IBO CHALLENGE II

32nd INTERNATIONAL BIOLOGY OLYMPIAD

Lisbon, PORTUGAL - July 21st, 2021

THEORETICAL TEST

(Time available: 180 minutes)

- This test consists of 249 questions arranged in 54 Groups (Q1-Q54).
  本試卷共有 54 大題，249 個子題。
- All questions have the same value – 1 point each correct answer.
  所有題目分數相同--答案正確得 1 分
- Maximum score: 249 points
  總分為 249 分
- Only answers marked in the ANSWER SHEET will be validated
  只有註記在答案紙上者，才會計分。

GENERAL INSTRUCTIONS 一般說明

1. Your exam is composed of seven topics.
   本試卷分成七大主題

2. Your exam is composed of three types of questions:
   本試卷的問題分為三種類型
   - Multiple choice questions 選擇題
   - True / False questions 是非題
   - Matching items questions 配對題

3. The students are not supposed to use words to answer the questions, only codes of letters placed in the appropriate locations in the answer sheet.
   不能用文字來回答問題，只能用對應的代碼填在答案紙上的適當處。
   - Multiple choice questions should be answered by selecting the correct answer on the Answer sheet

   選擇題的答案須在答案卷上選出正確答案
   - True / false questions should be answered by selecting either a "**T**" for true or an "**F**" for false on the Answer sheet

   是非題的答案須在答案紙上用"**T**" 代表正確、"**F**" 代表錯誤
   - Matching items questions should be answered on the Answer sheet by selecting the appropriate letter in the key provided in each case
     配對題須在答案紙上選用題目所提供對應的適當字母來回答

ENJOY AND HAVE FUN!!!

THEORETICAL TEST 理論題

Topics:

I. Q1 - Q12 – Cell Biology 細胞生物

II. Q13 - Q21 – Plant Anatomy and Physiology 植物解剖與生理

III. Q22 - Q33 – Animal Anatomy and Physiology 動物解剖與生理

IV. Q34 - Q35 – Ethology 行為學

V. Q36 - Q45 – Genetics and Evolution 遺傳與演化

VI. Q46 - Q51 – Ecology 生態

VII. Q52 - Q54 – Biosystematics 生物系統分類

I. Cell Biology 細胞生物學

Q1

To trace the path of a secretory protein from its synthesis to its export from a cell, suppose that you have added radioactive amino acids to a culture of cells, and then measured the amount of radioactivity that shows up in the proteins of each of the following cell fractions at different times after addition.

I – secretory vesicles
II – Golgi complex
III – rough ER
IV – nucleus

Q1

為了追蹤細胞內一個分泌型蛋白質從合成到輸出的途徑，假設你將帶有放射性的胺基酸添加到細胞培養基中，然後測量在添加之後不同時間點，出現在以下胞器內蛋白質的放射性訊號。

I – 分泌囊泡
II – 高基氏體
III – 粗糙內質網
IV – 細胞核

Mark as true(T)or false(F)the order in which the proteins of these fractions exhibit radioactivity (*4 points, 1 point each correct answer*)
依照下列胞器內蛋白質出現放射性訊號的先後次序，**標示正確（T）或錯誤 （F）**
（4 分，每一個正確答案 1 分）

A. III → II → IV → I → out of the cell 細胞外
B. III → II → I → out of the cell 細胞外
C. IV → III → II → I → out of the cell 細胞外
D. IV → II → III → I → out of the cell 細胞外

Q2

For each of the following phases of the cell cycle, indicate whether the chromosome number is haploid (H) , diploid (D) or could be either (E) . Also indicate whether chromosomes have replicate (R) or have not replicated (N/R) (Chromosome status) . *(5 points, 1 point each correct answer)*

針對下列每一個細胞週期的階段，指出染色體數目在該階段時是單倍體（H），雙倍體（D），或是都有可能（E）。也請指出該階段的染色體狀態是已經複製（R），或是尚未複製（N/R）。（5 分，每一個正確答案 1 分）

Chromosome number 染色體數目	Chromosome status 染色體狀態	Cell cycle phase 細胞週期階段
		G_2
		Meiotic metaphase I 減數分裂 中期 I
		Mitotic prometaphase 有絲分裂 前中期
		Meiotic interkinesis 減數分裂 間期
		G_1

Q3

Indicate whether each of the following statements is true(T)or false(F).

(4 points, 1 point each correct answer)

指出下列敘述是正確（T）或錯誤（F）（4 分，每一個正確答案 1 分）

A. Centrosomes replicate independently of chromosomes.
中心體獨立複製於染色體之外

B. The nuclear envelope becomes fragmented at mitosis, and it is distributed between the daughter cells like other membrane-bounded organelles such as ER and Golgi
在有絲分裂時，核膜會片段化，並分布在兩個子細胞之間，如同內質網與高基氏體這類膜狀胞器一樣

C. The total DNA content of a cell following meiosis is half that of a cell after mitosis.
一個完成減數分裂之後的細胞，其總 DNA 含量是一個完成有絲分裂的細胞的一半

D. Microtubule polymerization, depolymerization, and microtubule motor proteins are required for DNA replication.
DNA 複製時需要微管的聚合、解聚合以及微管動力蛋白

Q4

Indicate whether each of the following statements is true (T) or false (F).
(*4 points, 1 point each correct answer*)

指出下列敘述是正確（T）或錯誤（F）（4 分，每一個正確答案 1 分）

A. Plasmolysis occurs when a plant tissue is placed in a hypotonic medium.
當植物組織被放置在低張溶液時，會發生原生質離的現象

B. Animal cells will lyse when they are placed in distilled water.
當動物細胞被放置在蒸餾水中時，細胞會裂解

C. When plant cells are placed in a hyperosmotic sucrose solution, sugar crosses the cell wall but not the cell membrane, keeping the cell the same size.
當植物細胞被放置在高滲透壓的蔗糖溶液中，蔗糖會穿透細胞壁但不會穿透細胞膜，因此細胞保持原本尺寸

D. In plant cells water loss is normally a reversible phenomenon, while in animal cells it is not.
在植物細胞中，水份喪失是一個可逆的現象，但是在動物細胞則是不可逆的

Q5

Observations in optical microscopy are often accompanied by the measurement of the specimen under study. Among other methodologies, the measurement can be performed after calibration, of each objective, with the aid of an eyepiece micrometer (ocular lens) and a microscope stage micrometer.
在光學顯微鏡下觀察樣品時，通常也伴隨著有量測尺寸的需求。在各種方法之中，我們可以靠著接目鏡（目鏡）測微尺以及載物台測微尺的幫助，在各個物鏡倍率下校正之後就可以直接進行尺寸量測。

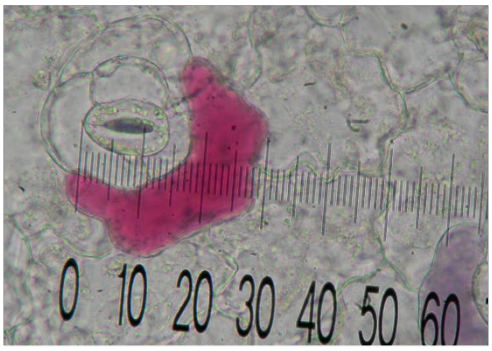
I. To calibrate an objective, it is necessary to start by placing the eyepiece micrometer (EM in Plate 1) in position on the microscope tube and installing the microscope stage micrometer (SM in Plate 1) on the microscope stage.
校正一個物鏡倍率時，我們必須先將目鏡測微尺（在插圖 1 中的 EM）放置在顯微鏡筒上，並且在載物台上安裝載物台測微尺（在插圖 1 中的 SM）。

II. Then, the scales of the eyepiece micrometer and the microscope stage micrometer must be aligned, so that they are parallel, partially overlap, and so that the beginning of the graduation of the two scales superimpose.
接著，接目鏡測微尺的刻度與載物台測微尺的刻度必須並排，讓它們彼此平行且部分重疊，並使兩個測微尺的起始刻度是相互重疊。

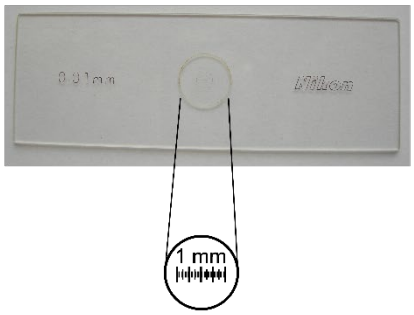
III. Having superimposed the zeros of the two scales, look for the point at which the two scales overlap equally.
當兩個尺規在零的位置重疊在一起時，尋找下一個兩個尺規刻度重疊在一起的位置。

IV. In the example of Figure C from Plate 1, 70 divisions of the eyepiece micrometer correspond exactly to 0.4 mm (= 400 µm) of the microscope stage micrometer. This value is only valid for the lens used.
在插圖 1 的圖 C 範例中，目鏡測微尺上 70 個區隔單位，剛好相對應載物台測微尺的 0.4 mm（=400 µm）。此數值只適用於這個鏡頭。

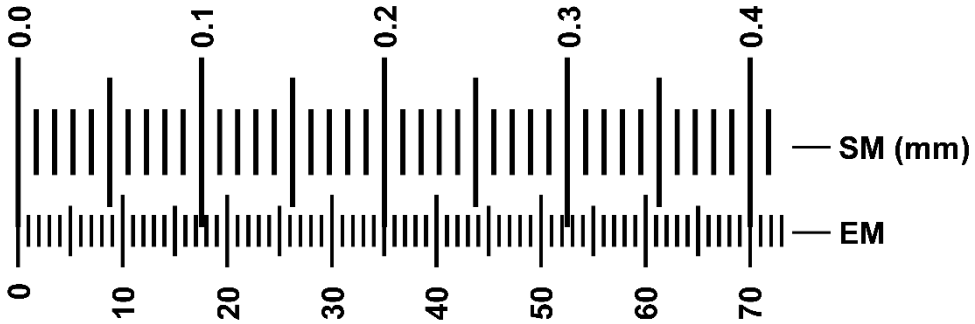
A



B



C



Based on the description above, and Plate 1, **indicate whether each of the following statements is true (T) or false (F).** (*4 points, 1 point each correct answer*)

依照上面的描述以及插圖 1 **指出下列敘述是正確 (T) 或錯誤 (F)** (**4 分，每一個正確答案 1 分**)

A. 1 ocular unit = 5.7 µm.
一個目鏡單位 = 5.7 µm

B. The procedure described in II is represented schematically in Figure B.
圖 B 就是在步驟 II 描述內容的示意圖

C. Figure B shows a microscope stage micrometer.
圖 B 代表了載物台測微尺

D. The stoma in Figure A is approximately 80 µm in length.
圖 A 的氣孔大約長 80 µm

Q6

Cellular life depends on maintaining a balance between external and internal environments. Any change may have major consequences, so exchange is dynamic and moves in both directions across the cell membrane.

細胞的生命依賴於內部與外在環境平衡的維持。任何的改變都可能帶來重大的後果。因此，跨越細胞膜兩側的交換是動態的而且也是雙向運輸。

Mark with **true (T) or false (F),** the characteristics listed in the table below about membrane transport. (*8 points, 1 point each correct answer*)

請在下表所列有關細胞膜運送特徵的描述中，**標示正確（T）或錯誤（F）（8 分，每一個正確答案 1 分）**

	Features **特徵**	**Passive Transport** **被動運輸**		**Active transport** **主動運輸**
		Simple diffusion **簡單擴散**	**Facilitated diffusion** **促進性擴散**	
A	Membrane constituents responsible for transport 負責運輸功能的膜成分	Proteins 蛋白質	Proteins 蛋白質	Lipids 脂質
B	Binding of the substance to be transported 與要被運輸的物質結合	Yes 會	Yes 會	No 不會
C	Source of energy 能量來源	Concentration gradient 濃度梯度	Concentration gradient 濃度梯度	ATP hydrolysis ATP 水解
D	Sensitiveness to oxidative metabolism inhibitors 對氧化代謝抑制劑敏感	Yes 會	No 不會	No 不會
E	Sensitiveness to denaturation or removal of membrane proteins 對於膜蛋白的變性或移除敏感	No 不會	Yes 會	Yes 會
F	Direction of transport 運送的方向	In favour of the gradient of substance to be transported 順著被運輸物質的濃度梯度	In favour of the gradient of substance to be transported 順著被運輸物質的濃度梯度	Against the gradient of substance to be transported 逆著被傳送物質的濃度梯度
G	Degree of specificity 專一性程度	Nonspecific 不專一	Specific 專一	Specific 專一
H	Saturation with high concentrations of the molecule to be transported 對被運輸分子在高濃度下的飽和性	No 不會	Yes 會	Yes 會

Q7

Most plants are monoecious species, having complete flowers that allow for self-pollination to occur. However, there are several incompatibility mechanisms present in different families to prevent inbreeding.

One of the most described systems, entitled GSI, or Gametophytic Self-incompatibility, is based on allelic composition from the mother plant (transmissive tract) and the pollen tube; if there is recognition of the self, the pollen tube stops growing and dies.

Briefly, the self-incompatibility mechanism is activated when the pollen tubes reach 1/3-2/3 of the total distance in the style, coincident with the entry of nutrients from the transmissive tissue (or transmitting tract) to the pollen tube.

The mechanism is based on the uptake of S-RNase by the pollen tube.

大部分的植物是雌雄同株，具有完全花可以自花授粉。然而，在一些不同的植物中也有一些不親合的機制來避免近親繁殖。

其中一種最常被提到稱為配子體自交不親合（GSI）系統，是根據來自母本植物（傳送路徑）與花粉管的等位基因組成來決定。如果辨識結果發現是自我的，那麼花粉管會停止生長並死亡。簡單的說，這種自交不親合的反應機制會發生在花粉管到達花柱全長 1/3-2/3 的時候，此時正好也是一些營養物質從花柱的傳送組織（傳送路徑）送入花粉管的時候。花粉管吸收了 S-核糖核酸酶（S-RNase）就是這個機制的關鍵。

Q7.1

Considering the explanation above, **indicate whether each of the following statements is true (T) or false (F).** (*4 points, 1 point each correct answer*)

根據上面的解釋，指出**以下描述是正確（T）還是錯誤（F）**（**4 分，每個正確答案 1 分**）

A. The RNases are of maternal origin.
這個核糖核酸酶（S-RNase）是來自母本植物

B. The RNases degrade pollen RNA, leading to cessation of tip growth in case of self-recognition.
在辨識到自我時，這個核糖核酸酶（S-RNase）會降解花粉的 RNA，導致端點生長停止

C. The RNA enters the cell through the endocytosis pathway.
這個 RNA 透過胞吞途徑進入細胞

D. The S-RNase is degraded in case of identical alleles.
在相同等位基因的狀況下，這個 S-核糖核酸酶（S-RNase）會被降解

Q7.2

Considering this type of self-incompatibility, **indicate whether each of the following statements is true (T) or false (F).** (*4 points, 1 point each correct answer*)

根據此型的自交不親合性，指出**以下描述是正確（T）還是錯誤（F）**（**4 分，每個正確答案 1 分**）

A. The pollen haplotype S3 would be rejected in a S2S2 pistil.
單倍體基因型 S3 的花粉會被 S2S2 的雌蕊拒絕

B. The pollen haplotype S3 would be rejected in a S2S3 pistil.
單倍體基因型 S3 的花粉會被 S2S3 的雌蕊拒絕

C. The pollen tube metabolism changes from autotrophic to heterotrophic in the transmitting tract in the pistil
花粉管在雌蕊的傳送路徑中，其代謝模式會從自營轉換成異營

D. Self-incompatibility mechanisms are very important to ensure genetic variability.
自交不親合機制是維持遺傳多樣性非常重要的機制

Q8

Fungi are everywhere, including in the marine environments (sandy beaches, salt marshes and mangroves). Considerable efforts have been made in documenting their diversity, ecology, phylogeny and biotechnological applications. The marine fungal distribution comprises temperate, tropical, arctic and cosmopolitan species. The majority are Ascomycota, presenting microscopic fruit bodies and spores, mostly with appendages or mucilaginous sheaths (**Figure 1**).

Marine fungi play a key role in marine ecosystems' balance and dynamic. A wide range of organic to inorganic substrates are colonized by marine fungi: wood, halophytes, seaweeds/algae, marine animals, sand, sea foam and sediments.

真菌無所不在，在海洋的環境之中（沙灘、鹽沼以及紅樹林）也有。對於它們的多樣性、生態、親緣關係以及生物科技上的應用已有許多研究記載。海洋真菌物種可以依照其分佈，區分為溫帶的、熱帶的、極地的以及各地皆有的物種。最主要的物種是子囊菌門（Ascomycota），在顯微鏡下可看到子實體與孢子，而它們大多具有附屬器與黏液鞘（**圖 1**）。

海洋真菌對於海洋生態系統的平衡與動態扮演了重要的角色。在各種有機與無機基質上，包括樹木、耐鹽植物、海草/藻類、海洋動物、沙、海面泡沫與沈積物等，都可以發現有海洋真菌的群聚。

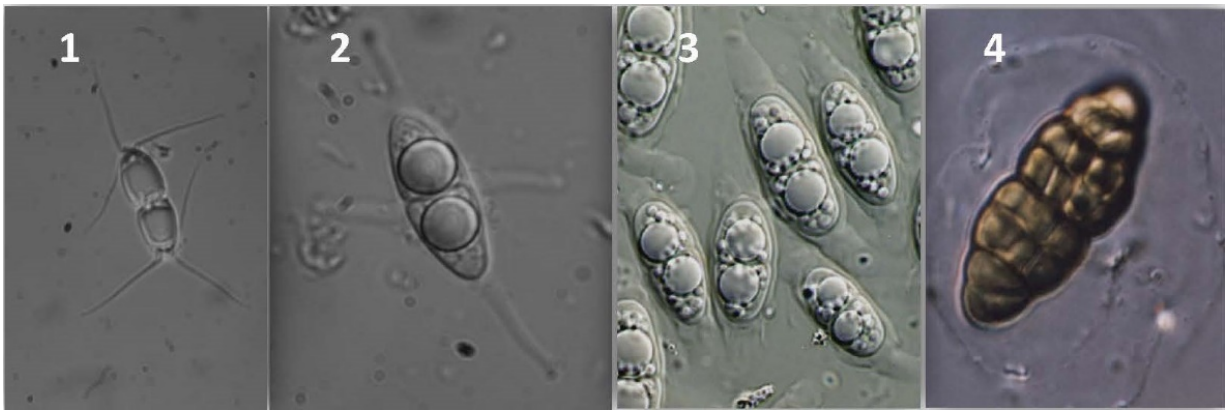


Figure 1 – Microscopic photos of marine fungi: ascospores with appendages (1-2) and ascospores with sheaths (3-4).

圖 1 – 海洋真菌的顯微照片：具附屬器的子囊孢子 （1-2） 以及具有鞘的子囊孢子 （3-4）.

Indicate whether each of the following statements is true (T) or false (F).
(4 points, 1 point each correct answer)

指出以下描述是正確（T）還是錯誤（F）（4 分，每個正確答案 1 分）

A. Fungi major ecological role is the decomposition of organic matter
真菌主要的生態角色是分解有機物質

B. Sheaths and appendages of spores are morphological adaptations to marine life
孢子的鞘與附屬器是對海洋生活的形態適應

C. Temperature and salinity are not important factors on marine fungal distribution
溫度與鹽度並不是影響海洋真菌分佈的重要因子

D. Some marine fungi produce extracellular enzymes that enable them to break down lignocellulosic materials.
有些海洋真菌產生胞外酵素，讓它們能分解木質纖維物質

Q9

In the 1850s and 1860s, the French chemist and microbiologist Louis Pasteur became the first scientist to study fermentation, when he demonstrated that this process was performed by living cells.

Fermentation processes to produce bread, wines, beers and ciders are traditionally carried out with *Saccharomyces cerevisiae* strains, the most common and commercially available yeast.

In nature, they are found on the surface of fruits and leaves. *Saccharomyces cerevisiae* is an Ascomycota fungus that reproduces asexually by budding and sexually by ascospores.

在 1850 與 1860 年代，法國化學家與微生物學家路易斯．巴斯德，首先證明發酵是由活細胞所執行的一個程序，使他成為第一位研究發酵的科學家。

傳統上利用發酵程序製造麵包、葡萄酒、啤酒、與蘋果酒是使用釀酒酵母菌 (*Saccharomyces cerevisiae*) 菌株，這是最常用的市售酵母菌。

在自然界中，它們出現在水果與葉片的表面上。釀酒酵母菌是一種子囊真菌 (Ascomycota fungus)，它們的繁殖可利用無性的出芽方式，或是有性的子囊孢子。

The fermentation biochemical pathway is illustrated in **Figure 2**.

發酵的生化代謝途徑如**圖 2**

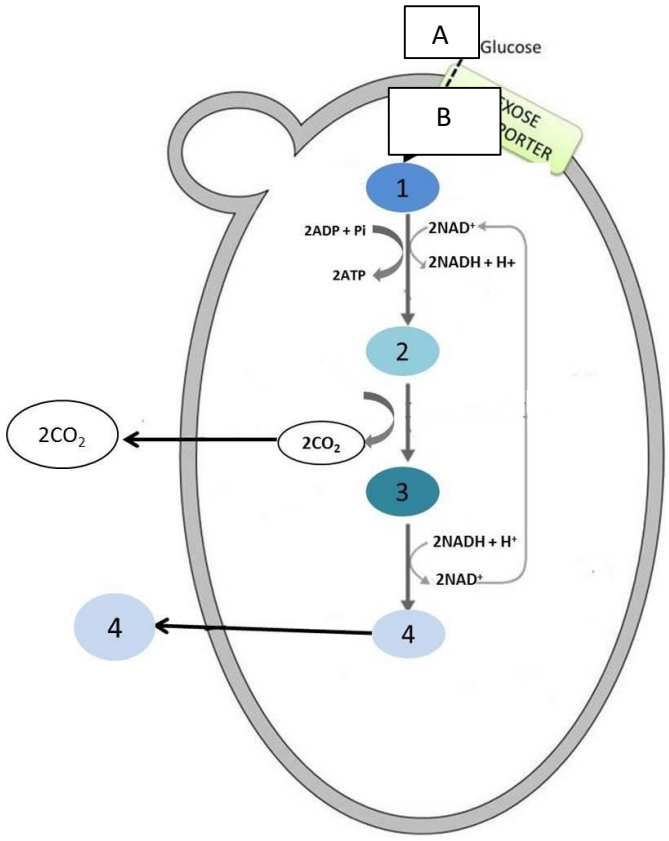


Figure 2 - Central metabolism of fermentation in yeasts. 1. Glucose. 2. Pyruvic acid. 3.Acetaldehyde. 4. Ethanol. A. Glucose; B. Hexose transporter

圖 2 – 酵母菌發酵的主要代謝 1. 葡萄糖 2. 丙酮酸 3. 乙醛 4. 乙醇 A. 葡萄糖 B. 六碳糖運輸蛋白

Indicate whether each of the following statements is true (T) or false (F).
(*4 points, 1 point each correct answer*)
指出下列各敘述為對 (T) 或錯 (F) (共 4 分, 每一個正確答案得 1 分)

A. The oxygen presence determines pyruvate oxidation via tricarboxylic acid cycle to carbondioxide and water.
氧的存在，決定了丙酮酸的氧化反應是透過三羧酸循環 (tricarboxylic acid cycle) 而成為二氧化碳與水。

B. The main components of *S. cerevisiae* cell wall are cellulose and hemicellulose.
釀酒酵母菌細胞壁的主要成分是纖維素 (cellulose) 與半纖維素 (hemicellulose)。

C. Vegetative cells multiply by budding but on nitrogen starvation may give rise to asci in which meiosis occurs to give four haploid ascospores
營養細胞利用出芽方式繁殖，但於缺乏氮源時就可產生子囊，並在其內進行減數分裂產生 4 個單套的子囊孢子。

D. During fermentation CO_2 is removed from pyruvate and 38 ATP are formed per one molecule of glucose.
在發酵過程中，會從丙酮酸中移除 CO_2，且每一個葡萄糖分子可產生 38 個 ATP。

Q10

Researchers from Harvard University show that the concentration of nutrients in the environment can set the strength of interactions between species of a microbial community. An important environmental parameter that all microbes influence and are influenced by is pH. The change in environmental pH by bacterial species was measured at high and low nutrient concentrations (**Fig. I**). Different soil bacteria were grown at low and high nutrient concentrations, then that spent media was used to re-grow each of the species in the spent media of the others (**Fig**. **II**). To determine the consequence of these environmental modifications on the coexistence of bacterial pairs, the scientists co-cultured all pairwise combinations of the eight species in batch culture with daily dilution in both low and high nutrient concentrations, then the cultures were assayed by counting the bacteria colonies (**Fig**. **III**).

哈佛大學的研究人員發現環境中養分的濃度，可影響一個微生物群落中各物種之間交互作用的強度。在所有能夠影響微生物或被微生物影響的環境因子之中，pH 是最重要的因子之一。在低養分濃度與高養分濃度的環境下，不同細菌改變其環境 pH 的量測結果（**圖 I**）。將不同的土壤細菌，分別在低養分濃度與高養分濃度下培養。然後把培養後用剩的培養基（spent media），再度用來培養其他菌種（**圖 II**）。為了找出這種環境差異對於共存的細菌所造成的影響，科學家將 8 個菌種兩兩配對，將所有配對組合的菌種進行批式培養（batch culture）。各組每日分別以低養分濃度或高養分濃度培養基的稀釋液培養，然後取樣分析各培養組中的菌落數目（**圖 III**）。

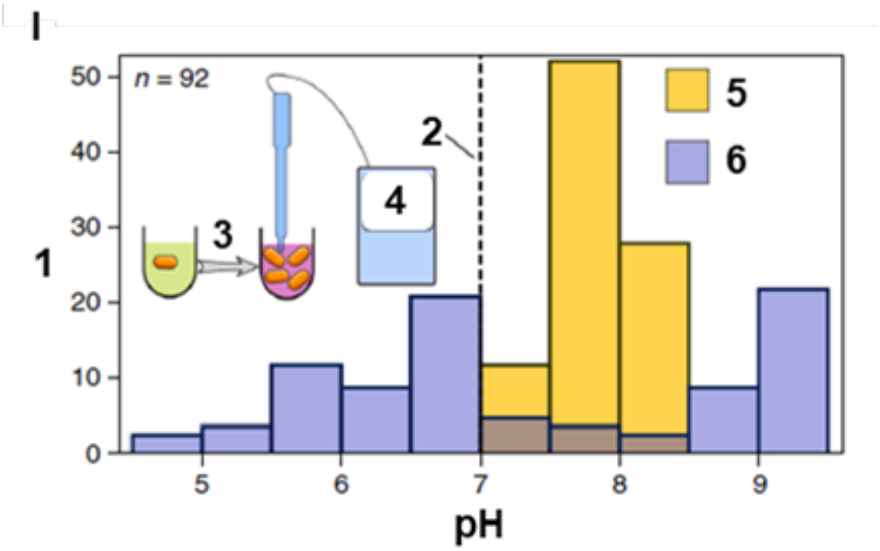


Figure I. pH – Final pH. 1. Number of strains; 2.Initial pH 7; 3.Growth; 4.Final pH; 5. Low nutrient; 6. High nutrient.

