30th International Biology Olympiad
SZEGED, HUNGARY

Theoretical Exam 理論測驗

Morning 早上

18th July 2019

COUNTRY 國家
LANGUAGE 語言

Theoretical Exam Morning 理論測驗 早上

General instructions 一般說明

This exam consists of 38 questions and lasts 180 minutes.

- Cell Biology (Q1-9)
- Animal Anatomy and Physiology (Q10-19)
- Plant Anatomy and Physiology (Q20-24)
- Genetics and Evolution (Q25-30)
- Ecology (Q31-33)
- Biosystematics (Q34-36)
- Ethology (Q37-38)

此考試包含 38 個問題，考試時間 180 分鐘。

- 細胞生物學（Q1-9）
- 動物解剖學和生理學（Q10-19）
- 植物解剖學和生理學（Q20-24）
- 遺傳與演化（Q25-30）
- 生態學（Q31-33）
- 生物系統分類學（Q34-36）
- 動物行為學（Q37-38）

1. **Please remember to attach your BARCODE sticker to all pieces of paper on the answer sheet.**
2. Write your answers in the separate answer sheet provided. **Only answers given in the answer sheet will be considered.**
3. Stop answering and put down your pencil immediately when the bell rings signalling the end of the exam.
4. No paper, materials or equipment should be taken out of the exam room.

1. 請記得把你的條碼貼紙貼在答案紙的每一頁上。
2. 把答案分別寫在所提供的答案紙上。只有寫在答案紙上的答案才會評分。
3. 當鈴聲響起，表示考試結束時，請立即停止作答並放下鉛筆。
4. 不可將任何紙張、材料或設備帶出考場。

1.	2.				3.
	U	C	A	G	
U	F F L L	S S S S	Y Y STOP STOP	C C STOP W	U C A G
C	L L L L	P P P P	H H Q Q	R R R R	U C A G
A	I I I M	T T T T	N N K K	S S R R	U C A G
G	V V V V	A A A A	D D E E	G G G G	U C A G

Cell Biology 細胞生物學

Q1

The effect of knocking out specific genes in worms on apoptosis (programmed cell death) was studied.
探討線蟲的細胞凋亡相關的特定基因剔除效應

GENE 基因	MANIPULATION 操縱	CELL DEATH 細胞死亡
ced9	knock-out 剔除	increased 增加
ced4	knock-out 剔除	reduced 降低
ced3	knock-out 剔除	reduced 降低
egl1	knock-out 剔除	reduced 降低
ced4 & ced9	knock-out 剔除	reduced 降低
ced9 & ced3	knock-out 剔除	reduced 降低
ced9 & egl1	knock-out 剔除	increased 增加

Q.1.1 Write the letters A-D corresponding to the genes into the correct rectangle in the model of the control of cell death (CD) on your answer sheet.
在下方細胞死亡 (CD) 控制模式表格的正確方格中填入 A-D 字母相對應的基因
A. Ced3
B. Ced4
C. Ced9
D. Egl1

Q.1.2 Indicate whether an interaction is activating (+) or repressing (-) in the circles above the arrows.
在箭頭上方的圈中填入其作用為活化 (+) 或抑制 (-)

Q2

Hall, Rosbash and Young were awarded the 2017 Nobel Prize for their discoveries of the molecular mechanisms that control circadian rhythms. ’Period’ (PER) is a gene of the Drosophila that undergoes strict circadian oscillations. Mutations to PER alter or abolish the periodicity and phase of these rhythms. Another gene regulating the circadian rhythm is ’clock’ (CLK). Drosophila with a certain mutation in the CLK gene sometimes have disrupted circadian rhythms as shown in Table 1.

Hall, Rosbash 及 Young 等人因其發現控制生物時鐘的分子機制而獲得 2017 年諾貝爾獎，’Period’ (PER) 是與果蠅生物時鐘強韌同步表現的基因，PER 基因突變會改變或破壞此生物時鐘節奏及時期，另一生物時鐘調控基因為 clock(CLK)，如表 1 所呈現的，CLK 突變會破壞果蠅的生物時鐘。

Col 1	Col 2	Col 3	Col 4
Row 1	*CLK +/+*	24.3	0
	CLK +/-	24.3	36
	CLK -/-	24.2	86
Row 2	*CLK +/+*	24.3	1
	CLK +/-	24.8	47
	CLK -/-	*ARR*	100

Table 1. Col 1 = Condition. Col 2 = Genotype. Col 3 = Period of activity (h). Col 4 = % arrhythmic. Row 1 = 12 hr light:12 hr dark. Row 2 = Constant darkness. ARR = Arrhythmic

表 1、Col 1 = 條件 1. Col 2 = 基因型；Col 3 = 活躍時間 (h)；Col 4 = % 無節奏比例。Row 1 = 日夜比 12:12 小時；Row 2 = 永夜。ARR = 無節律。

Cloning revealed that these identified CLK mutant flies have a premature stop codon that truncates the protein, making it non-functional. To determine the in vivo regulatory pattern of the PER gene, they generated transgenic Drosophila strains carrying a luciferase cDNA fused to the promoter region of the PER gene. Then they assayed the activity of luciferase (quantified in counts/s) in Drosophila of the various CLK genotypes. Results are shown in Figure 1. Note that the luciferase activity is proportional to the expression of the examined gene.

這些果蠅 CLK 突變基因選殖分析顯示其具有一提前終止密碼子造成無活性的不完整蛋白。為探討 PER 基因在活體的調節形式，他們將 Luciferase cDNA 與 PER 啟動子接合後用以建構轉基因果蠅，並用以分析據具各式 CLK 基因型態的轉基因果蠅中的 Luciferase 活性，分析結果呈現在圖 1 中。注意: Luciferase 活性以其與所檢視基因的表現比率來呈現。

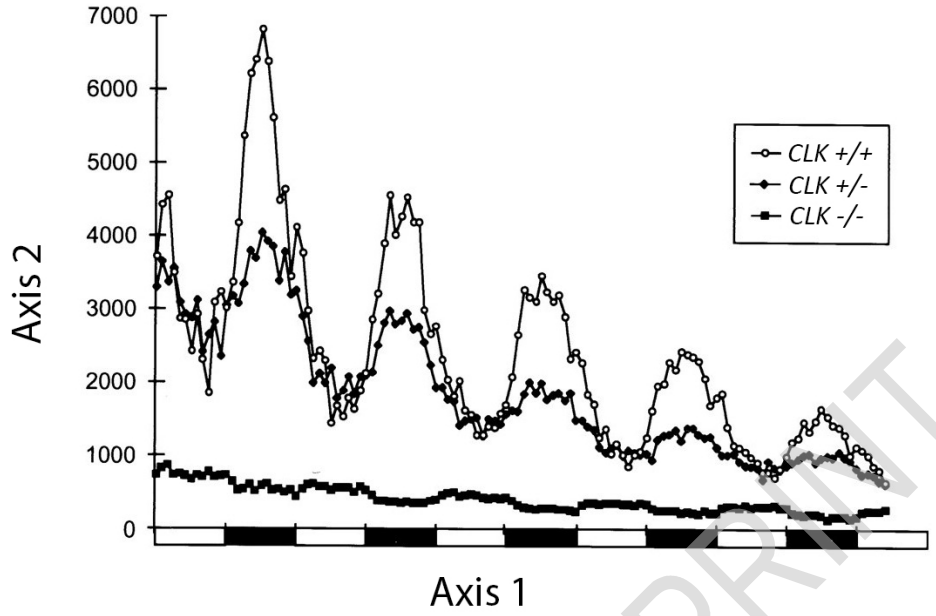


Fig.1. Axis 1 = Time (hours), white bars represent a 12 hour period of light, dark bars represent a 12 hour period of darkness. Axis 2 = Counts per Second

圖 1、軸 1 = 時間 (小時)，白色條表示 12 小時光照時段，黑色條表示 12 小時黑暗時段。; 軸 2 = 每秒鐘的計數。

Indicate with an **X** if each the following statements are true (T) or false (F).

以”**X**” 標示下列敘述為正確 (T) 或 錯誤 (F)

Q.2.1 Behavioural effects of CLK mutation are largely due to a defect in the degradation of circadian rhythm proteins, including PER.
CLK 突變對行為之效應大致是由於包括 PER 在內的生物時鐘相關蛋白降解所致

Q.2.2 The main effects of CLK mutation are fully penetrant at the molecular level.
CLK 突變的主要作用在分子層次為完全外顯性。

Q.2.3 The main effects of CLK mutation are fully penetrant at the behavioural level.
CLK 突變的主要影響在行為層次具完全外顯性。

Q.2.4 PER promoter activity cycled with a reduced frequency in CLK +/- flies compared to CLK +/+ flies.
與 CLK + / + 果蠅相比，在 CLK +/-果蠅中 PER 啟動子活性呈循環性頻率降低情形。

Q.2.5 The results shown could be explained by CLK acting as a transcription factor on PER.
結果可以詮釋成 CLK 可作為 PER 的轉錄因子。

Q.2.6 In constant dark, the circadian periodicity of wild-type Drosophila is approximately 24 hours.
在恆黑暗中，野生型果蠅的晝夜節律週期約為 24 小時。

Q3

G protein-coupled receptors (GPCRs) interact with G proteins that subsequently affect cell function through the generation of second messengers. Cyclic AMP (cAMP) generated by adenylyl cyclase controls cell functions via activation of protein kinases. GPCRs may either activate or inhibit the cyclase through the G proteins Gs and Gi, respectively. The difference between Gs and Gi resides in the α subunit, which binds and hydrolyses GTP. The Gs protein cycle is illustrated below.

G 蛋白偶聯受體（GPCR）與 G 蛋白相互作用，隨後產生第二信使，進而影響細胞功能。由腺苷酸環化酶作用產生的環 AMP（cAMP）會激活蛋白激酶來控制細胞功能。GPCR 可以分別通過 G 蛋白 Gs 和 Gi 來活化或抑制環化酶。Gs 和 Gi 之間的區別存在於 a 次單元，其可與結合及水解 GTP。Gs 蛋白作用流程如下所示。

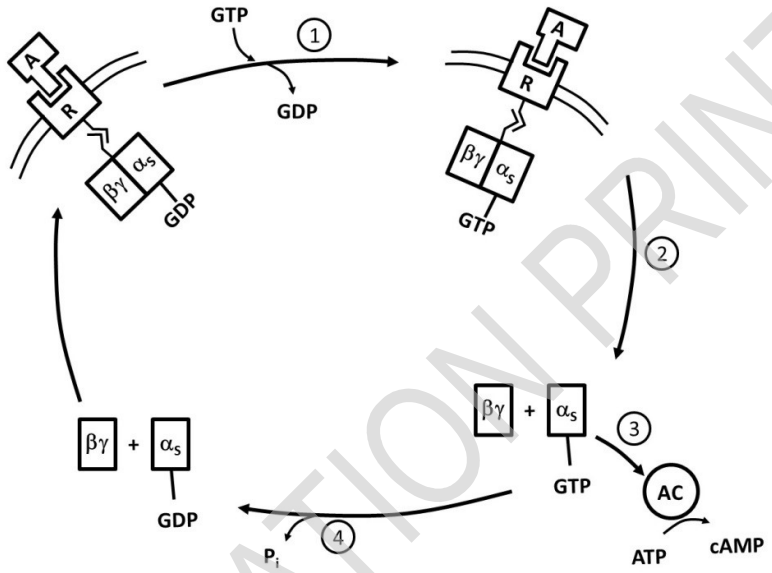


Fig.1

A lab is working on a pair of newly identified GPCRs, “GPCR-A” and “GPCR-B”. Each binds the same small ligand with the same affinity but activates different G-proteins that act on adenylyl cyclase. When activated, GPCR-A causes an increase in adenylyl cyclase activity, while GPCR-B causes a decrease in adenylyl cyclase activity. They have a cell line that expresses both GPCR-A, GPCR-B, the corresponding G-proteins, and adenylyl cyclase. There is a basal level of adenylyl cyclase activity that produces a baseline cAMP concentration.

有一研究團隊正在探討一對新發現的 GPCRs，“GPCR-A”和“GPCR-B”。其都可分別以相同親和力結合到相同的小配體，但激活不同 G 蛋白並作用於腺苷酸環化酶。當在活化態時，GPCR-A 造成腺苷酸環化酶的活性增加，而 GPCR-B 則腺苷造成酸環化酶活性的降低。該研究是有一細胞株可表達 GPCR-A 及 GPCR-B，其相應的 G 蛋白和腺苷酸環化酶。並具有基礎腺苷酸環化酶活性用以產生基礎量的 cAMP。

A member of the lab studying a pathogenic bacterium has discovered that it secretes a toxin that interferes with the mentioned signalling pathway. To determine how this toxin acts, she did an experiment in which she looked at intracellular cAMP levels in untreated and toxin treated cells (the original ligand of the receptors was not added in either of the experiments).

該研究有一成員正探討一致病細菌，發現該菌會分泌一種干擾上述信號傳導路徑的毒素。為了確認該毒素如何作用，她做了一個實驗，她觀察了未經處理和毒素處理細胞中的胞內 cAMP 量（在任一實驗中都未曾添加受體的原配體）。

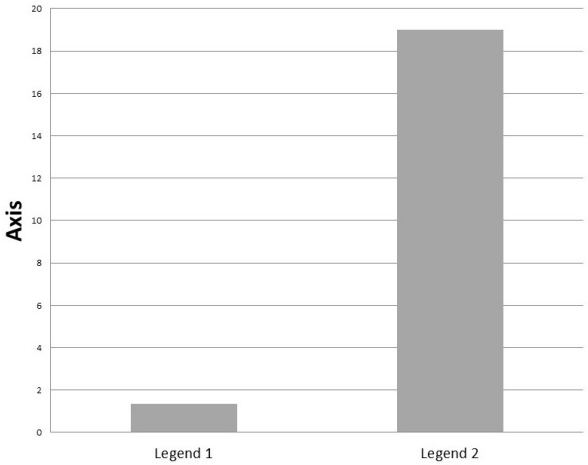


Fig.2. Axis = cAMP concentration (pmol/mL). Legend 1 = Toxin -. Legend 2 = Toxin +.

圖 2、縱軸 = cAMP 濃度 (pmol/mL)。圖說 1 = 未經毒素處理，圖說 2 = 有毒素處理。

Indicate with an **X** whether each of the following mutations increase (A), not changed (B) or decrease (C) the intracellular levels of cAMP upon ligand addition in the absence of the toxin? **Remember, both GPCR-A and GPCR-B bind the same ligand!**

以一個”**X**” 註明下列突變在無毒素存在下，加入配體時會 增加 (A), 沒改變 (B) 或 降低 (C) 胞內 cAMP 量？請注意，**GPCR-A 和 GPCR-B 結合相同的配體！**

Q.3.1 A mutation in GPCR-A that prevents G protein activation
一種在 GPCR-A 的突變阻止 G 蛋白的活化

Q.3.2 A mutation in GPCR-B that prevents G protein activation
一種在 GPCR-B 的突變阻止 G 蛋白的活化

Q.3.3 A mutation in Gs that prevents release of bound GDP
一種在 Gs 的突變可阻止結合 GDP 的釋放

Q.3.4 A mutation in Gi that prevents release of bound GDP
一種在 Gi 的突變可阻止結合 GDP 的釋放

Q.3.5 A mutation in Gs that prevents GTP hydrolysis
一種在 Gs 的突變可阻止 GTP 水解

Q.3.6 A mutation in Gi that prevents GTP hydrolysis
一種在 Gi 中的突變可阻止 GTP 水解

What is/are the **possible** explanation(s) for the mechanism in which the toxin in paragraph 3 affects adenylyl cyclase activity? Indicate with an X if each the following statements are true (T) or false (F)!

在第 3 段中的毒素會如何影響腺苷酸環化酶的活性？以一個 X 註明下列敘述為正確（T）或 錯誤（F）！

Q.3.7 The toxin inhibits activation of Gi in response to receptor stimulation.
該毒素因應受體刺激而抑制 Gi 的活化。

Q.3.8 The toxin inhibits GTP hydrolysis in Gs.
該毒素抑制 Gs 中的 GTP 水解。

Q.3.9 The toxin mimics GTP and causes persistent activation of all G proteins.
該毒素模擬 GTP 並導致所有 G 蛋白的持續活化。

Q.3.10 The toxin is an inhibitor of GPCR-A receptor.
該毒素是 GPCR-A 受體的一種抑製劑。

Q.3.11 The toxin is an activator of GPCR-B receptor.
該毒素是一種 GPCR-B 受體的活化劑。

Q4

CDK is a family of cyclin dependent kinases which drive the cell cycle. A portion of the liver was removed in WT mice, or in livers which had a particular CDK gene knocked-out. Mice were allowed to regenerate, then their regenerated livers were weighed, measured and stained. Individual liver cells were removed and stained for total DNA content, or for newly synthesised DNA (Figure 1).

CDK 是一種細胞週期素依賴性激酶家族，可驅動細胞週期。將野生型 (WT) 小鼠中或 CDK 基因剔除小鼠的一部分肝臟切除，使小鼠肝臟再生，然後稱重，測量和染色。將各別肝細胞取出並染色量測其總 DNA 含量，或量測新合成的 DNA 含量（圖 1）。

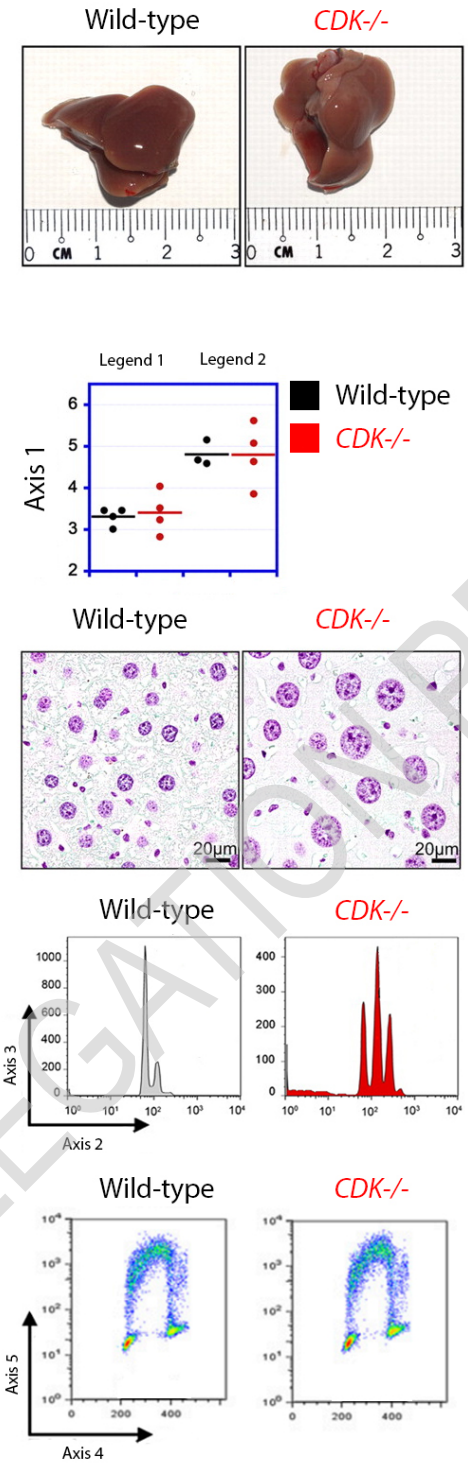


Fig.1. Axis 1 = Liver mass. Axis 2 = DNA content. Axis 3 = # of cells. Axis 4 = DNA content. Axis 5 = Newly synthesised DNA. Legend 1 = 4 days. Legend 2 = 21 days (left side = wild-type, right side = CDK-/-)

圖.1. 軸 1 = 肝臟重量。軸 2 = DNA 含量。軸 3 =# 細胞。軸 4 = DNA 含量。軸 5 = 新合成的 DNA。Legend 1 = 4 天。Legend 2 = 21 天 (左側 = 野生型，右側 = CDK-/-)

Indicate with an **X** whether you would expect number or amount increased (A), not changed (B) or decreased (C) of the following structures in CDK knock-out livers versus wild-type ones.

用”**X**” 註明您預期的 CDK1 剔除肝臟與野生型肝臟的下列結構的數目或數量會 增加 (A)、未改變 (B) 或減少

(C)。

Q.4.1 Liver mass
肝臟重量

Q.4.2 Hepatocyte number
肝細胞數

Q.4.3 Average hepatocyte ploidy
平均肝細胞染色體倍體數

Q.4.4 Number of mitotic spindles
有絲分裂紡錘體的數目

Q.4.5 DNA synthesis
DNA 合成

Q5

One way of heat production is non-shivering thermogenesis, mediated by norepinephrine via upregulation of mitochondrial uncoupling channel proteins (UCP) in brown adipose tissue (BAT). UCP increases the H^+ conductance of the inner mitochondrial membrane to dissipate the mitochondrial H^+ gradient and convert the energy of substrate oxidation into heat. To identify the member(s) of the UCP family responsible for the process, we carried out two experiments.

有種非顫抖性產熱方式是發生在棕色脂肪組織（BAT）中，當其受到正腎上腺素作用後，造成粒線體內非偶聯通道蛋白（UCP）的增加。UCP 增加使粒線體內膜氫離子導電性上升，以消散粒線體氫離子梯度，並將基質氧化能轉化為熱。為了確定在膜上負責該過程的 UCP 家族成員，我們進行兩個實驗。

Figure 1. compares relative effects of acclimation to a cool environment for mice (from thermoneutrality at 30°C to the relative cold of 18°C) on the mRNA levels of different members of the uncoupling protein family in BAT.

圖 1. 比較從 30°C 熱中性到 18°C 的相對冷環境，溫度適應小鼠的 BAT 中非偶聯通道蛋白家族中不同成員基因的 mRNA 表現量。

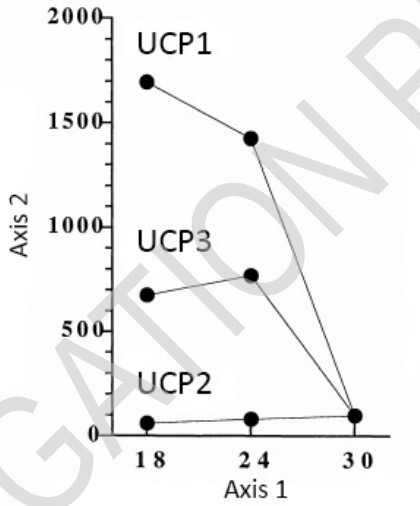


Fig.1. Axis 1 = Acclimation temperature (°C). Axis 2 = % of 30°C level

圖.1. 軸 1 = 適應溫度 (°C)。軸 2 = % 30°C 量

In a following experiment, three transgenic mouse strains were generated, bearing a single knock out mutation of either UCP1 or UPC3 and another bearing knock out mutations of both UCP1 and UCP3. We then measured metabolic rate in warm acclimated (30°C) and cool acclimated (18°C) conditions. In each case, besides the basal metabolic rate, we also measured metabolic rate following the injection of norepinephrine (NE).

在後續實驗中製備了兩種轉殖基因小鼠品系，一種為 UCP1 剔除突變小鼠，另一種為 UCP1 和 UCP3 雙剔除突變鼠。我們暖適應（30°C）和冷適應（18°C）溫度條件下分別測其代謝率。除基礎代謝率外，我們也測量了注射正腎上腺素（NE）後的代謝率。

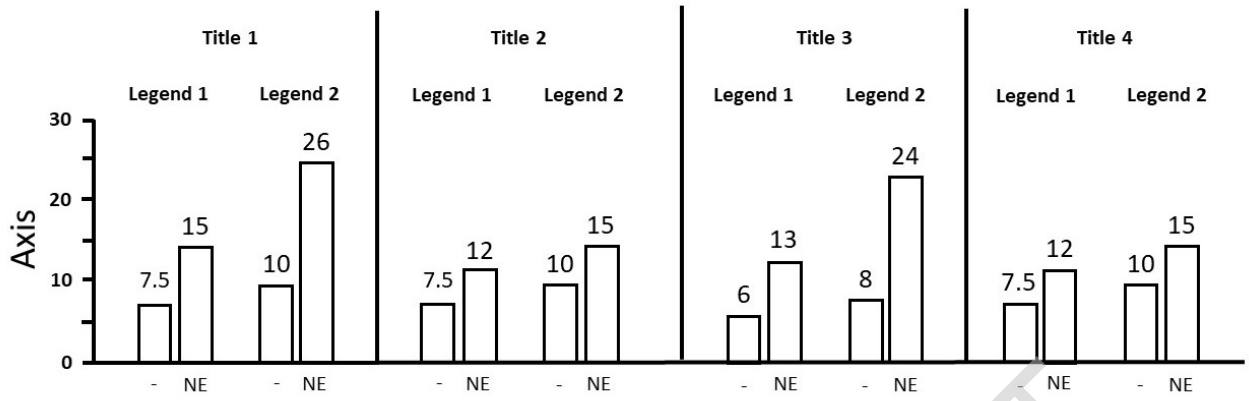


Fig.2. Axis = Metabolic rate ($mlO_2 \cdot min^{-1} \cdot kg^{-1}$). Title 1 = Normal mice. Title 2 = UCP1-knockout mice. Title 3 = UCP3-knockout mice. Title 4 = UCP3-UCP1-double knockout mice. Legend 1 = Warm-acclimated. Legend 2 = Cool-acclimated

圖 2。軸 = 代謝率 ($mlO_2 \cdot min^{-1} \cdot kg^{-1}$)。Title 1 = 正常小鼠。Title 2 = UCP1 剔除小鼠。Title 3= UCP3-剔除小鼠。Title 4 = UCP3-UCP1-雙剔除小鼠。Legend 1 = 暖適應。Legend 2 = 冷適應

Q.5.1 Estimate the increase in metabolic rate due to UCP1 dependent thermogenesis after NE stimulation in cool-acclimated mice. (in $mlO_2 \cdot \text{min}^{-1} \cdot kg^{-1}$)
估算在冷適應小鼠受 NE 刺激後 UCP1 依賴性產熱導致的代謝率增加。($mlO_2 \cdot \text{min}^{-1} \cdot kg^{-1}$)

Q.5.2 Calculate the increase of O_2 consumption in a 25-gram cool-acclimated mouse that is the result of NE stimulation but cannot be explained by UPC1 or UPC3 activity. ($ml \cdot \text{min}^{-1}$)
計算在 25 克重冷適應小鼠在 NE 刺激下，但無法用 UPC1 或 UPC3 活性來解釋的氧消耗量的增加 ($ml \cdot \text{min}^{-1}$)

Indicate with an X if each the following statements are true (T) or false (F).

以 X 註明下列敘述為正確（T）或錯誤（F）。

Q.5.3 UCP1 actively pumps H^+ ions across the inner mitochondrial membrane.
UCP1 主動地將氫離子送穿過粒線體內膜。

Q.5.4 The results from this experiment suggest that UCP1 is the most important UCP for non-shivering thermogenesis in response to cold.
該實驗的結果顯示 UCP1 是在因應寒冷的非顫抖性產熱的最重要 UCP 蛋白。

2,4-Dinitrophenol (DNP) is an organic compound historically used as a weight loss drug. DNP allows protons to leak across the mitochondrial inner membrane making ATP production less efficient.

2,4-二硝基苯酚（DNP）是常用於減肥的有機化合藥物。DNP 使得氫離子穿過粒線體內膜，使得 ATP 產生效率降低。

Indicate with an **X** if each the following statements are true (T) or false (F).

以 X 註明以下敘述為正確（T）或錯誤（F）。

Q.5.5 Patients taking DNP experience hypothermia as their cells are not able to generate energy.
服用 DNP 的患者體溫過低，因為他們的細胞無法產生能量。

Q.5.6 A paient with mild DNP overdose can be treated by glucose administration.
葡萄糖可用來治療 DNP 輕度過量的患者。

Q.5.7 Mitochondrial uncoupling occurs under certain physiological conditions in animals.
動物在某些生理狀況下會發生粒線體解偶聯情況。

Q.5.8 DNP reduces the oxygen consumption of cells.
DNP 可降低細胞的耗氧量。

Q.5.9 DNP increases the pH in the mitochondrial intermembrane space.
DNP 會提升粒線體膜間空隙內的 pH。

Q6

You are studying a small protein-coding locus the sequence of which is shown below. The sequence is shown from the 5' transcriptional START position to the 3' transcriptional STOP position. This part is responsible for coding of two different polypeptides. There is a short intron sequence which is shown with **BOLD** letters here.

您正在研究一種小蛋白編碼基因座，其序列如下所示。序列顯示從轉錄起始位置到轉錄終止位置。該部分負責編碼兩種不同的多肽。序列中的**粗體字母**顯示其含有一個短的內含子。

```
          5.        10.       15.       20.       25.       30.       35.       40.       45.       50.       55.
5′ –CTACGTACTATGTATTCC GATCTATA CTCGATCTAGTCGCATTCCGATAAGATCGTAC– 3`
3′ –GATGCATGATACATAAGG CTAGATAT GAGCTAGATCAGCGTAAGGCTATTCTAGCATG– 5`
```

Q.6.1 How many nucleotides long would the final processed mRNA made from this gene be (not including the 5' cap and the 3' polyA tail)?
該基因最終產生 mRNA 的長度是多少核苷酸（不包括 5' cap 和 3' polyA tail）？

Q.6.2 Indicate with an **X** which strand is used as a template in transcription for the shorter polypeptide, the 5'-3' strand or the 3'-5' strand (read in a left → right direction)?
用 X 註明哪股用以作為轉錄模板以合成較短的多肽鏈，5'-3' 股或 3'-5' 股？(從左到右的方向讀)

Q.6.3 What is the ratio of the numbers of amino acids in longer/shorter polypeptide (including the amino acid built in because of the START codon)? Give your answer to the nearest second decimal place!
長/短多肽鏈 (包括 START 密碼子對應的胺基酸) 中胺基酸數目的比例為何？將你的答案至小數點後第二位！

Q.6.4 What is the third amino acid of the shorter polypeptide, if the Met is counted to be the first one? Add the one-letter code of amino acid based on the **codon table** in the beginning of your question sheet!
如果 Met 被認為是第一個胺基酸，則較短多肽鏈中的第三個胺基酸為何？請依據在你題目卷開始的密碼表加上胺基酸的單字母代碼！

Q.6.5 Say that the C:G base pair that is underlined in the sequence above were changed to an A:T basepair to make a mutant form of this gene. Indicate with an **X** which kind of mutation would this be for the shorter polypeptide?
假設上面序列中其下方劃線的 C：G 鹼基對被置換為 A：T 鹼基對以製備該基因的突變型序列。用 X 註明對較短的多肽鏈而言，其屬於下列何種突變？

A. a frameshift mutation
B. a nonsense mutation
C. a silent mutation
D. a missense mutation
A. 一個框移突變
B. 一個無義突變
C. 一個靜默突變
D. 一個錯義突變

Q7

A microbiology lab studies the microbe Thermus szegediensis, which has recently been isolated from a thermal spring in Szeged. In a sequence of experiments (Exp), first, they grew T. szegediensis under different conditions to test its nutritional requirements. Conditions and results are in the table below.

有個微生物學實驗室研究了近年從賽格德的溫泉中分離出來的嗜熱異球菌 Thermus szegediensis 。在一系列實驗（Exp）中，首先，他們在不同條件下培養 T. szegediensis 以測試其營養需求。條件和結果如下表所示。

Conditions 條件	**Exp 1**	**Exp 2**	**Exp 3**	**Exp 4**
light 光照	+	+	-	-
oxygen 氧	+	+	+	+
nitrogen 氮	+	+	+	+
phosphorus 磷	+	+	+	+
thermal water salts 熱泉中的鹽類	+	+	+	+
glucose 葡萄糖	+	-	+	-
trace minerals 微量礦物質	+	+	+	+
Growth? 增長與否	**yes**	**yes**	**yes**	**yes**

Table 1

The lab was further interested in finding genes from T. szegediensis that are important for the microbe to exist at high temperatures. They isolated 6 mutants (M1-M6). Then, they performed a complementation test between each (“+” means growth, “- “means no growth) to see how they grow at high temperatures (T = 56°C).

該實驗室還對尋找 T. szegediensis 在高溫下生存所必須的相關基因感興趣。使用下面的方法，他們分離了 6 個突變體（M1-M6）。並進行其相互之間的互補實驗測試（“+” 表示生長，“- ” 表示沒有生長），以了解它們在高溫下生長（T = 56°C）的情況。

	M1	M2	M3	M4	M5	M6	WT
M1	-	-	+	-	+	+	+
M2		-	-	-	-	-	-
M3			-	+	-	-	+
M4				-	+	+	+
M5					-	-	+
M6						-	+
WT							+

Table 2 表 2

Q.7.1 Which of the following best describes T. szegediensis? Indicate with an **X.** 請以 X 註明下列何者最能描繪 T. szegediensis?

A. Photoautotroph 光合自營生物
B. Chemoautotroph 化學自營生物
C. Photoheterotroph 光合異營生物
D. Chemoheterotroph 化學異營生物

Q.7.2 Which of the following does T. szegediensis most likely use as an energy source to produce complex organic compounds? Indicate with an **X.**
以 X 註明下列何者是 T. szegediensis 最可能用以做為其能量來源以合成複合有機化合物。

A. SO_4^{2-}
B. Light
C. H_2S
D. NO_3^-
E. H_2O
F. Chlorophyll 葉綠素
G. lactic acid 乳酸

Q.7.3 Indicate the dominant and recessive mutations with an **X**.
用 X 註明 A. 顯性 及 B. 隱性突變。
A. Dominant
B. Recessive

Q.7.4 From the data in Table 2, at least how many different genes can you identify as being important for allowing T. szegediensis to exist at high temperatures?
根據表 2 中的數據，至少有多少種不同的重要基因可確保 T. szegediensis 能在高溫下生存？

Q.7.5 Indicate which mutants have mutations in the same genes. Indicate with an **X.** Incorrectly marked cells will incur a penalty.
用 X 註明哪些突變菌株其突變發生在相同基因中。錯誤標記的答案格會被扣分。

Q8

Beadle and Tatum proposed that one gene produces one enzyme. They mutated mould and observed that different colonies required a different supplement to their normal media to survive (Figure 1).

Beadle 和 Tatum 提出一種基因產生一種酶。他們突變黴菌並觀察到不同的突變菌落的培養基需補充不同的營養劑才能存活（圖 1）。

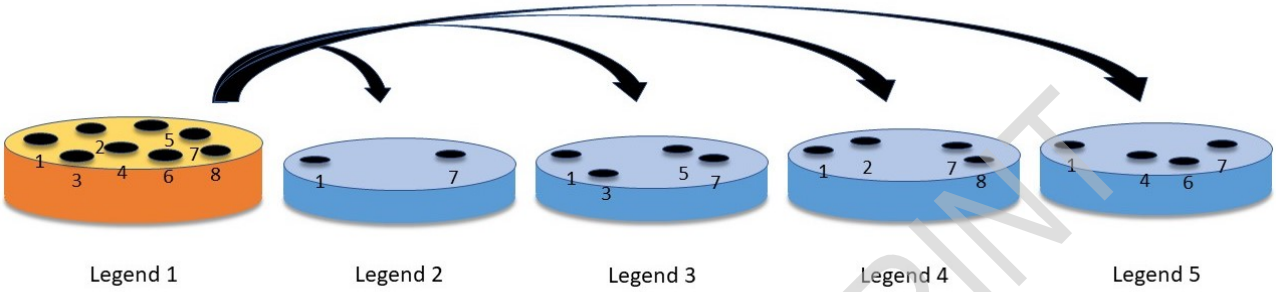


Fig.1. Legend 1 = Rich Medium. Legend 2 = Minimal Medium. Legend 3 = Minimal Medium + Phenylalanine. Legend 4 = Minimal Medium + Leucine. Legend 5 = Minimal Medium + Arginine

圖 1、Legend 1 = 富培養基。Legend 2 = 基本培養基。Legend 3 = 基本培養基 + 苯丙氨酸。Legend 4 = 基本培養基 + 亮氨酸。Legend 5 = 基本培養基 + 精氨酸

Indicate with an **X** which colonies (1-8) the statements are true for based on Figure 1. Mark all other cells with **O.**

依據圖 1. 用 X 註明哪個菌落（1-8）的敘述為正確，並用”**O**” 標記所有其它細胞。

Q.8.1 Which mutants have the same nutritional requirements as WT cells?
哪些突變體與 WT 細胞具有相同的營養需求？

Q.8.2 Which colonies would you use to discover genes involved in the arginine synthesis pathway?
您將使用哪些菌落來找尋出參與精氨酸合成途徑的基因？

In another experiment you take a different set of mutants and plate them as seen in Figure 2.

在另一個實驗中，您使用一組不同的突變體，並依據圖 2 所示方式來塗盤培養。

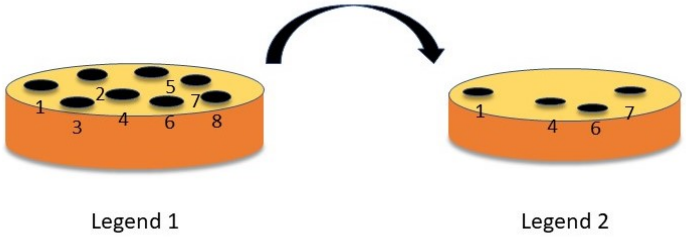


Fig.2. Legend 1 = Rich Medium. Legend 2 = Rich Medium without Arginine

圖 2、Legend 1 = 富培養基。Legend 2 = 不含有精氨酸的富培養基

Q.8.3 Which colonies (1-8) cannot produce arginine in Figure 2?
圖 2 中哪些菌落（1-8）不能產生精氨酸？

Q8.4 is concerned with a different set of arginine synthesis mutant strains. You identify 9 haploid yeast strains with single mutations in the amino acid production pathway. You perform complementation experiments, the crossing of different mutants to get a diploid progeny, and allow them to grow out in medium deficient in your amino acid of interest. (-) in the table below indicates where no growth occurs.

Q8.4 涉及不同胺基酸的合成。你鑑定其胺基酸生產途徑各具有單個突變的有 9 個單倍體酵母菌株。你進行互補實驗，將不同突變體交配以獲得二倍體後代，並將它們培養生長在缺乏你所感興趣的胺基酸的培養基中。下表中的（- ）表示沒有菌株生長。

	1	2	3	4	5	6	7	8	9
1	-						-		
2		-		-		-		-	
3			-						-
4		-		-		-		-	
5					-				
6		-		-		-		-	
7	-						-		
8		-		-		-		-	
9			-						-

Table 1 表 1

Q.8.4 Based on these results how many at least genes are involved in the arginine synthesis pathway?
基於這些結果，至少有多少基因參與精氨酸合成途徑？

Q.8.5 QUESTION REDACTED
此題已刪除

Q9

Bulb1 and Bulb2 are transcription factors involved in the survival response of plants exposed to UV radiation. Wild-type (wt) and homozygous mutant (Bulb1-/-) Arabidopsis plants were exposed to UV-B for various times and their RNA extracted. RNA was dissolved in 20 µl of buffer. A 2 µl aliquot was taken from one of the stock solutions and diluted to 1 ml. The absorbance of the solution at 260 nm was found to be 0.046.

Bulb1 和 Bulb2 是轉錄因子，當 UV 輻射暴露時參與植物存活因應路徑。將野生型（wt）和同型合子突變體（Bulb1 - / - ）阿拉伯芥暴露於 UV-B 下不同時間，並抽取它們的 RNA。將 RNA 溶於 20µl 緩衝液中，如從此儲備 RNA 溶液取出 2µl 並稀釋成 1ml，在 260 nm 波長下測得吸光度為 0.046。

Q.9.1 Given that a 40 µg/ml solution of RNA gives an absorbance of 1.0 at 260 nm, calculate the concentration of RNA in the stock solution in µg/ml.
如 40µg/ ml RNA 溶液在 260 nm 波長的吸光度為 1.0，請計算該儲備 RNA 溶液中的 RNA 的濃度，單位為 µg/ ml。

Q.9.2 In each experiment the scientists carried out, they are required to use 2 µg of RNA. What volume of stock would they need to use? Give your answer in µl, rounded to two decimal places.
如當科學家進行每個實驗時，他們會使用 2µg 的 RNA。則他們需要使用多少體積的儲備 RNA 溶液？以 µl 為單位作答，並四捨五入到小數點後兩位。

Q.9.3 How many experiments could the researchers conceivably carry out with the original stock of RNA?
研究人員將可使用此最初萃取的儲備 RNA 溶液進行多少次實驗？

The RNA samples were used for measurement of bulb2 transcript levels by quantitative PCR (Figure 1A). In a different experiment Bulb1 and Bulb2 protein levels in wild-type Arabidopsis, exposed to UV-B radiation for various times were assessed (Figure 1B).

