

International Biology Olympiad – Hong Kong Contest 2020

國際生物奧林匹克 – 香港區比賽 2020

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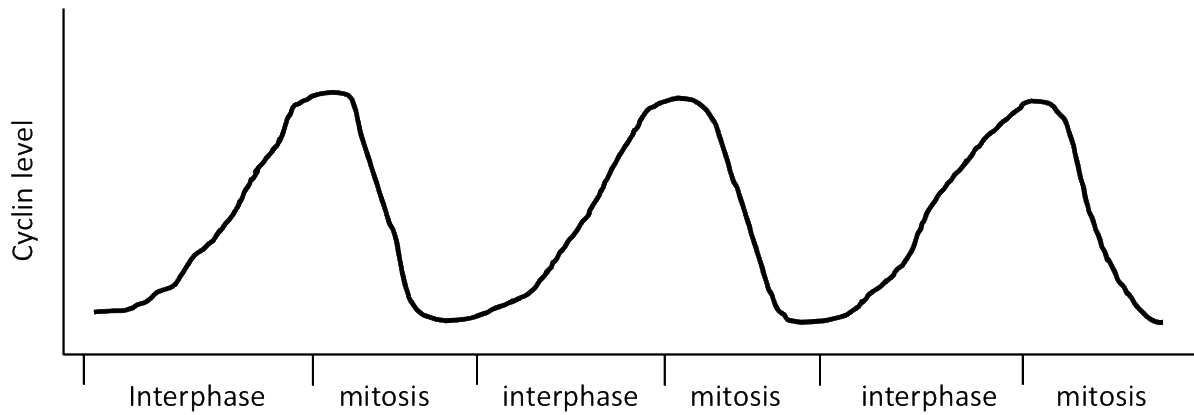
A novel strategy of drug design employs nucleic acid macromolecules to inhibit the expression of a gene. The target of the drug can be a gene in a bacterial cell, a cancer cell, or a virus-infected eukaryotic cell. Normally produced messenger RNA (mRNA) molecules are known as the sense RNA. Antisense nucleic acids, which are complementary to a portion of the sense mRNA, can be synthesized. The antisense molecules will bind specifically to the sense mRNA and prevent the production of the natural gene product.

1. When used as described in the above passage, antisense drugs prevent:
 - A. RNA translation.
 - B. RNA transcription.
 - C. DNA replication.
 - D. Cell replication.

2. Phenylketonuria is a genetic disease caused by a mutation in the gene for the enzyme phenylalanine hydroxylase, which loses its enzymatic activity. Could an antisense drug help patients with this disease?
 - A. No, because mRNA does not persist in the cytoplasm of the cell.
 - B. No, because blockage of phenylalanine hydroxylase gene expression will not remedy the original disorder, no normal phenylalanine hydroxylase is produced.
 - C. Yes, if it binds to the mRNA of the phenylalanine hydroxylase gene and prevents its translation.
 - D. Yes, if it is incorporated into the chromosome and prevents the expression of the phenylalanine hydroxylase gene.

The level of the cyclin protein rises and falls during the cell cycle as shown below.

Changes in the level of cyclin during phases of the cell cycle



3. What mechanism could explain for this oscillation of cyclin protein concentration?
- A. Replication of the cyclin gene during S phase of interphase
 - B. Segregation of chromosomes carrying the cyclin genes during mitosis
 - C. Translation of cyclin mRNA in mitosis and proteolysis of cyclin protein in interphase
 - D. Translation of cyclin mRNA in interphase and proteolysis of cyclin protein in mitosis

Bone is composed of a hard mineral portion (mostly calcium), together with an organic, collagen-like matrix. Bone tissue contains about 99% of the body's calcium. Throughout life, bone is continuously resorbed and reformed—a process closely related to the maintenance of an adequate level of calcium in the blood plasma. Some important factors that affect this process are:

Parathyroid hormone, which acts on bone tissue to encourage the formation and activity of osteoclasts (which break down bone cells) and to impair new bone formation.

Vitamin D, which in its activated form functions like a hormone. This nonpolar compound acts on the small intestine to stimulate absorption of calcium and also on bone tissue to enhance the effect of parathyroid hormone. It can be obtained from the diet or by the action of ultraviolet light on the skin.

Calcitonin, which decreases bone resorption; however, its effect is small (more like fine-tuning).

Vitamin C, which is required for the synthesis of bone matrix and is therefore needed for bone formation.

4. A low level of calcium in the plasma will trigger an increase of:

- I. osteoclast activity
- II. parathyroid hormone
- III. vitamin C

- A. I only
- B. I and II only
- C. I and III only
- D. II and III only

Healthy weight is defined as a body mass index (BMI) of 25 or less. $BMI = w/h^2$, where w is weight (kg) and h is height (m). Studies suggest that genes account for about 40% of the factors that determine BMI. Two genes affecting weight in mice are related to leptin, a hormone that is released by fat cells and required for maintaining normal weight. One gene (designated *ob*) codes for leptin, and the other gene (designated *db*) codes for a leptin receptor. Stable weight is also believed to be regulated by metabolic feedback loops linking the brain, fat cells, the digestive tract, and muscles.

5. What type or class of chemical messenger traveling in the blood would most probably link the brain with the digestive tract and fat cells in the control of body weight?
- A. Neurotransmitters
 - B. Digestive enzymes
 - C. Protein receptors
 - D. Hormones

Humans in hot, dry environments regulate their body temperatures by circulatory adjustment (vasodilation of cutaneous blood vessels) and evaporative cooling (increased sweat gland secretions). However, during severe heat stress and dehydration, temperature regulatory mechanisms (particularly sweating) may upset physiological homeostasis. Excessive sweating may upset homeostasis by impairing water and salt regulation. During dehydration, the kidneys may reduce their urinary output from the normal level of 1.0-1.5 L H₂O/day to as little as 0.5 L H₂O/day, and renal salt excretion may decline to nearly zero. Excessive sweating also reduces the volume of blood available for delivering O₂ to the internal body tissues.

6. When the environmental temperature is 33° C, vasodilation of cutaneous blood vessels helps to regulate the body temperature of a human by:
- A. slowing blood flow through the skin
 - B. radiating excess body heat into the environment
 - C. maintaining an even distribution of heat throughout the body
 - D. preventing body heat needed from being lost to the environment

Census was done to monitor the fluctuation of wolves and moose on the Isle Royale National Park for the past 50-60 years. They are the major carnivore and herbivore on this island. The ups and downs of the populations appear to change with an opposite trend.

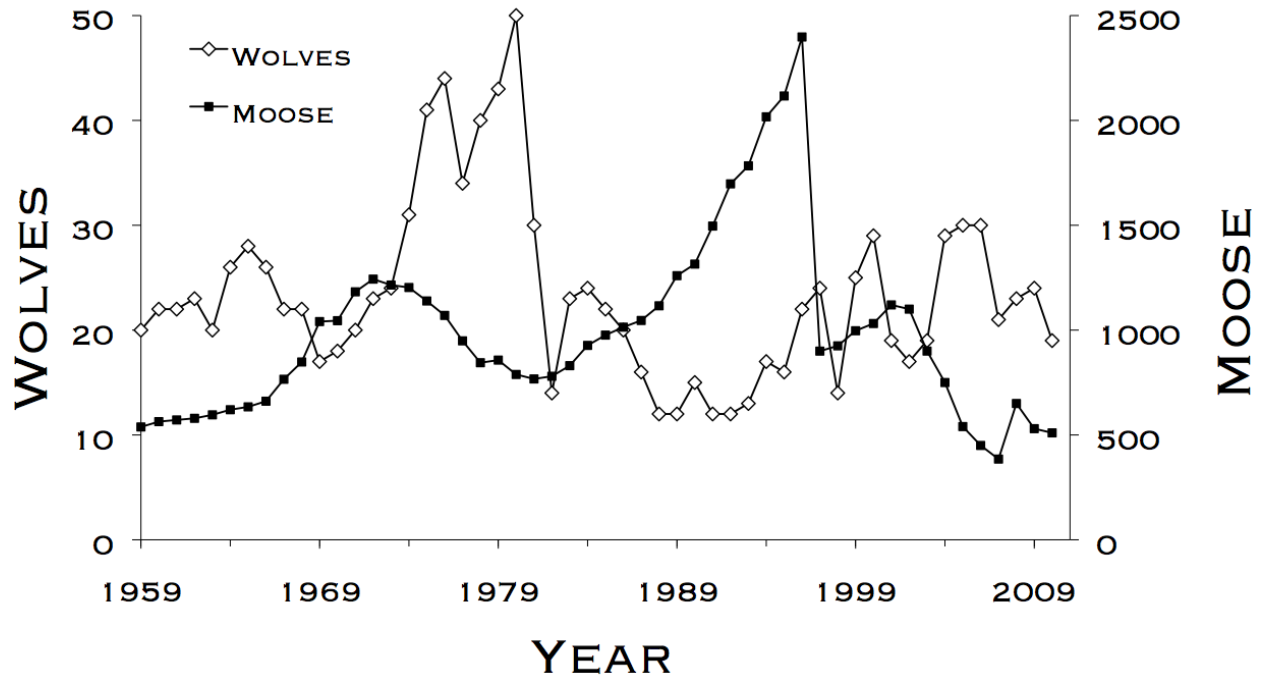
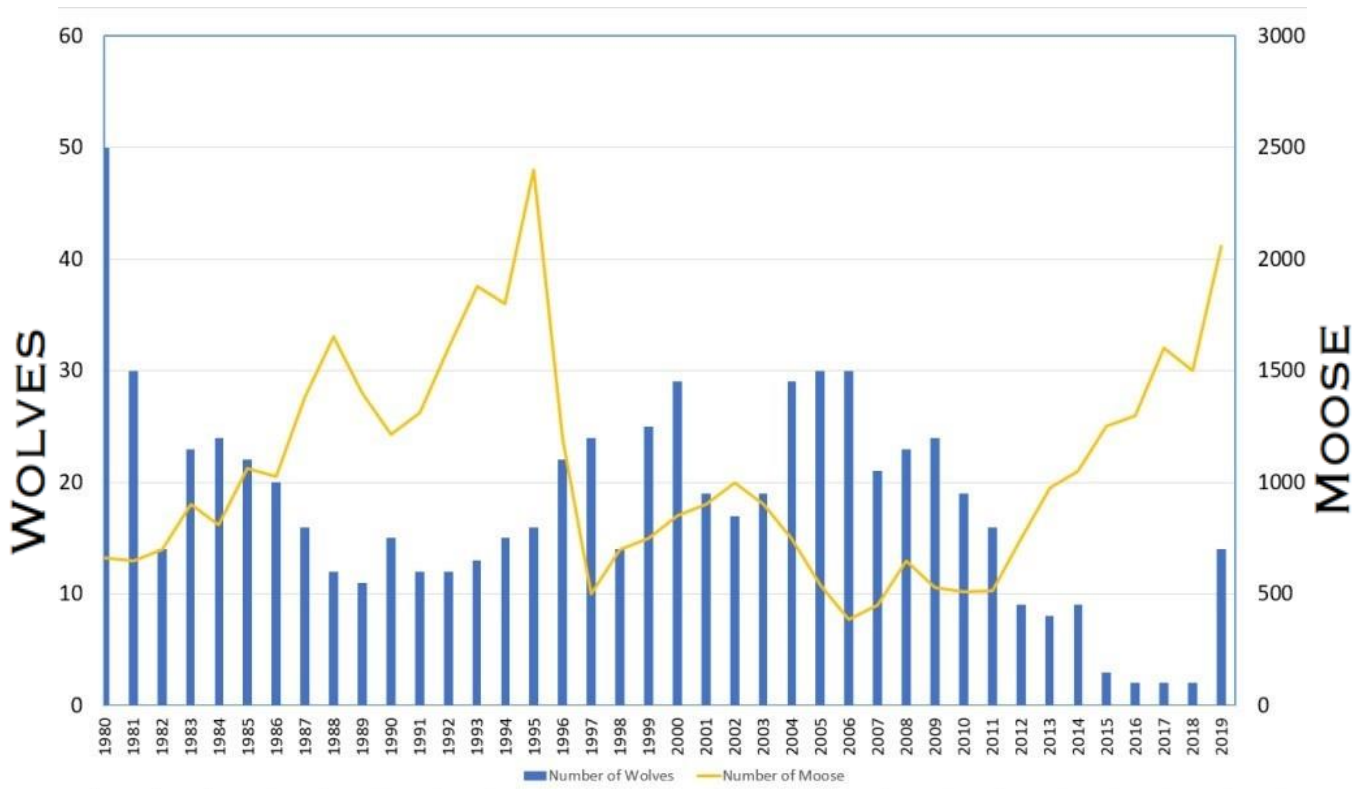


Photo source: <https://www.nps.gov/isro/learn/nature/wolf-moose-populations.htm>

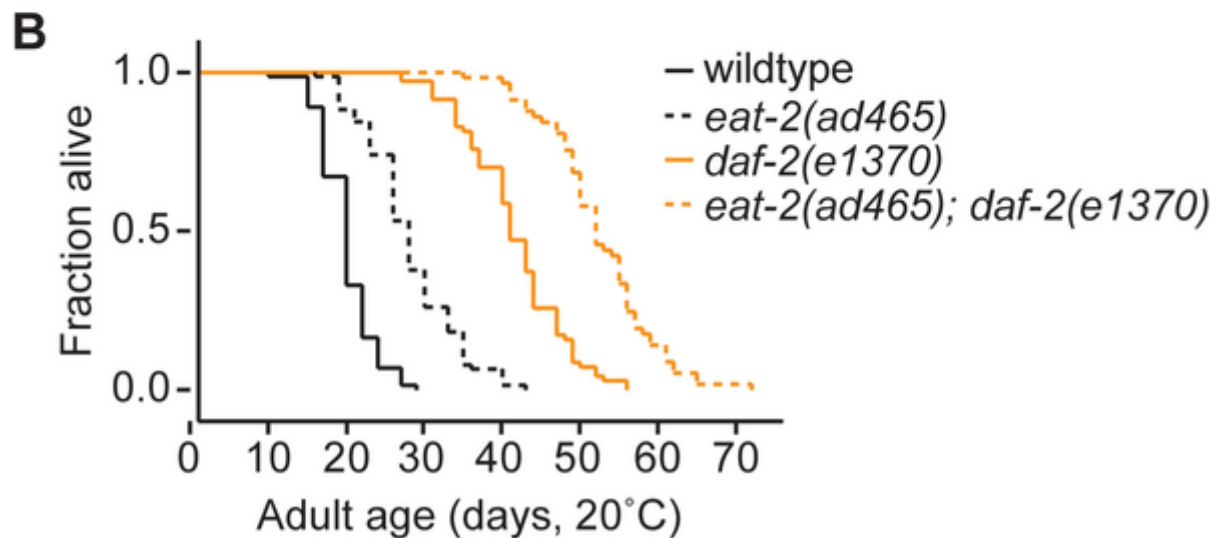
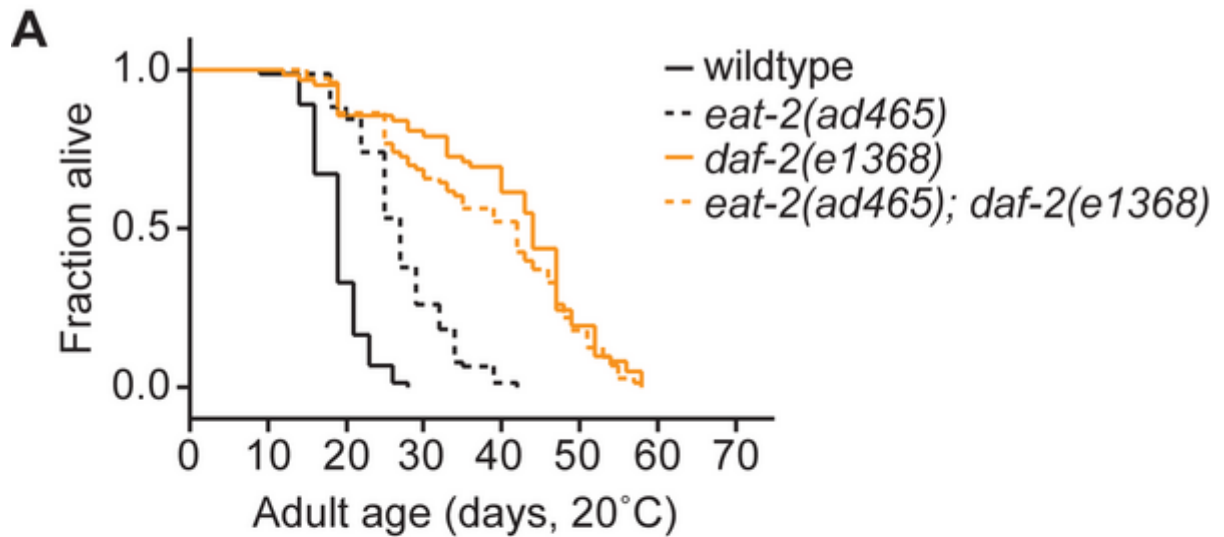
7. Based on this observation, which of the following statement conclusively describes the ecological relationship?
- A. Moose are a reliable food source for wolves in this national park.
 - B. When the number of wolves increases, it is always followed by a delayed decline of the number of moose.
 - C. Change of wolf population in the park is influenced by the availability of other food sources and factors.
 - D. Increase in the number of moose is a driver for the increase in number of wolves in the park.



8. From 2009-2015, i.e., an extension of the graph from Question (7), there is a rapid decline of wolves, the number of moose rapidly increases. To make the balance, 12 wolves were introduced back to the Isle Royale National Park in 2019 to control the moose population. Which of the following statement provides the logical rationale to support this introduction of wolves from outside the Isle?
- A. Breeding cycle of the wolves is too slow to allow gradual increase of wolves in the park, hence external introduction is required to restore the number to control the moose population.
 - B. With over a thousand moose on the Isle for a long time, the habitat would be permanently damaged that will be no longer suitable for the wolves to survive.
 - C. The few wolves remained in 2015 were too timid. Only more aggressive wolves introduced back to the park would be able to curb the growth of the moose population.

D. The small number of wolves would limit the genetic diversity and a healthy wolf population will never be restored when no new wolves are introduced.

Wild type worms live a normal life span of about 18-20 days as indicated in graph A. If you start off with 100 animals, 50% of them would be dead by 18-20 days. Some recessive mutant alleles of genes, *eat-2* and *daf-2*, live longer with an average life span of 25-30 days and 40-45 days, respectively.



9. If you now have a homozygous *eat-2 (ad465)* mutant animal and it is crossed with a mutant animal *daf-2(e1368)*. What would be the expected maximum life span of all its first generation progeny?

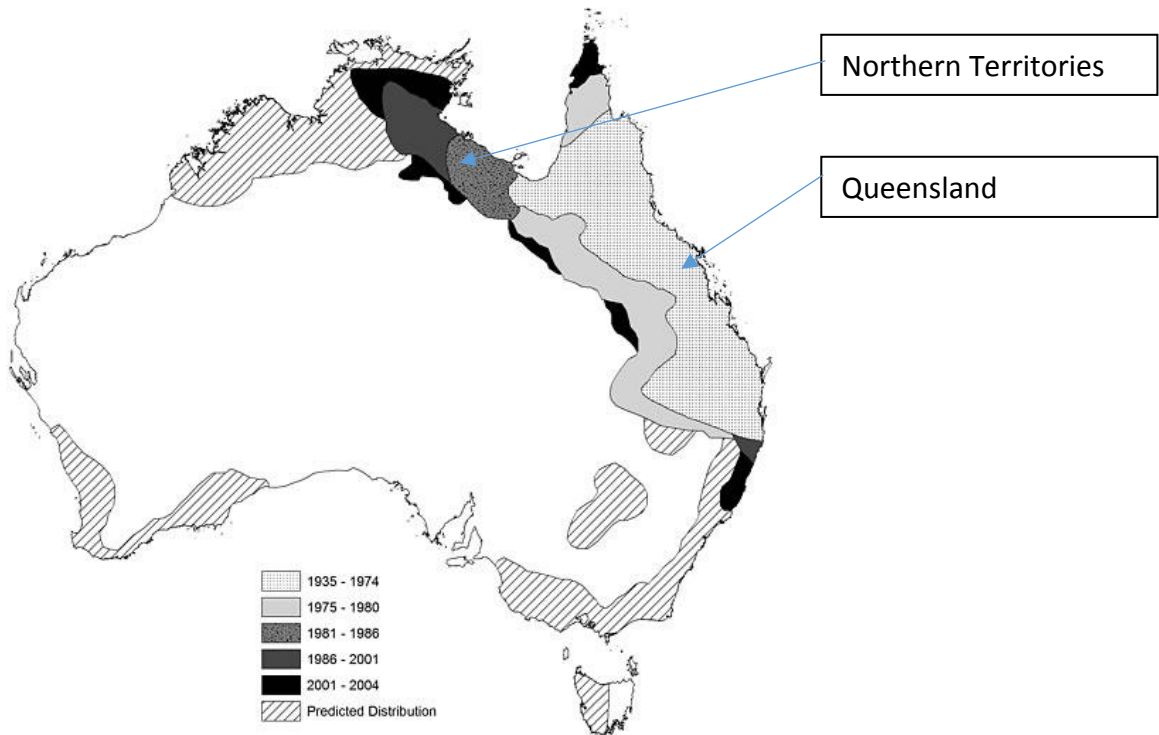
- A. Maximum life span of 25-30 days
- B. Maximum life span of 18-20 days
- C. Maximum life span of 40-45 days

D. Maximum life span of over 50 days

10. Based on graph B, analyzing the interaction of *eat-2(ad465)* and *daf-2(e1370)* alleles, if you cross *eat-2(ad465)* animal with *daf-2(e1370)* animal, and cross their progeny with each other to obtain a second generation of animals. Counting the birth date of these 2nd generation animals to be day 0, please estimate by day 45, what percentage of the animals would be alive.