圖 1. pH – 最終 pH； 1. 菌株數目；2. 初始 pH 為 7；3. 生長過程；4.最終 pH 量測；5. 低養分；6. 高養分

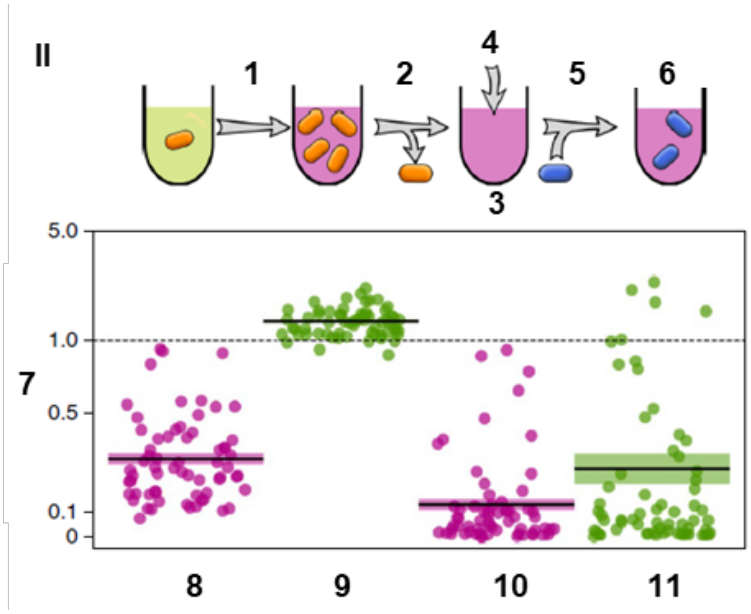


Figure II.1. Growth; 2. Remove bacteria; 3. Spent media; 4. ± fresh nutrients; 5. Add bacteria; 6. Regrowth; 7. Final OD* spent media / final OD* fresh media; 8. Low nutrient; 9. Low nutrient replenished; 10. High nutrient; 11. High nutrient replenished.
**OD = Optical Density.*

圖 II. 1. 生長過程；2. 移除細菌；3. 用剩的培養基；4. ±新鮮的培養基；5. 加入細菌；6. 再次培養；7. 用剩培養基之最終 OD*/新鮮培養基之最終 OD*；8. 低養分；9. 低養分補充後；10. 高養分；11. 高養分補充後
*OD = 光學密度

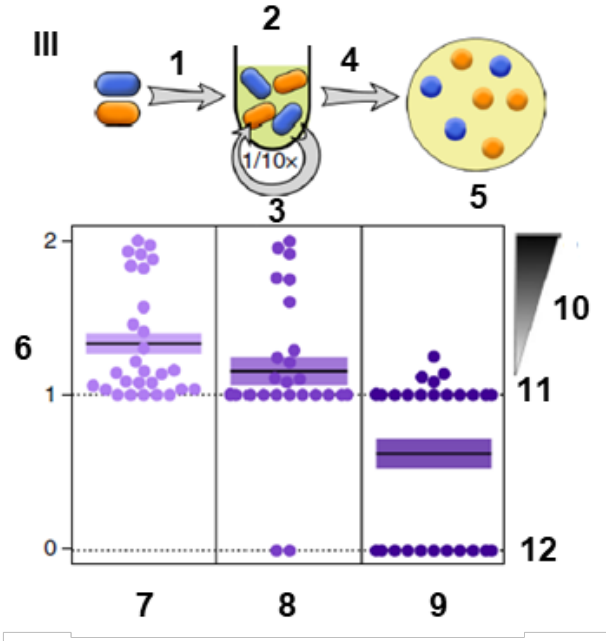


Figure III.1. Mix; 2. Cultivate; 3. Daily dilution; 4. Plate; 5. Count colonies; 6. Diversity; 7. Low nutrient 10 mM PO_4; 8. High nutrient 100 mM PO_4; 9. High nutrient 10 mM PO_4; 10. Coexistence; 11. One species wins; 12.Extinction.

圖 III. 1. 混合；2. 培養；3. 逐日稀釋；4. 置入平板培養基；5. 計算菌落；6. 差異性；7. 低養分 10 mM PO_4；8. 高養分 100 mM PO_4；9. 高養分 10 mM PO_4；10. 共同存在；11. 其中一個物種贏了；12. 滅絕

After a close evaluation of the results, **indicate if each of the following statements is true (T) or false (F).** (*4 points, 1 point each correct answer*)
經過仔細評估此結果，**指出下列各敘述是對（T）或是錯（F）**（共 4 分，每一個正確答案得 1 分）

A. At high nutrient concentrations bacteria either increased or decreased the pH.
在高養分濃度下，細菌可提高或降低 pH
B. Spent media from high nutrient concentrations repressed bacterial growth completely in many cases and this was driven by resource competition.
在很多實驗中發現，使用高養分濃度的用剩培養基會完全抑制細菌的生長，這是因為資源競爭所驅使的
C. An increase in nutrient concentrations led to stronger negative interactions, resulting in a loss of coexistence
增加養分濃度會導致負交互作用 (negative interactions) 強化，最終菌種無法共存
D. Higher buffer concentrations prevented the loss of coexistence at high nutrient concentrations, showing that pH is a major driver of the species interactions in this system.
使用較高濃度的緩衝液可避免高養分濃度下菌種無法共存的現象，顯示出在此系統中 pH 是菌種互動的主要驅動者

Q11

~~Bacteria are everywhere and if the conditions are suitable they multiply. If growth is not possible, nongrowing states can be adopted. Two of those states are spores and viable but nonculturable (VBNC) cells.~~
~~如果條件適合細菌繁殖，它們全在各處生存。如果無法生長時，它們會進入非生長狀態。其中兩種狀態為孢子或是成為活著但無法培養的(VBNC) 的細胞。~~

~~**Indicate whether each of the following statements is true (T) or false (F).**~~
~~(*4 points, 1 point each correct answer*)~~
~~**請指出下列各敘述為對 (T) 或錯 (F)**~~
~~**(共 4 分, 每一個正確答案得 1 分)**~~

A. ~~Bacterial spores and VBNC cells allow bacteria to cope with unsuitable growth conditions and resume growth later.~~
~~細菌孢子與 VBNC 細胞可使細菌應付不良的生長條件，之後又可恢復生長~~
B. ~~A viable bacterial cell is always culturable.~~
~~一個活的細菌細胞總是可培養的~~
C. ~~Bacterial spores and VBNC cells represent viable cells, and they can grow in most media commonly used in microbiology laboratories~~
~~細菌孢子與 VBNC 細胞代表活的細胞，它們可在微生物實驗室大多數常用的培養基上生長~~
D. ~~The recognition of dormant cells led scientists to hypothesize that sometimes those cells are responsible for the same disease, later in life, in a formerly healed patient.~~
~~識別出休眠的細胞，使科學家提出假設，認為這些細胞可在病人痊癒後的有生之年導致其再罹患相同疾病~~

Q12

Prebiotics function as dietary fibers that are not digestible in the upper gastrointestinal tract and promote the growth of intestinal bifidobacteria. Inulin is a prebiotic that originates from plants. Like starch, it is a plant storage product, but unlike starch it cannot be stained with Lugol's. In the pharmaceutical industry, it is extracted from the root of chicory (*Cichorium intybus*). Inulin's low caloric content permits it to replace sucrose.

益生元（Prebiotics）在上消化道無法被消化，可作為一種食用纖維及促進腸道比菲德菌（bifidobacteria）的生長。菊糖（Inulin）是一種源自植物的益生元，它像澱粉一樣，是植物儲存的產品，但與澱粉不同的是，它無法被魯格爾試劑（Lugol's）染上顏色。於製藥工業上，它是從菊苣（*Cichorium intybus*）的根部萃取而得到。菊糖由於含有較低的卡路里，使其可以取代蔗糖。

Select from **Table 1**, the number corresponding to the appropriate word, to complete the blank spaces from A to J in the text. (**More than one option may be correct**)
(*10 points, 1 point each correct answer*)

表 1 中數字對應的單字可適切的填入，文章中 A 到 J 的空格中以完成文字敘述。
（**可能有超過一個選項是正確的**）（**共 10 分，一個正確答案得 1 分**）

Table 1

1. Inulin 菊糖	6. Vacuole 液胞	11. Endoplasmic reticulum 內質網	16. Acidity and hydrolysis 酸性與水解
2. Lipids 脂質	7. *Cichorium intybus* *菊苣*	12. Starch 澱粉	17. Polysaccharides 多糖
3. Cell wall 細胞壁	8. Sweetener 甜味劑	13. Fibers 纖維	18. Digestible 可消化的
4. Amyloplasts 澱粉體	9. Plastids 質體	14. Pharmaceutical 藥品	19. Cosmetics 化妝品
5. Carbohydrates 碳水化合物	10. Proteins 蛋白質	15. Aromatherapy 芳香療法	20. *Daucus carota* *胡蘿蔔*

Some examples of plants that contain large amounts of inulin are Jerusalem artichoke (*Helianthus tuberosus*), chicory root [**A**…], garlic (*Allium sativum*), asparagus root (*Asparagus officinalis*), among others. Inulin has been used as a low calorie [**B**…], to form gels, increase viscosity, improve aroma and taste properties and as a non [**C**…] [**D**…]. As a [**E**…] inulin is used as a diagnostic tool to measure kidney function. Cellulose and starch are the most common [**F**…] of plants, but [**G**…], xylans, and hemicelluloses are also examples of this group. However, inulin does not accumulate in [**H**…], like cellulose, or in plastids like [**I**…]. Under physiological conditions, inulin is in solution. By artificial dehydration, numerous crystals are formed that aggregate, giving rise to fan shaped structures, which remain inside the [**J**…], surrounded by the tonoplast.

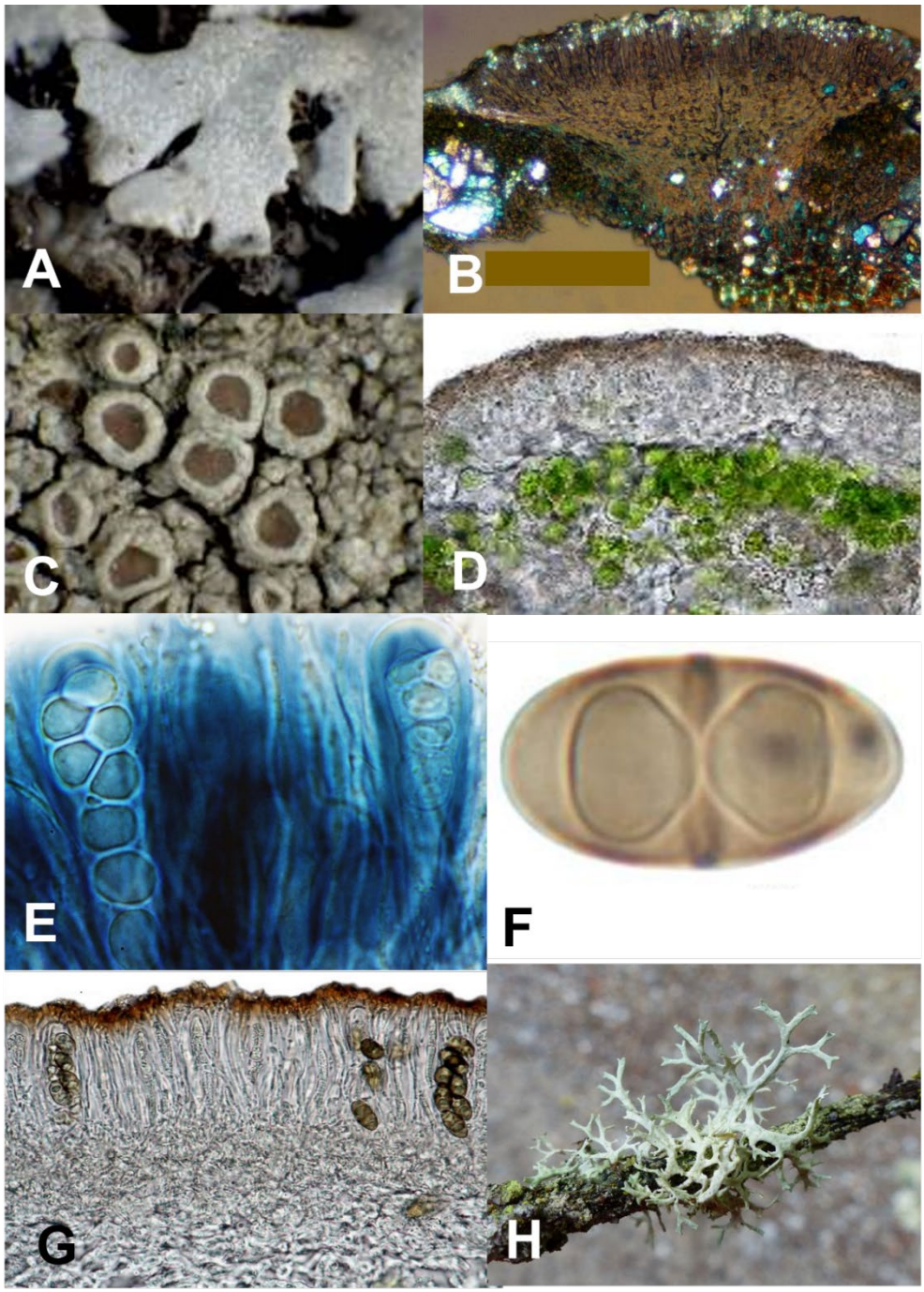
一些具有大量菊糖的植物例子如菊芋 (*Helianthus tuberosus*)、菊苣的根 [**A**…]、大蒜 (*Allium sativum*)、蘆筍的根 (*Asparagus officinalis*)，以及其他。菊糖被使用為低卡路里的 [**B**…]，可形成凝膠、增加黏性、改進香味和口感，並作為一種非 [**C**…] [**D**…]。作為一種 [**E**…] ，菊糖可被用來作為診斷腎臟功能的工具。纖維素與澱粉是植物最常見的 [**F**…]，但是 [**G**…]、木聚糖、以及半纖維素也是這類群物質中的例子。然而菊糖不會像纖維素一樣堆積在 [**H**…] 中，也不像 [**I**…] 一樣堆積在質體中。在生理條件下，菊糖是存在於溶液中。如果將之人為脫水，則會形成無數的結晶而聚集在一起，在 [**J**…] 內產生一個扇形的構造，並被液胞膜 (tonoplast) 所包覆。

Plant Anatomy and Physiology 植物解剖與生理

Q13

A description of three lichen species is provided. Associate each figure (**A-H**) to the corresponding species description (**A, B and C**) based on anatomical structures and morphological characters. *(8 points, 1 point each correct answer)*

有三種地衣物種，請根據解剖構造及形態特徵，對應每個圖（**A-H**）至物種（**A**、**B and C**）描述。**（8 分，每個正確答案得 1 分）**



DESCRIPTION: 描述

Species A - Thallus crustose, smooth to slightly verrucose, white to pale grey. Apothecia with a pale brown disc and a thick, smooth to usually crenulate margin. Margin of the apothecia (in section) with abundant, very large crystals. Asci with 8 spores, elongate Ascospores 1-celled, translucent, broadly ellipsoid.

物種 A - 菌體呈現硬殼狀、平滑至些微疣狀，白至灰白色。子囊盤有一個淺棕色盤，且有厚而平滑至通常細圓齒狀的邊緣。子囊盤邊緣的切面具有大量的大型結晶。子囊含有 8 個孢子，這些長的子囊孢子為單細胞，呈現半透明、寬橢圓體。

Species B - Thallus foliose to fruticose, erect and tufted to pendent, to 10 cm long (usually less), not rigid; branches flattened, strap-shaped to almost linear, green to yellowish green. Apothecia. Photobiont: chlorococcoid (green algae).

物種 B - 菌體呈現葉狀至枝狀，直立且叢生至下垂，長達 10cm（通常較短），不堅硬；分枝呈現扁平、帶狀至幾乎線狀；綠色至黃綠色。具子囊盤。光合共生生物為綠色球狀藻（綠藻）。

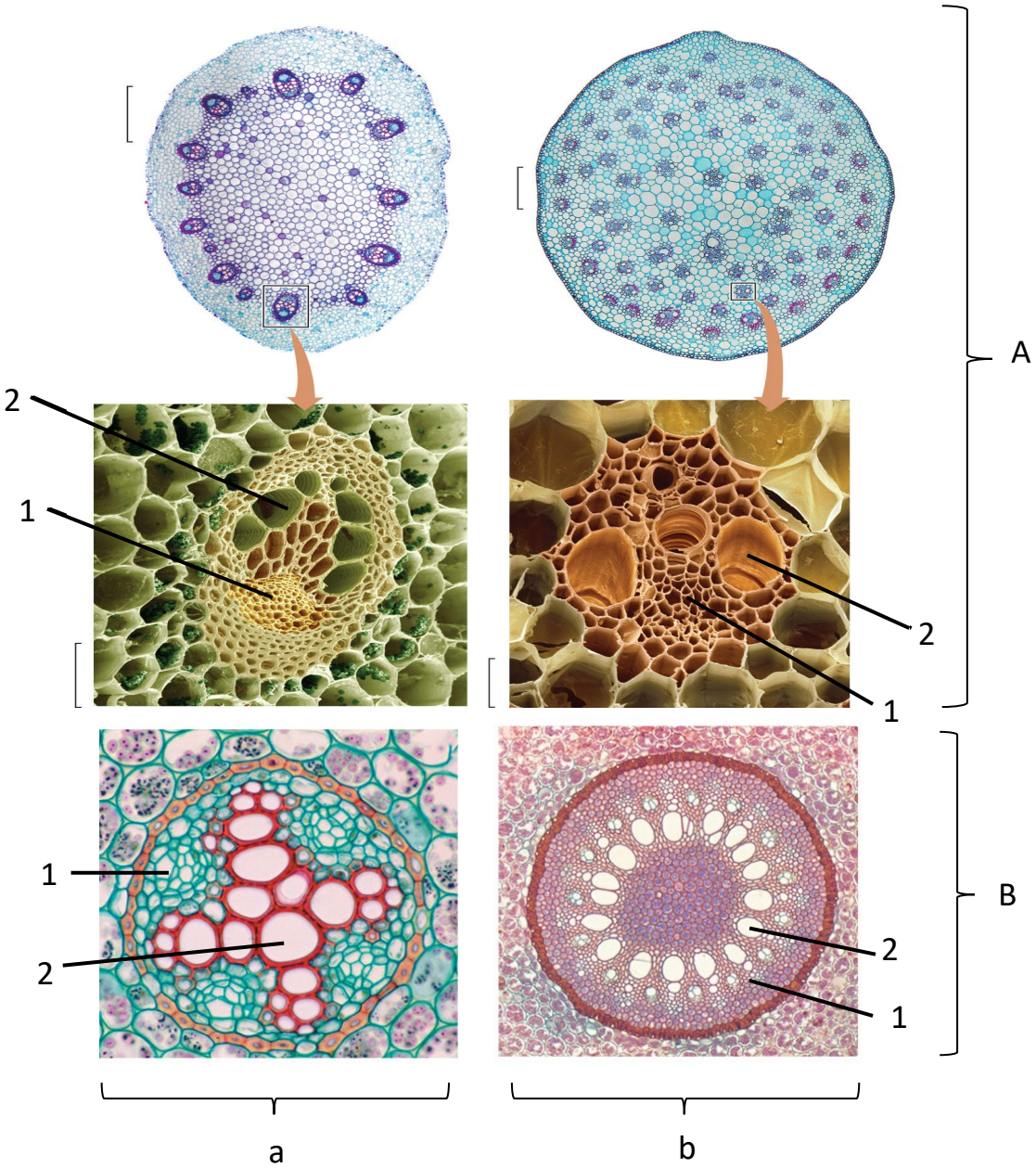
Species C - Thallus foliose, narrow-lobed, closely adpressed, forming orbicular rosettes to 5 cm diameter. Lobes up to 2 mm broad, flat to slightly convex, whitish grey, distinctly white-maculate. Apothecia common, to 3 mm across, with a white-pruinose disc and a smooth margin. Asci 8-spored. Ascospores: 1-septate, brown, ellipsoid.

物種 C - 菌體呈現葉狀、窄的瓣片、密生緊貼，整體形成直徑達 5 cm 的圓形蓮座狀。瓣片寬達 2 mm，扁平至些微鼓起，灰白色，具明顯白斑。子囊盤很常見，直徑達 3 mm，具有一個白粉覆蓋的盤，且其邊緣平滑。子囊有 8 個孢子，子囊孢子為具 1 個隔板、棕色的橢圓體。

Q14

The figure shows the vascular tissue of young stems and roots (capital letters) of two groups of plants, dicotyledonous (eudicots) and monocotyledonous (monocots) (lowercases).

圖顯示雙子葉植物及單子葉植物（以小寫字母代表）的幼莖與根（以大寫字母代表）的維管束組織。



Indicate whether each of the following statements is true (T) or false (F).
(*4 points, 1 point each correct answer*)
指出下列敘述是正確（T）或錯誤（F）（4 分，每個正確答案得 1 分）

A. The vascular systems of stems differ from those of roots. In a root, the vascular tissue lies deep in the interior, with the xylem at or near the centre.
莖的維管束系統與根不同。在根中，維管束組織位在中間內部，且木質部位於或靠近中央。

B. In monocots, the vascular bundles in the stem are arranged in concentric circles while in eudicots they are scattered.
在單子葉植物的莖中，維管束排列成同心圓，而在雙子葉植物則是散生。

C. Each vascular bundle contains both xylem and phloem. The xylem in vascular bundles in stems and roots is indicated with the number (1) and the phloem with the number (2).
每個維管束包括木質部和韌皮部。在莖和根中，維管束的木質部標示為數字(1)，韌皮部標示為數字(2)。

D. In addition to the vascular tissues, the stem contains other important storage and supportive tissues. In eudicots the pith lies inside the ring of vascular bundles and also extends between them, to the outside, the cortex, which may contain supportive collenchyma.
除了維管束組織之外，莖還有其他重要的儲存與支持組織。在雙子葉植物中，髓位在環狀的維管束的內側，並且在維管束之間向外延伸至皮層，皮層包含具支持功能的厚角組織。

Q15

Ammophila arenaria, also known as marram grass or European beachgrass is a plant species that grows in beach sand dunes. The work “The adaptive power of *Ammophila arenaria*: biomimetic study, systematic observation, parametric model and experimental tests” recently published in Polymers (Andrade *et al.* 2021) explores the potential of the *A. arenaria* reversible leaf opening and closure mechanism that acts in response to stress to create responsive facade solutions in architecture (biomimicry).

Ammophila arenaria 又稱為馬蘭草或歐洲沙地蘆葦，是一種長在海邊的沙丘植物。最近發表在 Polymers 期刊的研究 " *Ammophila arenaria* 的適應力：仿生研究、系統觀察、參數模式、以及實驗測試 "（Andrade *et al.* 2021）應用此植物葉片因應逆境所產生可逆性的打開與關閉機制，來探討其應用在建築上解決建築物外牆快速反應的潛力（仿生學）。

Mechanical/technical models can be made to mimic the *A. arenaria* leaf behaviour.
機械式 / 技術式模式可用以模仿 *A. arenaria* 的葉片行為。

Figure 1.a) Shows the leaf characteristics responsible for the leaf movements in response to stress. The figure represents leaf transverse section, showing the abaxial surface (**ab**) and the adaxial surface (**ad**) in conditions of water availability (**W**) and water stress (**WS**) and the motor cells in the adaxial surface (**TBC** – turgid bulliform cells and **FBC** – flaccid bulliform cells).
圖 1.a）顯示葉片對逆境而反應出的葉片運動特徵。此圖代表葉片橫切，顯示背軸（**ab**）與近軸面（**ad**）在水分充足（**W**）以及缺水逆境（**WS**）下的情況，以及在近軸面的運動細胞（**TBC** – 膨大的泡狀細胞和 **FBC** – 縮小的泡狀細胞）。

Figure 1.b) Shows the thermobimetal response to changes in temperature. A – active layer, B – passive layer.

圖 1.b) 顯示對溫度變化之熱雙金屬反應。A –主動層，B –被動層。

Figure 1.c) Shows the prototype material based on the combined use of *A. arenaria* and bio-inspired thermometal materials at two distinct temperatures.

圖 1.c) 顯示，根據混合使用 *A. arenaria* 植物材料以及仿生熱金屬材料，所建構的原型材料，其在兩種不同溫度下所呈現的變化。

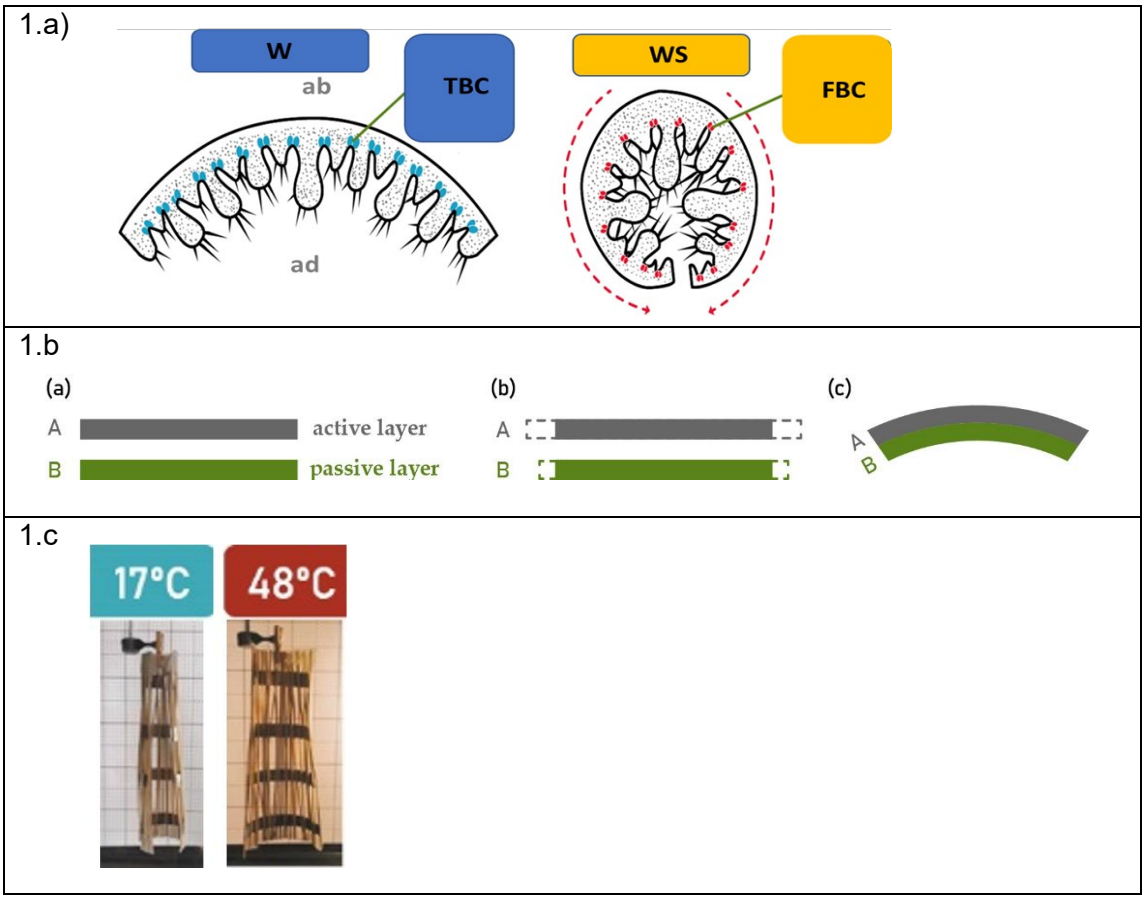


Figure 1 - *Ammophila arenaria* leaf characteristics, thermobimetal response and thermometal materials. 1.b Active layer , Passive layer

圖 1 - *Ammophila arenaria* 葉片特徵、熱雙金屬反應、以及熱金屬材料。1.b 中，Active layer = 主動層，Passive layer =被動層。

Indicate whether each of the following statements is true (T) or false (F).
(4 points, 1 point each correct answer)

分別指出下列敘述的正確（T）或錯誤（F）（4 分，每個正確答案得 1 分）

A. Leaf turgid bulliform cells are crucial in the leaf opening and closing in response to water stress.
在葉片對於缺水逆境做出打開及關閉的反應中，葉片膨大的泡狀細胞具重要功能

B. Comparing the functional surfaces of leaf and thermobimetal materials we can say that the leaf adaxial face corresponds to the active layer of the thermobimetal material.
比較葉片以及熱雙金屬材料的功能性表面，可得知葉片的近軸面相當於熱雙金屬材料的主動層。

C. The model/prototype build with both materials showed an increased area in face of an increased temperature and therefore have potential to be used to shade building facades

由兩種材料構築的模型 / 原型顯示在溫度增加時，其表面積增加，因此具有應用在建築物遮光上的潛力。

D. The results show that the use of thermobimetal materials to cover building facades increases facade temperatures from 17 to 48 °C.