RNA 樣品將用於進行定量 PCR(圖 1) 以測量 bulb2 轉錄物含量。在不同的實驗中，也分析了暴露於 UV-B 輻射不同時間的野生型阿拉伯芥的 Bulb1 和 Bulb2 蛋白含量（圖 2）。

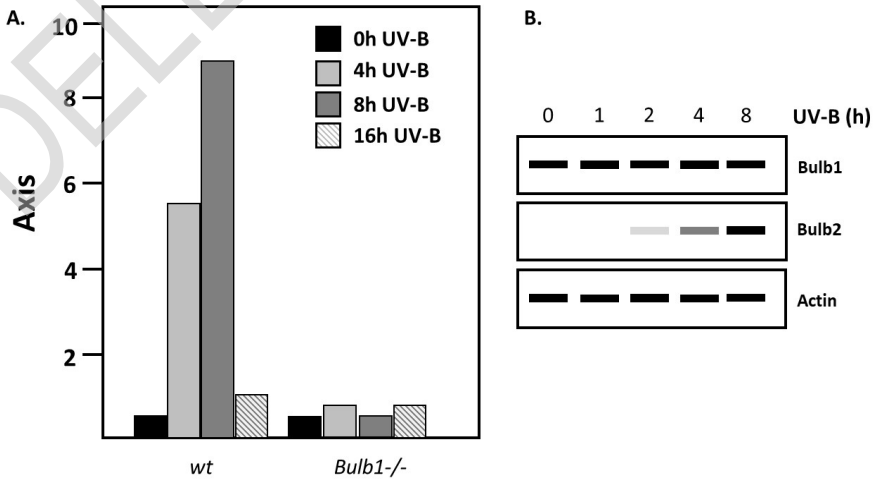
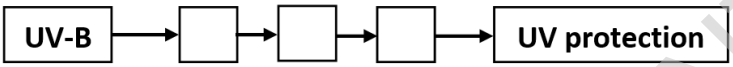


Fig.1. Axis = Fold change relative to control. wt = Wild-type

圖 1。Axis = 相對於對照的倍數變化。wt = 野生型

Q.9.4 Build a model of UV-B response in Arabidopsis based on the available information.
根據已知資訊，建立阿拉伯芥對 UV-B 的反應模型。
A. Bulb1 transcription Bulb1 轉錄
B. Bulb2 transcription Bulb2 轉錄
C. Bulb1 translation Bulb1 轉譯
D. Bulb2 translation Bulb2 轉譯
E. Bulb1 degradation Bulb1 降解
F. Bulb2 degradation Bulb2 降解
G. Bulb1 nuclear translocation Bulb1 核移位
H. Bulb2 nuclear translocation Bulb2 核移位



Animal Anatomy and Physiology 動物解剖學與生理學

Q10

The graph below illustrates the pressure and volume changes during breathing.
下圖說明了呼吸過程中的壓力和體積變化。

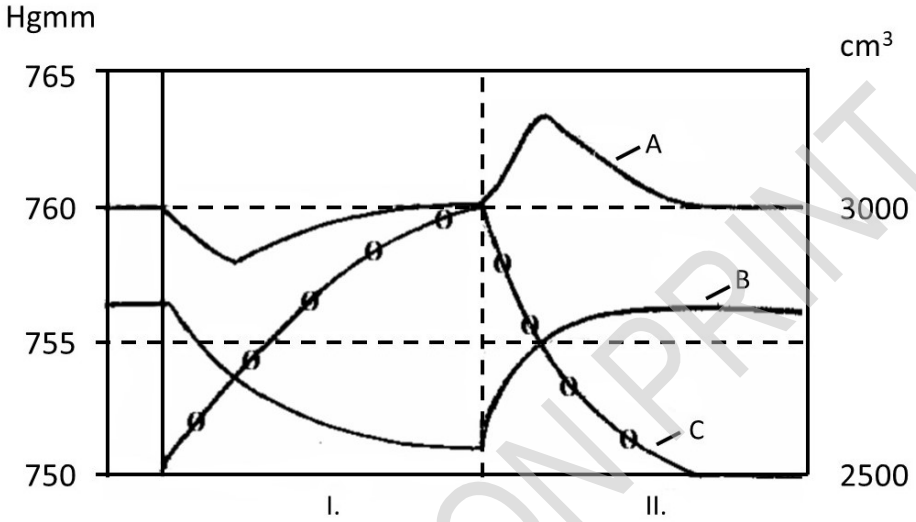


Fig.1 圖 1

Identify what is represented by letters A, B and C, and the Roman numerals I. and II. Match these symbols (A-C and I-II) with the descriptions below (Q.10.1-8). Every symbol matches one description only, but there are descriptions that do not match any of those. Indicate correct answers by putting an X in the appropriate box on the answer sheet. **Match those that do not match any symbols with the "0" column on your answer sheet.**

請分別寫出字母 A，B 和 C 以及羅馬數字 I. 和 II 所表示的內容。並將這些符號（A，B，C; I，II）填入 Q.10.1-8 題中相對應的描述。請注意，每個符號僅對應一個描述，但有些描述可能沒有相對應之字母。在答案卷上正確答案的空格中填入 X。若無任何字母符合描述，請在答案卷上填入"0"。

Q.10.1 Volume changes of the intrapleural space during breathing
呼吸過程中胸腔內空間的體積變化

Q.10.2 Inhalation phase of breathing
呼吸過程中的吸入階段

Q.10.3 Pressure change in the lungs during breathing
呼吸期間肺部壓力變化

Q.10.4 Pressure change in the left ventricle of the heart during breathing
呼吸過程中心臟左心室的壓力變化

Q.10.5 Pressure change of the intrapleural space during breathing
呼吸過程中胸腔內壓力的變化

Q.10.6 Volume change of the lung during breathing
呼吸期間肺的體積變化

Q.10.7 Exhalation phase of breathing
呼吸過程中的呼氣階段

Q.10.8 Volume change of abdominal cavity during breathing
呼吸過程中腹腔容積變化

Q11

The pH value of the human blood is kept in a strict range, in order to maintain the vital functions of the body. There are three main mechanisms which can help blunting acidic or alkaline shifts:

人體血液的 pH 值必須嚴密調控，維持在一穩定的範圍內，以維持身體的重要功能。有三種主要機制可以維持 pH 值穩定：

- Buffer systems, especially the bicarbonate system. 緩衝系統，尤其是碳酸氫鹽系統。
- Exhalation of carbon dioxide in the lungs. 肺部呼出二氧化碳。
- Excretion of protons and the reabsorption and production of bicarbonate-ions by the kidney.
- 利用腎臟，將氫離子排出體外或調節碳酸氫根離子的再吸收和生成作用。

These three regulatory systems usually operate simultaneously, compensating each other' s malfunctions when needed. Conditions A to F are depicted in the Figure below. 一般而言，這三種調節系統通常同時運作，若任一系統失去功能，可相互支援，維持 pH 穩定。以下有六種不同生理狀態 (A 至 F)，如下圖所示。

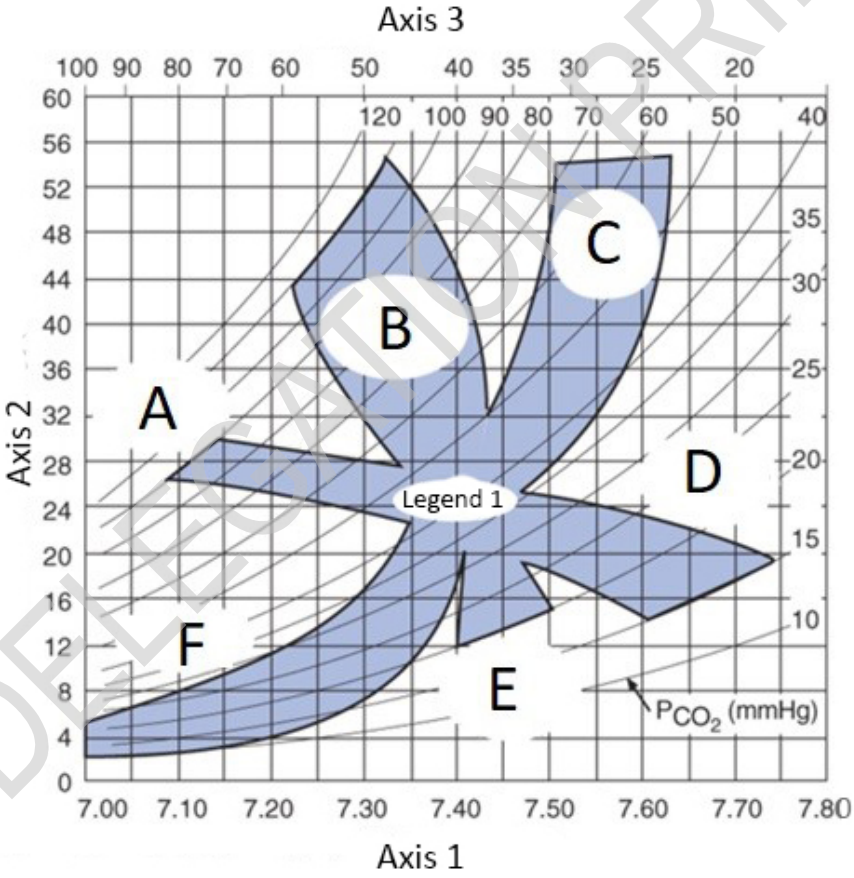


Fig.1. Axis 1 = Arterial blood pH. Axis 2 = Arterial plasma $[HCO_3^-]$ (mmol/L). Axis 3 = Arterial blood $[H^+]$ (nmol/L). Legend 1 = Normal.

圖 1。軸 1 = 動脈血 pH。軸 2 = 動脈血漿中碳酸氫根濃度 (mmol / L)。軸 3 = 動脈血氫離子濃度 (nmol / L)。Legend 1 = 正常。

Match the letters from the figure (from A to F) to the corresponding clinical conditions in the list below. Note that acute implies a sudden effect, while chronic conditions last for an extended period and involve compensatory mechanisms.

請將圖中的字母（從 A 到 F）與下面表中的所列出的臨床條件相對應。注意急性意味著突然之間生理狀態的改變，而慢性病持續較長時間並涉及補償機制。

Indicate your answer by putting an X in the appropriate box on the answer sheet. Note that not all the letters are used.

在答案紙上之正確答案格中畫 X，請注意，並非所有字母都會用到。

Q.11.1 Condition following vomiting
嘔吐後的情況

Q.11.2 Acute respiratory acidosis due to ineffective respiration caused by a stroke affecting the brainstem
中風影響腦幹引起的無效呼吸進而引發急性呼吸性酸中毒

Q.11.3 Acute respiratory alkalosis caused by hyperventilation
過度換氣引起的急性呼吸性鹼中毒

Q.11.4 Chronic respiratory acidosis associated with asthma
與氣喘相關的慢性呼吸性酸中毒

Q.11.5 Chronic respiratory alkalosis associated with anaemia
與貧血有關的慢性呼吸性鹼中毒

Q12

The Hungarian Grey is a rare breed of cow which was threatened by an epidemic caused by a new bacterial strain. An antibiotic was given to the cows to prevent infection. It has a half-life in cows of 6 hours, and at equilibrium, 25% of the antibiotic circulates in the blood, whilst 75% is found in interstitium.

匈牙利灰牛是一種罕見的乳牛，最近受到因一種新菌株感染所引發流行病的威脅。目前可投予抗生素以預防細菌感染。此抗生素在匈牙利灰牛體內之半衰期為 6 小時，並且在體內達到平衡時，25%的抗生素在血液中循環，而 75%在間質中發現。

A healthy cow received a single dose of 4400 mg intravenously at 11am. At 11pm, 10 ml of blood was withdrawn and 5 mg/l of antibiotic was present in this sample.

健康的乳母牛在上午 11 點靜脈注射單一劑量 4400 mg 之抗生素。晚上 11 點，取出 10 毫升血液，該樣品中含有 5 毫克/升抗生素。

Q.12.1 Calculate the total blood volume of this cow in litres (L).
以公升為單位，請算出這頭乳牛的總血量。

Q.12.2 Certain fruits (e.g., pomegranate) can inhibit metabolic enzymes in the liver. Using the equation below, calculate the concentration of the antibiotic in blood **at 5pm** ($N(t)$) after time (t) has passed, assuming the **half-life** ($t_{\frac{1}{2}}$) of the drug has **doubled** due to pomegranate consumption. N_0 is the starting concentration. Give your answer in milligrams/millilitres (mg/ml) to two decimal place accuracy.
某些水果（例如石榴）可以抑制肝臟中的代謝酶。使用下面的方程式，假設藥物的**半衰期** ($t_{\frac{1}{2}}$) 由於石榴消耗而加倍，計算在時間 (t) 過去後 **5 點** ($N(t)$) 的血液中抗生素的濃度。N_0 是起始濃度。以毫克/毫升（mg / ml）給出您的答案，精確到兩位小數。

$$t_{\frac{1}{2}} = \frac{t}{\log_{\frac{1}{2}}(\frac{N(t)}{N_0})}$$

Consider the effects of a cow’s treatment with strong oral antibiotics. Indicate with an X if each of the following statements is true (T) or false (F).

考慮強效口服抗生素治療的效果，利用 X 指出下列陳述何為正確（T）或錯誤（F）。

Q.12.3 The cow will eventually develop antibiotic resistance
乳牛最終會對抗生素產生抗藥性

Q.12.4 The cow will have increased blood clotting times
乳牛的血液凝固時間會增加

Q.12.5 The cow will have reduced nutrient absorption
乳牛營養吸收量會降低

Q.12.6 The cow will have elevated circulating insulin levels
乳牛的血液內胰島素含量會上升

Q13

The following graph shows how glucose handling in the kidney changes with plasma concentration.

下圖顯示了腎臟如何因應血漿內葡萄糖濃度調節腎臟血糖濃度

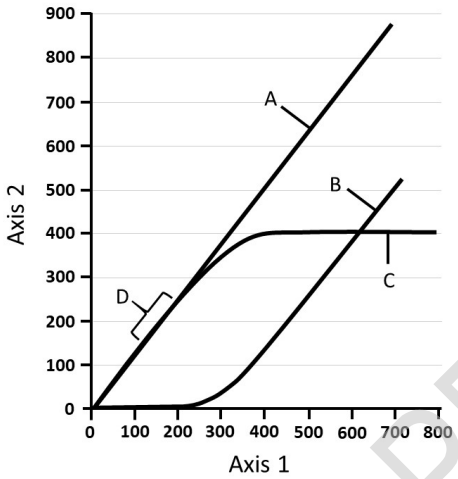


Fig.1. Axis 1 = Plasma glucose concentration (mg/100 ml). Axis 2 = Glucose filtered load, reabsorption or excretion (mg/min).

圖 1。軸 1 = 血漿葡萄糖濃度（mg /100ml）。軸 2 = 葡萄糖過濾負荷量，再吸收或排出（mg / min）。

Q.13.1 Indicate with an X on your answer sheet if the following statement is true (T) or false (F).
在答案卷紙上用 X 表示敘述為正確 (T) 或錯誤 (F)。
Glucose is freely filtered in glomeruli.
葡萄糖在腎小球中自由過濾。

Match the letters from the figure (A-D) to the correct parameter in the list below. Indicate your answer by putting an X in the appropriate box on the answer sheet.

將圖中的字母（A 到 D）與下列表中的正確參數配對，在答題卷紙上的正確空格中畫上 X。

Q.13.2 Glucose excreted 葡萄糖排出體外

Q.13.3 Glucose filtered 葡萄糖被過濾

Q.13.4 Glucose reabsorbed 葡萄糖被再吸收

Q.13.5 Normal levels 正常水平

Q.13.6 What is the maximum rate of glucose reuptake? Round your answer to the nearest hundred and give your answer in milligram/minute (mg/min).
葡萄糖再攝取 (re-uptake) 的最大速率是多少？以毫克/分鐘（mg / min）為單位，將答案四捨五入到最接近的百位。

Q14

Answer the question using the letters from the figure.

使用圖中的字母回答問題。

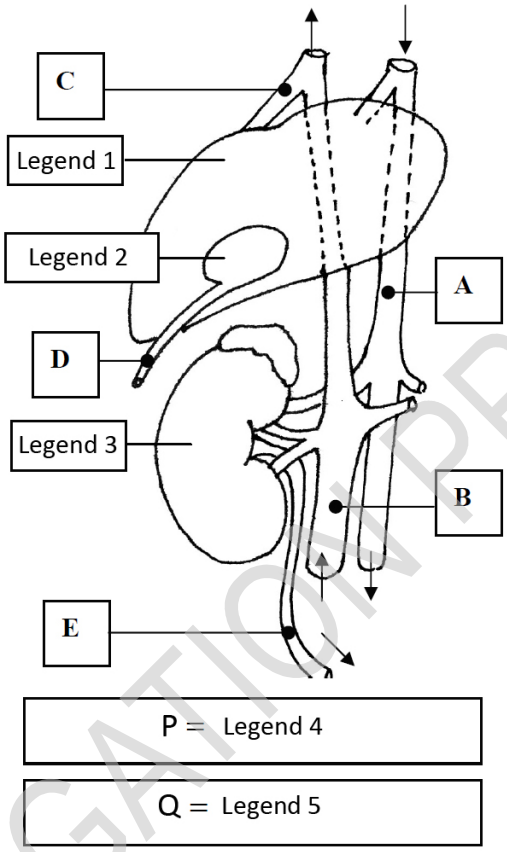


Fig.1. Legend 1 = Liver. Legend 2 = Gallbladder. Legend 3 = Kidney. Legend 4 = All of the above. Legend 5 = None of the above

圖 1。Legend 1 = 肝臟，Legend 2 = 膽囊，Legend 3 = 腎臟，Legend 4 = 以上皆是，Legend 5 = 以上皆非

Match the following statements with the letters in the figure above (A-E and P-Q). You may need to use the same letter more than once.

將以下敘述與上圖中的字母（A 到 E 和 P 到 Q）配對。字母可能出現不止一次。

Q.14.1 Blood enters this vessel from the right ventricle
血液從右心室進入該血管

Q.14.2 The blood carried in the vessel will drain into the left atrium of the heart
血管中攜帶的血液將流入心臟的左心房

Q.14.3 Carries urine
攜帶尿液

Q.14.4 Contains digestive enzymes
含有消化酶

Q.14.5 Contains steroid salts
含有類固醇鹽類

Q15

There are four different types of hypersensitivity reactions in the human body as it can be seen in the list below.

在人體免疫系統中存在四種不同類型的超敏反應 (hypersensitivity)，如下面的列表中所示。

TYPE I: 第一型

Fast response which occurs in minutes, rather than multiple hours or days. Free antigens cross link the IgE on mast cells and basophils which causes a release of vasoactive biomolecules.

快速反應: 多為急性反應，多發生於幾分鐘內，較少在幾小時或幾天後才引起反應。主要是因為游離抗原與肥大細胞和嗜鹼性粒細胞上的 IgE 結合，導致血液內活性生物分子的釋放。

TYPE II: 第二型

IgG or IgM antibody binds to cellular antigen, leading to complement activation and cell lysis. IgG can also mediate Antibody Dependent Cell Cytotoxicity (ADCC) with cytotoxic T cells, natural killer cells, macrophages and neutrophils.

IgG 或 IgM 抗體與細胞抗原結合，導致補體激活和細胞裂解。IgG 還可媒介細胞毒性 T 細胞，自天然殺手細胞，巨噬細胞和嗜中性球等之需抗體之細胞毒性（ADCC）作用。

TYPE III: 第三型

Antigen-antibody complexes are deposited in tissues. Complement activation provides inflammatory mediators and recruits neutrophils. Enzymes released from neutrophils damage tissue.

抗原-抗體複合物平時存在於組織中。補體激活提供發炎反應因子與募集嗜中性球，嗜中性球所釋放的酶會傷害組織。

TYPE IV: 第四型

Cell-mediated reactions are initiated by T-lymphocytes and mediated by effector T-cells and macrophages. This response involves the interaction of antigens with the surface of lymphocytes.

細胞媒介的反應由 T 淋巴細胞誘發，並由效應 T 細胞 (effectorT-cell) 和巨噬細胞媒介。該反應涉及抗原與淋巴細胞表面的相互作用。

Match each of the following conditions (Q.15.1-6) with one of the hypersensitivities described above. Indicate your answer by putting an X in the appropriate box on the answer sheet.

請將上述的其中一種過敏反應，填入以下所描述之各種情況 (Q.15.1-6)，在答案卷紙上正確的答案格中填入 X。

Q.15.1 The type of reaction that occurs during a mismatched blood transfusion.
輸血過程若配對錯誤時所發生的反應類型。

Q.15.2 This reaction occurs when one is exposed to poison ivy, which produces a toxin that binds to human proteins causing them to become self-antigens.
毒藤漆會產生與自體抗原結合之毒素，當一個人暴露於毒藤漆時就會發生這種反應，導致它們成為自體抗原。

Q.15.3 Dermatologists make use of this reaction to identify specific allergens found in food to which patients are sensitive.
皮膚科醫生利用這種反應來確認患者對食物敏感的特定過敏原。

Q.15.4 This type of reaction occurs after certain pathogenic bacteria entering the body are destroyed by the immune system, but some of their macromolecules stay intact afterwards.
這種類型的反應發生在某些致病菌進入人體後，雖被免疫系統摧毀，但其中一些大分子仍保持完整。

Q.15.5 This type of reaction cannot be transferred from one patient to another by serum.
這種類型的反應不能通過血清從一個患者轉移到另一個患者。

Q.15.6 Hay fever is an example of this condition.
花粉症是這種情況的一個例子。

Q16

The Hungarian biophysicist, György Békésy was awarded the 1961 Nobel Prize for his research on the function of the mammalian cochlea. He showed that each frequency of sound causes a specific part of the basilar membrane to vibrate the most. This point is determined by the resonant properties of the membrane, with narrower parts vibrating more at higher frequencies.

匈牙利生物物理學家 György Békésy 因其對哺乳動物耳蝸功能的研究而獲得 1961 年諾貝爾獎。他表明聲音的每個頻率都會導致基底膜的特定部分達到最大振動。這一點由基底膜的共振特性決定，基底膜較窄的部分在較高頻率下振動更多。

Neurons sense this vibration and encode the sound with two different mechanisms:

神經元感知這種振動並用兩種不同的機制對聲音進行編碼：

1. **Place code:** Each neuron connects to the membrane in one place and signals the presence of the narrow frequency band that causes maximal vibration in that part of the membrane. 位置訊號：每個神經元都會連結到基底膜上特定區域，當窄頻帶出現時發出訊號，引起基底膜最大的振動。
2. **Periodicity code:** If the frequency is below 4 kHz, the timing of action potentials in the cochlear nerve is synchronised with individual cycles of the stimulus (this is called phase-locking). 週期性代碼：如果頻率低於 4 kHz，則耳蝸神經中動作電位的時間與每個刺激的各個週期同步（這稱為相位鎖定反應）。

The intensities of audible sounds are expressed in **decibel sound pressure level** (dB SPL).

聽覺可聽見之聲音強度以分貝（dB SPL）表示。

$$dB\ SPL = 20\ \log_{10} \frac{Pressure\ of\ sound\ in\ Pa}{2 \cdot 10^{-5}}$$

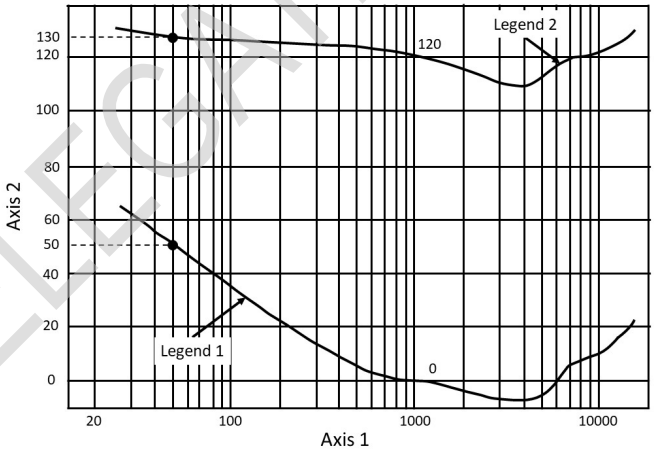


Fig.1. Axis 1 = Frequency (Hz). Axis 2 = Intensity (dB). Legend 1 = Threshold of audibility. Legend 2 = Threshold of pain

圖 1。軸 1 = 頻率（Hz）。軸 2 = 強度（dB）。Legend 1 = 可聽度閾值。Legend 2 = 疼痛的閾值

Based on the information above, indicate with an X if each of the following statements is true (T) or false (F).

根據上述所提供之背景知識，利用 X 指出以下陳述何為正確（T）或錯誤（F）。

Q.16.1 Sounds detected by hair cells towards the narrowest part of the cochlea are coded in a phase-locked manner.
毛細胞朝向耳蝸的最窄部分所檢測到的聲音以鎖相方式編碼。

Q.16.2 For sounds detected near the base of the membrane, the number of fibres firing is proportional to the amplitude of the displacement of the basilar membrane.
對於在基底膜底部附近檢測到的聲音而言，所活化的神經纖維數量與基底膜的位移幅度成比例。

Q.16.3 What is the absolute refractory period of fibres in the cochlear nerve? Give your answer in milliseconds (ms) in the appropriate box on the answer sheet.
耳蝸神經中纖維的絕對不反應期是多少？以毫秒（ms）為單位，將答案寫在答案卷上。

Q.16.4 At 50 Hz, how many times is the pressure of the sound that is painful greater than that of the sound that is just audible? Give your answer in the appropriate box on the answer sheet.
在 50 赫茲時，造成痛苦的聲音所造成之的壓力是多少倍於剛好可聽見的聲音所造成之的壓力？請在答案卷上的寫出答案。

Q17

The impact of feeding on the central circadian clock of the brain, and the peripheral clocks of other cells was assessed. Mice were either fed only from 6.00-18.00 (daytime feeding) or only from 18.00-6.00 (night time feeding). The amount of Per1 and Per2 protein in liver is shown. The central brain clock was stained with labelled DNA complementary to the per1 or per2 sequences.

本題將評估進食時間對大腦中樞生理時鐘對大腦影響，及周邊生理時鐘對其他細胞的影響。小鼠僅會在 6.00-18.00 餵食 (白天餵食時間) 或僅在 18.00-6.00 餵食 (夜間餵食)。下圖顯示了肝臟中 Per1 和 Per2 兩個蛋白質的表現量。中樞大腦時鐘是由與 per1 或 per2 序列互補的標記 DNA 來染色。

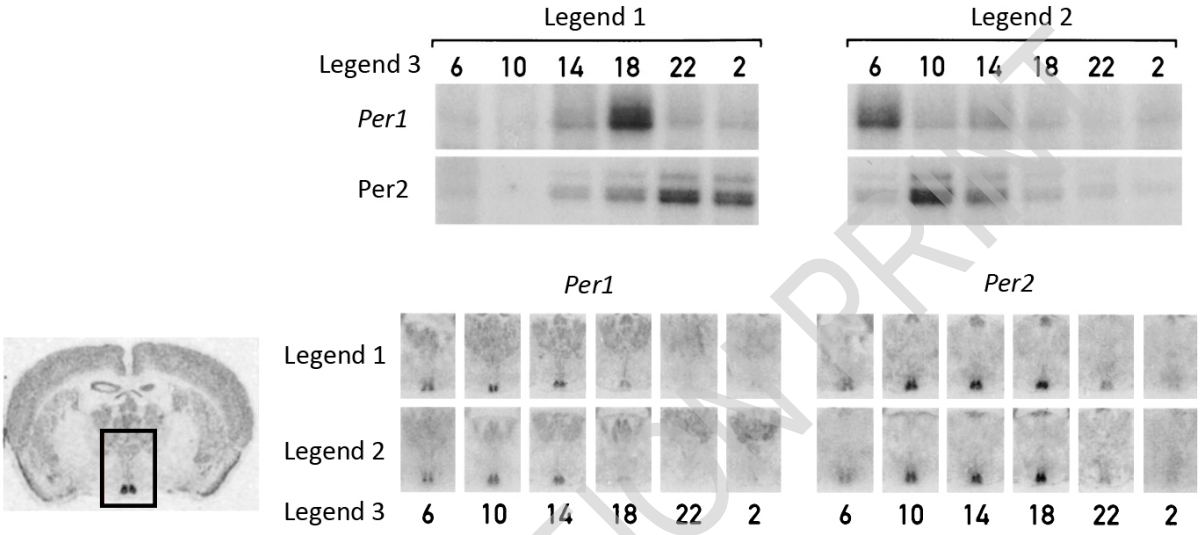


Fig.1. Legend 1 = Nighttime feeding. Legend 2 = Daytime feeding. Legend 3 = Time of the day (h)

圖 1。Legend 1 = 夜間餵食。Legend 2 = 白天餵食。Legend 3 = 一天中的時間（h）

For the following three questions, indicate your answer by putting an X in the appropriate cells of the table on the answer sheet.

針對以下三個問題，請在答案卷之正確答案格中畫上 X。

Q.17.1 How many hours has peripheral circadian rhythm shifted by following a change in feeding time?
隨著進食時間的改變，周邊生理時鐘晝夜節律移動了多少小時？

Q.17.2 How many hours has central circadian rhythm shifted by following a change in feeding time?
隨著餵食時間的變化，中樞生理時鐘晝夜節律移動了多少小時？

Q.17.3 How many hours do central Per1 peaks precede peripheral peaks during night feeding?
在夜間餵食期間，中樞系統中 Per1 之最大量較周邊 Per1 最大量前要增加多少小時？

Q.17.4 What time would you expect peripheral Per1 peaks to occur if animals were fed between 14.00-2.00? Indicate your answer by putting an X in the appropriate box on the answer sheet.
如果動物在 14.00-2.00 之間餵食，你會預期周邊 Per1 最大表現量出現於何時？請在答案卷上的正確欄位中畫 X。
A. 06
B. 10
C. 14
D. 18
E. 22
F. 02

Q18

Thyroid hormones (T3 and T4) regulate metabolism. Their release is controlled as shown in the figure. T4 can be metabolised to T3 in tissues.

甲狀腺激素（T3 和 T4）調控新陳代謝。如圖所示甲狀腺素釋放之調節系統，T4 可在組織中代謝為 T3。

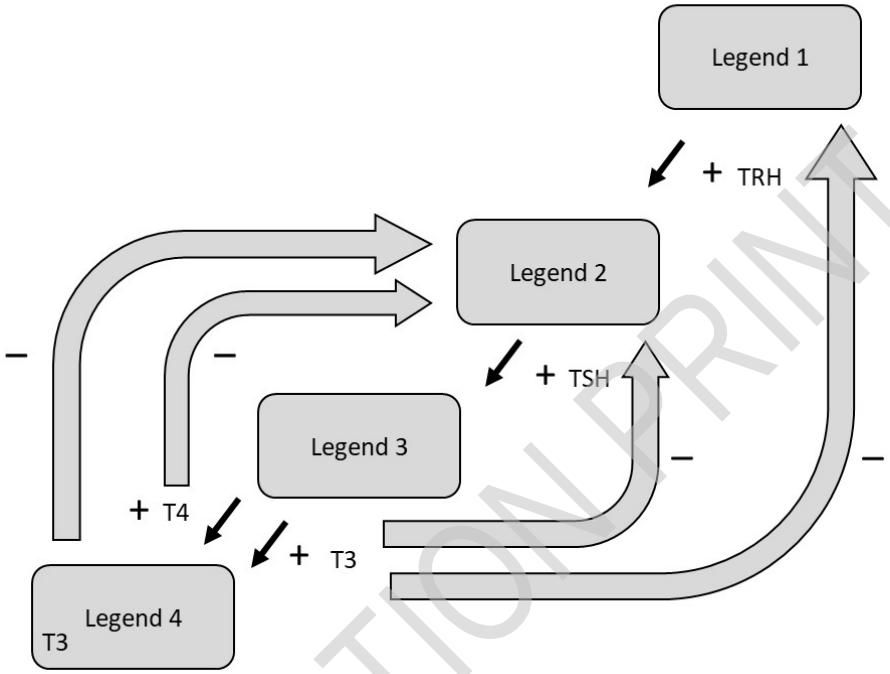


Fig.1. Legend 1 = Hypothalamus. Legend 2 = Anterior Pituitary. Legend 3 = Thyroid. Legend 4 = Peripheral body / blood. TRH = Thyrotropin-releasing hormone. TSH = Thyroid-stimulating hormone.

圖 1。Legend 1 = 下視丘。Legend 2 = 腦垂體前葉。Legend 3 = 甲狀腺。Legend 4 = 周邊身體/血液。

Which hormone’s levels would you expect to be **increased** in patients with the following conditions relative to healthy individuals? Indicate your answer by putting an X in the appropriate box on the answer sheet.

相對於健康個體，你認為罹患下列各種疾病的患者體內激素會有那些改變?，請在答案卷上的正確答案格中輸入 X。

Q.18.1 A patient with Hashimoto thyroiditis that causes the gradual immune destruction of thyroid tissue.
患有橋本甲狀腺炎 (Hashimoto thyroiditis) 的患者，免疫系統將導致甲狀腺組織日漸損壞。

Q.18.2 A patient with Graves’ disease, where the body produces antibodies against the TSH receptor (TSHR) that stimulate its activation.
患有格雷夫斯病 (Graves’ disease) 的患者，身體會產生抗 TSH 受體（TSHR）的抗體。

Q.18.3 A patient abusing medication, taking T4 supplement pills hoping it would help them with weight loss.
一名濫用藥物的患者，服用 T4 補充劑，希望有助於減肥。

Q.18.4 Patient with a very rare TSH-secreting anterior pituitary tumour.
患有非常罕見的分泌 TSH 之腦垂體前葉腫瘤的患者。

Q.18.5 Patient with thyroid hormone resistance, a mutation of the thyroid hormone receptor.
患者有甲狀腺激素阻抗，即因甲狀腺激素受體突變所造成。

Q19

Thyroid hormones play a crucial role in metabolism and the cardiovascular system. Too much or too little thyroid hormone can result in insufficient blood flow to the heart. Insufficient blood flow generates reactive oxygen species (ROS) which damage the heart further.

甲狀腺素在新陳代謝和心血管系統中扮演相當重要的角色。甲狀腺激素過多或過少都會導致回心血流不足。血液供給不足會產生活性氧（ROS），進一步損害心臟。

Methimazole prevents the production of thyroid hormones, whilst T4 is a thyroid hormone. Either was given to rats, and the expression of antioxidant enzymes in the heart was measured (Figure).

甲巯咪唑可以防止甲狀腺激素的產生，而 T4 則是其中一種甲狀腺素。分別投予甲巯咪唑與 T4 於大鼠，測量心臟中抗氧化酶的表現（圖）。

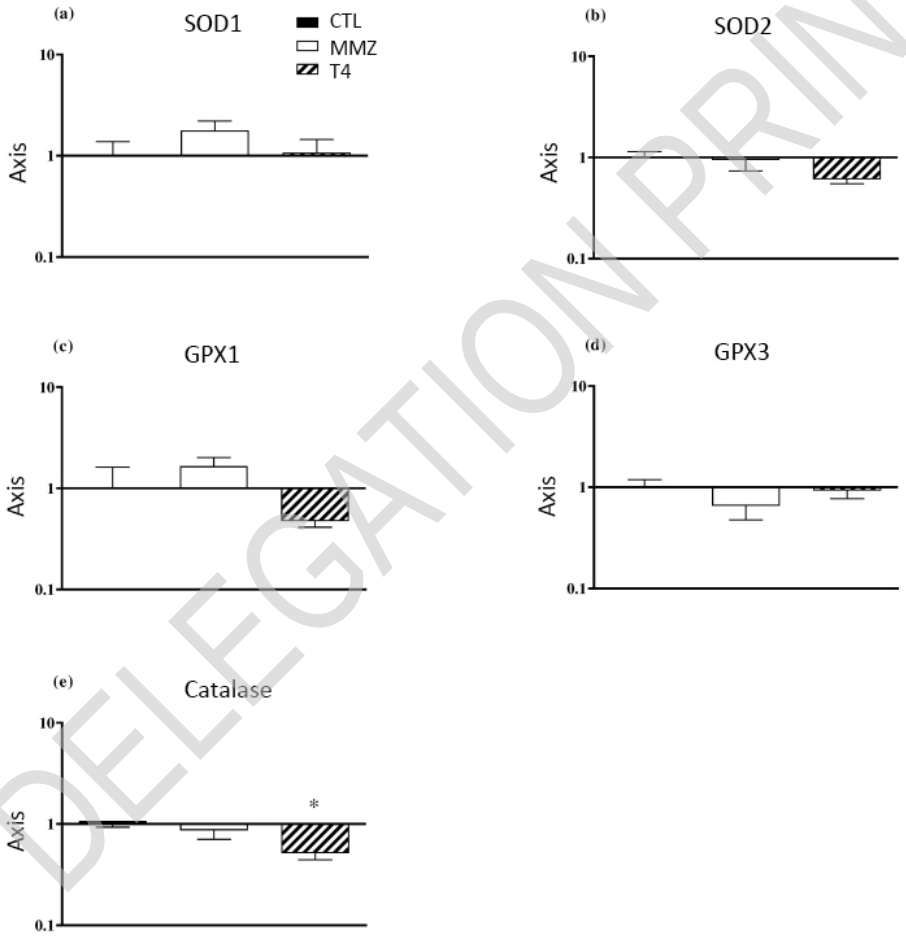


Fig.1. Axis = Fold change (Logarithmic scale). CTL = Untreated Control group. MMZ = Treated with Methimazole. T4 = Treated with thyroxine. SOD = Superoxide dismutase. GPX = Glutathione peroxidase.

圖。1。軸 = 增加量（對數）。CTL = 未治療的對照組。MMZ = 投予甲巯咪唑處理組。T4 = 投予甲狀腺素處理組

Assess how the following variables change under the conditions described below using the symbols (A-C). Indicate your answer by putting an X in the appropriate box on the answer sheet.

使用符號 (A-C) 評估在下述條件下的變化情形。將你的正確答案在答案紙上的相應方框中輸入”X”來表明。

A = increase 增加

B = no change 無變化

C = decrease 減少

Q.19.1 The expression of catalase enzyme on a thyroxine supplemented diet.
補充甲狀腺素後過氧化氫酶的表達。

Q.19.2 Severity of ROS damage in patients treated with thyroid stimulating hormone.
投予甲狀腺刺激素後患者 ROS 損傷的嚴重程度。

Q.19.3 SOD1 expression of thyrotropin releasing hormone treated rats.
促甲狀腺激素釋放激素投予後大鼠 SOD1 的表現。

Q.19.4 Risk of heart failure in patients with Graves’ disease, an autoimmune disease resulting in hyperthyroidism, treated with methimazole, as compared to untreated patients.
Graves 症為一自體免疫疾病，會導致患者甲狀腺功能亢進，患者投予甲巯咪唑後罹患心臟衰竭之風險。

Q.19.5 Core temperature of animals on the T4 supplemented diet.
補充 T4 對動物的核心溫度之影響。

MOR2

Plant Anatomy and Physiology 植物解剖學和生理學

Q20

Two families of transcription factors, GNC and GLK, have been implicated in regulating chloroplast development. The promoters which these transcription factors bind to were identified. These promoters were grouped according to whether the genes were upregulated, or downregulated when these transcription factors were overexpressed (colour of bar). The percentage of these promoters which contained certain hexamer or octamer sequences was plotted (height of bar). The asterisks indicate significant difference compared to the control.

在葉綠體發育的調節中，有兩群轉錄因子 GNC 和 GLK，也知道這兩群轉錄因子所連接的啟動子。如圖 1 所示，這些啟動子則依據當轉錄因子被過度表現時，其基因是否被正調控或負調控而分群 (圖 1 中的條帶顏色)；而含有特定六鹼基或八鹼基重複序列的啟動子分別所占百分比 (圖 1 中的條帶長度)，條帶上的星號表示與控制組的顯著差異程度。

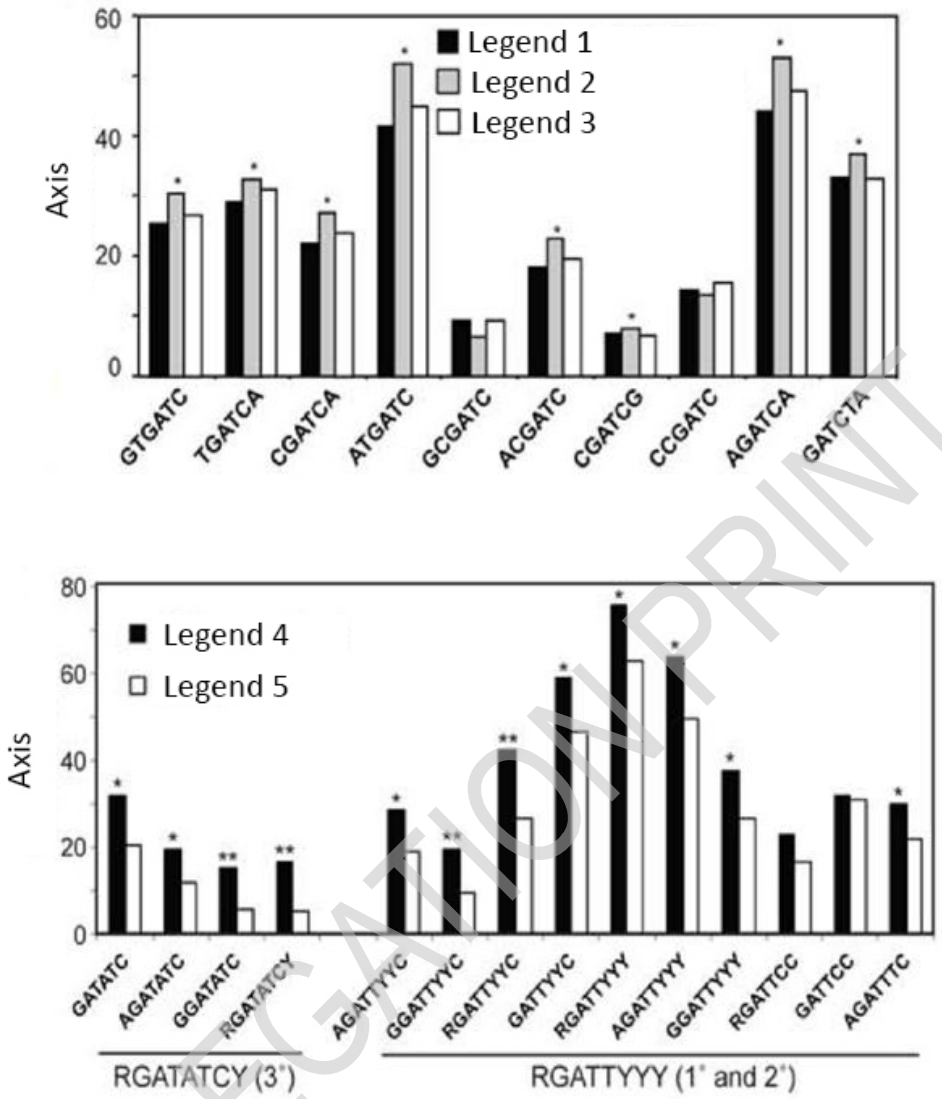


Fig.1. Axis = % of promoters. Legend 1 = Up-regulated by 35S:GNC. Legend 2 = Down-regulated by 35S:GNC. Legend 3 = Control. Legend 4 = Up-regulated by GLK. Legend 5 = Control

Fig.1. Axis = 啟動子百分比. Legend 1 = 被 35S:GNC 正調控. Legend 2 = 被 35S:GNC 負調控. Legend 3 = 控制組. Legend 4 = 被 GLK 正調控. Legend 5 = 控制組

Q.20.1 The frequency of each nucleotide at each position of the nucleotide sequences which most strongly bound GNC were plotted. Deterimne the best estimate of the hexanucleotide sequence which GNC most prefers to bind (“consensus sequence”). Write your answer in the appropriate box on the answer sheet.
在序列中，每個核苷酸與 GNC 強力連接的位置所佔頻率如圖 2 所示。找出 GNC 最喜歡連接的六鹼基序列 (“共識序列”)，將答案填入答案卷上適當空格中。

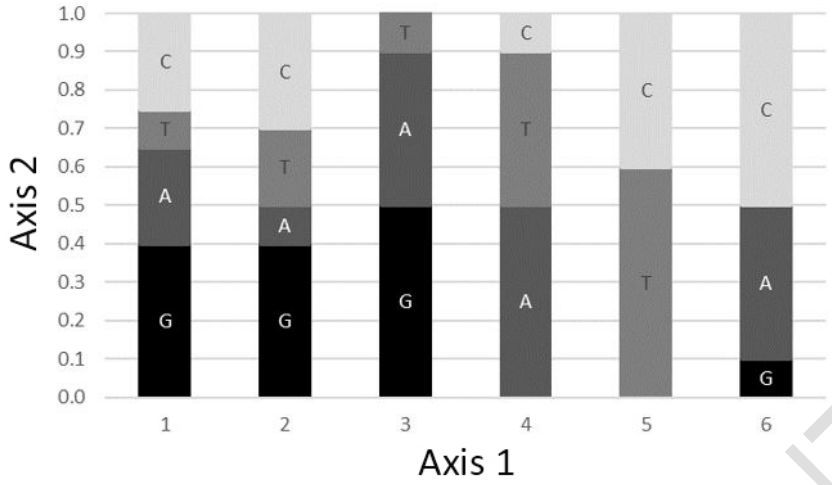


Fig.2. Axis 1 = Nucleotide position. Axis 2 = Nucleotide frequency
圖 2、Axis 1 = 核酸位置；Axis 2 = 核酸頻度。

Q.20.2 Determine for both GNC and GLK transcription factors whether they are repressors or activators of the genes they control. Indicate your answer by putting an X in the appropriate box on the answer sheet **for both GNC and GLK.**
判斷 GNC 和 GLK 轉錄因子是否會抑制 (R) 或促進 (A) 其控制基因的活動。在答案卷上正確答案的空格中填入”X”。
A = activator 促進
R= repressor 抑制

Q.20.3 Which of the high-affinity binding sites are not specifically active (i.e. do not modulate gene expression) from those investigated above (see Figure 1)? Write the binding site sequences in the appropriate boxes on the answer sheet for both GNC and GLK.
在高親和連接位置上，何者並非特別活躍 (即：不會調節基因表現)？在答案紙上的適當空格中填入連接位置，分別針對 GNC 和 GLK，填入答案序列。

Q21

The effect of drought on leaf anatomy was investigated in two types of Olive: Chemlali and Meski. Data is shown in the tables below.

有關乾旱對兩個橄欖品種 Chemlali 和 Meski 葉片構造上的影響，如下表 1 所示。

	r (µm)							
Parameter	UE		SP		LE		TL	
CULT								
'Chemlali'								
WW	18.0	*	196.3	*	16.5	*	30.6	
UW	23.8		215.7		20.7		40.5	
'Meski'								
WW	26.8		224.9		16.3		37.9	
UW	20.1		234.8		16.4		47.9	

Parameter	LA (mm^2)		D($g\ kg^{-1}$)		S (mg H_2O cm^{-2})	
CULT						
'Chemlali'						
WW	537.2	*	535.0	*	24.23	*
UW	405.0		485.5		30.45	
'Meski'						
WW	746.0	*	543.0	*	23.99	
UW	634.7		521.7		29.44	

Table 1. r = Thickness (µm), UE = Upper epidermis, SP = Spongy parenchyma, LE = Lower epidermis, TL = Trichome layer, WW = well-watered, UW = under-watered, LA = leaf area, D = density of leaf tissue, S = succulence, CULT = Cultivar x watering regime , asterisks * indicate significant differences

Table 1. r = 厚度 (µm), UE = 上表皮, SP = 海綿組織, LE = 下表皮, TL = 毛茸層, WW = 充分澆水, UW = 較少澆水, LA = 葉表面積, D = 葉組織密度, S = 肉質, CULT = 品種 X 澆水方式, 星號 * 表示顯著差異

Q.21.1 Calculate "A" and "B" in the following table by quantifying the effect of under-watering (UW) relative to the well-watered (WW) condition on spongy parenchyma, as we have done for the effect on upper epidermis. Write your results as percentages in the appropriate box on the answer sheet.
根據表 1，依照所示之對上表皮的影響，計算"A"和"B"在較少澆水 (UW) 相對於充分澆水 (WW) 情況下，海綿組織的改變狀況。將所得答案填入答案卷的適當空格中。

	UE	SP
Chemlali	132	"A"
Meski	75	"B"

What are the consequences of the following changes? Assign the correct physiological consequence from the list below (A-F) to each of the anatomical changes listed (Q.21.2-7). In some of the boxes you may have to use more than one letter. You can use the same letter more than once.

在下列的改變之下，會產生怎樣的後果？從以下 A-F 的生理後果選出能與下列解剖改變 (Q.21.2-7) 對應者。在答案卷的適當空格上劃記"X"；有些空格中，可有多於一個字母，且字母可多次採用。

A. Increase in CO_2 fixation rate

in CO_2 fixation 固碳速率上升

B. Decrease in CO_2 fixation rate

CO_2 固碳速率下降

C. Increased transpiration rate

蒸散速率上升

D. Decreased transpiration rate

蒸散速率下降

E. Increased CO_2 conductance of leaves

葉片的 CO_2 通透量上升

F. Decreased CO_2 conductance of leaves

葉片的 CO_2 通透量下降

Q.21.2 Increased upper and lower epidermis thickness
上、下表皮的厚度增加

Q.21.3 Increased upper palisade thickness
近上表皮的柵狀組織厚度增加

Q.21.4 Increased spongy parenchyma thickness
海綿組織厚度增加

Q.21.5 Increased trichome density
毛茸密度增加

Q.21.6 Increased leaf area
葉表面積增加

Q.21.7 Increased succulence
變得更肉質

Q.21.8 Determine the difference in the degree of drought resistance for the two cultivars. Indicate your answer using the symbols, < or > or =.
A. Resistance of Chemlali
B. Resistance of Meski
比較兩個品種的耐旱程度差異，答案用”<”或”>”或”=”來表示。A 是 Chemlali 的耐旱性、B 是 Meski 的耐旱性。

Q22

To understand the relationship between different factors and tree height, Sequoia sempervirens, one of the tallest known tree species was studied. Multiple physiological parameters were determined at different heights of multiple individual trees as shown in Fig.1. A changing ratio of stable ^{13}C / ^{12}C isotopes in leaf tissues, $\delta^{13}C$, is a consequence of changing water stress (Fig.1c). For xylem pressure and $\delta^{13}C$, two sets of samples were taken: right before dawn (filled datapoints) and at midday (empty datapoints).