- A. About 25%
- B. About 15%
- C. About 50%
- D. About 6%

Australia was infested by pest beetles heavily in the last century. A biological control was introduced, 102 cane toads from South America, which then fed on the cane beetles and French beetles. These animals were first introduced in Northern Queensland in 1935. Since they produce poisonous secretion on their skin, they have no major predator that controls their expansion and they start to spread to other region. The following diagram illustrates the sighting of cane toads in different regions of Australia.



The spread from Queensland to the Northern Territories, western frontier and New South Wales of Australia is largely based on the animals migrating on land. The migration from 1994 onward is at a rate of 40-60 kilometers per year. All these lead to the current population of cane toad to reach beyond 200 million. No good control of the cane toads was found except by natural selection of natural predators.

11. Which of the following was found to be less likely to help control the cane toad?

- A. Torresian crow, local birds, kills and eats cane toads by flipping it onto its back and use the bill to kill and feed only on the visceral (internal organs)
- B. Native rakali rats have learned to make an incision to the stomach of the toads and retrieve only the heart and liver for food, avoid the lethal skin and glands
- C. A red-bellied black snake had evolved to have increased resistance to toad toxin and develop a distaste of toads as prey

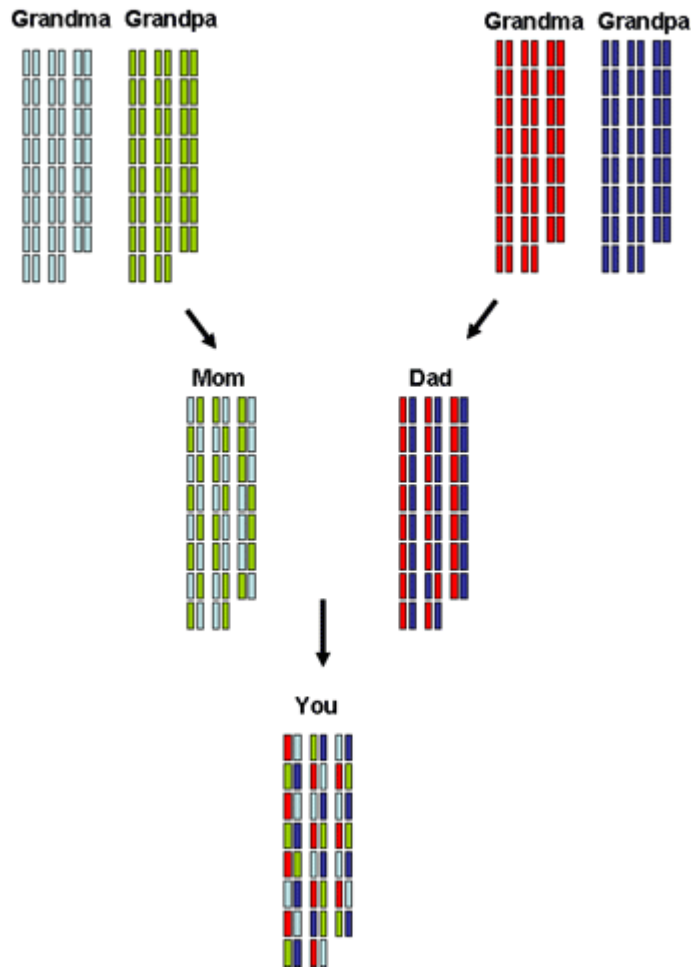
D. Native meat ant is immune to the toads' poison and prey on young cane toads, while native frogs all have a natural reflex to avoid the meat ants

12. Under the same context, cane toad from Queensland (Q) and those in the North Territories and Western frontier (NW) were compared. Which of the following biological features facilitate their fast invasion effectively?

- I. NW toads have longer legs for faster movement
- II. NW toads are larger in size to fend off predators
- III. NW has fewer predators for cane toads
- IV. NW coastal region with humidity and species diversity provides a breeding ground for the toads.

- A. (I) and (II)
- B. (II) and (III)
- C. (I), (II) and (III)
- D. (I), (II) and (IV)

By schematically plotting the distribution of DNA passed from grandparents to the child, the following graph was obtained for illustration purpose.



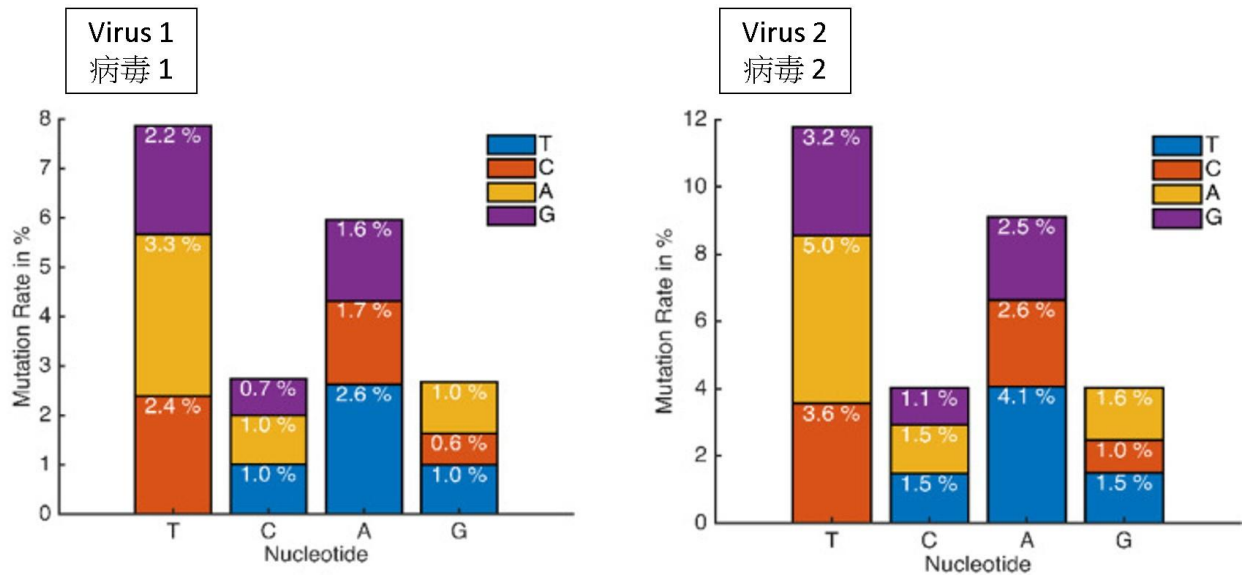
13. Base on this probability, if you are a girl and you have a younger sister. Which of the following would be correct?

- A. You always share more DNA with your mother than your father since you don't have the Y chromosome
- B. Your paternal grandma would share no common DNA with your maternal grandpa
- C. Paternal grandma would have more influence on you than your Maternal grandma
- D. You and your sister would share 50% of DNA

14. On September 16, 2020, the director of the National Institute of Allergy and Infectious Diseases, Dr. Anthony Fauci, made a reply to the media responding to a question on the effect of Vitamin D on COVID-19 infection. He said, “If you are deficient in Vitamin-D, taking Vitamin D pills does have an impact on your susceptibility to infection. So I would not mind recommending—and I do it myself—taking Vitamin-D supplements.” Based on this comment, which of the following act is a correct response.

- A. If one is infected by COVID-19, Vitamin-D is a supplement that alleviates the symptoms
- B. A person lacking Vitamin-D would be more likely to suffer from COVID-19 infection
- C. Vitamin-D is a specific drug against COVID-19
- D. Taking in Vitamin D pills regularly for a healthy person will serve to better protection from COVID-19 infection

Virus 1 and Virus 2 are viral strains of the same family. The bar graphs below show the nucleotide mutation rates of these 2 strains.



15. Based on the graphs, which of the following statements is incorrect?

- A. There are more T and A in the viral genome than G and C
- B. Both strains have a high mutation rate of T and A
- C. The overall mutation rate of Virus 2 is significantly higher compared to Virus 1
- D. T is most commonly mutated to A in both viral strains

16. Fast-growing gene (F) is a dominant gene found in an average strawberry line and is absent from the elite strawberry. To add gene F into the elite strawberry, a homozygous fast-growing average plant is mated with a homozygous elite plant. A fast-growing F1 is then selected and backcrossed with its elite parent. Theoretically, how many rounds of backcrossing is required in total to achieve a fast-growing strawberry with at least 98% of elite genes?

- A. 4 rounds
- B. 5 rounds
- C. Number of rounds vary with the size of the genome

D. Number of rounds cannot be determined with the data provided

17. Tyrosinase controls initial production steps of skin pigment, melanin. Altered function of this enzyme is responsible for several types of human albinism. Two hair samples were collected from an albino patient (Female, 18 years of age). The skin temperature at sites of collection is recorded. The tyrosinase activities of these 2 samples were assayed. Based on the information in the table below, which of the following statements is correct?

Sample	Site of collection	Skin temperature	Tyrosinase activity ($\mu\text{mol}/\text{min}$)
1	Lower leg	30°C	0.844
2	Underarm	37°C	0.216

- A. The patient has white leg hairs and dark underarm hairs
- B. The tyrosinase of the patient is heat sensitive
- C. The tyrosinase activities changed when the patient entered puberty
- D. The tyrosinase is more active at areas with higher body temperature

Below is a phylogenetic tree of complete genome sequences of human coronaviruses (HCoVs) and selected mammalian CoVs. Numbers at nodes indicate bootstrap support. CoVs are colored according to genus and lineage. The pictures at the end of each branch represents the host of that viral strain.

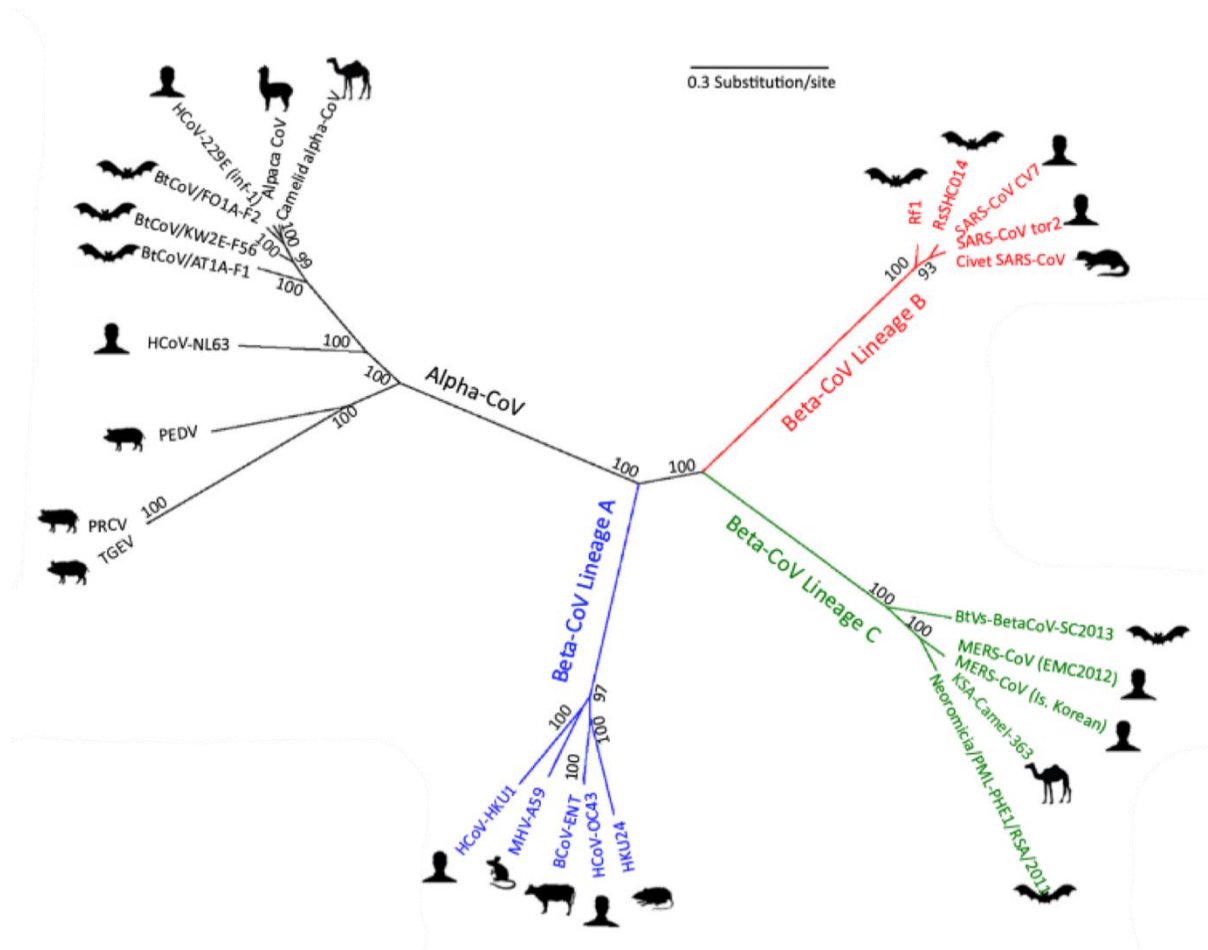


Figure from Forni et al. (2017) Molecular evolution of human coronavirus genomes. Trends in Microbiology 25: 35–48.

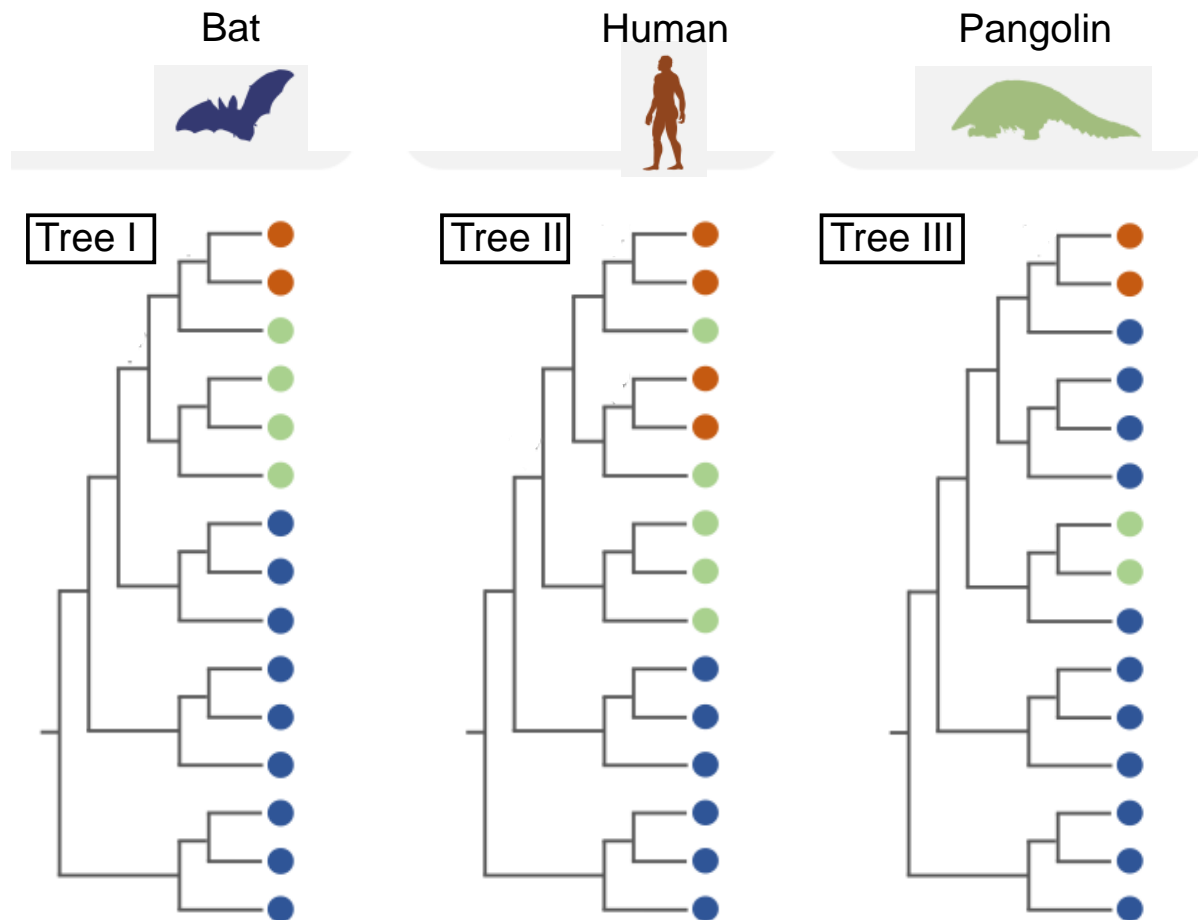
18. Based on the above phylogenetic tree, which statement is FALSE?

- A. There are four major clades of CoVs in this phylogenetic tree
- B. Bats are the likely origin of all CoV genera/lineages
- C. Alpha-CoV strains form a monophyletic group
- D. All relationships in this phylogenetic tree can be considered statistically well supported.

19. Based on the above phylogenetic tree, what statement is true?

- A. All HCoV's in this study are likely originated from bats
- B. Beta-CoV Lineage B and Beta-Cov Lineage C are sister lineages
- C. Alpha-CoV is the outgroup in this study
- D. Alpha-CoV exhibits the most genetic diversity

Below are three phylogenetic trees (Tree I, II, III) depicting three potential cross-species transmission scenarios. Colors of circles in the phylogenetic trees correspond to the animal colors above.

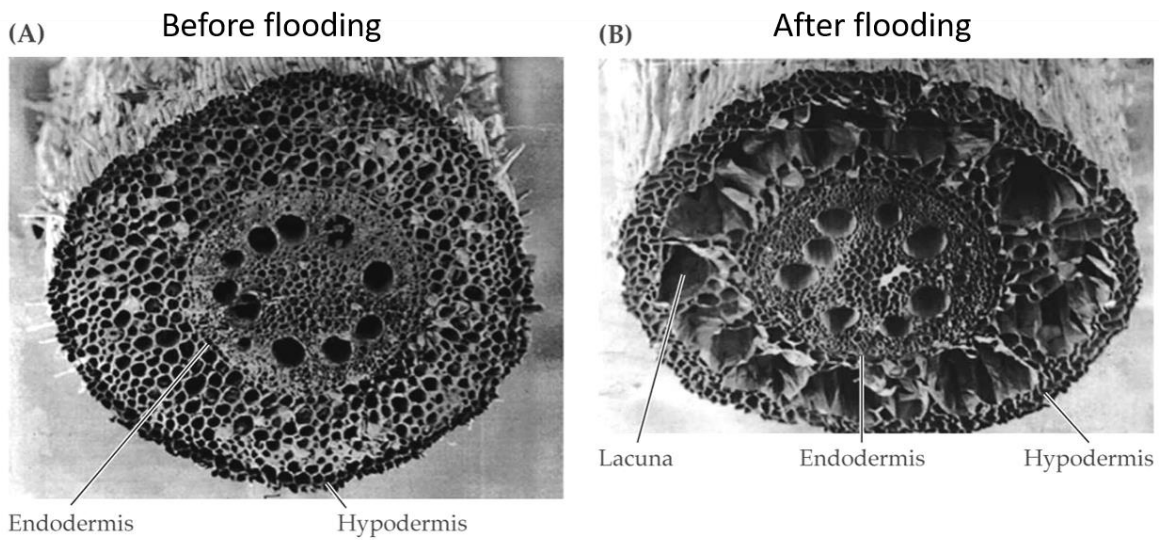


Adapted from Han (2020) Pangolins harbor SARS-CoV-2-related coronaviruses. Trends in Microbiology 28: 515–517.

20. Based on the principle of parsimony (i.e., involving minimal number of character changes), which scenario(s) indicates that human viral strains are the results of two independent transmissions?
- A. Tree I
 - B. Tree II
 - C. Tree III
 - D. All (Tree I, II, and III)
21. Which scenario(s) indicate that pangolins are the intermediate between bats and humans?

- A. Tree I
- B. Tree II
- C. Tree III
- D. Tree I and II

Transverse sections of a root in a flood-tolerant plant are shown below.



[Adapted from “Biochemistry and molecular biology of plants” by Buchanan et al. (2000), American Society of Plant Biologists, Fig. 22.18, p1179.]

22. After flooding, lacunae are generated by the death of the cortical cells in roots. What is/are the possible purpose(s) for the formation of lacunae?
- I. Removal of water during flooding
 - II. Facilitation of oxygen transport from aerial tissues
 - III. Reduction of photosynthetic rate

- A. (I) only
- B. (II) only
- C. (I) and (II) only
- D. All of the above

23. Which of the following is unlikely to be true about genetically modified crops?

- I. Some GM crops can look the same as non-GM crops in the same species
- II. Growing some GM crops can be environmentally friendly
- III. Alteration of genetic information occurred in crops produced by GM technology but not by traditional breeding
- IV. If a GM tomato carries a gene from a fish, it is a hybrid of tomato and fish

- A. (I) and (II) only
- B. (II) and (III) only
- C. (IV) only
- D. (III) and (IV) only

Meiosis produces sex cells that are essential for sexual reproduction. A diploid human germ cell, having 46 chromosomes ($2n = 46$), divides twice to produce four haploid daughter cells ($1n = 23$). The sexual reproductive cycle involves fusion of two haploid cells, forming a zygote totally distinct from that of either parent.

