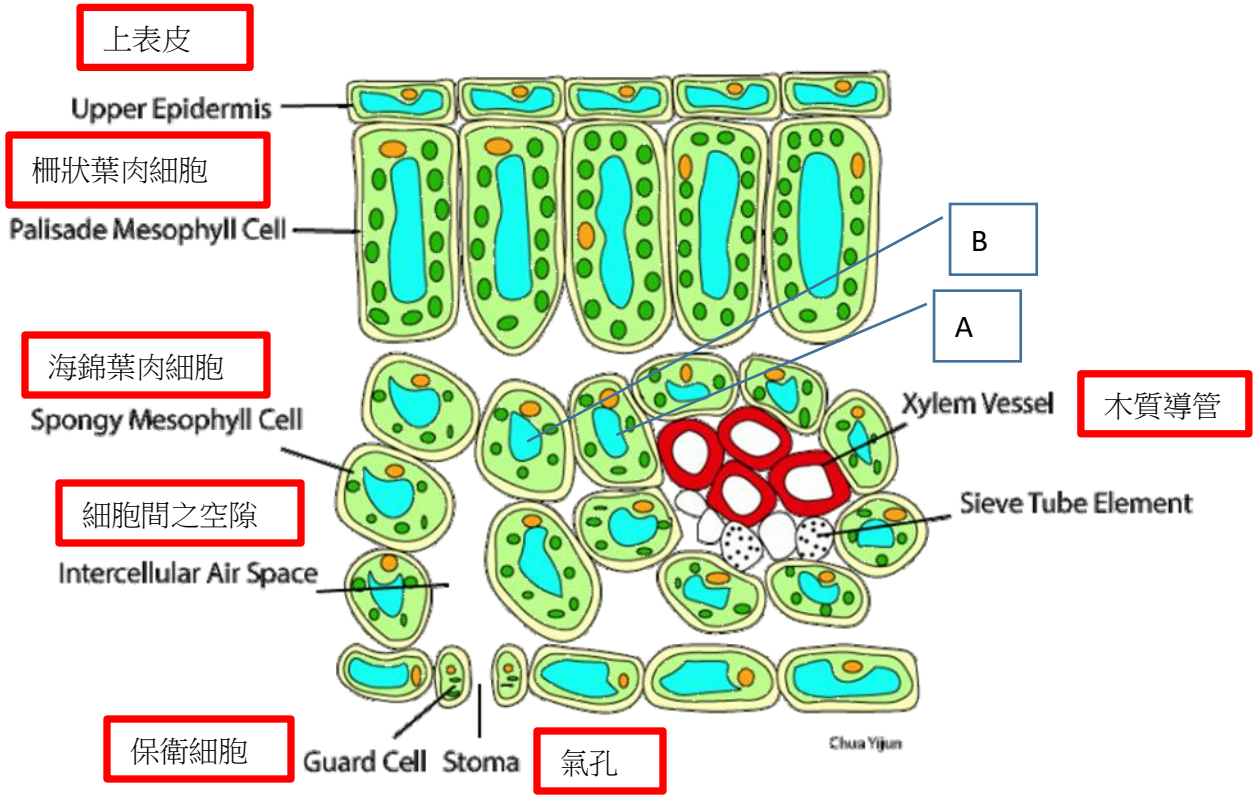
A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

49. 以下是葉片的切面。



https://biologyform4secondaryschoolofmalaysia.wordpress.com/2017/12/04/density-of-chloroplast-in-palisade-mesophyll-cell/

根據內聚力學說，以下哪項可以預測？

(1) 木質導管內的水勢比細胞 B 低

(2) 細胞 A 的水勢比細胞 B 的高

(3) 在葉肉細胞表面持續蒸發水份

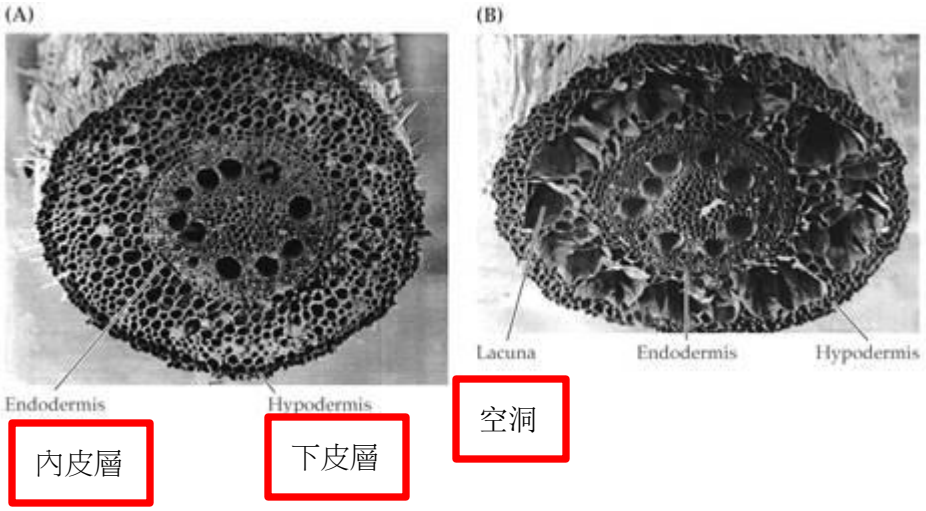
A. 只有 (1)

B. 只有 (1) 和 (2)

C. 只有 (2) 和 (3)

D. 以上皆是

50. 以下是粟米根部先在(A) 正常情況和 (B) 水浸 72 小時之後的橫切面顯微照片。已死的角質細胞 (內皮層和下皮層之間) 會造成空洞，在受水淹沒的根部內形成柱狀的細胞間隙。



(取自 “Biochemistry & Molecular Biology of Plants” by Buchanan, Gruissem, and Jones 2000, American Society of Plant Biologists, Fig. 22.18, p.1179)

以下哪項最有可能是水浸後粟米根部出現空洞的正確功能？

A. 加強吸收水份轉到空氣中的構造
B. 保護淹沒的根部，避免病原體襲擊
C. 促使氧從空氣中的構造轉運到淹沒的根部
D. 令根部浮在水中

====全卷完====

Answer Key

Question	Answer
1	B
2	B
3	D
4	D
5	C
6	C
7	D
8	A
9	D
10	B
11	D
12	B
13	A
14	A
15	C
16	C
17	D
18	B
19	B
20	B
21	D
22	B
23	A
24	C
25	C
26	D
27	D
28	B
29	C
30	D
31	C
32	**B**
33	C
34	D
35	B
36	B
37	B
38	D
39	C
40	A
41	D

42	B
43	D
44	B
45	D
46	B
47	B
48	D
49	C
50	C

Updated on: 12th December 2019