欲了解不同因子和樹木高度的相關聯，以最高樹木之一的紅杉 (Sequoia sempervirens) 為研究材料。如圖 1 顯示多種生理變數在不同高度的樹木的改變。葉片組織中穩定同位素 ^{13}C / ^{12}C 比值 (☒ 13☒) 的改變，是水分逆境改變的後果 (Fig.1c)。針對木質部壓力和 $\delta^{13}C$ 的改變，選取兩組樣本，分別在清晨之前 (圖中的實心點)、中午 (空心點) 進行量測。

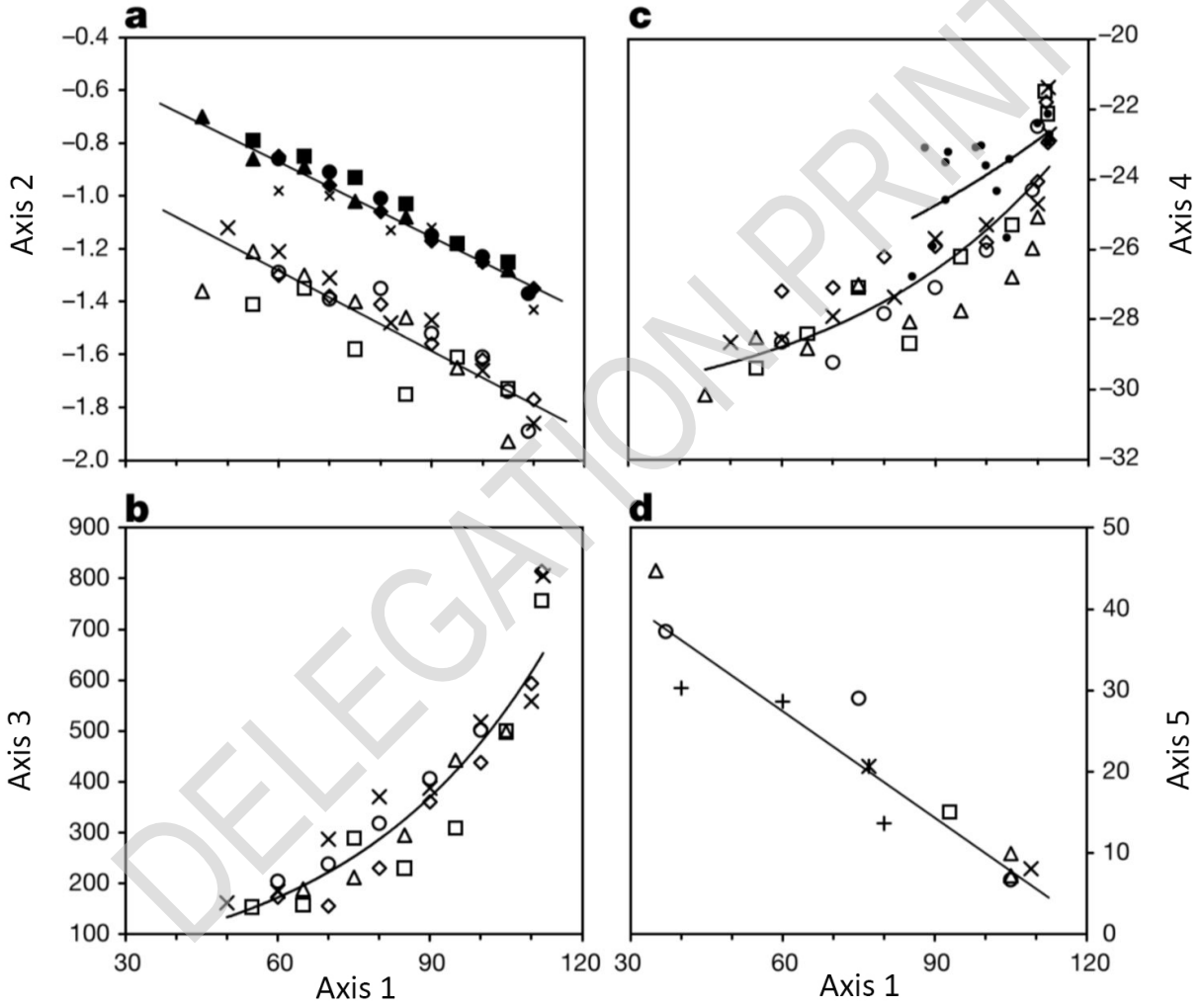
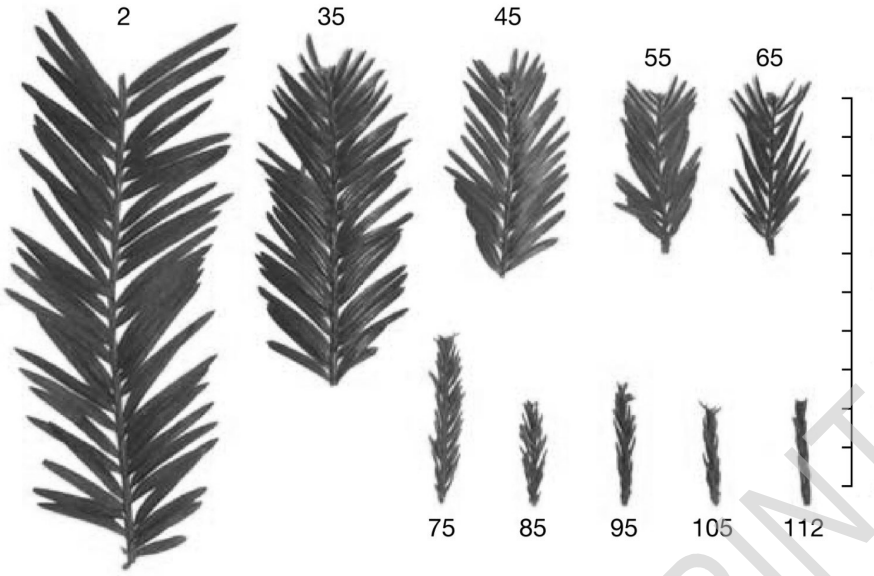


Fig.1. Axis 1 = Height above ground (m). Axis 2 = Xylem pressure (MPa). Axis 3 = Leaf mass:area ($g \cdot m^{-2}$). Axis 4 = Leaf $\delta^{13}C$ (‰). Axis 5 = " photosynthetic rate per unit mass" $P_{\text{max},m}$ ($nmolCO_2 \cdot g^{-1} \cdot s^{-1}$).

Fig.1. Axis 1 = 地表上方的高度 (m). Axis 2 = 木質部壓力 (MPa). Axis 3 = 單位面積的葉片重量 ($g \cdot m^{-2}$). Axis 4 = Leaf $\delta^{13}C$ (‰). Axis 5 = 單位質量的光合速率 $P_{\text{max},m}$ ($nmolCO_2 \cdot g^{-1} \cdot s^{-1}$).

Pictures of leaves were taken at different heights (numbers are meters of height of sampling) as shown in Fig.2.

不同高度下的葉片照片如圖 2 所示。圖中的數字代表取樣樹木的高度 (m)



Additionally, model equations were constructed to predict how different variables influence the maximum height of trees (Ψ leaf water potential; LMA Leaf Mass : Area ratio; “Maximum height”, h, in the equations, refers to the maximum height in meters predicted by the equations, values not shown).

此外，使用模式公式來預測不同變數如何影響樹木高度之最大值 (Ψ 為葉片水勢；LMA 為葉片重量：表面積的比值；公式中的”h”為最大樹高，代表根據公式所預測的植株高度 (m)，在此沒有呈現數值)

Col 1	Col 2	Col 3
ψ, midday (MPa)	$\psi = -0.00973h - 0.712$	−1.9
LMA ($g \cdot m^{-2}$)	$LMA = 37.43 \cdot e^{0.0255h}$	833
$\delta^{13}C(‰)$	$\delta^{13}C = 0.559 \cdot e^{0.0229h} - 31$	−20
$P_{max,m}(nmol \cdot g^{-1} \cdot s^{-1})$	$P_{max,m} = -0.434h + 54.3$	0

Table 1. Col 1 = Dependent value. Col 2 = Equation of max height (h). Col 3 = Limit value of dependent variable.

Table 1. Col 1 = 應變數. Col 2 = 最大樹高 (h) 的公式. Col 3 = 應變數的限制值

Q.22.1 Select the single best statement from the options below that describes how xylem pressure changes with increasing height. Indicate your answer by putting an X in the appropriate box on the answer sheet.
下列選項描述木質部壓力隨高度增加而變化的方式，選出一個最適當的敘述，將正確答案在答案卷上的適當空格中以”X”劃記。
A. Xylem pressure increases with increasing height at a significantly higher rate at night than during the day.
木質部壓力隨著樹高的增加而增加，在夜間的速率明顯高於白天。
B. Xylem pressure increases with increasing height at a significantly higher rate during the day than at night.
木質部壓力隨著樹高的增加而增加，在白天的速率明顯高於夜間。
C. Xylem pressure decreases with increasing height at a significantly higher rate at night than during the day.
木質部壓力隨著樹高的增加而降低，在夜間的速率明顯高於白天。
D. Xylem pressure decreases with increasing height at a significantly higher rate during the day than at night.
木質部壓力隨著樹高的增加而降低，在白天的速率明顯高於夜間。
E. Xylem pressure decreases with increasing height at a rate irrespective of the time of the day.
木質部壓力隨著樹高的增加而降低，與一天的時間無關。

Q.22.2 Indicate the relationship between the values of xylem pressure in the following scenarios using the symbols > or < or = in the appropriate boxes on your answer sheet.
在以下情境中，木質部壓力值之間的關係如何？在答案卷上對應的空格中，以＂>＂或”<”或“=“來表示。
A. Xylem pressure in the topmost leaves of most studied trees **before dawn**
清晨前，在大多數採樣樹木中，其最頂層葉片的木質部壓力
B. Xylem pressure in the topmost leaves of most studied trees **at midday.**
中午時，在大多數採樣樹木中，其最頂層葉片的木質部壓力

Q.22.3 Given the data above and that epiphytic saplings growing on branches at 95m show a similar leaf structure as leaves of non-epiphytes from 2m high, select the factor that is the most important in determining the leaf structure at a given height. Indicate your answer by putting an X in the appropriate box on the answer sheet.
根據上述數據，在 95 m 處樹枝上生長的附生性植物的樹苗，此樹苗的葉片構造顯示出與在 2 m 高的非附生性植物的葉片構造相似。選出影響在特定樹高的葉片構造的最重要因子。在答案卷上的適當空格中，以”X”劃記答案。
A. Light intensity
光的強度
B. Water availability
可利用的水量
C. $\delta^{13}C$
D. Ambient relative humidity (that of surrounding air)
周圍環境空氣中的相對濕度
E. Ambient partial pressure of carbon dioxide (that of the surrounding air)
周圍環境空氣中的二氧化碳分壓

Calculate the maximum possible height predicted by each equation. Write your results, rounded to the nearest integer, in the appropriate boxes on the answer sheet.

用所提供的算式來計算預測的最大可能樹高。將結果四捨五入到最接近的整數，填入答案卷上的適當空格中。

Q.22.4 Maximum height as predicted by Ψ
以水勢 Ψ 預測最大樹高

Q.22.5 Maximum height as predicted by LMA
以 LMA 預測最大樹高

Q.22.6 Maximum height as predicted by $\delta^{13}C$
以 δ13C 預測最大樹高

Q.22.7 Maximum height as predicted by $P_{\text{max},m}$
以 Pmax,m 預測最大樹高

Q.22.8 Based on your calculations above, state which parameter(s) is/are the most limiting to tree height. Indicate your answer by putting an X in the appropriate box on the answer sheet.
根據上面的計算，說明哪個/哪些變數是樹高的最大限制。在答案卷上的適當空格中，以”X”劃記答案。
A. Water potential (ψ)
水勢 (ψ)
B. Leaf Mass : Area ratio (LMA)
葉片重量：面積比值（LMA）
C. $\delta^{13}C$
D. $P_{\text{max},m}$

Q23

Statocytes are cells in the central root cap thought to be crucial in geotropism of the plant root. These cells possess starch-filled granules, statoliths, which have a higher density than the statocyte cytoplasm so their position in the statocyte depends on the root orientation relative to the direction of the gravitational force it experiences.

平衡細胞 (Statocytes) 是位在根冠中央的細胞，被認為在植物根的向地性有密切關係。這些細胞含有澱粉粒稱為平衡石 (statoliths)，其在平衡細胞中的密度較高，因此它們在平衡細胞的位置取決於根所在的重力方向。

In order to determine the role of statoliths in geotropism and their mechanism of action, Brassica napus seeds were taken to and grown on the International Space Station. Brassica seedlings were grown either in a centrifuge that exerts 1g force on the seedlings (fig A) or in microgravity (experiencing negligibly small gravity, fig B). The root tissues were fixed after 40 hours of germination and the position of statoliths was determined. Results are represented in a unified coordinate system whose origin (0;0) is the centre of the statocyte.

為了確定平衡石在向地性所扮演的角色及其作用機制，將大油菜 (Brassica napus) 種子帶到國際太空站生長。大油菜幼苗在離心機中生長，該離心機對幼苗施加 1 g 重力（圖 A）或是微重力（處在幾乎可忽略的微重力下，圖 B）。將發芽 40 小時後的小苗之根組織固定，並檢視其平衡石的位置。結果以統一座標系統表示，其原點 (0; 0) 是以平衡石為中心。

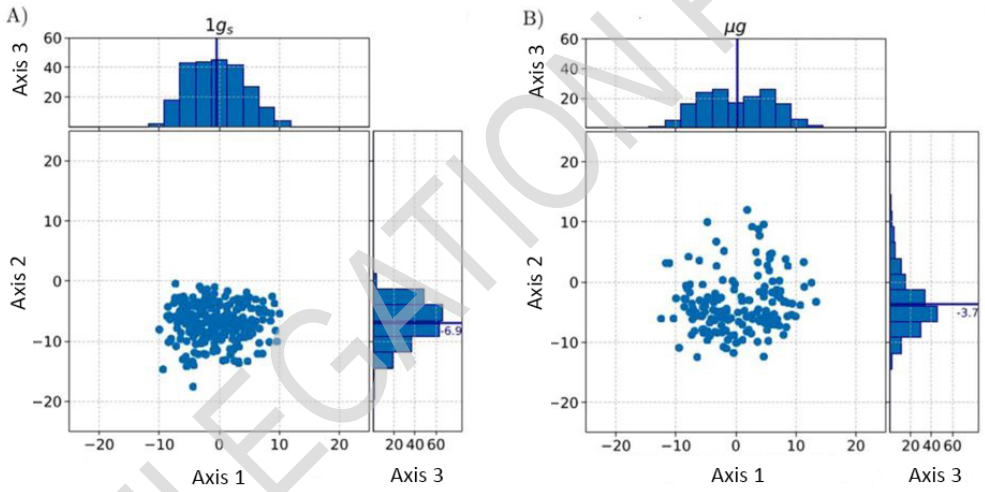


Fig.1. Axis 1 = Statocyte transverse position (μm). Axis 2 = Statocyte longitudinal position (μm). Axis 3 = Count

圖 1。Axis1 = 平衡石的橫向距離 (μm)。軸 2 = 平衡石的縱向距離 (μm)。軸 3 = 計數。

Each tile represents the final direction of a root tip of a seedling relative to direction of gravity (black arrow). Determine which of the following diagrams (A-G) depict the distribution of growing root tips in microgravity and in 1g gravitational force. There are two correct answers for both experimental conditions. Indicate your answer by putting **two Xs** in the appropriate boxes **in each line** on the answer sheet.

圖 2 中，每個灰色塊代表相對於重力方向的幼苗根尖之最終方向 (黑色箭頭)。確定以下哪個圖（A-G）描繪出在微重力下和 1 g 重力中的根尖生長分布。兩種實驗條件都有兩個正確的答案。在答案卷上的對應**每行空格**中，分別劃記**兩個”X”** 。

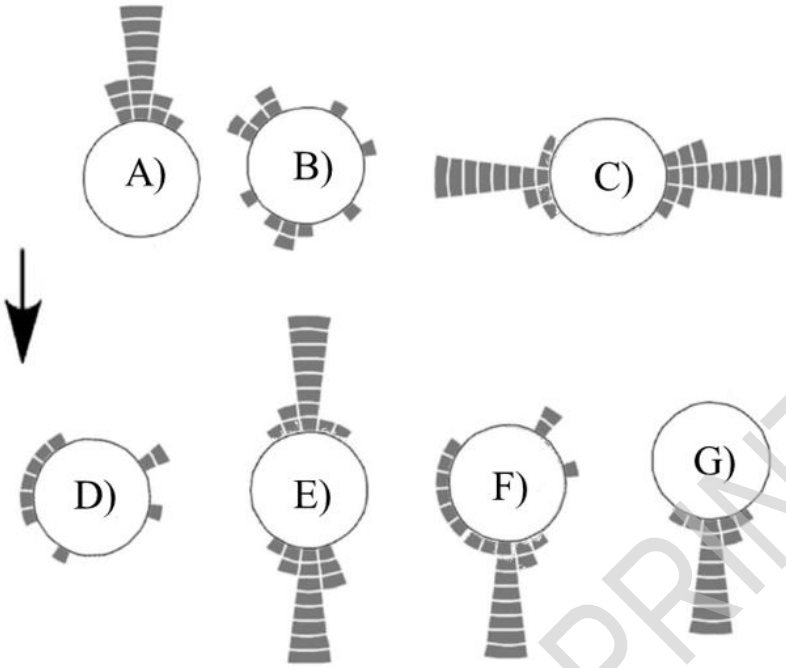


Fig.2

Q.23.1 In 1 g gravity 在 1 g 重力下

Q.23.2 In microgravity 在微重力下

Assume that statocytes are cylindrical. Statoliths can move freely across the diameter of the statocyte. Statoliths can move 40% of the length of the statocyte. Calculate the approximate diameter and length of a statocyte in μm. Write your results in the appropriate boxes on the answer sheet.

假設平衡石細胞是圓柱形，平衡石可以在整個細胞直徑上自由移動。平衡石可以移動 40%的平衡石細胞長度。以 μm 為單位，計算平衡石細胞的大約直徑和長度。將結果寫在答案卷上的適當空格中。

Q.23.3 Diameter
直徑

Q.23.4 Length
長度

Q24

Electrophysiological measurements were carried out on bean guard cells to measure outwards K+ currents and how they are modified by various factors. Assume that the K^+ currents shown here are proportional to the net changes in the intracellular K^+ concentration.

對豆類植物的保衛細胞進行電生理學測量，以測量 K + 向外流出的情形以及它們如何受各種因子影響而改變。假設在此顯示 K + 的外流與細胞內 K + 濃度的淨變化成正比。

Currents (I) across the plasma membrane at different voltages (V) were determined after each step of four different experiments.

在四個不同實驗的每個步驟之後，測定在不同電壓（V）下，穿過膜（I）的電流。

Experiment 1 實驗一
Step 1: Incubated in washing buffer.
步驟 1：在洗滌緩衝液中培養。
Step 2: Exposed to exogenous nitric oxide (NO).
步驟 2：暴露於外加的一氧化氮中。
Step 3: Washed in washing buffer
步驟 3：在洗滌緩衝液中洗滌。

Experiment 2 實驗二
Step 1: Injected with buffer to set cytoplasmic pH to 7.4.
步驟 1：用緩衝液注射以將細胞質 pH 值調整為 7.4。
Step 2: Exposed to exogenous NO.
步驟 2：暴露於外加的 NO 中。
Step 3: Washed in washing buffer.
步驟 3：在洗滌緩衝液中洗滌。

Experiment 3 實驗三
Step 1: Incubated in washing buffer.
步驟 1：在洗滌緩衝液中培養。
Step 2: Exposed to exogenous nitric oxide (NO).
步驟 2：暴露於外加的一氧化氮中。
Step 3: Exposed to BAL, a reducing agent that is known to reduce disulphide bridges in proteins.
步驟 3：暴露於 BAL (一種還原劑，已知可減少蛋白質中的雙硫鍵結)。
Step 4: Exposed to exogenous nitric oxide (NO).
步驟 4：暴露於外加的一氧化氮中。

Experiment 4 實驗四
Step 1: Incubated in washing buffer.
步驟 1：在洗滌緩衝液中培養。
Step 2: Exposed to PAO, an oxidising agent that localises to membranes within the cell.
步驟 2：暴露於 PAO (一種氧化劑，其會附在細胞內的膜上)。
Step 3: Washed in washing buffer containing 0.3mM BAL
步驟 3：在含有 0.3 mM BAL 的洗滌緩衝液中洗滌。

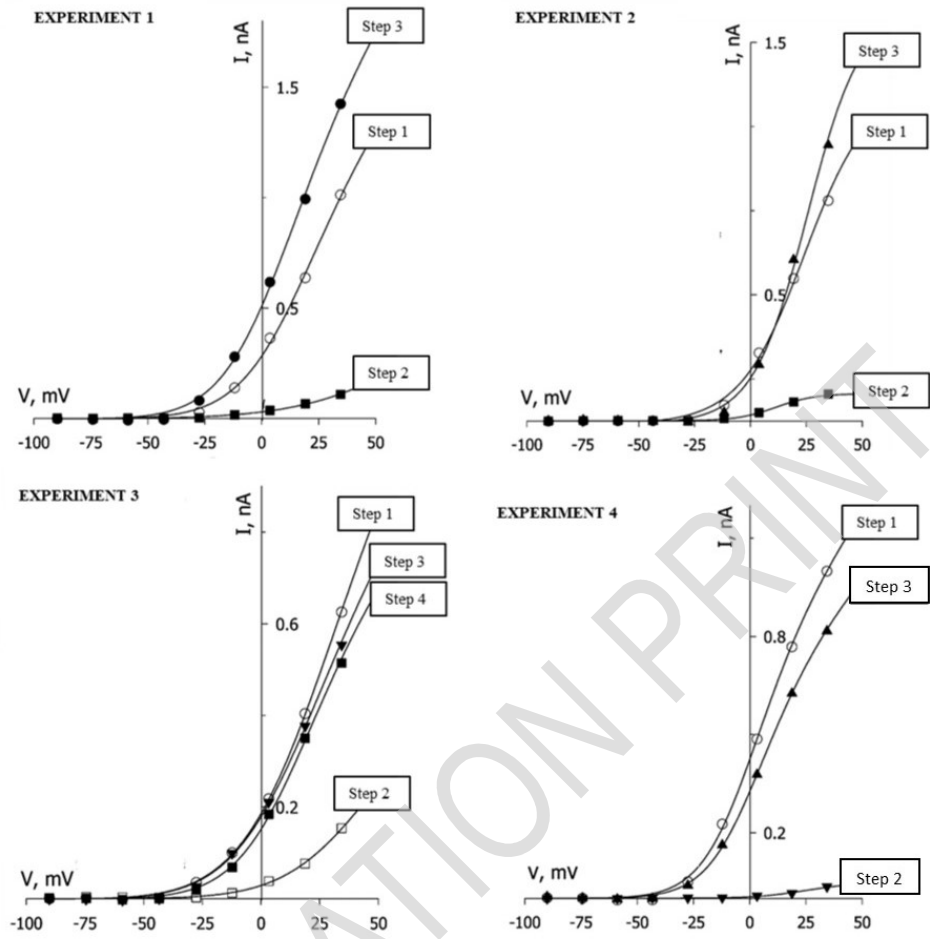


Fig.1 圖 1

Based on the information above, indicate with an **X** if each of the following statements is true (T) or false (F).

根據以上資訊，判斷以下每個敘述是正確（T）或錯誤（F），並用 X 劃記。

Q.24.1 Guard cells treated in experiment 1 have a higher turgor and the stoma they form is more open when treated with NO compared to before the NO treatment.
在實驗 1 中處理的保衛細胞具有較高的膨壓，且與 NO 處理之前相比，用 NO 處理時所形成的氣孔較大。

Q.24.2 Intracellular pH significantly influences the NO-mediated reduction of K^+ efflux.
細胞內的 pH 值會顯著影響因 NO 調節 K+ 外流減少的現象。

Q.24.3 BAL is a hydrophilic molecule.
BAL 是親水性分子。

Q.24.4 According to these data alone, infection of a bean leaf with a pathogen results in stomatal closure.
僅根據這些數據，用病原體感染豆類葉片會導致氣孔關閉。

Genetics and Evolution 遺傳學與演化學

Q25

A test tube contains a suspension of bacteria that were never exposed to the antibiotic kanamycin. The bacteria were spread onto a so-called master plate, which contains nutrients for the bacteria and does not contain kanamycin. Millions of colonies (descendants of a single founder bacterium) developed on the master plate. Replicas (copies) of the master plate colonies were stamped - with a sterile velvet plate - onto three replica plates that contained growth medium supplemented with kanamycin (Figure 1).

一試管中含有未暴露於抗生素卡那黴素的細菌懸浮液。將細菌塗抹在母版平面培養基上，該培養基含有細菌所需的營養物質但不含有卡那黴素。在培養基上產生了數百萬個菌落 (單個前驅細菌的後代)。將培養基菌落的複製品 (拷貝) 用無菌天鵝絲絨板蓋印到三個複製培養基上，上述複製培養基為含有卡那黴素的生長培養基（圖 1）。

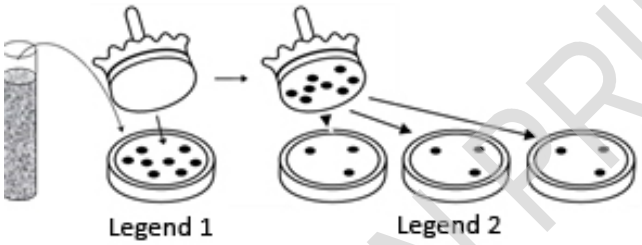


Fig.1. Legend 1 = Master plate. Legend 2 = Replica plates

圖. 1、說明 1 = 母版培養基。說明 2 = 複製培養基

Indicate with an **X** if each the following statements are true (T) or false (F).

如果以下的敘述為正確（T）或錯誤（F），則用 X 表示。

Q.25.1	A spontaneous frameshift mutation caused the kanamycin resistance in bacteria which previously didn’t contain the gene responsible for kanamycin degradation. 因自發的框移突變導致細菌中的卡那黴素抗藥性，其先前不含有導致卡那黴素降解的基因。	
Q.25.2	The resistance of certain colonies is uncovered on the Replica plates. 複製培養基上發現某些菌落具有抗藥性。	
Q.25.3	A mutation induced by the kanamycin caused the resistance. 由卡那黴素誘導的突變導致抗藥性。	
Q.25.4	The kanamycin resistance occurred first on the ‘Replica plates’. 卡那黴素抗藥性首先發生在”複製培養基”上。	
Q.25.5	The best explanation is that kanamycin has a mild mutagenic effect on these bacteria. 最好的解釋是卡那黴素對這些細菌具有輕微的誘導突變作用。	

Q.25.6 QUESTION REDACTED.
題目刪除

Q.25.7 There were no kanamycin resistant bacteria in the tube originally.
最初在試管中沒有卡那黴素抗藥性細菌存在。

Q.25.8 The kanamycin resistance can spread on the Master Plate.
卡那黴素抗藥性可以在母版培養基上散布。

Q26

The pedigree shows inheritance of a trait in a model organism. The symbols are as follows: ” empty circle” = healthy female; ” empty square” = healthy male; ” black circle” = sterile female, ” black square” = sterile male.

譜系分析顯示模型生物中的性狀遺傳。符號如下：“空心圓圈”= 健康女性; “空心正方”= 健康男性; “黑色圓圈”= 不育女性，“黑色方塊”= 不育男性。

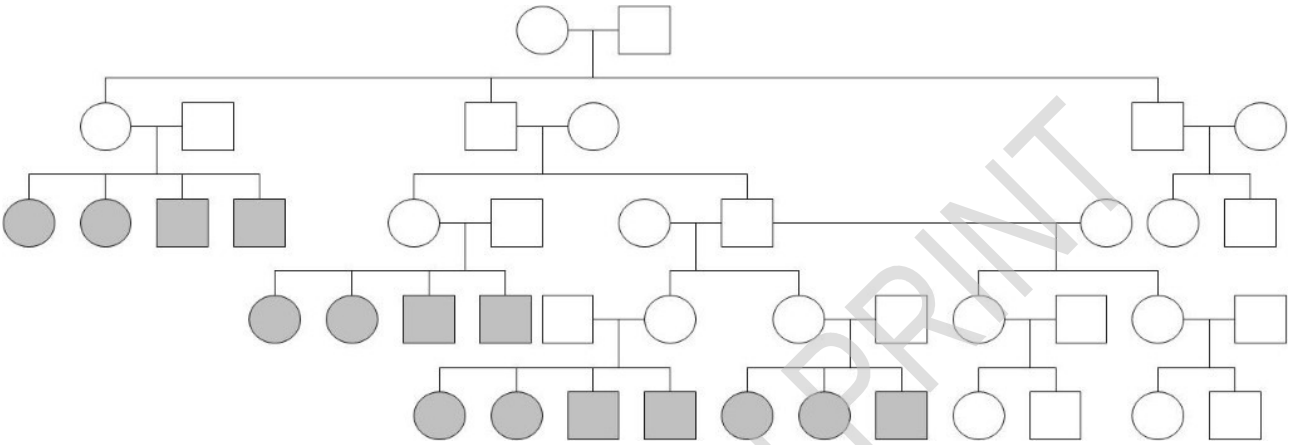


Fig.1 圖 1

Q.26.1 Which **one** of the following options explains how sterility is inherited? Indicate your answer with an **X**.
下列**哪一個**選項可以解釋如何導致不育的基因突變是可遺傳嗎？用”**X**”表示你的答案。

A. Autosomal dominant
B. Autosomal recessive
C. X-chromosome linked dominant
D. X-chromosome linked recessive
E. Mitochondrial inheritance
F. Maternal effect

A. 體染色體顯性遺傳
B. 體染色體隱性遺傳
C. X 染色體連鎖顯性遺傳
D. X 染色體連鎖隱性遺傳
E. 粒線體遺傳
F. 母體效應

The change giving rise to sterility can be explained either through loss-of-function or gain-of-function mutation of the affected gene.

不育性改變可以經由受影響基因的”功能喪失突變”或”功能獲得突變”來解釋。

Q.26.2 Indicate individuals that are certainly heterozygous assuming a loss-of function change to the affected gene, by writing an **X** symbol into the appropriate empty circles and/or squares.
在特定的空心圓和/或空心正方形中填入”X”符號，指出假設受影響基因的功能喪失變化的個體應該是雜合子

Q.26.3 Indicate individuals that are certainly heterozygous assuming a gain-of-function change to the affected gene, by writing an **O** symbol into the appropriate empty circles and/or squares.
在特定的空心圓和/或空心正方形中填入”O”符號，指出假設受影響基因的功能獲得變化的個體應該是雜合子

Q27

Lily and Jacob visit a genetic counselling office where the doctor gathers the data summarized in the table below.

Lily 和 Jacob 訪問遺傳諮詢辦公室，醫生收集下表中匯總的數據。

Person 人	Bald?	Rh
Lily	No	Rh^+
Lily’s mother Lily’s 母親	Yes	Rh^+
Lily’s father Lily’s 父親	No	Rh^-
Jacob	Yes	Rh^-
Jacob’s mother Jacob’s 母親	Yes	Rh^-
Jacob’s father Jacob’s 父親	No	Rh^+

Table 1 表 1

Please note the following facts:

請注意以下事實：

1. Baldness is an example of the so-called sex-influenced traits. B/B women are bald, however B/b and b/b women are not. B/B and B/b men are bald, the b/b men are not.
2. Genotype of the Rh- people is r/r and that of Rh^+ people is R/R or R/r.
3. When the fetus of an Rh^- woman is Rh^+ the woman’s immune system may produce antibodies against the Rh^+ fetus during a second pregnancywhich may result in the death of the fetus. This phenomenon is known as Rh incompatibility.
4. The B (b) and the R (r) genes are autosome linked and are 20 cM apart.

1. 禿頂是所謂的性別影響性狀的例子。B / B 女性是禿頂，但 B /b 和 b /b 女性不是。B / B 和 B / b 男人都是禿頂，b / b 男人不是。
2. Rh-人的基因型是 r / r，Rh+ 人的基因型是 R / R 或 R / r。
3. 當 Rh-女性的胎兒是 Rh + 時，女性的免疫系統可能在第二次懷孕期間產生針對 Rh + 胎兒的抗體，這可能會導致胎兒死亡。這種現象稱為 Rh 不相容性。
4. B (b) 和 R (r) 基因是同一體染色體連鎖的且二者間相隔 20cM。

Q.27.1 Determine Lily’s and Jacob’s genotype. Indicate your answer with an **X** in the appropriate boxes.
確定 Lily 和 Jacob 的基因型。在相應的方框中用”**X**”代表你的答案。

Q.27.2 Determine what percentage of their children will be bald. Give your answer as a whole number.
確定他們的小孩將禿頂的百分比。以整數答案回答你的答案。

Q.27.3 What percentage of their bald children will be female? Give your answer as a whole number.
他們的禿頂小孩中女性的比例是多少？以整數答案回答你的答案。

Q.27.4 What percentage of their daughters may face the problem of Rh incompatibility once they will become pregnant? Give your answer as a whole number.
一旦他們的女兒懷孕，他們的女兒有多少百分比可能面臨 Rh 不相容的問題？以整數答案回答你的答案。

Q.27.5 What percentage these daughters with the potential to develop Rh incompatibility would also be bald?
這些有潛在發展為 Rh 不相容性的女兒中，有多少百分比也會禿頂？

Q28

The human genome is composed from about $3 \cdot 10^9$ base pairs. Assume that the distribution of base pairs is random. How long should a random sequence be to appear once in the human genome, on average?

人類基因組大約由 $3 \cdot 10^9$ 鹼基對構成。假設核苷酸鹼基對的分布是隨機，那麼平均來說在人類基因組中僅出現一次的逢機核苷酸序列應該多長？

Q.28.1 Indicate your answer on the answer sheet, rounded to the nearest integer.
在答題紙上填入答案，四捨五入到最接近的整數。

Q29

The genetic code can be used to reverse engineer the genetic information coding for peptides of a desired amino acid sequence. Your task is to design possible nucleotide substitution mutations that change the DNA coding for the peptide that comprises the M-A-R-C-E-L-L-A amino acid sequence to a peptide whose amino acid sequence is M-A-R-C-E-L.

遺傳密碼可用於逆向遺傳工程編碼所需胺基酸序列的胜肽之遺傳資訊。你的實作是設計可能的核苷酸取代突變，該突變將編碼包含有 M-A-R-C-E-L-L-A 的胺基酸序列之胜肽的 DNA 序列改變為胺基酸序列為 M-A-R-C-E-L 的胜肽。

Q.29.1 What are the potential numbers of substitutions you would have to make to achieve the goal set out in the question? Give your answer(s) as a number(s) on the answer sheet.
你為了完成這題目所預期的目標，必須要有多少次的可能取代數目？在答案卷填入你要回答的數字。

Q.29.2 Fill in the cells corresponding to codon 7 with the nucleotides that code for the new M-A-R-C-E-L peptide using the minimum possible number of substitutions. If there is more than one correct option, use only one.
在空格中填入對應使用最小取代數目產生的新 M-A-R-C-E-L 胜肽之核苷酸第七密碼子。如果有多個正確選項，請僅使用一個。

Q.29.3 Circle the nucleotide base(s) that had to be changed in order to turn the original peptide into the new one.
圈出必須替換的核苷酸鹼基，以便將原始胜肽轉變為新的胜肽。

Q30

Ec+ is an X-linked gene found in a newly discovered mammalian species. Females homozygous for the mutant allele (Ec) have green eyes, while a single copy of Ec+ is sufficient to result in the wild-type brown eyes.

Ec + 是在新發現的哺乳動物物種所找到的”X”連鎖基因。Ec 的雌性同型合子突變體具有綠眼睛，而具有單一 Ec + 拷貝則為產生野生型的棕色眼睛。

Ec codes for an enzyme which catalyses the chemical reaction converting an inert substrate, commonly found throughout the body, into molecule X which diffuses freely in the animal and can be detected in bodily secretions. Molecule X is a very potent epigenetic regulator such that a few particles are sufficient to induce life-long effects on the eye phenotype.

Ec 編碼產物為一種具有催化反應的酵素，此酵素可將動物在整個身體中存在的惰性基質轉化成為分子”X”，此物質可以在動物體中自由擴散並且可以在身體分泌物中檢測出來。分子”X”是一種非常有效率的表觀遺傳調節因子，因此僅少數顆粒便足以誘導對眼睛外表型的終身影響。

Consider the following crossing experiments. What are the genotypes and the eye colors of the progeny of animals that descend from the following crosses, and what are the proportions of the various descendants?

考慮以下的交叉實驗。從下列交叉實驗的動物後代之基因型和眼睛顏色的表現，推測各種後代的比例是多少？

1. Ec/Ec females and Ec+/Y males

   Ec/Ec 雌性和 Ec+/Y 雄性

2. Ec+/Ec females and Ec/Y males

   Ec+/Ec 雌性和 Ec/Y 雄性

3. Ec+/Ec females and Ec+/Y males

   Ec+/Ec 雌性和 Ec+/Y 雄性

Use **one** letter of each group [(A-C), (D-H), (K-L)] in one of the four boxes to indicate the (i) proportions, (ii) genotype and (iii) phenotype of different groups progeny. There should be three letters in each cell that you fill in, but note that not all cells need to be filled in. If you think a cell should remain empty, please write an “X” in it.

在四個方框之一中使用每組 [（A-C）、（DH）、（K-L）] 中的一個字母來表示（i）比例，（ii）基因型和（iii）不同群子代的外表型。在你填寫的每個單元格中應該有三個字母，但請注意，並非所有單元格都需要填充。如果您認為單元格應保持為空白，請在其中寫入“X”。

A. 25%

B. 50%

C. 100%

D. Ec+/Ec+ female

D. Ec+/Ec+ 雌性

E. Ec+/Ec female

E. Ec+/Ec 雌性

F. Ec/Ec female

F. Ec/Ec 雌性

G. Ec+/Y male

G. Ec+/Y 雄性

H. Ec/Y male

H. Ec/Y 雄性

K. brown eyed

K. 棕色眼睛

L. green eyed

L. 綠色眼睛

Ecology 生態學

Q31

The smallmouth bass (Micropterus dolomieu) is an introduced species in the area examined in the following experiment. To protect native fish species, a smallmouth bass removal program was initiated in Little Moose Lake in 2000 (indicated by the vertical line in Fig.1). It continued until 2007. A research group examined the effect of the removal on the smallmouth bass population. They found that while the total biomass of the population decreased during the program, the population size increased. To determine the cause of this phenomenon, they subdivided the population to three groups based on the size of individuals (Fig.1): yearlings (size <100 mm, Fig.1/a), juveniles (100-200 mm, Fig.1/b) and adults (>200 mm, Fig.1/c). They collected two samples in each year (spring and fall). Their results shown in Figure 1.

對下面所述研究地區而言，小嘴黑鱸（Micropterus dolomieu ）是美一個外來物種。為了保護本地魚類，2000 年在小穆斯湖開始了一項小嘴黑鱸清除計劃（圖 1 中的垂直線表示）。它一直持續到 2007 年。一個研究小組研究了去除對小嘴黑鱸族群的影響。他們發現，雖然該計劃期間族群總生物量減少，但族群數量卻在增加。為了確定這種現象的原因，他們根據個體的大小將族群分為三組（圖 1）：一歲幼體（體型 <100 mm，圖 1 / a），亞成體（100-200 mm，圖 1）。1 / b）和成體（> 200 mm，圖 1 / c）。他們每年收集兩個樣本（春季和秋季）。結果如圖 1 所示。

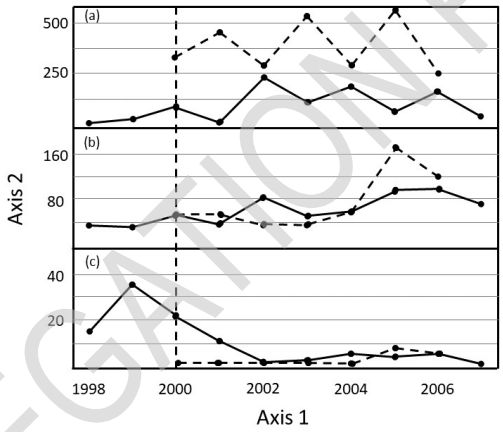


Fig.1. The change of the abundance of the subpopulations (y-axis) by time (x-axis). Solid lines = spring samplings, dashed lines = fall samplings. Axis 1 = Year. Axis 2 = Catch per unit effort (CPUE)

圖 1。亞族群的豐度（y 軸）隨時間（x 軸）的變化。實線 = 春季採樣，虛線 = 秋季採樣。軸 1 = 年。軸 2 = 每單位作業的捕獲量（CPUE）

Which of the following models can possibly describe how the removal of individuals affected the population? Indicate with an **X** if each the following models can describe (T) or cannot describe (F) the changes.

以下哪一個模型可能可以描述小口黑鱸個體被移除以後對族群的影響？請填入”X” 指出下面的陳述哪一個模型描述正確 (T) 或失敗 (F)。

Q.31.1	The percentage of removal was highest between adult fishes. 成魚之間的去除率最高。

Q.31.2	The decrease in the abundance of the adults leads to higher per capita birth rate. 成魚數量的減少導致個體平均出生率上升。

Q.31.3 The decrease in the abundance of the adults lowered the intraspecific competition, so more yearlings and juveniles could survive.
成體數量的減少降低了種內競爭，因此更多的一歲幼魚和青少個體可以存活。

Q.31.4 The removal program was less effective at removing small fish than large fish.
移除計畫在去除小魚方面不如大型魚類有效。

Q.31.5 The size of breeding adults decreased over time due to this removal program.
由於這種移除計劃，可繁殖成體的尺寸可能隨著時間的推移而減少。

Q32

The population dynamics of parasite species is complex, because the size of the parasite and the host population affect each other. One of the popular models for describing parasite population size is SIR model (Susceptible –Infected –Recovered model). The model is shown in Figure 1 with the description of the symbols below. You can get the changes in the host type numbers by multiplying the original host number with the factor above the arrow. For example, the number of hosts recovered in a given time is $\gamma \cdot I$.

寄生蟲物種的族群動態是複雜的，因為寄生蟲和宿主種群的大小相互影響。常用來描述寄生蟲族群大小的模型之一是 SIR 模型（易感 - 感染 - 恢復模型）。該模型如圖 1 所示，下面是符號說明。藉由原始宿主的數量乘以箭頭上方的係數你可以得到宿主數量的變化。例如，在既定時間內恢復的宿主數量是 γ⊠I 。

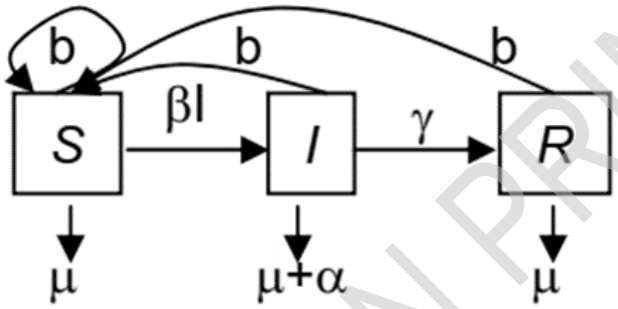


Fig. 1. The SIR model 圖 1 SIR 模型

Symbols:

S = susceptible hosts 易感宿主

I = infected and infectious hosts 感染和傳染性宿主

R = recovered/immune hosts 恢復/免疫宿主

N = total host population = S+I+R 總宿主族群 = S + I + R

b = per capita birth rate 個體均出生率

β = transmission rate (contact rate*infectiousness) 傳播率（接觸率 * 傳染性）

μ = mortality rate without disease 沒有疾病時的死亡率

α = mortality rate due to disease 由於疾病導致的死亡率

γ = host recovery rate from infection

受感染宿主的恢復率

Indicate with an **X** if each the following statements are true (T) or false (F).