結果顯示，將熱雙金屬材料覆蓋建築物外牆，可使外牆溫度從 17 增加至 48°C。

Q16

Serendipita indica is a non-obligate endophytic fungus, known generally a plant growth and defence promoter with high potential to be used in agriculture. The work by Dias *et al.* (2020) published in Frontiers in Microbiology explores how carbon (C) availability in the growth medium during the free-living stage of *S. indica* can influence its phenotype. Further, this study shows that the growth conditions leave a legacy to the symbiosis stage and regulate *S. indica*'s potential to promote plant growth.

Serendipita indica 是一種非絕對內生性的真菌，常被應用在農業上，具有促進植物生長與防禦的功能。Dias *et al.*（2020）發表在 Frontiers in Microbiology 期刊的研究，探討 *S. indica* 在自由生長階段中，生長培養基中的碳（C）可用量會影響真菌的表徵。此研究進一步顯示，真菌的生長情況對於共生階段有深刻影響，並可調節 *S. indica* 促進植物生長的潛力。

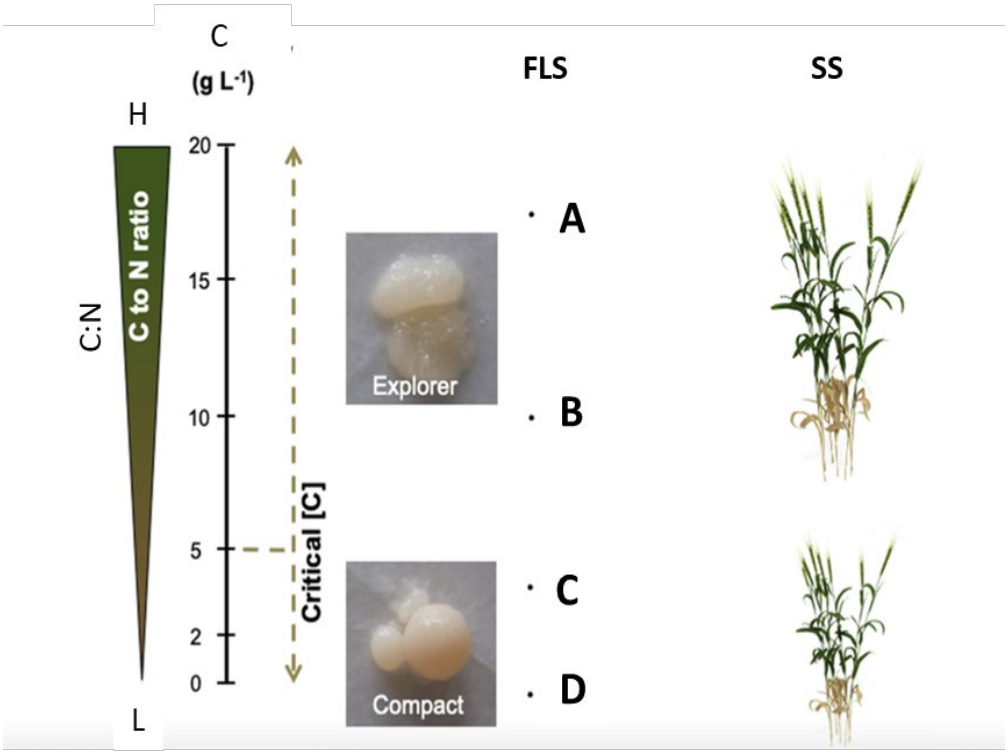


Figure 2 - Carbon (C) availability in the growth medium triggers nutrient imbalances which regulate *Serendipita indica*'s phenotype during the free-living stages and symbiosis stages (when later colonising the plant host). FLS: Free-living stage. SS: Symbiosis stage. L: Low. H: High, **A**: Glucose/sucrose is the main C source; casein and yeast extract are also the N sources, **B**: N and P scavenging, **C**: Peptone is the main C and N source, **D**: C scavenging.

圖 2 - 生長培養基中的碳（C）可用量會誘發營養失衡，進而在 *Serendipita indica* 自由生長階段與共生階段（當其進駐在宿主植物中）時，調節其表徵。FLS：自由生長階段；SS：共生階段；L：低；H：高；**A**：葡萄糖 / 蔗糖為主要碳源，而酪蛋白和酵母菌萃取物也是氮源；**B**：氮（N）和磷（P）清除；**C**：蛋白胨 主要碳源和氮源； **D**：碳（C）清除

Indicate whether each of the following statements is true (T) or false (F).
(*4 points, 1 point each correct answer*)
分別指出下列敘述的正確（T）或錯誤（F）（4 分，每個正確答案得 1 分）

A. *S. indica*'s compact phenotype develops when the fungus is submitted to carbon deprivation.
當 *S. indica* 處在碳喪失的培養下，會產生聚集型 (compact) 表徵

B. *S. indica*'s explorer phenotype displays higher capacity to decompose carbon containing molecules.
S. indica 的探勘型(explorer)表徵是較能分解含碳分子。

C. Under high C/N ratio in the growth medium, *S. indica* obtains the distinct nutrients from different sources.
在高的碳/氮比之生長培養基中，*S. indica* 從不同資源中分別取得其營養

D. The N availability during the free-living stage is likely to leave a legacy to the symbiosis stage, regulating *S. indica*'s potential to promote plant growth.
在自由生長階段的氮可用量，可能會對共生階段帶來深刻的影響，調節 *S. indica* 促進植物生長的潛力。

Q17

The work by Ramos *et al.* (2020) published in Planta explores how inoculation with the endophytic plant-growth promoting bacterium (PGPB) *Herbaspirillum seropedicae* can be a strategy for promoting growth, nutrient uptake (Table 1) and photosynthetic efficiency (**Figure 3**) in rice (*Oryza sativa*).

Ramos *et al.* (2020)發表在 Planta 期刊的研究，探討在水稻(*Oryza sativa*)中，接種內生性植物生長促進細菌（PGPB）*Herbaspirillum seropedicae* 之後，其如何成為一種促進生長、養分吸收（Table 1）以及光合作用效率（**Figure 3**）的策略。

Table 1 – Effect of *H. seropedicae* inoculation on rice shoot mineral contents. * Marks significant effects at p ≤ 0.05. Values are means ± SE (n = 5). **NI** – Non-inoculated, **I** - inoculated, **IE** - Inoculation effect, **Ma** – Macronutrients, **Mi** – Micronutrients

表 1 - *H. seropedicae* 接種在水稻莖後，對礦物質含量的影響。 * 表示具顯著影響 (p ≤ 0.05)。表中的數值為平均值 ± 標準偏差（n = 5）。**NI** – 未接種；**I** - 接種； **IE** - 接種的影響； **Ma** – 巨量營養素； **Mi** – 微量營養素。

	NI	**I**	**IE**
Ma (mg shoot^{-1})			
N *	15 ± 1	33 ± 1	+ 120%
P *	1 ± 0	6 ± 1	+350%
K *	14 ± 1	77 ± 1	+430%
Ca *	4 ± 1	11 ± 1	+150%
Mg *	3 ± 0	6 ± 1	+110%
S *	2 ± 0	6 ± 1	+300%
Mi (µg shoot^{-1})			
Fe *	323 ± 12	576 ± 19	+80%
B *	15 ± 1	50 ± 2	+230%
Cu *	10 ± 1	39 ± 0	+280%
Mn *	682 ± 28	465 ± 17	-30%
Mo *	0 ± 0	2 ± 0	+1020%
Ni *	11 ± 0	50 ± 1	+340%
Zn *	95 ± 13	3385 ± 193	+ 3460%

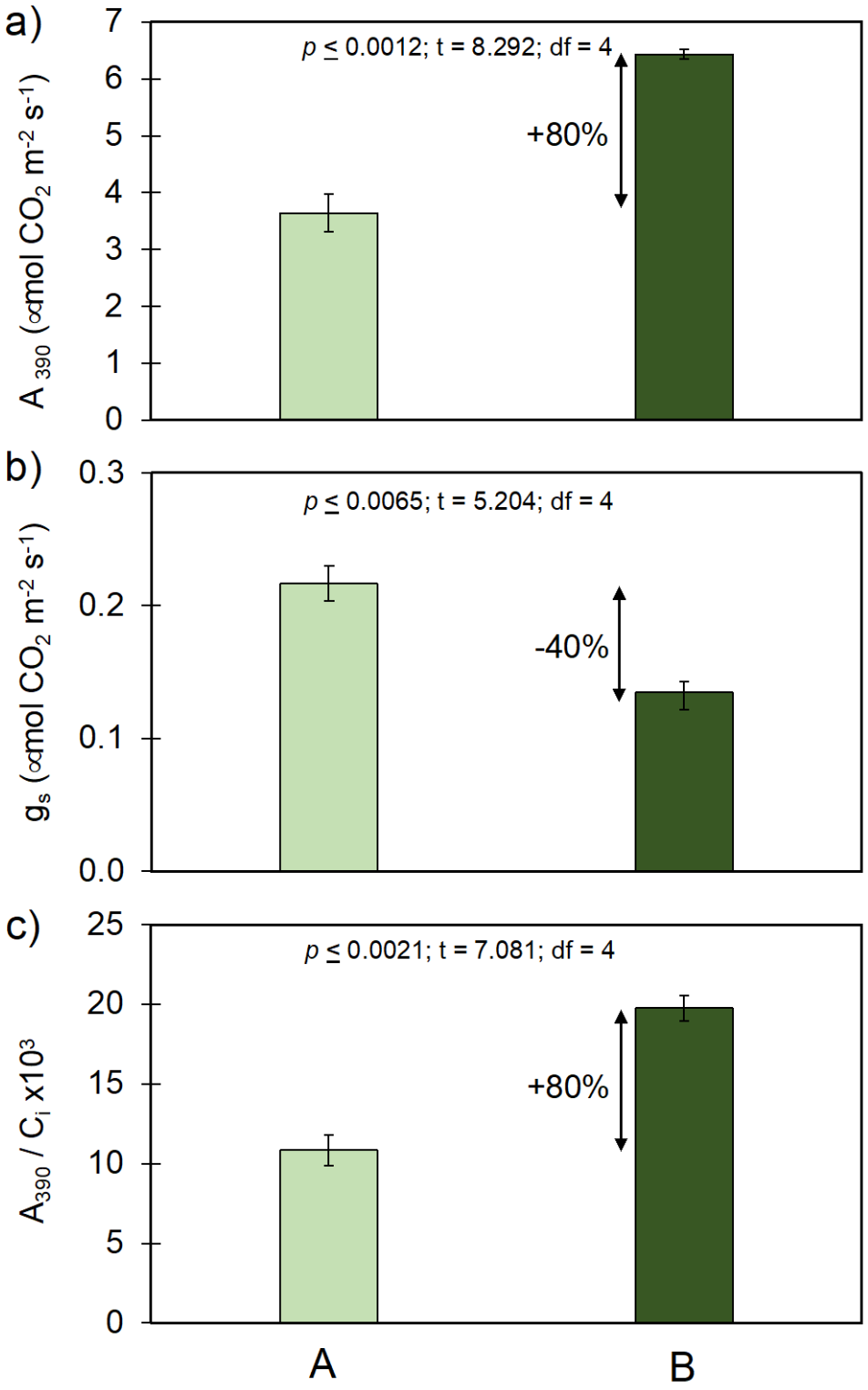


Figure 3 – Effect of *H. seropedicae* inoculation on rice photosynthetic activity. Photosynthetic activity was evaluated by determining (a) net carbon assimilation at ambient CO_2 concentrations (A_{390}), (b) stomatal conductance (g_s), and (c) carboxylation efficiency (A_{390}/Ci x 10^3). Bars are means ± SE (n = 5). A- Non-inoculated; B- Inoculated.

圖 3 - *H. seropedicae* 接種在水稻後之光合作用效率。光合作用是藉由(a) 在空氣中，不同 CO_2 濃度下之淨碳同化作用(A_{390})、(b) 氣孔導度 (g_s)、以及(c) 羧化作用 效率(A_{390}/Ci x 10^3)來決定。直條表示為平均值 ± 標準誤差(n = 5)。**A** – 未接種；**B** - 接種。

Indicate whether each of the following statements is true (T) or false (F).
(*4 points, 1 point each correct answer*)
分別指出下列敘述的正確（T）或錯誤（F） （**4** 分，每個正確答案得 **1** 分）

A. The effect of *H. seropedicae* inoculation on rice nutrient uptake was similar for all nutrients.
H. seropedicae 的接種對水稻養分吸收的影響，在所有營養素皆相似。

B. *H. seropedicae* inoculation resulted in higher stomatal resistance to CO_2 diffusion.
H. seropedicae 的接種導致氣孔對 CO_2 擴散的抗性較高。

C. For the same internal CO_2 concentration, rice plants inoculated with *H. seropedicae* assimilated less carbon.
在相同的內部 CO_2 濃度下，接種 *H. seropedicae* 的水稻之碳同化量較低。

D. Rice plants inoculated with *H. seropedicae* had a higher nutritional value for human diet.
對人類飲食營養量而言，接種 *H. seropedicae* 的水稻所含營養量較高。

Q18

Global wheat yield is affected by climatic variation, including water deficit and heatwaves. The work “Photoprotection and optimization of sucrose usage contribute to faster recovery of photosynthesis after water deficit at high temperatures in wheat” (Correia *et al.* 2020), presents results obtained with two wheat genotypes (Paragon and Sokoll) under water deficit and elevated temperature, in isolation or combination, and part of that results are used here. Table 1 shows plant water status estimated by leaf relative water content (LRWC) and leaf water potential (LWP), and Figure 4 the rate of net photosynthetic CO_2 assimilation, stomatal conductance and electron transport in the photochemical reactions of photosynthesis.

全球小麥產量受到氣候變遷的影響，包括缺水和熱浪侵襲。“在小麥中，光保護作用和蔗糖利用的最佳化有助於植物在經歷高溫且缺水的逆境之後，可較快速恢復其光合作用”由 (Correia *et al.* 2020) 所發表，此研究結果是從兩種小麥基因型(Paragon and Sokoll)處在缺水及高溫(單一條件或兩者並存)的情況下取得，在此使用其中部分結果。表 1 顯示植物含水情況，包括葉片相對含水量（LRWC）以及葉片的水勢（LWP）。圖 4 是淨光合 CO_2 同化作用率、氣孔導度、以及光合作用中光化學反應之電子傳遞。

Table 1 Leaf water status, and canopy temperature of Paragon and Sokoll wheat plants exposed to a combination of heat stress and water deficit and recovery from heat stress conditions.

表 1. 葉片含水情況、以及 Paragon and Sokoll 兩種基因型小麥處在熱逆境且缺水情況下之植株頂層的溫度，以及從熱逆境情況恢復的情形。

		Genotype	LRWC (% H_2O)	LWP (MPa)	Tcanopy (°C)
25°C	WW	Paragon	90.11 ± 8.82 c	−0.50 ± 0.08 c	26.87 ± 0.65 a
		Sokoll	90.20 ± 1.73 c	−0.81 ± 0.12 bc	26.33 ± 0.19 a
	WD	Paragon	68.24 ± 12.45 b	−1.16 ± 0.16 ab	28.79 ± 0.62 b
		Sokoll	31.89 ± 8.87 a	−1.39 ± 0.10 a	27.89 ± 1.10 b
38°C	WW	Paragon	78.60 ± 8.47 bc	−0.82 ± 0.06 bc	35.04 ± 0.98 c
		Sokoll	80.38 ± 4.74 bc	−0.77 ± 0.09 bc	33.37 ± 0.40 d
	WD	Paragon	39.60 ± 17.71 a	−1.30 ± 0.59 a	36.95 ± 0.74 e
		Sokoll	43.06 ± 26.64 a	−1.55 ± 0.58 a	37.52 ± 0.47 e
Recovery	RWW 38°C	Paragon	86.46 ± 1.36 c	−0.76 ± 0.03 bc	25.71 ± 0.3 a
		Sokoll	94.91 ± 4.82 cd	−0.74 ± 0.05 bc	25.58 ± 0.4 a
	RWD 38°C	Paragon	90.83 ± 3.42 c	−0.72 ± 0.1 bc	26.33 ± 0.44 a
		Sokoll	78.31 ± 21.18 bc	−0.98 ± 0.16 ab	26.43 ± 0.21 a

***Note*:** Plants were grown for 3 weeks, then exposed to heat stress (38ºC vs. control, 25ºC), water deficit (WD vs. well-watered WW) and re-watered at control temperature (25ºC) after heat stress conditions (RWW38ºC and RWD38ºC). Values are means ± SD (n = 5 biological replicates). Different letters denote statistically significant differences between treatments (Duncan analysis, $p < 0.05$). Abbreviations: LRWC, leaf relative water content; LWP, leaf water potential; Tcanopy, canopy temperature.

注意: 植株生長 3 週後，分別以熱逆境(38ºC vs. 控制組 25ºC)、缺水(WD vs. 充分澆水 WW) 、以及在熱逆境之後，在控制組溫度(25ºC)下再度澆水 (RWW38ºC and RWD38ºC) 處理。數值為平均值±標準偏差(n = 5)。不同的字母代表處理之間有統計上的顯著差異(鄧肯統計分析， $p < 0.05$)。縮寫: LRWC, 葉片相對水含量；LWP, 葉片水勢； Tcanopy 頂層溫度。

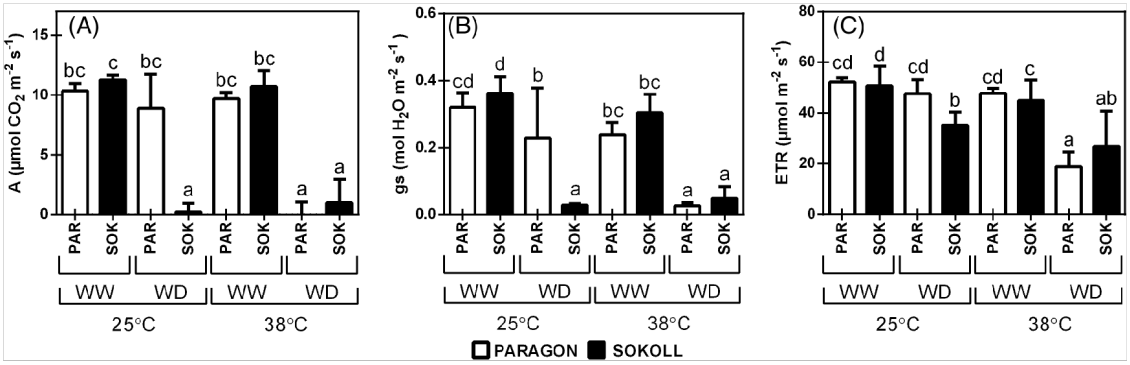


Figure 4 - Steady-state photosynthesis of Paragon (PAR) and Sokoll (SOK) wheat plants exposed to a combination of heat stress and water deficit. (A) Net CO_2 assimilation, (B) stomatal conductance (gs) and (C) electron transport rate (ETR) were measured at growth light and ambient CO_2 in fully expanded leaves of wheat 3-week-old plants under well-watered (WW) and water deficit (WD) conditions and exposed to control (25ºC) and heat stress conditions (38ºC). Values are means ± SD (n = 5 biological replicates). Different letters denote statistically significant differences between treatments (Duncan analysis, $p < 0.05$)

圖 4 - Paragon（PAR）and Sokoll（SOK）小麥植株處在熱逆境且缺水的光合作用穩定狀態。以三週大的植株，給予充分澆水（WW）及缺水（WD），並且處在控制組溫度（25ºC）及熱逆境（38ºC），在相同生長光度及空氣 CO_2 條件之下，分別測量完全平展葉片的（A）淨光合 CO_2 同化作用、（B）氣孔導度（gs）、以及（C）電子傳遞速率（ETR）。數值為平均值±標準偏差（n = 5）。不同的字母代表處理之間有統計上的顯著差異（鄧肯統計分析，$p < 0.05$）。

Based on the text, **Table 1** and **Figure 4**, decide if the following sentences are **true (T) or false (F).** (*4 points, 1 point each correct answer*)
根據文字說明、**表 1** 以及**圖 4**，判斷下列敘述的**正確（T）或錯誤（F）**
（4 分，每個正確答案得 1 分）

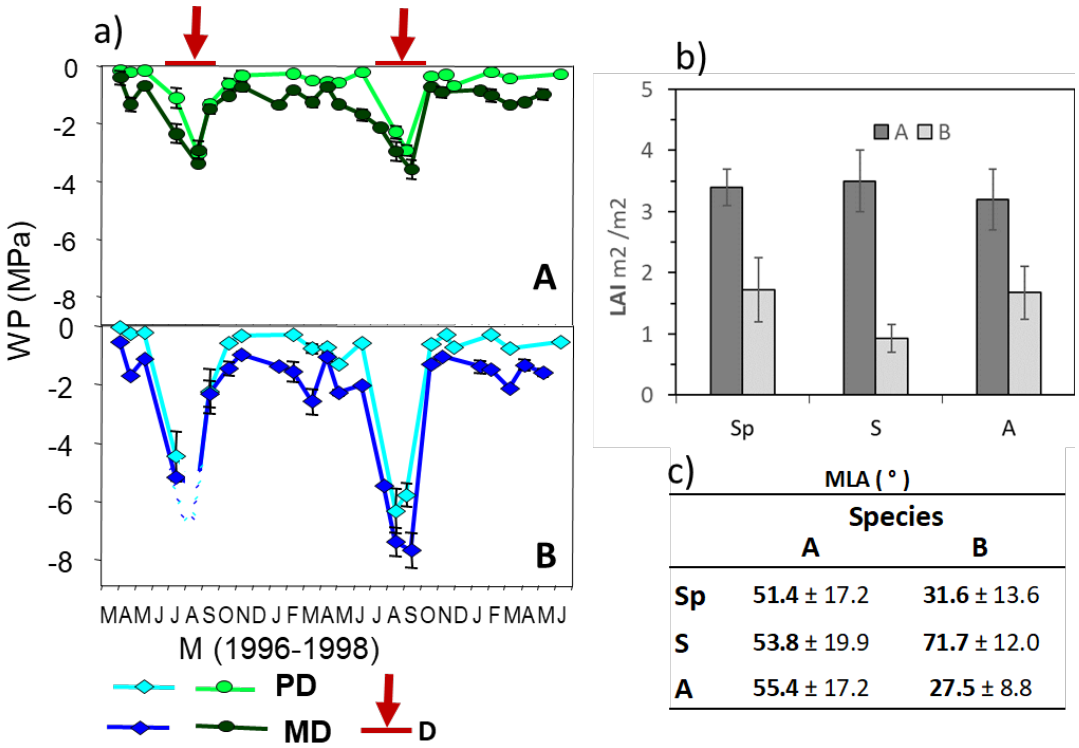
A. Plant water deficit (WD) conditions increased more the driving force for water movement through the plant in wheat genotype Paragon than in genotype Sokoll.
在 Paragon 基因型小麥中，植物缺水(WD)的情況所增加水移動的驅動力，較 Sokoll 基因型多。

B. Under plant well-watered (WW) conditions, wheat genotype Paragon will avoid cellular heat stress better than genotype Sokoll.
在充分澆水(WW)的情況下，Paragon 基因型小麥比 Sokoll 基因型 更能避免細胞中的熱逆境。

C. Under plant water deficit (WD) conditions, without heat stress, net photosynthesis of genotype Paragon is maintained, as opposed to Sokoll, and the higher capacity to conserve cellular hydration observed in genotype Paragon can contribute to this.
在缺水(WD)情況下，且沒有熱逆境，相較於 Sokoll 基因型，Paragon 基因型的淨光合作用維持穩定，進而導致 Paragon 基因型的細胞保水能力較高。

D. With the increasing occurrence of heatwaves and drought in Mediterranean region a relevant decrease is expected in vegetative growth of wheat genotypes Paragon and Sokoll, caused by limitations in net photosynthetic rate at photochemical level and CO_2 assimilation.
隨著地中海地區熱浪及乾旱發生漸增，Paragon 和 Sokoll 基因型小麥的營養生長預期會對應地下降，這是由於在光化學含量以及碳同化作用中，淨光合作用率的限制。

Q19
The plant community of the Mediterranean maquis comprises mainly two functional groups: the evergreen sclerophylls and the drought semi-deciduous species, which differ in their physiological and structural adaptations to environmental stress factors. **Figure 5** shows the seasonal variation of leaf water potential (WP) at pre-dawn and midday (a), Leaf Area Index (LAI) (b) and leaf angles relative to the horizontal (MLA) (c) in different seasons for evergreen sclerophylls and drought semi-deciduous species.
地中海密林的植物群集主要由兩個功能群所組成：常綠耐旱型與旱生半落葉型物種。這兩類在生理與構造上，對外界逆境因子之適應有所差異。**圖 5** 顯示在不同季節中，常綠耐旱型與旱生半落葉型物種之測量數據：（a）在黎明前和中午的葉片水勢（WP）、（b）葉面積指數（LAI）、以及（c）葉片與水平面的相對角度（MLA）。



c)

MLA (°)	Species A	Species B
Sp	51.4 ± 17.2	31.6 ± 13.6
S	53.8 ± 19.9	71.7 ± 12.0
A	55.4 ± 17.2	27.5 ± 8.8

Figure 5. A, B – Two different species A and B; **a) WP** - Leaf water potential, **PD** - Pre-dawn water potential, **MD** - Midday water potential, **D** - Drought period in summer **b) LAI** - Leaf area index (m^2 m^{-2}), **c) MLA** - Mean leaf angle (° from the horizon). **Sp** - Spring, **S** - summer, **A** - autumn.