24. What is the number of chromosomes in human germ cells of the third subsequent generations if meiosis produced diploid gametes?

- A. 92
- B. 184
- C. 368
- D. 736

25. Which of the following event occurs in mitosis, but not in meiosis?

- A. Separation of homologous chromosomes
- B. Separation of sister chromatids
- C. Pairing of homologous chromosomes
- D. None of the above

A student measures oxygen consumption by a variety of marine organisms in a laboratory. Animals are weighed using electronic balance before adding it to different jars containing seawater at 25 °C. Measurements will be made using a probe which is capable of measuring dissolved oxygen in seawater at 0, 30, 60 and 90 minutes respectively. Table below shows the results:

Animal(s)	Weight of animal (g)	Oxygen concentration (mg/L)			
		0 min	30 min	60 min	90 min
Seawater	0	8.2	6.0	5.9	6.0
Clam	40.02	8.2	5.7	4.6	2.9
Snail	9.68	8.2	6.3	5.1	3.8
Hermit crab	10.69	8.2	4.6	2.9	1.4

- What is the rate of oxygen consumption (mg/L/kg/hr) of the clam over 30 minutes?
 - 124.94
 - 144.93
 - 284.86
 - 409.80

- Rank the rate of oxygen consumption (mg/L/kg/hr) of animals from high to low over 90 minutes:
 - Hermit crab > Clam > Snail
 - Snail > Hermit crab > Clam
 - Clam > Snail > Hermit crab
 - Hermit crab > Snail > Clam

- Based on the results, which of the following conclusion(s) can be made?
 - Animals with higher body mass consume more oxygen in seawater
 - Hermit crab consumes more oxygen due to high mobility in the environment
 - Clam requires seawater at higher dissolved oxygen levels for survival

- A. (I) only
- B. (II) only
- C. (II) and (III)
- D. All of the above

The student repeats the experiment with another snail adding to a jar with seawater at 40 °C.
Below are the results:

Animal(s)	Weight of animal (g)	Oxygen concentration (mg/L)			
		0 min	30 min	60 min	90 min
Seawater	0	6.5	6.4	6.5	6.5
Snail	12.24	6.5	3.6	3.0	2.7

4. Which of the following statement(s) is/are the appropriate explanations of the differences in oxygen concentration of the snail between the results of the first and second experiments?

- (I) Oxygen concentration in water is directly proportional to water temperature
- (II) Rate of oxygen consumption of the snail in second experiment is higher than the one in the first experiment over 90 minutes
- (III) Second snail expresses higher levels of stress than the first snail as it stops consuming oxygen in water

- A. (I) & (II)
- B. (II) and (III)
- C. (III) only
- D. All of the above

5. What are the behavioural/ physical responses of the snails during low tide in summer?

- (I) Move to subtidal areas where seawater is plenty
- (II) Hide under rocks or crevices
- (III) Have heat stress protein to withstand high temperature on rocks
- (IV) Elevate the shell on the rocks to reduce desiccation

- A. (I) and (II)
- B. (II) and (III)
- C. (III) and (IV)

D. (I), (II) and (III)

A number of animal groups produce alarm calls to warn their groupmates when a predator is sighted. An experiment on Richardson's squirrels was conducted to investigate the response of groupmates when alarm calls produced by a less reliable signaler. One group of squirrels received a recorded alarm call and then saw a predator. The same treatment was repeated and the responses of the squirrels were recorded at the fifth and tenth times of treatment. Another group of squirrels received the same frequencies of alarm calls, but no predator was presented. Their postural change (elevation of the head in the direction of the perceived threat) was recorded and a larger value of postural change indicated an increase in vigilance to the predation risk.

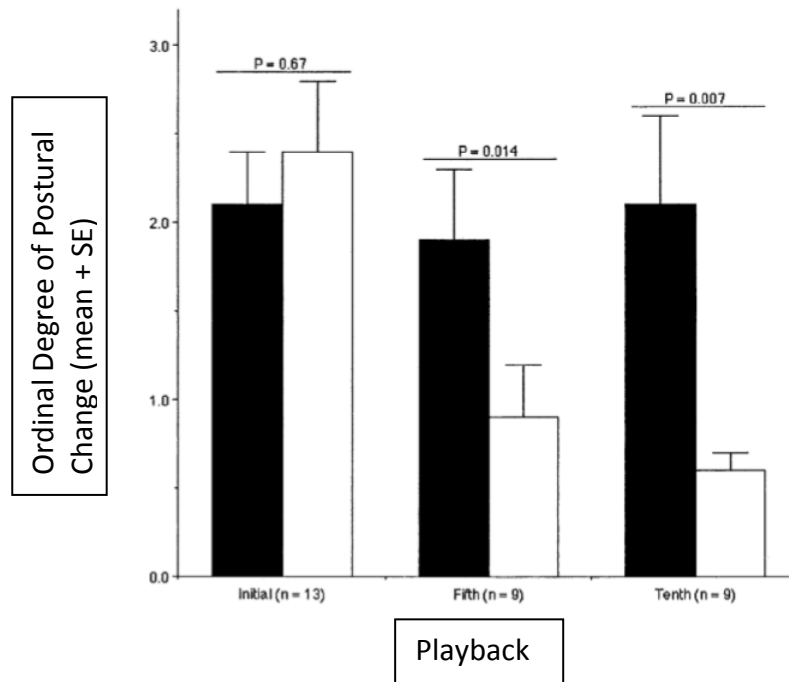


Fig. 2. Ordinal degree of postural change to reliable (filled bars) versus unreliable (open bars) callers at the initial, fifth, and tenth call playback. Significant values shown are for the contrast of responses to reliable versus unreliable callers at each time interval. (Hare and Atkins (2001) *Behavioural Ecology and Sociobiology* 51, 108-112)

6. Which of the following descriptions is INCORRECT?

- No difference in the postural change between the two treatment groups after one alarm call was given because the squirrels had no knowledge beforehand which alarm calls would be reliable and which would not.
- The squirrels paid less attention to the alarm calls when they were unreliable.
- The level of vigilance to predation risk remained unchanged when the alarm calls were reliable
- The time the squirrels remained vigilant to the predation risk was irrelevant to the reliability of the alarm calls

In the monogamous mating system, a male and female mate with each other, and only each other, during a given breeding season. This mating system should have significant fitness consequences associated with choosing a high-quality mate. In an experiment a male Oldfield mouse was given the choice between two virgin, but sexually mature, females. The number of pups produced by the male and his preferred female was compared with the number produced by that male which paired with a female that he did not prefer (Fig 3a). Another experiment involved a naïve male (a male that had no experience with either of the females) which paired with either the female preferred by the male used in the first experiment or the female not preferred by that male. The number of pups produced by these two mating pairs was compared (Fig. 3b). (Ryan and Altmann (2001) Behavioural Ecology and Sociobiology 50, 436-440.)

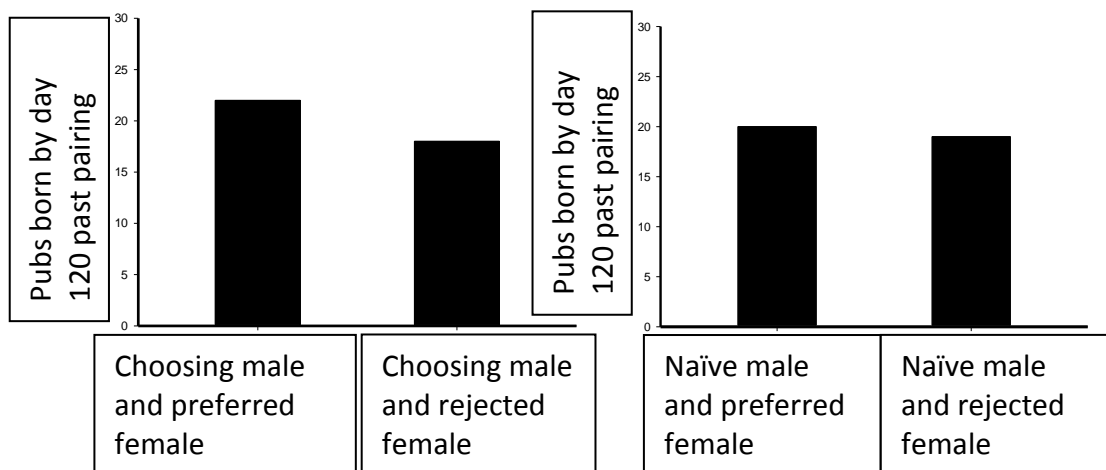


Fig. 3a. Number of pups produced by a male which paired with either a female preferred by this male or a female not preferred by this male. (The difference between the two bars is statistically significant, i.e., $p < 0.05$.)

Fig. 3b. Number of pups produced by a naïve male which paired with either a female preferred by the male in the first experiment, or the female not preferred by that male. (The difference between the two bars is statistically insignificant, $p = 0.99$.)

7. Choose a correct conclusion of the above experiment.
- A. What constituted a good mate was different for each individual male Oldfield mouse
 - B. A female with a higher fertility was preferred by the male Oldfield mouse
 - C. The chance of survival was higher for pups produced by the female which was preferred by a male
 - D. All the conclusions above are wrong

The male-male aggression in copperhead snakes was investigated in an arena that housed a female in the center and two males, one at each end. The males were allowed to fight until one of them was dominant to the other. The individuals were separated immediately and a blood sample was collected for hormonal analysis. Parallel to this treatment group were two controls. One control included a single male in his own cage and in the second control a cage included a male and a female. The level of corticosterone, a stress hormone, was measured for all the male snakes in the experiment. (Schuett et al. (1996) *Hormones and Behavior* 30, 60-68.)

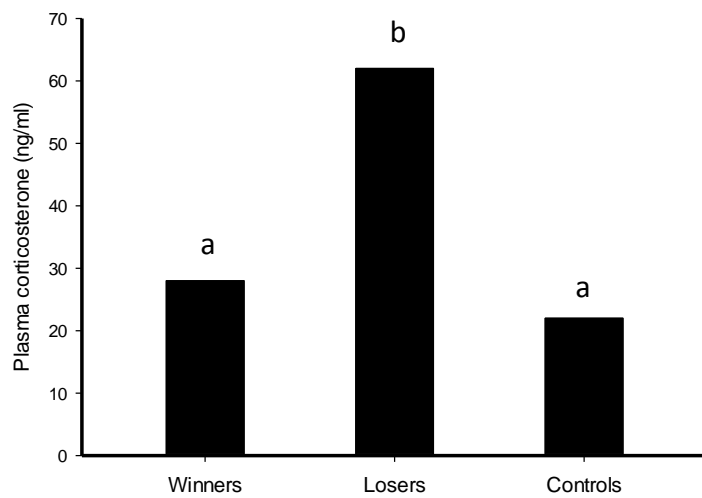


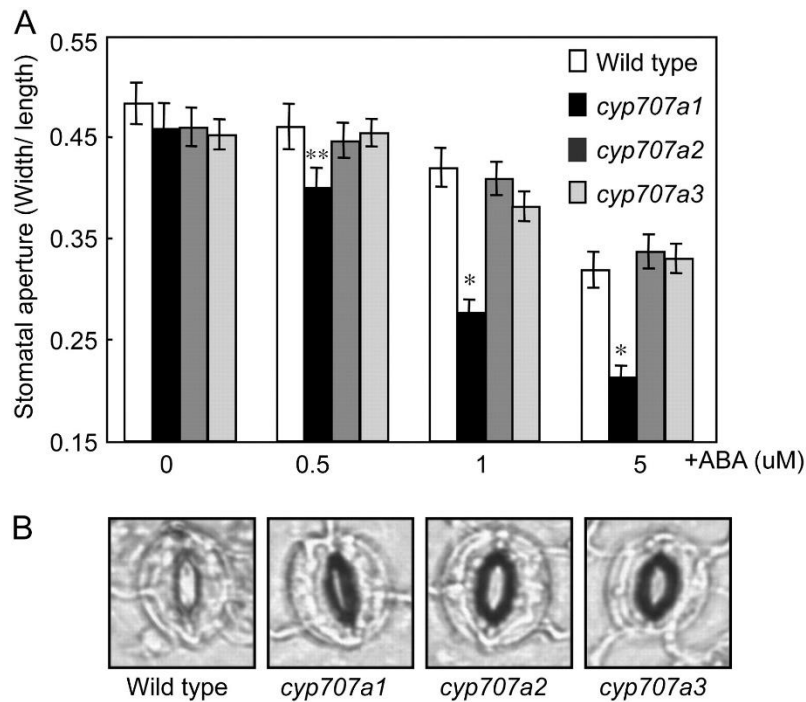
Fig. 4. Plasma corticosterone levels in winners, losers and controls of male copperhead snakes. Bars with the same lowercase letter were statistically insignificant, i.e., $p > 0.05$).

8. Which of the following conclusions is correct?

- A. The increase in the corticosterone level in the male copperhead snake was due to male-male aggression.
- B. The aggressiveness of a male copperhead snake was determined by the level of plasma corticosterone.
- C. Fighting induced the production of corticosterone in male copperhead snakes.
- D. The presence of the female copperhead snake could prevent an increase in the corticosterone level in the male snake.

Stomatal aperture changes in response to humidity. Abscisic acid (ABA) is a plant hormone playing major roles in the response to reduced water availability. During water deficiency, ABA level builds up in leaves and reduces stomatal aperture inside guard cells.

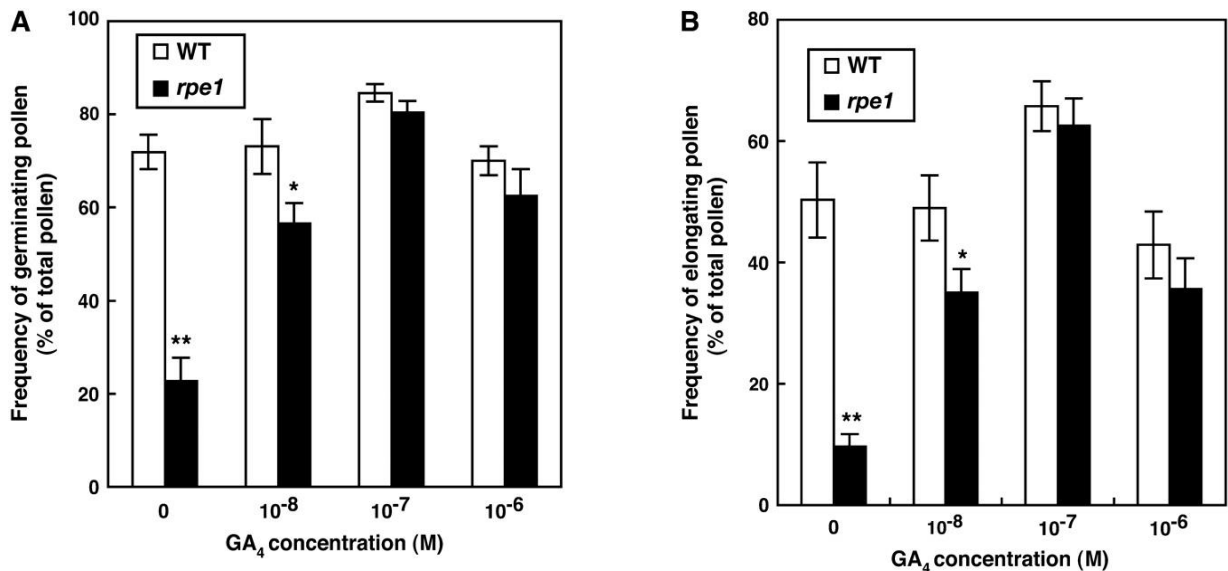
ABA 8'-hydroxylase, a key enzyme which degrades ABA inside guard cells, is encoded by CYP707a gene family. The figure below shows the effect of exogenous ABA treatment on the stomatal apertures of wild type and three *cyp707a* mutants (*cyp707a1*, *cyp707a2* and *cyp707a3*) in epidermal peels.



[Figure adopted from Okamoto *et al* (2009) *Plant Physiology*, 149: 825-834.]

9. Based on the above figure, which statement is false?
- Exogenous ABA reduce stomatal aperture of both wild type and all *cyp707a* mutants
 - The *cyp707a2* and *cyp707a3* mutants showed similar response to the wild type
 - cyp707a2* and *cyp707a3* are responsible for degradation of ABA inside guard cells.
 - The *cyp707a1* mutant was hypersensitive to exogenous ABA

Gibberellins (GAs) are plant hormones that regulate pollen tube growth in rice. The rice mutant *reduced pollen elongation1* (*rpe1*) exhibited reduced pollen germination and tube elongation caused by a defect in GA biosynthesis. The effects of exogenous GA₄ treatment on the frequency of pollen germination (A) and tube elongation (B) in wild type and *rpe1* mutant were shown in the figure below.



[Figure adopted from Chhun *et al* (2007) *The Plant Cell* 19: 3876-3888.]

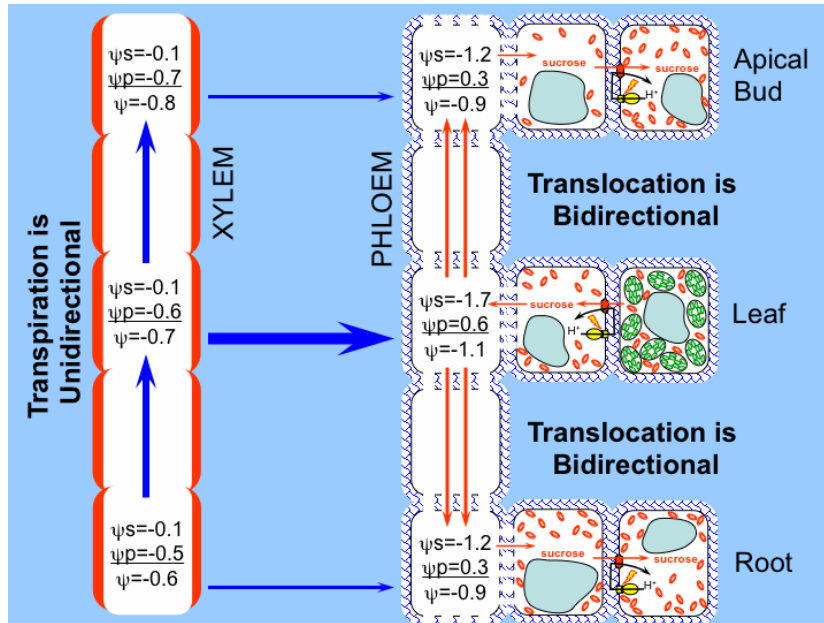
10. Which of the following statement(s) is/are consistent with the data above?

- I. Treatment with the highest GA₄ concentration had an inhibitory effect on pollen germination and tube elongation.
- II. For treatments with GA₄ below 10⁻⁷ M, the results indicated that the impaired germination and tube elongation of pollen in the *rpe1* mutant were due to defect in GA synthesis.
- III. GA treatment shows dose-dependent promotion of pollen germination and tube elongation

- A. (I) only
- B. (I) and (II) only
- C. (I) and (III) only

D. (II) and (III) only

The figure below shows how fluid is transported in xylem and phloem of plants.



ψ_s – solute potential: the water potential contributed by the solutes; more negative represents higher solute concentration

ψ_p – pressure potential: the water potential contributed by the osmotic pressure; more positive represents higher pressure

ψ – water potential, which has two components: solute and pressure potential

11. Which of the following(s) is/are correct about the movement of fluid inside phloem with reference to the figure?

- I. It is from high to low solute potential
 - II. It is from high to low pressure potential
 - III. It is from high to low water potential
- A. (I) only
 - B. (II) only
 - C. (I) and (II) only
 - D. All of the above

12. Which of the following(s) is/are correct about the movement of fluid inside xylem with reference to the figure above?

- I. It is from high to low solute potential
 - II. It is from high to low pressure potential
 - III. It is from high to low water potential
- A. (I) only
 - B. (II) only
 - C. (I) and (II) only
 - D. All of the above

13. What are the causes of lower water potential at the upper end of xylem?

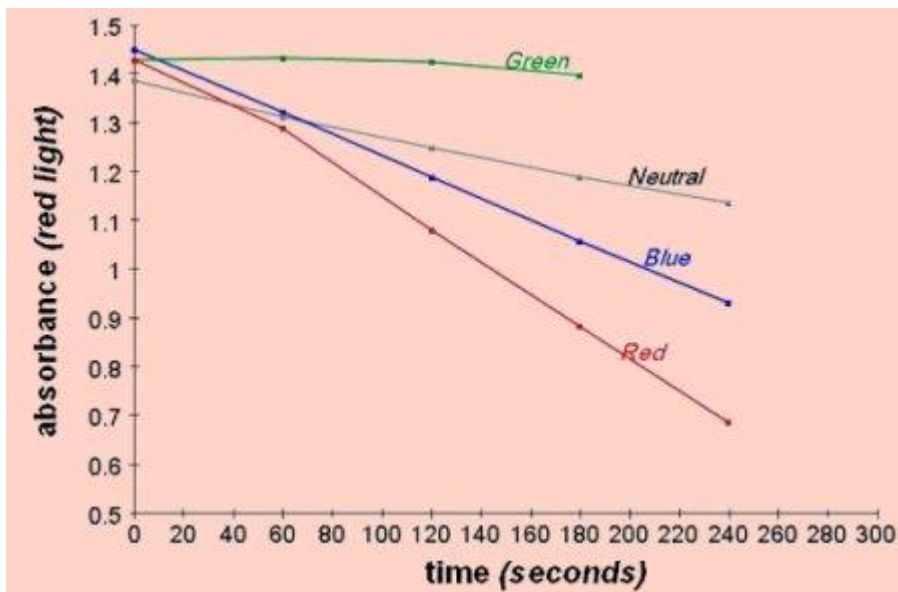
- I. Transpiration
 - II. Sugars produced by photosynthesis in leaves
 - III. Gravity
- A. (I) only
 - B. (II) only
 - C. (I) and (II) only
 - D. (II) and (III) only

In an experiment investigating photosynthesis, green algae are mixed with DCPIP in a test tube without carbon dioxide. Different colours of light are shone on the test tube and the change of the colour of DCPIP is measured. DCPIP is blue in an oxidized state and will turn colourless when reduced.

the algae DCPIP suspension



The change in colour intensity (absorbance) of the algae DCPIP suspension along with time at different colours of light.