指出以下敘述何者為正確 (T) 或錯誤 (F)，用 X 表示。

Q.32.1	The mortality rate of the infected hosts is higher than the others’. 受感染宿主的死亡率高於其他個體。

Q.32.2	The average number of offspring of surviving individuals is higher for non-infected hosts than for infected ones. 非感染宿主的存活個體的後代平均數量高於感染者。

Q.32.3 The parasite can be transmitted both vertically (from parent to offspring before birth) and horizontally (infection after the birth of organism).
寄生蟲可以垂直 (從父母到子代) 和水平 (在不是父母 - 子女關係的個體之間) 傳播。

Q.32.4 The individuals who recovered from the disease will be immune to it for the rest of their life.
從此疾病中恢復過來的個體將在其餘生中對它免疫。

Q.32.5 The number of new infections in a given time depends only on the number of susceptible hosts and is not affected by the number of infected and recovered hosts.
在既定時間內新感染的數量僅取決於易感宿主的數量，其不受已感染和恢復宿主數量的影響。

Q.32.6 Give the relationship between the ratio of infected (I) and the sum of susceptible (S) infected (I) individuals and the number of new infections in a given time! Draw the curve of the equation in the coordinate system in your answer sheet (Figure 2). The transmission rate (β) is constant.
給出感染（I）與易感（S）感染（I）個體的總和的比例與既定時間內新感染個體數量間的關係！在答案紙的坐標系中繪製變化曲線（圖 2）。假設疾病傳輸速率 (β) 不變。

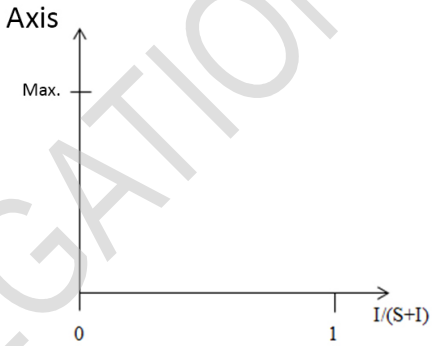


Fig. 2. The number of new infection in a given time in as the function of the ratio of infected hosts (I) to the sum of susceptible and infected hosts (S+I). Max. = the maximal value of the new infections. Axis = Number of new infections.

圖 2. 既定時間內新感染的數量與感染宿主（I）與易感宿主和感染宿主總和（S + I）之比的函數關係。Max. (最大) = 新感染的最大值。Axis (軸) = 新感染的數量。

Many parasites cause diseases with high mortality rate (α) in spite of the death of the host being evidently disadvantageous for the parasite.

許多寄生蟲導致高死亡率 (α) 的疾病儘管寄主死亡顯然對寄生蟲不利。

Indicate with an **X** if each the following statements are true (T) or false (F).

指出以下敘述何者為正確 (T) 或錯誤 (F)，用 X 表示。

Q.32.7 Higher transmission rate (β) is advantageous for the parasite, but usually high infectiousness means the parasite causes more harm to the host.
較高傳輸速率 (β) 對寄生蟲有利，但通常高傳染性意味著寄生蟲對宿主造成更多傷害。

Q.32.8 The bigger the mortality rate due to the disease, the bigger the ratio of the susceptible hosts in the population, which the parasites can infect, so the parasites spread easier.
由於疾病導致的死亡率越大，寄生蟲可以感染的群體中易感宿主的比例越大，因此它們更容易傳播。

Q.32.9 There may be a long incubation period after the infection, in which case the parasite has enough time to spread before the host die.
感染後可能存在很長的潛伏期，在這種情況下寄生蟲有足夠的時間在宿主死亡前傳播。

Q.32.10 The big mortality rate (α) doesn’ t mean problem for the parasite, if the transmission rate (β) is low.
高死亡率 (α) 並不意味著寄生蟲的問題，如果傳播率 (β) 低。

Q.32.11 If the weakening of the host body results in a lower host recovery rate (γ), that will cause a higher mortality rate for the whole population.
對於這種疾病如果宿主體弱化導致宿主恢復率降低 (γ)，可能導致更高的死亡率 (β)。

Q33

The scheme below shows the model of interactions between the populations of an ecosystem. The capital letters indicate the populations. The two-ended arrows (⟷) indicate whether there are any direct interactions between the two populations. The interactions can be beneficial (+), harmful (-) or neutral (0) for each of the populations, which is indicated at the ends of the arrows.

下面的方案顯示了生態系統種群之間的相互作用模型。大寫字母表示族群。雙頭箭 (⟷) 表明兩個族群間是否存在任何直接的相互作用。對於每個群體，相互作用可以是有益的（+），有害的（-）或中性的（0），其在箭頭的末端指示。

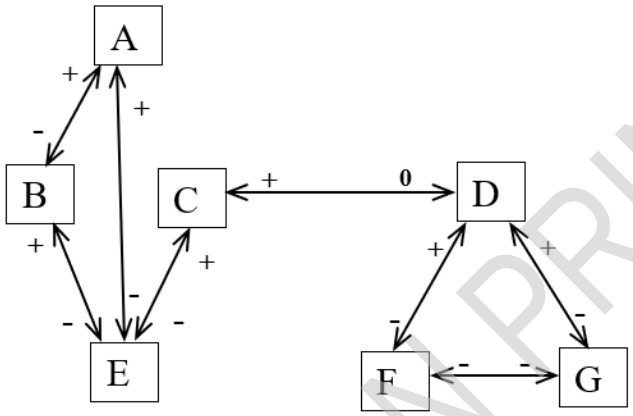


Fig.1 圖 1

Determine, how the change of the size of one population affects (both directly and indirectly) the size of other populations in the ecosystem.

確定一個族群的大小變化（直接和間接）如何影響生態系統中其他族群的大小。

Indicate your answer by putting an **X** in the appropriate box on the answer sheet.

在答題紙上的相應框中置入 X 來表明你的答案。

A: Increase

增加

B: Not change

沒有變化

C: Decrease

減少

D: Cannot be predicted (i.e. the change has both increasing and decreasing effect on the other population)

無法預測（即變化對其他族群有增加和減少的影響）

What will be the effect of the decrease in the size of population A on the other populations listed below?

族群 A 數量減少對下列其他族群的影響為何？

Q.33.1 Population B
族群 B

Q.33.2 Population D
族群 D

Q.33.3 Population E
族群 E

What will be the effect of the increase in the size of population D on the other populations listed below?

族群 D 規模增加對下列其他族群的影響是什麼？

Q.33.4 Population G
族群 G

Q.33.5 Population C
族群 C

Q.33.6 Population A
族群 A

Biosystematics 生物系統分類學

Q34

In this task you get a few parts of a phylogenetic tree of birds and you should assemble the full tree based on them.

在這個試題中你會看到有關鳥類親緣關係研究的幾個樹，你需要試圖把它們整合成一個完整的樹。

The trees given: 以下就是你現有的樹。

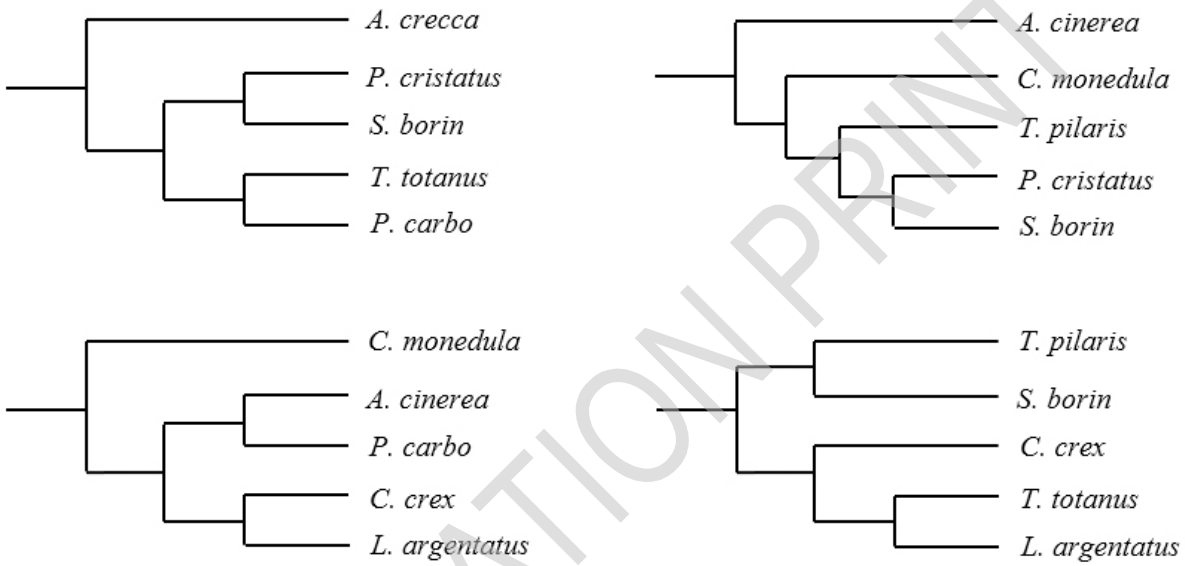


Fig.1

The species you should place in the full phylogenetic tree are indicated with letters:

你應該使用這些字母來代表你最後擺在完整親緣關係樹中的鳥種。

A –A. cinerea

B –A. crecca

C –C. crex

D –C. monedula

E –L. argentatus

F –P. carbo

G –P. cristatus

H –S. borin

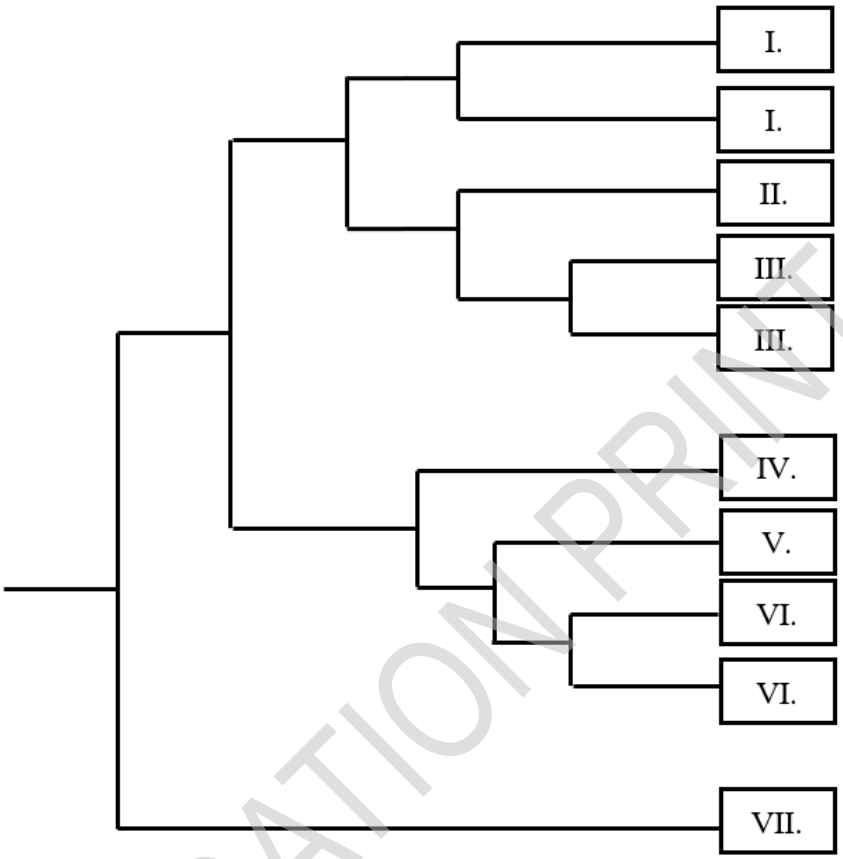
I –T. pilaris

J –T. totanus

You should find the place of the species in the tree below. Match the letter of the species (A-J) with the roman numerals (I.-VII.) of the places in the tree. One numeral can belong to more letters.

在這個被整合過的樹上，分類群以羅馬數字代表，請你把”A 到 J” 與 I” 到 VII” 進行配對。請注意一個羅馬數字可以與一個以上物種配對。

Indicate your answer by putting an X in the appropriate box on the answer sheet.
請你在答案卷中的空格中寫入 X 來回答問題。



Q35

A research group collected and examined gall wasp (Cynipidae) specimens. By examining their morphological traits they found a new genus (Lithosaphonecrus) with four species (L. formosanus, L. huisuni, L. dakengi and L. yunnani). To confirm these results, and determine their phylogenetic relationship to other closely related gall wasp species, they compared the sequence of two DNA fragment (COI and 28S D2) of each species. They calculated the pairwise distance (p-distance) between each species (Table 1.). The p-distance of two species is the number of nucleotide sites at which homologous sequences of the two species are different, divided by the total number of nucleotides compared.

有一個研究團隊採集並鑑定了癭蜂科 (Cynipidae) 的標本。在檢查了特徵後他們發表了一個新屬 (Lithosaphonecrus)，內含四個新種 (L. formosanus、L. huisuni、L. dakingi 與 L. yunani) 。為了確認這個結論並檢定牠們與其他進源癭蜂的親緣關係，研究團隊比較了每一個相關物種的 COI 與 28S D2 基因序列。他們計算了樹上的每一個物種之間的配對距離 (pairwise distance) (p-distance) (Table 1)。所謂的 p-distance 就是兩個被比較物種的核酸序列差異量，被除以所有被拿來比較的核酸序列數量。

	L. yunnani	*L. dakengi*	*L. formosanus*	*Sapho. shirakashii*	*Sapho. undulates*	*Sapho. gallaepo-miformis*	*Sapho. conatus*	*Ufo nipponicus*
COI								
L. huisuni	0.0770	0.1478	0.1289	0.1619	0.1588	0.1525	0.1619	0.1525
L. yunnani	0	0.1305	0.1085	0.1745	0.1572	0.1447	0.1541	0.1399
L. dakengi		0	0.1242	0.1950	0.1792	0.1855	0.1824	0.1777
L. formosanus			0	0.1792	0.1557	0.1588	0.1682	0.1557
28S D2								
L. huisuni	0.0041	0.0081	0.0183	0.0568	0.0487	0.0507	0.0507	0.0487
L. yunnani	0	0.0122	0.0223	0.0568	0.0527	0.0507	0.0507	0.0487
L. dakengi		0	0.0142	0.0629	0.0548	0.0527	0.0527	0.0548
L. formosanus			0	0.0669	0.0588	0.0568	0.0568	0.0588

Table 1. p-distances among the two sequence (COI and 28S D2) of the species.

表 1、被納入分析物種兩兩之間在 COI 與 28S D2 序列上的 p-distances。

Indicate with an **X** if each the following statements are true (T) or false (F).

請以”X” 回應以下陳述何者為正確 (T) 何者為錯誤 (F)。

Q.35.1 The L. huisuni and the L. yunnani are the two most closely related species in the genus. L. huisuni 和 L. yunnani 在這個屬中是最近緣的物種。

Q.35.2 Phylogenetically Ufo nipponicus is more closely related to the L. yunnani than to the L. dakengi.
Ufo nipponicus 與 L. yunnani 的關係比與 L. dakingi 接近。

Q.35.3 The differences between the results obtained for the two sequences (COI and 28S D2) means an error has occurred during the sequencing of the DNAs.
對於兩個序列 (COI 和 28S D2) 所獲得的結果之間的差異意謂 DNA 定序過程中的錯誤。

Q.35.4 The COI region is more useful in research of phylogenetic relationship between more distantly related species, than 28S D2.
比起 28S D2 來說，COI 這個片段比較適合拿來研究親緣關係較遠的生物。

Q36

One of the main purposes of phylogenetics is to construct trees which represent the evolutionary relationship of the taxa. A major challenge is to combine the results from independent researchers in this field.

親緣關係研究的主要目的之一就是重建一個可以代表物種之間演化歷史的樹。然而將獨立研究所產生的樹合併是這個研究領域的挑戰。

You can see two phylogenetic trees of legume genera below from two independent research groups (Fig 1. and 2.).

你可以在如下兩圖看到兩個獨立團隊所產出的豆類各屬間親緣關係樹。

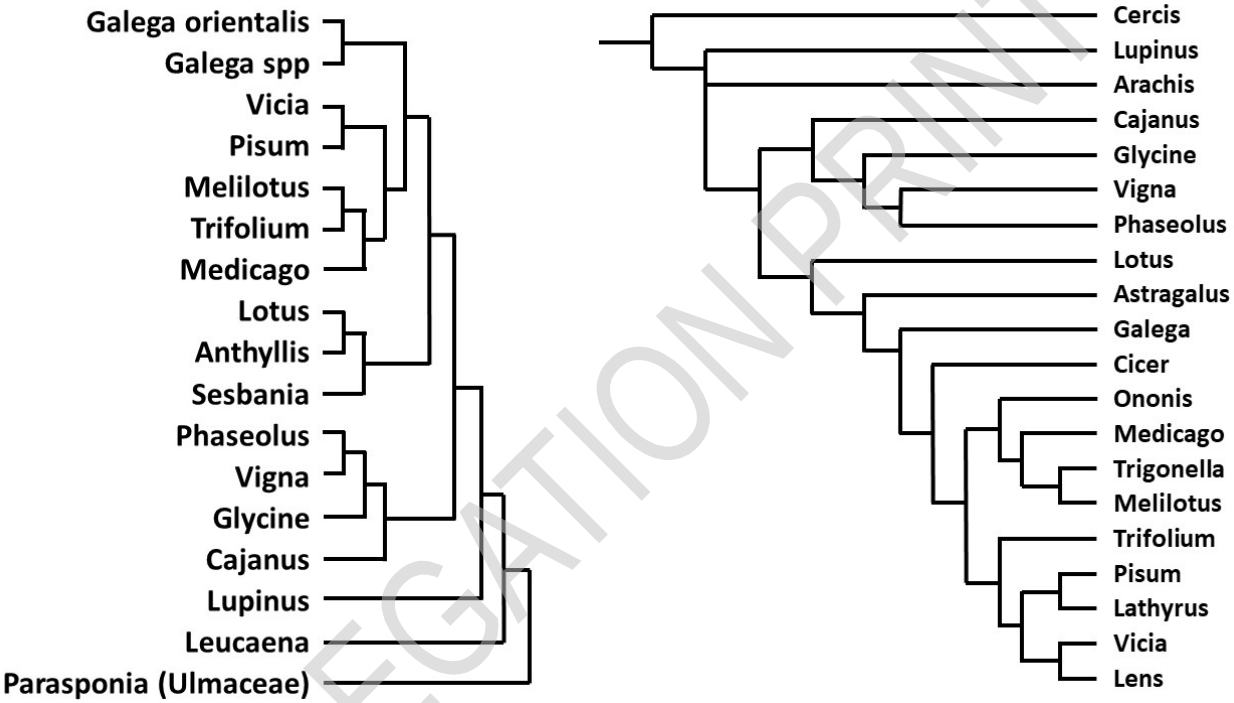


Fig 1. & Fig.2. Phylogenetic trees of legume genera.

兩個獨立研究產出的豆類屬間演化樹

Q.36.1 Is there any genus with conflicting results from the phylogenetic trees above?
有沒有哪個屬的親緣位置在這兩樹間有衝突？
Indicate the correct answer (A-E) with an **X** in your answer sheet.
請用 X 在答案卷上回答 A 到 E 的問題指出何者正確。
A. No, there isn’ t.
沒有
B. Yes, the genus Galega.
有，是 Galega。
C. Yes, the genus Lotus.
有，是 Lotus。
D. Yes, the genus Trifolium.
有，是 Trifolium。
E. Yes, the genus Vigna.
有，是 Vigna。

Q.36.2 This is the combined tree from the two trees above. Some missing genera are indicated with letters (A, B, etc.). Your task is to find which genus belongs to which letter. Indicate the appropriate genus with an X in your answer sheet. It's possible that a letter can symbolize more than one genus. If a genus doesn't occur in the tree, you should indicate that by putting an **X** in column Q.
這個演化樹就是從上面兩個樹整合而來。有些消失的屬以 A、B 等記號標示。你的任務就是找出哪一個以上提到的屬應該與哪一個字母配對。請在答案卷上使用"X"來指出正確的屬。一個字母有可能代表一個以上的屬。如果該屬並沒有出現在樹上，請你把 X 填在 Q 欄位中。

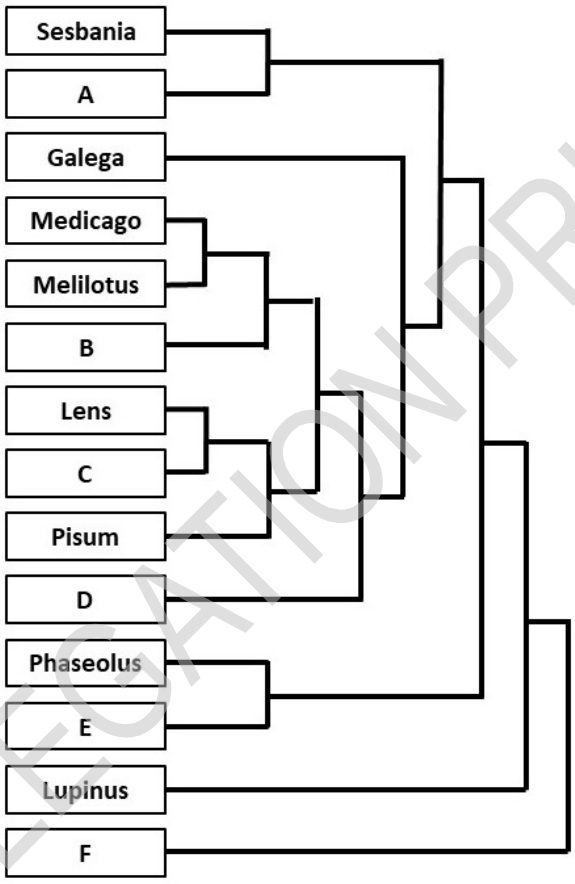


Fig.3 圖 3

Ethology 行為生態學

Q37

Twenty-eight rare and protected species of bat live in Hungary. Bats sense their environments using echolocation, which is disrupted by different surfaces. A smooth metal plate was attached to the wall as shown in Figure 1. The bats were recorded attempting to drink from, or colliding with, the floor, walls or the plate on the wall.

二十八種稀有和受保護的蝙蝠生活在匈牙利。蝙蝠使用迴聲定位來感知牠們的環境，迴聲定位會被不同物體的表面破壞。如圖 1 所示，將光滑的金屬板黏貼到牆壁上。而那些蝙蝠當時正從地板、牆壁或牆壁上的金屬板上試圖飲水或碰撞。

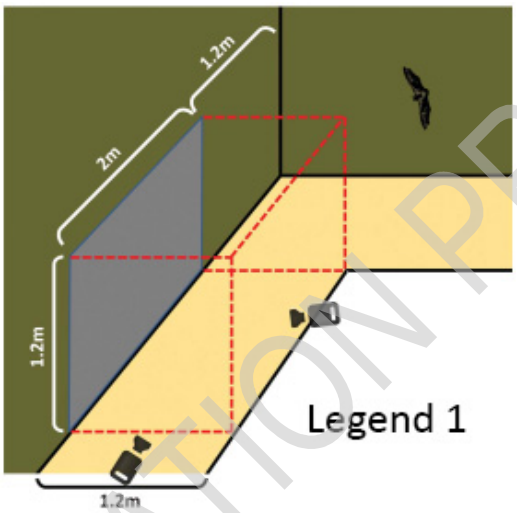


Fig.1. Legend 1 = High-speed cameras

圖 1。圖例 1 = 高速攝像機

In a second a experiment, the metal plate was instead placed on the floor, and the bats were recorded attempting to drink from, or colliding with the wall, floor or the plate on the floor.

在第二個實驗中，金屬板被放置在地板上，而蝙蝠被記錄從牆壁，地板或地板上的金屬板試圖飲水或碰撞。

The reaction of bats to different surfaces shown in Fig. 2.

蝙蝠對不同表面的反應如圖 2 所示。

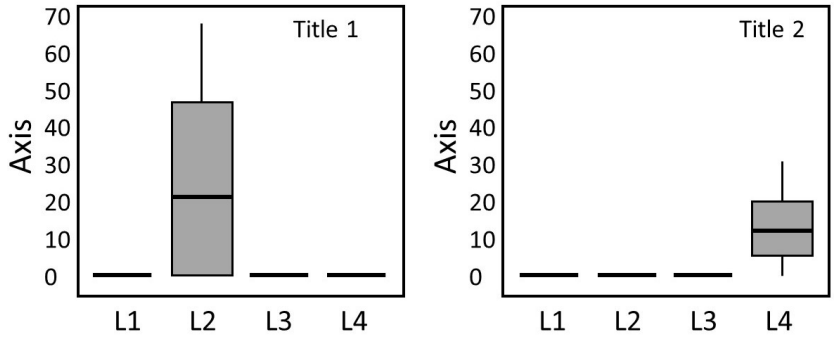


Fig. 2. Percentage of drinking attempts and collision events in box plots. Values were calculated per individual relative to its total number of passes through the corridor. Title 1 = Horizontally placed metal plate. Title 2 = Vertically placed metal plate. Axis = Percentage of occurrence. L1 = drink from ground. L2 = drink from plate. L3 = collision with wall. L4 = collision with plate

圖 2. 此圖呈現了嘗試飲水和碰撞事件的百分比。每隻個體值的計算為其相對於通過走道的總次數。標題 1 = 水平。標題 2 = 垂直。軸 = 發生的百分比。L1 = 從地面喝水。L2 = 從板喝水。L3 = 與牆壁碰撞。L4 = 與板碰撞

Why do bats react differently to smooth surfaces than to others? indicate with an X if each of the following statements is true (T) or false (F).

為什麼蝙蝠對光滑表面的反應不同於其他？指出以下敘述何者為正確 (T) 或錯誤 (F)，用 X 表示。

Q.37.1 The smooth metal plate/surface absorb more sound than the rough ones.
光滑的金屬板/表面比粗糙的金屬板吸收更多的聲音。

Q.37.2 The smooth metal plate/surface only reflect sound back to the bat if the sound reaches the surface perpendicularly.
光滑的金屬板/表面僅將垂直到達表面的聲音反射回至個體。

Q.37.3 The vertical smooth metal plate/surface reflects sound in a way that attracts the bats.
垂直光滑的金屬板/表面反射聲音的方式會吸引蝙蝠。

Q.37.4 The bat can only detect a small part of a smooth surface.
蝙蝠只能偵測到光滑表面的一小部分。

Why do bats react differently to vertical and horizontal smooth surfaces? Indicate with an X if each of the following statements is true (T) or false (F).

為何蝙蝠對垂直和水平光滑表面的反應不同？指出以下敘述何者為正確 (T) 或錯誤 (F)，用 X 表示。

Q.37.5 The sound reflected from a horizontal versus vertical smooth surface is different.
從水平與垂直光滑表面反射的聲音是不同的。

Q.37.6 The bats' reaction is different because in nature bats usually only meet with horizontal smooth surfaces.
蝙蝠的反應是不同的，因為在自然界中蝙蝠通常只與水平光滑的表面相遇。

Q.37.7 Bats use their sense of gravity to help them recognise water.
蝙蝠利用牠們對引力的感應來幫助牠們識別水。

Q.37.8 The bats collided with vertical smooth surfaces because they sensed it as open space.
蝙蝠與垂直光滑的表面相撞，因為它們將它感知為開放空間。

Q38

The following experiment was used to determine whether Pharaoh ants (Monomorium pharoaonis) use attractive or repulsive chemical signals to sign their foraging routes. The researchers used two ant colonies in the experiment (Fig.1).

以下實驗用於確定法老蟻（Monomorium pharoaonis）是否使用有吸引或令動物避忌的化學物質來標示其覓食途徑。研究人員在實驗中使用了兩個蟻群（圖 1）。

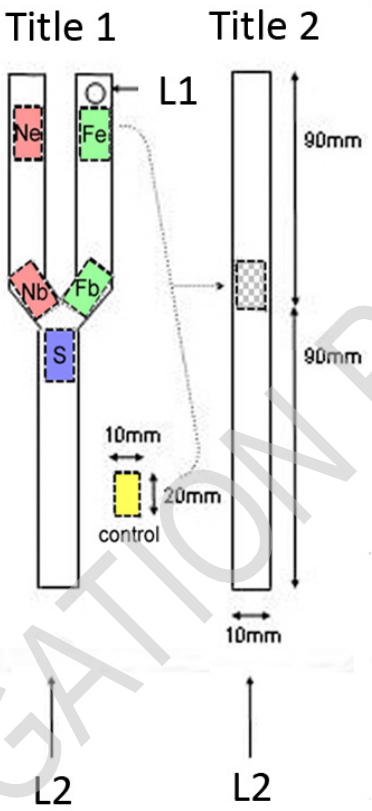


Fig.1. Experimental setup. Title 1 = Trail sections. Title 2 = Test position of section. L1 = feeder. L2 = From nest

圖 1。實驗裝置。Title 1 = 行進路徑段落。Title 2 = 測試段落。L1 = 餵食站。L2 = 出自巢穴

The first colony was used as trail-laying colony in a paper Y-bifurcation apparatus (left side), where they were able to leave pheromon trails. The researchers put a feeder with sucrose in the end of one branch (feeder branch) and left the other branch’s end empty (non-feeder branch). After foraging, they removed five sections (S, F_b, N_b, F_e, N_e) and a control from the apparatus and put them alternately in different unbranched apparatuses (right side). The following sections were used:

第一個蟻群在一紙製的 Y 型管中活動以產生氣味路徑（左側）。研究人員在其中一個分叉（餵食分支）的末端放置了一個裝有蔗糖的餵飼器，將另一個分叉的末端留空（非餵食分支）。覓食後，他們從設備中取出五個段落的路徑（它們也使用了一個控制組段落）並將它們放入不同的不分叉設施（右側），並使用以下部分：

- S: 1 mm before bifurcation S：分叉前 1 mm
- F_b: 3 mm after bifurcation in the feeder branch Fb：在飼養分支中分叉後 3 mm
- N_b: 3 mm after bifurcation in the non-feeder branch Nb：在非飼養分支中分叉後 3 mm
- F_e: 60 mm after bifurcation in the feeder branch Fe：在飼養分支中分叉後 60 mm

- N_e: 60 mm after bifurcation in the non-feeder branch Ne：在非飼養分支中分叉後 60 mm
- Control: no ant trail pheromones used 控制組：使用沒有螞蟻費洛蒙的段落

The researchers tested sections with 50 ants from another colony. They checked, how many times the ant made U-turns in each case. The number of U-turns compared to the control is shown in Fig.2.

研究人員用另一巢的 50 隻螞蟻來測試其對各段落的反應。他們檢查螞蟻在不同段落內 U 形轉彎次數。並與對照相段落比較如圖 2 所示。

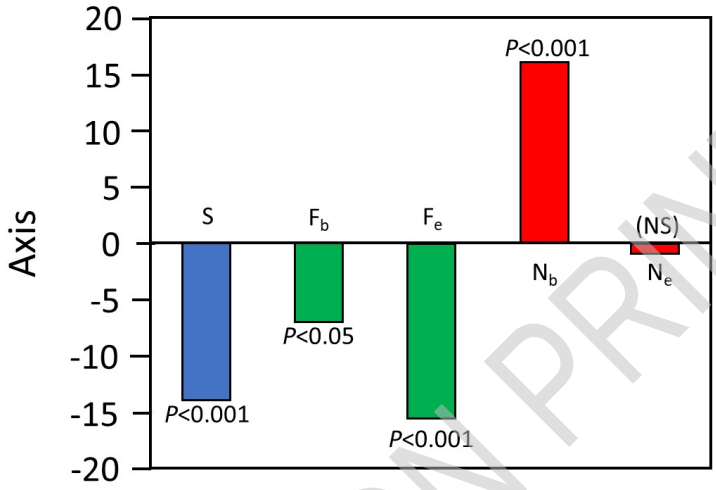


Fig.2. The result of the experiment. The number of U-turns compared to control. P<0.001 and P<0.05 indicates the significance level of the difference compared to control. (The lower the value, the stronger the significance.) NS means no significant difference compared to control. Axis = Number U-turns ants made relative to control

圖 2。實驗結果。與對照相比，U 形轉彎的數量。P <0.001 及 P <0.05 表示與對照相比差異的顯著性。(值越低，顯著性越強)。NS 表示與對照相比沒有顯著差異。軸 = 相對於對照組螞蟻的 U 形轉彎數

Q.38.1 Based on the **significant** results of the experiment, determine which type of pheromone the ants used in each of the five sections. Indicate your answer by putting an **X** in the appropriate box on the answer sheet.
根據實驗的重要結果，確定螞蟻在五個段落中的每一個其所使用費洛蒙的類型。在答案卷上的相應框中置入 X 來表示你的答案。

- A –attractant pheromone 引誘費洛蒙
- R –repellent pheromone 忌避費洛蒙
- Q –no trail pheromone used 沒有使用費洛蒙

30th International Biology Olympiad
SZEGED, HUNGARY

Theoretical Exam 理論考試

Afternoon 下午

18th July 2019

COUNTRY 國家
LANGUAGE 語言

Theoretical Exam Afternoon 下午理論考試

General Instructions 一般說明

This exam consists of 38 questions and lasts 180 minutes.

- Cell Biology (Q1-7)
- Animal Anatomy and Physiology (Q8-16)
- Plant Anatomy and Physiology (Q17-22)
- Genetics and Evolution (Q23-30)
- Ecology (Q31-34)
- Biosystematics (Q35-36)
- Ethology (Q37-38)

該考試包含 38 個問題，持續 180 分鐘。

- 細胞生物學（Q1-7）
- 動物解剖學和生理學（Q8-16）
- 植物解剖學和生理學（Q17-22）
- 遺傳學與演化學（Q23-30）
- 生態學（Q31-34）
- 生物系統分類學（Q35-36）
- 動物行為學（Q37-38）

1. **Please remember to attach your BARCODE sticker to all pieces of paper on the answer sheet.**
2. Write your answers in the separate answer sheet provided. **Only answers given in the answer sheet will be considered**.
3. Stop answering and put down your pencil immediately when the bell rings signalling the end of the exam.
4. No paper, materials or equipment should be taken out of the exam room.

1. 請記得把你的條碼貼紙貼在答案紙的每一頁上。
2. 把答案分別寫在所提供的答案紙上。只有寫在答案紙上的答案才會評分。
3. 當鈴聲響起，表示考試結束時，請立即停止作答並放下鉛筆。
4. 不可將任何紙張、材料或設備帶出考場。

1.	2.				3.
	U	C	A	G	
U	F F L L	S S S S	Y Y STOP STOP	C C STOP W	U C A G
C	L L L L	P P P P	H H Q Q	R R R R	U C A G
A	I I I M	T T T T	N N K K	S S R R	U C A G
G	V V V V	A A A A	D D E E	G G G G	U C A G

Cell Biology 細胞生物學

Q1

The nematode C. elegans develops as either a male having only one sex chromosome (XO) or a hermaphrodite with two sex chromosomes (XX). When maintained in groups containing both sexes, hermaphrodites live significantly longer than males. Two signalling pathways, the IGF-1 signalling and the sex determination pathways play pivotal roles in the control of C. elegans ageing.

秀麗隱桿線蟲 (C. elegans) 可發育成僅具有一個性染色體（XO）的雄性，或具有兩個性染色體（XX）的雌雄同體。當族群中兩種性別個體皆有時，則雌雄同體個體的壽命顯著長於雄性。兩種信號路徑，也就是 IGF-1 信號傳導和性別決定路徑，在控制秀麗隱桿線蟲衰老上扮演關鍵角色。

DAF-2 and DAF-16 are elements of the IGF-1 signalling pathway. Loss-of-function mutations in their genes were introduced, and the lifespan of generated transgenic animals of the two sexes were measured (Figure 1) DAF-2 和 DAF-16 是 IGF-1 信號傳導途徑的成員。利用”功能喪失法 (Loss of function)”將基因突變，並分析此種基因轉殖動物體中兩種性別之壽命（圖 1）

In all graphs, NS = not significant difference; *** = significant difference.

在所有圖中，NS = 無顯著差異; *** = 顯著差異。

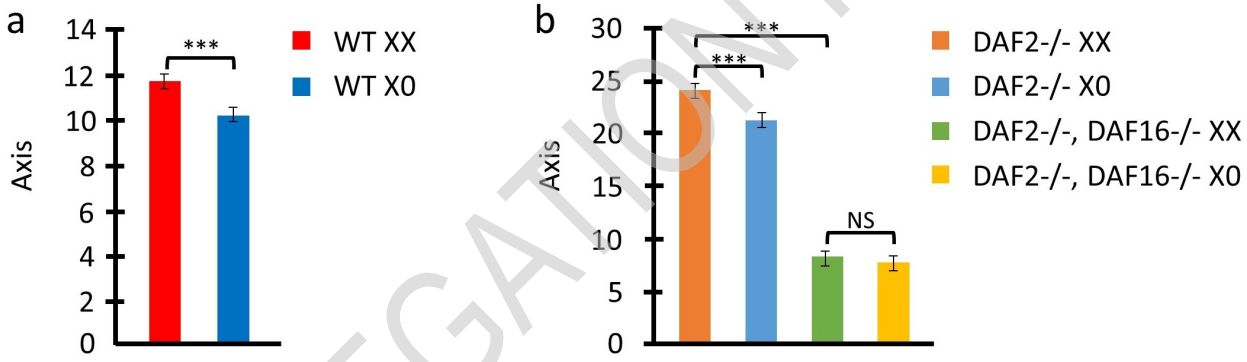


Fig.1. Axis = Mean lifespan (days). WT = Wild-type.

圖 1。軸 = 平均壽命（天）。WT = 野生型。

To test whether the nematode sex-determination cascade is involved in the sex-specific regulation of aging, researchers modified the activity of two elements of this pathway, TRA-1 and TRA-3. The mutations of transgenic hermaphrodites were as follows in Figure 2.

為了測試線蟲性別決定徑路參與性別特異性老化調控，研究人員修改該路徑的兩個要素 TRA-1 和 TRA-3 的活性加以修改。突變後的轉基因雌雄同體基因轉殖動物如圖 2 所示。

- MUT1 - TRA-1-/-
- 突變體 1: 不具 TRA
- MUT2 - TRA-1 low activity, with some function
- 突變體 2: TRA 活性低，僅具一些功能
- MUT3 - TRA-1 hyperactive function
- 突變體 3:TRA-1 功能過度活化
- MUT4 - TRA-3 loss of function
- 突變體 4: TRA-3 功能喪失

- MUT5 - TRA-1 hyperactive function AND TRA-3 loss of function
- 突變體 5: TRA-1 功能過度活化且 TRA-3 功能喪失

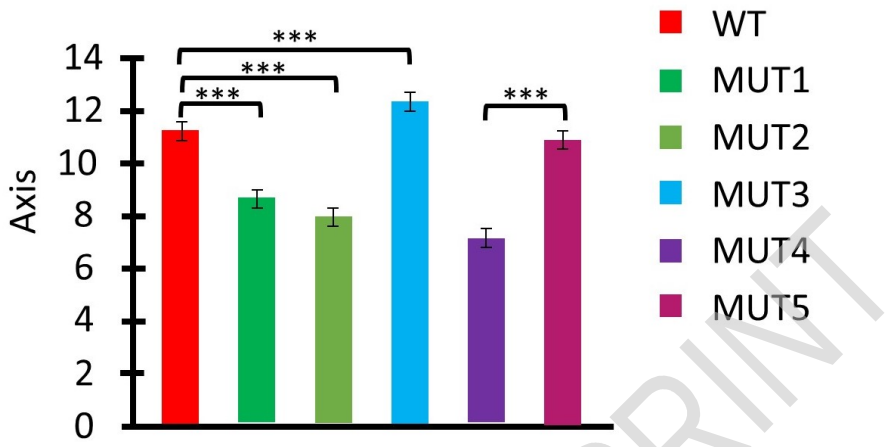


Fig.2. Axis = Mean lifespan (days). WT = Wild-type.

圖 2。軸 = 平均壽命（天）。WT = 野生型。

TRA-1 was identified as a transcription factor. The expression of DAF-16 was measured in various TRA-1 mutants to assess the functionality of a potential TRA-1-binding site in the DAF-16 gene (Figure 3).

TRA-1 被確定為轉錄因子。為了評估在 TRA-1 可能在 DAF-16 基因上的鍵結位置，本實驗所以會量測各種 TRA-1 突變體中 DAF-16 的表現量（圖 3）。

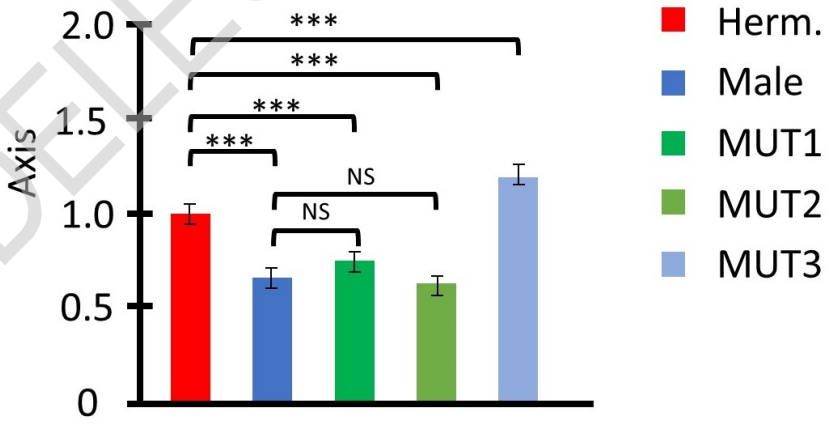


Fig.3. Axis = Relative DAF-16 expression level.

如圖 3 所示。軸 = 相對 DAF-16 表達量。

Q.1.1 Based on the information above, create a model of protein interactions that affect lifespan (LS). Use the options below (A-D) to fill in the boxes in the flowchart and indicate in the circles by the arrows whether the interaction is stimulatory (put **+**) or inhibitory (put **-**).
依據上述資訊，本實驗將建立創建影響壽命（LS）的蛋白質交互作用模型。使用下面的（A-D）選項填寫流程圖中的方框，並在箭頭旁的圓圈中用 (+) 表示其相互作用是促進性的，或用 (-) 表示交互作用是抑制性的。
Options: 選項
A. TRA-1
B. TRA-3
C. DAF-2
D. DAF-16

Q2

The ATP content of an average muscle fibre at rest is very low. Under short, high energy demand exercise (e.g. a 100 m sprint), the initially very low ATP levels in the muscle fibres are buffered by phosphocreatine (PCr, Figure 1).

靜止時肌纖維的 ATP 含量非常低。在短時間的高能量需求運動（例如 100 米衝刺）下，肌纖維中最初非常低的 ATP 量可用磷酸肌酸（PCr，圖 1）加以補充，以因應緊急需求。

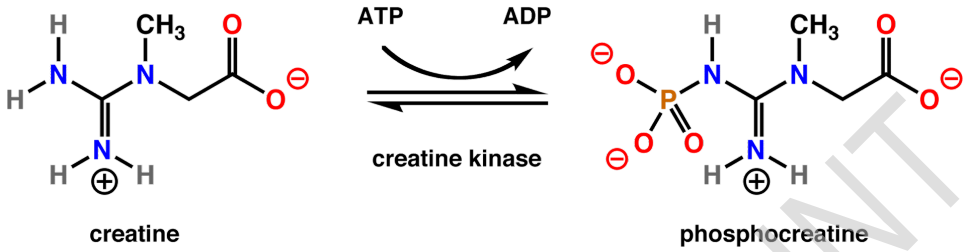


Fig.1 圖 1

We can measure levels of phosphocreatine and ATP in a working tissue using 31P NMR spectroscopy, through the height of the corresponding NMR peak. Figure 2 shows the NMR-spectroscopy results of muscle intracellular fluid from a subject who had done 2 minutes of vigorous exercise. A: before exercise, B: first minute of exercise, C: last minute of exercise, D: after exercise; I, II and III are peaks that represent the three phosphate groups in ATP molecules, IV: PCr, V: Pi, VI: phospho-monoesters.

我們可以使用 31P NMR 光譜，透過相應的 NMR 波峰的高度，測量正在運動的組織中的磷酸肌酸和 ATP 的含量。圖 2 顯示分析一個進行 2 分鐘劇烈運動受試者的肌肉細胞內液的 NMR 光譜結果。A：運動前，B：運動的第一分鐘，C：運動的最後一分鐘，D：運動後; I，II 和 III 代表 ATP 分子中三個磷酸根造成的峰，IV：磷酸肌酸 (PCr)，V：磷酸根 (Pi)，VI：磷酸單酯。

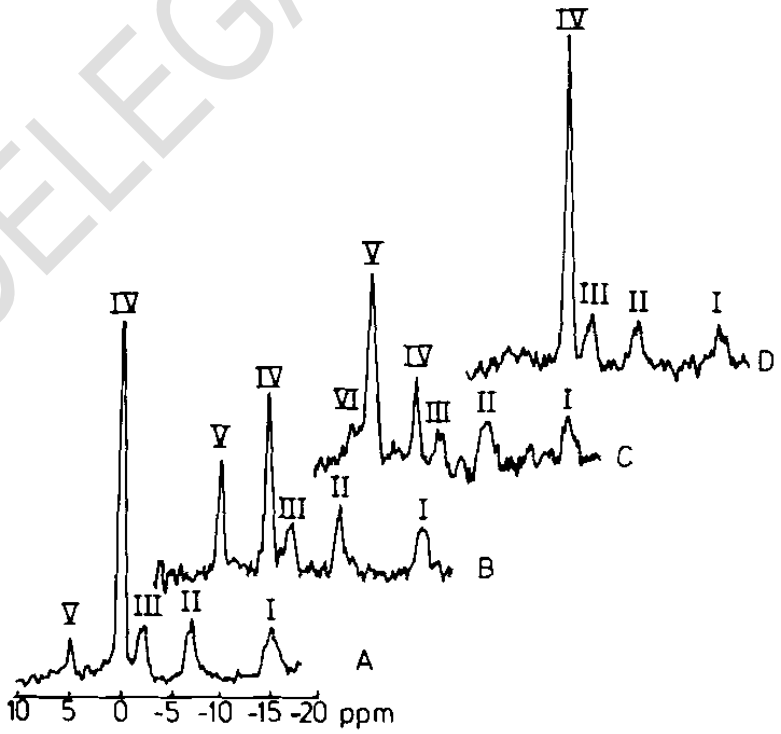


Fig. 2 圖 2

Immediately when the actin-myosin interaction starts producing ADP, the activity of the enzyme adenylate kinase, which catalyses the near-equilibrium reaction 2 ADP $\leftrightarrow$ ATP + AMP becomes significant. Besides the generation of the negligible amount of available ATP, the reaction is essential because both ADP and AMP can allosterically upregulate glycolytic enzymes –and therefore prepare the muscle for longer exercise.