圖 5. A, B – 兩物種 A and B；**a) WP** – 葉片水勢；**PD** – 黎明前水勢； **MD** – 中午的水勢； **D** – 夏季乾旱期。**b) LAI** – 葉面積指數 (m^2 m^{-2})。 **c) MLA** – 平均葉片角度 (° 從水平面的角度)。**Sp** – 春季；**S** –夏季；**A** –秋季。

Indicate whether each of the following statements is true (T) or false (F).
(4 points, 1 point each correct answer)
分別指出下列敘述的正確（T）或錯誤（F）（4 分，每個正確答案得 1 分）

A. Species A is considered a drought semi-deciduous species since it partially avoid stress through higher water potentials.
A 物種是旱生半落葉型，因為它可藉由較高的水勢而局部地避免逆境。

B. In species B the pronounced leaf shedding during summer, which may reach 50%, involves some advantages for water economy, by reducing the transpiring surface during the period of maximum water stress
B 物種中，在夏季有高達 50%的明顯落葉情形，此涉及某些水分經濟的優勢，亦即在水分逆境最高時期，藉由落葉以降低蒸散面積。

C. Predawn water potentials decline below -6 MPa in species B due to their deep and well-developed root system which can reach water at depth.
B 物種的黎明前水勢下降至低於-6 MPa，是由於其深入且發達的根系，可獲得地下深層的水分。

D. Species B exhibits pronounced structural changes in leaf architectures, reducing the interception of excessive radiation during the summer drought period, avoiding photoinhibition.
B 物種在葉的立體結構上呈現明顯構造上的變化，在夏季乾旱時期，降低過量輻射的攔截，而避免光抑制。

Q20

Lichen species differ in their tolerance to environmental nitrogen availability, with some species tolerating high atmospheric concentrations of ammonia (NH_3) and others disappearing at low ammonia concentrations.
地衣物種對環境中氮可用量之耐受程度有差異。有些物種可耐受大氣中高濃度的氨氣（NH_3），有些物種則在氨濃度低時，會消失不見。

Chlorophyll *a* fluorescence is a parameter commonly used as a vitality index of photosynthetic organisms, providing information about the physiological performance of the organism. Approximately, this index varies between 0.8 (optimal value = healthy conditions) and 0 (high stress conditions = complete inhibition of the system). It is commonly used to investigate lichens' response to nitrogen excess.
葉綠素 ***a*** 的螢光，此參數常被當作光合作用生物的活力指數，其可提供有關該生物的生理表現資訊。大致而言，此指數變化在 0.8（最佳值 = 健康狀態）and 0（高逆境狀態 = 系統完全受抑制）之間。它常被應用在地衣對氮過量的反應。

Consider **Species1**, a nitrogen-tolerant lichen species, and **Species2**, a nitrogen-sensitive one.
物種 1 是一種氮耐受的地衣，**物種 2** 則是氮敏感。

Figure 6 shows the frequency of the two species along a gradient of ammonia; **Figure 7** shows the physiological performance of the two species indicated by the vitality index.
圖 6 顯示兩個物種在不同氮濃度下的出現頻率；**圖 7** 以活力指數來顯示兩個物種的生理表現。

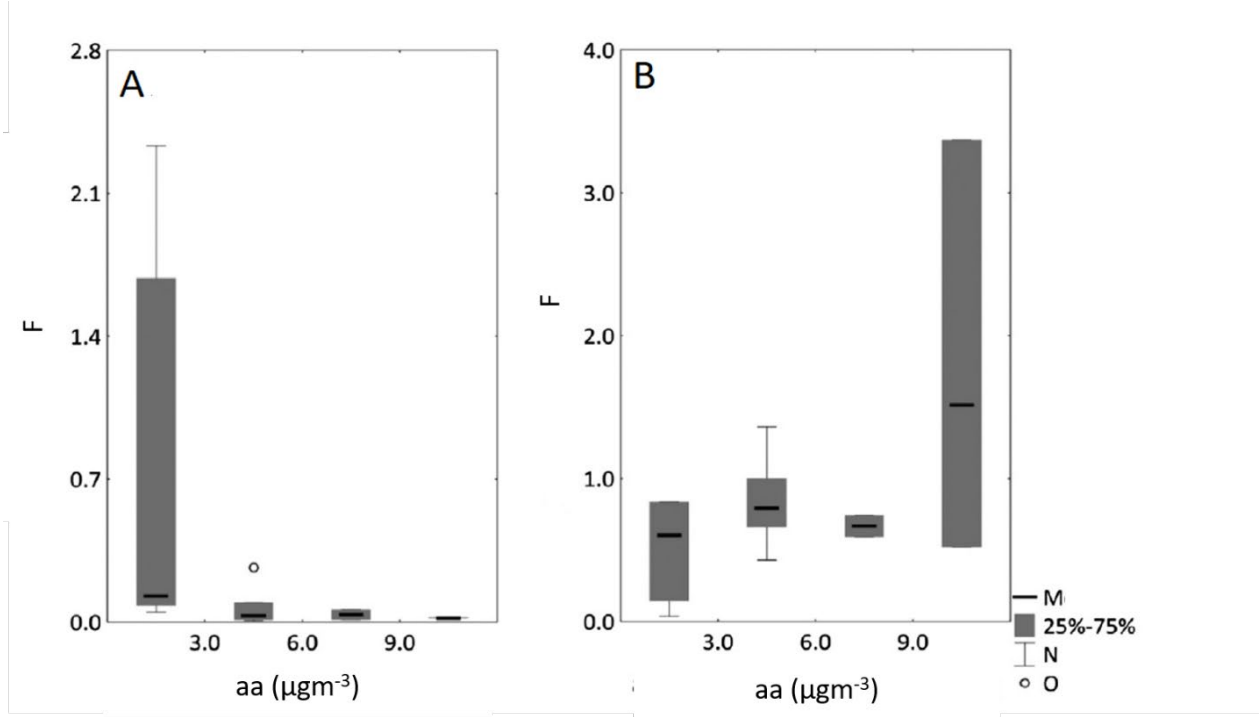


Figure 6. F = Frequency; aa = atmospheric ammonia; M = median; N = Non-Outlier Range; O = Outliers
圖 6. F = 頻率；aa = 大氣中的氨量； M = 中位數； N = 非離群值的範圍； O = 離群值

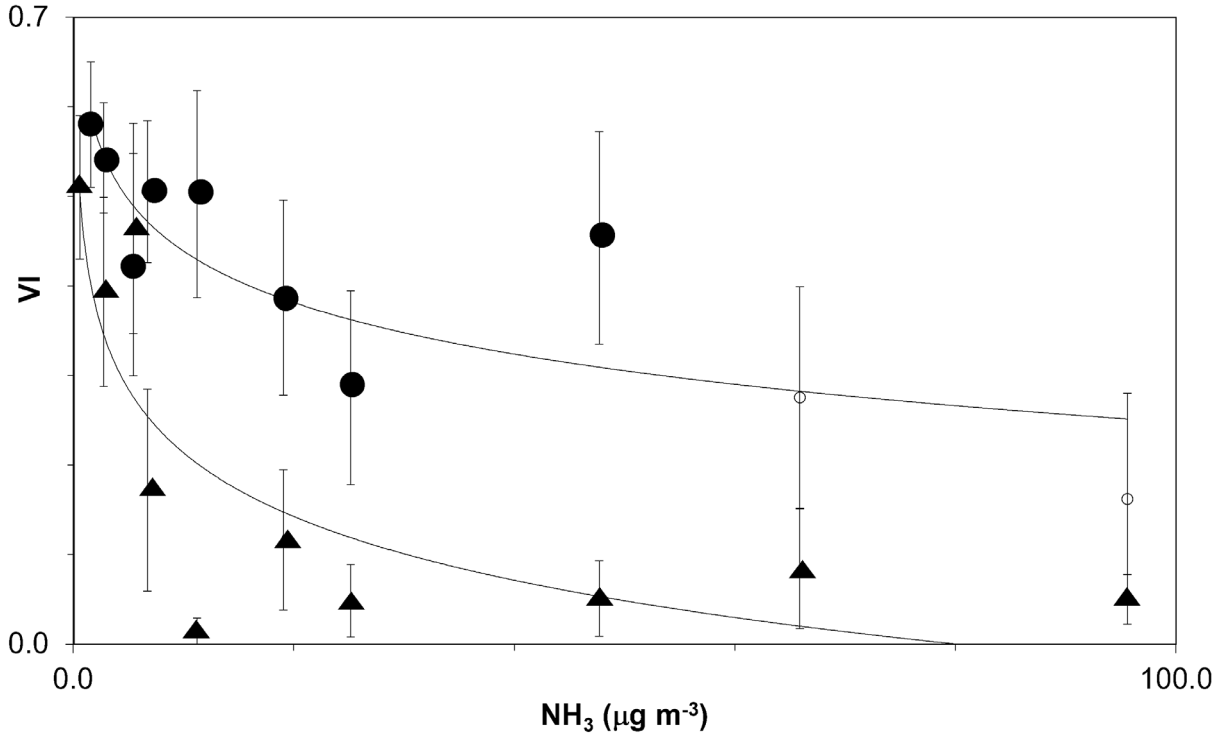


Figure 7. VI = Vitality Index

圖 7. VI = 活力指數

Lichens have several physiological mechanisms of nitrogen tolerance. One of them is to store excess nitrogen in non-toxic forms, like chitin, inside their tissue. Chitin can incorporate nitrogen in excess since nitrogen represents around 6.3% of chitin's mass.

地衣有許多氮耐受的生理機制。其中之一是將過多的氮以非毒性如幾丁質的形式，而儲存在其組織中。幾丁質能夠與過多的氮結合，因為氮在幾丁質含量中約佔 6.3%。

Table 1 shows two values obtained for the concentration of chitin and nitrogen in the tissue of the two species.

表 1 顯示兩物種組織中的幾丁質和氮的濃度。

	Chitin (mg g^{-1})	Total N (mg g^{-1})
Value 1	3.40 ± 1.42	12.34
Value 2	20.74 ± 3	23.37

Q20.1

Select the correct answer scheme to associate each parameter to **Species1 or Species2**.
(*5 points, 1 point each correct answer*)

選擇正確的答案組合，來將每個參數對應至**物種 1 或物種 2**（**5 分，每個正確答案得 1 分**）

	Species 1 物種 1	Species 2 物種 2
Graph A, fig. 6 圖 6 中的 A 小圖		
Graph B, fig. 6 圖 6 中的 B 小圖		
Circle, fig. 7 圖 7 中的圓圈		
Value 1, tab. 1 表 1 中的 Value 1		
Value 2, tab. 1 表 1 中的 Value 2		

Q20.2

Indicate whether each of the following statements is true (T) or false (F).
(*4 points, 1 point each correct answer*)

分別指出下列敘述的正確（T）或錯誤（F）（4 分，每個正確答案得 1 分）

A. Increased NH_3 promotes an enhanced physiological performance in one of the species
氨氣增加可促使其中一個物種的生理表現增強。

B. Intermediate values of ammonia concentration increase lichen frequency.
氨濃度的中間值會增加地衣頻率。

C. Nitrogen pollution affects competition dynamics among lichen species.
氮污染會影響地衣物種間的競爭動態。

D. The difference in the nitrogen content in the two species is exclusively due to the difference in chitin content
兩物種的氮含量差異純粹是導因自幾丁質含量的不同。

Q21

Figure 8 shows that some plants require a prolonged cold period (vernalization) as experienced during winter (W), before they will flower (**Fig. A**). The flowering time is controlled by a "well characterized" epigenetic mechanism that targets FLOWERING LOCUS C (FLC). This FLC encodes a MADS box transcription factor that binds and represses the FT gene. Thus, the mutant *flc* is characterized by a precocious flowering in autumn (A) (**Fig. B**). The molecular mechanisms by which the FLC control the flowering are illustrated in **Fig. C**.

圖 8 顯示有些植物需要一段長時間的寒冷期（春化作用）當作經歷過冬季（W），才能順利開花（**Fig.A**）。此開花時期是受到表觀遺傳機制的控制，這個特性已被清楚描述的機制是作用在開花調控基因（FLC）上。此 FLC 編碼成 MADS box 轉錄因子，然後與 FT 基因鍵結並抑制其表現。因此，找到 *flc* 突變株，其會在秋季（A）提早開花（**Fig.B**）。FLC 調控開花的分子機制如 **Fig. C** 所示。

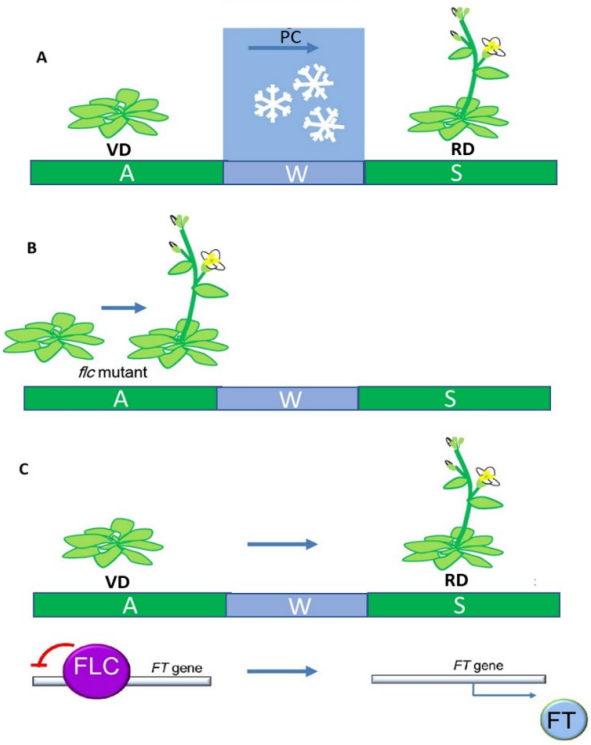


Figure 8. **A** - Autumn, **W** – Winter, **S** –Spring, **VD** – Vegetative development, **RD** – Reproductive development, **PC** – Prolonged cold.

圖 8. A – 秋季；**W** – 冬季； **S** –春季； **VD** – 營養發育； **RD** – 生殖發育； **PC** – 長時間寒冷

Indicate if each of the following statements is true (T) or false (F).
(*5 points, 1 point each correct answer*)
分別指出下列敘述的正確（**T**）或錯誤（**F**）（**5 分，每個正確答案得 1 分**）

A. FLC is an inhibitor of flowering
FLC 是一種開花的抑制劑

B. Transcription of FT gene is activated by FLC binding.
FT 基因的轉錄可因 FLC 的鍵結而被活化

C. FT is mainly expressed in vegetative plant tissues in autumn.
FT 的表現主要是在秋季時的營養組織中。

D. The transcriptional activity of FLC is influenceed by a cold-sensitive epigenetic process
FLC 的轉錄活化作用受到一個有賴於寒冷之表觀遺傳過程影響

E. Cold induces the silencing of FLC, allowing FT to be expressed and induce flowering.
寒冷誘使 FLC 靜默，讓 FT 表現並誘導開花。

Animal Anatomy and Physiology 動物解剖及生理學

Q22

Phylum Nematoda (Roundworms) has approximately 12 000 known species, although estimates point out the existence of 500 000. They live in all habitats, from aquatic to terrestrial, from tropics to polar regions, from mountain tops to the depths of the sea. One of the most known Nematoda is *Ascaris lumbricoides*, a human parasite causing discomfort, disease and in severe cases death. A female *Ascaris* may lay 200 000 eggs a day. Females' reproductive system consists of a paired structure with two very long tubes coiled inside the organism, that can be differentiated in three regions: ovary, oviduct, and uterus with increasing diameter (**Figure 1**). In cross-section, these regions present different aspects (**Figure 2**).

線蟲動物門目前已知約 12,000 種，但推估實際上可能超過 500,000 種。線蟲的棲地分布極廣，從水中到陸地，從熱帶到極地，從高山到深海，都有線蟲的分布。最廣為人知的線蟲就是蛔蟲（Ascaris lumbricoides），蛔蟲是造成人類不適及疾病，嚴重時甚至會致死的寄生蟲。一般來說，一隻雌蛔蟲一天可以產下 200,000 個卵，雌性的生殖系統為體內成對的彎曲長管構造，依管徑的增大可分為卵巢（ovary），輸卵管（oviduct）及子宮（uterus）三個部位（**圖一**）。橫切面圖顯示這些部位的位置（**圖二**）。

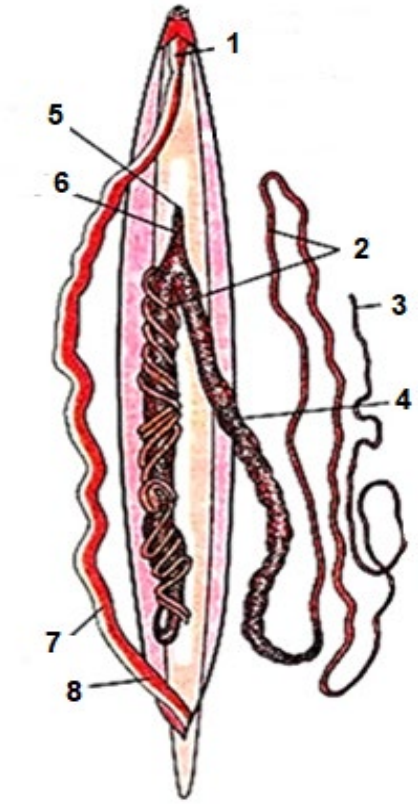


Figure 1. Structure of a Nematoda.
圖一、線蟲的構造
1.Pharynx, 2. Oviduct, 3. Ovary, 4. Uterus, 5. Vulva, 6.Vagina, 7. Intestine, 8. Rectum
1.咽 2.輸卵管 3.卵巢 4.子宮 5.外陰 6.陰道 7.小腸 8.直腸

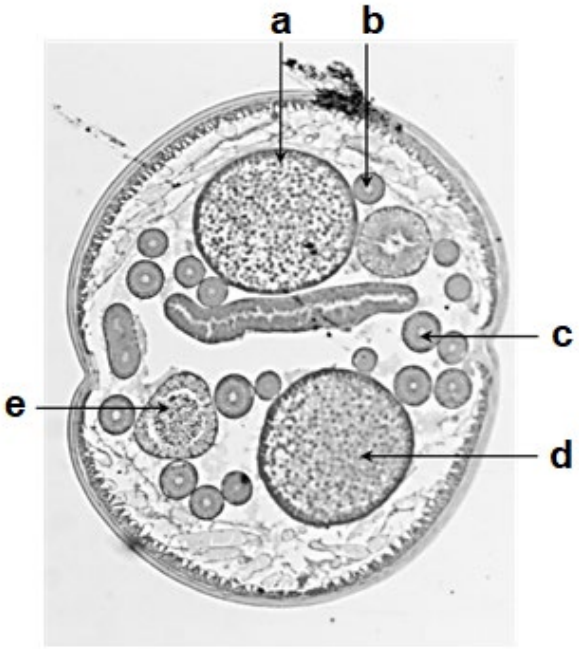


Figure 2. Cross section of *Ascaris lumbricoides*.
圖二、蛔蟲的橫切面圖

Indicate whether each of the following statements is true (T) or false (F).
(4 points, 1 point each correct answer)
判別下列哪些為正確（T）或錯誤（F）的敘述 （共四分，一題一分）

A. The uterus is full of eggs because it is where they are collected before spawning.
子宮是產卵前收集卵的部位，因此子宮內載滿了卵

B. The letters b and c correspond to the ovary, e to the oviduct, a and d to the uterus.
b 和 c 對應的是卵巢，e 是指輸卵管，a 和 d 對應的是子宮。

C. The presence of several sections of the same region of the reproductive system indicates that in this specific individual the reproductive system is haggard.
在生殖系統中相同部位呈現多個組織切面，顯示此雌性個體的生殖系統已萎縮

D. The letters b and c correspond to the uterus, e to the oviduct, a and d to the ovary
b 和 c 都是指子宮，e 是指輸卵管，a 和 d 指的是卵巢。

Q23

Circulatory systems of two Fishes (**P and Q**) are shown.
兩種魚類（**P 和 Q**）的循環系統如下圖所示

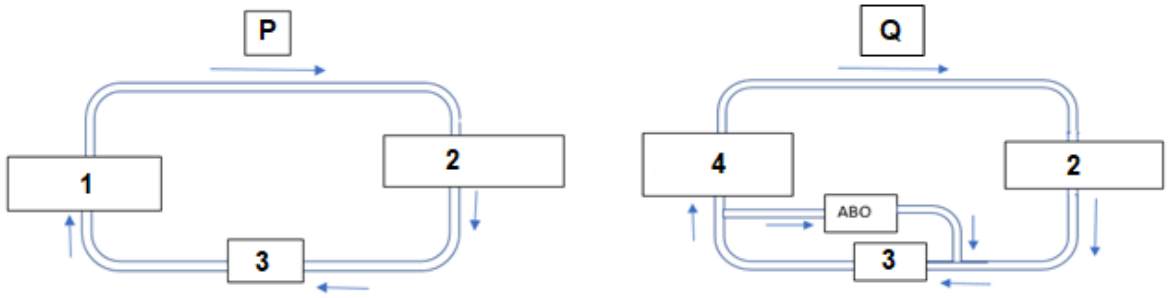


Figure 1. Gills; 2. Systemic Tissues; 3. Heart; 4. Partially functional gills; ABO: Air Breathing Organ
圖 1. 1.鰓；2. 身體組織；3. 心臟；4. 具部分功能的鰓； ABO: 呼吸空氣器官

Q23.1
Observe them carefully and mark the following statements as **true (T) or false (F).**
(4 points, 1 point each correct answer)
仔細觀察上圖，並判別下列哪些為正確（T）或錯誤（F）的敘述 （共四分，一題一分）

A. Oxygen saturation levels of blood reaching heart in P is higher than that in Q.
送達 P 魚心臟的血液中的氧氣的飽和度較 Q 魚高

B. Under highly anoxic water body conditions, fish Q will have survival advantage over P.
在高度缺氧的水體中，Q 較 P 更具生存優勢

C. Delivery of oxygenated blood to tissues is less in P as compared to Q.
P 將充氧血運送到周邊組織的能力較 Q 為差

D. Emptying of oxygenated blood from ABO to systemic arteries would improve the delivery of oxygen to body parts.
將充氧血從 ABO 送到體動脈中會增強氧氣輸送到身體部位

Q23.2

The heart tissue or myocardium of fishes such as P and Q can be of two types. In many bony fishes, it is entirely spongy and absorbs oxygen from the blood flowing through heart during circulation. In many other fishes, myocardium is compact (non-spongy) and oxygen is supplied to heart tissue via coronary artery. (Refer to the figure 1.)

以 P，Q 為例，魚的心臟組織或心肌層可分成兩種。多數硬骨魚的心臟組織呈現海綿狀，其氧氣是由經循環系統送至心臟的血液所供給；而其他多數魚類的心肌為緻密排列（非海綿狀），其氧氣主要是透過冠狀動脈供給（請參考圖一）。

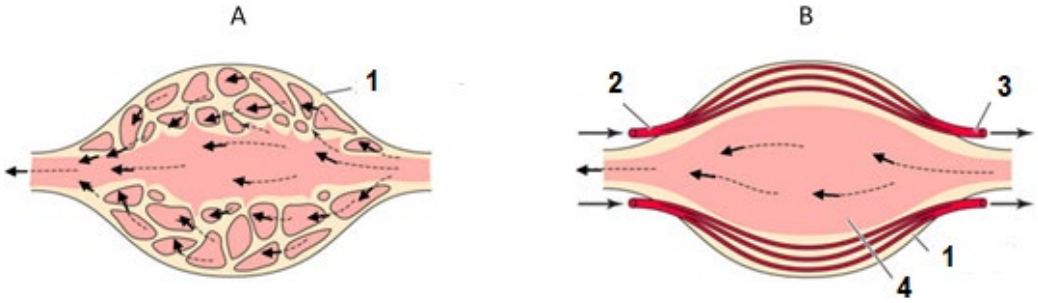


Figure 1. A. Spongy myocardium; B. Compact myocardium; 1. Myocardium; 2. Coronary artery; 3. Coronary vein; 4. Ventricular lumen. (*Reference: Animal Physiology by Hill, Wyse and Anderson.(3rd Edition)).*

圖一 A. 海綿狀心肌 B 緻密排列的心肌 1.心肌層 2 冠狀動脈 3 冠狀靜脈 4 心室管腔

Mark the statements as true (T) or false (F). (*4 points, 1 point each correct answer*)

判別下列哪些為正確（T）或錯誤（F）的敘述（共四分，一題一分）

A. Exercise performance or migratory abilities of fish with spongy myocardium will be limited as compared to a fish with compact myocardium.
魚類的海綿狀心肌組織相較緻密排列心肌組織，具海綿狀心肌的魚其運動或者移動能力會比較受限

B. For an active fish having spongy myocardium, circulatory system as found in fish Q is more advantageous than the one found in fish P.
若活動中的魚其心肌組織為海綿狀，Q 魚的循環系統會較 P 魚的循環系統有利

C. Circulatory system P is more advantageous for a fish with compact myocardium tissue over a fish with spongy myocardium.
循環系統 P 對於具有緻密心肌的魚而言，比具海綿狀心肌的魚有優勢

D. For a fish with compact myocardium, the extent of delivery to the tissues will be the same irrespective of the type of circulatory system.
對於具有緻密心肌的魚而言，無論循環系統的類型如何，向周邊組織輸送的量都是相同的

Q24

When simultaneous deletion of two genes leads to cell death, deleting each gene individually does not. This is known as synthetic lethality. Synthetic lethal compounds have been screened in order to identify new drugs for cancer treatment, namely for breast cancer, where targeting different DNA repair pathways is a promising strategy for BRCA1/2 mutated tumors.

同時剔除兩個基因會導致細胞的死亡，但剔除任一個則不會導致細胞死亡的現象稱合成致死(synthetic lethality)。最近科學家大量篩選可造成合成致死的藥物以治療乳癌；其中對 BRCA1/2 突變所致的乳癌，針對不同的 DNA 修復路徑是具有前景的治療策略。

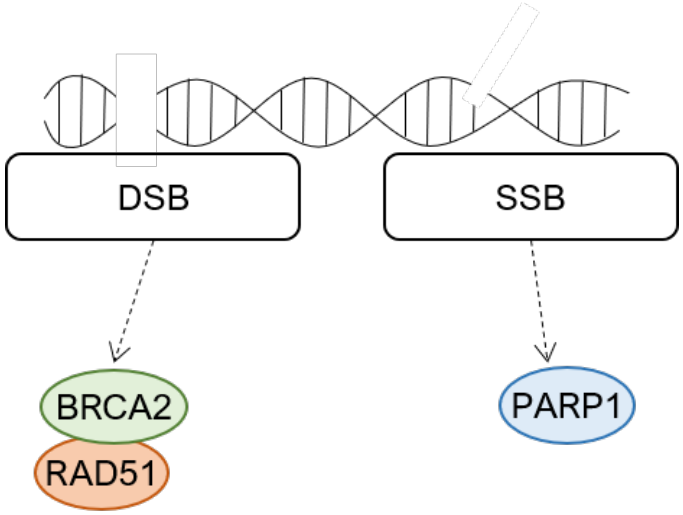


Figure 1. DNA repair. **DSB** – double strand break; **SSB** – single strand break.

圖一. 1. DNA 修復。**DSB**：雙股斷裂。**SSB**：單股斷裂

Indicate whether each of the following statements are true (T) or false (F).
(*4 points, 1 point each correct answer*)

判別下列哪些為正確（T）或錯誤（F）的敘述（共四分，一題一分）

A. Synthetic lethality is not a promising strategy since treatment with the identified drug may cause death of both normal and tumor cells.
合成致死並非是有前景的癌症治療策略，因為投予此類藥物可能同時造成正常細胞和癌細胞的死亡。

B. Using an inhibitor against BRCA2 is not a successful strategy to target BRCA2-deficient tumors.
利用 BRCA2 的抑制劑治療 BRCA2 缺損的乳癌不會成功

C. Inhibiting RAD51 is a possible therapeutic approach to target BRCA2 deficient tumors.
抑制 RAD51 是一種針對 BRCA2 缺損乳癌的可能治療方法

D. The use of PARP inhibitors is a synthetic lethal approach to target BRCA2 deficient tumors.
使用 PARP 抑制劑，可視作一種針對 BRCA2 缺陷乳癌的合成致死方法

Q25

Iron is an essential nutrient for the vast majority of organisms, participating in several different reactions and acting as a co-factor of many proteins. However, when not properly regulated and stored, free iron can also be detrimental because…

鐵是大部分生物的必要養分，它參與多種不同的反應，而且可以當很多蛋白質的輔因子。然而，若無適當地調節與儲存，游離態的鐵也會造成傷害，其原因為……

Indicate whether each of the following statements are true (T) or false (F).

(*4 points, 1 point each correct answer*)

判別下列哪些為正確（T）或錯誤（F）的敘述（共四分，一題一分）

A. It alters redox-state mitochondrial proteins, promoting their reduction.
游離態的鐵會影響粒線體蛋白的氧化還原狀態，會促進還原反應

B. It promotes iron intake from food.
游離態的鐵會促進從食物中攝取鐵

C. It leads to the oxidation of different macromolecules, such as DNA, proteins and lipids.
游離態的鐵會促進多種大分子，例如 DNA，蛋白質和脂質的氧化反應。

D. It promotes tissue healing and regeneration.
游離態的鐵可促進組織癒合和再生。

Q26

The transcription factor p53 is a protein that regulates a variety of pathways including cell proliferation, DNA repair, cell death and metabolism. In an experiment, hepatocytes isolated from a healthy donor were cultured *in vitro* and the gene encoding p53 (*TP53*) was deleted. The impact on glycolysis and gluconeogenesis was assessed by Real Time quantitative PCR (RT-qPCR), comparing the wild type cell line (wt) and the p53 deleted cell line (ko).

轉錄因子 p53 可以調節多種不同的路徑，例如細胞增生，DNA 修復，細胞死亡及代謝。在本實驗中，從健康受試者體內取出正常的肝細胞，進行體外培養後，剔除編碼 p53 的基因（TP53），而後利用即時定量聚合酶連鎖反應(real-time quantitative PCR, RT-qPCR)去比較野生型細胞(wt)跟 p53 基因剔除細胞（ko），以評測其對糖解作用（glycolysis）及糖質新生作用中（gluconeogenesis）的影響。

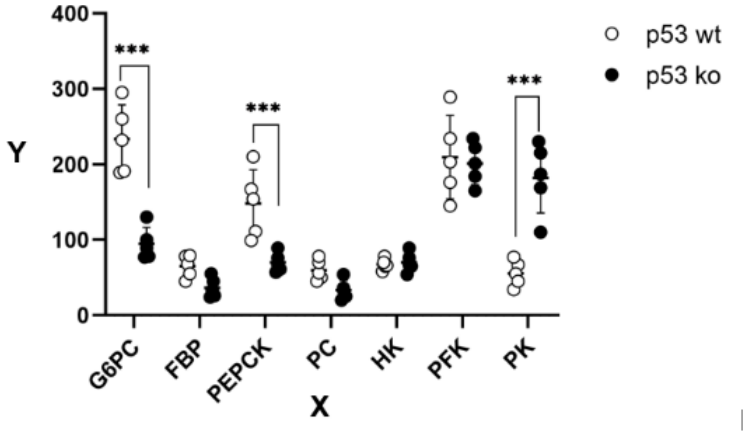


Figure 1 mRNA expression of different genes involved in glucose metabolism. Y – mRNA expression; X- Housekeeping genes. G6PC – glucose-6-phosphatase; FBP – Fructose - fructose-1,6-bisphosphatase; PEPCK – PEP carboxylkinase; PC – pyruvate carboxylase; HK – hexokinase; PFK – phosphofructokinase; PK - pyruvate kinase.