14. Which of the following(s) is/are a correct explanation of the results by red light?

- I. Carbohydrate is produced in the test tube
- II. Water donates electrons to reduce DCPIP directly
- III. DCPIP accepts electrons emitted from chlorophyll induced by light

- A. (I) only
- B. (III) only
- C. (II) and (III) only
- D. All of the above

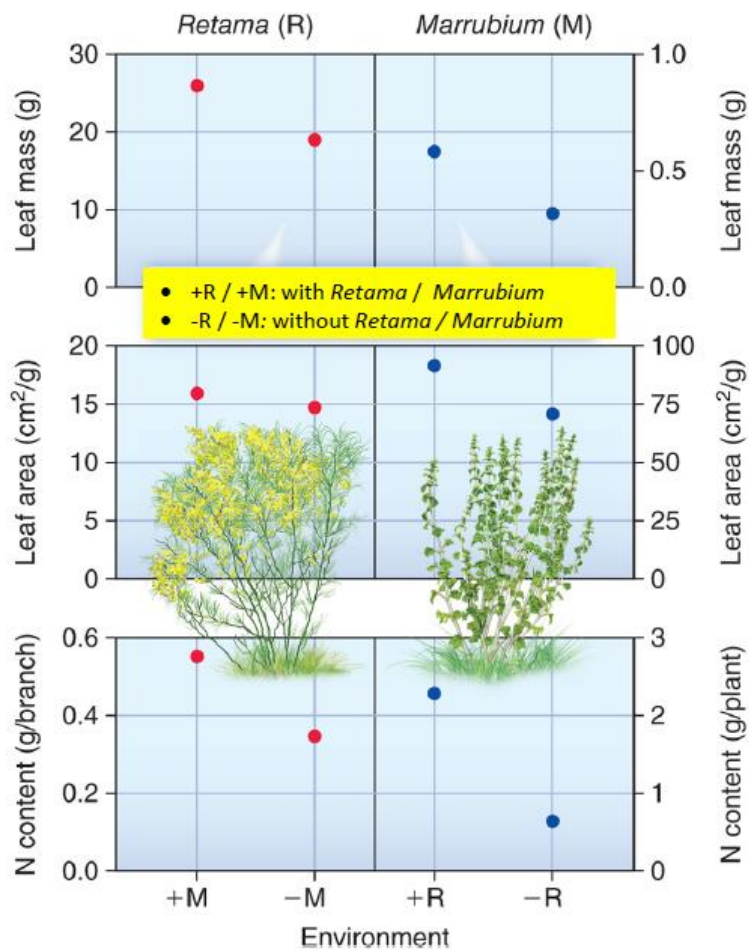
15. Comparing the results under different colours of light, which of the following conclusions can be drawn?

- I. Chlorophyll absorbs green light best
- II. Chlorophyll absorbs red light best
- III. Photosynthetic rate is independent of the colour of light

- A. (I) only
- B. (II) only
- C. (I) and (III) only
- D. All of the above

Species interactions can occur in a variety of forms:

Nature of Interaction	Population of Species A	Population of Species B
Amensalism	Negative effect	No effect
Commensalism	Positive effect	No effect
Competition	Negative effect	Negative effect
Mutualism	Positive effect	Positive effect
Herbivory, Parasitism, Predation	Positive effect	Negative effect
Neutralism	No effect	No effect



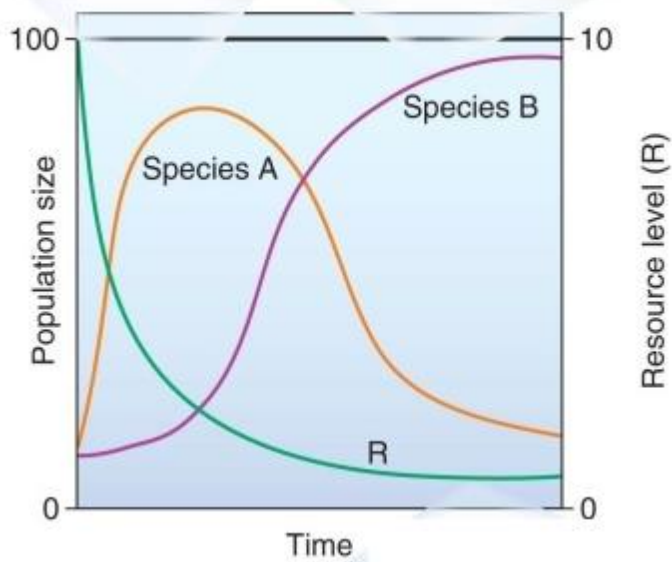
Source: McGraw-Hill Education

16. Which of the interaction types best describes the relationship between *Retama* and *Marrubium*:

- A. Amensalism
- B. Commensalism
- C. Mutualism
- D. Neutralism

Competition can be characterized as Exploitation Competition (indirect competition through the consumption of a limited resource), or Interference Competition (direct interaction with one another by physical force).

The diagram below indicates the relationship between two plant species, A and B.



Source: McGraw-Hill Education

17. Which of the following statements is true?

- A. There is no competition between Species A and Species B.
- B. Species A outcompetes Species B because it can deplete resources as quickly as possible.
- C. Species B outcompetes Species A as resources become more scarce.
- D. Species A and Species B are under Interference Competition.

18. Which of the following statements is NOT true?

- A. Aphids sucking leaf sap and caterpillars chewing leaf on the same plant is an example of Exploitation Competition

- B. Fly maggots feeding on a mouse carcass is an example of Exploitation Competition
- C. Both intraspecific competition (between individuals of the same species) and interspecific competition (between individuals of different species) may be caused by exploitation competition, interference competition, or both
- D. None of the above

In predation, attacks by predators more often fail than succeed. Where preys are easily caught, substandard individuals are not often taken. Where preys are more difficult to catch, weak, sick or injured animals are more often taken.

A hawk was trained to catch three types of prey in the field. The intact carcasses were retrieved from the hawk and scored as to their condition. Preys with fractured bones, defective eyes, or wounds were classified as substandard.

19. The 'Percentages Prey that were Substandard' were collected (9%, 19%, 31%). Put them in the table below:

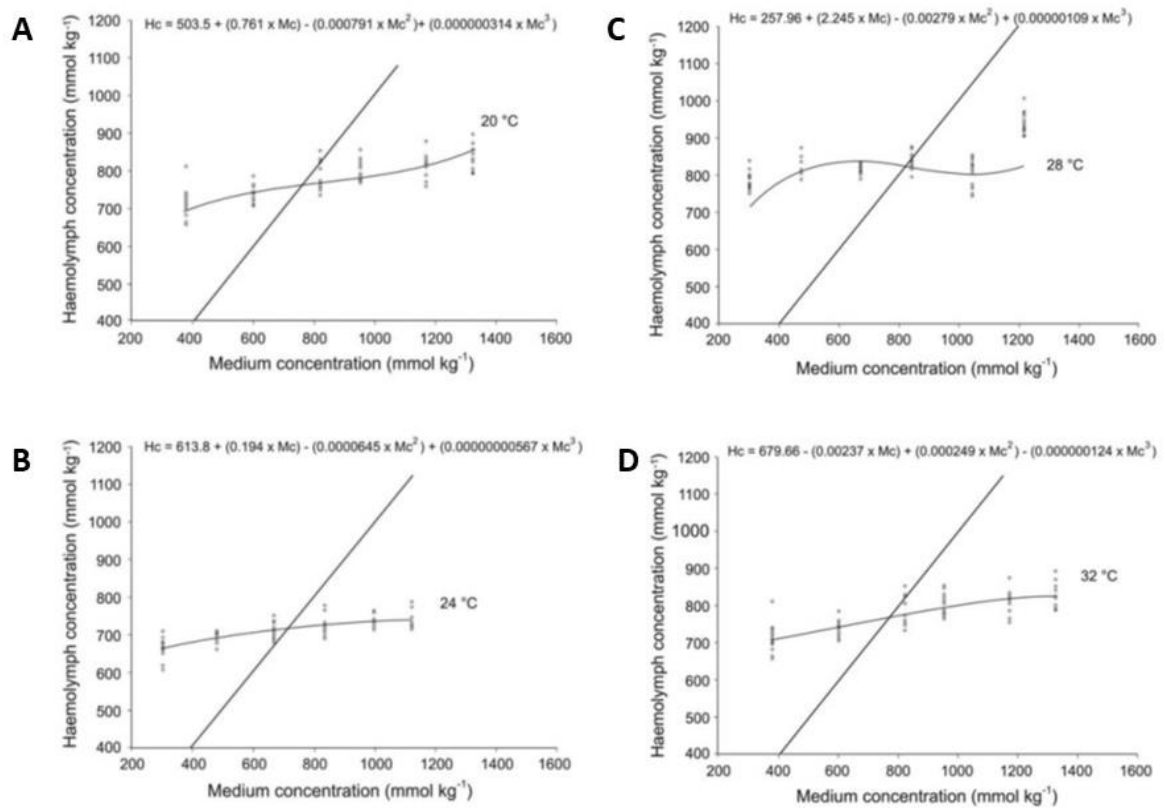
Prey Species	Percent of Attacks Failed	Percent Prey that were Substandard
Rodent	68	A
Rabbit	81	B
Squirrel	85	C

- A. A(9), B(19), C(31)
- B. A(31), B(19), C(9)
- C. A(19), B(31), C(9)
- D. A(19), B(9), C(31)

20. Cod feeds on small fish and crabs, which in turn feeds on zooplankton. Zooplankton in turn feeds on phytoplankton which themselves use up nitrates in the water. If cod were overharvested, which organisms should decrease in population size?

- A. Small fish and crabs
- B. Zooplankton
- C. Phytoplankton
- D. The population size of all the species (small fish, crabs, zooplankton, phytoplankton) remains unchanged because the species have reached an equilibrium in the ecosystem

Osmoregulation is one of the most important regulatory functions controlling osmotic pressure of an organism's body fluids. Marine organisms are facing the same challenges in maintaining an internal balance against external osmotic pressures. Temperature and salinity affect the osmotic characteristics of fluids by influencing water movements across cell membranes and in the uptake and loss of ions. A study evaluating the osmoregulatory capacity (difference between the osmotic pressures of the hemolymph and of the external medium) in shrimp *Litopenaeus vannamei* exposed to different temperatures and salinities to find the isosmotic point, where the organism utilizes minimum energy for osmoregulation and therefore channels for optimum growth.



Osmoregulation (mmol kg^{-1}) of *L. vannamei* exposed to 20 (A), 24 (B), 28 (C) and 32 °C (D). The intersection indicates the respective isosmotic point. The open circles depict each individual. Hc, haemolymph concentration (mmol kg^{-1}); Mc, external medium concentration (mmol kg^{-1}).

Retrieved from Buckle et al. (2006) Rev. Biol. Trop. 54(3): 745-753

21. What is the optimum temperature for the growth of *L. vannamei*?

- A. 20 °C.
- B. 24 °C.
- C. 28 °C.
- D. 32 °C.

22. Based on the results, which of the following conclusion(s) can be made?

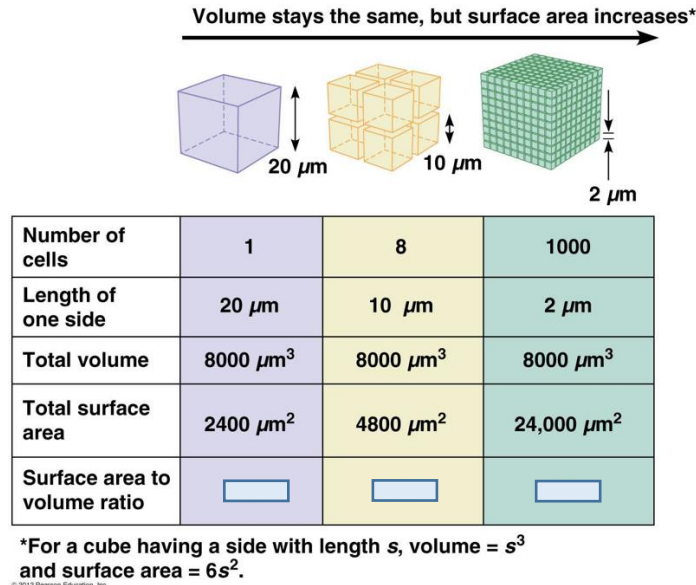
(I) The osmoregulatory responses of *L. vannamei* are mainly affected by temperatures.

(II) *L. vannamei* is an example of osmoconformer as its body fluids are isotonic with seawater.

(III) *L. vannamei* is capable of osmotic regulation in seawater at different salinities.

- A. (II) only.
- B. (III) only.
- C. (I) and (II).
- D. (I) and (III).

23. Cells come in various sizes and shapes. The major limitation on cell size is set by the need to maintain an adequate surface area to volume ratio. Surface area affects exchange rate between a cell and its surrounding. The following figure demonstrates the relationship between the total volume and surface areas with various cell sizes.



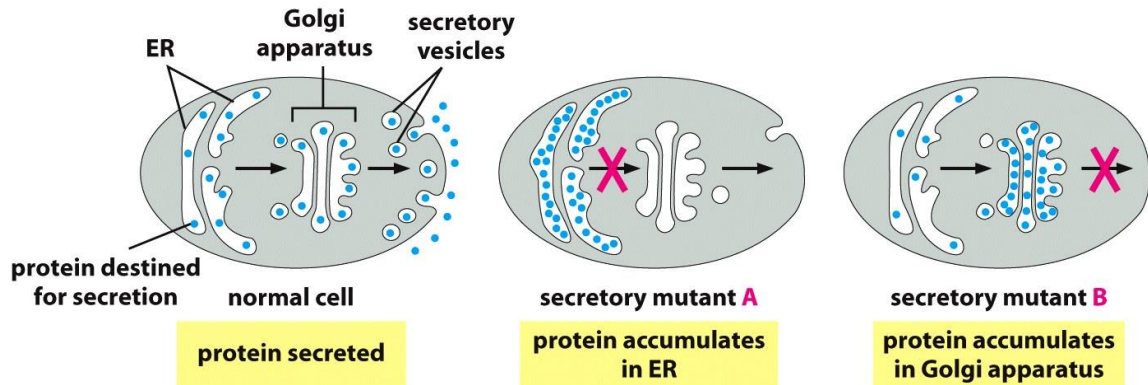
(Adapted from “Campbell Biology: concepts and connections 7th edition” by Reece et al., 2012 Pearson Education, Inc. Figure 4.1)

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

- (I) The smaller the cells, the larger the surface area to volume ratio.
- (II) The smaller surface area to volume ratio will lead to the cell being unable to sustain itself as its uptake is too little as compared to its requirements.
- (III) Cells being small would lead to a tissue of larger volume because the cells are able to sustain itself for maintaining rate of exchanges.

- A. (I) only
- B. (I) and (II) only
- C. (I) and (III) only
- D. (II) and (III) only

24. Mutation in genes involved in intracellular transport process results in the accumulation of proteins in the intracellular compartments, such as endoplasmic reticulum (ER) or Golgi apparatus. Mutated yeast cells are usually used to dissect the protein secretory pathway. The following figure illustrates the defect in protein secretory process of mutants A and B.



(Adapted from “Essential Cell Biology 3rd edition” by Bruce Alberts et al., 2010, Garland Science, Figure 15.30)

Based on the figure, which statement(s) is/are correct?

- (I) Gene A is essential in transporting protein from ER to Golgi apparatus.
- (II) Gene B is essential in transporting protein from Golgi to extracellular space.
- (III) Mutations of A and B will cause accumulation of proteins in ER.

- A. (I) only
- B. (I) and (III) only
- C. (II) and (III) only
- D. All of the above.

25. DNA damage can arrest the cell cycle at a G1 phase during cell division cycle. It can increase a tumor suppressor gene p53 activity. p53 protein can prevent the cell from driving into S phase by regulating another target gene, p21 expression. p21 protein binds on another target protein Y to control the G1 to S phase transition process. It was found that some cancer patients have abnormally activated Y protein.

According to the above passage, which of the following statement(s) is/are correct?

- (I) p21 activates Y and promotes the G1 to S phase transition.
- (II) p21 inactivates Y and prevents the G1 and S phase transition.
- (III) Activation of p21 can prevent the cell division.
- (IV) Activation of p53 can inactivate Y.

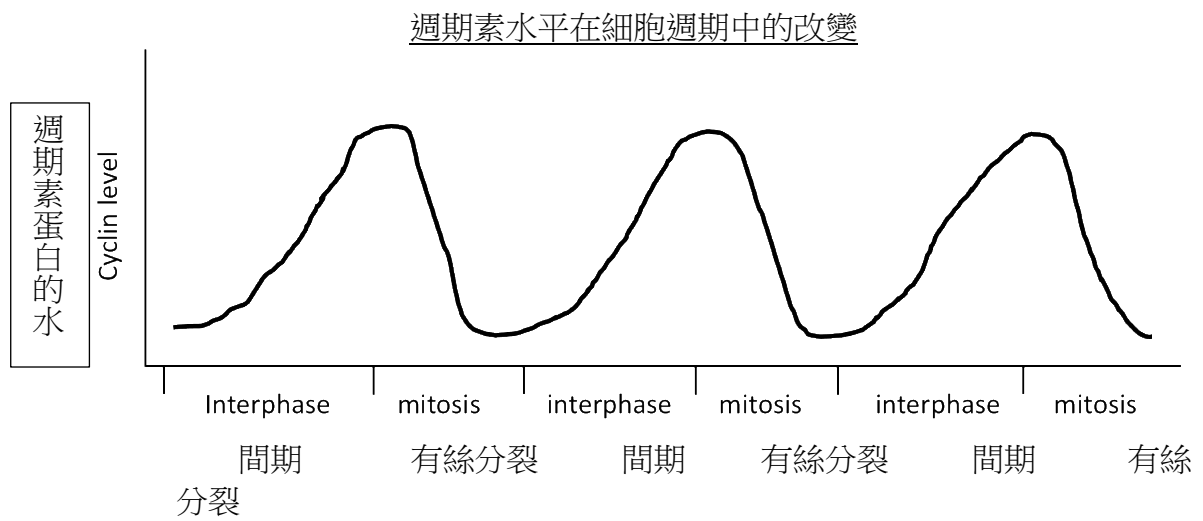
- A. (I) only
- B. (I) and (III) only
- C. (II), (III) and (IV) only
- D. (I), (III) and (IV) only

一個新型藥物設計策略是利用大分子核酸去抑制基因的表達。藥物的目標可以是細菌、癌細胞、或是受病毒感染真核細胞的基因。正常被製造的信使核糖核酸 (mRNA) 分子被稱為有義核糖核酸。我們可以製造跟一段有義核糖核酸互補的反義核糖核酸。反義核糖核酸會專門跟有義核糖核酸結合，並阻止天然基因產物製成。

1. 當藥物按以上描述使用，反義藥物阻止
 - A. 核糖核酸轉譯。
 - B. 核糖核酸轉錄。
 - C. 去氧核糖核酸複製。
 - D. 細胞複製。

2. 苯丙酮尿症是遺傳性疾病，因苯丙氨酸羧化酶基因的變異引起酶變性。反義藥物可以幫助這些病人嗎？
 - A. 不可以，因為信使核糖核酸不會在細胞質中持續存在。
 - B. 不可以，因為制止苯丙氨酸羧化酶基因的表達不能補救原有毛病 - 沒有正常的苯丙氨酸羧化酶產生
 - C. 可以，如果跟苯丙氨酸羧化酶基因結合並阻止它的轉譯。
 - D. 可以，如果跟染色體合併並阻止苯丙氨酸羧化酶基因的表達。

以下顯示週期素蛋白的水平在細胞週期中的升跌。



3. 有甚麼機制可以用來解釋週期素蛋白水平的波動？
- A. 週期素基因在間期中的合成期進行複製
 - B. 帶著週期素基因的染色體在有絲分裂時分離
 - C. 週期素信使核糖核酸在有絲分裂時轉譯，週期素蛋白在間期時出現水解
 - D. 週期素信使核糖核酸在間期時轉譯，週期素蛋白在有絲分裂時出現水解

骨頭由堅硬的礦物質部分(主要是鈣質)和有機的類似膠原蛋白的基質所組成。人體中大概 99%的鈣質都在骨組織裡。骨頭會終生不斷被吸收和重造，這過程與維持足夠血液鈣水平有密切關係。影響這過程的一些重要因素包括：