當肌動蛋白-肌球蛋白相互作用開始產生 ADP 時，腺苷酸激酶立即被激活，其所催化的近平衡反應 2 ADP⇌ ATP + AMP 至為重要。除了產生微量的可用 ATP 外，這個反應也是必需的，因為 ADP 和 AMP 兩者都可以易構性的調升糖解酶 的活性，使肌肉能進行更長時間運動。

Based on the information above, indicate with an X if each of the following statements is true (T) or false (F).

根據上述信息，請以 X 註明下列敘述為正確（T）或錯誤（F）。

Q.2.1 Hydrolysis of the high energy bond of PCr can be used directly as energy source of enzymes.
PCr 的高能鍵的水解可直接用作酶的能量來源。

Q.2.2 The relatively constant ATP concentrations shown on the NMR results are due to the buffering effect of PCr.
NMR 結果顯示的相對恆定的 ATP 濃度是源於 PCr 的緩衝作用。

Q.2.3 The phosphocreatine system is the main energy source in marathon runners.
磷酸肌酸系統是馬拉松運動員的主要能量來源。

Q.2.4 AMP and ADP levels are similarly sensitive indicators of energy status (as shown by ATP concentration).
AMP 和 ADP 含量可同樣的當作能量狀態的敏感指標（如 ATP 濃度所示）。

Q3

Abscisic acid (ABA)-and salicylic acid (SA) are involved in stomatal closure. It’s known that the Ca2+-independent protein kinase OST1 and Ca2+-dependent protein kinases (CPK3 and CPK6) are key for abscisic acid induced activation of an anion channel SLAC1 and stomatal closure. SLAC1 has two phosphorylation sites: S59 and S120 are both serines. Coexpression of the CPKs or OST1 together with SLAC1 genes in an observed cell leads to the following result:

離層酸（ABA）和水楊酸（SA）參與氣孔關閉。已知 Ca2 + 非依賴性蛋白激酶 OST1 和 Ca2 + 依賴性蛋白激酶（CPK3 和 CPK6）是離層酸誘導的陰離子通道 SLAC1 活化和氣孔關閉的關鍵。SLAC1 具有兩個磷酸化位點：S59 和 S120 都是絲胺酸。在 CPK 或 OST1 與 SLAC1 基因共表達的細胞中，可觀察到以下結果：

Col 1				Col 2		Col 3
CPK3	CPK6	OST1	SLAC1	S59	S120	An
–	–	–	+	@	@	@
+	–	–	+	@	@	@
–	+	–	+	@	@	@
+	+	–	+	***	@	***
–	–	+	+	@	***	***

Table 1. Col 1 = Expression of . Col 2 = Phosphorylation of . Col 3 = Current. An = Anionic. ‘+’ = expressed; ‘– ‘= not expressed; ‘@’ = does not happen; ‘***’ = happens

表 1. Col 1 = 表現。Col 2 = 磷酸化。第 3 欄 = 電流。An = 陰離子。’+’ = 有表現; ’ -’ = 沒有表現;’@’ = 沒發生;’***’ = 發生

The effect of salicylic acid (SA) on stomata closure of wild type (WT) Arabidopsis thaliana was determined in a standardized way. Salicylic acid was added to a leaf fragments and stomata opening was measured. The stomatal assay was also carried out with some KO-mutant lines. The results are shown below.

以標準方法測定水楊酸（SA）對野生型（WT）阿拉伯芥（Arabidopsis thaliana ）氣孔關閉的影響。將水楊酸加到葉片中，並測量氣孔開度。有些氣孔測定分析在基因剔除突變體葉片上進行。結果如下所示。(*–significant change, ns –non-significant change)

(* - 顯著變化，ns - 非顯著變化)

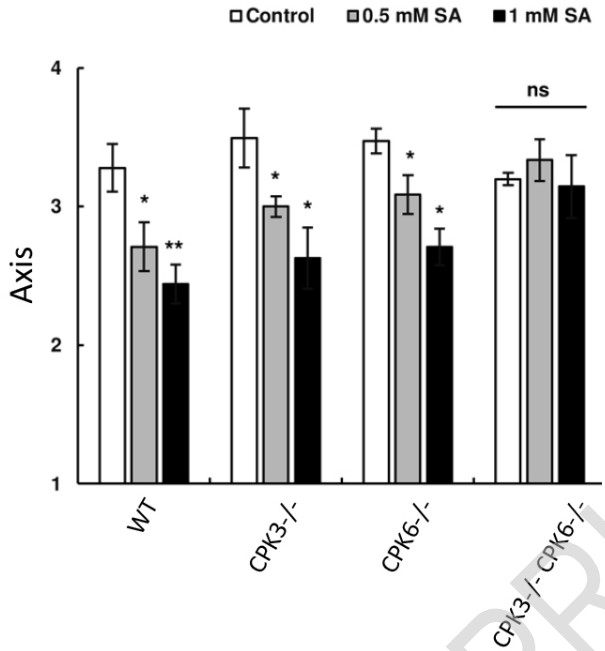


Fig.1. Axis = Stomatal aperture (μm). WT = Wild-type.

圖 1。軸 = 氣孔孔徑（μm）。WT = 野生型。

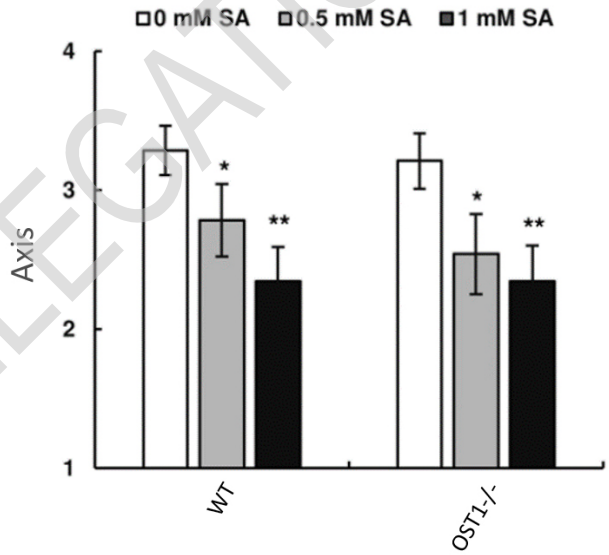


Fig.2. Axis = Stomatal aperture (μm). WT = Wild-type.

圖 2。軸 = 氣孔孔徑（μm）。WT = 野生型。

For the following questions indicate your answer with an **X.**

以下問題以 X 表示您的答案。

A. CPK3

B. CPK6

C. OST1

D. either CPK3 or CPK6

E. either CPK3 or OST1

F. either CPK6 or OST1

G. CPK3 and CPK6

H. CPK3 and OST1

I. CPK6 and OST1

Q.3.1 Which of the kinase(s) (A-I) are required for the phosphorylation of the two sites in SALC1?
哪些激酶（A-I）是 SALC1 中兩個位點磷酸化所必需？

Q.3.2 Which of the kinase(s) (A-I) are required for the phosphorylation of site S120 in SLAC1?
SLAC1 中磷酸化位點 S120 需要哪種激酶 (A-I)？

Q.3.3 Which of the kinase(s) (A-I) is required for salicylic acid dependent stomata closure?
水楊酸依賴性氣孔關閉需要哪種激酶（A-I）？

Q.3.4 Which site or sites need to be phosphorylated to open the SALC1 anion channel?
哪個 (些) 位點需被磷酸化後才能打開 SALC1 陰離子通道？
A. S59
B. S120
C. S59 or S120
D. S59 and S120

Q4

Each year, the WHO forecasts which H and N antigens the dominant flu strain is likely to carry to make vaccines. In 2017, an outbreak of strains H1N1 and H3N2 was forecast for the following year. However, in 2018, H1N2 actually became dominant.

每年，世界衛生組織都會預測哪種 H 和 N 抗原是主要的流感病毒株可用來製備疫苗。2017 年，預測第二年爆發 H1N1 和 H3N2 病毒株。然而，在 2018 年，H1N2 卻成為主流行病毒株。

Three people (1-3) are vaccinated, and their antibodies are used in immunodiffusion assays. Virus and antibodies are loaded into neighbouring wells of an agar plate according to the table below. They diffuse towards each other and precipitate in a visible band if they crosslink.

三個人（1-3）接種了疫苗，他們的抗體用於免疫擴散測定。根據下表所示，將病毒和抗體加到瓊脂平板的相鄰孔中。它們相互擴散，如果它們會交聯結合，則可見到沉澱帶。

Antibody 抗體	Well A 孔 A	Well B 孔 B
1	H1N1	H1N2
2	H1N1	H3N2
3	H1N1	H1N2

The results of the experiment are presented in Figure 1.

實驗結果呈現如圖 1 所示。

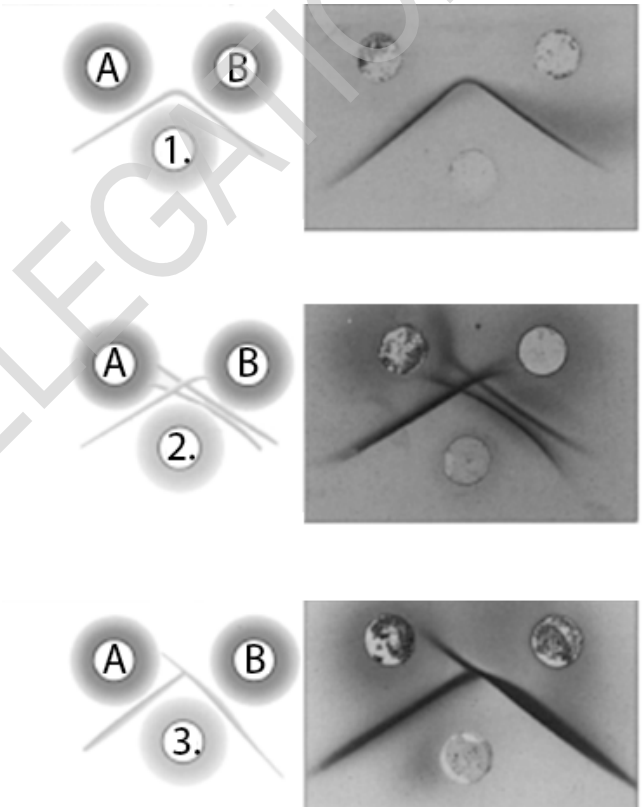


Fig.1 圖 1

Indicate with an X if each the following statements are true (T) or false (F).

用 X 表示下列敘述何者為正確（T）或錯誤（F）。

Q.4.1 The developed vaccine provided protection for antigens predicted by the WHO.

用世界衛生組織預測的抗原來開發疫苗以提供保護

Q.4.2 Antibody 1 and 2 can from the same subject.
抗體 1 和 2 可來自相同的受試者。

Q.4.3 The subject that gave Antibody 2 is protected against the new H1N2 influenza outbreak.
給予抗體 2 的受試者免受新的 H1N2 流感爆發的影響。

Q.4.4 Based on the available information mark antigens the samples (1-3) provide immunity against with an X. Mark all other boxes with O.
基於可用的信息，以 X 標記患者肯定已免疫的抗原。用 O 標記所有其他空格。

Catumaxomab is a new anti-cancer antibody, unlike natural antibodies, binds two different antigens, CD3 and EpCAM.

Catumaxomab 是一種新的抗癌抗體，與天然抗體不同，其可以結合兩種不同的抗原。

Indicate with an X if each the following statements are true (T) or false (F).

以 X 註記下列敘述何者為正確（T) 或錯誤（F）。

Q.4.5 Catumaxomab in an immunodiffusion assay with purified CD3 protein in both antigen wells will give precipitation similar to Antibody 1 in Figure 1.
在兩個抗原孔中，用純化的 CD3 蛋白與 Catumaxomab 進行免疫擴散測定，將產生類似於圖 1 中的抗體 1 的沉澱帶。

Q.4.6 The different specificity chains of Catumaxomab are held together by covalent bonds.
Catumaxomab 上的不同特異性鏈以共價鍵結合在一起。

Q5

In 1963, a series of experiments were performed by John Cairns and peers to test the mechanism of DNA replication. An experimental organism with circular dsDNA chromosomes was grown for several generations in a medium containing radiolabelled $[^3H]$ thymidine. The organism used these bases to replicate their circular dsDNA chromosomes and therefore the subsequently synthesised DNA became radiolabelled. Samples were rapidly frozen during DNA synthesis and then observed so radiolabelled bases appeared as a line of dark beads on a string in a radiographic picture. They found that each circular chromosome contains a single "eye" during replication, resembling the Greek letter θ (theta structures, Figure 1).

1963 年，John Cairns 等人進行了一系列實驗，以測試 DNA 複製的機制。將具有環狀 dsDNA 染色體的實驗生物培養在含有 $[^3H]$ 放射性標記胸腺嘧啶核苷的培養基中生長幾代。生物體會使用這些鹼基來複製它們的環狀 dsDNA 染色體，因此其新合成的 DNA 具有放射性標記。在 DNA 合成期間將樣品快速冷凍，然後觀察放射性標記的鹼基在放射性顯影照片中呈現如暗珠串在細繩上。他們發現每個圓形染色體在複製過程中都包含單一個"眼睛"，類似於希臘字母 θ（theta 結構，圖 1）。

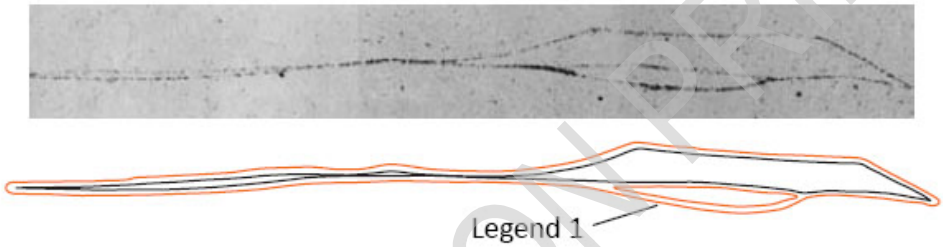


Fig.1. Radiograph and its interpretive drawing of a replicating chromosome. Legend 1 = Replication eye

圖 1 放射顯影影像及複製中染色體的解析圖。圖例 1 = 複製眼睛

In a second experiment, researchers grew the cells in a medium that contained both non-labelled and $[^3H]$ thymidine but the latter was only present at low concentrations. Then, during the replicative period, they increased the concentration of $[^3H]$ thymidine in the medium and immediately isolated samples to freeze and photograph. The results are shown in Figure 2.

在第二個實驗中，研究人員將細胞培養在含有非標記及低濃度 $[^3H]$ 標記的胸腺嘧啶核苷之培養基中。然後，在複製期間，他們增加 $[^3H]$ 標記的胸腺嘧啶核苷在培養基內的濃度，並立刻分離樣品進行冷凍和照相。其結果如圖 2 所示。

Fig.2. Radiograph of the replication forks
圖 2。複製叉的放射性顯影照片

Indicate with an X if each the following statements are true (T) or false (F).

利用 X 指出下列陳述何者為正確 (T) 或錯誤 (F)。

Q.5.1 The experiments show that there is a single replication origin in in one chromosome in this organism. 實驗表明，該生物體的一條染色體上存在一個單一複制起始點。

Q.5.2 The experiments suggest bidirectional replication. 實驗表明雙向複製。

Q.5.3 Which of the following DNA replication models is consistent with the results above? Indicate with an X.
以下哪種 DNA 複製模式與上述結果一致？用 X 表示。
A. Conservative
保守
B. Semi-conservative
半保守
C. Dispersive
分散
D. None of the above
以上皆非

Q.5.4 What can you conclude from the results on the relative abundance of thymidine? Indicate with an X.
你能從胸苷相對豐度的結果中得出什麼結論？用 X 表示。
A. Thymine is more abundant in the replication origin(s), than in other area of the DNA.
胸腺嘧啶在複製起點中比在 DNA 的其他區域中更豐富。
B. Thymine is less abundant in the replication origin(s), than in other area of the DNA.
胸腺嘧啶在複製起點中的含量低於 DNA 的其他區域。
C. Thymine is equally abundant in the replication origin(s) and in other area of the DNA.
胸腺嘧啶在複製起點和 DNA 的其他區域同樣豐富。
D. Relative thymine abundancy in the replication origin(s) cannot be inferred from these results without doubt.
毫無疑問，不能從這些結果推斷出複制起點的相對胸腺嘧啶豐度。

Q6

During DNA replication, RNA primers are synthesised, which are then extended by DNA polymerase. On the lagging strand, DNA polymerase is then released, forming an Okazaki fragment, and the process repeats.

在 DNA 複製期間，先合成 RNA 引子，再由 DNA 聚合酶加以延長。在遲滯股，DNA 聚合酶合成岡崎片段後釋出，並重複該步驟。

The lagging strand was immobilised at one end to a flow cell. The other end is attached to a florescent bead. Liquid is moved across the cell to stretch the DNA and the position of the bead is measured and plotted as ' DNA length change'.

將遲滯股的一端固定在 flow cell 樣品槽上。另一端連著到螢光珠。將液體流經樣品槽以推移延伸 DNA，並測量記錄珠子位置並製圖呈現“DNA 長度變化”。

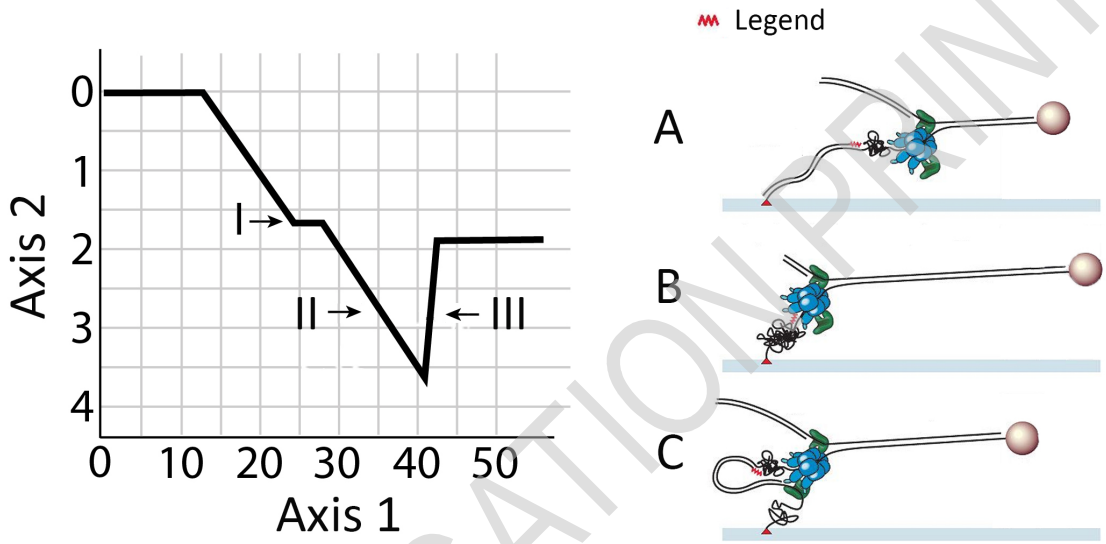


Fig.1. Axis 1 = Time (s). Axis 2 = DNA length change (kb). Legend = Primer.

圖。1。Axis1 = 時間。Axis2 = DNA 長度變化（kb）。Legend = Primer。

Q.6.1 Indicate with an X which position on the graph (I-III) may correspond to which step of DNA replication (A-C).
用 X 註記圖（I-III）上可以對應於 DNA 複製的（A-C）步驟的位置。

Q.6.2 How many base pairs long is the Okazaki fragment based on the figure (to the nearest 500bp)?
由該圖判斷岡崎片段有多少個鹼基對（最接近的 500bp）？

Q.6.3 What is the rate of DNA synthesis? (in bp/second)
DNA 合成的速度是多少？（以 bp /sec 為單位）

Q.6.4 1U of Taq polymerase is defined as the amount of enzyme required to incorporate 10nmol dNTP into DNA in 30 minutes under optimal conditions (72°C). In a PCR mixture (25µL) made with 1U of Taq pol, assuming unlimited template DNA and optimal conditions throughout, how long would it theoretically take for dNTPlevels to drop from a starting 400µM concentration to 200µM in minutes?

1 單位 (U) 的 Taq 聚合酶定義為在最佳條件（72°C）下，在 30 分鐘內，能將 10 nmol dNTP 箝入 DNA 所需的聚合酶量。在用 1U Taq 聚合酶製備的 PCR 混合物（25 µL）中，假設無限制模板 DNA 量和使用最佳條件，理論上 dNTP 量從起始 400 µM 濃度下降到 200 µM 需要多少分鐘？

Q7

You find a mutation in p53 (’ the guardian of the genome’) at nucleotide 42. In your sequence, it is an adenine (A), whereas it is usually guanine (G) in the wild-type, as shown in Figure 1.

您在核苷酸 42 處發現了 p53（“基因組的守護者”）的突變。在您的序列中，它是腺嘌呤（A），而在野生型中通常是鳥嘌呤（G），如圖 1 所示。

Fig.1 圖 1

Q.7.1 You design a test for the mutant allele using restriction enzymes. Indicate with an X which enzyme (A-D) can be used to distinguish patient samples?

您使用限制酶設計了突變等位基因的測試。用 X 表示哪種酶（A-D）可用於區分患者樣本？
A. MboII
B. BglII
C. DpnI
D. HgaI

A clinician uses the appropriate enzyme to carry out restriction fragment length polymorphism analysis. Results for patient A-G are shown in Figure 2.

臨床醫生使用適當的酶進行限制性片段長度多態性分析。患者 A-G 的結果顯示在圖 2 中。

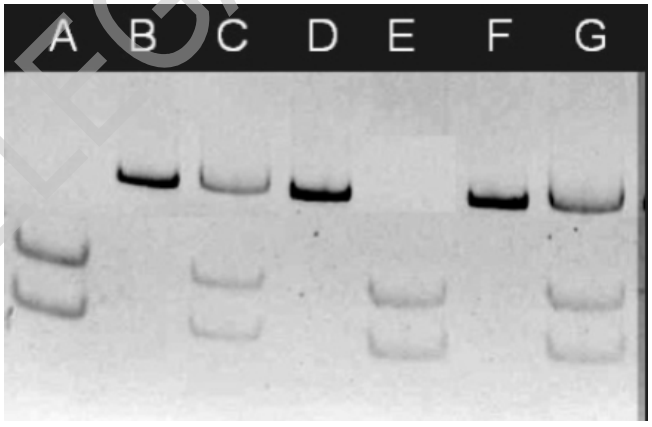


Fig. 2 圖 2

Q.7.2 Determine the genotype of the patients by marking in it with an X. The letters in the table refer to the nucleotides found at position 42.
用 X 標記來決定患者的基因型。表中的字母表示在 42 位點的核苷酸。

Following genotyping you look at p53 transcript and protein levels as seen in Figure 3.

在進行基因型鑑定後，你可檢測 p53 轉錄物和蛋白質的含量，結果如圖 3 所示。

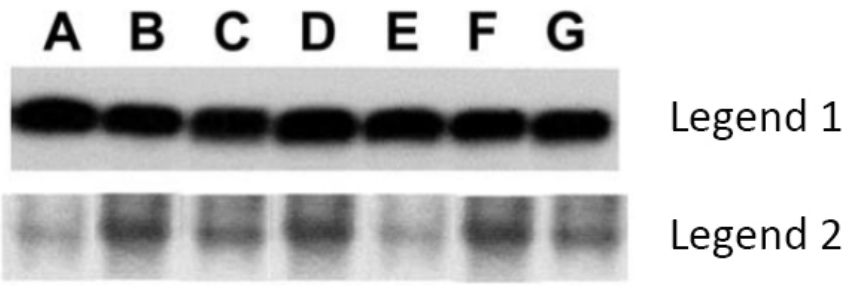


Fig.3. Legend 1 = RNA. Legend 2 = Protein.

圖 3。Legend 1 = RNA。Legend 2 = 蛋白質。

Q.7.3 Indicate with an X whether the mutation affects:
用 X 表示突變是否影響：
A. p53 transcription
p53 轉錄
B. p53 translation
p53 轉譯
C. Both
兩者

Q.7.4 Normally, when the genome is damaged, four molecules of p53 form a complex which can then bind to DNA as a transcription factor. In an experiment a cell is heterozygous for a mutation which produces p53 that prevents DNA binding. If the amount of transcription is proportional to the level of active p53, what fraction of transcription occurs in this cell compared to normal cells?

通常，當基因組受損時，四個 p53 分子形成一個複合物，然後可以作為轉錄因子與 DNA 結合。在一個實驗中，細胞對於 p53 突變是異型合子狀態，其產生的 p53 無法結合 DNA。如果轉錄產量與活性 p53 量呈正比，那麼與正常細胞相比，該 p53 突變細胞中轉錄的比例是多少？

Animal Anatomy and Physiology 動物解剖學與生理學

Q8

In an experiment, the breathing tube of the spirometer was filled with oxygen and fitted with a carbon dioxide absorber that removed all exhaled CO_2, as illustrated in Figure 1. Test subject "A" was allowed to breathe from the apparatus for 4 minutes. The result of this experiment is presented in Figure 2.

如圖一所示，在本實驗中，肺活量計的呼吸管充滿了氧氣，並配有二氧化碳吸收劑，以清除呼出氣體中所有的二氧化碳。受試者"A"將從裝置中呼吸 4 分鐘，實驗的結果如圖 2 所示。

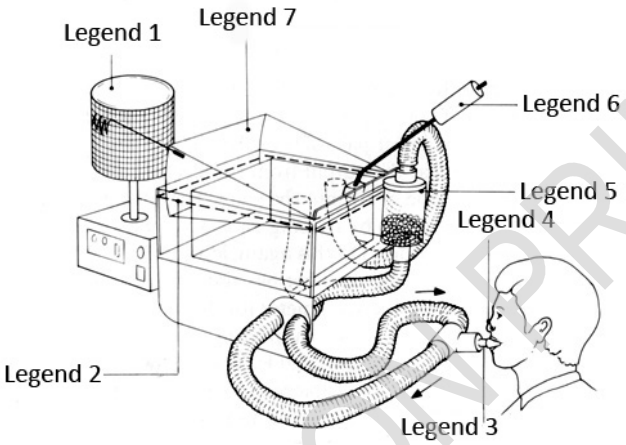


Fig.1. Legend 1 = Kymograph (graphical registry of mechanical movement over time). Legend 2 = Water level. Legend 3 = Mouthpiece. Legend 4 = Nose clip. Legend 5 = Carbon dioxide absorber. Legend 6 = Counterpoise. Legend 7 = Spirometer chamber.

圖。1。Legend 1 = Kymograph（隨時間推移的機械運動的圖形登記）。Legend 2 = 水位。Legend 3 = 以口呼氣或吹氣處。Legend 4 = 鼻夾。Legend 5 = 二氧化碳吸收劑。Legend 6 = 平衡。Legend 7 = 肺活量計。

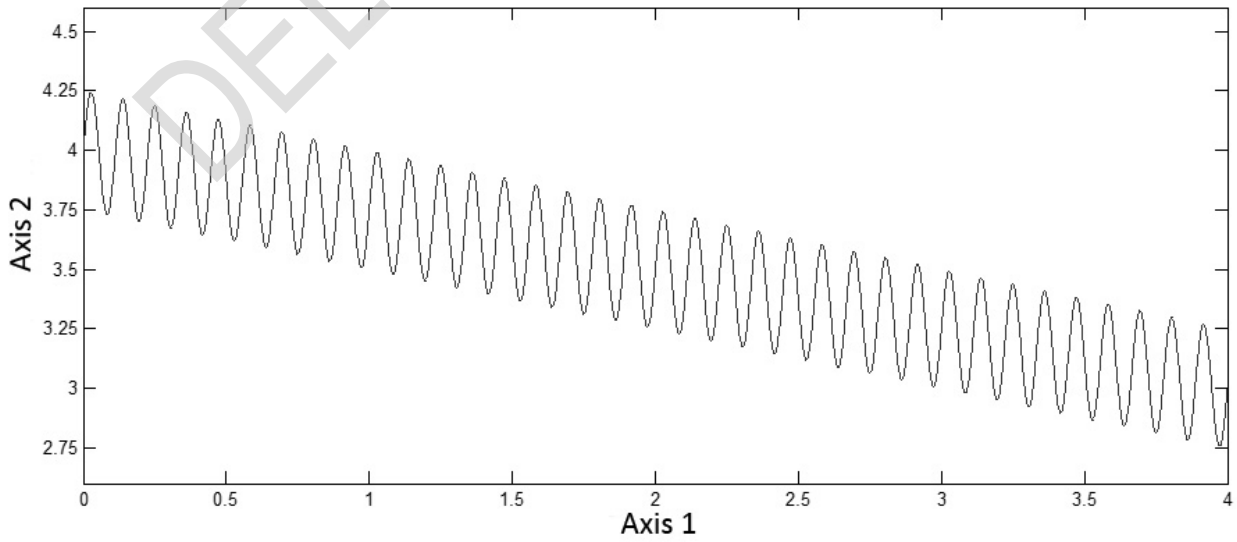


Fig.2. Spirometer experiment. Axis 1 = Time (min). Axis 2 = Spirometer volume (L).

圖 2。肺活量計實驗。軸 1 = 時間（分鐘）。軸 2 = 肺活量計體積（L）。

Q.8.1 What is the tidal volume of test subject “A”? (in mL)
以 mL 為單位，請問受試者“A”的潮氣容積 (tidal volume) 是多少?

Q.8.2 What is the breathing frequency of test subject “A”? (in breaths/min)
以呼吸次數/分鐘為單位，請問受試者”A”的呼吸頻率是多少?

Q.8.3 What is the oxygen consumption of test subject “A”? (in mL/min)
以 mL / min 為單位，請問受試者”A”的耗氧量是多少?

Q.8.4 In an experiment where the CO_2 absorber is removed, how would the test subject’s breathing frequency change? Indicate your answer by putting an X in the appropriate box on the answer sheet.
A. Increase
B. Not change
C. Decrease

在實驗中若移除 CO_2 吸收劑，受試者的呼吸頻率將如何變化？在答案卷上正確答案的空格中填入 X。
A. 增加
B. 不變
C. 減少

In a different spirometry experiment, we measured the volume and speed of air during normal and forced exhalation and inhalation.

在不同的肺活量測定實驗中，我們測量了正常和強制呼氣和吸氣期間的空氣體積和速度。

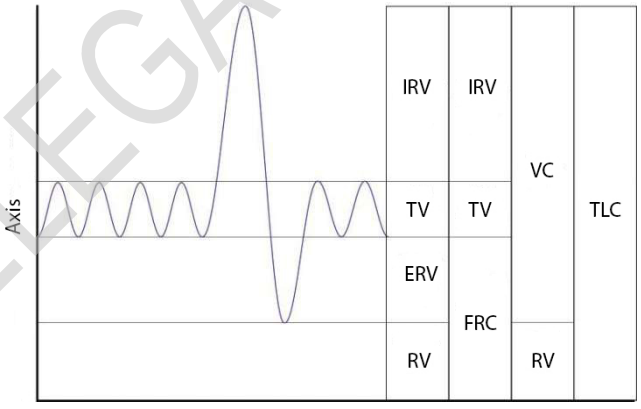


Fig.3. Axis = Volume (ml/kg).

如圖 3 所示。軸 = 體積（ml / kg）。

- TLC - Total lung capacity: the volume in the lungs at maximal inflation, the sum of VC and RV.
- TV - Tidal volume: that volume of air moved into or out of the lungs during quiet breathing
- RV - Residual volume: the volume of air remaining in the lungs after a maximal exhalation
- ERV - Expiratory reserve volume: the maximal volume of air that can be exhaled from the end-expiratory position
- IRV - Inspiratory reserve volume: the maximal volume that can be inhaled from the end-inspiratory level

- VC - Vital capacity: the volume of air breathed out after the deepest inhalation.
- FRC - Functional residual capacity: the volume in the lungs at the end-expiratory position

- TLC(肺總量)：盡可能吸氣之後，肺中容積的總和，即 VC 和 RV 的總和。
- TV(潮氣容積)：正常呼吸期間，吸進呼出肺部的空氣容積
- RV(肺餘容積)：用力呼氣到不能再呼為止後肺部殘留的空氣容積。
- ERV(呼氣儲備容積)：正常呼氣後，再繼續用力呼氣所能呼出的最大空氣容積
- IRV(吸氣儲備容積)：正常吸氣後，再用全力吸氣後所多吸入的氣體容積
- VC(肺活量)：盡全力深吸氣後再呼出的空氣量。
- FRC (功能性肺餘量)：正常呼氣狀態下，留在肺內的空氣

Consider test subject “B” who had the following results:

- VC = 5,200 mL
- IRV = 3,300 mL
- FRC = 2,500 mL
- RV = 1,300 mL

受試者“B”相關生理參數如下：

- 肺活量 = 5,200 mL
- 吸氣儲備容積 = 3,300 mL
- 功能性肺餘量 = 2,500 mL
- 肺餘容積 = 1,300 mL

Q.8.5 Calculate the tidal volume of test subject “B” and give your answer on the answer sheet in millilitres (mL).
以毫升 (mL) 為單位，算出受試者“B”的潮氣容積。

Test subject “C” was also tested. After several measurements, researchers found that her tidal volume is 500 mL and respiratory rate is 15/min when resting. During intense exercise her O_2 consumption rises leading to a 3-fold higher volume of air inhaled per minute and an increased respiratory rate of 25/min.

本實驗另外還有一位受試者“C”，幾次測量後，研究人員發現她在休息狀態下，潮氣容積為 500 毫升，呼吸頻率為 15 次 /分鐘。在激烈的運動時，她氧氣大量消耗，使她每分鐘吸入空氣體積增加為原來的 3 倍，呼吸頻率上升至 25 次/分鐘

Q.8.6 Based on the graph above and the data provided, calculate the tidal volume of test subject “C” during exercise. Give your answer on the answer sheet in millilitres (mL).
基於上圖和所提供的數據，計算運動期間受試者“C”的潮氣容積。以毫升 (mL) 為單位，在答案卷上寫出答案。

Q9

In the brainstem there is a neuronal regulation network which maintains the rhythmic breathing as it can be seen in the list below.

腦幹中有一個神經調節網絡以保持個體規律呼吸，如下表所示。

Pneumotaxic center (PC):

- Controls the duration of inhalation by signalling to inspiratory area
- Strong activity $\longrightarrow$ length of inspiration < 0.5 seconds
- Weak activity $\longrightarrow$ length of inspiration > 5 seconds

呼吸調節中樞（PC）：

- 藉由發出訊號至吸氣區，控制吸氣的持續時間
- 活性高時 $\longrightarrow$ 吸氣時間 <0.5 秒
- 活性低時 $\longrightarrow$ 吸氣時間 >5 秒

Apneostic center (AC):

- Promotes inhalation by stimulating the DRG
- Inhibited by pulmonary stretch receptors
- Inhibits PC

長吸中樞（AC）：

- 長吸中樞會刺激背側呼吸群 (DRG) 以促進吸氣作用
- 受肺部拉伸受體抑制
- 抑制呼吸調節中樞

Dorsal respiratory group (DRG):

- Controls the basic rhythm by triggering respiratory impulses
- Vagal and glossopharyngeal nerves bring peripheral chemosensory information to it

背側呼吸群 (DRG)：

- 基本的呼吸節律主要在此產生，主要是藉由誘發呼吸衝動來控制基本呼吸節律
- 迷走神經和舌咽神經為帶來周邊化學接受器之訊息。

Ventral respiratory group (VRG):

- Inactive during normal baseline respiration
- High DRG activity (increased need for ventilation) stimulates it
- Has neurons for both inhalation and exhalation
- Inhibits AC

腹側呼吸群 (VRG)：

- 正常平靜呼吸時不活化但當背測呼吸群活性增加時 (如換氣量上升)，會刺激腹側呼吸群以提供額外的呼吸動力
- 同時具備吸氣和呼氣的功能
- 抑制長吸中樞 (AC)

Central chemosensitive area (CC):

- Stimulated by high blood pCO_2

- Excites other respiratory centres

中樞化學敏感區（CC）：

- 血液中二氧化碳濃度過高會刺激中樞化學敏感區
- 活化其他呼吸中樞

Decide how the described features would change (increase, no change or decrease) in the following scenarios. Indicate your answer by putting an X in the appropriate box on the answer sheet.

- A. Increase
- B. No change
- C. Decrease

請指出下列各項敘述中的功能將如何變更 (增加、不更改或減少)。請在答案紙上正確的答案欄中畫 X。

- A. 增加
- B. 沒有變化
- C. 減少

Q.9.1 Respiratory rate upon damage to pneumotaxic center
當呼吸中樞受到損害時，呼吸頻率的變化

Q.9.2 Blood pH after a stroke affecting central chemosensitive area neurons
病患中風後血液 pH 值對中樞化學敏感區域神經元的影響

Q.9.3 Ventral respiratory group activity upon a deep inhalation
深吸氣時腹側呼吸群之活性

Q.9.4 Central chemosensitive area neuron membrane hyperpolarisation upon voluntarily holding one’s breath
受試者自願屏住呼吸時，中樞化學敏感區域神經元膜過極化情形

Q.9.5 Length of inhalation upon overstimulation of apneostic center
在過度刺激長吸中樞時吸氣的長度

Q10

Pressure–volume work (or PV work) occurs when the volume of a system changes. It can be calculated as the product of Δ volume and Δ pressure. The work of breathing is mainly determined by the compliance of the lungs, which is defined as:

Compliance = Δ volume (mL) /Δ pressure (cm H_2O)

當系統的體積發生變化時，會影響系統的壓力，即為所謂壓力容積功 (Pressure-Volume work)，它可以計算為 Δ 體積和 Δ 壓力的乘積。呼吸所作的功主要取決於肺的順應性，其定義如下：

順應性 = 體積改變量（mL）/壓力改變量 (cm H_2O)

Compliance itself is dependent on two main factors, (1) the elastic characteristics of the lung, and (2) the surface tension generated by the air-liquid interface at the inner alveolar surface. In 1929, von Neergaard excised the lung of a cat which he then inflated and then deflated using air and then inflated and deflated using saline solution. The results are plotted in the figure below.

而肺的順應性本身取決於兩個主要因素，(1) 肺本身的彈性特質，和 (2) 由內部肺泡表面所產生的表面張力。1929 年，von Neergaard 取出了貓的肺臟，首先將空氣打入離體肺臟，而後將空氣打出肺臟；接下來用生理食鹽水打入離體肺臟後將生理食鹽水打出肺臟。結果繪製在下圖。

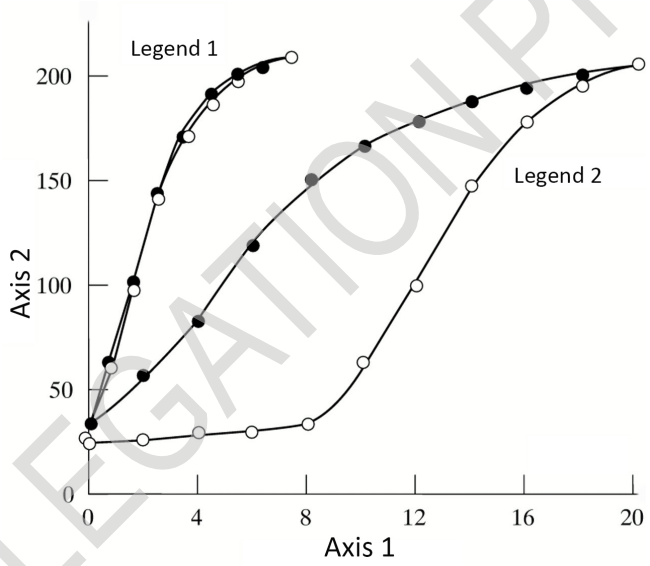


Fig.1. Axis 1 = Pressure (cm H_2O). Axis 2 = Volume (ml). Legend 1 = Saline inflation. Legend 2 = Air inflation. Empty circles ◦ : inflation. Full dots • : deflation.

圖 1。軸 1 = 壓力（釐米水柱）。軸 2 = 體積（ml）。Legend 1 = 打入鹽水。Legend 2 = 打入空氣。空白圓圈: 充填。黑圈: 排出。

For the following pairs of statements (A and B), evaluate the mathematical relationship between the values. Indicate your answers using the following symbols > or < or = in the cells provided on the answer sheet.

針對以下成對說明（A 和 B），請評估兩者之間的數學關係 (大於 >，小於 < 或等於 =)。將答案 (大於 >，小於 < 或等於 =) 填在答案紙上。

Q.10.1 A: Work of inflating the cat lung with saline solution.
B: Work of inflating the cat lung with air.
A：用生理食鹽水充填入貓肺所作的功。
B：用空氣充填入貓肺所作的功。

Q.10.2 A: The compliance of the lung at volumes above 35 mL (upon normal air inhalation).
B: The compliance of the lung at volumes below 35 mL (upon normal air inhalation).
A：當肺體積超過 35 mL 時，肺的順應性（正常空氣吸入時）。
B：當肺體積小於 35 mL 時，肺的順應性（正常空氣吸入時）。

Q.10.3 A: Contribution of intrinsic elastic forces to total lung compliance.
B: Contribution of surface tension to total lung compliance.
A: 內在彈力對肺整體順應性的貢獻。
B：表面張力對肺整體順應性的貢獻。

Q.10.4 A: Compliance of a healthy, normally functioning lung.
B: Compliance of a lung in which surfactant production is abolished by genetic mutations.
A：健康，正常運作時，肺部的順應性。
B：通過基因突變阻斷肺部表面張力素產生時，肺的順應性。

Q.10.5 A: Total lung capacity in a normally functioning cat lung.
B: Total lung capacity in the same cat’s lung after chemical inhibition of surfactant production.
A：正常運作時貓肺的肺總量。
B：利用藥物抑製肺表面張力素產生後，同一貓肺中的肺總量。

Q11

The electromyogram (EMG) is a technique used to measure the collective electrical activity of active skeletal muscle fibres using electrodes placed on the skin. A human subject was prepared for a muscle electrophysiology experiment to test the conduction velocity of their motor neurons. The experimental setup and a trace of one of their measurements are illustrated below.

肌電圖 (EMG) 主要是將電極置於皮膚上，用以偵測骨骼肌活性的裝置。科學家可用以量測人體動作神經元之傳導速度來進行肌肉電生理的研究。實驗裝置和其如何測量如下所示。

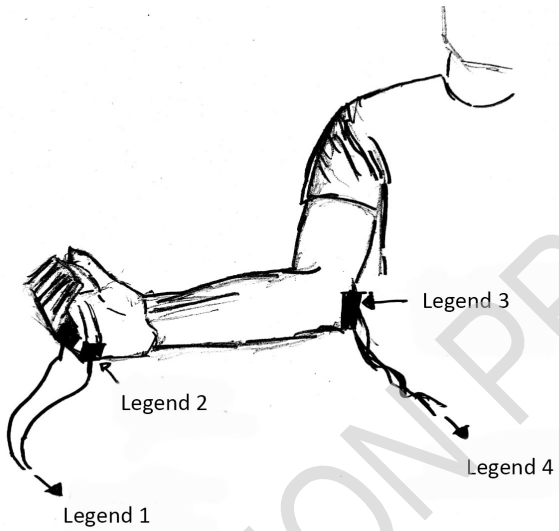


Fig.1. Legend 1 = Connected to amplifier and detector. Legend 2 = Stick-on electrodes. Legend 3 = Stimulator applied to notch in back of elbow. Legend 4 = To isolated stimulator

圖。1。Legend 1 = 連接到放大器和探測器。Legend 2 = 粘貼電極。Legend 3 = 刺激器黏貼於肘部後方的凹陷處。Legend 4 = 連接至獨立的刺激器

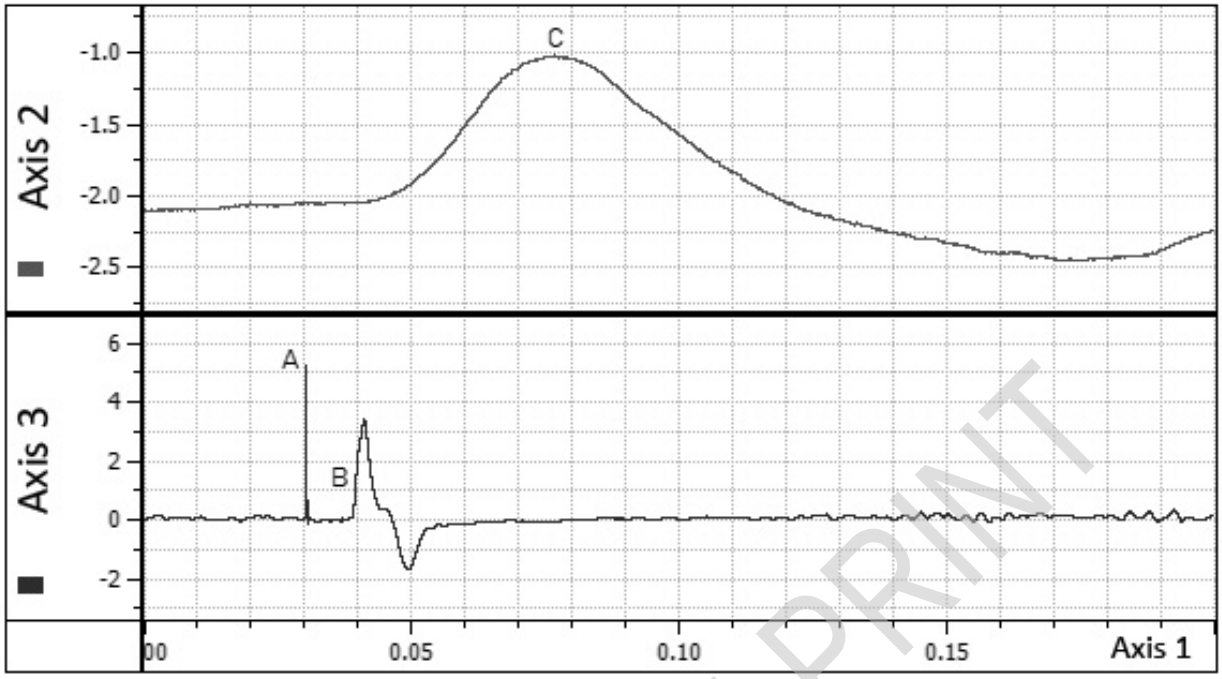


Fig.2. Axis 1 = Time (sec). Axis 2 = Force transducer (N). Axis 3 = Electromyogram (mV).