圖一、與葡萄糖代謝有關的基因其 mRNA 的表現。Y 軸為 mRNA 的表現，X 軸為恆常基因(housekeeping gene)。G6PC: glucose-6-phosphatase，葡萄糖-6-磷酸酶；FBP: Fructose - fructose-1,6-bisphosphatase，果糖 1,6-雙磷酸酶；PEPCK: PEP carboxylkinase，磷酸烯醇丙酮酸羧化激酶; PC: pyruvate carboxylase，丙酮酸羧化酶；HK: hexokinase，六碳糖激酶；PFK: phosphofructokinase，磷酸化果糖激酶；PK: pyruvate kinase，丙酮酸激酶。

Indicate whether each of the following statements are true (T) or false (F).
(4 points, 1 point each correct answer)

判別下列哪些為正確（T）或錯誤（F）的敘述 （共四分，一題一分）

A. Analysis of the graph suggests that p53 promotes glycolysis.
結果顯示 p53 會促進糖解作用

B. Glucose-6-phosphatase expression is regulated by p53.
Glucose-6-phosphatase 的表現會受到 p53 調控

C. In the absence of p53 gluconeogenesis is downregulated.
P53 缺乏時，糖質新生作用會調降

D. There is no effect of *TP53* deletion on either glycolysis or gluconeogenesis.
TP53 基因剔除對糖解作用或糖質新生作用都不會有影響

Q27

Under normal feeding conditions, our glucose supply is obtained from food intake. After food has been absorbed and subsequently stored, our body initiates a starvation period, initially referred as postabsorptive state. If food deprivation is extended, we enter a prolonged fasting period that can ultimately lead to death. At each stage, glucose is obtained via different strategies that are sequentially put in place.

在正常飲食狀態下，我們透過攝食來獲得葡萄糖的供應。當食物被吸收及儲存後，身體就開始進入飢餓時期，稱為後吸收狀態。然而，當食物持續匱乏時，人體就會進入最終可導致死亡的延長禁食時期。在各個時期，會通過不同的策略而獲得葡萄糖。

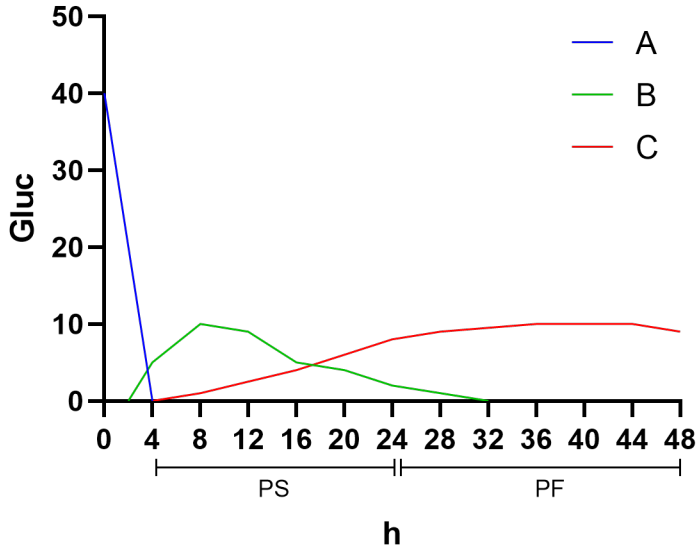


Figure 1 Usage of glucose during different phases of starvation. A, B and C indicate different sources of glucose. Gluc – glucose used (g/h); h – time in hours; PS – postabsorptive state: PF – prolonged fasting.

圖一、飢餓狀態下不同時期葡萄糖的使用。A,B,C 顯示葡萄糖的不同來源。Gluc: 消耗的葡萄糖 (g/h)，h: 小時，PS: 後吸收狀態；PF：延長禁食

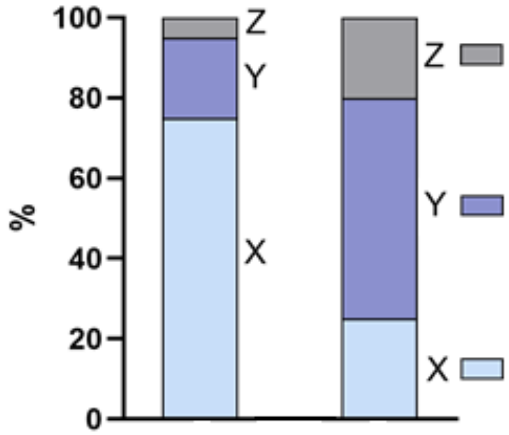


Figure 2 Percentage (%) of glucose production in different gluconeogenic organs. X, Y, Z correspond to these different gluconeogenic organs.

圖二、各種可進行糖質新生作用器官，所生成的葡萄糖百分比(%)。X，Y，Z 分別表示各個可進行糖質新生作用器官

Indicate whether each of the following statements are true (T) or false (F).
(4 points, 1 point each correct answer)
判別下列哪些為正確（T）或錯誤（F）的敘述（共四分，一題一分）

A. On figure 1, A corresponds to gluconeogenesis, B to glycogen and C to exogenous source.
圖一中，A 為糖質新生作用，B 為肝糖，C 為外源性的糖

B. On figure 1, A corresponds to exogenous source, B to glycogen and C to gluconeogenesis.
圖一中，A 為外源性的糖，B 為肝糖，C 為糖質新生作用

C. On figure 2, X corresponds to kidney, Y to liver and Z to intestine
圖二中，X 為腎臟，Y 為肝臟，Z 為小腸

D. Glycogen is an important source for glucose synthesis that can be found primarily in the liver and adipose tissue.
肝糖主要存在於肝臟和脂肪組織，為葡萄糖合成之重要來源

Q28

In the motor end plate, there is a type of rapid chemical transmission, mediated by the neurotransmitter acetylcholine (ACh). ACh vesicles are concentrated in the area of the motor nerve closest to the muscle, the active zone, and are then released (via exocytosis) into the synaptic cleft. Botulinum toxin has a great impact at motor end plate and ACh-mediated chemical transmission.

在運動終板處利用乙醯膽鹼進行快速的化學傳遞反應。包裹著乙醯膽鹼的突觸小泡密集分布在運動神經靠近肌肉的地方，即所謂的活性區域（active zone），然後利用胞吐作用釋放到突觸間隙（synaptic cleft）。肉毒桿菌毒素對於運動終板的乙醯膽鹼化學傳遞有著重大的影響。

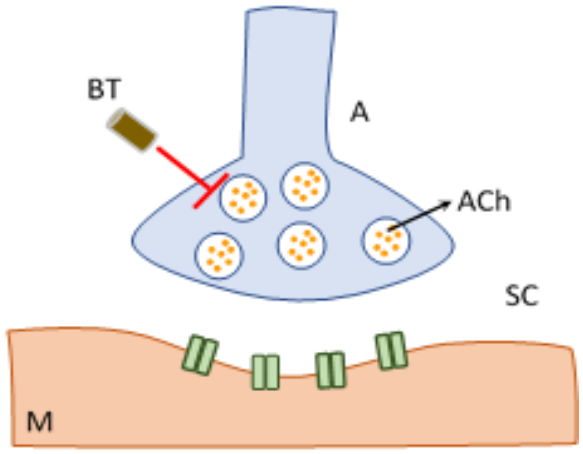


Figure 1 Motor end plate. Impact of Botulinum toxin. BT - Botulinum toxin; M – muscle; SC – synaptic cleft; Ach – acetylcholine; A – motor axon.

圖一、運動終板。肉毒桿菌的作用。BT： 肉毒桿菌毒素。M: 肌肉；SC：突觸間隙；ACh： 乙醯膽鹼；A: 運動神經的軸突。

Indicate whether each of the following statements are true (T) or false (F).
(4 points, 1 point each correct answer)

判別下列哪些為正確（T）或錯誤（F）的敘述（共四分，一題一分）

A. Botulinum toxin blocks the release of ACh
肉毒桿菌毒素會阻斷乙醯膽鹼的釋放

B. Botulinum toxin promotes constant muscle contraction.
肉毒桿菌毒素會促進持續的肌肉收縮

C. Botox, the alternative name of botulinum toxin is produced by the fungus *Clostridium botulinum*
Botox，是肉毒桿菌毒素的別名，由肉毒桿菌這種真菌所產生

D. Under steady-state conditions ACh release from the motor axon allows action potential.
穩定狀態下，由運動神經軸突所釋放的乙醯膽鹼可產生動作電位

Q29

Thermogenesis is the process by which organisms produce heat. Heat production is mediated by uncoupling protein 1 (UCP1), which uncouple the proton gradient formation of electron transport chain from ATP production, in oxidative phosphorylation.

產熱作用為個體產生熱能之重要過程，主要是透過解偶聯蛋白-1（Uncoupling protein 1, UCP1）消除氧化磷酸化過程中，電子傳遞鏈內用以生成 ATP 的質子濃度差異。

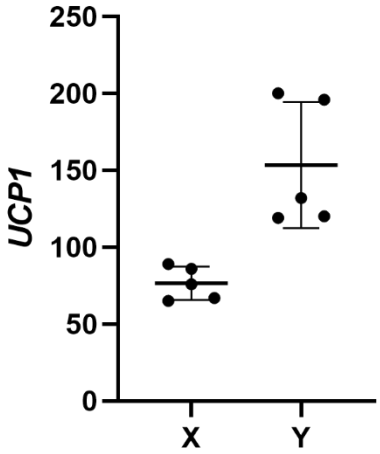


Figure 1 mRNA expression of UCP1 gene comparing two different polymorphisms (X and Y).
圖一、兩種不同多形體(X 和 Y)中 UCP1 基因之 mRNA 表現的比較。

Indicate whether each of the following statements are true (T) or false (F).
(*4 points, 1 point each correct answer*)

判別下列哪些為正確（T）或錯誤（F）的敘述（共四分，一題一分）

A. On figure 1, the expression of *UCP1* could relate to polymorphisms found in European (X) and Arctic (Y) populations
圖一顯示 UCP1 在不同多形體的表現，其中 X 來自歐洲，Y 來自極地

B. An increase in *UCP1* expression can be an adaptation to regions with high environmental temperatures.
UCP-1 表現量上升，可視為個體到高溫環境時的適應作用。

C. Non-shivering thermogenesis occurs primarily in white adipose tissue
非顫抖產熱作用主要發生於白色脂肪。

D. In humans, brown fat progressively reduces from newborn to adults.
人類之棕色脂肪自新生兒到成年，會隨年齡持續減少。

Q 30

Figure 1 shows histological section of the thin skin is depicted, where the different tissues that constitute the skin can be observed. (1) is the external part, which is exposed to the air.
圖一為皮膚的組織切片，圖中可看到多種構成皮膚之組織。（1）為暴露於空氣之外部構造

Figure 1. Histological section of the human thin skin. Mixed haematoxylin (purple basic dye) and eosin (pink acid dye) staining.
圖一:利用蘇木精(Hematoxylin，紫色鹼性染劑)-伊紅(Eosin，粉紅色酸性染劑) 製作的人類薄皮膚之組織染色切片。

Indicate whether each of the following statements are true (T) or false (F).
(4 points, 1 point each correct answer)
判別下列哪些為正確（T）或錯誤（F）的敘述（共四分，一題一分）

A. (1) and (2) are, respectively, the dermis and the epidermis
圖中(1)為真皮，(2)為表皮

B. In mammals, (1) is a dry, keratinized, tissue that prevents water loss from the body as an adaptation to terrestrial life.
以哺乳類而言，為適應陸地生活(1)為乾燥且角質化之組織，可防止水分散失

C. (3) are cells that accumulate a pigment in order to protect the basic layer of tissue (1), where the germinal (stem) cells are present, against the deleterious action of ultra-violet radiation.
在 (3) 的細胞中可累積一種色素，其可抵禦紫外線的輻射傷害以保護(1)內具有幹細胞的基底層組織。

D. (3) are cells that accumulate a hormone called melatonin.
(3)為可累積褪黑激素的細胞

Q 31

The following figure depicts a histological section that represents a physiological system where two types of cells interact. Striated skeletal muscular fibers of the mammalian body contract under voluntary decision.

下圖描繪了一個組織切片，代表了兩種細胞相互作用的生理系統。哺乳動物體內骨骼肌為橫紋肌，可受意識控制而收縮。

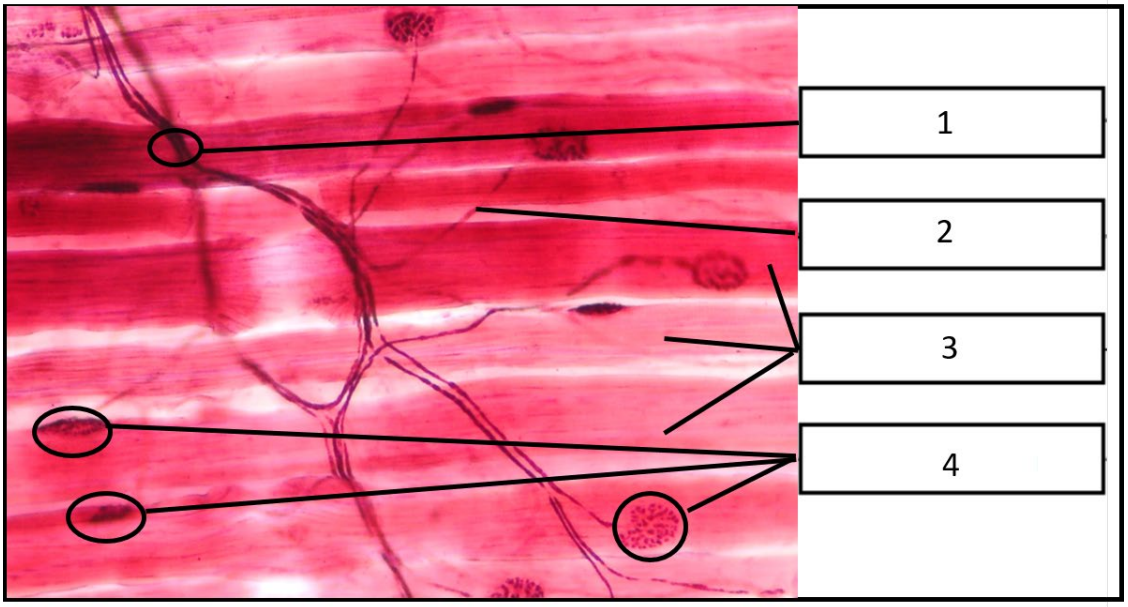


Figure 1. Histological section. (1) Nerve bundle (2) Individual axons (3) Muscle fibers (4) neuromuscular junctions. Striated skeletal muscle is stained in pink and the dark staining is the result of acetylcholinesterase activity.

圖一、組織切片顯示: (1) 神經束 (2) 單一軸突 (3) 肌纖維 (4) 神經肌肉連結。具橫紋的骨骼肌染成粉紅色，染成黑色的部分為具有可作用之乙醯膽鹼酯酶。

Indicate whether each of the following statements are true (T) or false (F).
(4 points, 1 point each correct answer)

判別下列哪些為正確（T）或錯誤（F）的敘述（共四分，一題一分）

A. Individual axons use acetylcholine as neurotransmitter. A single axon can innervate several fibers and give rise to a coarse and uniform movement of several fibers in the muscle while a “one axon-one fiber” type of neuromuscular junction gives rise to a very fine-tuned and precise movement of individual fibers within the muscle

軸突利用乙醯膽鹼作為神經傳遞物質，單一軸突可支配多個肌纖維，造成多條肌纖維進行粗略且一致之移動。然而，”1 軸突-1 肌纖維”可讓肌肉產生細緻協調且精準的移動。

B. Individual axons use adrenaline as neurotransmitter. A single axon can innervate several fibers and give rise to a coarse and uniform movement of several fibers in the muscle while a “one axon-one fiber” type of neuromuscular junction gives rise to a very fine-tuned and precise movement of individual fibers within the muscle.

軸突利用腎上腺素作為神經傳遞物質，單一軸突可支配多條肌纖維，造成多條肌肉纖維進行粗略且一致之移動。然而，1 軸突-1 肌纖維”可讓肌肉產生細致微調且精準的移動。

C. Individual axons use acetylcholinesterase as neurotransmitter. A single axon can innervate several fibers and give rise to a very fine-tuned and precise movement of individual fibers within the muscle while a “one axon-one fiber” type of neuromuscular junction gives rise to a coarse and uniform movement of several fibers in the muscle
軸突利用乙醯膽鹼酯酶作為神經傳遞物質，單一軸突可支配多條肌纖維，讓肌肉產生細緻微調且精準的移動。然而，”1 軸突-1 肌纖維”可造成多條肌纖維進行粗略且一致之移動。

D. Individual axons use serotonin as neurotransmitter. A single axon can innervate several fibers and give rise to a very fine-tuned and precise movement of individual fibers within the muscle while a “one axon-one fiber” type of neuromuscular junction gives rise to a coarse and uniform movement of several fibers in the muscle
軸突利用血清素作為神經傳遞物質，單一軸突可支配多條肌纖維，讓肌肉產生細緻微調且精準的移動。然而”1 軸突-1 肌纖維”可造成多條肌纖維進行粗略且一致之移動。

Q 32

The following figure is a scheme that represents the Vertebrate spinal cord and the three connective tissue membranes (4) that ensheath it.
下圖是代表脊椎動物之脊髓和包覆它的三個結締組織膜 (4) 的示意圖。

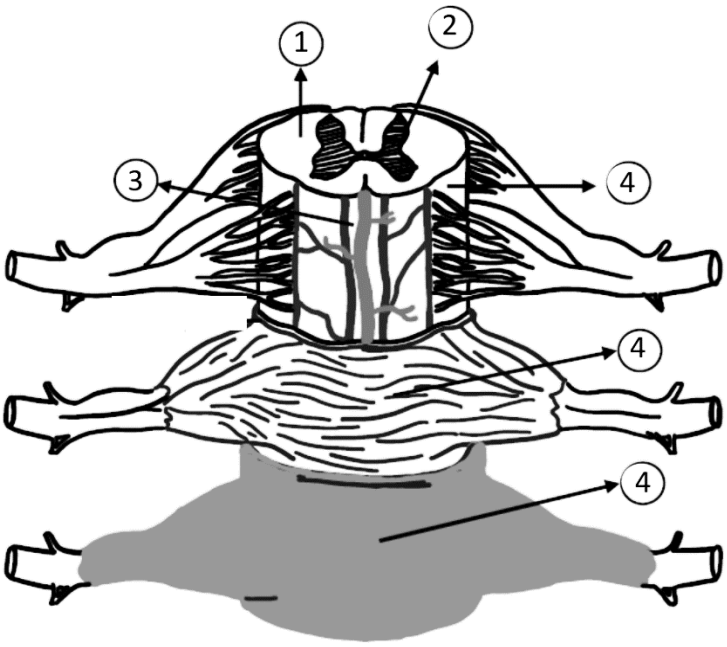


Figure 1. Schematic representation of the spinal cord.
脊隨的示意圖

Indicate whether each of the following statements are true (T) or false (F).
(4 points, 1 point each correct answer)
判別下列哪些為正確（T）或錯誤（F）的敘述（共四分，一題一分）

A. (1) is the white matter, which consists of neuronal cell bodies and glial cells such as astrocytes and oligodendrocytes
(1) 是白質，由神經元細胞本體和神經膠細胞如星狀細胞和寡突膠細胞組成

B. The white matter (1) and the grey matter (2) are in the same relative position to one another in the brain, when compared to the spinal cord: (2) inside and (1) outside, closer to the meninges.
大腦中之白質 (1) 和灰質 (2) 也呈現相同的相對位置，然而與脊髓相比，(2)在內側 ，(1)在外側，更靠近腦膜。

C. (4) are known as the meninges and are named pia-mater, arachnoid and dura-mater.
(4) 被稱為腦脊髓膜，被命名為軟腦膜、蛛網膜和硬腦膜。

D. (3) are blood vessels (arteries and veins), located between the arachnoid and the pia-mater meninges, that irrigate the spinal cord nervous tissue.
(3) 是血管（動脈和靜脈），位於蛛網膜和軟腦膜之間，用以提供脊髓神經組織養分及運送廢物。

Q 33

Organoids are three-dimensional culture models where cells grow and differentiate into several cell types, allowing a partial reconstitution of a complex cellular organisation where organotypic interactions can take place and so mimicking some of the functions of the respective *in vivo* organ. Providing the proper stimuli, such as culture medium supplements, appropriate growth and differentiation factors, hormones, etc, as well as an adequate physical scaffold, tissues can self-organize to a certain extent and generate organoids that have proven very useful in basic and applied biomedical research. One of the examples of organoids that have already been successfully produced in several laboratories are brain organoids (the so-called “mini-brains”).

類器官培育是 3D 培養模型，在此模型中，細胞可生長並分化為多種細胞類型，以提供複雜的細胞組織部分重建，也可藉此觀察到器官內細胞之相互作用，故可模擬體內相應器官之功能。若提供適當的刺激，如培養基補充劑、適當的生長和分化因子、激素等，以及足夠的物理支架，其內組織可自我組織成類器官構造，許多研究顯示此模型可廣泛應用於基礎研究或生醫臨床應用。目前有些實驗室已可透過此方法，成功培育出大腦之類器官培育模型(亦稱為迷你大腦)。

Indicate whether each of the following statements are true (T) or false (F).
(*4 points, 1 point each correct answer*)

判別下列哪些為正確（T）或錯誤（F）的敘述（共四分，一題一分）

A. Using organoids made from cells harvested from a specific donor carrying a particular disease would make them especially useful for studying the disease progression and the personalized use of therapeutic agents in that particular patient.
從帶有特殊疾病的病患體內，抽取細胞後進行類器官培育，可使科學家了解此特殊疾病之發展過程，並可用以篩選針對該病患之治療藥物。

B. Organoids are safe biological materials to be transplanted in human patients.
類器官培育是安全的生物材料，可移植至病患體內

C. Entire organs (a whole kidney or liver, for instance) can easily be grown *in vitro* for the purpose of transplantation into patients, with no limitations, making organoids a useless technology.
由於利用體外培養可得到整個器官（例如完整腎臟，肝臟）以提供病患移植所需，所以類器官培育為一無實用價值之技術

D. “Mini-brains” are appropriate models to study complex behaviours *in vitro*.
迷你大腦為進行體外研究複雜行為的適當模式

Ethology 行為學

Q34

Cicadas are singing insects whose presence is easily detected by the male-calling song during the mating season. **Figure 1** shows species of the genus *Tettigettalna*, a group of small-sized cicadas from southern Europe with similar morphology but distinct male calling songs. They have overlapping distributions, being often found in sympatry, suggesting an important role for acoustic behaviour in their diversification and maintenance of reproductive isolation between sister species. In fact, results from acoustic, morphometric and genetic analyses showed that *T. mariae* and *T. argentata* from the southernmost locations exhibit significant acoustic and morphological variation without genetic differentiation. These results may point to different scenarios. Statements are specifically about *T. mariae* and *T. argentata*.

蟬是鳴唱的昆蟲，牠的存在很容易藉由雄性在繁殖季唱歌察覺到。**圖 1** 展示了 *Tettigettalna* 屬中的部分物種，一群具有相似型態來自南歐的小型蟬，但雄性具有相當不同的鳴唱聲。他們具有重疊的分布，常發現有共域種存在，顯示鳴唱行為的分化在維持不同姊妹種間的生殖隔離上扮演了重要的角色。事實上，來自聲音、形態與基因遺傳的分析的結果，顯示來自最南邊的 *T. mariae* 和 *T. argentata* 這兩個種，呈現出聲音與形態上的顯著變異，但無遺傳的差異。這個結果可能指向不同的局面。這是針對 *T. mariae* and *T. argentata*.這兩個種的敘述。

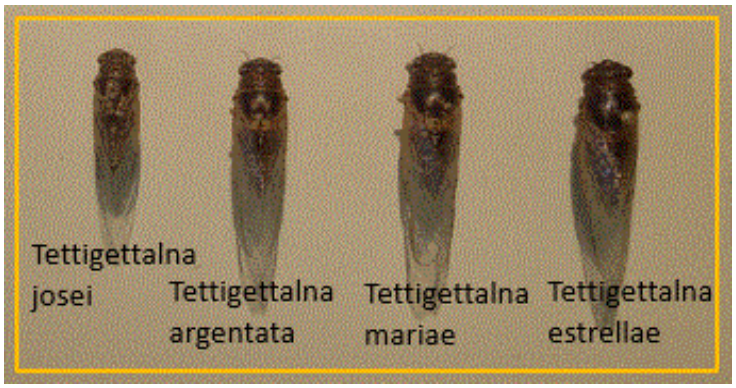


Figure 1 – Several cicada species from genus *Tettigettalna*
圖 1. 數種 *Tettigettalna* 屬的蟬

Indicate whether each of the following statements are true (T) or false (F).
(4 points, 1 point each correct answer)
指出下列敘述何者正確（T）或錯誤（F）（4 分，每個正確答案 1 分）

A. A past introgression episode between the two species
這兩個物種間在早期有基因交流

B. There is no gene flow between these sibling species, but they still retain ancestral polymorphism.
在這兩個近親種間沒有基因交流，但是他們仍舊保有祖先的多型性

C. *T. mariae* haplotypes are only found in *T. argentata* specimens sampled in sympatry or allopatric locations within predicted past distribution of *T. mariae.* Since these haplotypes are not present in the majority of *T. argentata* distribution area, they are likely to belong to the original gene pool of *T. argentata*.
T. mariae 的單套基因體只有在和 *T. argentata* 現在是同域，或現在異域但過去是同域的分布中出現。因為這些單套基因體出現在 *T. argentata* 分布區域內並非主流，他們很可能屬於 *T. argentata* 的原始基因庫。

D. Divergence in acoustic behaviour probably restricts gene flow in sympatry.
鳴唱行為的分化可能在同域狀況下限制基因交流。

Q35

Cicada orni is one of the most abundant and common cicadas in Mediterranean areas of southern Europe. Males of the species show intense acoustic behaviour. The analyses of the structure of the calling song in *C. orni* over a wide distribution range of the species in the Mediterranean region was performed to better understand the pattern of its geographic variation. **Figure 1** shows some of the studied acoustic variables.