副甲狀腺素，能促進骨組織中破骨細胞 (可破壞骨頭細胞)的生成和活動，並減少新骨頭生成。

維他命 D。活化維他命 D 有賀爾蒙般功用。這個非極性分子能刺激小腸吸收鈣質，及在骨組織中增強副甲狀腺素的功能。它可以從食物或從紫外線照射皮膚得到。

降鈣素。能減少骨吸收，功效不大，只是微調的作用。

維他命 C。製造骨基質的必需品，所以骨生成需要維他命 C。

4. 血液中鈣質在低水平時會促進以下哪項陳述？

- I. 破骨細胞的活動
- II. 副甲狀腺素的增加
- III. 維他命 C 的增加

- A. 只有(I)
- B. 只有(I)和(II)
- C. 只有(I)和(III)
- D. 只有(II)和(III)

健康體重的定義是身高體重指數(BMI)在 25 或以下。BMI = w/h^2 ， w 是體重(公斤)， h 是身高(米)。研究指出，在影響 BMI 的因素當中，百分之四十的因素跟基因有關。兩個影響小鼠體重的基因都是跟瘦素有關的。瘦素是一種脂肪細胞分泌的激素，是維持正常體重所需要的。一個基因 (稱為 *ob*) 製造瘦素。另一個基因 (稱為 *db*) 製造瘦素受體。穩定體重相信也是跟腦部、脂肪細胞、消化道和肌肉的新陳代謝回饋迴路有關。

5. 在控制體重時，哪一種或哪一類在血液中運行的化學信使最有機會將腦部、消化道和脂肪細胞連繫起來？

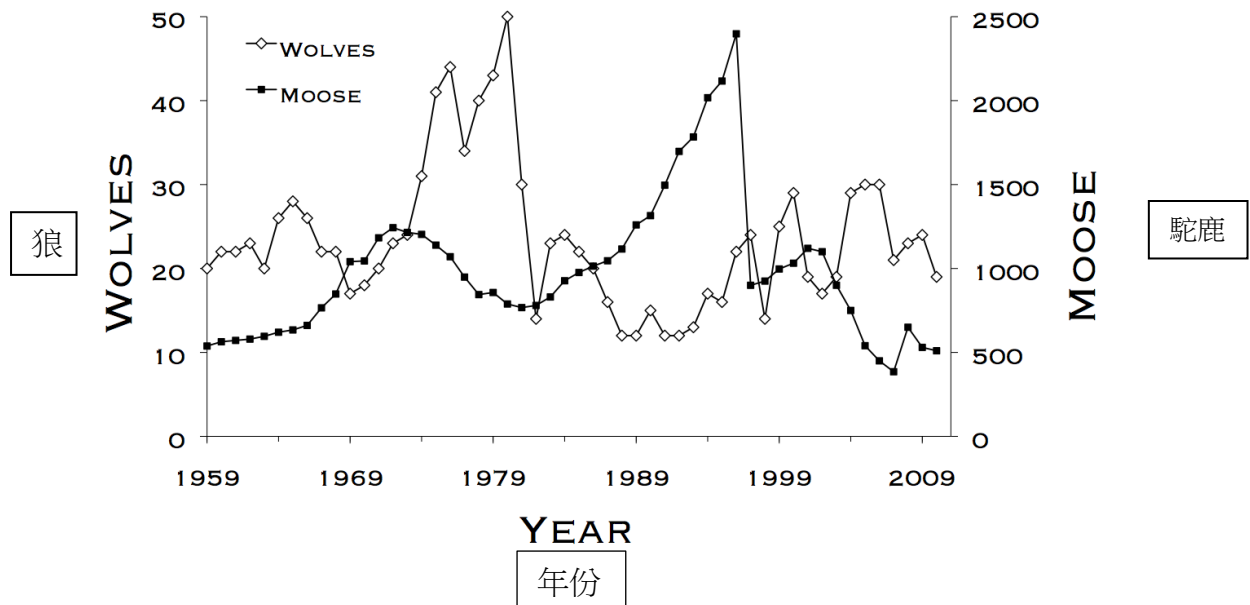
- A. 神經遞質
- B. 消化酶
- C. 蛋白受體
- D. 激素

天氣炎熱乾燥時，人會透過循環系統(皮下血管擴張)和蒸發冷卻(增加汗腺分泌)去調整體溫。但是在非常高溫和脫水的情況下，體溫調節機制(尤其是出汗)有機會打亂生理常態。流汗過多會削弱水分和鹽分的調整。當脫水時，腎臟可能減少尿量，從正常水平 1.0-1.5 升水分/日減少至 0.5 升水分/日，而從腎臟排出的鹽分可能會跌至近零。流汗過多亦會減少輸送氧氣至身體組織的血液容量。

6. 當環境溫度是攝氏 33 度，皮下血管擴張是怎樣幫助調節體溫？

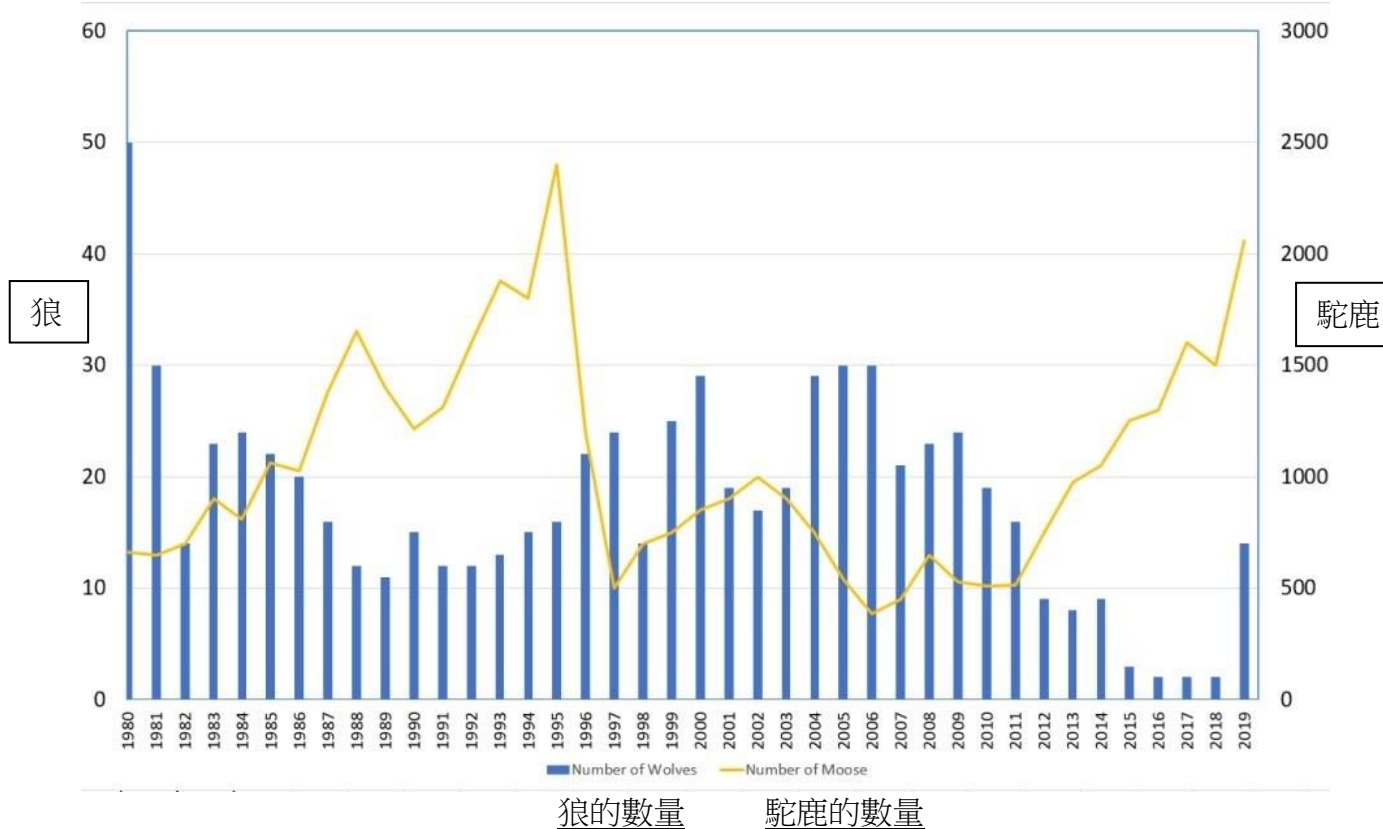
- A. 減慢皮膚血液的流動
- B. 輻射多餘的體熱到環境
- C. 保持身體熱力平均分佈
- D. 防止身體所需的熱力流失到環境

在過去 50-60 年，皇家島國家公園進行普查去監測狼和駝鹿數量的變化。狼和駝鹿是島上主要的肉食性和草食性動物，下圖顯示動物族群的增減出現相反趨勢的變化。



圖源：<https://www.nps.gov/isro/learn/nature/wolf-moose-populations.htm>

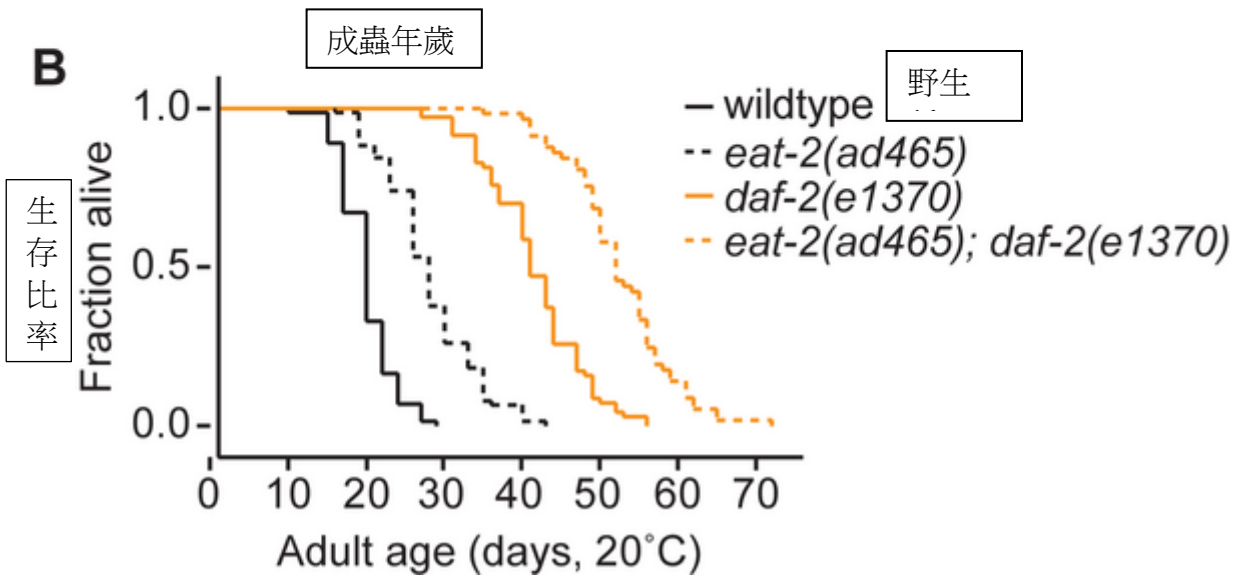
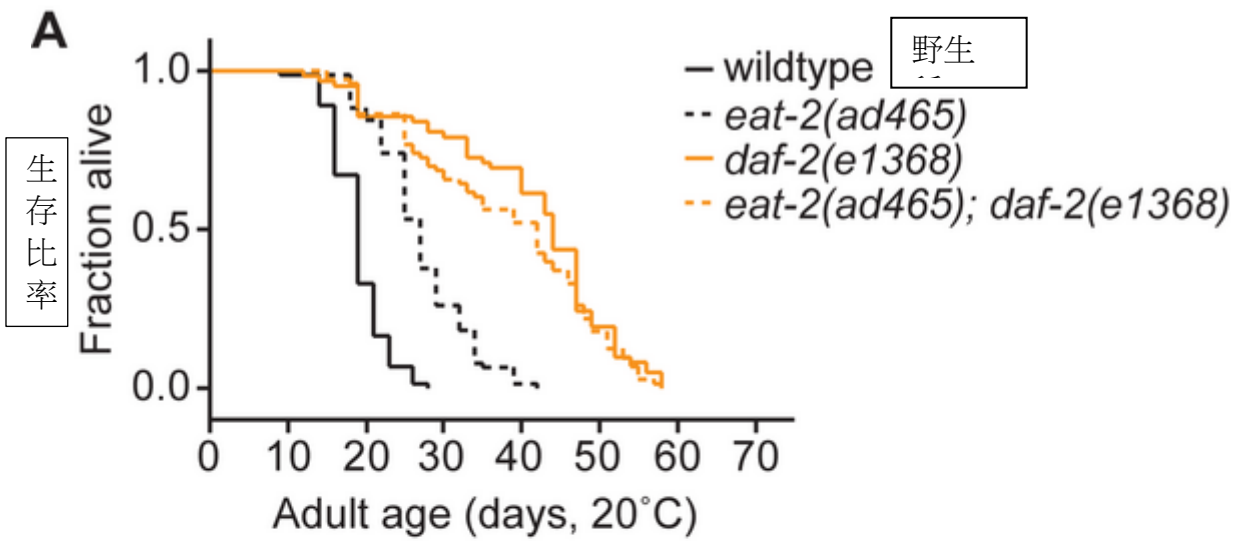
7. 按這個觀察，以下哪項陳述可概括形容其生態關係？
- A. 在這國家公園中，駝鹿是狼可靠的食物來源。
 - B. 當狼的數量增加，其後駝鹿數量一定會延遲下降。
 - C. 在這公園中，狼的數量受其他食物來源的供應和因素所影響。
 - D. 在這公園中，駝鹿數量增加會導致狼數量的增加。



8. 自 2009-2015，即題(7)圖表的延伸，狼的數量急速下降，而駝鹿的數量急速上升。為了維持平衡，皇家島國家公園在 2019 年引入 12 隻狼去控制駝鹿的數量。以下哪項陳述為從園外引入狼的邏輯依據？

- A. 狼的繁殖週期太慢，未能逐漸增加園中狼的數量，所以從外引入，增加數量去控制駝鹿的數量是必需的。
- B. 在島上長時間有超過 1000 頭駝鹿，棲息地會永久被破壞，以後不再適合狼的生存
- C. 2015 年剩下的幾頭狼太過溫馴，只有引進更具攻擊性的狼到公園才可以限制駝鹿族群的增長。
- D. 狼的數量少會限制基因的多樣性，若沒有引進新狼，便永遠不能重建健康的狼族群。

圖 A 顯示野生種的蟲的平均壽命約 18-20 日。如果一開始有 100 條蟲，百分之五十會
 在第 18-20 日死亡。帶等位基因 *eat-2* 和 *daf-2* 隱性變異的蟲會有更長的平均壽命，分
 別是 25-30 日和 40-45 日。



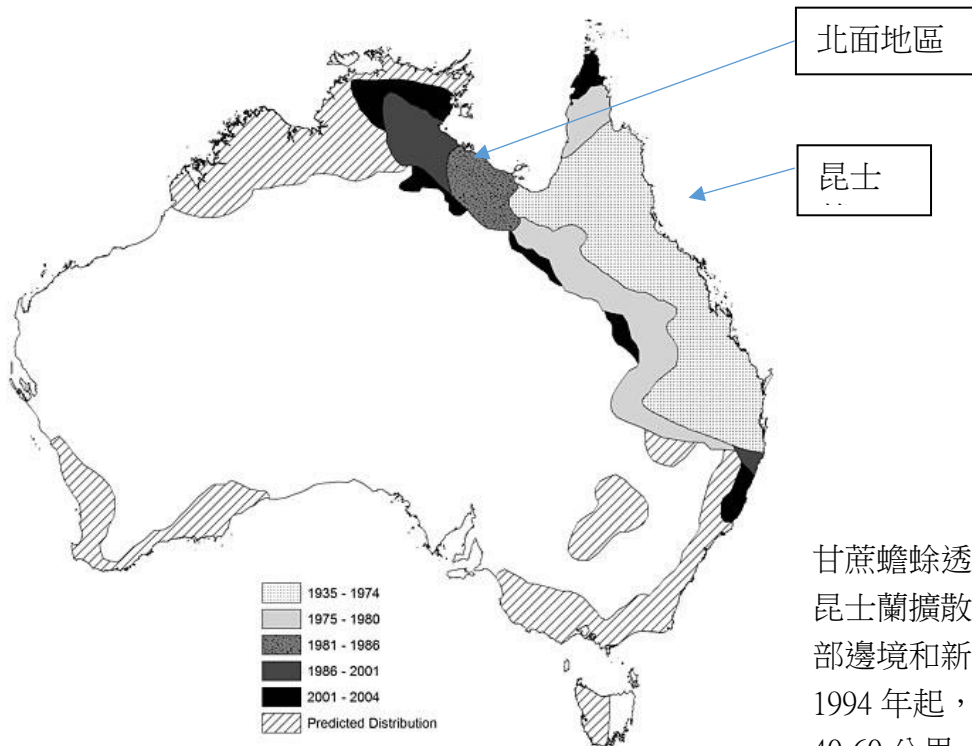
9. 如果你現在有同型 *eat-2(ad465)* 變異的蟲，讓它跟 *daf-2(e1368)* 變異的蟲交配，第一代的預期最長壽命是多少？

- A. 最長壽命為 25-30 日
- B. 最長壽命為 18-20 日
- C. 最長壽命為 40-45 日
- D. 最長壽命為超過 50 日

10. 按圖 B，分析 *eat-2(ad465)* 和 *daf-2(e1370)* 等位基因的相互作用。讓 *eat-2(ad465)* 動物跟 *daf-2(e1370)* 動物交配，再讓它們的第一代互相交配得出第二代動物。以第二代的出生日為第 0 日，估算動物在第 45 日時仍然生存的。

- A. 大約 25%
- B. 大約 15%
- C. 大約 50%
- D. 大約 6%

上一世紀，澳洲被害蟲甲蟲嚴重入侵。102 隻從南美來的甘蔗蟾蜍被引入，進行生物控制。牠們以甘蔗甲蟲和法國甲蟲為食物。這些動物於 1935 年首先引入到昆士蘭北部。因為它們背部皮膚會分泌出毒液，沒有主要捕食者去控制牠們的增長，牠們開始遷移到其他地區。下圖顯示在澳洲不同地區都可以發現甘蔗蟾蜍。



甘蔗蟾蜍透過陸路遷移，從昆士蘭擴散到北部地區，西部邊境和新南威爾斯。自 1994 年起，遷移速度是每年 40-60 公里。因此，現時甘蔗蟾蜍的族群數目已超過 2 億。除作天擇的天然捕食者的外，仍未找到有效控制甘蔗蟾蜍的方法。

除作天擇的天然捕食者的外，仍未找到有效控制甘蔗蟾蜍的方法。

11. 以下哪個比較不可能有效控制甘蔗蟾蜍？

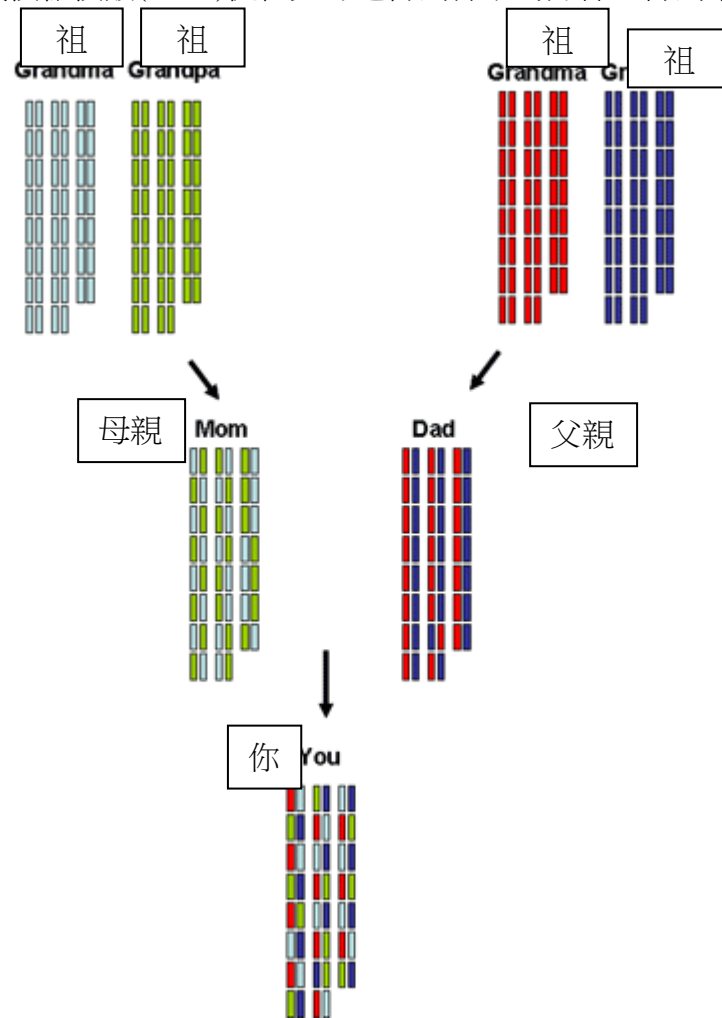
- A. 澳洲鴉和本地鳥會反轉甘蔗蟾蜍，腹部朝天，用喙殺死牠們和進食其內臟。
- B. 澳洲水鼠學會在甘蔗蟾蜍腹部開一個切口，以其心臟和肝臟做食物，避開可致命的皮膚和腺體。
- C. 紅帶黑蛇演化出更強的蟾蜍毒液抵抗力，並發展出厭惡蟾蜍為獵物。
- D. 土生肉螞蟻是對蟾蜍毒液免疫的，會捕食年幼甘蔗蟾蜍。而土生青蛙全都能反射地避開肉螞蟻。