(The spike in the "Electromyogram" trace at "A" (time = 0.03 sec) is added by the computer to show when the stimulus was presented.)

圖 2。軸 1 = 時間（秒）。軸 2 = 壓力傳導器（N）。軸 3 = 肌電圖（mV）。

(電腦會顯示"肌電圖"軌跡在"A"（時間 = 0.03 秒）的刺激波型（spike）以顯示何時出現刺激。)

Q.11.1 Calculate the conduction velocity of the motor neuron. Assume that the initiation and transmission of signalling within the muscle cells take zero milliseconds. The distance between the stimulation electrode and the EMG electrode was 420 mm. Give your answer in m.sec-1 and round it to the nearest whole number.
請計算運動神經元的傳導速度：假設肌肉細胞內信號的啟動及傳遞為零毫秒。刺激電極和 EMG 電極之間的距離為 420mm。以 m/sec 為單位，將答案四捨五入到最接近的整數。

For the following questions, answer with the letters of the processes listed below (A-I). Note that not all of the options are actually involved in the illustrated process. Indicate your answer by putting an X in the appropriate box on the answer sheet.

對於以下問題，請利用下述各流程之字母回答 (A 到 I)。請注意，並非所有選項都實際涉及所示流程。請在答案紙上正確的空格中畫 X。

A. Ca^{2+} channel opening in the membrane of the sarcoplasmic reticulum

B. Acetylcholine released

C. Ca^{2+} binding to troponin

D. Action potential initiated in muscle fibre membrane

E. Action potential propagated along motor neuron

F. Actin-myosin cross-bridge cycling

G. Troponin blockage of myosin binding sites restored

H. Active transport of Ca^{2+} across membrane of sarcoplasmic reticulum

I. Ca^{2+} concentration increases in the muscle fibre’s cytoplasm

A. 鈣離子通道開口於在肌漿網

B. 釋放乙醯膽鹼

C 鈣離子與肌鈣蛋白 (troponin) 結合

D. 肌纖維膜上產生動作電位

E. 動作電位沿運動神經元傳播

F. 肌動蛋白 (actin) 與肌凝蛋白 (myosin) 之橫橋週期

G. 肌鈣蛋白與肌凝蛋白間結合之阻斷被恢復

H. 主動運輸鈣離子跨越肌漿網膜

I. 肌纖維細胞質中的鈣離子濃度增加

Q.11.2 Which **2** processes happen between time points A and B?
時間點 A 和 B 之間發生了哪兩個過程？

Q.11.3 What happens immediately at point B?
B 點會立即發生什麼？

Q.11.4 Which process accounts for the observation of the peak labelled C?
哪個過程可說明標記為 C 的峰值？

Q.11.5 Which process is most likely to account for the slowness of the fall of the trace after point C?
哪個過程最有可能解釋 C 點之後軌跡緩慢的下降？

Q12

Nitric oxide (NO) plays a role in physiological regulation of the circulatory system. NO is the activator of soluble guanylyl cyclase, leading to the formation of cyclic GMP (cGMP), an important second messenger in vascular smooth muscle.

一氧化氮（NO）在循環系統的調節中扮演相當重要的角色。NO 活化可溶性鳥苷酸環化酶 (soluble guanylyl cyclase)，導致環狀 GMP（cGMP）的形成，cGMP 是血管平滑肌中重要的第二傳訊者。

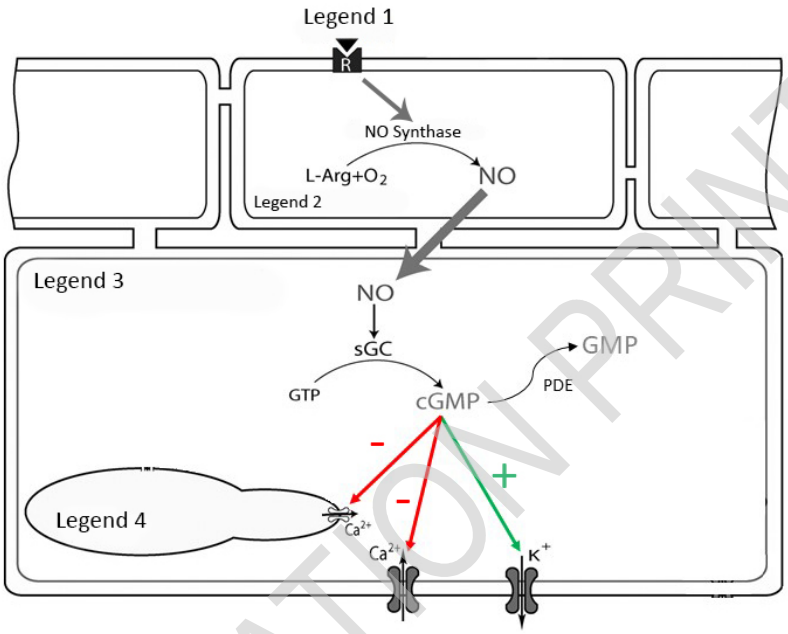


Fig.1. Legend 1 = Adrenaline. Legend 2 = Endothelial Cell. Legend 3 = Smooth Muscle Cell. Legend 4 = Sarcoplasmic Reticulum.

圖。1。Legend 1 = 腎上腺素。Legend 2 = 內皮細胞。Legend 3 = 平滑肌細胞。Legend 4 = 肌漿網。

The contraction of vascular smooth muscle determines the diameter of a blood vessel. The relationship between vessel diameter, pressure, and flow is described by Poisseuille’s law.

血管平滑肌的收縮決定了血管的直徑。Poisseuille 定律描述了血管直徑，壓力和血流之間的關係。

$$Q = \frac{\pi r^4 \Delta P}{8 \mu L}$$

Where:

- Q is flow in mL/min
- r is the vessel radius
- ΔP is the pressure gradient
- μ is the viscosity of the fluid in the vessel
- L is the length of the vessel

哪裡：

- Q 是血流（mL / min）

- r 是血管半徑
- ΔP 是壓力梯度
- μ 是血管中液體（血液）的粘度
- L 是血管的長度

Based on the above, how would the specified characteristics be changed in the following scenarios? For the **next three questions**, decide if the result is increase, no change or decrease. Indicate your answer by putting an X in the appropriate box on the answer sheet.

A. Increase

B. No change

C. Decrease

基於以上所述，在以下情境中特定參數的變化如何? 請描述在**接下來的三個問題**中，生理參數是增加，不變或減少。通過在答題卷上的相應框中輸入 X 來表明您的答案。

A. 增加

B. 沒有變化

C. 減少

Q.12.1 Flow in the vessel in case of fight-or-flight response in a living organism.
在生物體內的戰鬥或逃跑反應的情況下，血液在血管中之血流量。

Q.12.2 Flow in the vessel upon administration of the drug sildenafil, which inhibits cGMP specific phosphodiesterase (PDE).
予藥物 sildenafil(作用為抑制 cGMP 特異性磷酸二酯酶 (cGMP specific phosphodiesterase (PDE)) 後之血流量。

Q.12.3 Membrane potential of the smooth muscle cell upon adrenaline infusion into a perfused vessel preparation.
注射腎上腺素到血管後時平滑肌細胞的細胞膜電位。

Q.12.4 By how many fold must pressure increase, to create an increase in flow equivalent to a 10-fold increase in vessel radius? Provide your answer in the appropriate box on the answer sheet.
管半徑增加 10 倍後，壓力需增加幾倍才能導致血流量也增加十倍？在答案紙上寫出你的答案。

Q13

The water content of the human body is about 60%. The distribution of this huge amount of fluid and their content are both important to understand the main processes of homeostasis. Figure 1 shows the amount of fluid in, and the ionic content of, different body compartments.

人體的含水量約為 60%。這些液體的分佈及其內含物在生物的恆定過程中扮演重要角色。圖 1 顯示了體液的分佈及其離子含量。

Fig.1. Distribution of the different fluid compartments in a healthy adult. Axis 1 = Mass (kg). Axis 2 = Osmotic concentration (mOsmol/kg). Legend 1 = Intracellular fluid. Legend 2 = Interstitial fluid. Legend 3 = Blood plasma.

圖。1。健康成人中不同液體的分佈。軸 1 = 體重（kg）。軸 2 = 滲透濃度（mOsmol / kg）。Legend 1 = 細胞內液。Legend 2 = 細胞間質液。Legend 3 = 血漿。

Inadequate supply of water and ions or the abnormal loss of these substances alter the values found in Figure 1. In Figure 2, four physiological conditions with their distinctive values are shown, in which changes occur in the mass and/or osmotic concentration of body fluids. The diagrams only show the intracellular (dark grey) and the extracellular (light grey) fluid compartments and their mass and osmotic concentration values. The areas surrounded by the dashed lines represent the normal values of the compartments shown in the previous diagram.

水和離子的供應不足或異常流失改變了圖 1 中的數值。圖 2 顯示了四種不同的生理條件及其特殊生理參數，主要是體重和/或體液滲透濃度之間的變化。該圖僅顯示細胞內（深灰色）和細胞外（淺灰色）液體分佈及其質量和滲透濃度值。虛線圍繞的區域表示上圖中所示的各區域的正常值。

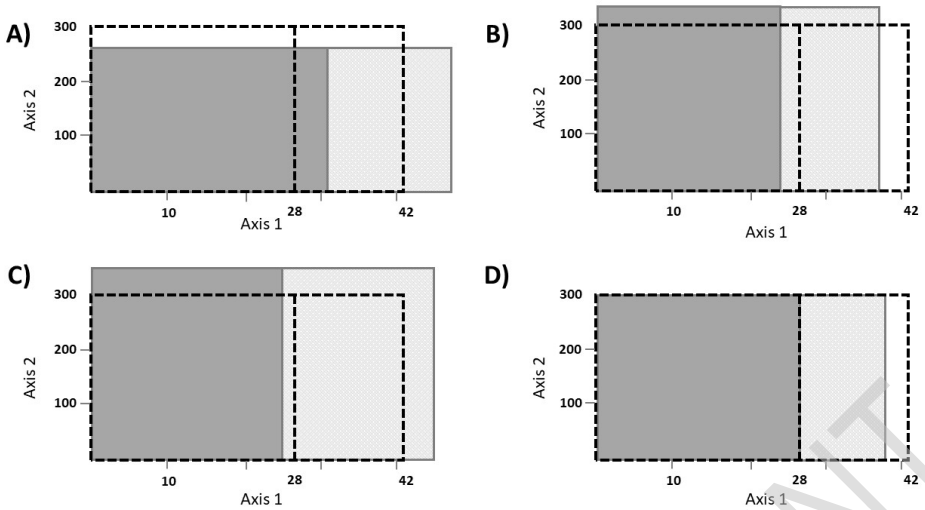


Fig.2. Axis 1 = Mass (kg). Axis 2 = Osmotic concentration (mOsmol/kg)

圖 2。軸 1 = 質量（kg）。軸 2 = 滲透濃度（mOsmol / kg）

Q.13.1 Calculate the extracellular fluid mass / intracellular fluid mass ratio of sodium ions, using normal (healthy) values. Assume that the concentration of sodium ions is 140 mOsm/kg in extracellular fluid, and 10 mOsm/kg in intracellular fluid. Give your answer to the nearest integer (whole number).
利用所提供之健康人之正常值，計算鈉離子的細胞外液/細胞內液質量比。假設細胞外液中鈉離子濃度為 140 mOsm / kg，而細胞內液中鈉離子濃度為 10mOsm / kg。寫出最接近整數的答案。

Match the following statements describing different physiological conditions with the letters in Figure 2 (A-D). Indicate your answer by putting an X in the appropriate box (A-D) on the answer sheet.

將以下描述不同生理條件的說明與圖 2(A 到 D) 中的字母相配對。在答案紙上的 A 到 D 前空格畫 X 以顯示正確答案。

Q.13.2 A condition typical after drinking large quantities of diluted liquid.
飲用大量稀釋液後的典型狀況。

Q.13.3 A condition typical of dehydration (loss of water).
典型的脫水（失水）狀況。

Q.13.4 A condition brought about after severe vomiting and diarrhoea.
嚴重嘔吐和腹瀉後出現的狀況。

Q.13.5 A condition most likely to cause the blood pressure to increase.
最容易導致血壓升高的症狀。

Q.13.6 Which of these conditions will inhibit release of vasopressin (ADH) into the blood?
哪些症狀會抑制血管加壓素 (ADH) 釋放到血液中？

Q14

Insulin is a 51-amino acid protein consisting of 2 polypeptide chains linked by disulphide bonds.

胰島素是 51 個胺基酸的蛋白質，由 2 個通過二硫鍵連接的多肽鏈組成。

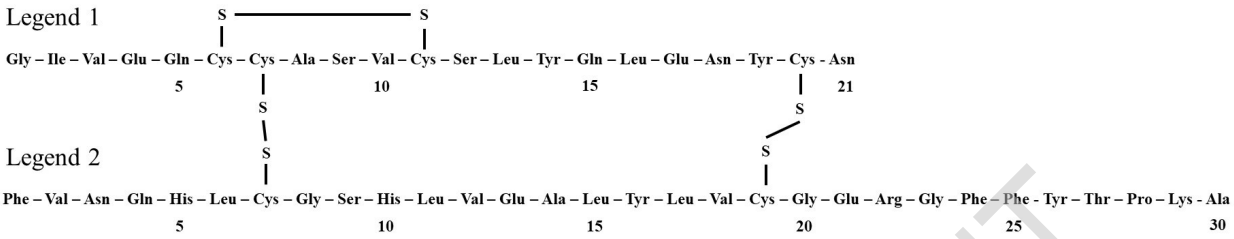


Fig.1. Legend 1 = A chain. Legend 2 = B chain

圖 1。Legend 1 = A 鏈。Legend 2 = B 鏈

In type 1 diabetes mellitus, there is no adequate insulin release due to the loss of beta-cells of the pancreas. Therefore, the only treatment is insulin injection, which is most commonly administered into the fat under the skin. Here it forms hexamers, which then dissociate to be absorbed into the blood stream.

在第一型糖尿病中，由於胰島 β 細胞的喪失，所以無法沒有分泌足夠的胰島素。唯一的治療方法是注射胰島素於體內，最常注射於皮下脂肪。在這裡它形成六聚體，然後解離被吸收到血流中。

The graph shows the plasma level of three available insulins (1-3) after subcutaneous injection:

該圖顯示皮下注射後三種可用胰島素 (1-3) 後血液中的濃度：

1. Human insulin produced in Saccharomyces cerevisiae by recombinant DNA technology.

2. An insulin analogue in which swapping one amino acid reduces dimer and hexamer formation.

3. An insulin analogue in which amino acid changes to the A and B chains change the molecule's isoelectric point from 5.7 to a more neutral pH.

1. 通過重組 DNA 技術在酵母菌 (Saccharomyces cerevisiae) 中所產生人類胰島素。

2. 一種胰島素類似物，其中交換一種胺基酸可減少二聚體和六聚體的形成。

3. 一種胰島素類似物，其中 A 和 B 鏈的胺基酸改變將分子的等電點從 5.7 變為更中性的 pH 值。

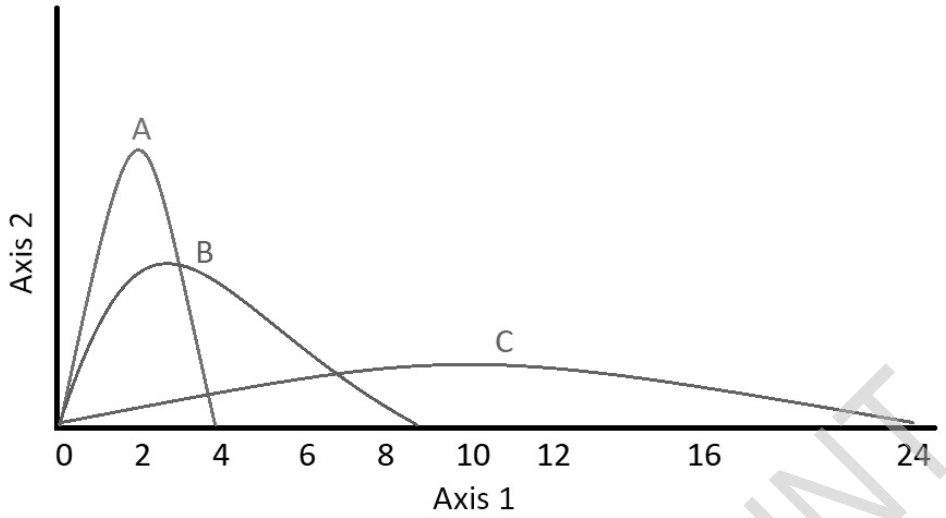


Fig.2. Axis 1 = Time. Axis 2 = Relative plasma insulin level

圖 2。Axis 1 = 時間。Axis 2 = 相對血漿胰島素含量

Q.14.1 Match the insulin types (1-3) with the plots (A-C) based on the information above. Indicate your answer by putting an X in the appropriate box on the answer sheet.
根據上述信息將胰島素類型（1-3）與圖 (A 到 C) 相配對。在答案卷上的正確空格中畫上 X。

Indicate with an X if each of the following statements is true (T) or false (F).

利用 X 顯示下列陳述何者為真（T）或假（F）。

Q.14.2 Oral administration (e.g. in the form of pills) of insulin is approximately as effective as subcutaneous administration.
胰島素的口服給藥（例如以丸劑的形式）與皮下給藥大致同樣有效。

Q.14.3 Stimulation of insulin release from pancreatic beta cells can be an alternative therapy in type 1 diabetes mellitus.
從胰島中促進 β 細胞釋放胰島素可作為第一型糖尿病的替代療法。

Q.14.4 Immunosuppressant therapy could slow down the onset of type 1 diabetes mellitus if it is diagnosed early.
如果早期診斷，免疫抑製劑治療可以減緩 1 型糖尿病的發作。

Q.14.5 The long-acting, subcutaneously administered insulins (e.g. plot C) act longer because their degradation in the circulation is slower.
長效透過皮下給藥的胰島素 (例如，圖 C) 作用時間更長，因為它們在循環系統中的降解較慢。

Q15

An audiometry exam tests a subject’s ability to hear sounds at different frequencies. Sound waves travel to the inner ear through the ear canal, eardrum, and the bones of the middle ear (air conduction, empty circles (○) or alternatively, through the bones around and behind the ear (bone conduction, full dots (●).

聽力檢查可用以測試受試者聽到不同頻率聲音的能力。聲波通過耳道，耳膜和中耳的聽小骨頭傳播到內耳 (空氣傳導，以空心圓 ○ 表示)，或者通過耳朵周圍和後面的骨骼傳播到內耳 (骨傳導，以黑圓圈 ● 表示)。

Figure 1. shows the lowest sound intensity (in dB) at a given frequency (Hz) the test subject can still perceive, where a 0 value is the population average and any positive value suggests that a higher than average intensity is required for the subject to hear the sound.

圖 1 顯示了測試對象仍可感知的特定頻率（Hz）下的最低聲音強度（以分貝 dB 為單位），其中 0 值是總體平均值，任何正值表示受試者需要高於平均強度的強度才聽得到。

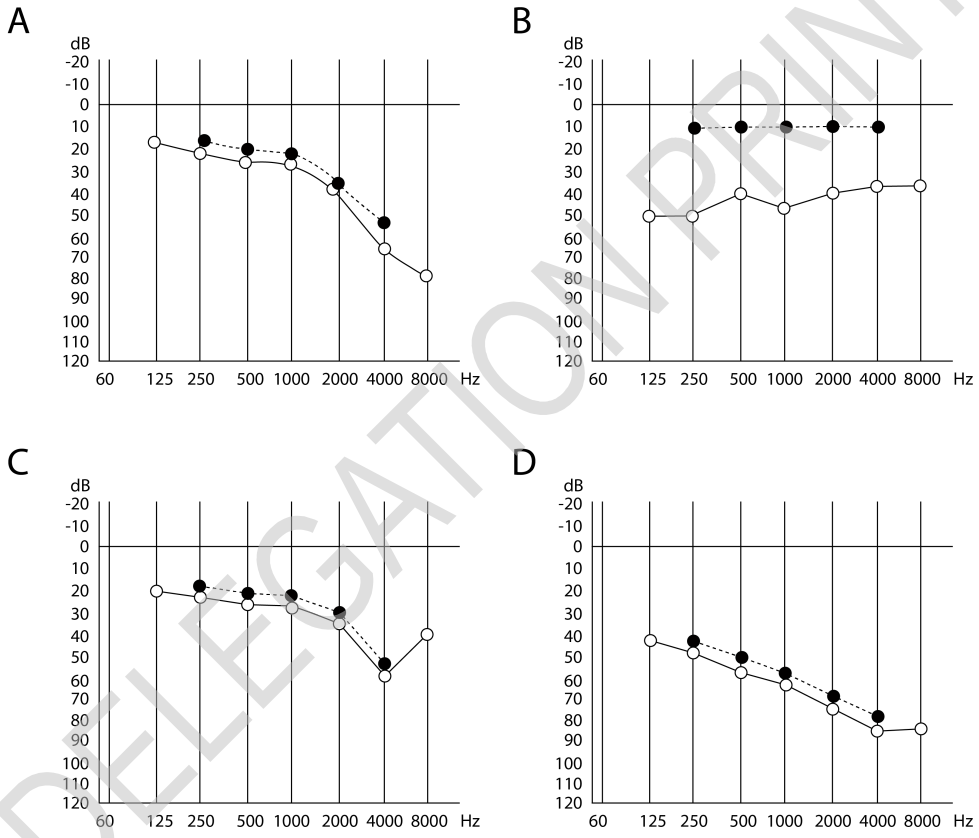


Fig.1

圖 1.

Q.15.1 What is the highest frequency at which bone conduction is tested? (Hz)
以 Hz 為單位，請問骨傳導的最高頻率是多少？（赫茲）

Match the following conditions with the test results in Figure 1 (A-D). Indicate your answer by putting an X in the appropriate box on the answer sheet.

將以下條件與圖 1 中的測試結果 (A 到 D) 相配對，在答案紙的正確空格中畫 X。

Q.15.2 Old age related reduced sensitivity to high frequency.
老年時期對高頻的敏感性降低。

Q.15.3 Middle ear infection impeding the movement of the auditory bones.
如果中耳感染了則會阻礙了聽骨的運動。

Q.15.4 Neurological hearing damage causing overall reduction in hearing acuity.
神經性聽力損傷會導致整體聽力敏銳度降低。

Q.15.5 Damage caused by an air horn.
空氣喇叭造成的損壞。

Q16

In eutherians (placental mammals), the developing fetus and the placenta are surrounded by two membranes, the chorion and the amnion. In monozygotic twin pregnancies, these membranes can be either separate or shared. This depends on the developmental stage at which the initial conceptus splits into two separate ones.

在胎盤哺乳動物 (eutherians) 中，發育中的胎兒和胎盤被兩種膜包裹，即絨毛膜和羊膜。在同卵雙胎妊娠中，這些膜可以是獨立或彼此共享。這取決於在胚胎發育過程中何時分裂成兩個獨立的個體

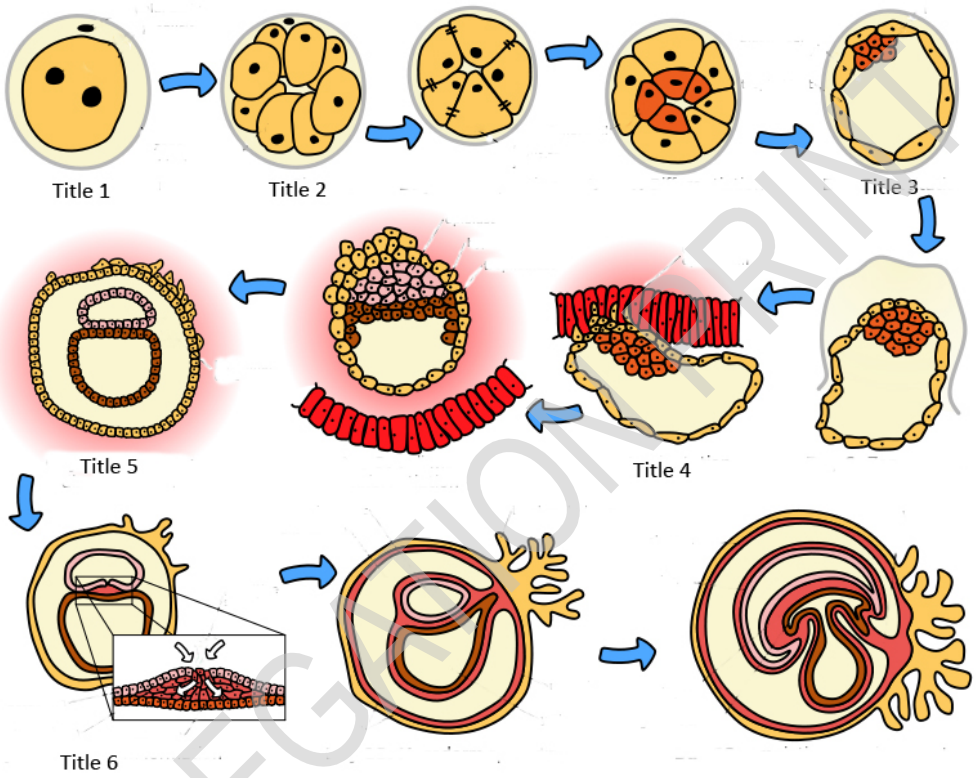


Fig.1. Title 1 = Day 1 Fertilization. Title 2 = Day 2 Morula formation. Title 3 = Day 5 Blastocyst formation. Title 4 = Day 7 Implantation. Title 5 = Day 9 Inner cell mass differentiation. Title 6 = Day 12 Germ disk and then primitive streak formation.

圖。1。標題 1 = 第 1 天受精。標題 2 = 第 2 天桑葚胚形成。標題 3 = 第 5 天囊胚形成。標題 4 = 第 7 天著床。標題 5 = 第 9 天內細胞質量分化。標題 6 = 第 12 天胚盤 (germ disk) 然後形成原線 (primitive streak)。

In each of the following scenarios (Q.16.1-4), decide if the chorion and the amnion are shared or separate. Indicate your answer by putting an X in the appropriate box (A-D) on the answer sheet.

判斷絨毛膜和羊膜在以下各種狀況（Q.16.1-4）中，是彼此共享還是獨立擁有。在答案紙上 A 到 D 的正確空格中畫 X。。

Your options:

A. Both chorion and amnion are shared

B. Chorion is separate, amnion is shared

C. Chorion is shared, amnion is separate

D. Both chorion and amnion are separate

你的選擇：

A. 共享絨毛膜 (chorion) 和羊膜 (amnion)

B. 絨毛膜各自獨立，羊膜是共享的

C. Chorion 是共享的，羊膜是各自獨立

D. 絨毛膜和羊膜都是分開的

Q.16.1 Dizygotic twins
雙卵雙胞胎

Q.16.2 Monozygotic twins where splitting occurred in the morula stage
單卵雙胞胎在桑葚胚階段發生分裂

Q.16.3 Monozygotic twins where splitting occurred in the inner cell mass stage
單卵雙胞胎，在內細胞團階段發生分裂

Q.16.4 Monozygotic twins where splitting occurred between the formation of the germ disc and the primitive streak
單卵雙胞胎在胚盤和原線形成時發生分裂

Plant Anatomy and Physiology 植物解剖與生理學

Q17

Nutrient availability is thought to be one of the most important conditions influencing stem structure. It is believed to induce changes in the structure of aerenchyma (a spongy tissue of air channels) and the distribution of lacunae (airspaces in aerenchyma tissue). To investigate this, biomechanical parameters of stems of two aquatic plant species (M. s. = M. scorpoides and M. a. = M. aquaticus) were measured under low (↓ in table) or high (↑ in table) nutrient conditions. Data were statistically evaluated and the mathematical relationships between these parameters determined as shown in Table1. (ns = non-significant, more stars show greater significant difference).

營養素可利用性是影響莖構造的最重要條件之一。它可引起通氣組織（具空氣通道的海綿狀組織）結構的變化和空隙的分布（通氣組織中的空隙）。為了研究此部分，在低或高濃度的營養條件下，測量了兩種水生植物（M. s. = M. scorpoides 和 M. a. = M. aquaticus）莖的生物力學變數。在表 1 中，(↓ 代表低營養；↑ 代表高營養) 數據已經統計評估，並確定這些變數之間的數學關係。(ns = 無顯著關係，更多星號表示其差異更顯著)。

	M.s. ↓	M.s. ↑	Sign.	M.a. ↓	M.a. ↑	Sign.
I (mm^4)	0.57±0.27	0.47±0.18	ns	2.68±1.95	3.40±2.30	ns
Icor(mm^4)	0.47±0.18	0.39±0.15	ns	2.39±1.63	2.96±2.11	ns
BF (N)	2.09±0.62	0.77±0.83	***	5.35±2.03	5.98±2.17	*

Table 1. M.s. ↓ = M. scorpoides in low nutrient conditions. M.s. ↑ = M. scorpoides in high nutrient conditions. Sign. = Statistical significance. M.a. ↓ = M. aquatica in low nutrient conditions. M.a. ↑ = M. aquatica in high nutrient conditions. BF = Breaking force.

Table 1. M.s. ↓ = 低營養條件下的 M. scorpoides；M.s. ↑ = 高營養條件下的 M. scorpoides；Sign. = 統計顯著性；M.a. ↓ = 低營養條件下的 M. aquaticus；M.a. ↑ = 高營養條件下的 M. aquaticus；BF = 斷裂力

$$I(M.s.) = \frac{\pi R^4}{4} \quad (1)$$

$$I(M.a.) = \frac{L^4}{12} \quad (2)$$

$$Icor = I(1 - P) \quad (3)$$

Where:

- **Second moment of area** (I) = describes the geometry of the stem cross section
  莖的截面積慣量 (I)= 描述莖橫切面的幾何形狀
- **Breaking force** (BF)= the maximum force (F) the stem fragment could withstand before breaking
  斷裂力（BF）= 莖段在斷裂前可承受的最大力（F）
- **Porosity** (P) = the ratio of total lacunar area and total cross-sectional area of stem
  孔隙率（P）= 孔隙的總面積與莖橫切面的總面積之比值
- **Icor** = I corrected by porosity
  經孔隙率校正的 I 值
- **Radius** of a circular stem cross section (R)
  莖橫切面的半徑 (R)

- **Side length** of a rectangular stem cross section (L)

  莖橫切面的邊長 (L)

Calculate the mean porosity of the stems of both plant species for both nutrient conditions using two significant figures for your result.

在兩種營養條件下，分別計算兩種植物莖的平均孔隙率，計算至小數點後兩位有效數字。

Q.17.1 Mean porosity of M.s. in low nutrient conditions
低營養條件下，M.s. 的平均孔隙率

Q.17.2 Mean porosity of M.s. in high nutrient conditions
高營養條件下，M.s. 的平均孔隙率

Q.17.3 Mean porosity of M.a. in low nutrient conditions
低營養條件下，M.a. 的平均孔隙率

Q.17.4 Mean porosity of M.a. in high nutrient conditions
高營養條件下，M.a. 的平均孔隙率

Representative cross sections of the stems of M.s. and M.a. are shown below.

M.s. 和 M.a. 兩種莖的橫切面代表圖，如下所示。

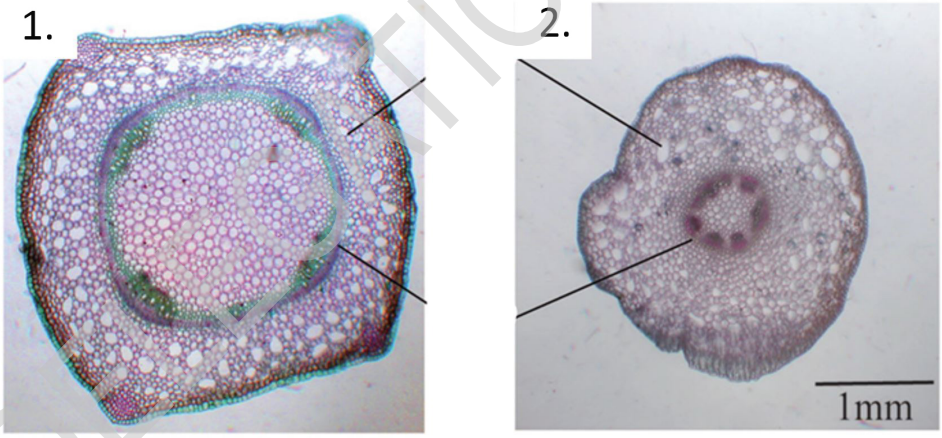


Fig.1 圖 1

Q.17.5 Match the following cross sections (1 and 2) with the two species (A and B, as specified below). Indicate your answer by putting an X in the appropriate box on the answer sheet.
A. if the species is M. scorpoides, and
B. if the species is M. aquaticus.
將圖 1 中的橫切面（1 和 2）與兩個物種（A 和 B，如下所述）相配對。在答案紙上的對應空格中，以 X 來劃記。
A. 如果物種是 M. scorpoides；
B. 如果物種是 M. aquaticus。

Q.17.6 In a sudden flood, which M. s. plants are more likely to be damaged? Indicate your answer by putting an **X** in the appropriate box on the answer sheet.
A. Growing on high nutrient soil.
B. Growing on low nutrient soil.
在一場突然的水災中，
M. s. 植物在哪種情況下較可能受損？在答案紙上的適當空格中，以 X 劃記。
A. 生長在高營養土壤中。
B. 生長在低營養土壤中。

Q18

Two transcription factors, GNC and GLK, have been implicated in regulating chloroplast development. Three mutants with different combinations of knock-out mutations in these genes were created in A. thaliana as follows: GNC or GLK only and GLC-GNK with mutations in both genes. These mutants and the wild type plant (WT) were then analysed with respect to various parameters associated with chloroplast development as shown in Figure 1. (different letters indicate significantly different values; NPQ = non-photochemical energy quenching, quantifies the ability of photosystems to dissipate excess excitation energy, higher values indicate greater ability)

兩種轉錄因子 GNC 和 GLK 與調控葉綠體的發育有關。在阿拉伯芥中，產生出三種具有這些基因剔除突變不同組合的突變體如下：在此二基因中，僅 GNC 突變、僅 GLK 突變、以及 GLC-GNK 皆突變。然後根據多種與葉綠體發育相關的變數來分析這些突變體和野生型植株（WT），結果如圖 1 所示。(圖中數值上方的不同字母表示顯著性不同；NPQ = 非光化學能猝滅，是量化之光系統耗散過多激發能量的能力，值越大表示能力越強)。

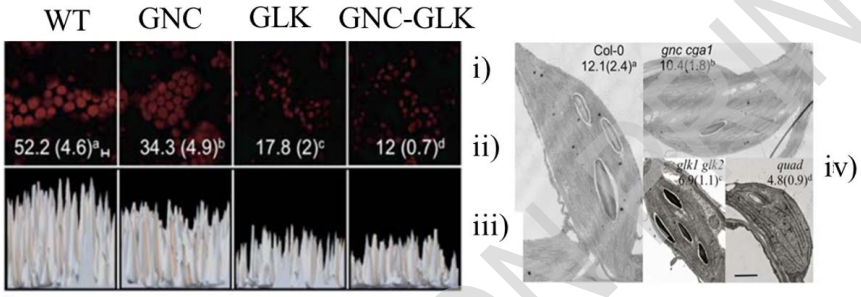


Fig.1. i) Average chloroplast fluorescence. ii) Chlorophyll a content (ng/mm2 ± SD). iii) Chloroplast relative fluorescence intensities. iv) Microscopic images of chloroplasts

圖 1. i）平均葉綠體螢光。ii）葉綠素 a 含量。iii）葉綠體相對螢光強度。iv）葉綠體的顯微圖像

Q.18.1 Select the microscopic technique used to take the images shown in Figure 1.i and Figure 1.iv. Indicate your answer by putting an X in the appropriate box on the answer sheet.
從圖 1 選出用以拍攝圖 1i 和圖 1iv 所示圖像的技術。在答案紙上的對應空格中，以 X 來劃記。
Microscopic techniques:
A. Bright-field light microscopy
B. Fluorescence microscopy
C. X-ray microscopy
D. Atomic force microscopy
E. Transmission electron microscopy
F. Scanning electron microscopy
顯微技術：
A. 明場光學顯微技術
B. 螢光顯微技術
C.X 射線顯微技術
D. 原子力顯微技術
E. 穿透式電子顯微技術
F. 掃描式電子顯微技術

Q.18.2 Which of the GLK and GNC transcription factor families is the stronger positive regulator of chloroplast development? Indicate your answer using the symbols, > or < or = in the appropriate box on the answer sheet.
在 GLK 和 GNC 轉錄因子家族中，哪個因子對葉綠體的發育有較強的正調控？在答案紙上的對應空格中，以“> “或”< “或”= " 來表示答案。

Q.18.3 Select the single best statement describing the contribution of the GLK and GNC genes to chlorophyll biosynthesis. Indicate your answer by putting an X in the appropriate box on the answer sheet.
選出一個最佳敘述來描述 GLK 和 GNC 基因對葉綠素生物合成的貢獻。在答案紙上的對應空格中，以 X 來劃記。
A. The GLK and GNC genes modify the expression of chlorophyll biosynthetic genes in separate pathways for chlorophyll biosynthesis.
GLK 和 GNC 基因在葉綠素生物合成的不同途徑中，改變葉綠素生物合成基因的表現。
B. GLK genes modify the expression of chlorophyll biosynthetic genes more upstream than the chlorophyll biosynthetic genes controlled by GNC.
相較於 GNC，GLK 基因在更上游處修飾葉綠素生物合成基因的表現。
C. GNC genes modify the expression of chlorophyll biosynthetic genes more upstream than the chlorophyll biosynthetic genes controlled by GLK.
相較於 GLK，GNC 基因在更上游處修飾葉綠素生物合成基因的表現。
D. The relative contribution of the GLK and GNC regulated chlorophyll biosynthetic genes cannot be determined based on the data above.
根據上述數據，無法確定 GLK 和 GNC 調節的葉綠素生物合成基因的相對貢獻。

Q19

Two transcription factors, GNC and GLK, have been implicated in regulating chloroplast development. Three mutants, GNC single-, GLK single-, and GNC-GLK double mutants were analysed for the expression of nine genes (PSAE-2, PSAF, PSBY,CHLM, LHCA2, LHCB3, rbcL, psaC and psbA) using reverse transcription quantitative PCR (RT-qPCR).

兩種轉錄因子 GNC 和 GLK 與調節葉綠體發育有關。使用逆轉錄定量 PCR（RT-qPCR）分析三種突變體（GNC 單突變體、GLK 單突變體和 GNC-GLK 雙突變體）中 9 種基因（PSAE-2，PSAF，PSBY，CHLM，LHCA2，LHCB3，rbcL，psaC 和 psbA）的表現。

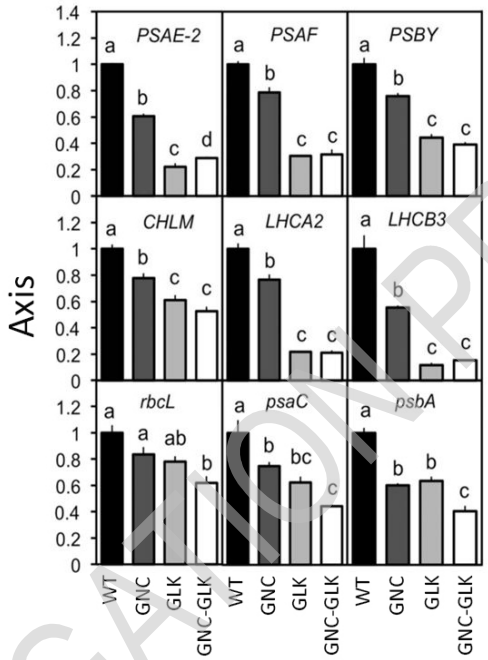


Fig.1. Axis = Relative expression. Note that different letters indicate significantly different values.

圖 1. Axis = 相對表現。注意不同的字母代表顯著不同的數值。

Q.19.1 Arrange the following experimental steps in the appropriate order and fill in the flowchart to summarise the workflow of a RT-qPCR. Put one letter in each box. You do not have to use all the letters. We already put letter A in the correct position for you.
將以下實驗步驟按照適當的順序排列，並填入流程圖，以總結 RT-qPCR 的工作流程。每個空格中填一個字母。不須用到所有字母；字母 A 已放在正確的位置。

- **A. Reverse transcribe into cDNA (complementary DNA) using reverse transcriptase**
  使用逆轉錄酶來逆轉錄成 cDNA（互補 DNA）
- B. Add primers of random sequence and DNA-dependent DNA polymerase
  添加隨機序列和 DNA 依賴之 DNA 聚合酶的引子
- C. Analyse the results by determining the number of PCR cycles needed for each sample to reach a threshold fluorescence and compare these to one another
  藉由確定每個樣品到達螢光閾值所需的 PCR 循環數來分析結果，並將它們相互比較
- D. Take plant tissue samples 採取植物組織樣本
- E. Purify total mRNA 純化總 mRNA
- F. Add a sequence-specific probe containing a quencher and a fluorophore, primers for the sequence of interest and DNA-dependent DNA polymerase
  添加含有猝滅劑和螢光團之序列專一性的探針，以及目標序列和 DNA 依賴之 DNA 聚合酶的引子
- G. Measure the fluorescence intensity at the end of the PCR amplification with a spectrophotometer
  用分光光度計測量 PCR 擴增結束時的螢光強度
- H. Purify total DNA with RNase
  用 RNase 純化總 DNA
- I. Incubate in a thermocycler under the appropriate conditions to allow for the amplification of the sequence of interest and the release of the fluorophore from the probe. Simultaneously, computationally quantify the increase in fluorescence due to the fluorophore release
  在適當條件下，在熱循環儀中培養以擴增目標序列，並從探針釋放螢光團。同時，計算測量螢光團釋放所引起的螢光增加量。
- K. Create cell lysate 製作細胞裂解液

Q.19.2 Given that GNC and GLK act as transcription factors, determine if they are positive or negative regulators of each of the the nine target genes (PSAE-2, PSAF, PSBY,CHLM, LHCA2, LHCB3, rbcL, psaC and psbA). Select the genes that are **upregulated** by GNC and GLK and indicate your answer by putting X in the appropriate boxes on the answer sheet.
以 GNC 和 GLK 作為轉錄因子，判斷它們對 9 種目標基因（PSAE-2，PSAF，PSBY，CHLM，LHCA2，LHCB3，rbcL，psaC 和 psbA）分別是正調節劑或負調節劑。選出被 GNC 和 GLK **正調節** 的基因，並在答案紙上的對應空格中，以 X 劃記。

Q20

The following question concerns the electron transport chain of photosynthesis. Note that NADP+/NADPH is at a higher free energy state than the manganese cluster of the oxygen evolving complex but lower than the central chlorophyll pair of photosystem II in the excited state.