歐洲蠟蟬（*Cicada orni*）是南歐地中海區域最常見的蟬。此種雄性顯示強烈的鳴唱行為。分析在地中海地區廣大分布的 *C. orni* 他們鳴唱的組成，以進一步的了解他們在地理分布變異的型態。**圖 1** 顯示某些聲音變項的研究。

These acoustic variables revealed some variation among specimens from different regions, such as shown by in **Figure 2.**

這些聲音變項在不同區域內的種間有一些變異，**如圖 2** 所示。

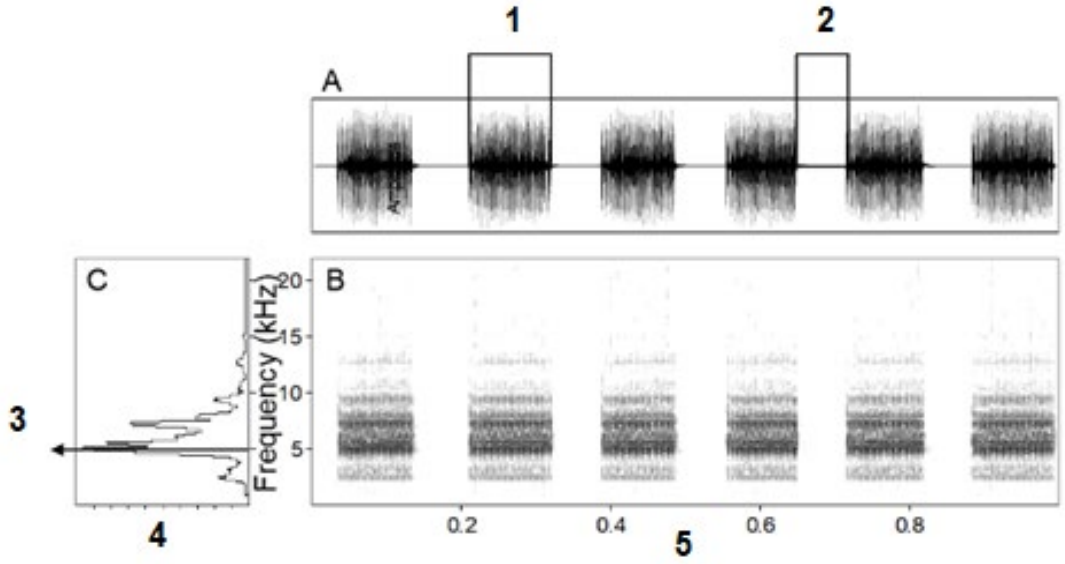


Figure 1. Calling song of *C. orni* **A**. Oscillogram (amplitude vs time); **B.** Sonogram (frequency vs time); **C**. Mean amplitude spectrum (frequency vs amplitude). **1**. Echeme duration (s); **2**. Inter-echeme interval (s); **3**. Peak frequency (Hz). **4.** Intensity (V) **5.** Time (s). The echemes are composed by groups of pulses, and the duration of the interval between them is the inter-echeme.

圖 1、*C. orni* 的鳴唱。A.波型圖（振幅 vs 時間）；B 聲波圖（頻率 vs 時間）；C 平均振幅（頻率 vs 振幅）。1.音節長度（s）； 2.音節間的間隔（s）；3.頻率最高峰（Hz）；4.強度（V）；5.時間（s）。每個音節由許多波動組成，在音節之間有音節間隔。

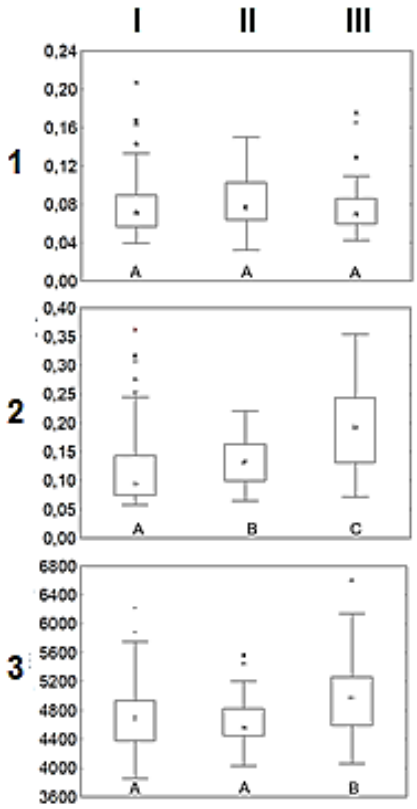


Figure 2. Boxplots of three acoustic variables of the calling song of *C.orni* in (**I**) Iberian Peninsula, (**II**) France and (**III**) Greece. Regions with significant differences (Mann-Whitney, p«0.05) share no letters. **1**. Echeme duration (s); **2**. Inter-echeme interval (s); **3**. Peak frequency (Hz). The echemes are composed by groups of pulses, and the duration of the interval between them is the inter-echeme.

圖 2、三個地區的歐洲蠟蟬 *C.orni* 鳴唱的三種變項圖，（**I**）伊比利亞半島（Iberian Peninsula）、（**II**）法國、（**III**）希臘。這些地區之間若有顯著差異（統計分析，p«0.05），則以不同字母標示。**1.**音節持續時間（s）；**2.**音節間的間隔（s）；**3.**頻率最高峰（Hz）。每個音節由許多波動組成，在音節之間有音節間隔。

Indicate whether each of the following statements are true (T) or false (F).
(*4 points, 1 point each correct answer*)

指出下列敘述何者正確（T）或錯誤（F）（4 分，每個正確答案 1 分）

A. Echeme duration is not important in species recognition.
音節持續時間在物種中的辨識不重要

B. Inter-echeme interval is probably not important in species recognition.
音節間的間隔在物種中的辨識不重要

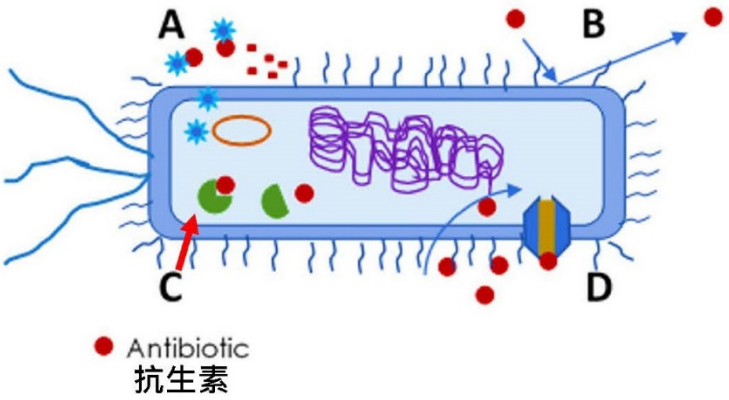
C. Iberian Peninsula appears as the most differentiated area.
伊比利亞半島（Iberian Peninsula）是最特化的區域

D. Differentiation in Greek specimens might have been the result of strong geographic isolation.
希臘的物種變異性可能是高強度的地理分隔所造成的

Genetics and Evolution 遺傳學及演化生物學

Q36

Antibiotic resistance is a constant Public Health problem as more antibiotics are rendered ineffective by drug-resistant bacteria which have developed resistant mechanisms to conventional antibiotics.
Bacteria can resist antibiotics via different resistance mechanisms. In the **figure below**, identify the mechanisms **A – D** from the list **1 – 6**: (*4 points, 1 point each correct answer*)
抗生素(Antibiotic)抗藥性一直是公共衛生問題，越來越多抗生素因細菌產生抗藥機制而失效。細菌經由不同機制對抗生素產生抗藥性，請由**選單 1-6** 中選出下**圖中 A-D** 的抗藥機制
（4 分，答對一個正確答案得 1 分）



1. Modification of the antimicrobial drug target.
   針對抗菌藥物標的進行修飾
2. Production of hydrolytic enzymes, such as β-lactamases, that inactivate the surrounding antimicrobial drug.
   產生水解酶如β-lactamases 使周圍的抗菌藥物失去活性
3. Production of bacteriocins that destroy the antibiotic.
   產生殺菌素破壞抗生素
4. Reduction of the antimicrobial drug concentration in the intracellular environment by pumping them out before they can take effect.
   在藥效發揮前，將細菌胞內的殺菌藥物運輸出去以降低胞內濃度
5. Antibiotic degradation inside the cell
   將抗生素在胞內分解
6. Natural resistance due to an unusually impermeable cell membrane or lack of the target recognized by the antibiotic
   產生天然抗藥性的原因為細胞膜異常地不通透性或者缺乏可供抗生素辨識的標的

Q37

Concerning the mechanisms of action of antibiotics and the molecular mechanisms responsible for antibiotic resistance and spread.

關於抗生素作用機制及抗藥性產生與傳播的分子機制

Indicate whether each of the following statements are true (T) or false (F).
(4 points, 1 point each correct answer)

請指出下列各敘述是正確（T）或錯誤（F）(4 分，答對一個答案得 1 分)

A. Antibiotic resistance can be acquired through mutations in the bacterial DNA.
細菌可經由其 DNA 突變而獲得抗生素抗藥性

B. The presence of antibiotics is thought to play an important role in antibiotic resistance (selective pressure). This suggests a Lamarckian mechanism of adaptive evolution.
抗生素之存在被認為是篩選壓力，在抗生素抗藥性產生上扮演重要角色，此意味著為一種拉馬克適應性演化機制

C. Plasmids, belonging to a class of genetic elements known as mobile genetic elements, can transfer antibiotic resistance genes when moving from bacterial cells to eukaryotic cells.
質體是一種移動性遺傳物質，當其由細菌移動到真核細胞時可傳遞抗生素抗藥性基因

D. Chloramphenicol is a bacteriostatic antibiotic that inhibits the peptidyl transferase activity of the bacterial ribosome (responsible for peptide bond).This directly prevents transcription.
氯黴素是一種抑制細菌的抗生素，可抑制細菌核醣體的肽基轉移酶活性（負責胜肽鍵形成），因而直接阻止轉錄作用

Q38

Advances within biotechnology, genetic engineering, and synthetic chemistry have opened new possibilities towards the search for antimicrobial treatment of bacterial infections, which can substitute for antibiotics. Some are currently undergoing clinical trials, while others are in different stages of research. Some will work by themselves, while others exhibit the potential to act synergistically when combined with certain chemical antibiotics already available on the market.
生物技術、遺傳工程及合成化學的進展為細菌感染的抗菌治療開發新的可能抗生素替代性藥物。有些目前正進入臨床試驗，其它則正在不同的研究階段。有些可以自行作用，有些當與某些已上市化學抗生素合併使用時，則具有協同作用之潛力。

Match the new antimicrobial therapies on the left (1-6) with the advantages mentioned on the right side of the table (A-F) below:
(*6 points, 1 point each correct answer*)
請將左列（1 - 6）新抗菌治療與右側（A - F）所列舉優點進行配對
（6 分，答對一個答案得 1 分）

New promising antimicrobial therapies **新的抗菌治療**	**Advantages** **優點**
1. Antibodies 抗體	A. Silences gene expression of resistance genes by interfering with their transcription. 藉干擾基因轉錄的方式以抑制抗藥性基因的表現
2. Probiotics 益生菌	B. Safe method, because do not possess any affinity whatsoever with eukaryotic cells. 是安全的方法，因對真核細胞不具任何親和性
3. Bacteriophages /phage therapy 噬菌體 / 噬菌體治療	C. Enhances the human microbiota. When consumed or applied to the body may bring health benefits. 強化人類微生物群相，當攝食或應用在人體會有益健康
4. Antimicrobial peptides 抗菌胜肽	D. Specificity and the inability of bacteria to develop resistance against them. 具專一性及使細菌無法產生對抗性
5. Lysin therapy 溶解酶治療	E. Causes disruption of the bacterial membrane and can be used in the treatment of bacterial, fungal and viral infections, as well as in the prevention of biofilm formation 造成細菌膜破壞，可用以治療細菌、黴菌及病毒感染，並可阻止生物膜之形成。
6. Antibacterial oligonucleotides 抗菌寡聚核苷酸	F. Targets one of the five bonds in peptidoglycan (murein) and amounts in the order of nanograms cause immediate lysis of the target Gram-positive bacterial cells. 以肽聚醣(murein)的五個鍵結之一為標的，僅需奈克(nano gram)的量即可造成格蘭氏陽性菌細胞立即溶解。

Q39

SARS-CoV-2 is a coronavirus (CoV) that emerged in 2019 and is responsible for the COVID-19 disease in humans. Other coronaviruses affecting humans are the SARS-CoV and MERS-CoV, responsible for the previous epidemics Severe Acute Respiratory Syndrome in 2002, and Middle East Respiratory Syndrome in 2012. Transmission of coronavirus to humans has likely occurred through civets for SARS-CoV and camels for MERS-CoV. The origin of SARS-CoV-2 is under intense debate. Studies based on full-genome CoV variants isolated from bat (Bt), pangolin (Pn), camel (Cm), civet (Cv), pig (Pi) and humans (Hu) have provided information on the ancestry and evolution of coronaviruses. Several authors suggest a zoonotic origin and different hypotheses have been proposed about the last animal intermediate before transmission to humans using phylogenetics.

SARS-CoV-2 是一種冠狀病毒（CoV），於 2019 年出現，是造成人類 COVID-19 疾病的元兇。其他影響人類的冠狀病毒包含 SARS-CoV 和 MERS-CoV ，它們分別是造成 2002 年嚴重急性呼吸道症候群和 2012 年中東呼吸症候群等流行病的病毒源。SARS-CoV 和 MERS-CoV 的冠狀病毒可能分別經由麝香貓和駱駝傳染給人類。而 SARS-CoV-2 的起源現在仍在激烈爭論中。經由分析從蝙蝠（Bt）、穿山甲（Pn）、駱駝（Cm）、麝香貓（Cv）、豬（Pi）和人類（Hu）中分離出不同變異體的冠狀病毒（CoV）全基因組研究，提供了有關冠狀病毒之祖先和演化的資訊，多位學者提出了人畜共患病的起源，使用親緣關係學對於 CoV 傳染給人類之前的最後一個動物中間傳遞者提出了不同的假設。

Figure 1 below shows an inferred phylogeny from the ORF1ab genomic region of coronavirus. The prefixes of virus names indicate the host species. The strains A (isolated from bat), B (isolated from pangolin) and C (SARS-CoV isolated from a human in 2003) are also represented in Figure 1 in Q40. HuCoV2 WH01 represents the human SARS-CoV-2 isolated from Wuhan, China in 2020.

下面**圖 1** 顯示了從冠狀病毒 ORF1ab 基因組區域推斷的親緣關係。 病毒名稱前方縮寫代表宿主物種。病毒株 A（從蝙蝠中分離）、B（從穿山甲中分離）和 C （2003 年從人類分離出的 SARS-CoV）也同樣在 Q40 的圖 1 中顯示。HuCoV2 WH01 代表 2020 年從中國武漢分離出的人類 SARS-CoV-2。

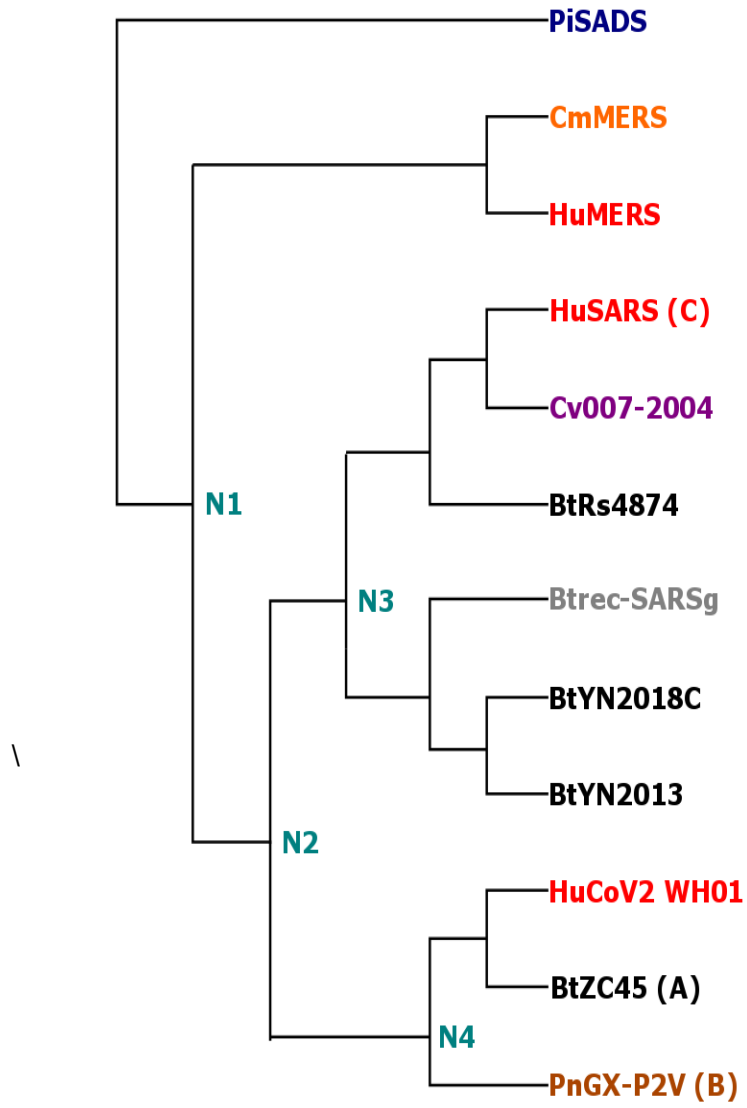


Figure 1. Topology of the phylogenetic tree inferred from the ORF1ab genomic region. Coronavirus analysed were isolated from different hosts (represented by different colors in the tree): Bat (Bt): BtRs4874, BtYN2018C, BtYN2013, BtZC45 (**A in Fig.1 from Q40**); lab recombinant (bat+cell culture): Btrec-SARSg; Pangolin: PnGX-P2V **(B in Fig. 1 from Q40)**; Civet (Cv): Cv007-2004; Camel (Cm): CmMERS; Pig (Pi)(PiSADS); Human CoV variants (Hu): HuSARS (isolated in from a patient in 2003, **C in Fig.1 from Q40**), HuMERS, HuCoV2. Data from Sallard *et al.* 2021.
圖 1. 從 ORF1ab 基因組區域推斷的親緣關係樹的拓撲結構。分析由不同宿主分離的冠狀病毒（樹形圖中用不同顏色表示）：蝙蝠（Bt）：BtRs4874、BtYN2018C、BtYN2013、BtZC45（**圖 1 中的 A，來自 Q40**）；實驗室重組（蝙蝠+細胞培養）：Btrec-SARSg；穿山甲：PnGX-P2V（**圖 1 中的 B，來自 Q40**）；麝香貓（Cv）：Cv007-2004；駱駝（Cm）：CmMERS；豬（Pi）（PiSADS）；人類 CoV 變異體 (Hu)：HuSARS（由 2003 年的某名患者中分離，**圖 1 中的 C 來自 Q40**）、HuMERS、HuCoV2：依據 Salard 等人 2021 的資料。

Based on the inferred phylogeny, indicate whether the following statements are true (T) or false (F). *(4 points, 1 point each correct answer)*
根據推測的親緣關係，指出下列敘述何者正確（T）或錯誤（F）（4 分，每個正確答案 1 分）

A. The most recent common ancestor of human SARS-CoV and SARS-CoV-2 (HuCoV2) is N2.
人類 SARS-CoV 和 SARS-CoV-2（HuCoV2）的最近共同祖先是 N2。

B. The lineage most closely related to the human SARS-CoV-2 (HuCoV2) is the bat isolate BtYN2013.
與人類 SARS-CoV-2（HuCoV2）最密切關連的譜系是蝙蝠分離株 BtYN2013。

C. The Pig (PiSADS) lineage gave rise to all other coronaviruses shown in the phylogenetic tree
在親緣關係樹中顯示豬（PiSADS）譜系產生了其他所有冠狀病毒

D. The recombinant bat isolate (Btrec-SARSsg) obtained from cell culture in the laboratory is not directly related to SARS-Cov-2, as descendent lineages from their common ancestor include other isolates.
從實驗室細胞培養中獲得的重組蝙蝠分離株（Btrec-SARSsg）與 SARS-Cov-2 沒有直接關係，因為他們的共同祖先的後代譜系中還包括其他分離株。

Q40

The coronavirus genome is about 30,000 nucleotides, organized in ten genes (represented at the top in **Figure 1** below), including the ORF1ab, coding for a polyprotein precursor involved in replication, and the S gene coding for the spike protein that recognizes the receptors of the host cells. Profiles of Percent of Identical Positions (PIP) reveal the percentage of sites that are identical between two genomes. **Figure 1** below shows PIPs produced from full-genome alignments between the SARS-CoV-2 and three other coronaviruses (**A**: bat CoV isolate; **B**: pangolin CoV isolate; and **C**: human SARS-CoV isolated in 2003).
冠狀病毒基因組大約 30,000 個核苷酸，由 10 個基因組成（如下**圖 1** 的上部所顯示），包括一個編碼參與複製過程的多蛋白質前體 ORF1ab 基因，以及編碼識別宿主細胞受體的棘蛋白 S 基因。相同位置百分比 (PIP)代表了兩個基因組間相同位點的百分比。下面的**圖 1** 顯示了由 SARS-CoV-2 和其他三種冠狀病毒（**A**：蝙蝠 CoV 分離株；**B**：穿山甲 CoV 分離株；**C**：2003 年分離的人類 SARS-CoV）之間的全基因組比對所產生的 PIP。

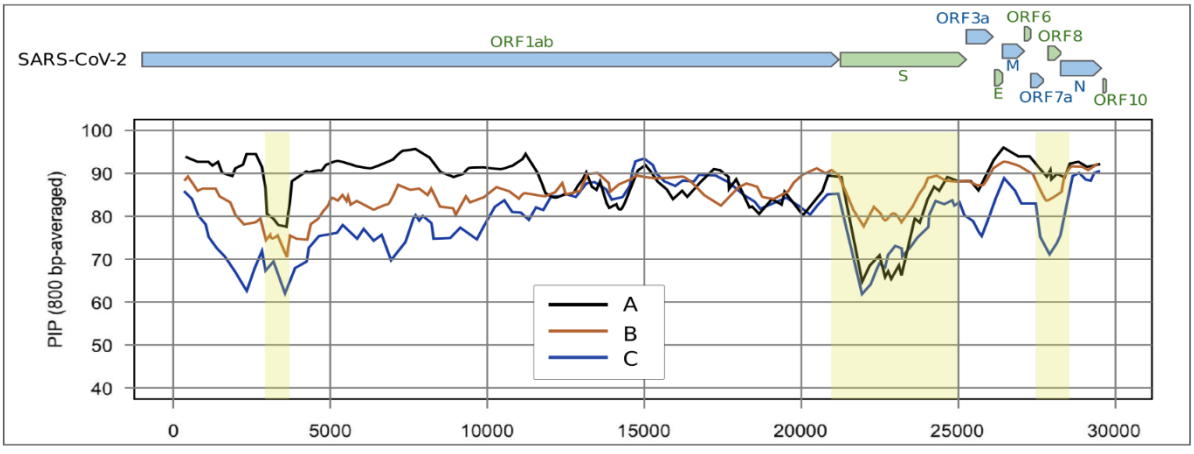


Figure 1. Profiles of Identical Positions (PIP) along the genome between human SARS-CoV-2 and other coronavirus sequences isolated from bat (A), pangolin (B) and human SARS-CoV isolated in 2003 (C).
圖 1. 人類 SARS-CoV-2 與從蝙蝠 (A)、穿山甲(B)和 2003 年分離的人類 SARS-CoV(C)等其他冠狀病毒序列之間基因組的相同位置百分比(PIP)分佈圖。

Based only on PIP results from Figure 1 indicate whether the following statements are true (T) or false (F). (*4 points, 1 point each correct answer*)
僅依據於圖 1 中的 PIP 結果指出下列敘述何者正確（T）或錯誤（F）（4 分，每個正確答案 1 分）

A. The fact that important genomic regions in the infection/viral replication process (highlighted in yellow) have lower PIP indicates that SARS-CoV-2 originated from SARS-CoV.
感染/病毒複製過程中的重要基因組區域（以黃色區域顯示）具有較低 PIP 的事實顯示出 SARS-CoV-2 源自於 SARS-CoV。

B. The genetic similarity in the S region between pangolin and human SARS-CoV-2 is lower than that between bat and human SARS-CoV-2. Given the importance of the S region on the cell infection process, this shows that the last animal host before transmission to humans was a bat.
穿山甲與人 SARS-CoV-2 在 S 區的遺傳相似性低於蝙蝠與人 SARS-CoV-2 之間的遺傳相似性。基於 S 區域在感染細胞過程中的重要性，顯示在傳染給人類之前的最後一個動物宿主是蝙蝠。

C. Recombination between coronavirus infecting bats and pangolins can explain that a pangolin isolate is closer to SARS-CoV-2 at protein S whereas a bat isolate is closer to SARS-CoV-2 in the rest of the genome
感染蝙蝠和穿山甲的冠狀病毒之間的重組可以解釋 SARS-CoV-2 在蛋白質 S 更接近穿山甲分離株，而 SARS-CoV-2 在基因組的其餘部分更接近蝙蝠分離株。

D. The phylogenetic relationship between the pangolin isolate and HuCoV2 would be different at the S gene than at the rest of genome.
穿山甲分離株和 HuCoV2 之間的親緣關係，在 S 基因和在基因組的其餘區域有所不同。

Q41

Knowing that a population of a diploid organism is at Hardy-Weinberg equilibrium for a certain locus with 5 alleles (a1, a2, a3, a4, a5) and knowing that:
已知為二倍體生物之族群，在具有 5 個等位基因（a1、a2、a3、a4、a5）的某基因座呈現哈溫平衡，並且已知：

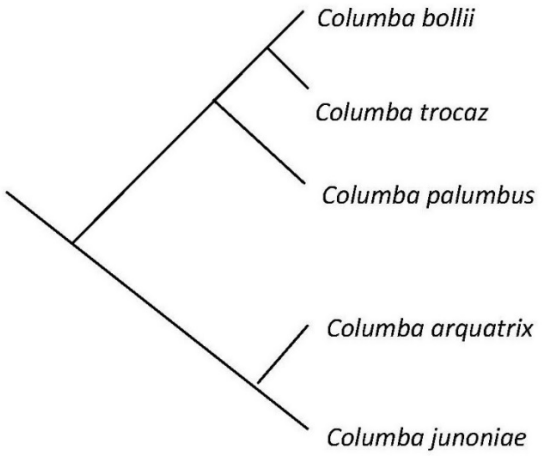
- the relative frequencies of certain alleles are: a1 = 0.2, a3 = 0.2, a4 = 0.2;
  某些等位基因的相對頻率為：a1 = 0.2，a3 = 0.2，a4 = 0.2；
- the relative frequency of the heterozygotic a4a5 is 0.04;
  異型合子 a4a5 的相對頻率為 0.04；
- the homozygotic a2a2 is 0.09.
  同型合子 a2a2 為 0.09。

Indicate whether each of the following statements is true (T) or false (F).
(5 points, 1 point each correct answer)
請指出下列敘述何者正確（T）或錯誤（F）（5 分，每個正確答案 1 分）

A. The frequency of the allele a2 is 0.03
等位基因 a2 的頻率為 0.03
B. The frequency of the allele a2 is 0.3
等位基因 a2 的頻率為 0.3
C. The sum of the relative frequency of the five alleles is 1
五個等位基因之相對頻率的總和為 1
D. The sum of the relative frequency of the five alleles is 2
五個等位基因之相對頻率的總和為 2
E. The frequency of the allele a5 is 0.1
等位基因 a5 的頻率為 0.1

Q42

Based on several mitochondrial DNA genes it is possible to obtain the phylogenetic relationship among the five bird species of the genus *Columba*. Samples from the species *Columba junoniae* and *Columba bollii* are from the Canary Islands, *Columba trocaz* from Madeira Island, *Columba palumbus* from Europe (mainland) and *Columba arquatrix* from Africa.
依據數個粒線體 DNA 基因資料，可以獲得鴿屬的五個物種之間的親緣關係。*Columba junoniae* 和 *Columba bollii* 二物種的樣本來自 Canary 群島，*Columba trocaz* 來自 Madeira 島，*Columba palumbus* 來自歐洲（大陸）和 *Columba arquatrix* 來自非洲。
Assuming that the cladogram shown represents the most parsimonious phylogeny:
假設這裡所示的支序圖代表最簡約親緣關係：
Indicate whether each of the following statements is true (T) or false (F).
(5 points, 1 point each correct answer)
請指出下列敘述何者正確（T）或錯誤（F）（5 分，每個正確答案 1 分）



Cladogram representing the phylogenetic relationship among the five bird species of the genus *Columba*.
代表鴿屬的五物種之間的親緣關係的支序圖。

A. The two Canary Island species are phylogenetically close to each other than they are to any other species of the cladogram
二個 Canary 群島鴿屬物種在親緣關係彼此相近，而不是與支序圖的其他物種的相近

B. One of the Canary Islands species is phylogenetically close to the Madeira Island species than they are to any other species of the cladogram
取樣自 Canary 群島中的一個鴿屬物種在親緣關係上與 Madeira 島鴿屬物種的關係比與親緣關係支序圖的其他物種更相近

C. The European and the African species are in the same clade and are phylogenetically close to each other than they are to any other species of the cladogram
歐洲鴿屬物種和非洲鴿屬物種在同一支序中，並且在親緣關係上彼此相近，而不是與支序圖的其他物種的相近

D. The two Canary Island species have two different origins
Canary 島的兩個物種有兩個不同的起源

E. The Madeira Island species is phylogenetically close to the African species than they are to any other species of the cladogram
Madeira 島物種在親緣關係上更接近非洲物種，而不是與支序圖中的其他物種相近

Q43

Several codons of the mitochondrial DNA *cytochrome b* gene are shown.