12. 在同一條件下比較昆士蘭 (Q) 和北部地區和西部邊境 (NW) 的甘蔗蟾蜍。以下哪些生物特徵促進牠們有效地快速入侵？

- I. NW 蟾蜍有較長的腳，可較快移動。
- II. NW 蟾蜍體形較大，可抵擋捕食者。

- III. NW 有較少甘蔗蟾蜍的捕食者。
 - IV. NW 海岸潮濕地區和多樣物種，提供蟾蜍的繁殖地。
-
- A. (I) 和 (II)
 - B. (II) 和 (III)
 - C. (I)、(II) 和 (III)
 - D. (I)、(II) 和 (IV)

以示意圖描繪去氧核糖核酸(DNA)從祖父母遺傳到孫子的分佈，得到下圖作說明。



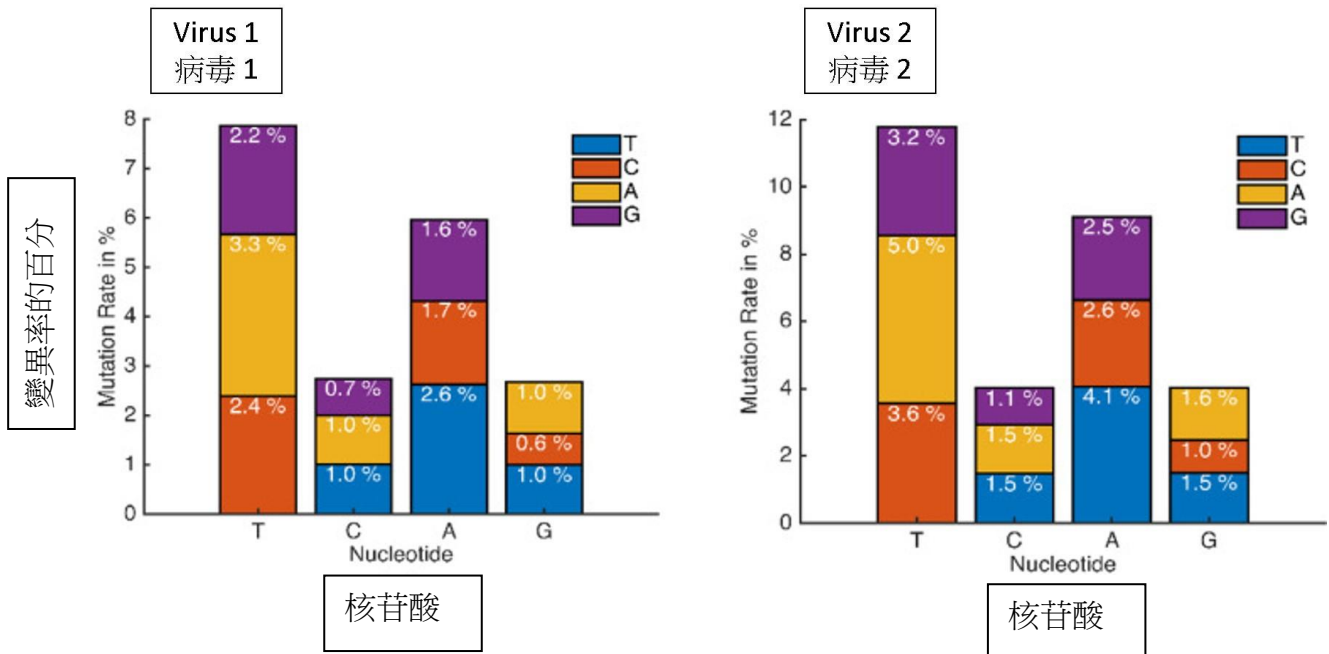
13. 如果你是一個女孩子，有一個妹妹，以此機率來說，以下哪項是正確的？

- A. 相對於爸爸，你跟媽媽必定有更多共同的去氧核糖核酸，因為你沒有 Y 染色體。
- B. 你父系的祖母跟你母系的祖父沒有共同的去氧核糖核酸。
- C. 相對於母系的祖母，父系的祖母會對你有更多影響。
- D. 你跟妹妹有百分之五十共同的去氧核糖核酸。

14. 在二零二零年九月十六日，美國國家過敏和傳染病研究所的理事 Dr. Anthony Fauci，回覆傳媒關於維他命 D 對 COVID-19 的功用時，他說：「如果你缺乏維他命 D，進食維他命 D 藥丸可減低你的傳染易感性。我不諱言推薦，我正在這樣做，會進食維他命 D 補充劑。」按這評論，以下哪項是正確的回應？

- A. 如果已感染 COVID-19，維他命 D 是可消除症狀的補充劑。
- B. 一個缺乏維他命 D 的人會更容易受 COVID-19 感染。
- C. 維他命 D 是針對 COVID-19 藥物。
- D. 健康的人恒常地進食維他命 D 藥丸，會更有效地保護這個人不受 COVID-19 感染。

病毒 1 和病毒 2 是屬同一家族的病毒株。以下棒圖顯示這兩個病毒株的核苷酸變異率。



15. 按上圖，以下哪一項陳述是不正確的？

- A. 相對 G 和 C，病毒基因組中有更多的 T 和 A。
- B. 兩個病毒株的 T 和 A 都有高的變異率。
- C. 病毒 2 的整體變異率明顯比病毒 1 為高。
- D. 兩個病毒株的 T 都是最常變異成 A。

16. 快速生長基因 (F) 是在普通種草莓中找到的顯性基因，而優秀種草莓缺乏這個基因。要將 F 基因加到優秀種草莓中，一棵同型合子快速生長的普通種草莓跟一棵同型合子優秀種草莓交配。選出快速生長的 F1 跟優秀種父母回交。理論上，總共需要多少次回交才可達至擁有至少 98% 優秀種基因的快速生長草莓？

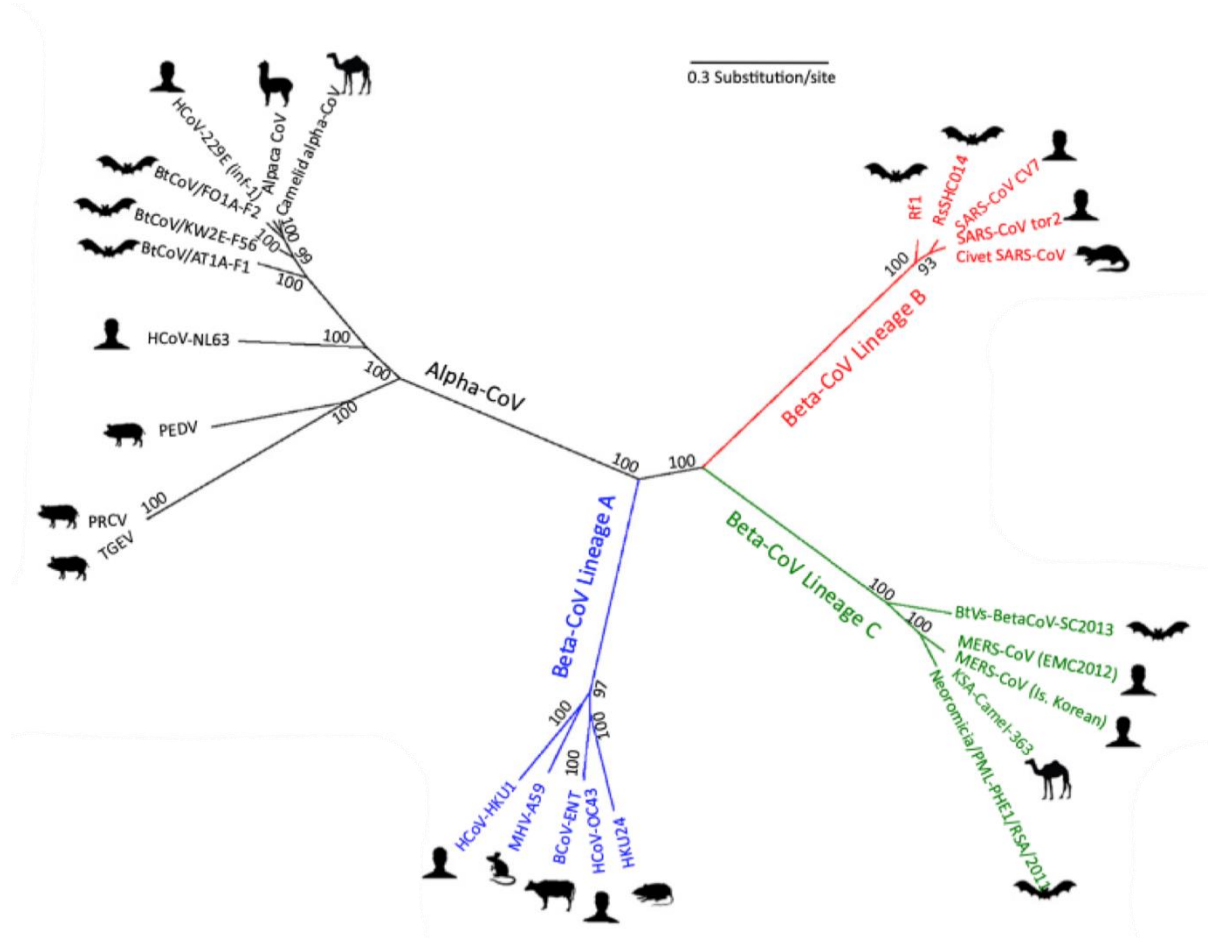
- A. 4 次
- B. 5 次
- C. 次數是按基因組大小而有所不同
- D. 以上所提供資料不足以決定次數

17. 酪氨酸酶控制製造皮膚色素 — 黑色素的起始步驟。改變這個酶的功能會導致幾種人類白化症。從白化症病人 (女性, 18 歲) 身上收集兩個毛髮樣本, 並記錄樣本收集處的皮膚表面溫度。然後, 測試兩個樣本的酪氨酸酶的活性。按以下表列資料, 哪一項陳述是正確的?

樣本	收集處	皮膚溫度	酪氨酸酶的活性 ($\mu\text{mol}/\text{min}$)
1	小腿	30°C	0.844
2	腋下	37°C	0.216

- A. 病人有白色的腳毛和深色的腋下毛髮
- B. 病人的酪氨酸酶對熱力敏感
- C. 酪氨酸酶的活性因病人進入青春期而改變
- D. 酪氨酸酶在體溫較高的地方更活躍

以下是人類冠狀病毒和幾個哺乳類冠狀病毒的完整基因排序的親緣關係樹。節點的數字表示靴帶式支持。冠狀病毒按屬和演化路徑配以不同顏色。每個分支的盡頭的圖是該病毒株的宿主。



圖取自 Forni et al. (2017) Molecular evolution of human coronavirus genomes. Trends in Microbiology 25: 35–48.

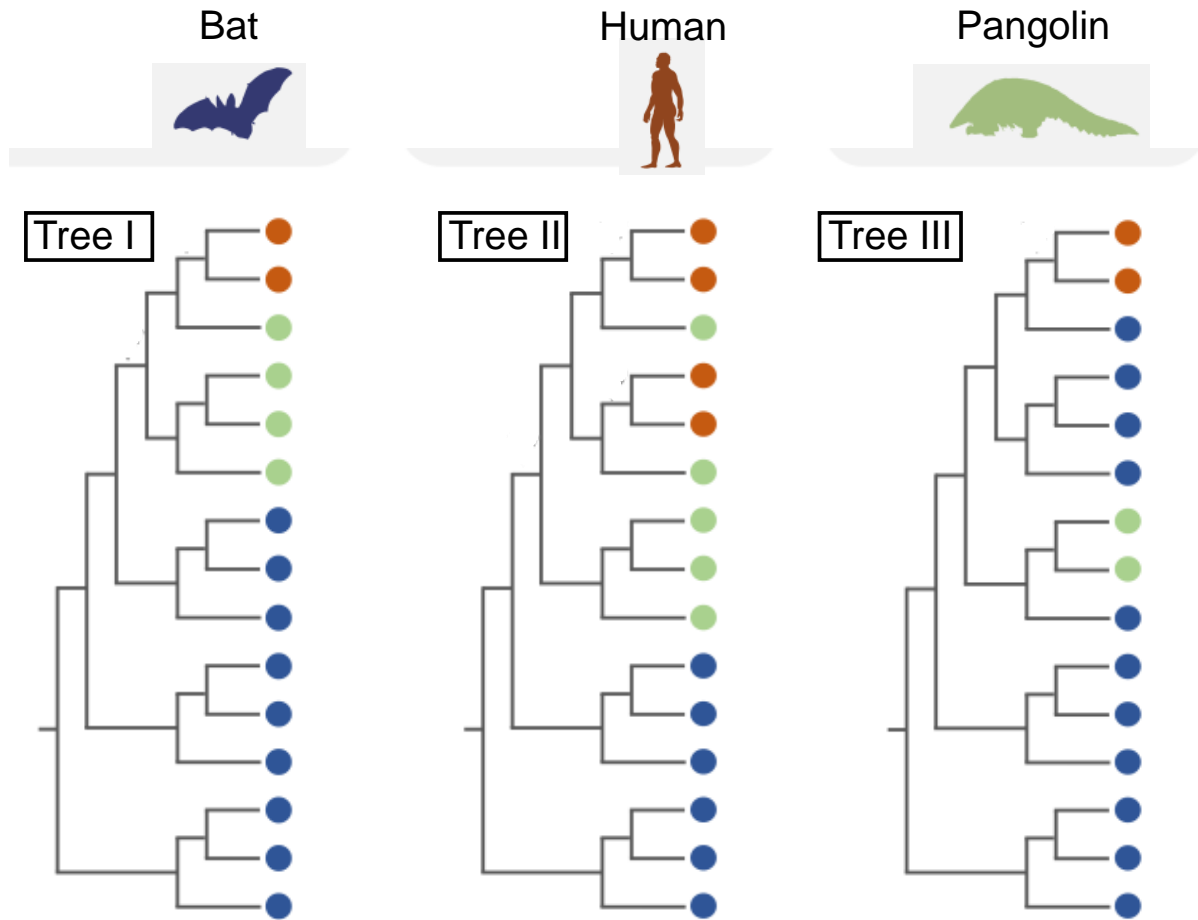
18. 按以上親緣關係樹，哪一項陳述是錯誤的？

- A. 親緣關係樹有四個主要的冠狀病毒進化枝
- B. 蝙蝠似乎是所有冠狀病毒屬和演化路徑的源頭
- C. Alpha-CoV 株組成一個單系類群
- D. 這親緣關係樹上的所有關係可以說在統計學上有良好支持

19. 按以上親緣關係樹，哪一項陳述是正確的？

- A. 這個研究中的所有人類冠狀病毒的源頭都是蝙蝠
- B. Beta-CoV 演化路徑 B 和 Beta-CoV 演化路徑 C 是姊妹路徑
- C. Alpha-CoV 在這個研究中是外群
- D. Alpha-CoV 在基因表現上是最高的多樣性

以下是三個親緣關係樹 (樹 I, II, III) 顯示三個潛在的跨物種傳播方案。圓點顏色跟圖中動物的顏色對應。



取自 Han (2020) Pangolins harbor SARS-CoV-2-related coronaviruses. Trends in Microbiology 28: 515–517.

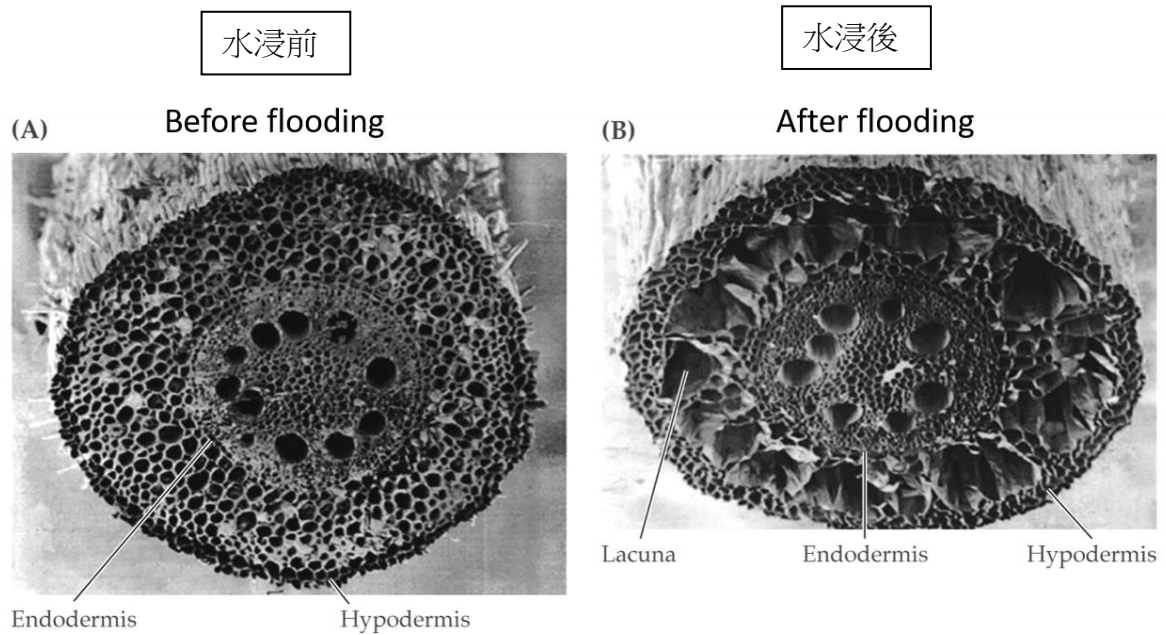
20. 按簡約原則 (牽涉最少次數的性狀改變)，以下哪方案顯示人類病毒株是兩個獨立傳播的結果？

- A. 樹 I
- B. 樹 II
- C. 樹 III
- D. 全部 (樹 I, II, III)

21. 哪方案顯示穿山甲是蝙蝠和人類的中介者？

- A. 樹 I
- B. 樹 II
- C. 樹 III
- D. 樹 I 和 II

以下顯示一種耐浸水性的根部橫切面。



[取自 “Biochemistry and molecular biology of plants” by Buchanan et al. (2000), American Society of Plant Biologists, Fig. 22.18, p1179.]