以下問題涉及光合作用的電子傳遞鏈。注意：NADP + / NADPH 處於比在氧複合物的錳群有較高自由能的狀態，但比在激發態的光系統 II 的中央葉綠素還低。

Q.20.1 Put the following oxidised/reduced pairs in an order of increasing redox potential. Put one letter in each box on your answer sheet. We already put letter F in the correct box.
將以下氧化/還原對按照氧化還原電位漸增而排序。在答案紙的每個空格中填入一個字母；字母 F 已填在正確的空格中。

- A. Oxidised/reduced central chlorophyll pair of photosystem I in the excited state
  處於激發態之光系統 I 的氧化/還原的中央葉綠素對
- B. $NADP^+$ or NADPH
- C. Fully reduced/fully oxidised manganese cluster of the oxygen evolving complex
  氧複合物的完全還原/完全氧化之錳群
- D. Oxidised/reduced central chlorophyll pair of photosystem II in the ground state
  處於基態之光系統 II 的氧化/還原的中央葉綠素對
- E. Oxidised/reduced central chlorophyll pair of photosystem II in the excited state
  處於激發態之光系統 II 的氧化/還原的中央葉綠素對
- **F. Oxidised/reduced electron carrier Tyr residue**
  氧化/還原的電子載體之 Tyr 殘基

Q21

Not all flowers use the ABC model of genetic regulation. Nigella species have spiral flowers and variable numbers of sepals (C), petals (D), stamens (E) and carpels (F) under the control of a genetic system different from that of ABC. In an experiment (Fig.1) Genes involved in flowering (leftmost column) were silenced and their morphology was assessed. The number of each organ (C-F) was measured and results are indicated in the bar charts (right column). Bar G shows the sum of all the numbers (C-F).

並非所有的花都使用基因調控的 ABC 模式。Nigella 屬的物種在不同於 ABC 的遺傳系統的控制下，具有螺旋排列的花和不同數量的萼片（C），花瓣（D），雄蕊（E）和心皮（F）。在實驗中，圖 1 涉及開花的基因（最左側）被靜默並檢視它們呈現的形態。測量每個器官（C-F）的數量，並顯示在條狀圖的右側。條狀圖 G 顯示出所有數字（C-F）的總和。

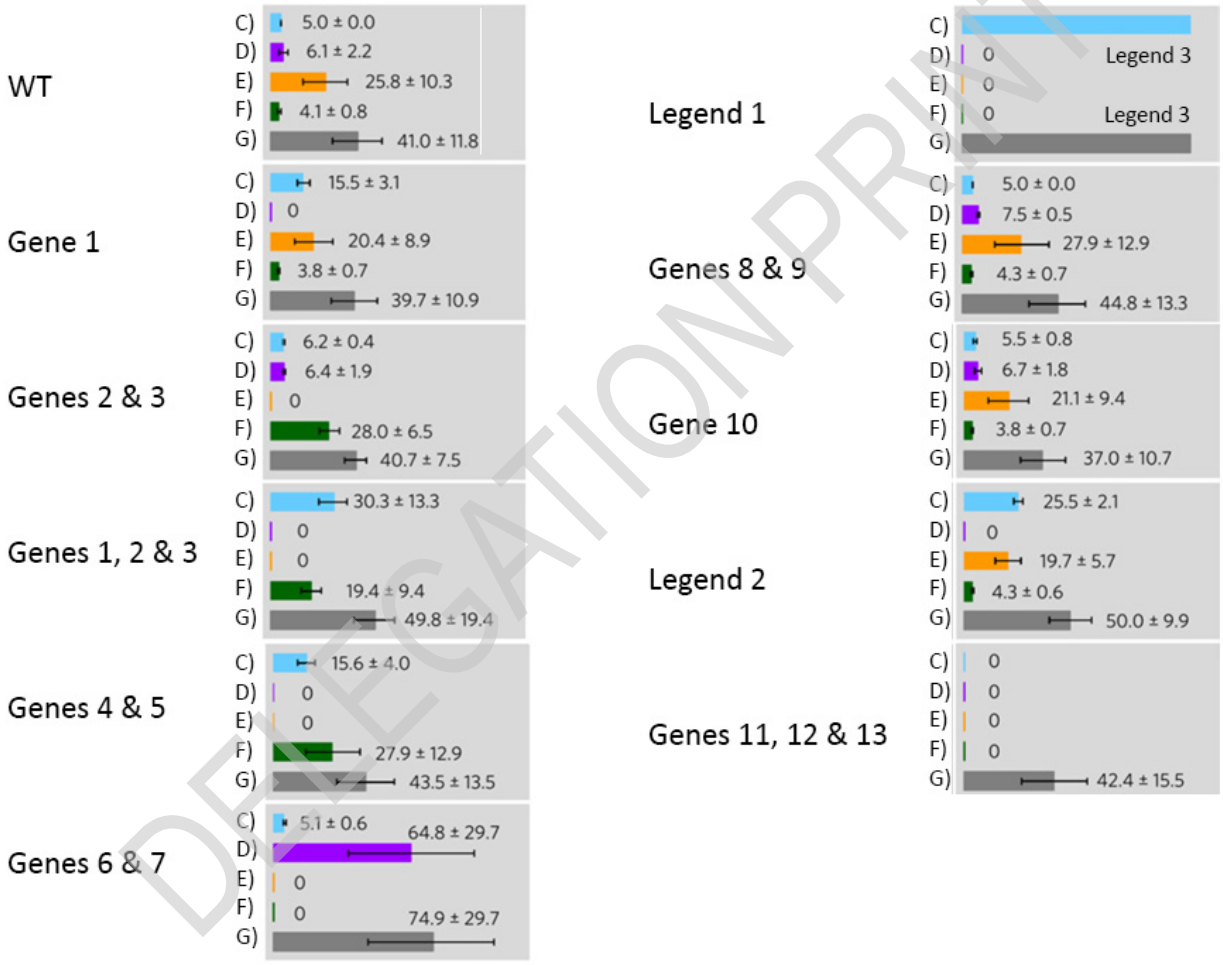
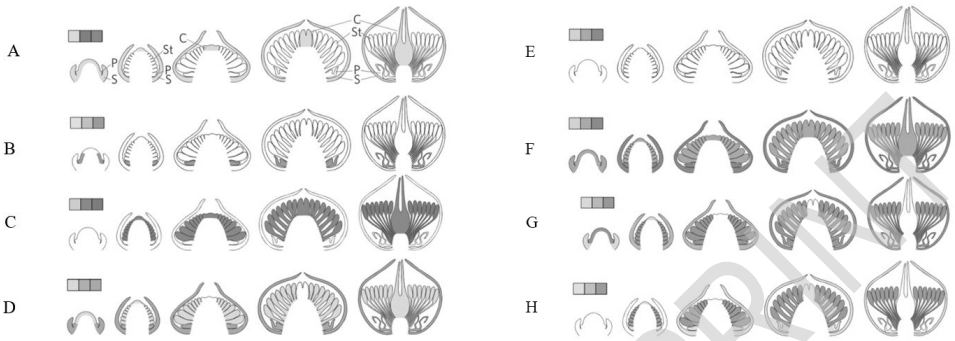


Fig.1. WT = Wild-type. Legend 1 = Naturally occurring gene 1 KO mutant + genes 6 and 7 silenced. Legend 2 = Naturally occurring gene 1 KO mutant + gene 10 silenced. Legend 3 = Countless

Fig.1. WT = 野生型；Legend 1 = 天然存在的基因 1 剔除突變體 + 基因 6 和 7；Legend 2 = 天然存在的基因 1 剔除突變體 + 基因 10；Legend 3 = 不可數

Q.21.1 Each gene is expressed according to one of the following patterns (darker = more expression). Match the genes (1-13) with the patterns (A-H). Indicate your answer with an **X** in the appropriate boxes on the answer sheet. Each letter is only used once!
每個基因根據下列模式中的一種方式表現（較暗 = 表現較多）。將基因（1-13）與模式（A-H）配對。在答案紙上的適當空格中，填入 X 來代表你的答案。每個字母只使用一次！



Q22

Venation and size of leaves are important factors influencing plant physiology. Veins can be categorised hierarchically into four groups: midvein (1°), secondary (2°), tertiary (3°) and quaternary (4° or minor veins) as indicated by arrows on Figure 1. Scaling between vein density (= vein length per total leaf area) and leaf area as well as vein diameter and leaf area were determined for 500 species of dicotyledons. [● = data from species with branched veins; ◦ = data from species with parallel veins]

葉片的脈相和大小是影響植物生理的重要因素。葉脈依層次可分為四組：主脈 (1°)、次級脈 (2°)、三級脈 (3°) 和四級脈 (4° 或小脈)，如圖 1 中的箭頭所示。從 500 種雙子葉植物中量測 葉脈密度（= 葉總面積下的葉脈長度）和葉面積之間的比例，以及葉脈直徑和葉面積之間的比例。[實心點 = 來自具有分支葉脈的物種之數據；空心點 = 來自具有平行葉脈的物種之數據]

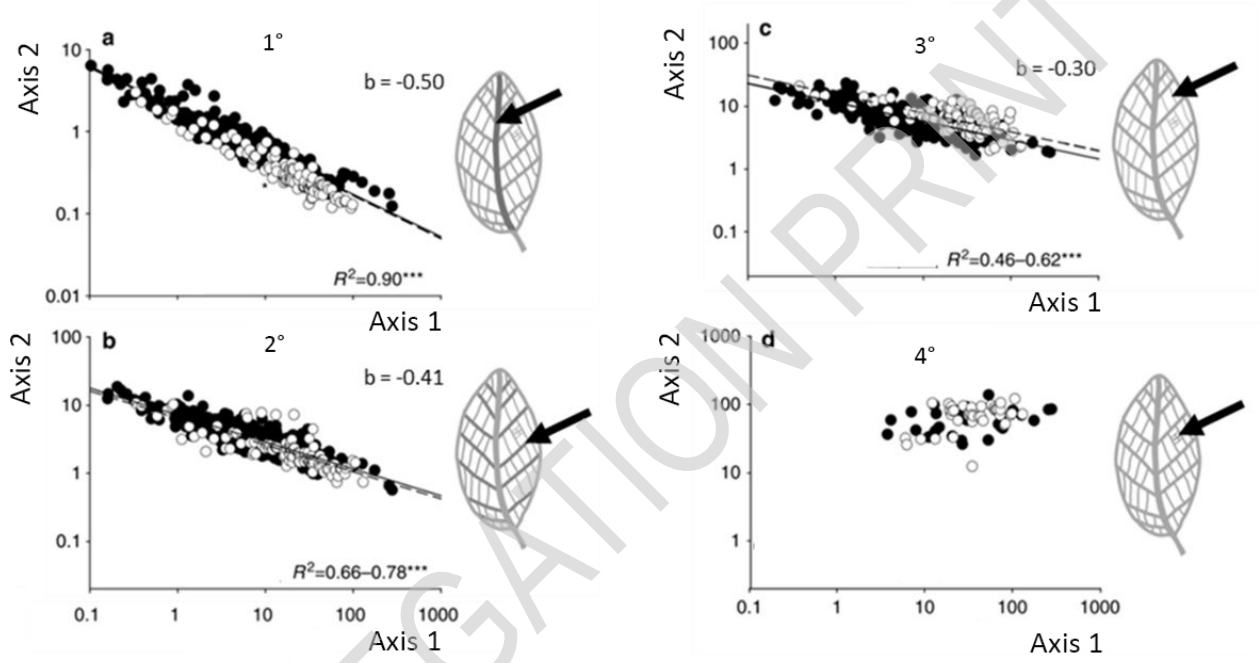


Fig.1. Axis 1 = Leaf area (cm^2). Axis 2 = Vein density (= vein length per leaf area; $cm \cdot cm^{-2}$).

Axis 1 = 葉面積；Axis 2 = 葉脈密度（= 葉面積下的葉脈長度；cm⊠cm－2）

Based on these data, a model was created (Figure 2) which is generally true for most of the species examined. It details the change of various structural features during the development of a dicotyledonous leaf.

根據這些數據，建構出一個模式（圖 2），適用於大多數檢視的物種。它詳細描述了雙子葉葉片發育過程中各種構造特徵的變化。

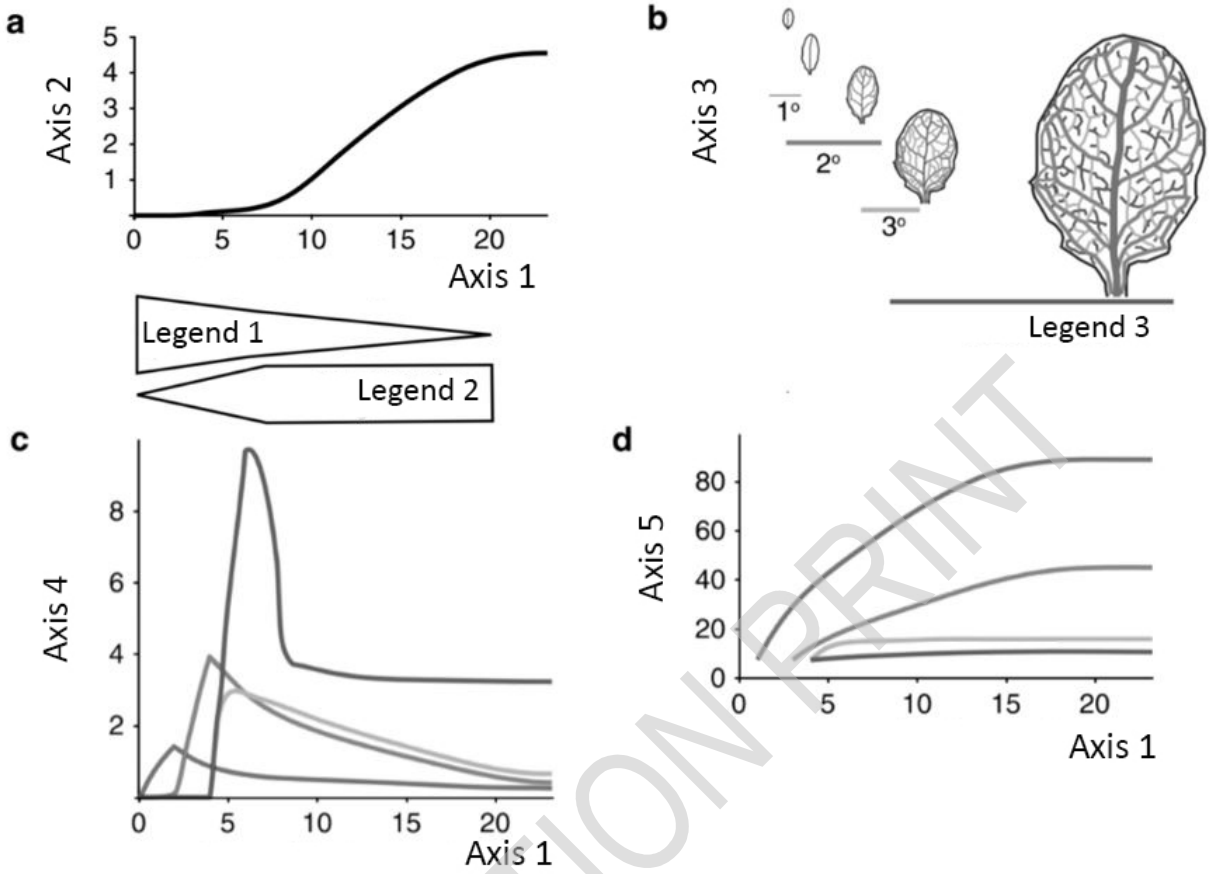


Fig.2. Axis 1 = Days of leaf expansion. Axis 2 = Leaf area (cm^2). Axis 3 = Vein development. Axis 4 = Vein density ($mm \cdot mm^{-2}$). Axis 5 = Vein diameter (mm). Legend 1 = Cell division growth. Legend 2 = Cell expansion growth. Legend 3 = Minor veins.

Fig.2. Axis 1 = 葉片平展的天數. Axis 2 = 葉面積 (cm^2). Axis 3 = 葉脈發育. Axis 4 = 葉脈密度 ($mm \cdot mm^{-2}$). Axis 5 = 葉脈直徑 (mm). Legend 1 = 細胞分裂之生長. Legend 2 = 細胞擴大之生長. Legend 3 = 小脈.

Determine the relationship between the following pairs (A and B). Indicate your answer on the answer sheet by using the symbols > or < or =.

判斷下列組對（A 和 B）之間的關係。在答案紙上，以”>“或”<“或“=“指出答案。

Q.22.1 A. Vein density scaling with leaf surface area for midvein and 2°.
B. Vein density scaling with leaf surface area for 3° and 4°.
A. 對於主脈和次級脈，葉脈密度和葉面積之間的比例。
B. 對於三級脈和四級脈，葉脈密度和葉面積之間的比例。

Q.22.2 A. Vein density scaling with leaf surface area in species with branched veins.
B. Vein density scaling with leaf surface area in species with parallel veins
A. 具有分枝葉脈的物種中，葉脈密度和葉面積之間的比例。
B. 具有平行葉脈的物種中，葉脈密度和葉面積之間的比例。

Q.22.3 Identify how density of veins of different hierarchical levels change over time and label Fig.2.c below accordingly. Match the letters below (A-D) with the appropriate roman numeral on your answer sheet. Indicate your answer by putting an X in the appropriate box on the answer sheet.
確定不同層次葉脈之密度如何隨時間而改變，並對應標出圖 2.c 中所代表的曲線，將下面的字母（A-D）與答案紙上的羅馬數字配對。在答案紙上的對應空格中，以 X 來劃記答案。
A. 1° veins
B. 2° veins
C. 3°veins
D. Minor veins

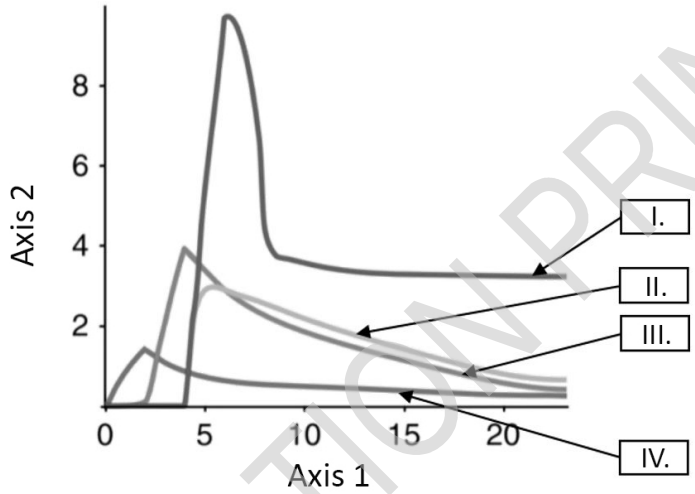


Fig.3. Axis 1 = Days of leaf expansion. Axis 2 = Vein density ($mm \cdot mm^{-2}$)

Fig.3. Axis 1 = 葉片平展的天數. Axis 2 = 葉脈密度 ($mm \cdot mm^{-2}$)

Genetics and Evolution 遺傳與演化

Q23

The gene that determines red or black fur colour is X chromosome linked. During female embryonic development one of the two parental copies of chromosome X becomes inactivated. If a female cat inherits different alleles from its parents, we can observe the mosaicism. For example, if the maternally derived X chromosome becomes inactivated and the paternally remains active such cells form black patches on the cat’s coat. If the paternally derived X chromosome becomes inactive and the maternally derived remains active such cells form red patches. (The white patches originate through a different mechanism.)

決定紅色或黑色皮毛顏色的基因是 X 染色體連鎖的基因。在雌性胚胎發育期間，兩個親本拷貝來源的 X 染色體之其中一個發生失活現象。如果雌性貓從其父母那裡繼承了不同的等位基因，我們將會觀察到毛髮鑲嵌現象。例如，如果母系來源的 X 染色體失去活性而父系來源 X 染色體保持活性，則在此貓的毛皮的細胞則形成黑色斑塊。如果父系來源的 X 染色體失去活性而母系來源 X 染色體保持活性，則此貓的毛皮的細胞則形成紅色斑塊。(白色斑塊的來源為由不同的機制產生。)

Fig. 1 Kittens 各種毛色的小貓

You have a list of possible observations regarding the inheritance of red/black coat colour:

A. There are no smaller red spots in the middle of the large black spots or vice versa.

B. Black spots are predominantly located towards the back of the animals

C. The mosaic spots are large.

D. The red/black spot boundaries are sharp.

E. The feet of the cats are usually white.

F. The distribution of spots in different cats is very variable.

你有一個有關紅/黑色毛髮顏色遺傳的可能觀察列表：

A. 大黑點中間沒有較小的紅點，反之亦然。

B. 黑點偏向分布於動物的背部。

C. 大型鑲嵌斑點塊。

D. 紅色/黑色毛髮斑點界線明顯。

E. 貓的腳通常是白色的。

F. 不同貓的斑點分佈變化很大。

Match the conclusions (Q23.1-4) with one of the observations listed above. Only one letter should be matched with one conclusion and one letter may only be used once. Indicate your answer by putting an X in the appropriate box on the answer sheet.

將 (Q23.1-4) 結論與上面列出的觀察結果其中之一相配對。只有一個字母應與一個結論相配對，且每一個字母只能使用一次。在答案紙上的相對應方框中輸入”X”來代表你的答案。

Q.23.1 X chromosome inactivation takes place during early embryogenesis.
X 染色體失活發生在早期胚胎發生期間。

Q.23.2 Inactivation of the maternal or paternal X chromosome is a random event.
母系或父系 X 染色體的失去活性是隨機發生。

Q.23.3 X chromosome inactivation is irreversible.
X 染色體失去活性是屬於不可逆的。

Q.23.4 X chromosome inactivation is a cell autonomous process, i.e. the neighboring cells do not influence it.
X 染色體失去活性是細胞自主發生，即相鄰細胞不會互相影響。

Q24

Carolyn does not know who the father is of her daughter Lucy. She knows that the father is one of the five members of the Happening rock band. You collected DNA samples from the seven people listed in the table and analyzed five (A through E) of the VNTR sequences. (The VNTRs - variable number tandem repeats - are DNA sequences present in variable number of tandemly arranged copies in both autosomes and sex-chromosomes) The figures in the table represent the number of copies in the different VNTRs.

卡羅琳 (Carolyn) 不知道她女兒露西 (Lucy) 的父親是誰。她只知道他女兒的父親是”Happening 搖滾樂隊”的五位成員其中之一。你收集了表中所列 7 個人的 DNA 樣本，並且分析了 5 個 VNTR 序列 (A 到 E)。(VNTRs - 可變數目串聯重複序列 - 是在體染色體和性染色體中具有可變數量的串聯排列的拷貝存在的 DNA 序列) 表中的數字代表不同 VNTR 中的拷貝數。

VNTR	Carolyn	Lucy	Frank	Conrad	Andrew	Bill	Lewis
A	7 + 8	2 + 7	3 + 3	5 + 7	2 + 8	3 + 7	2 + 3
B	4 + 5	4 + 6	4	7	6	4	6
C	11 + 18	9 + 11	9 + 10	8 + 13	10 + 11	9 + 12	9 + 13
D	7 + 19	7 + 21	7 + 21	9 + 15	7 + 21	8 + 15	15 + 21
E	6 + 10	6 + 12	6 + 9	9 + 12	17 + 17	6 + 12	12 + 17

Table 1

表格 1

Q.24.1 Indicate Lucy’s father with an **X.** 用”X”表示來指出露西的父親
A. Frank
B. Conard
C. Andrew
D. Bill
E. Lewis

Q.24.2 Carolyn and Frank have a son called Rupert. List all possible VNTRs copy numbers Rupert can have at the analysed VNTR loci (A-E). Treat the rows independently from one another. If an individual has two alleles of a specific VNTR locus, the number of repeats in each allele should be indicated with a ‘+’ sign between them.
卡羅琳 (Carolyn) 和弗蘭克 (Frank) 有一個叫魯珀特 (Rupert) 的兒子。列出魯珀特 (Rupert) 在分析的 VNTR 基因座（A - E）中可能具有的所有可能出現的 VNTR 拷貝數。把每個橫列視為獨立。如果一個個體具有特定 VNTR 基因座的兩個等位基因，那麼每一個等位基因的重複數用 “+” 符號表示。

Q25

The EcoRI restriction enzyme recognizes the 5’ G*AATTC3’ nucleotide sequence and cuts the DNA at the “*” site. You have a plasmid preparation with billions of copies of a plasmid composed of 1.3×10^4 base pairs. Let’s assume that the sequence of base pairs is random in the plasmid DNA.

EcoRI 限制酶辨識區域為 5’ G * AATTC 3’ 核苷酸序列，並在“*”位點切割 DNA。你有一個含有數十億拷貝數量、大小為 1.3×10^4 含氮鹼基的質體。假設鹼基對的序列在質體 DNA 中是隨機的。

Q.25.1 On average, how many DNA fragments form following the digestion of the plasmid DNA by the EcoRI restriction enzyme? Give your answer rounded to the nearest integer.
平均而言，EcoRI 限制酶分解質體 DNA 後，會形成多少個 DNA 片段？請以最接近整數來代表你的答案。

Q26

A single base pair deletion mutation occurred in a short gene, which changes the MATE peptide’s amino acid sequence to MATEK. The peptide sequence is given based on the one letter codon table. You can find the original peptide and nucleotide sequence below, but some nucleotides are missing.

在一短基因中發生單一鹼基對缺失突變，導致 MATE 胜肽的胺基酸序列改變而成為 MATEK 胜肽。請依據單字母密碼子表列出胜肽序列。你可以在下面找到原始的胜肽和核苷酸序列，但其中缺少一些核苷酸。

PS	M			A			T			E			(STOP)							
NS	A	T	G	G	C	T	A	C	T	G	A	A	T	*1*	*2*	*3*	*4*	G	*5*	

Fig.1. Original sequence. PS = Peptide sequence. NS = Nucleotide sequence.

圖.1. 原始序列。PS = 胜肽序列。NS = 核苷酸序列。

Q.26.1 Give the letter of the missing nucleotides (1-5). If in any one position more than one type of nucleotide can occur, give only one of them.
填入缺失核苷酸的字母（1-5）。如果在任何一個位置可以出現多於一種類型的核苷酸，則只需寫出其中一種。

Q27

Karolyn and Fred visit your genetic counselling office. They tell you the data summarized in the table. You aware of the fact that:

Karolyn 和 Fred 拜訪你的遺傳諮詢辦公室。他們告訴你表中匯整的資料。你注意到這樣的事實：

(i) the absence of patella is caused by the dominant mutation Np (Nail-patella).

髕骨的缺失是由 Np(Nail-patella) 顯性突變所引起的。

(ii) The Np mutant allele (and of course the Np^+ wild-type gene) and the ABO blood group gene (with alleles I^A, I^B and i) are inherited on chromosome 9 and are 18 cM apart.

Np 突變等位基因 (當然還包括 Np^+ 正常基因) 和 ABO 血型群基因 (分別為 I^A, I^B 和 i) 皆位於第 9 號染色體，其中相距 18cM。

Person 人	Does she/he have patella? 她/他有髕骨嗎？	Blood group 血型群
Karolyn	No	B
Karolyn’s mother Karolyn 的媽媽	Yes	B
Karolyn’s father Karolyn 的爸爸	No	0
Fred	Yes	0
Fred’s mother Fred 的媽媽	Yes	A
Fred’s father Fred 的爸爸	Yes	0

Determine Karolyn’s and Fred’s genotypes. The alleles on one side of ‘/’ sign are linked. (For example, in case of $Np\,i$ / $Np^+\,I^A$ genotype, Np and i alleles are linked and Np^+ and I^A alleles are linked.)

請決定 Karolyn 和 Fred 的基因型。“/”符號同一側的等位基因是互相連鎖的。(例如：如果是 $Np\,i$ / $Np^+\,I^A$ 基因型，Np 和 i 對偶基因是互相連鎖的、Np^+ 和 I^A 對偶基因是互相連鎖的。)

Q.27.1 What is Karolyn’s genotype? Indicate your answer with an **X**.
Karolyn 的基因型是什麼？請用”X”來表示你的答案。
A. $Np\,I^B$ / $Np\,I^B$
B. $Np\,I^B$ / $Np^+\,i$
C. $Np\,I^B$ / $Np\,i$
D. $Np^+\,I^B$ / $Np\,i$
E. $Np^+\,i$ / $Np\,I^B$

Q.27.2 What is Fred’s genotype? Indicate your answer with an X. Fred 的基因型是什麼？請用”X”來表示你的答案。
A. $Np\,i$ / $Np\,i$
B. $Np^+\,i$ / $Np^+\,i$
C. $Np^+\,i$ / $Np^+\,I^A$
D. $Np\,i$ / $Np^+\,I^A$
E. $Np^+\,I^A$ / $Np^+\,I^A$

Q.27.3 Karolyn is pregnant and Fred is the father. Her foetus has blood group B. Add the probability in percentage that her child will have no patella.
Karolyn 懷孕了，而且 Fred 是孩子的爸。她的胎兒為 B 血型。請算出她孩子沒有髕骨的機率百分比。

Q28

The a, the b and the c recessive mutations (with the corresponding a^+, b^+ and c^+ wild-type alleles) are linked in an autosome, i.e. they belong to the same linkage group. From a genetic cross in which females heterozygous for the a, the b and the c recessive mutations were mated with males that were homozygous for a, b and c the following phenotypic offspring emerged (with the number of offspring):

a 、b 和 c 為在體染色體上互相連鎖的隱性突變 (相對於野生型的顯性突變)，即它們屬於相同的連鎖群。從遺傳交配實驗，其中具有 a、b 和 c 隱性突變的雌性異型合子與具有 a、b 和 c 隱性突變的雄性同型合子進行交配，出現了以下外表型後代 (具有後代數目)：

ab^+c –40;

abc^+ –12;

$a^+b^+c^+$ –3;

a^+b^+c –13;

ab^+c^+ –20;

a^+bc^+ –41;

a^+bc –19;

abc –2.

Q.28.1 What is the sequence of the genes? Choose the letter of the correct sequence! 下列何者是這三個基因的次序？選擇正確排列次序的字母！
A. a-b-c
B. a-c-b
C. b-a-c

Q.28.2 Indicate double recombinant offspring phenotypes with an **X**, and all other phenotypes with **O.** 用”**X**”來表示雙基因重組的後代外表型，用”**O**”來表示所有其他的外表型。

Q.28.3 Determine in cM units the distance between the given gene pair. Round your answer to the nearest integer.
以 cM 為單位來決定給定基因對之間的遺傳距離。以最大接近整數來回答這個問題。
b - c

Q29

A solution of linear DNA with billions of copies of the same sequence was distributed into eight equal samples. The samples were digested with the restriction enzymes as indicated in the top of the figure. All samples were loaded on a gel for size determination by gel electrophoresis. The figure shows the results of gel electrophoresis. The numbers give the number of base pairs (in thousands) of the fragments. Please construct restriction map (also called physical) of the studied DNA by placing the so-called restriction sites of the three enzymes on the line on the answer sheet The restriction map shows potential positions (boxes above the line) of the restriction sites (i.e. the positions where the restriction enzymes cut the DNA). Indicate which box represents which restriction site. Not all box represents actual restriction sites! Please notice that one of the bands in the ”All three” lane is twice as thick as any of the others. All digestion was complete.

將具有數十億拷貝之相同序列的線性 DNA 溶液分配至 8 個相同的樣品中。這些樣本使用如圖之頂部所示之限制酶進行切割，圖上數字代表 DNA 片段的鹼基對數 (以千為單位)。請在答案紙上的線上放置三種限制酶的限制酶切割位點來建構所研究之 DNA 的限制酶切割 (也稱為物理性) 圖譜。限制酶切割圖譜顯示限制酶切割位點的潛在位置 (線上方的框)(即限制酶切割 DNA 的位置)。指出哪個方框表示哪個限制酶切割位點。並非所有方框都代表實際限制酶切割位點！請注意，在“全三”道中的一個條帶的厚度是其他條帶的兩倍。所有切割都完成了。

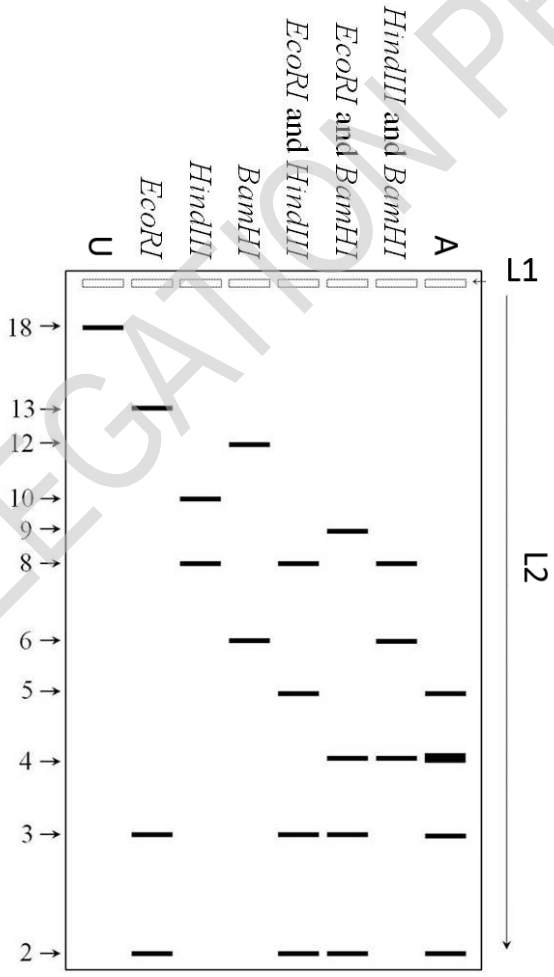


Fig.1. U = Undigested. A = All three. L1 = Pockets. L2 = Direction of gel electrophoresis

圖.1. U = 未切割。A = 全部三個。L1 = 凹穴。L2 = 凝膠電泳的方向

Q.29 Indicate which box represent which restriction site. Use the following notation:
E –EcoRI restriction site
H –HindIII restriction site
B –BamHI restriction site
X –no restriction site here

指出哪個方框代表哪個限制酶切割位點。使用以下表示法：

E - EcoRI 限制酶切割位點
H - HindIII 限制酶切割位點
B - BamHI 限制酶切割位點
X - 這裡沒有限制酶切割位點

Q30

DNA constantly accumulates mutations both during development and adult life, therefore several pathways exist which are meant to repair these damages. People with mutations in an autosomal gene encoding a DNA repair enzyme acquire more mutations in all chromosomes, including the X and Y chromosomes. However, the Y chromosome has fewer essential genes compared with the X chromosome. Three hypothetical couples are presented on your answer sheet.

DNA 在發育和成年時期不斷積累突變，因此存在多種可以修復這些損傷的途徑。人們具有一體染色體之 DNA 修復酶的突變，導致在所有染色體上產生了更多的突變，包括在 X 和 Y 染色體，和 X 染色體相比，Y 染色體具有更少的必需基因。在你的答案紙上有三對假設的夫妻。

Dr = homozygous mutant individuals, + = wild-type, M = male, F = female.

Dr = 同型合子突變個體，+ = 野生型，M = 雄性，F = 雌性。

Q.30 Indicate the expected relative number of female (F) versus male (M) offspring these couples may have surviving into adulthood. Use the following symbols in the cells provided: =, <, >.
指出這三對夫婦可能存活到成年期的女性 (F) 與男性 (M) 後代的預期相對數量。在下列提供的單元格中使用以下符號：=，<，>。

Ecology 生態學

Q31

The introduced black pines have displaced some dolomite rock grasslands in Hungary. Due to the shadowing effect of the pine trees and to the substances leached out of the litter layer, these pine forests almost completely changed the originally rich flora of rock grasses. In the 0th year of the experiment, forest fires devastated black pines in the Buda Mountains. Researchers wanted to find out whether the original rock grass community would be restored.

引進的黑松已經在匈牙利取代一些白雲石草原。由於松樹的遮蔭效果和從枯枝落葉層中釋出的物質，這些松林幾乎完全改變了原始豐富的岩生草叢植相。在實驗的第 0 年，森林火災摧毀了布達山脈的黑松。研究人員希望了解原始的岩生草原群落是否會因此復原。

Number of species (Figure 1A) and % coverage over time (Figure 1B) was measured. Sites in the burnt area on the North (N) and South (S) slopes of the mountains and also natural rocky grasslands as controls (NC & SC) were compared. They monitored the areas (except control) for 10 years.

他們測量物種數 (圖 1) 和隨時間變化的覆蓋率%(圖 2)。在山的北 (N) 和南 (S) 坡的燒焦區域及作為對照 (NC\ 和 SC) 的天然岩石草原的地點進行了比較。他們監測該區 (控制組除外) 長達 10 年。

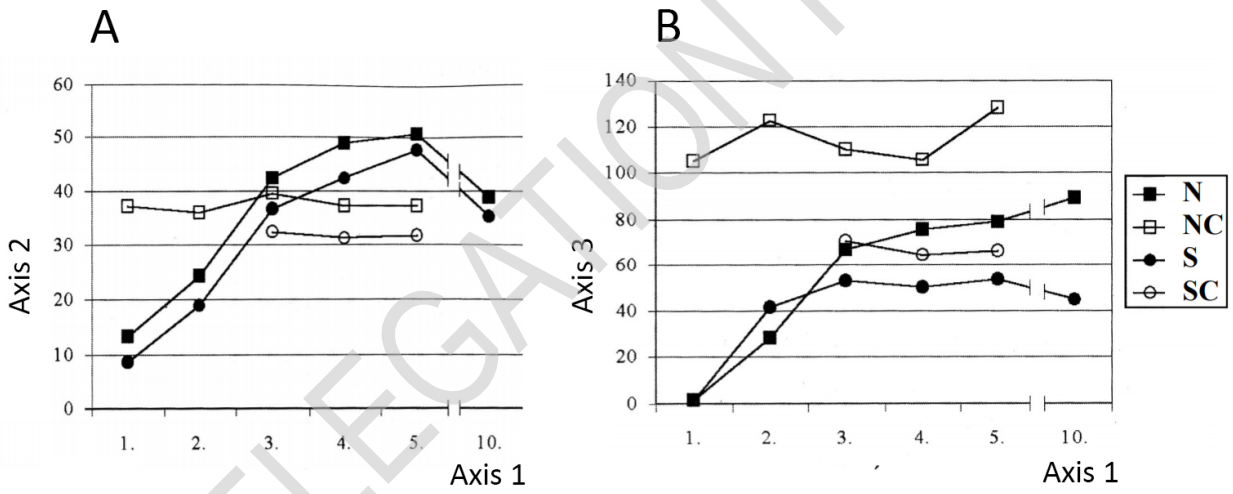


Fig.1. A = Average number of species found in the sampling squares. B = Average cumulative percentage of the area covered by plants. Axis 1 = Year. Axis 2 = Number of species. Axis 3 = Percentage

圖 1。採樣方格中找到的平均物種數。圖 2. 植物覆蓋面積的平均累積百分比。Axis1 = 年。Axis2 = 物種數（pcs）。Axis3 = 百分比

During the process researchers could detect different changes in the composition of plant community, which is shown in Figure 2.

在此過程中，研究人員可以檢測到植物群落組成的不同變化，如圖 2 所示。

Fig. 3

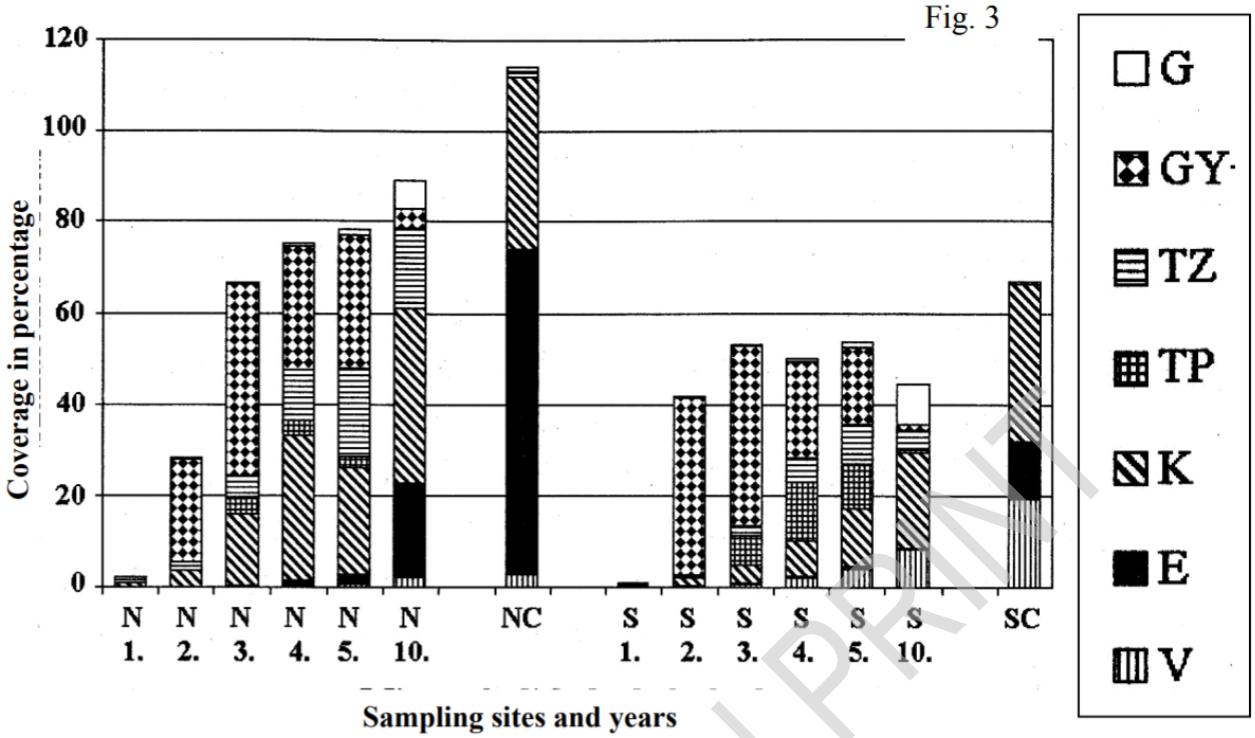


Fig.2. Composition of Plant Community. Axis 1 = Sampling sites and years. NC = northern control area. SC = southern control area. G = Economical plants (mainly black pine here). GY = Weed plants (heavy disturbance-tolerant, often invasive species); TZ = Natural (weak) disturbance-tolerant species. TP = Pioneer species (first colonialists on the parent rock). K = Accompanying species. E = Dominant species of the community. V = Protected species

圖 3。植物群落的組成。軸 1 = 採樣點和年份。NC = 北控制區。SC = 南控制區。G = 經濟植物（主要是黑松）。GY = 雜草植物（重度抗擾性，通常是入侵物種）; TZ = 自然（弱）抗擾種。TP = 先驅物種（母岩上的第一批拓殖植物）。K = 伴生物種。E = 群落中的主要物種。V = 受保護物種

What can be the cause of the species richness drop between year 5 and 10? Indicate with an **X** if each the following statements are true (T) or false (F).

5 到 10 年間物種豐富度下降的原因為何？指出下列敘述何者為真（T）或假（F），用 X 表示。

Q.31.1 The invasive weeds suppressed the native species.
入侵性雜草抑制了本地物種。

Q.31.2 The competition between the plants grew stronger between year 5 and 10 so the weak competitor species have disappeared.
植物間的競爭在 5 到 10 年間變得更強烈，因此弱勢競爭物種已消失。

Q.31.3 The soil ran out of nutrients which caused a plant biomass decrease which caused the decline of the species number.
土壤缺乏營養物質，導致植物生物量減少，進而造成物種數下降。

Q.31.4 The main cause can be the almost complete disappearance of weeds.
主要原因可能是雜草幾乎完全消失。

Q.31.5 The cause of the decline in species number is a stronger competition between plants than in natural grasslands.
物種數下降的原因顯示植物間的競爭比天然草地時更強。

Q32

Population dynamics models can be used to predict changes in population size. The Beverton-Holt model assumes discrete (not overlapping) generations. The model is given below:

種群動態模型可用於預測種群大小的變化。Beverton-Holt 模型假定分離（不重疊）世代。該模型如下：

$$N_{t+1} = \frac{BN_t}{1 + \alpha N_t^m}$$

N_t: The population size (number of individuals) in generation t.

Nt：世代 t 中的族群大小（個體數量）。

N_{t+1}: The population size (number of individuals) in the next generation (generation t+1).

Nt+1：下一代的族群大小（個體數量）（第 t + 1 代）。

B: The maximal growth of population size per individual.

B：族群平均個體的最大增長量。

α, m: Parameters that determine the effect of population size on per-capita rate of increase.

α, m：影響並決定族群平均個體增長率的參數。

One of the advantages of the Beverton-Holt model is that it can describe both exponential and logistic growth (growth which slows to a plateau) depending on the value of the parameters.

Beverton-Holt 模型的一個優點是它可以根據參數的值來描述指數和對數增長（增長漸放緩最終達到高原）。

Q.32.1 You can change the model to produce exponential growth by setting only one of the parameters B, α or m to a fixed value. There may be more than one option for this. State the parameters which must be fixed and the value or values they may take. Find all the possible parameter sets. Write the letter of the parameter(s) to column A and the value(s) to column B in the table in the Answer Sheet. Mark any potential unused cells with an **X**.
你可藉著僅設定其中一個參數 B，α 或 m 值來更改模型以產生指數成長。這可能有多個選項。說明必須固定的參數以及它或它們可能被採用的值。找到所有可能的參數組合。將參數的符號及數值分別填寫在答案卷上的表中 A 和 B 列。使用 X 標出任何可能會但未使用的單元格。

Q.32.2 The equilibrium population (N_{eq}) is a population size which remains constant with time. How can the equilibrium population size be calculated using the Berverton-Holt model? Indicate your answer with an **X.**
族群達到平衡 (Neq) 是一個族群的數量在任何時間內皆保持恆定。如何使用 Berverton-Holt 模型來計算平衡族群大小？用 X 表示你的答案。

A. $N_{eq} = \sqrt[m]{\frac{B-1}{\alpha}}$

B. $N_{eq} = \frac{\frac{m\sqrt{N_t}}{\alpha}-1}{B}$

C. $N_{eq} = \sqrt[m]{\frac{\alpha+1}{B}}$

D. $N_{eq} = \sqrt{\frac{B-1}{\alpha}}$

E. $N_{eq} = (\frac{\alpha+1}{B})^m$

Q33

A dolina is type of sinkhole common in Hungary home to important species. The goal of an experiment was to determine how the size of the dolina affects species richness in the Mecsek Mountains (Figure 1) and Aggtelek Karst (Figure 2). A = all species. B = Beech forest species (like average temperature conditions with plenty of rain). C = oak forest species (like warmer and drier conditions). D = cool environment specialists.