粒線體 DNA 細胞色素 b 基因內的數個密碼子，如下表所示

Columba junoniae	AAC GGG ATA CGT ACA GAT ATC ATT CCC CTA TAT CGG CCA CCC CTT ACA
Columba arquatrix	AAC AGG ATA CGT GCA AAT ATC ATT CCC CTA CAT CGG CCA TCC CTT ACA
Columba trocaz	GAC GGG ATA TGT ACA AAT ATC GTT CCC ATA CAT CGG CCA TCC CTT ACA
Columba palumbus	GAC AGG ATA TGT ACA AAT ATC GTT CCC ATA CAT CGG TCA CCC CTT ACA
Columba bollii	AAC GGG ATA TGT ACA AAT ATC GTT TCC ATA CAT CGG CCA TCC CTT GCA

Partial sequence of the mitochondrial DNA *cytochrome b* gene

粒線體 DNA 之細胞色素 *b* 基因的部分序列

The Vertebrate Mitochondrial Code (* *Indicate a stop codon)*

脊椎動物粒線體密碼（* 表示終止密碼子）

TTT F Phe	TCT S Ser	TAT Y Tyr	TGT C Cys
TTC F Phe	TCC S Ser	TAC Y Tyr	TGC C Cys
TTA L Leu	TCA S Ser	TAA * Ter	TGA W Trp
TTG L Leu	TCG S Ser	TAG * Ter	TGG W Trp
CTT L Leu	CCT P Pro	CAT H His	CGT R Arg
CTC L Leu	CCC P Pro	CAC H His	CGC R Arg
CTA L Leu	CCA P Pro	CAA Q Gln	CGA R Arg
CTG L Leu	CCG P Pro	CAG Q Gln	CGG R Arg
ATT I Ile	ACT T Thr	AAT N Asn	AGT S Ser
ATC I Ile	ACC T Thr	AAC N Asn	AGC S Ser
ATA M Met	ACA T Thr	AAA K Lys	AGA * Ter
ATG M Met	ACG T Thr	AAG K Lys	AGG * Ter
GTT V Val	GCT A Ala	GAT D Asp	GGT G Gly
GTC V Val	GCC A Ala	GAC D Asp	GGC G Gly
GTA V Val	GCA A Ala	GAA E Glu	GGA G Gly
GTG V Val	GCG A Ala	GAG E Glu	GGG G Gly

Based on DNA sequences and the Vertebrate mitochondrial DNA code:
Indicate which sentences are true (T) or false (F).
(5 points, 1 point each correct answer)
依據所提供的 DNA 序列和脊椎動物粒線體 DNA 密碼：
指出下列敘述何者正確（T）或錯誤（F）（5 分，每個正確答案 1 分）

A. There are no amino-acid substitutions between species *Columba junoniae* and *Columba bolli* in the codons shown.
在顯示的密碼子中，*Columba junoniae* 和 *Columba bolli* 物種之間沒有胺基酸取代。

B. There are two coden substitutions between species *Columba trocaz* and *Columba palumbus* in the codons shown
在顯示的密碼子中，*Columba trocaz* 和 *Columba palumbus* 物種之間有兩個密碼子取代

C. One amino-acid substitutionfrom *Columba arquatrix* to *Columba junoniae* , in the codons shown, is from Ala to Thr

在顯示的密碼子中，在 *Columba arquatrix* 到 *Columba junoniae* 間的一個胺基酸取代是由 Ala 改變為 Thr

D. There are 8 amino-acid substitutions between species *Columba junoniae* and *Columba bolli* in the codons shown
在顯示的密碼子中，在 *Columba junoniae* 和 *Columba bolli* 間有 8 個胺基酸取代

E. There are 18 amino-acid substitutions between species *Columba junoniae* and *Columba bolli* in the codons shown
在顯示的密碼子中，在 *Columba junoniae* 和 *Columba bolli* 間有 18 個胺基酸取代

Q44

The ABBA-BABA test is a commonly used approach in evolutionary biology to identify admixture (cases where two distinct populations interbreed) using genetic data. It involves the comparison of four populations or species (we will call them “groups” henceforth), whose phylogenetic relatedness can be represented as a tree (Figure 1), where X and Y are two closely related groups, W is a group that could have admixed with X or Y, and Z is an outgroup.

ABBA-BABA 檢驗是演化生物學中常用的方法，主要使用遺傳資料來鑑定混雜(admixture)（兩個界分族群的雜交情形）。它涉及四個族群或物種的比較（我們之後將它們稱為“群組”），其親緣關係的關聯可以表示為一棵關係樹（圖 1），其中 X 和 Y 是兩個關係密切的群組，W 是一個可以與 X 或 Y 混雜，Z 是外群。

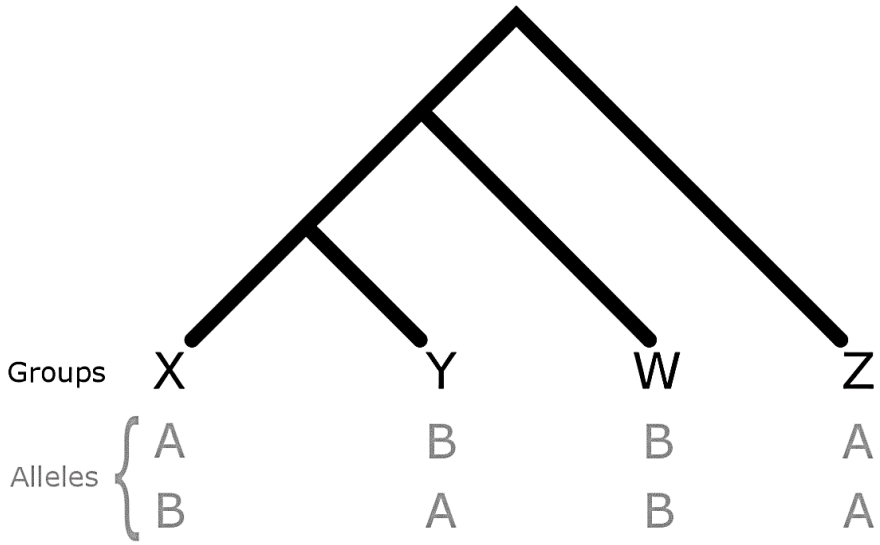


Figure 1. Phylogenetic relationship between four groups X, Y, W, Z and representation of ABBA and BABA allelic patterns across the four groups.

圖 1. X、Y、W、Z 之間的親緣關係和四群組中 ABBA 和 BABA 等位基因模式的表示。

The ABBA-BABA test focuses on single nucleotide polymorphisms sites in the genome that have two alleles: A and B. It is possible to detect admixture considering two possible allelic patterns across the four groups:

ABBA- BABA 檢驗著重於基因組中具有兩個等位基因的單核苷酸多型性位點：A 和 B。考慮到四個群組中兩種可能的等位基因模式來偵測檢測混雜：

- “ABBA” sites: where group X has the allele A, Y has the allele B, W has the allele B, Z has the allele A;

"ABBA"位置：在 X 組有等位基因 A，Y 組有等位基因 B，W 組有等位基因 B，Z 組有等位基因 A；

- "BABA" sites: where group X has the allele B, Y has the allele A, W has the allele B, Z has the allele A.
  "BABA"位置：X 組有等位基因 B，Y 組有等位基因 A，W 組有等位基因 B，Z 組有等位基因 A。

The *D* statistic is defined as (#BABA - #ABBA) / (#BABA + #ABBA), where #BABA is the number of BABA sites and #ABBA is the number of ABBA sites.
D 統計定義為(#BABA - #ABBA)/(#BABA+#ABBA)，其中#BABA 是 BABA 位置的數量，#ABBA 是 ABBA 位置的數量。
Imagine that a team of researchers sequenced the genomes of two modern humans from Kenya (X) and China (Y), one Neanderthal (W) and one Chimpanzee (Z), using ABBA-BABA to test if there was admixture between modern humans and Neanderthal. The researchers have identified 10,827 "ABBA" sites and 9,867 "BABA" sites.
想像一組研究人員對來自肯亞(X)和中國(Y)的兩位現代人、一尼安德塔人(W)和一黑猩猩(Z)的基因組進行了定序，使用 ABBA - BABA 來檢測現代人和尼安德特人。研究人員已經確定了 10,827 個 "ABBA"位置和 9,867 個 "BABA"位置。

Indicate whether each of the following statements is true (T) or false (F).
(*4 points, 1 point each correct answer*)
指出下列敘述何者正確（T）或錯誤（F）（4 分，每個正確答案 1 分）

A. If there is ***no* admixture**, we expect a nearly equal number of ABBA and BABA sites across the genome
如果**沒有混雜**，我們預測整個基因組中 ABBA 和 BABA 位置的數量幾乎相等

B. There is evidence of admixture between the Kenyan population and Neanderthal
已有證據顯示肯亞族群和尼安德特人之間存在混雜

C. The observed excess of ABBA sites (compared to BABA) could be explained by a structured ancestral population (of X, Y and W) such that the Neanderthal lineage was closer to the ancestral of Chinese
觀測到過多的 ABBA 位置（與 BABA 相比）可以用具結構化的祖先族群（X、Y 和 W）來解釋，即尼安德塔人的譜系更接近中國人的祖先

D. The ABBA–BABA test allows testing for admixture between Kenyan and Chinese modern human populations
ABBA-BABA 檢測用於檢測肯亞和中國現代人族群之間的混雜

Q45

Toehold switches are a class of synthetic RNA regulators that can repress gene expression by sequestering the Ribosome Binding Site (RBS) in a stable hairpin structure. Upon the addition of a small RNA called the toehold trigger, the hairpin structure unfolds, and the RBS is released.
指尖轉換(Toehold switches)是一類合成 RNA 調控子，可透過與核醣體結合位點(RBS)螯合形成穩定的髮夾結構方式來抑制基因表達。在另外加入一個稱為指尖觸發器(toehold trigger)的小片段 RNA 後，可以讓髮夾結構展開，而使 RBS 被釋放出來。

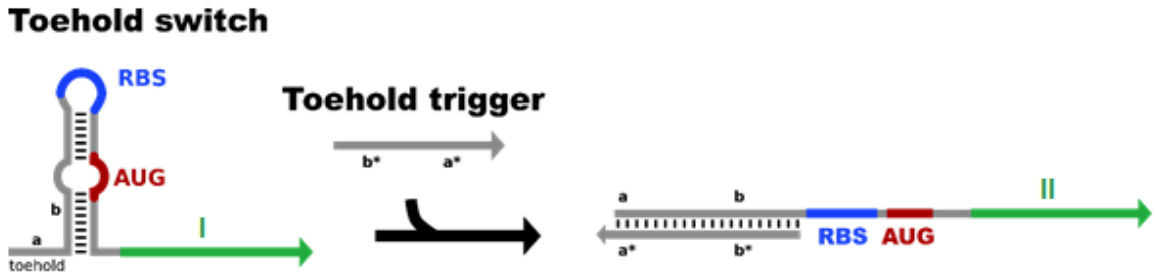


Figure 1. Toehold switch. I. Repressed gene; II. Activated gene.
圖 1. 指尖轉換。 一、被抑制的基因；二、激活的基因。
Image credits: Jacob Mejlsted, Own drawing. *Inspired by* Green *et al.* (2014)

Indicate whether the following statements are true (T) or false (F).
(*4 points, 1 point each correct answer*)
指出下列敘述何者正確（T）或錯誤（F）（4 分，每個正確答案 1 分）

A. Toehold switches work by repressing the translation of the gene
指尖轉換的機轉為抑制基因的轉譯
B. A strong hairpin structure can be made from direct repeats in the RNA sequence
一個強大的髮夾結構可以由 RNA 序列中的同向重複來構成
C. The toehold switch will work just as well in eukaryotes as in bacteria
指尖轉換在真核生物和細菌中都能同樣地運作
D. One toehold switch can control all genes in an operon
一個指尖轉換可以控制一個操縱組中的所有基因

Ecology 生態

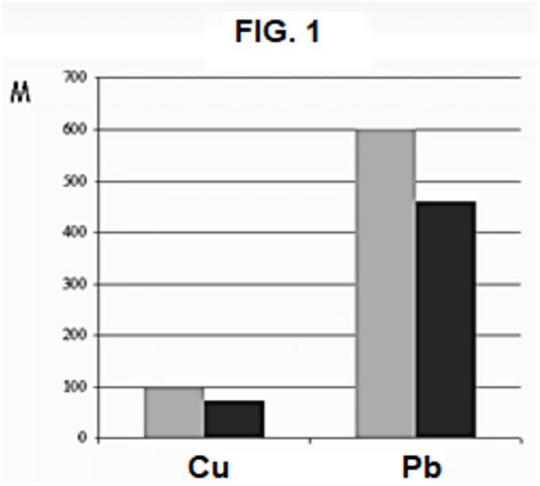
Q46

Salt marshes are complex coastal environments usually located within estuarine systems. Estuaries receive important inputs of pollutants as they are often situated in the vicinity of highly populated and industrialized areas. Once metal contaminants enter the salt marsh, they become distributed in sediments, pore water and plants, which are able to capture metals from the soil through their roots.

鹽澤屬於複雜的海岸環境，常常坐落於河口系統。河口由於常坐落於高人口密度區及工業區，常會接受到許多重要的汙染物。一旦金屬汙染物進入鹽澤，他們會存留在底質、孔隙水以及植物中，後者能藉由根從土壤中吸收金屬。

The uptake of metals by plants depends upon their availability in sediments, which is determined by the physical and chemical characteristics of the sediments. The activity of plants can alter these factors inducing variations in the speciation and availability of metals. Differences in metal accumulation levels occur between plant species and also between sediments colonized by different plant species.

植物對金屬的吸收主要取決於底質中可提供的金屬量，而金屬吸收量則取決於底質的物理與化學的特性。植物的作用能夠改變上述的特性，而引發種化的變異以及金屬可吸收性。金屬累積程度的差異發生在不同的植物種類間，同時也發生在不同植物種類與其生長不同的底質間。



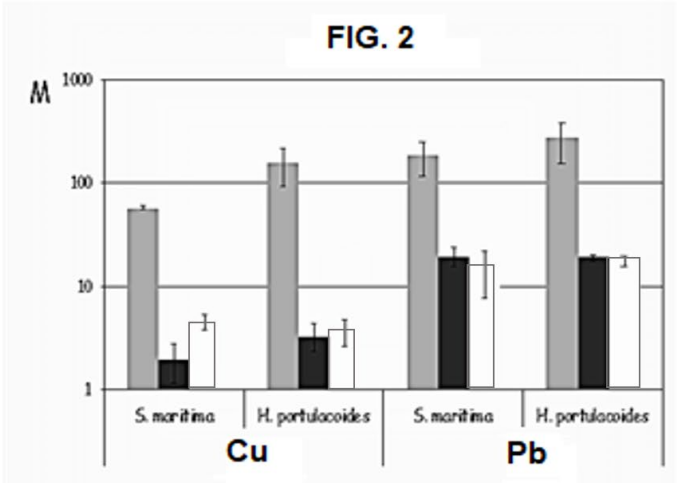


Figure 1 - M = Metal concentration (μg g^{-1} dry weight) of copper (Cu) and lead (Pb) in salt marsh sediments colonized by *Spartina maritima* (gray) and *Halimione portulacoides* (black).

圖 1、M 是在 *Spartina maritima*（灰色）和 *Halimione portulacoides*（黑色）這兩種植物生長的鹽澤中，底質中的銅與鉛的金屬濃度（μg g^{-1} dry weight）。

Figure 2 - M = Metal concentration (μg g^{-1} dry weight) in roots (gray), stems (black) and leaves (white) of *Spartina maritima* and *Halimione portulacoides.*

圖 2、M 是 *Spartina maritima* 和 *Halimione portulacoides* 這兩種植物的根（灰色）、莖（黑色）、葉（白色）中的金屬濃度（μg g^{-1} dry weight）。

Indicate whether each of the following statements is true (T) or false (F).

(*4 points, 1 point each correct answer*)

指出下列敘述何者正確（T）或錯誤（F）（４分，每個正確答案１分）

A. Salt marshes dominated by *S. maritima* may have a stronger capacity for the retention and phytostabilisation of Cu and Pb than those dominated by *H. portulacoides*
相較於 *H. portulacoides* 為主的鹽澤，以 *S. maritima* 為主的鹽澤對銅及鉛的保有及植物穩定（phytostabilisation）能力比較強

B. Salt marshes mainly colonised by *H. portulacoides* can translocate more metals above ground , sourcing these metals to the marsh ecosystem
以 *H. portulacoides* 為主的鹽澤能夠傳輸更多的金屬到地表，提供沼澤生態系的金屬來源

C. The use of these species for phytoremediaton of polluted marshes could be applicable from two different perspectives: phytostabilisation of metals in sediments, or phytoextraction by accumulation in aboveground plant tissues for subsequent plant removal.
利用這些植物對於被汙染沼澤進行植物修補（phytoremediaton），可能可應用在兩個不同的面向：植物穩定（phytostabilisation）即是透過植物來穩定底質內的金屬，或是植物萃取（phytoextraction）即是透過植物將金屬累積至地上植物組織內，並在之後進行植物移除

D. *S.maritima* seems to be a more appropriate plant to use, for phytoextraction purposes
S.maritima 似乎比較適合用在植物萃取的目的

Q47

Topography creates contrasting microclimates, especially between northern and southern slopes in drylands, which result in clear differences of tree cover patterns in the landscape. In a study performed in a holm oak community (a key tree species in Mediterranean drylands) the impact of microclimatic conditions on holm oak trees regeneration success was studied using Potential Solar Radiation (PSR) as an integrated measure of microclimatic conditions.

地形會形成了明顯不同的微氣候，尤其是在乾旱地方的南北坡向之間，結果在景觀上造成很明顯的樹覆蓋型態的差異。在一項針對聖櫟（holm oak，是一種地中海乾旱地的關鍵物種）群集的研究，利用太陽輻射潛能 Potential Solar Radiation（PSR）的方法來整合性的測量微棲地環境，以了解其對聖櫟再生（小苗生長）的影響。

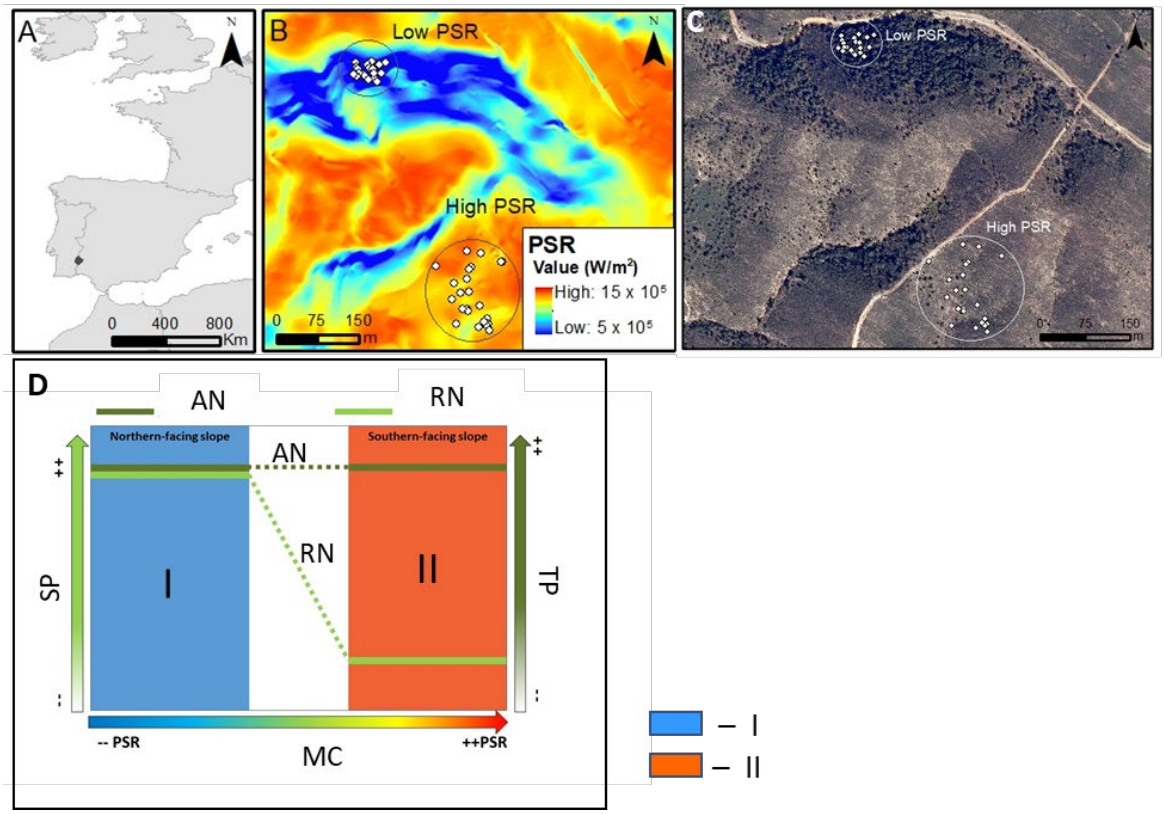


Figure 1- Location of the study area in Europe (A; dark circle) and sampling area with white points representing the trees sampled in high and low values of Potential Solar Radiation (PSR) (B) and with a 2010 background aerial photo (C) and a conceptual diagram of tree performance along contrasting microclimatic conditions for different tree stages (D): tree (adult niche - **AN**) and seedlings (regeneration niche - **RN**) in a PSR gradient (**MC** – microclimatic conditions) **SP** - seedling performance, **TP** - tree performance. **I** – Northern-facing slope; **II** – Southern-facing slope.

圖 1、A 是在歐洲研究地點的位置（黑圓圈）；B 是在樣區，太陽輻射潛能（PSR）高或低數值的樹木的分布（白點）；C 為 2010 年背景的空照圖；D 為不同年齡層的樹木在明顯不同的微氣候條件中的生長表現概念圖。樹木（成熟棲位 - **AN**）、苗木（再生棲位 - **RN**）在太陽輻射潛能（PSR）的梯度下（**MC** - 微氣候條件），苗木的表現（**SP**）、樹木的表現（**TP**）。**I** - 北向坡；**II** - 南向坡。

Indicate whether each of the following statements is true (T) or false (F).
(4 points, 1 point each correct answer)
指出下列敘述何者正確（T）或錯誤（F）（4 分，每個正確答案 1 分）

A. In the northern hemisphere, the microclimate conditions range from warm and dry (xeric) on northern slopes to cool and moist (mesic) on southern slopes
在北半球，微氣候的狀況從北向坡的溫暖及乾旱（旱生），到南向坡的涼爽及潮濕（中生）

B. These findings suggest that on northern slopes, natural regeneration is higher with established trees facilitating the germination and growth of new trees
這些發現指出在北向坡天然再生較高，其在於既有樹木的存在有利於小樹的萌芽與生長

C. Microclimate, as measured by the PSR, was the key driver in determining the natural regeneration and tree performance of holm oak on a local scale
根據太陽輻射潛能（PSR）測量而得的微氣候是關鍵的驅動者，來決定聖櫟的天然再生以及樹木在當地的表現

D. The width of the regeneration niche is expected to be narrower than that of adult trees, since their water sources are restricted to soil water content especially under more stressful microclimatic conditions
預期再生棲位的範圍相較於成樹是比較窄的，因為水資源受到土壤水含量的限制，尤其是在比較差的微氣候條件

Q48

Figure 1 shows the results obtained in a deforestation program in a hydrographic basin in two experimental plots. Control plot without any deforestation intervention (**P1**) and plot 2 (**P2**) where the forest (1-60 years old forest) was cut (arrow), and herbicide application prevented the vegetation development for the 3 following years (2 - succession supressed). After this time, herbicide was no longer applied, allowing vegetation to evolve naturally (3 -succession). (Plot 1 – dark circles, Plot 2 - red circles),

圖 1 顯示在一個水文盆地中的兩處實驗場域所執行的一項森林砍伐計畫結果。區塊 1（P1 - 黑圈）是控制組沒有執行任何的林木砍伐，以及區塊 2（P2 - 紅圈）是從 1 - 60 年的樹木全部被砍伐（箭頭），並噴灑除草劑以阻止之後三年內植物的生長（2 - 抑制演替）。在此時間之後，不再使用除草劑，讓植物自然生長（3 - 演替）。

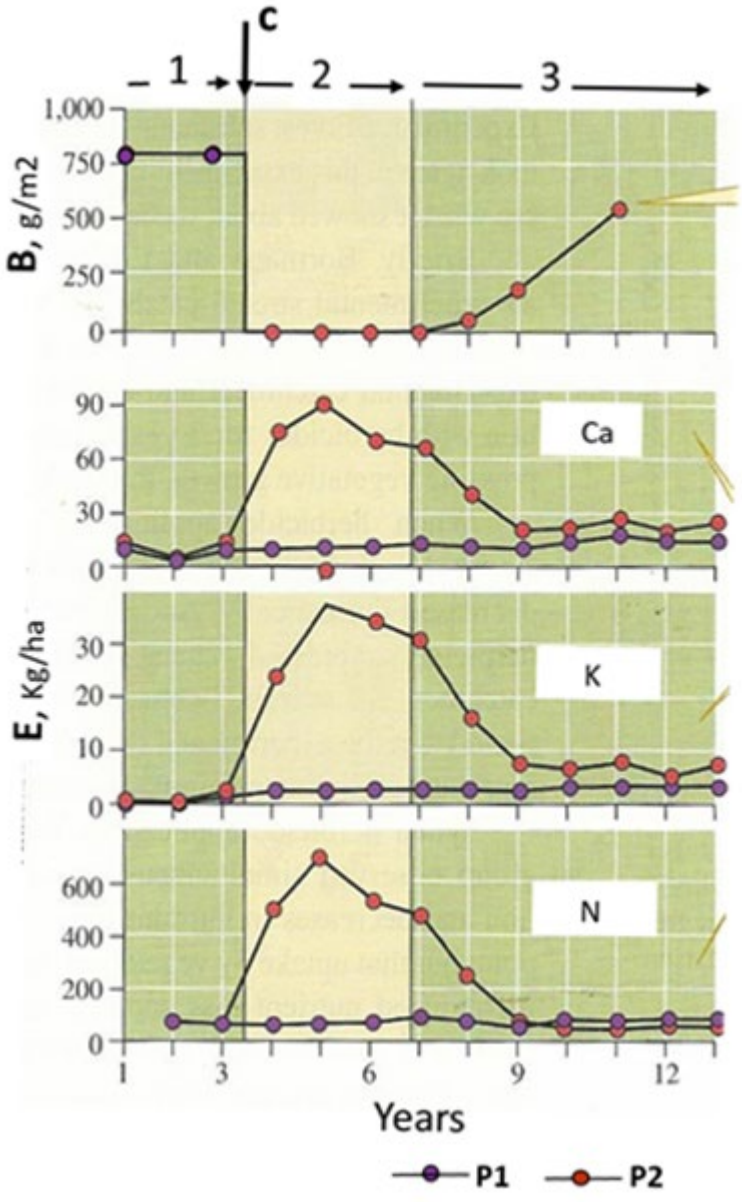


Figure 1. Periods: **1** – 60 years old forest, **2** - succession supressed, **3** – succession; **C** (arrow) – forest clear cut, **B** – plant biomass (g m^{-2}), **E** - annual net export (Kg ha^{-1}) for **Ca** – calcium, **K** -potassium, **N** – nitrogen. **P1** – Plot 1, **P2** – Plot 2

圖 1、期間：**1** - 60 年樹木，**2** - 演替抑制，**3** - 演替；**C**（箭頭）-森林全部砍伐，**B** - 植物生物量（g m^{-2}），Ca - 鈣、**K** - 鉀、**N** - 氮的每年淨輸出量（**E**）（Kg ha^{-1}）。P1 區塊 1、P2 區塊 2。

Indicate whether each of the following statements is true (T) or false (F).
(4 points, 1 point each correct answer)
指出下列敘述何者正確（T）或錯誤（F）（4分，每個正確答案1分）