22. 水浸後，根部皮質細胞的死亡造成空隙。以下哪個是形成空隙的目的？

- I. 水浸時清除水分
- II. 促進氣生組織運送氧氣
- III. 減少光合作用

- A. 只有(I)
- B. 只有(II)
- C. 只有(I)和(II)
- D. 以上所有

23. 以下哪項關於基因改造農作物不太可能是真實的？
- I. 有些品種的基因改造農作物跟同品種的非基因改造農作物看來一樣
 - II. 種植一些基因改造農作物對環境友善
 - III. 基因改造技術改變農作物基因信息但傳統繁殖卻不能
 - IV. 如果基因改造蕃茄帶著魚的基因，便是蕃茄和魚的雜種
-
- A. 只有 (I) 和 (II)
 - B. 只有 (II) 和 (III)
 - C. 只有 (IV)
 - D. 只有 (III) 和 (IV)

減數分裂製造性細胞，而性細胞是有性繁殖必需的。二倍體的人類生殖細胞有 46 條染色體 ($2n = 46$)；分裂兩次去製造 4 個單倍體子細胞 ($1n = 23$)。有性繁殖週期包括兩個單倍體生殖細胞的結合，形成一個完全跟父母迥異的合子 (受精卵)。

24. 如果減數分裂製造二倍體配子，隨後第三代人類生殖細胞染色體的數量是甚麼？

- A. 92
- B. 184
- C. 368
- D. 736

25. 以下哪一情況會出現於有絲分裂，但不會出現在減數分裂？

- A. 同源染色體分離
- B. 姊妹染色單體分離
- C. 同源染色體配對
- D. 以上皆非

-End of Part 1-

一個學生在實驗室量度海洋生物的攝氧量。先用電子磅為動物量重，然後分別放入裝有攝氏 25 度海水的容器。溶氧探測儀會於第 0, 30, 60 和 90 分鐘時量度海水的溶氧濃度。以下圖表顯示結果：

動物	動物重量 (克)	氧氣濃度 (mg/L)			
		0 分鐘	30 分鐘	60 分鐘	90 分鐘
海水	0	8.2	6.0	5.9	6.0
蛤	40.02	8.2	5.7	4.6	2.9
海螺	9.68	8.2	6.3	5.1	3.8
寄居蟹	10.69	8.2	4.6	2.9	1.4

- 蛤在 30 分鐘間的攝氧率 (mg/L/kg/hr) 是多少？
 - 124.94
 - 144.93
 - 284.86
 - 409.80

- 按在 90 分鐘間的動物攝氧率 (mg/L/kg/hr)，從高到低排列：
 - 寄居蟹 > 蛤 > 海螺
 - 海螺 > 寄居蟹 > 蛤
 - 蛤 > 海螺 > 寄居蟹
 - 寄居蟹 > 海螺 > 蛤

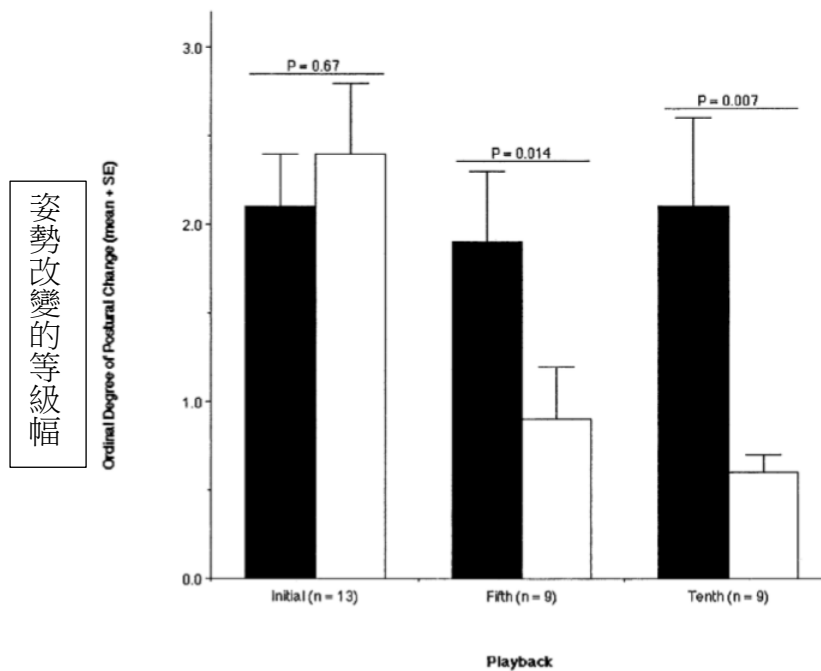
- 按實驗結果可以作出以下哪個結論？
 - 身體質量較大的動物使用更多海水中的氧氣
 - 寄居蟹使用更多氧氣因為牠在環境中有較多移動
 - 蛤需要更高溶氧度的海水才能生存
 - 只有 (I)
 - 只有 (II)
 - (II) 和 (III)
 - 以上所有

學生用另一隻海螺和攝氏 40 度的海水重複實驗，以下圖表顯示結果：

動物	動物重量 (克)	氧氣濃度 (mg/L)			
		0 分鐘	30 分鐘	60 分鐘	90 分鐘
海水	0	6.5	6.4	6.5	6.5
海螺	12.24	6.5	3.6	3.0	2.7

4. 以下哪項陳述是海螺於實驗一和實驗二的不同氧氣濃度的合適解釋？
- I. 水的氧氣濃度跟水溫是成正比的
 - II. 在 90 分鐘間，實驗二的海螺攝氧率比實驗一的海螺為高
 - III. 相對第一隻海螺，第二隻海螺表現出更高壓力水平，因為牠停止使用水中氧氣
- A. (I) 和 (II)
 - B. (II) 和 (III)
 - C. 只有 (III)
 - D. 以上所有
5. 退潮時，海螺的行為和生理上的反應是怎樣的？
- I. 移動到有大量海水的潮下地區
 - II. 躲藏在石塊下或裂縫間
 - III. 有熱壓力蛋白去抵抗石塊的高溫
 - IV. 在石塊上將殼提高以減少脫水
- A. (I) 和 (II)
 - B. (II) 和 (III)
 - C. (III) 和 (IV)
 - D. (I), (II) 和 (III)

一些動物看見捕食者時會發出示警訊號去警告同伴。實驗利用理查森地松鼠去研究當發出示警訊號的示警者不可靠時松鼠群的反應。一組松鼠聽到預錄的示警訊號，並且看見捕食者。同樣的做法重複，在警示發出第 5 次和第 10 次把松鼠的反應記錄下來。另一組松鼠聽到相同頻率的示警訊號，但沒有捕食者出現。牠們姿勢的改變 (抬頭朝感知威脅的方向) 會被記錄。姿勢改變的幅度越大顯示對捕食危機有更高警覺性。

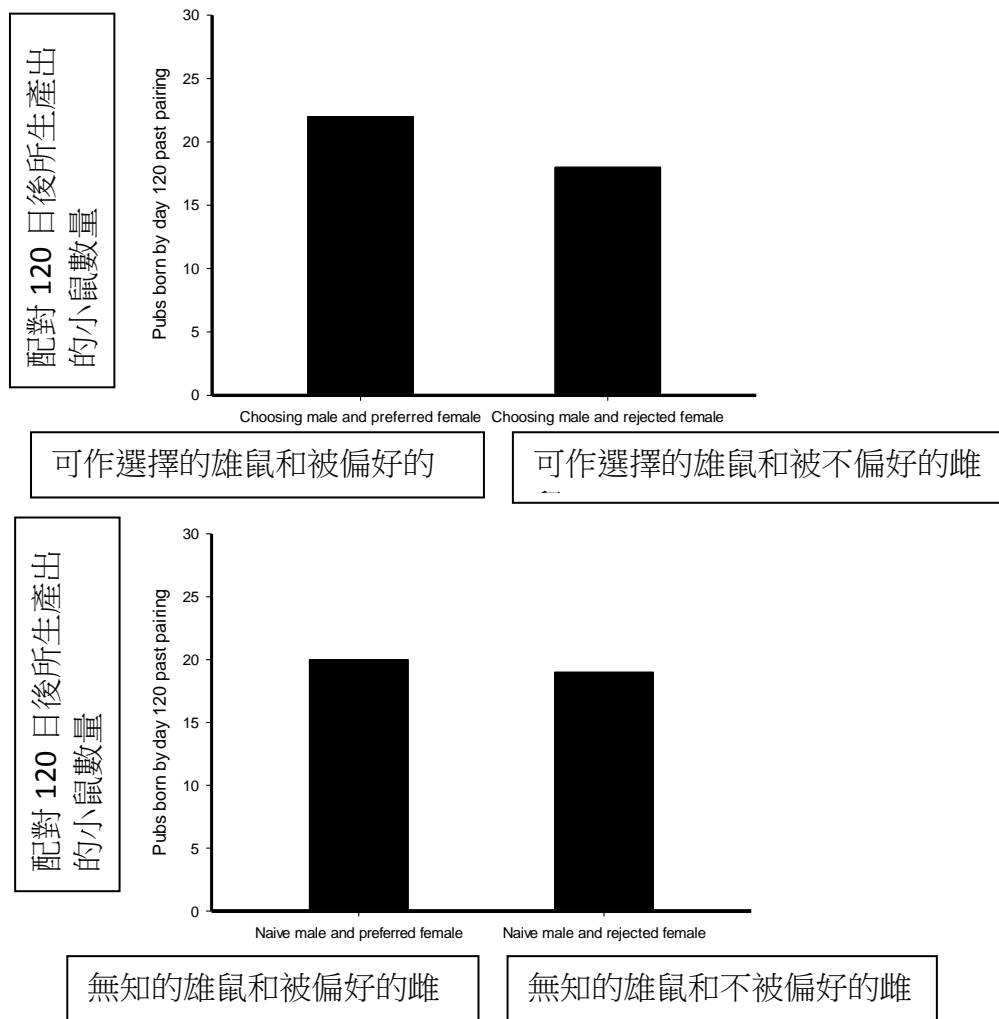


對可靠 (填充棒) 和不可靠 (開放棒) 示警者的姿勢改變的等級幅度，於起始、第 5 次和第 10 次播放示警訊號。顯著性值(P)表示在每個時間點對可靠和不可靠示警者的反應差異。(Hare and Atkins (2001) Behavioural Ecology and Sociobiology 51, 108-112)

6. 以下哪一個形容是不正確的？

- A. 在第一次示警訊號時，兩個實驗組的姿勢改變沒有分別，因為松鼠事前對哪一個示警者是可靠，哪一個不是沒有認知。
- B. 松鼠對不可靠的示警者會更少注意。
- C. 當示警者是可靠的，松鼠對捕食危機的警覺性保持不變。
- D. 松鼠對捕食危機的警覺性時間跟示警者是否可靠沒有關係。

在一夫一妻制的交配系統中，一個雄性和一個雌性在一個繁殖季節中只會跟對方交配。在這系統下，選擇一個高質素的伴侶明顯地是正向的適應後果。在一個實驗中，一隻雄性灰背鹿鼠可從兩隻性成熟的處女鼠中選擇。雄鼠跟牠偏好的雌鼠交配所生產的小鼠數量，和雄鼠跟牠不偏好的雌鼠交配所生產的比較 (圖 3a)。在另一個實驗，一隻無知的雄鼠 (跟兩隻雌鼠都沒有經驗的雄鼠) 分別跟在第一個實驗被偏好和不被偏好的雌鼠交配，比較兩隻雌鼠所生產出來的小鼠數量 (圖 3b)。(Ryan and Altmann (2001) *Behavioural Ecology and Sociobiology* 50, 436-440.)



7. 就以上實驗選擇一個正確的結論。

- A. 每一隻雄性灰背鹿鼠對好伴侶的定義都不同
- B. 雄灰背鹿鼠偏好高生產力的雌鼠
- C. 被雄鼠偏好的雌鼠所生產的小鼠存活率較高
- D. 以上所有結論都是不正確的

一個研究銅頭蛇雄性和雄性間侵略性的實驗，一條雌性被放置在競技場中間，而兩個雄性放在兩邊，兩雄性可以鬥爭直至有一個是較佔優勢。之後立即將牠們分開並收集血液樣本作激素分析。跟這實驗組是有兩個對照組，一個對照組是一個單獨關在籠內

的雄性，另一個對照組是關在籠內的一雄一雌。在實驗會量度所有雄蛇的壓力激素皮質酮水平。

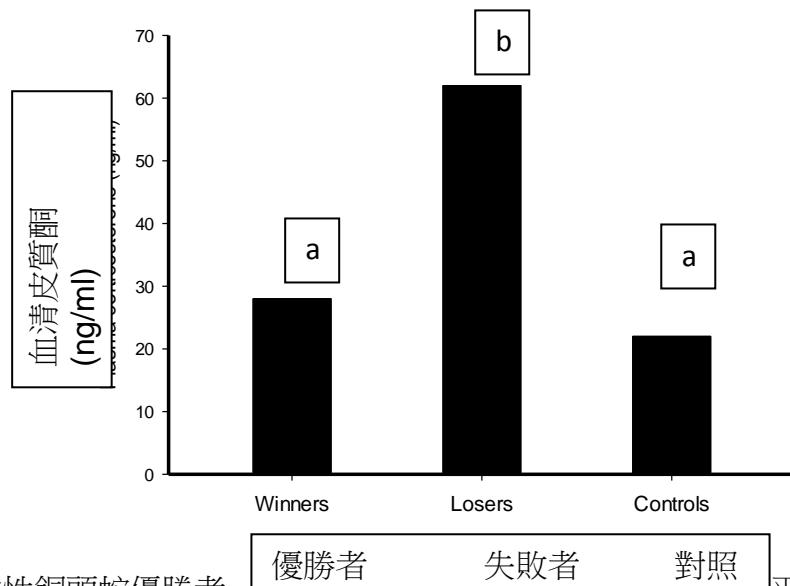
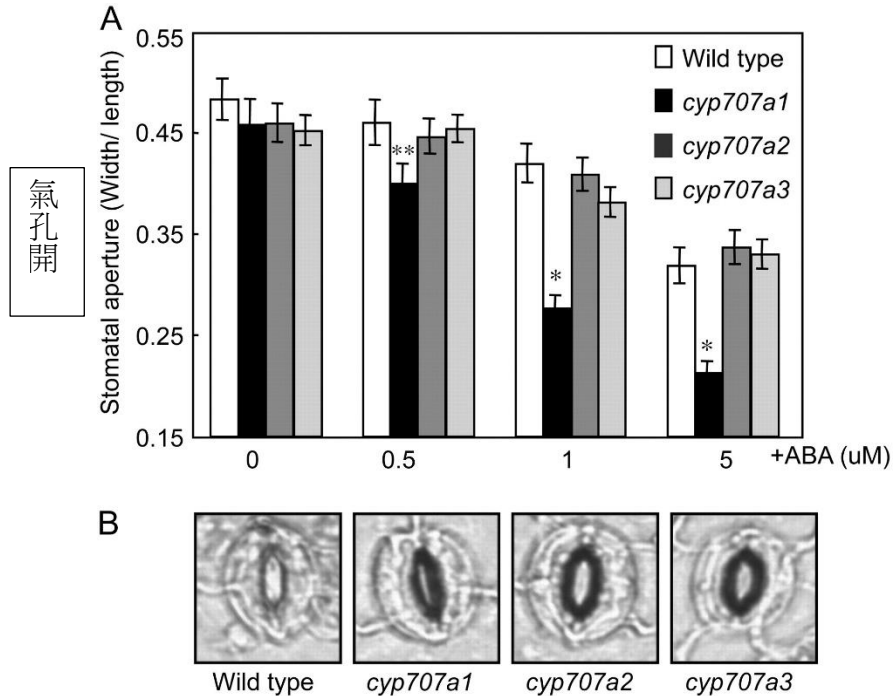


圖 4：雄性銅頭蛇優勝者、優勝者 失敗者 對照。有相同小楷字母的棒是統計上沒有明顯分別的 (>0.05)。

8. 以下哪個結論是正確的？

- A. 雄性銅頭蛇的皮質酮水平增加是因為雄性間的侵略性
- B. 雄性銅頭蛇的侵略性是由血清皮質酮水平來決定
- C. 鬥爭刺激雄性銅頭蛇皮質酮的產生
- D. 雌性銅頭蛇的存在會防止雄蛇皮質酮的增加

氣孔的開度會按濕度改變，離層酸 (ABA) 是一種植物激素，主要功用是在可用水量減少時作出反應。缺乏水分時，ABA 在葉片中聚積並減少保衛細胞中氣孔的開度。ABA 8'-羥化酶，是一種在保衛細胞的酶，主要功用是降解羥化酶。羥化酶是由 *cyp707a* 基因家族編碼。下圖顯示外源 ABA 處理對野生組和三個 *cyp707a* 變異組 (*cyp707a1*, *cyp707a2* 及 *cyp707a3*) 的表皮氣孔開度的效用。

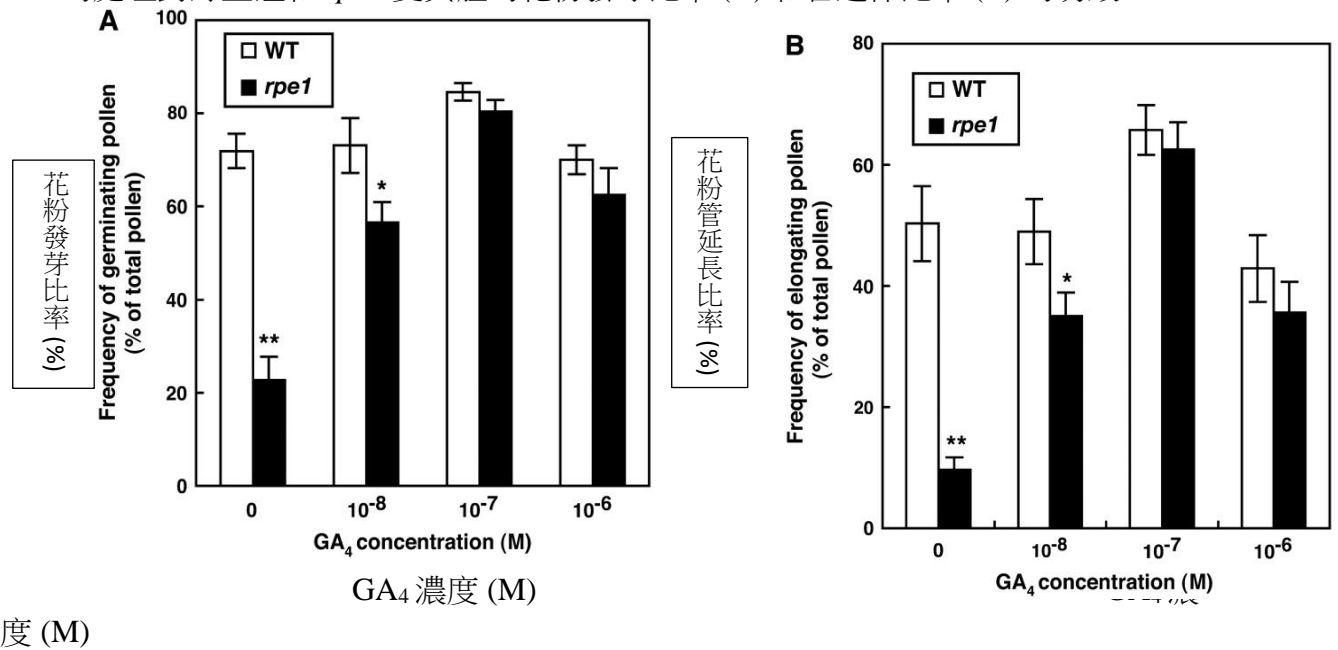


[圖取自 Okamoto *et al* (2009) *Plant Physiology*, 149: 825-834.]

9. 按上圖，哪一個陳述是錯的？

- A. 外源 ABA 同時減少野生組和所有 *cyp707a* 變異組氣孔的開度。
- B. *cyp707a2* 和 *cyp707a3* 變異組顯示跟野生組有近似反應。
- C. *cyp707a2* 和 *cyp707a3* 負責在保衛細胞內 ABA 的降解。
- D. *cyp707a1* 變異組會對外源 ABA 過敏。

赤霉素 (GA) 是植物激素，可調節稻米花粉管的生長，稻米變異體 *reduced pollen elongation1* (*rpe1*) 因 GA 的生物合成的缺陷而減少花粉發芽和管延伸。下圖顯示外源 GA₄ 的處理對野生組和 *rpe1* 變異體的花粉發芽比率 (A) 和管延伸比率 (B) 的功效。

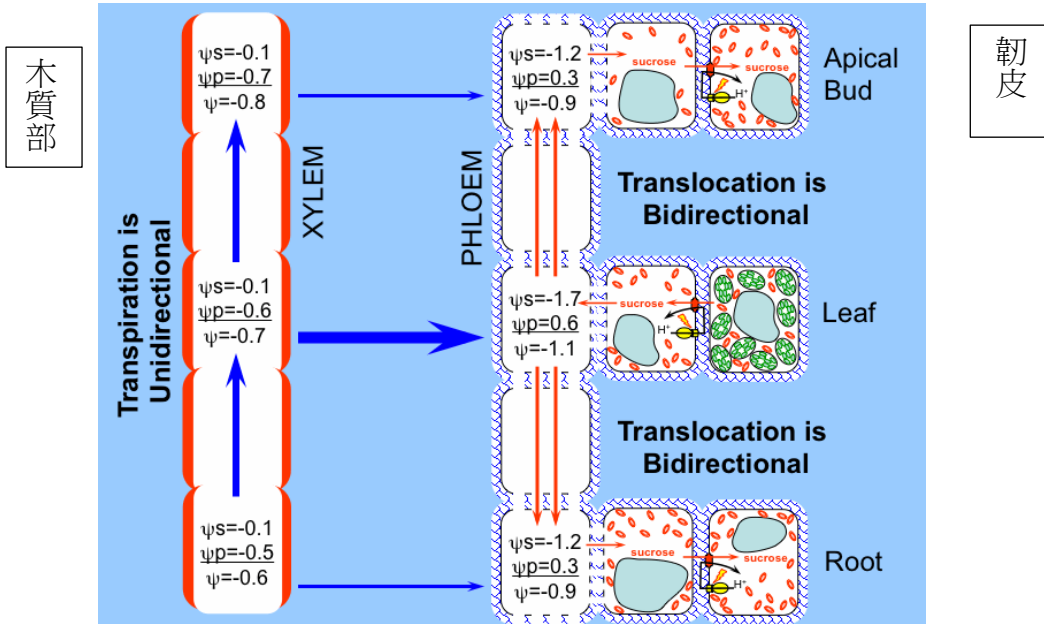


[圖取自 Chhun *et al* (2007) *The Plant Cell* 19: 3876-3888.]