Dolina 是匈牙利常見的一種下陷坑型的地型，也是許多重要物種的家園。本實驗的目的是要了解 dolina 的大小如何影響 Mecsek 山脈（圖 1）和 Aggtelek Karst（圖 2）的物種豐富度。A = 所有物種。B = 山毛櫸林物種（均溫條件及有大量降雨）。C = 橡樹林物種（溫暖和乾燥的條件）。D = 特別適應涼冷環境的物種。

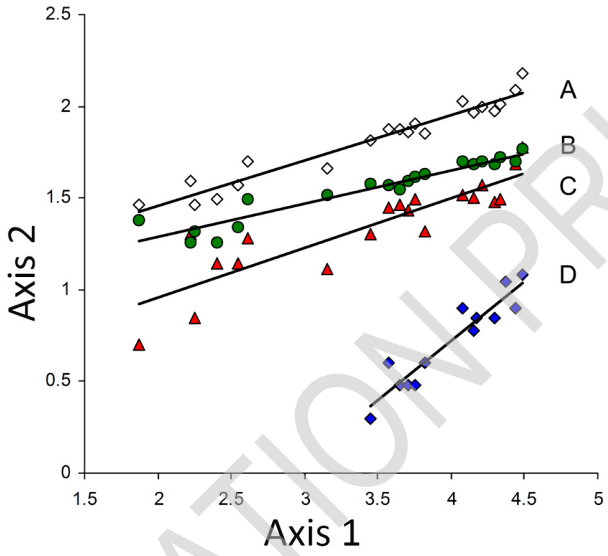


Fig.1. The correlation between the area of the dolina and the species richness in the Mecsek Mountain. The values of the axes are in $\log_{10}$ transformed. Axis 1 = log area (m^2). Axis 2 = log species richness

圖。1。dolina 面積與 Mecsek 山區物種豐富度之間的相關性。軸的數值係 log10 的轉化。Axis1 = 對數區域（m2）。Axis2 = 對數種類

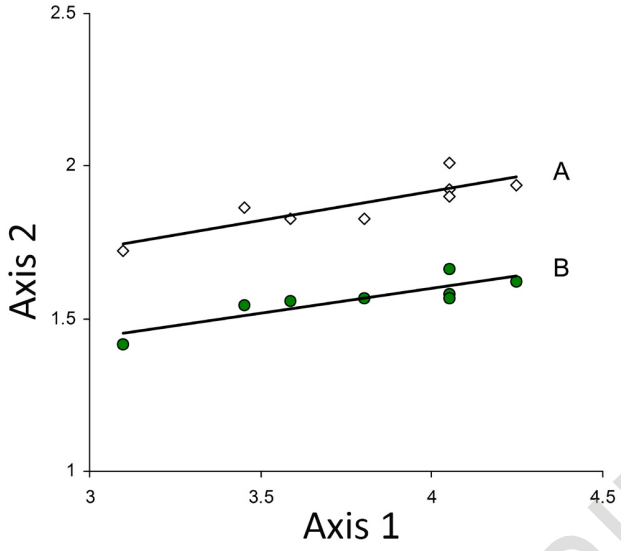


Fig.2. The correlation between the area of the dolina and the species richness in the Aggtelek Karst. The values of the axes are in log10 transformed. Here the oak forest and cool-adapted species are not shown separately, because there was no significant correlation between their species richness and the size of the dolina. Axis 1 = log area (m^2). Axis 2 = log species richness

圖 2。Dolina 面積與 Aggtelek 喀斯特地區物種豐富度之間的相關性。軸的值係 log10 轉化。橡樹林和涼冷適應的物種，在此處沒有單獨顯示，因為它們的物種豐富度和 dolina 的大小之間沒有顯著的相關。Axis1 = 對數區域（m2）。Axis2 = 對數種類

Indicate with an **X** if each the following statements are true (T) or false (F).

指出以下敘述何者為真（T）或假（F），用 X 表示。

Q.33.1 In the Mecsek Mountains the number of cool-adapted species grows faster with increasing dolina size, than the number of all species.
在 Mecsek 山區，適應涼冷物種的數量隨著 dolina 面積的增加，與所有物種相比，其生長得更快。

Q.33.2 According to the data below a certain dolina size, no cool-adapted plant was found.
根據數據，低於一定的 dolina 面積，則無適應涼冷環境的植物。

Q.33.3 The proportion of beech forest species relative to all species increases with increasing dolina size in the Aggtelek Karst.
在阿格泰萊克喀斯特地區，山毛櫸林物種相對於所有物種的比例隨著 dolina 面積的增加而增加。

Q.33.4 The number of beech forest species compared to all is affected by dolina size but not by geographic location
山毛櫸森林物種的數量與所有的物種相比，是受到 dolina 面積的影響，但與地理位置無關

Q.33.5 Regardless of size, every dolina plays an equally important role in conservation of rare plant species.
無論大小如何，每個 dolina 在保護珍稀植種方面都扮演著同樣重要的角色。

Q.33.6 Most of the examined Mecsek Mountains dolinas are in oak forest covered areas.
大部分被檢視的 Mecsek Mountains dolinas 都在橡樹林覆蓋的地區。

Q.33.7 According to the data, the bigger dolinas have positive effect only to the cool-adapted plants.
根據數據，較大的 dolinas 僅對涼冷適應植物有正向作用。

Q34

Scientists studied how abandoned agricultural fields become mature grassland through succession. They studied lands which were partly colonised by species from surrounding natural grasslands. They classified the plots of lands into those colonised mainly by grasses which dominate natural grassland (D), those colonized mainly by grasses which are subordinate in natural grassland (S1), those colonized mainly by subordinate dicots in natural grassland (S2), and those colonized mainly by alien weeds (A).

科學家研究被遺棄的農地如何經過演替成為成熟的草原。他們研究了被周遭天然草原物種部分拓殖的土地。他們將這些土地歸類為 D 主要由天然草地占主導地位草種（D）拓殖的土地，S1 主要由天然草地次要草種（S1）拓殖的土地，S2 主要由天然草地上屬次要物種的雙子葉植物（S2）拓殖的土地。A 主要由外來雜草（A）拓殖的土地。

For different types of land they measured the following values:

對此 4 類土地，他們測量了（圖 1）：

(a) Diversity of species

(a）物種多樣性

(b) Equitability (evenness) index: The lower the value, the bigger the difference between the abundance of the different species. An index of 1 indicates equal numbers of individuals from all species.

(b）平等性（均勻度）指數：值越低，不同物種豐度之間的差異越大。指數為 1 表示來自所有物種的個體數量相等。

(c) Similarity (Bray-Curtis): Measures how similar the abandoned land is to natural grassland based on the abundance of the species.

(c）相似度（Bray-Curtis）：根據物種的豐富程度，評量廢棄土地與天然草地的相似程度。

$$BC = \frac{2L}{M+N}$$

BC: Bray-Curtis similarity

BC：Bray-Curtis 相似度

L: Is the sum of only the lesser abundance (in this case coverage) of the species found in both place.

L：兩個地方較小豐富度物種（在此情況下是指覆蓋範圍）的總和。

M: Total abundance (coverage) of species found in the first community.

M：第一個群落中物種的總豐富度（覆蓋率）。

N: Total abundance (coverage) of species found in the second community.

N：第二個群落中物種的總豐富度（覆蓋率）。

(d) Similarity (Sorensen): Measures how similar the abandoned land is to natural grassland based on the presence of the species.

(d）相似度（Sorensen）：根據物種的存在與否，測量廢棄土地與天然草地的相似程度。

$$Ss = \frac{2a}{2a+b+c}$$

SS: Sorensen similarity

SS：Sorensen 索倫森相似度

a: the number of species found in each community

a：每個群落中發現的物種數

b: the number of species found just in the first community

b：僅出現在第一個群落的物種數

c: the number of species found just in the second community

c：僅出現在第二個群落的物種數

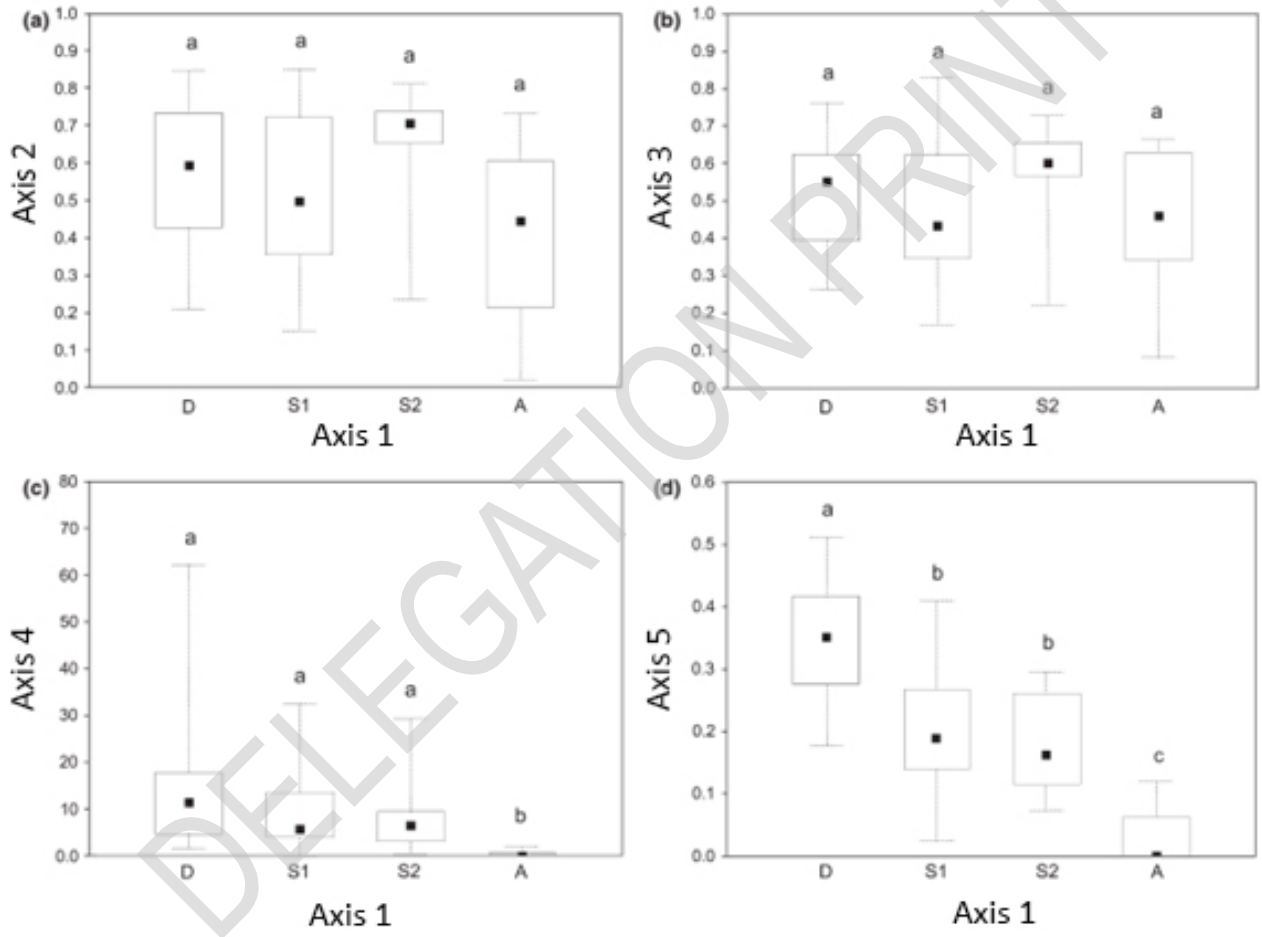


Fig.1. The measured values for different land types. (Values for a, b, d between 0-1, for c between 0-100%.) Letters above bars indicate statistical significance, where two bars with same letter are not statistically different, but different letters are. Axis 1 = Groups. Axis 2 = Species diversity. Axis 3 = Similarity (Bray-Curtis). Axis 4 = Equitability. Axis 5 = Similarity (Sorensen). D = Species that are dominant in natural grasslands. S1 = Subordinate grasses in natural grasslands. S2 = subordinate dicots in natural grasslands. A = alien weeds

圖 1。不同土地類型的測量值。（a，b，d 的值在 0-1 之間，對於 c 在 0-100%之間。）條形上的字母表示統計顯著性，其中具有相同字母的兩個條形在統計上是不顯著，但若是不同的字母則是顯著。軸 1 = 群。軸 2 = 二次多樣性。軸 3 = 相似度（Bray-Curtis）。軸 4 = 平等性。軸 5 = 相似度（Sorensen 索倫森）。D = 在天然草原中占主導地位的物種。S1 = 天然草原中占次要地位的草種。S2 = 天然草原中屬次要物種的雙子葉植物。A = 外來雜草

Indicate with an **X** if each the following statements are true (T) or false (F).

指出下列敘述何者為真（T）或假（F），用 X 表示。

Q.34.1 In grasslands the species D as a dominating species supresses the others more than S1 and S2 do.
D 物種在草原上更多地抑制其他物種，它們占主導地位，然後是 S1 和 S2 物種。

Q.34.2 In this study grasslands dominated by alien weeds (A) had lower species diversity.
在這項研究中，以外來雜草為主的草地（A）的物種多樣性較低。

Q.34.3 Results show, that in alien weed (A) dominated communities only few species have high abundance, and all the other has very low compared to the other communities.
結果顯示，外來雜草（A）佔優勢的群落中與其他群落相比，只有少數物種具有高豐富度，而其他物種非常低。

Q.34.4 Based on abundance of species, the D species dominated communities are definitely more similar to surrounding natural grasslands, than S1 and S2 communities.
基於物種豐富度，D 物種主導的群落與 S1 和 S2 群落相比，其與周圍的天然草地必然更相似。

Q.34.5 The (c) and (d) graphs show that among these communities the S1 and S2 types are the most similar.
（c）和（d）圖表顯示，在這些群落中，S1 和 S2 類型最相似。

Q.34.6 There are communities with no common species with the surrounding natural grasslands.
有些群落與周圍的天然草原沒有共同的物種。

Q.34.7 There are some S2 communities, which have only some rare common species with the surrounding natural grasslands.
有一些 S2 群落與周圍的天然草原相較，只有一些罕見的常見物種。

Biosystematics 生物系統分類學

Q35

The following question is about nutritional strategies and levels of organization in Eukaryotes. 以下問題是有關真核生物的營養策略和組成層級。

Q.35 Write the numbers of the species or group of living organisms listed below (1-8) into the appropriate spaces of the figure on your answer sheet. 將下列物種或生物類群的編號（1-8）填入答案紙上圖中的適當空格。

1. Amoeba (Amoeba proteus) 巨型變形蟲
2. Chlamydomonas (single-celled green algae) in the presence of light 光照下的單胞藻（單細胞綠藻）
3. Baker’ s yeast (Saccharomyces sp.) 烘焙用的酵母
4. Nitrifying bacteria, which rely on the energy deriving from oxidising nitrogen containing inorganic compounds for fixing/reducing atmospheric carbon dioxide. 硝化細菌，其依賴於來自氧化含氮之無機化合物的能量來固定/減少大氣中的二氧化碳。
5. Fresh water sponge 淡水海綿
6. Bacterium causing pneumonia 引發肺炎的細菌
7. Sporophyte of ferns (e.g. Pteridium sp.) 蕨類的孢子體
8. Protonema of mosses (e.g. Sphagnum sp.) 蘚苔的原絲體

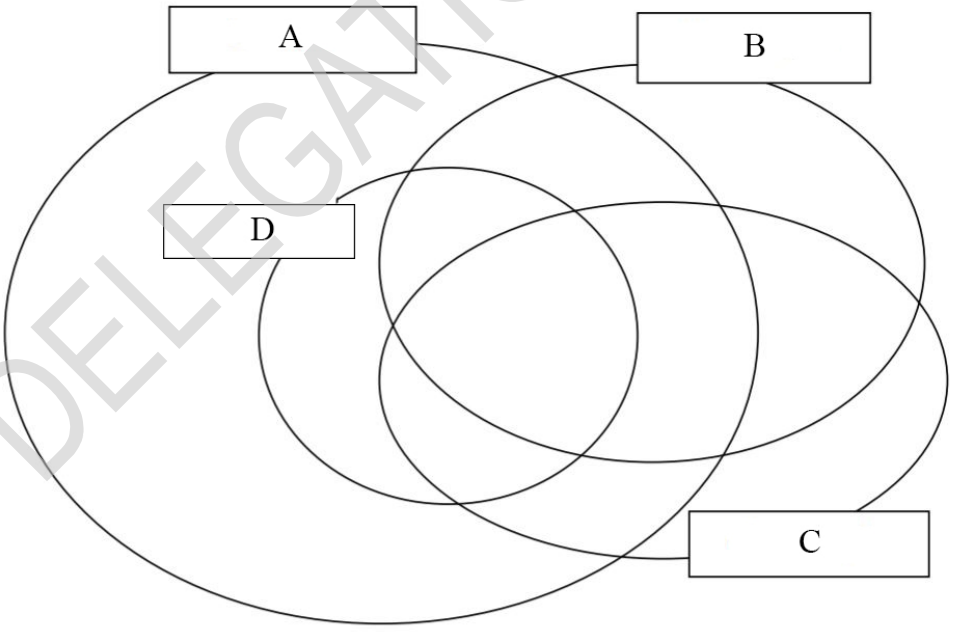


Fig.1. A = Eukaryotes. B = Heterotrophs. C = Chemotroph. D = Multicellular, but below tissue level

圖 1。A = 真核生物。B = 異營生物。C = 化學營養生物。D = 多細胞，但未及組織這個層級

Q36

A Hungarian research group examined the diversity of biochemical processes of a group of fungi called dark septate endophytes (DSE). They used api-ZYM, a biochemical assay for detecting the activity of enzymes, the results of which is illustrated in Figure 1. They want to use these to create an identification key based on the enzyme activities of the species.

一個匈牙利研究小組研究了一群叫做暗隔膜內生菌（DSE）的真菌之生化過程多樣性。他們使用 api-ZYM，一種用於檢測酶活性的生化分析，其結果如圖 1 所示。他們希望根據這些物種的酶活性來建構一個鑑定用的檢索表。

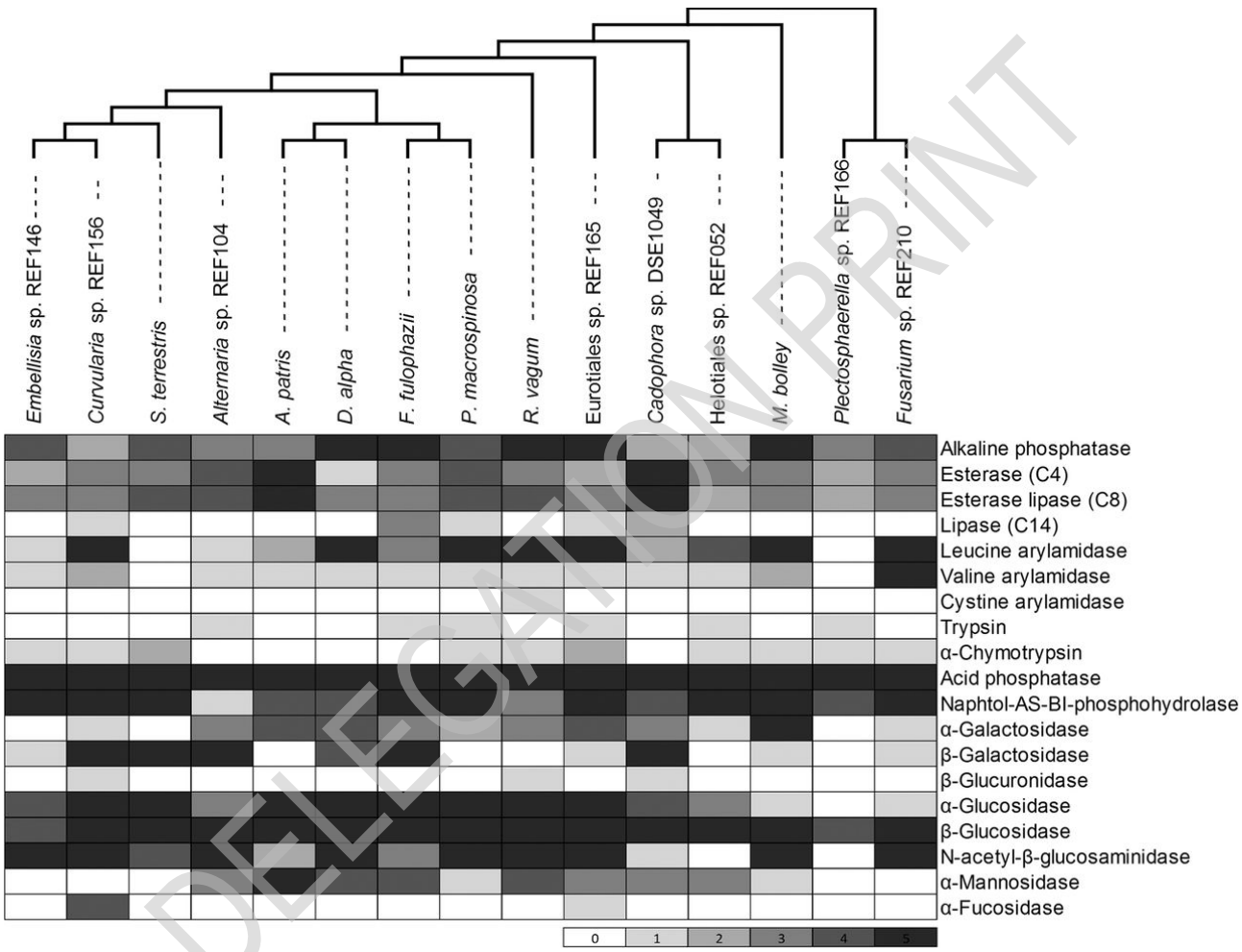


Fig. 1. The phylogenetic tree and the measured enzyme activities of the examined fungus species. The darker color shows stronger enzyme activity. (As shown below the table: 0 –no enzyme activity, 5 –maximal enzyme activity.)

圖 1. 系統發生樹和所檢視真菌物種的酶活性。顏色較暗者代表酶活性較強。（如下表所示：0 –沒有酶活性，5 - 最大的酶活性。）

Q.36.1 Which enzyme's activity gives us no information about identifying the examined species? Indicate your answer by putting an **X** in the appropriate box on the answer sheet.
哪種酶的活性沒有提供有關鑑定被檢視物種的資訊？在答案紙上的適當空格中，以 X 來劃記。
A. Esterase (C4) 酯酶（C4）
B. Valine arylamidase 纈氨酸 氨基肽酶
C. Cysteine arylamidase 半胱氨酸 氨基肽酶
D. Acid phosphatase 酸性磷酸酶
E. β-glucosidase β-葡萄糖苷酶

We created an identification key for some of the examined species, but the names are missing. The roman numerals indicate the species in the key.

我們為部分已被鑑識的物種建立了檢索表，但上面並沒有物種的名稱。羅馬數字則代表檢索表中的物種。

1. a) The leucine arylamidase activity is very high (5). **Go to 2.**
   b) The leucine arylamidase activity is lower (0-4). **Go to 5.**
   a）白氨酸氨基肽酶的活性非常高（5）。轉到 2。b）白氨酸氨基肽酶的活性較低（0-4）。轉到 5。
2. a) The β-galactosidase activity is very high (5). **I.**
   b) The β-galactosidase activity is lower (0-4). **Go to 3.**
   a）β-半乳糖苷酶的活性非常高（5）。**I**。
   b）β-半乳糖苷酶的活性較低（0-4）。轉到 3。
3. a) The esterase lipase (C8) activity is high (4 or 5). **II.**
   b) The esterase lipase (C8) activity is lower (0-3). **Go to 4.**
   a）酯酶脂酶（C8）的活性高（4 或 5）。II。
   b）酯酶脂酶（C8）的活性較低（0-3）。轉到 4。
4. a) The α-galactosidase activity is 4. **III.**
   b) The α-galactosidase activity is 1. **IV.**
   a）α- 半乳糖苷酶的活性為 4. III。
   b）α- 半乳糖苷酶活性為 1. IV。
5. a) The β-galactosidase activity is very high (5). **Go to 6.**
   b) The β-galactosidase activity is lower (0-4). **Go to 7.**
   a）β- 半乳糖苷酶的活性非常高（5）。轉到 6。
   b）β- 半乳糖苷酶的活性較低（0-4）。轉到 7。
6. a) The α-glucosidase activity is 3. **V.**
   b) The α-glucosidase activity is 4. **VI.**
   a）α- 葡萄糖苷酶的活性為 3. V.
   b）α- 葡萄糖苷酶的活性為 4. VI。
7. a) The N-acetyl-β-glucosaminidase activity is 5. **VII.**
   b) The N-acetyl-β-glucosaminidase activity is 2. **VIII.**
   a）N-乙醯 -β- 葡萄糖胺酶的活性為 5. VII。
   b）N-乙醯 -β- 葡萄糖胺酶的活性為 2. VIII。

Q.36.2 Match the roman numerals in the key (I-VIII) with the letters of the species below (A-L). Only one species (letter) belongs to each numeral. Indicate your answer by putting an **X** in the appropriate box on the answer sheet.
將檢索表中的羅馬數字（I-VIII）與下列物種（A-L）配對。每個數字只有一個物種（字母）。在答案紙上的適當空格中，以 X 來劃記答案。

A –D. alpha

B –Fusarium sp. REF210

C –Helotiales sp. REF052

D –S. terrestris

E –Altermaria sp. REF104

F –Curvularia sp. REF156

G –A. patris

H –Embellisia sp. REF 146

I –M. bolley

K –Cadophora sp. DSE1049

L –R. vagum

Ethology 行為生態學

Q37

Cuckoos lay their eggs in the nests of Hungarian songbirds which unwittingly raise the cuckoo hatchling. Host parents will destroy a cuckoo egg if they notice it, but cuckoo eggs look similar to host eggs.

杜鵑在好幾種產於匈牙利的鳴禽巢中產卵，鳴禽無意間撫育了杜鵑幼鳥。宿主父母如果注意到就會摧毀杜鵑卵，但杜鵑卵看起來與寄主卵相似。

Scientists painted eggs of Reed Warblers (a common songbird in Hungary) to look like cuckoo eggs. The different treatments are described in Fig 1.

科學家們把葦鶯的卵塗成似杜鵑卵。不同的實驗處理如圖 1 所示。

Scientists counted how many eggs the Reed Warblers destroyed. (Fig.2) In control nests, there were no rejections. In the “parasitized” nests, the warblers rejected some of the eggs. Most of the rejected eggs were painted, but sometimes the birds rejected their unpainted eggs also.

科學家統計葦鶯摧毀了多少卵（圖 2）。在對照巢中，沒有被排斥的卵。在“模擬寄生”的巢中，葦鶯排斥了一些卵。大多數被排斥的卵上被塗了染劑，但有時葦鶯也會排斥未上染劑的卵。

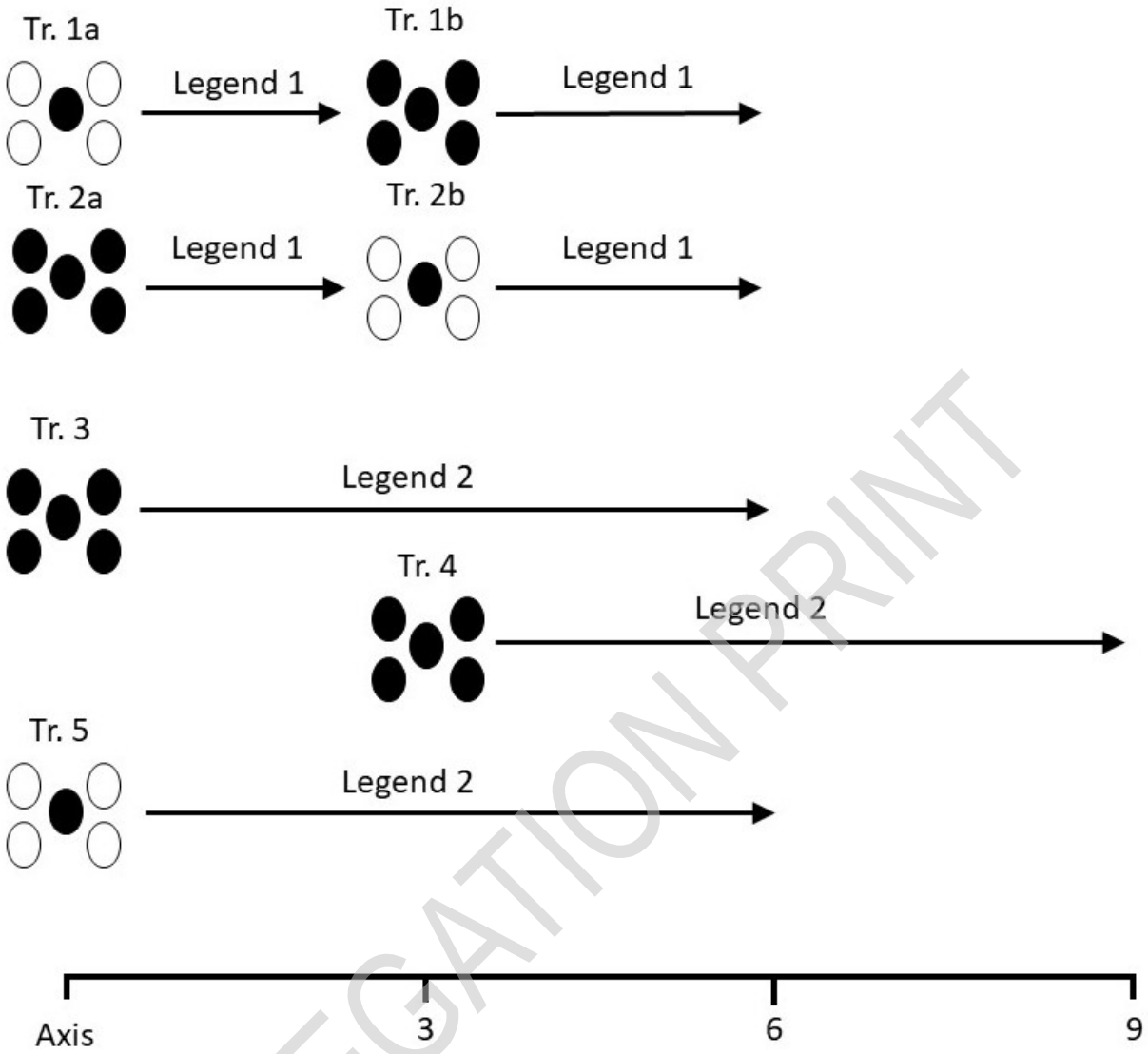


Fig.1. The schematic representation of treatments (Tr.) applied. White eggs denote unpainted ('host') eggs, and dark eggs denote painted ('parasitic') eggs. Monitoring periods after parasitism (3 or 6 days) are also shown. Axis = day of clutch completion. Legend 1 = 3d monitoring. Legend 2 = 6d monitoring.

圖 1 操作處理（Tr.）的示意圖。白卵表示未上染劑的（'宿主'）卵，黑卵表示染色（'寄生'）的卵。並顯示了寄生後（3 或 6 天）的監測期。軸 = 完成巢產卵數的日子。圖說 1 = 3d 監測。圖說 2 = 6d 監測。

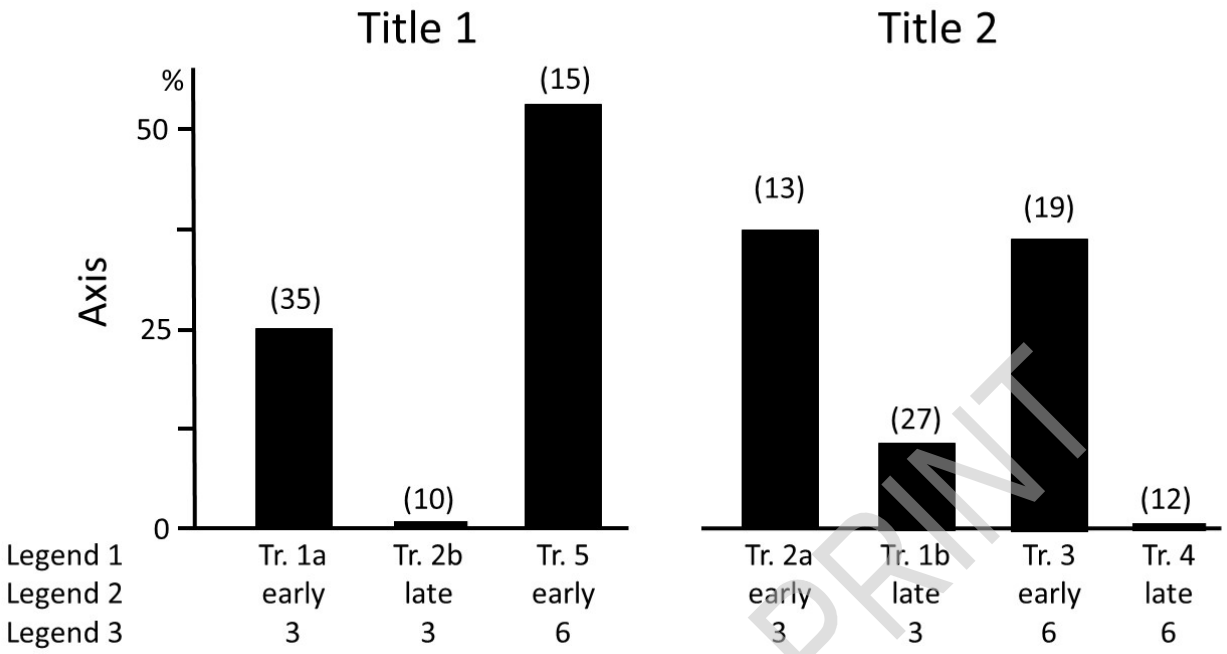


Fig. 2. The rejection rate of the eggs (y axis, %) in each treatment (x axis). Title 1 = Single parasitism. Title 2 = Multiple parasitism. Axis = Rejection rate. Legend 1 = Treatment. (The numbering of the treatments is the same as in Fig. 1.) Legend 2 = Start of experiment: early = immediately after clutch completion, late = 3 days after clutch completion. Legend 3 = Monitoring period (days).

圖 2。每次（x 軸）處理中卵的排斥率（y 軸，\%)。標題 1 = 單次寄生。標題 2 = 多次寄生。軸 = 排斥率。圖說 1 = 操作處理。(處理的編號與圖 1 相同。) 圖說 2 = 實驗開始：早期 = 產卵後 5 天，晚期 = 產卵後 8 天。圖說 3 = 監測期（天）。

Based on the information above, indicate with an X if each of the following statements is true (T) or false (F).

根據上述資訊，判別以下敘述何者為真（T）或假（F），用 X 表示。

Q.37.1 The rejection rate is higher during the earlier stages (5-8 days), than later (after 8th day).
排斥率在早期（5-8 天）高於後期（第 8 天後）。

Q.37.2 Adding one parasite egg early increased the rejection rate for later parasite eggs.
早期添加一個寄生卵會增加後期宿主對卵的排斥。

Q.37.3 The probability of the host ejecting its own egg is higher in the later period, than during the egg laying period.
宿主排斥自己卵的概率在後期高於產卵期。

Q.37.4 The later the cuckoos lay their eggs, the higher chance their offspring have to be rejected.
杜鵑產卵愈晚，他們的後代被排斥的可能性就愈大。

Q38

It can be difficult to determine the strength of natural selection on traits in wild fish. Scientists measured the length of Atlantic silverside (Menidia menidia) before winter (dark bars) and after winter (grey bars), in three different locations. Assume that changes in length can be attributed to differential mortality.

確定野生魚類性狀的天擇強度可能會有一定的難度。科學家在冬季前（黑條）和冬季後（灰條），在三個不同的地點測量了大西洋銀漢魚（Menidia menidia）的長度。假設魚體長度的變化可歸因於死亡率的差異。

Col 1	Col 2	Col 3		Col 4
		Col 3A	Col 3B	
Nova Scotia (NS)	44°40’ N	29 Sep 1987 26 Sep 1988	30 May 1988 3 Jun 1989	244 250
New York (NY)	42°45’ N	27 Oct 1987 25 Oct 1988	27 Apr 1988 18 Apr 1989	183 175
South Carolina (SC)	33°20’ N	1 Dec 1987 28 Nov 1988	30 Mar 1988 20 Mar 1989	120 112

Table 1. Sample sites of the experiment. Col 1 = Site (State). Col 2 = Latitude. Col 3 = Sample dates. Col 3A = Autumn. Col 3B = Spring. Col 4 = Winter duration (days)

表 1。這個實驗的取樣地點。Col 1 = Site (State). Col 2 = 緯度. Col 3 = 取樣日期. Col 3A = 秋季. Col 3B = 春季. Col 4 = 冬季期間 (days)

The results of the two years and three sample sites are shown in Fig. 1.

兩年來三個樣點的研究結果如圖 1 所示。

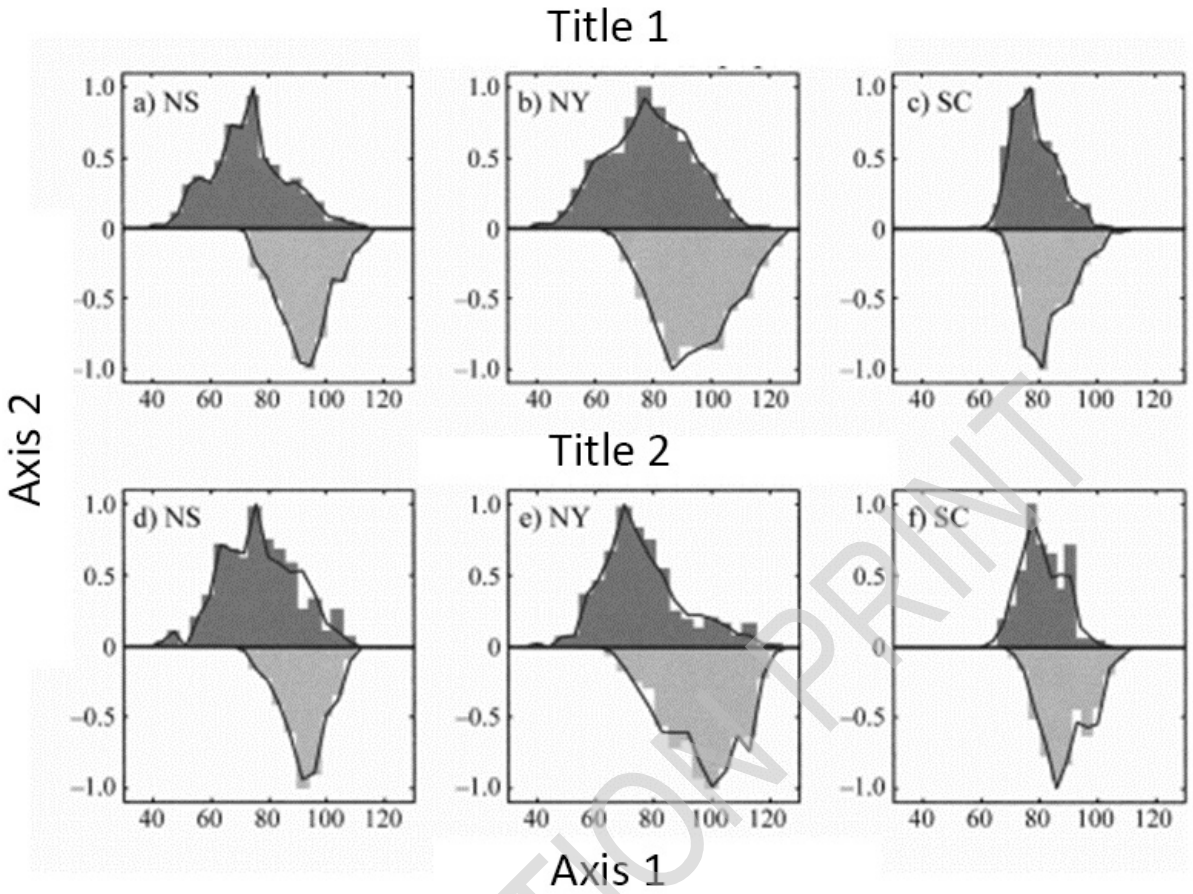


Fig. 1. The size distribution of Menidia menidia in the three sample sites (the meaning of abbreviation is shown in Table. 1.) The dark, upward bars show the autumn results, and the light downward bars show the spring results. Title 1 = 1987-1988 Menidia populations. Title 2 = 1988-1989 Menidia populations. Axis 1 = Total length of Menidia (mm). Axis 2 = Relative frequency of Menidia.

圖 1。三個樣點中 Menidia menidia 的大小分佈（縮寫的含義如表 1 所示）。黑色向上條顯示秋季結果，而淡色向下條顯示春季結果。TItle 1 = 1987-1988 Menidia 族群。Title 2 = 1988-1989 Menidia 族群。Axis1 = Menidia 的全長（mm）。Axis2 = Menidia 的相對頻度。

Based on the information above, indicate with an X if each of the following statements is true (T) or false (F).

根據上述資訊，判別以下敘述何者為真（T）或假（F），用 X 表示。

Q.38.1 According to the results, the 1987-88 winter should be colder in New York (NY) than the 1988-89 winter.
根據調查結果，紐約的 1987-88 冬季應該比 1988-89 冬季更冷。

Q.38.2 The longer and colder winter results stronger selection against smaller specimens.
冬季若越長又越冷那麼體型較小的秋刀魚就會面臨比較強大的天擇壓力。

Q.38.3 Size may affect the success of migration, which can help survival.
魚體大小可能會影響遷移的成功，這有助生存。

Q.38.4 The smaller sized fishes of the species have bigger chance to survive unfavorable conditions.
體型較小的魚類有更大的機會在不利的條件下生存。

Fig. 2 shows the relative rate of survival at two sample sites in two different years.

圖 2 顯示了兩個不同年份的兩個樣本取樣點的相對存活率。

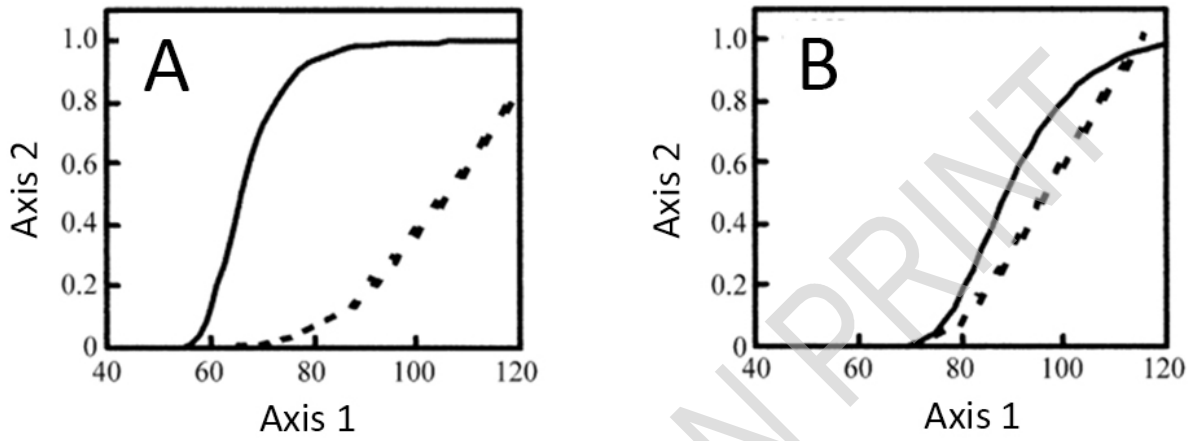


Fig. 2. The relative survival of Menidia as function of the total length (body size) from two sample sites. The solid lines indicate the 1987-88 year, while the dashed lines the 1988-89 year. Axis 1 = Total length of Menidia (mm). Axis 2 = Relative survival of Menidia

圖 2。兩個樣本點 Menidia 的相對存活率與其長度（體型）的關係。實線表示 1987-88 年，而虛線表示 1988-89 年。Title 1 = 曲線 A、Title 2 = 曲線 B。Axis1 = Menidia 的體長（mm）。Axis2 = Menidia 的相對存活率

Q.38.5 Match the curves in Figure 2 (A and B) with the sample sites. Indicate your answer by putting an **X** in the appropriate box on the answer sheet.
將圖 2（A 和 B）中的曲線與樣本點匹配。在答案卷上的相應框中置入 X 來表明你的答案。

- Nova Scotia = NS 新斯科舍省
- New York = NY 紐約
- South Carolina = SC 南卡羅萊納

END OF THE THEORY 2
理論二測驗結束