A. After the suppression of the herbicide application, a primary succession starts with a gradual increase in biomass
停止使用除草劑之後，新的初級演替開始，即植物生物量逐漸增加

B. After cutting the vegetation and during herbicide application there is a marked increase in leaching of nutrients out of the system, contributing to a gradual depletion of these nutrients
在砍伐植物後及使用除草劑期間，環境中營養鹽的流失很明顯增加，導致這些營養鹽逐漸缺失

C. During the 3-year period without vegetation cover, there is a change in the water balance of the system with a marked increase in evapotranspiration and runoff (streamflow)
在這三年沒有植物覆蓋的期間，由於顯著的植物蒸散作用以及逕流量的增加（溪流水），造成當地環境水平衡的改變

D. This deforestation experiment showed that succession can reduce the loss of nutrients caused by disturbance
森林砍伐實驗顯示，演替可以減少因干擾所造成的營養鹽損失

Q49

Figure 5 is a diagrammatic representation of sample plots (1 m^2) from two different herbaceous communities (**Community A** and **Community B**) containing the same six species but in different abundances. Each letter (a, b, c, d, e, f) represents a different species (Sp). The distribution of individuals among species is called species evenness or species equitability and is quite different between communities. Species diversity is a combination of richness and evenness. Here we use the Shannon-Wiener's index (H´) to calculate the diversity of the two communities (**Table 1**) where *s* is the total number of species, and ***pi*** is the proportion of all individuals in the sample that belongs to species *i*

$$H' = -\sum_{i=1}^{s} (pi).(\ln pi)$$

圖 5 的示意圖所顯示的是從兩個具有六個相同物種但豐富度不同的草本植物群集(群集 A 與群集 B)取樣區塊(1 平方公尺)。每一個小寫字母(a、b、c、d、e、f)代表不同的物種(Sp)。群集之間的物種均勻度或物種均等度（亦即物種間的個體分布樣態）相當不同。物種多樣性則是物種豐富度與均勻度的組合。在此處我們使用 Shannon-Wiener's Index (H')來計算兩個群集的物種多樣性(表 1)，其中 s 代表物種總數，pi 則是在取樣區塊中屬於物種 i 的個體比例。

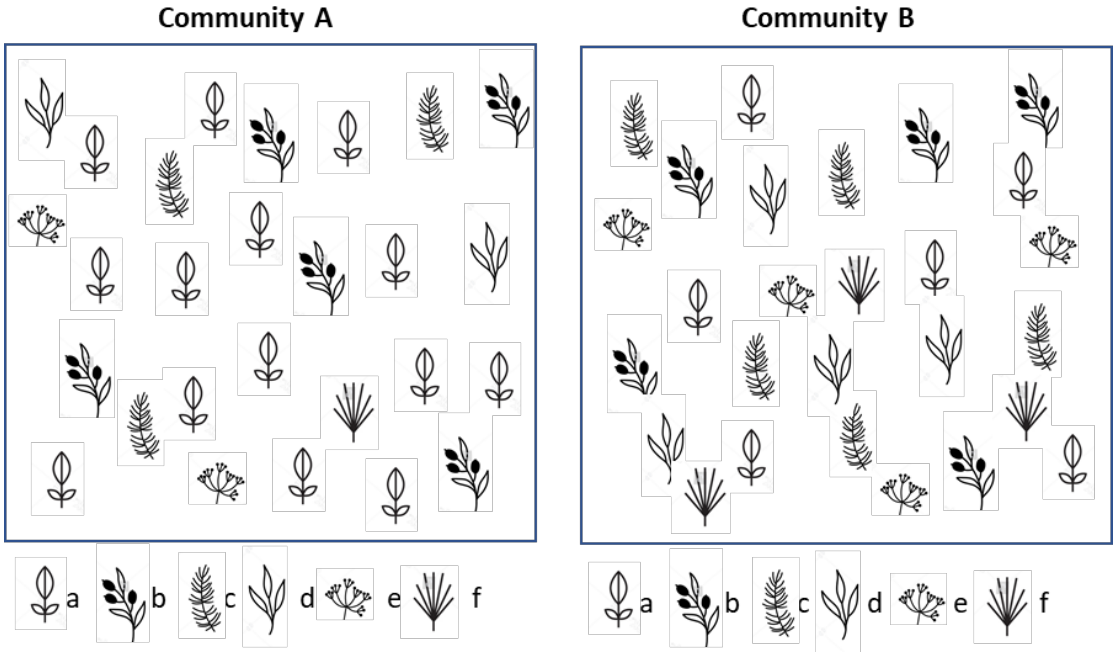


Figure 5 – Two different herbaceous Communities.

圖 5 – 兩個不同的草本植物群集。

Table 1 – Calculating species diversity (H´) for two hypothetical herbaceous communities. Nº - number of individuals of different species

表 1 – 計算兩個假想的草本植物群集的物種多樣性(H')。Nº - 不同物種的個體數目。

Com A					*Com B*				
Sp	*Nº*	*(pi)*	*ln pi*	*pi.lnpi*	*Sp*	*Nº*	*(pi)*	*ln pi*	*pi.lnpi*
a	14	0.56	-0.580	-0.325	a	6	0.24	-1.427	-0.343
b		0.20	-1.609	-0.322	b		0.20	-1.609	-0.322
c		0.12	-2.120	-0.254	c		0.20	-1.609	-0.322
d		0.08	-2.526	-0.202	d		0.16	-1.833	-0.293
e	2	0.08	-2.526	-0.202	e	4	0.16	-1.833	-0.293
f	1	0.04	-3.219	-0.129	f	3	0.12	-2.120	-0.254
Total					Total				

Indicate whether each of the following statements is true (T) or false (F).
(*4 points, 1 point each correct answer*)
指出下列說明何者為真（T）或假（F）（4 分，每個正確答案 1 分）

A. The total density (number of individuals m^{-2}) is the same in the two communities
兩個群集的總密度 (每平方公尺的個體數目)相同

B. The density of species b is higher in community A
A 群集中，b 物種的密度較高

C. The Shannon diversity index (H´) in community A is 1.827
A 群集的 Shannon diversity index (H´)為 1.827

D. Due to the dominance of one species in community A, Shannon-Wiener's diversity index is lower in this community
由於 A 群集中有一個物種比較優勢，所以其 Shannon-Wiener's diversity index 比較低

Q50

2021 is the International Year of Caves and Karst. The caves open real windows to the study of the vast subterranean ecosystem that hides under our feet. In a domain without light, the organisms that inhabit this environment evolve and adapt, showing convergent evolution similar to what occurs in the deep sea. What are the characteristics of cave-adapted animals?

2021 年是國際洞穴與喀斯特地形年。洞穴環境開啟了隱藏我們足下的地底生態系的一扇嶄新的研究之窗。在無光的環境中，棲息於這樣環境演化與適應的生物顯示出與深海生物類似的趨同演化現象。什麼是適應洞穴生物的特性呢？

Figure 1. Cave millipede, *Cylindroiulus villumi*, adapted to live in caves in Portugal, scale bar: 1 mm.

圖 1. *Cylindroiulus villumi* 是一種生存於葡萄牙洞穴中的馬陸。

Indicate whether each of the following statements is true (T) or false (F).
(*4 points, 1 point each correct answer*)

指出下列說明何者為真（T）或假（F）（4 分，每個正確答案 1 分）

A. Are expected to live longer than their relatives at surface
洞穴生物比牠們在地表上的近親活得久

B. Have a pronounced circadian rhythm
具有明顯的生理時鐘

C. Are more diverse than surface organisms in their distribution areas
在其分布區域，洞穴生物的多樣性會高於地表上的生物

D. Have a high prevalence of endemic species
特有物種的比例很高

Q51

The salinization of groundwater is a global long-term environmental problem worldwide, exacerbated in arid and semi-arid regions by global warming. In a study, the dose-response curve and median lethal salt concentrations were estimated for three groundwater-adapted crustaceans (Cyclopoida, Harpacticoida and Syncarida) that live in aquifers of southern Australia (**Figure 1**).

因為全球暖化的因素，乾燥與半乾燥地區的地下水鹽化是一個長期的全球性環境問題，一項研究評估了生活在澳大利亞南部含水層中的三種適應地下水的甲殼類動物（Cyclopoida、Harpacticoida 和 Syncarida）的劑量反應曲線和中位數致死鹽濃度(半數致命劑量)

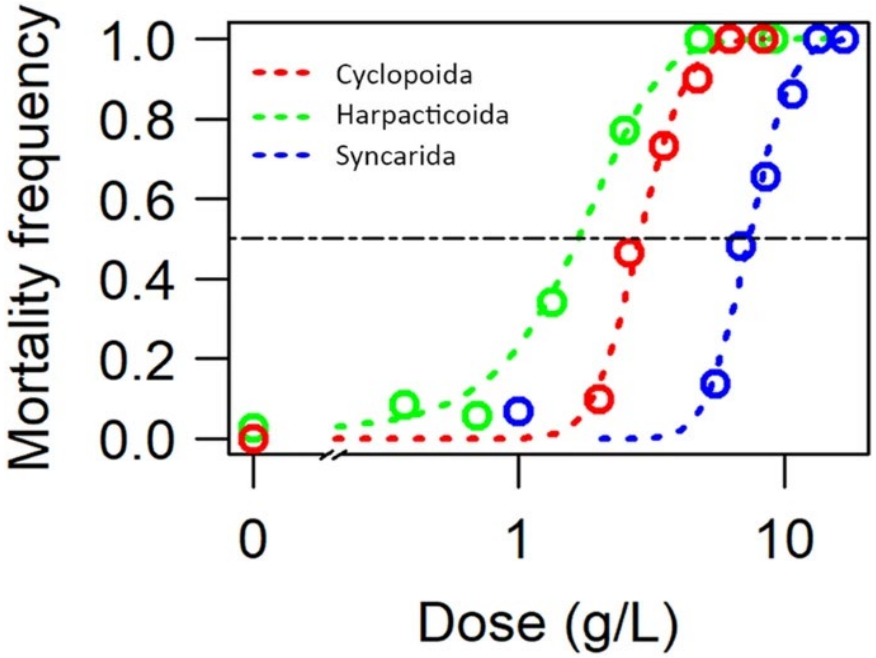


Figure 1 - Salt (NaCl) dose–response curves and median lethal concentrations (LC_{50}) at 96 hours. Y axis - Mortality frequency; X axis - Dose (g/L).

圖 1 - 96 小時的鹽 (NaCl) 劑量-反應曲線和中位數致死濃度(半數致命劑量) (LC_{50})。 Y 軸——死亡率； X 軸 - 劑量 (g/L)。

Indicate whether each of the following statements is true (T) or false (F).

(4 points, 1 point each correct answer)

指出下列陳述何者為真（T）或為假（F）（4 分，每個正確答案 1 分）

A. The crustaceans, Cyclopoida and Harpacticoida were less sensitive to salt than Syncarida
比起 Syncarida 來說，Cyclopoida 和 Harpacticoida 對鹽度比較不敏銳

B. The presence of high concentrations of salt groundwater stresses the osmotic balance of the studied crustaceans
高鹽度的地下水對所有被研究的甲殼類動物的滲透壓平衡都會造成逆境

C. If we measure a maximum environmental concentration of salt (NaCl) of 10g/L in groundwater in the area of distribution of these species, they are endangered by salinization
如果我們在這些物種的分佈區域測到地下水中鹽分(NaCl)的最大環境濃度為 10 克/升，牠們就會因鹽化而瀕臨滅絕

D. If the temperature of groundwater increases, together with the salt concentrations, the effect on the groundwater crustaceans is likely to be magnified.
如果地下水溫度升高，加上鹽分濃度升高，對地下水甲殼類動物的影響可能會被放大

Biosystematics 生物系統分類學

Q52

Leeches are organisms belonging to the Phylum Annelida, Class Hirudinea. They are found predominantly in freshwater habitats, few are marine, and some are adapted to terrestrial life. As fluid feeders and bloodsuckers, leeches are more highly specialized than other Annelida. **Figure 1** presents a transversal section of a leech at the intestine level and the arrows point to glandular cells identified just under the epidermis. **What is their function?**

水蛭是屬於環節動物門水蛭綱的生物。牠們主要生活在淡水棲息地，很少是海洋生物，有些適應陸地生活。作為取食體液和吸血者，水蛭比其他環節動物更加特化。**圖 1** 顯示了在水蛭腸道的橫切面，箭頭指向表皮下的腺細胞。**它們的作用是什麼？**

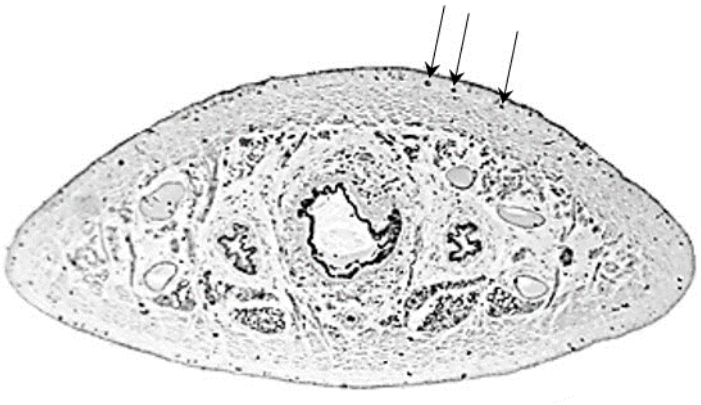


Figure 1. Transversal section of a leech at the intestine level.
圖 1. 水蛭腸道的橫切面

Indicate whether each of the following statements is true (T) or false (F).
(*4 points, 1 point each correct answer*)

指出下列陳述何者為真（T）或為假（F）（**4 分，每個正確答案 1 分**）

A. Allow the organism to glide better in the habitat
讓生物體可以在棲息地滑行得更好

B. Secrete substances that attract prey
分泌可吸引獵物的物質

C. Secrete substances that repel predators
分泌可嚇阻天敵的物質

D. Facilitate cutaneous respiration
促進皮膚呼吸

Q53

Insects have different mouthparts and for each type of feeding they are adapted in a specialized way. The 'primitive' arrangement of mouthparts is seen in the cockroach where they are used for chewing. When specialised food sources are exploited, the mouthparts are modified, sometimes considerably, so that the food may be ingested efficiently. Figure 1 shows different mouthpart types in insects and Figure 2 presents some insect species.

昆蟲有不同形式的口器，並且對於每種類型的取食方式都以專一特化的方式適應。在蟑螂中可以看到口器的“原始”排列，它們用於咀嚼。當食物來源變得更專一時，口器就會有所改變，有時變化的程度相當大，以便可以有效地攝取食物。圖 1 顯示了昆蟲的不同口器類型，圖 2 顯示了一些昆蟲種類。

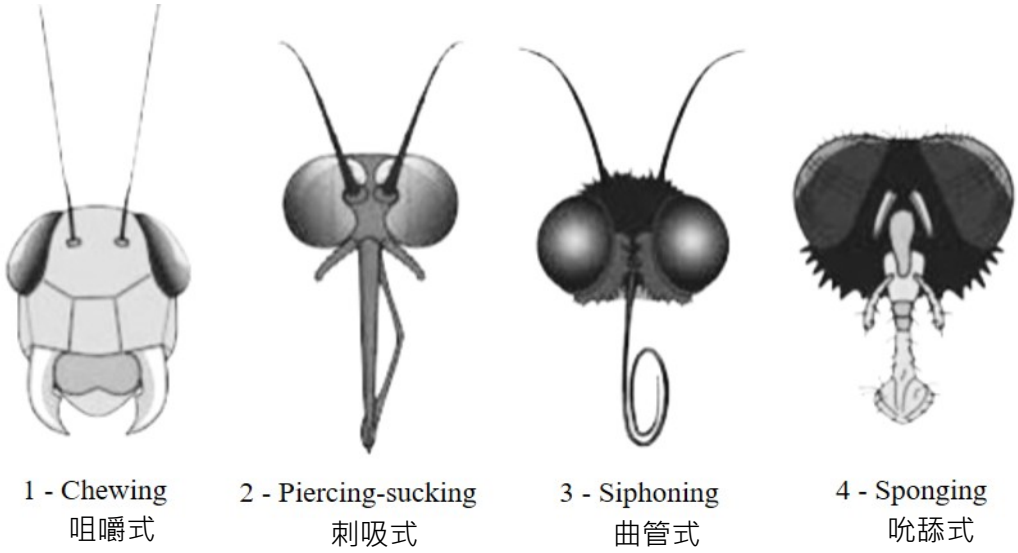


Figure 1. Four general types of mouthparts in insects. (insert nº with translation)
圖 1. 昆蟲中，四種口器的一般形式

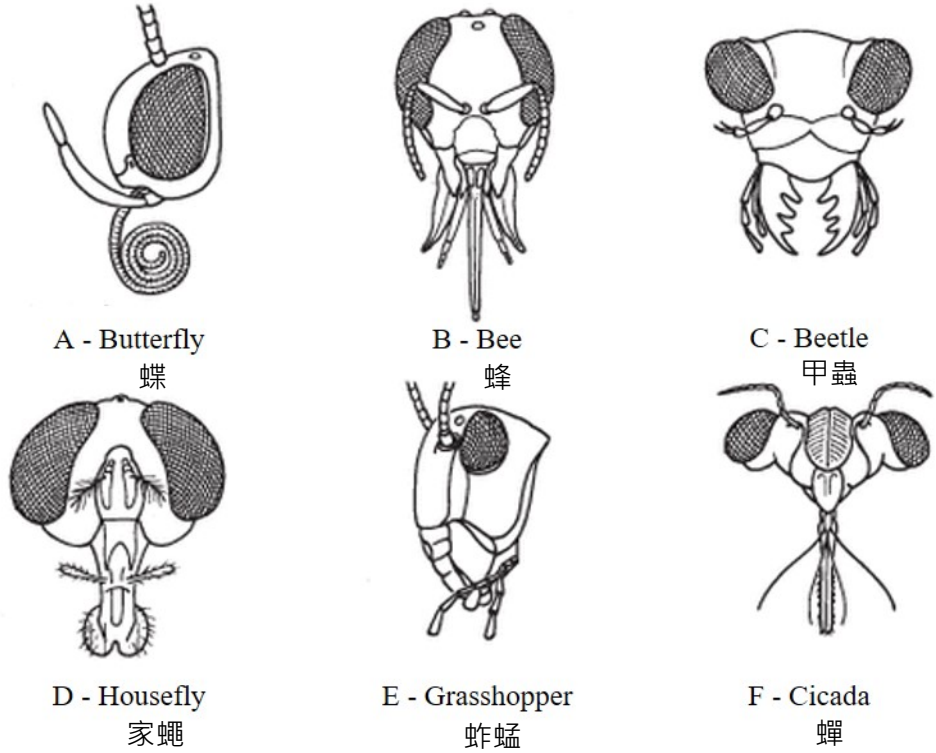


Figure 2. Mouthparts of six insect species. (insert Letter with translation)
圖 2. 六種昆蟲的口器。

Indicate whether each of the following statements is true (T) or false (F).
(4 points, 1 point each correct answer)
指出以下何陳述為真（T）或為假（F）（4 分，每個正確答案 1 分）

A. Species A is of the siphoning type, B is of the piercing-sucking type, D is of the chewing type, E of the piercing-sucking type
A 物種的口器是曲管式，B 是刺吸式，D 是咀嚼式，E 是刺吸式

B. Species A is of the piercing-sucking type, B is of the siphoning type, C is of the chewing type, D is of the sponging type
A 物種的口器是刺吸式、B 是曲管式、C 是咀嚼式、D 是吮舔式

C. Species A is of the siphoning type, C is of the chewing type, D is of the piercing-sucking type, E is of the sponging type
A 物種的口器是曲管式、C 是咀嚼式、D 是刺吸式、E 是吮舔式

D. Species A is of the siphoning type, B is of the piercing-sucking type, C is of the chewing type, D is of the sponging type
A 物種的口器是曲管式、B 是刺吸式、C 是咀嚼式、D 是吮舔式

Q54

Otoliths are acellular concretions of calcium carbonate and other inorganic salts, which develop over a protein matrix in the inner ear of vertebrates and are associated with balance and acoustic functions. In fish they record information in their microstructure and chemistry at different temporal scales related to their growth and environment. The largest of the three pairs of otoliths (sagitta) is the most studied presenting great morphological variability and being species specific.
耳石是碳酸鈣和其他無機鹽的非細胞凝結物，它們在脊椎動物內耳的蛋白質基質上發育，並與平衡和聲覺功能有關。在魚類中，在與其生長和環境相關的不同時間尺度上，耳石記錄其微觀結構和化學信息。三對耳石中最大的一個矢狀耳石是被研究最多的，其呈現出巨大的形態變異性和物種專一性。

Figure 1 presents the anatomical features of a fish sagitta otolith. **Table 1** presents five sagitta otolith descriptions. **Figure 2** presents sagitta otoliths from three species.
圖 1 展示了魚矢狀耳石的解剖特徵。表 1 列出了五個矢狀耳石描述。圖 2 顯示了來自三個物種的矢狀耳石。

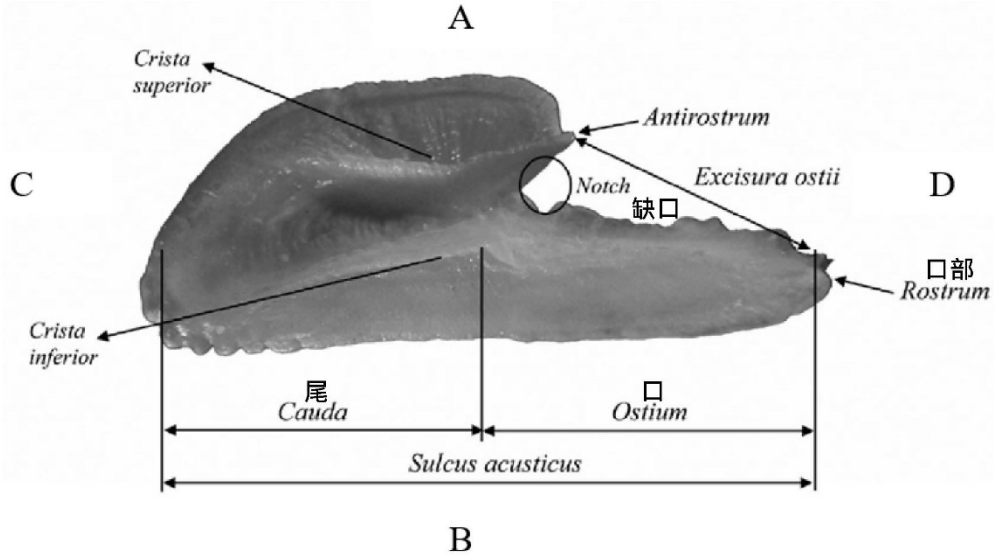


Figure 1. Anatomical features of a sagitta otolith used for morphological descriptions. A – Dorsal; B – Ventral; C – Posterior; D – Anterior.
圖 1. 用於形態描述的矢狀耳石的解剖特徵。 A – 背側； B – 腹側； C – 後部； D - 前部。

Table 1. Otolith descriptions for five fish species descriptions.

表 1. 五種魚類的耳石描述。

D1	**Forkbeard** (*Phycis phycis*) Shape: lanceolated to oblong, anterior region wider, margins crenate in the smaller otoliths. *Ostium* and *cauda*: undifferentiated. Anterior region: round to oblique-angled, *rostrum* poorly defined; *antirostrum* absent; *excisura ostii* very narrow without a notch. Posterior region: lanceolated to peaked. *Phycis phycis* 形狀：披針形至長圓形，前部區域較寬，在較小的耳石中邊緣具圓齒。 口和尾：未明顯分化。 前部：圓形至斜一邊，喙部界限不清；antirostrum 闕如； excisura ostii 非常窄，沒有缺口。 後部：披針形至尖。
D2	**Boardfish** (*Capros aper*) Shape: asymmetric with ventral and dorsal areas almost equally developed, ventral margin irregular. *Ostium*: funnel-like, shorter than the *cauda*. *Cauda*: tubular, straight, bordered by raised crests. Anterior region: double-peaked; *rostrum* and *antirostrum* large, broad and round or slightly pointed, *rostrum* longer; *excisura ostii* wide with an acute, deep notch. Posterior region: irregular to double-peaked. *Capros aper* 形狀：不對稱，腹側和背側區域幾乎同樣發達，腹側的邊緣不規則。 口：漏斗狀，比尾短。 尾：管狀，直，邊緣有隆起的波峰。 前部：雙峰；口部及 *antirostrum*、寬而圓或略尖，喙長； excisura ostii 寬，有一個銳利的深切缺口。 後部：不規則至雙峰。
D3	**Black scabbardfish** (*Aphanopus carbo*) Shape: elliptic to oblong, ventral margin sinuate to crenate. *Ostium*: funnel-like, shorter than the *cauda*. *Cauda*: tubular, straight, ending half way to the posterior margin. Anterior region: peaked; *rostrum* short, broad, pointed; *antirostrum* narrow, pointed; *excisura ostii* wide with or without a deep, acute notch. Posterior region: round. *Aphanopus carbo* 形狀：橢圓形至長圓形，腹緣波狀至圓齒。 口：漏斗狀，比尾短。 尾：管狀，直，終止於後緣的一半。 前部：尖尖的；口部又短又寬又尖；antirostrum 狹窄又尖；excisura ostii 寬闊 或沒有既深又銳利的缺口。 後部區域：圓形。
D4	**Blue jack mackerel** (*Trachurus picturatus*) Shape: lanceolated, dorsal margin sinuate to irregular. *Ostium*: funnel-like, shorter than the *cauda*.

	Cauda: tubular, curved, strongly flexed posteriorly, ending close to the posterior-ventral margin. Anterior region: peaked; *rostrum* long, broad, very pointed; *antirostrum* short, broad, round; *excisura ostii* wide with a shallow notch. Posterior region: angled to oblique. *Trachurus picturatus* 形狀：披針形，背緣波狀至不規則。 口：漏斗狀，比尾短。 尾：管狀，彎曲，向後強烈彎曲，末端靠近後腹緣。 前部：尖尖的；口部又長又寬又非常尖；antirostrum 又短又寬又圓； excisura ostii 寬，有一個淺凹口。 後部區域：斜斜的。
D5	**Bluemouth** (*Helicolenus dactylopterus*) Shape: elliptic. *Ostium*: funnel-like, longer than the *cauda*. *Cauda*: tubular, straight, wider posteriorly, ending far from the posterior margin. Anterior region: peaked; *rostrum* moderately long, broad, pointed, curved to the dorsal region; *antirostrum* absent; *excisura ostii* wide with a bite shaped notch in the larger otoliths. Posterior region: round to oblique. *Helicolenus dactylopterus* 形狀：橢圓形。 口：漏斗狀，長於尾。 尾：管狀，直，後部較寬，末端遠離後緣。 前部：尖尖的；吻部中等長，又寬又尖，向背部彎曲；antirostrum 闕如； excisura ostii 寬，在較大的耳石中有一個看起來像被咬過的凹口。 後部：圓形至斜斜的。

A B C

Figure 2. Three different species (A, B and C) sagitta otoliths.
圖 2. 三種魚類的矢狀耳石

Indicate whether each of the following statements is true (T) or false (F).
(*4 points, 1 point each correct answer*)
指出下列陳述何者為真（T）或為假（F）（4 分，每個正確答案 1 分）

A. Species A is *Aphanopus carbo*, B is *Capros aper* and C is *Phycis phycis*
A 是 *Aphanopus carbo*，B 是 *Capros aper* ，C 是 *Phycis phycis*

B. Species A is *Trachurus picturatus*, B is *Capros aper* and C is *Phycis phycis*.
A 是 *Trachurus picturatus*，B 是 *Capros aper* ，C 是 *Phycis phycis.*

C. Species A is *Aphanopus carbo*, B is *Capros aper* and C is *Helicolenus dactylopterus*
A 是 *Aphanopus carbo*，B 是 *Capros aper* ，C 是 *Helicolenus dactylopterus*

D. Species A is *Trachurus picturatus*, B is *Aphanopus carbo* and C is *Phycis phycis*
A 是 *Trachurus picturatus*，B 是 *Aphanopus carbo* ，C 是 *Phycis phycis*