10. 以下哪項陳述跟上面的資料一致？

- I. 以最高劑量的 GA₄ 處理對花粉發芽和管延伸有抑制效果。
 - II. 以少於 10⁻⁷ M 的 GA₄ 處理，結果顯示會妨礙 *rpe1* 變異體的花粉發芽和管延伸，是由於 GA 會成的缺陷。
 - III. 花粉發芽和管延伸的增長會依賴 GA 的劑量。
- A. 只有(I)
 - B. 只有(I)和(II)
 - C. 只有(I)和(III)
 - D. 只有(II)和(III)

下圖顯示液體怎樣在植物的木質部和韌皮部被運輸。



ψ_s - 溶質勢：溶質造成的水勢，負數值愈低代表溶質濃度愈高。
 ψ_p - 壓力勢：滲透壓造成的水勢，正數值愈高代表壓力愈高。
 ψ - 水勢：由溶質勢和壓力勢兩個部分造成。

11. 按上圖，以下哪個關於液體在韌皮部中移動是正確的？

- I. 從溶質勢高到低的
- II. 從壓力勢高到低的
- III. 從水勢高到低的

- A. 只有 (I)
- B. 只有 (II)
- C. 只有 (I) 和 (II)
- D. 以上所有

12. 按上圖，以下哪個關於液體在木質部中移動是正確的？

- I. 從溶質勢高到低的
- II. 從壓力勢高到低的
- III. 從水勢高到低的

- A. 只有 (I)
- B. 只有 (II)
- C. 只有 (I) 和 (II)
- D. 以上所有

13. 是甚麼導致較頂部的木質部有較低的水勢？

- I. 蒸騰作用
- II. 葉片光合作用所製造的糖分
- III. 地心吸力

- A. 只有 (I)
- B. 只有 (II)
- C. 只有 (I) 和 (II)
- D. 只有 (II) 和 (III)

一個實驗研究光合作用，將綠藻跟 DCPIP 在沒有二氧化碳的試管中混合。不同顏色的光照射到試管，然後量度 DCPIP 的顏色轉變。氧化狀態的 DCPIP 是藍色的，還原狀態的是沒有顏色的。

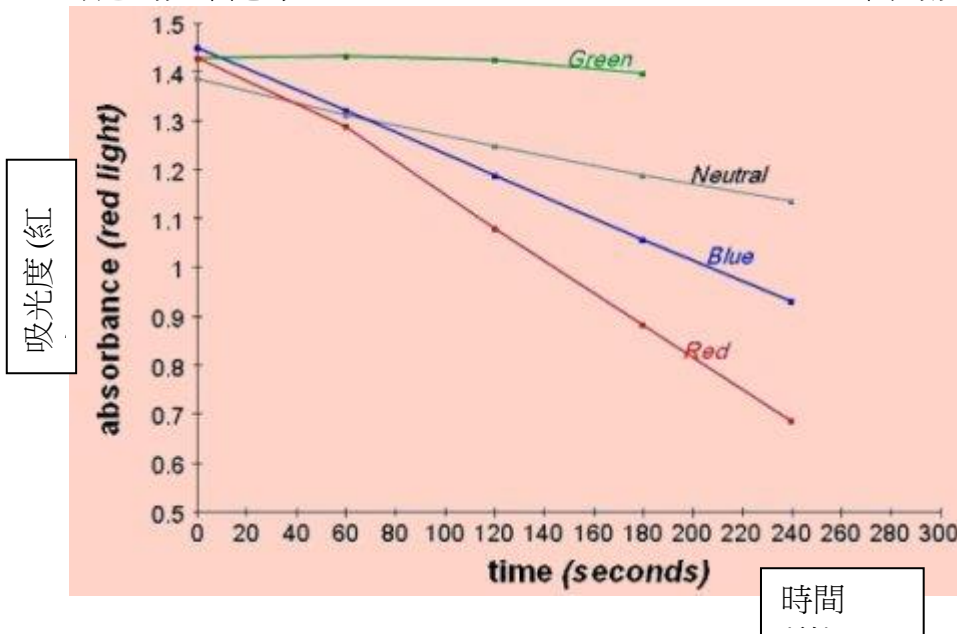
綠藻 DCPIP 懸浮液



綠藻 DCPIP 懸浮液顏色的光下隨時

液

液顏色濃度 (吸光度) 在不同間的改变。



14. 以下哪項正確解釋紅光下的結果？

- I. 碳水化合物在試管中產生
- II. 水釋出電子去直接還原 DCPIP
- III. DCPIP 接受從葉綠素受光照所釋出的電子

- A. 只有 (I)
- B. 只有 (III)
- C. 只有 (II) 和 (III)
- D. 以上所有

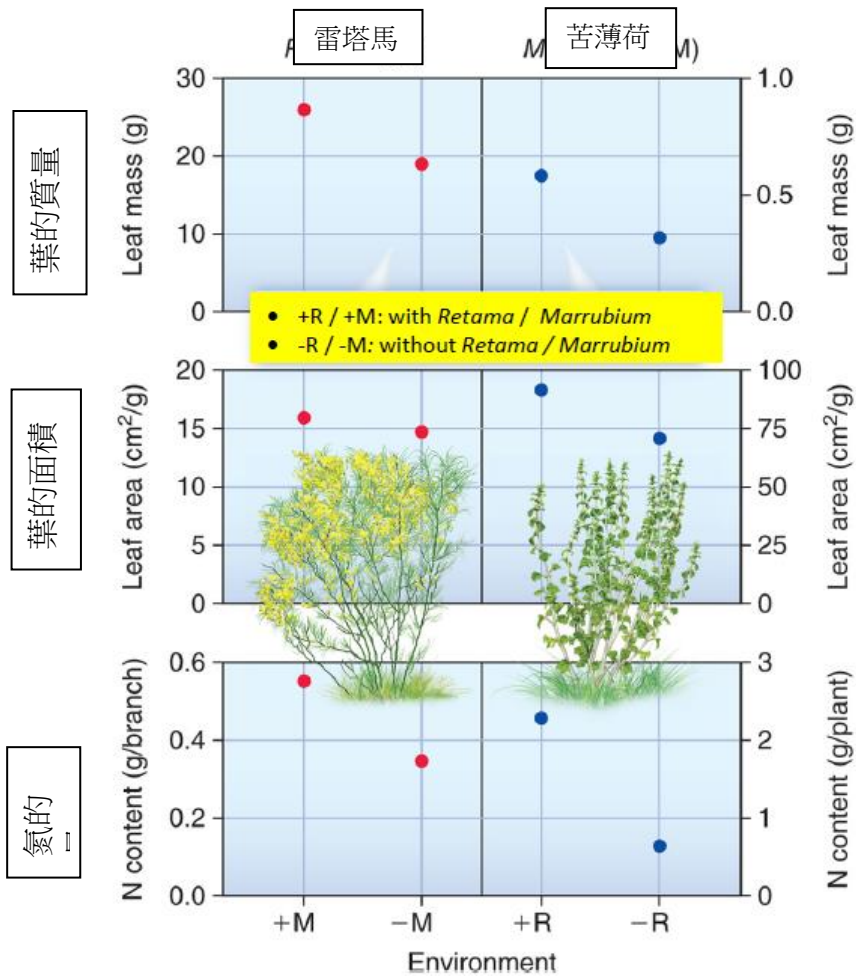
15. 比較不同顏色光照射下的結果，可以得出以下哪個結論？

- I. 葉綠素最吸收綠光
- II. 葉綠素最吸收紅光
- III. 光合作用速度與光顏色無關

- A. 只有 (I)
- B. 只有 (II)
- C. 只有 (I) 和 (III)
- D. 以上所有

物種間可以有不同互動方式：

互動性質	物種 A 族群	物種 B 族群
偏害共生	負面影響	沒有影響
偏利共生	正面影響	沒有影響
競爭	負面影響	負面影響
互利共生	正面影響	正面影響
草食性, 寄生, 捕食	正面影響	負面影響
無利害共棲	沒有影響	沒有影響

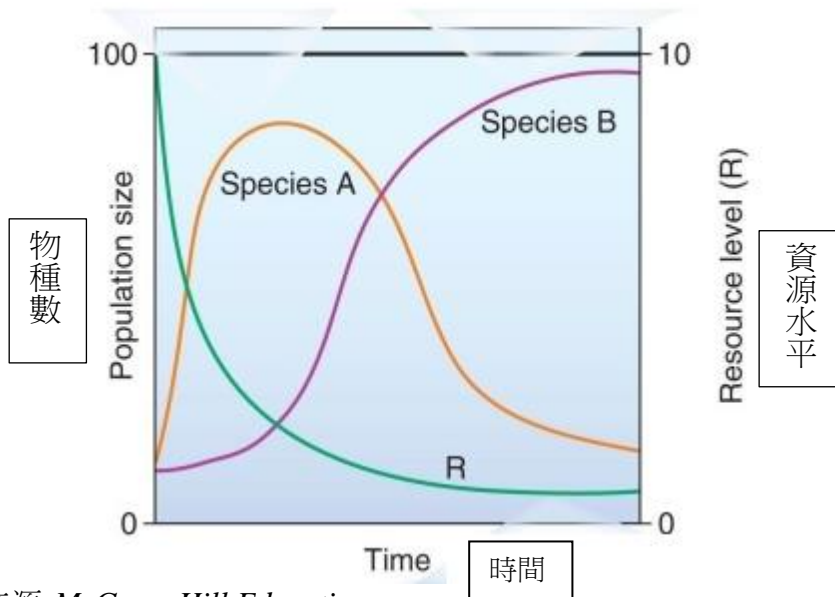


來源: McGraw-Hill Education

16. 以下哪個互動種類最貼切形容雷塔馬和苦薄荷間的關係？

- A. 偏害共生
- B. 偏利共生
- C. 互利共生
- D. 無利害共棲

競爭分為剝削性(透過消耗有限資源造成間接競爭)，或干擾性(個體之間直接以力量互動)。下圖表達兩植物物種 A 和 B 的關係。



來源: McGraw-Hill Education

17. 以下哪項陳述是真實的？

- A. 物種 A 和物種 B 之間沒有競爭。
- B. 物種 A 勝過物種 B，因為牠能盡快耗盡資源。
- C. 當資源減少，物種 B 勝過物種 A。
- D. 物種 A 和物種 B 進行干擾性競爭。

18. 以下哪項陳述不是真實的？

- A. 在同一棵植物上，芽蟲吸吮葉汁和毛蟲咀嚼葉子是剝削性競爭的例子。
- B. 蠅蛆以小鼠屍體為食物是剝削性競爭的例子。
- C. 種內競爭(同物種個體)和種間競爭(不同物種個體)可以由剝削性競爭，或干擾性競爭，或兩者一同引發。
- D. 以上皆否。

在捕食過程中，捕食者的攻擊失敗的比成功的多。當獵物是容易捕捉的，次等的個體常會不被捕捉。但當獵物是較難捕捉的，衰弱、生病或受傷的動物會較常被捕捉。一隻鷹受訓練去捕捉三種野外獵物，鷹帶回的完整屍體，會按狀態被評分。有骨折的、眼睛有缺陷的、或有傷口的獵物會被歸類為次等。

19. 收集到的「次等獵物的百分比」為 9%, 19%, 31%。將數字填到下表。

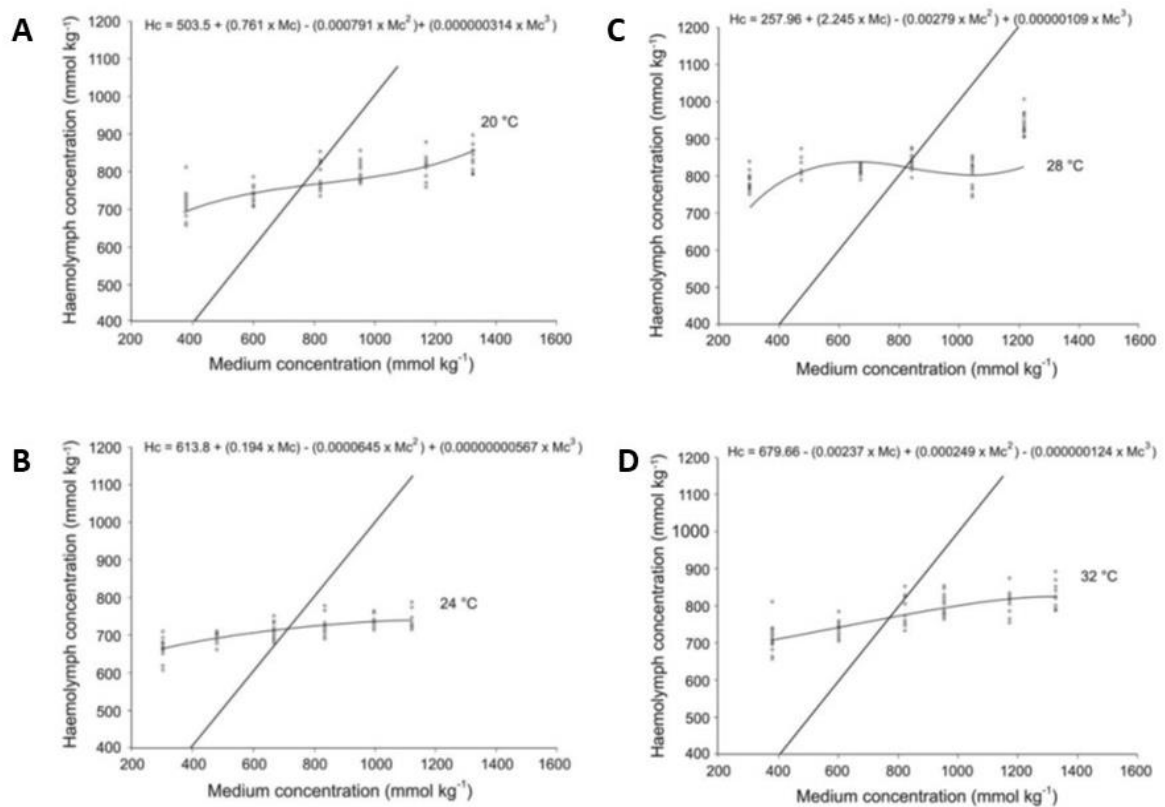
獵物物種	攻擊失敗的百分比	次等獵物的百分比
鼠類	68	A
兔子	81	B
松鼠	85	C

- A. A(9), B(19), C(31)
- B. A(31), B(19), C(9)
- C. A(19), B(31), C(9)
- D. A(19), B(9), C(31)

20. 鱈魚以小魚和蟹為食物，小魚和蟹以浮游動物為食物，浮游動物以浮游植物為食物，浮游植物則會消耗水中的硝酸鹽。如果鱈魚被過度捕獲。以下哪種生物的族群數量會減少？

- A. 小魚和蟹
- B. 浮游動物
- C. 浮游植物
- D. 所有物種的族群數量(小魚，蟹，浮游動物，浮游植物)會維持不變，因為物種已達至生態平衡

滲透壓調節是其中一個最重要調節功能，生物利用滲透壓調節來控制體液的滲透壓。所有海洋生物同樣要對抗體外滲透壓的挑戰以維持體內平衡。溫度和鹽度會影響水分穿過細胞膜，及獲取和失去離子的能力，從而影響液體的滲透壓特性。一個研究評估蝦(*Litopenaeus vannamei*) 滲透壓調節能力 (血淋巴和體外培養液的滲透壓差異)，蝦(*Litopenaeus vannamei*)被暴露在不同溫度和鹽度以找出等滲點，令生物用最少能量去進行滲透壓調節，並達至最理想的生長率。



L. vannamei 暴露在攝氏 20(A), 24(B), 28(C) 和 32(D)度的滲透壓調節 (mmol kg^{-1})。交點顯示各自的等滲點。開圓表示每個個體。Hc, 血淋巴濃度(mmol kg^{-1}); Mc, 體外培養液濃度 (mmol kg^{-1})。

從 Buckle et al. (2006) Rev. Biol. Trop. 54(3): 745-753 取得

21. *L. vannamei* 生長的最適溫度是甚麼？

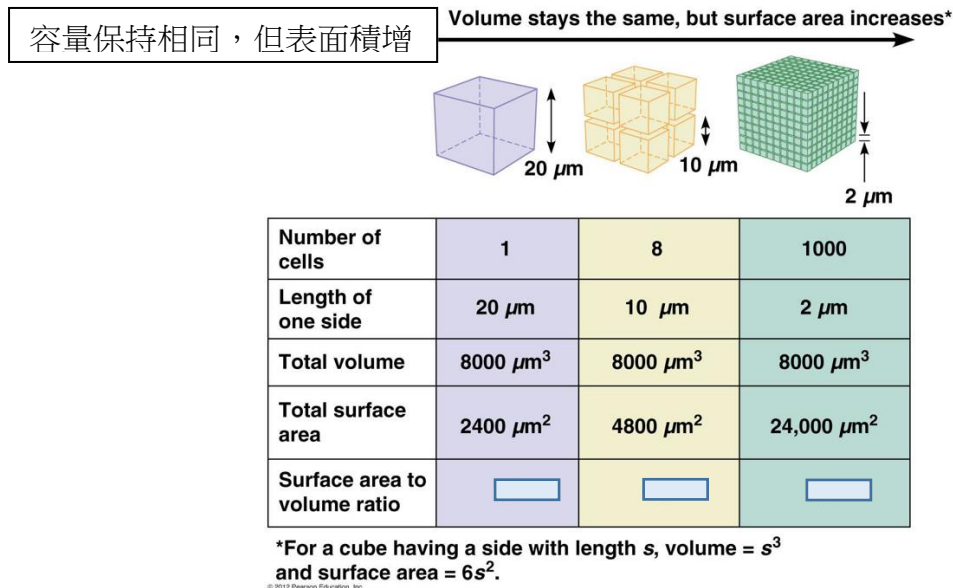
- A. 20 °C
- B. 24 °C
- C. 28 °C
- D. 32 °C

22. 按實驗結果可以得出以下哪個結論？

- I. *L. vannamei* 的滲透壓調節反應主要受溫度影響。
- II. *L. vannamei* 是滲透壓順應者的例子，因為牠的體液跟海水是等滲的。
- III. *L. vannamei* 在不同海水中均可做到滲透壓調節

- A. 只有 (II)
- B. 只有 (III)
- C. (I) 和 (II)
- D. (I) 和 (III)

23. 細胞有不同大小和形狀。細胞大小的主要限制是維持足夠的表面積和體積的比例。表面積影響細胞和外界的交換率。下圖展示不同大小細胞的整體體積和表面積的關係。

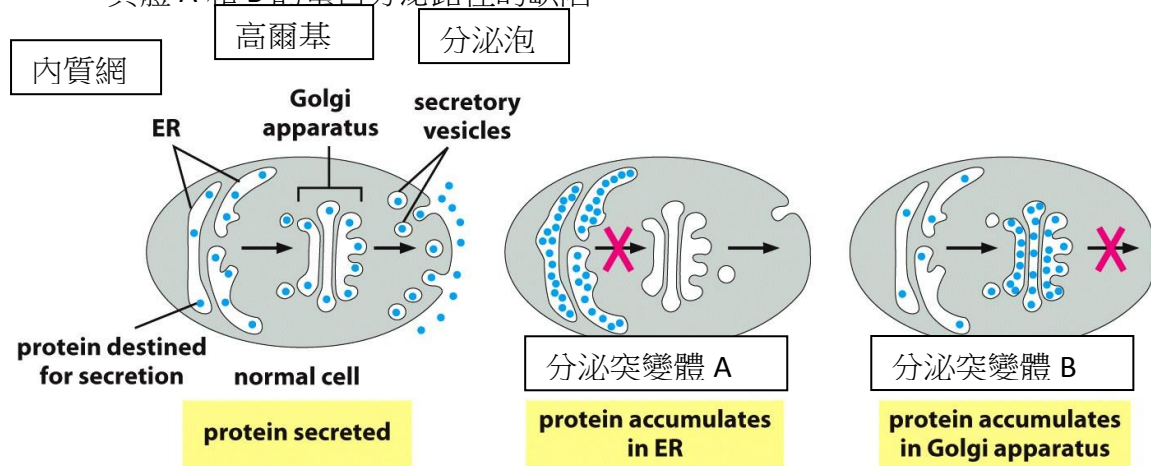


(取自 Campbell Biology: concepts and connections 7th edition” by Reece et al., 2012 Pearson Education, Inc. Figure 4.1)

參考上圖，以下哪個陳述是正確的？

- I. 細胞愈細，表面積和體積的比例愈大
 - II. 表面積和體積的比例愈細會令細胞不能夠維持自己，因為相對它的需要，細胞攝取太少
 - III. 細胞細小則可形成較大的體積的組織，因為細胞可以透過良好的交換率去維生
- A. 只有 (I)
 - B. 只有 (I) 和 (II)
 - C. 只有 (I) 和 (III)
 - D. 只有 (II) 和 (III)

24. 涉及細胞內運輸程序的基因變異會導致蛋白質積聚在細胞隔室內，例如內質網 (ER) 或高爾基體。通常用基因變異的酵母菌來剖析蛋白分泌路徑。下圖說明變異體 A 和 B 的蛋白分泌路徑的缺陷。



(取自 Essential Cell Biology 3rd edition” by Bruce Alberts et al., 2010, Garland Science, Figure 15.30)

按上圖。以下哪個陳述是正確的?

- I. 基因 A 是蛋白質從內質網運輸到高爾基體的必需品
- II. 基因 B 是蛋白質從高爾基體運輸到細胞外空間的必需品
- III. A 和 B 的變異會導致蛋白質積聚在內質網

- A. 只有 (I)
- B. 只有 (I) 和 (III)
- C. 只有 (II) 和 (III)
- D. 以上所有

25. 去氧核糖核酸受破壞，可以在細胞分裂週期令細胞週期停滯在第一間期。它會增加腫瘤抑制基因 p53 的活性。p53 蛋白可以調節另一個目標基因 p21 的表達，阻止細胞進入 DNA 合成期。p21 蛋白依附在另一個目標蛋白 Y 去控制第一間期到 DNA 合成期之間的過渡。研究發現有些癌症病人有不正常地活躍的 Y 蛋白。

按上文所述，以下哪個陳述是正確的？

- I. p21 激活 Y 並促進第一間期到 DNA 合成期之間的過渡
 - II. p21 抑制 Y 並防止第一間期到 DNA 合成期之間的過渡
 - III. 活化 p21 可以防止細胞分裂
 - IV. 活化 p53 可以抑制 Y
-
- A. 只有 (I)
 - B. 只有 (I) 和 (III)
 - C. 只有 (II), (III) 和 (IV)
 - D. 只有 (I), (III) 和 (IV)

Part A	ANS	Part B	ANS
1	A	1	A
2	B	2	D
3	D	3	B
4	B	4	C
5	D	5	B
6	B	6	D
7	C	7	A
8	D	8	A
9	A	9	C
10	B	10	B
11	C	11	B
12	C	12	C
13	D	13	A
14	B	14	B
15	A	15	B
16	B	16	C
17	B	17	C
18	A	18	D
19	D	19	A
20	B	20	B
21	D	21	C
22	B	22	B
23	D	23	B
24	C	24	B
25	D	25	C