Country:	Student Code: _____

19th INTERNATIONAL BIOLOGY OLYMPIAD

13th – 20th July, 2008

Mumbai, INDIA

THEORETICAL TEST – PART B

理論題 - 第 B 部分

Write all answers in the **ANSWER SHEET**.

所有的答案都必須回答於答案卷上

Dear Participants 親愛的參賽者

- You have a total of 2 hours 30 minutes for answering Part B.
  你有 150 分鐘作答。
- The questions in Part B may have more than one correct answer. Fill your answers in the **Answer Sheet** for Part B. The marks for the questions in Part B vary depending on the number of answers and the complexity of the question. These marks have been indicated along with the question.
  本試題全部爲**單選與複選混合**。分數記載在題目開頭。
- Mark your answers clearly. Avoid any corrections in the Answer Sheet.
  作答應清楚，並避免汙染非答案區。
- NOTE: Some of the questions may be marked “Skipped” / “Deleted”. DO NOT attempt these questions. Also, read the question completely before attempting it as some questions may continue from one page to the next.
  注意：如有遇到跳過或刪除的題目，請勿作答。題目可能跨頁，請詳細讀完。
- The maximum number of points is **120.5**
  總分數為 120.5
- Your Answer Sheets will be collected at the end of the examination.
  答案卷在考完後將會被收回。

Good Luck!! **祝好運**

Country: _____

First name: _____

Middle name: _____

Family name: _____

Student Code: _____

CELL BIOLOGY (26 points) 細胞學 (26 分)

1. (5 points) A bacterium has a single copy of a 4 x10^6 bp circular genomic DNA.
   (5 分) 細菌有單套的環形的基因體 DNA，4 x10^6 bp

   Use a value of 3 for π, 6 x 10^{23} for the Avogadro's number and 660 for the molecular weight of 1 bp of DNA.
   以下列數值進行計算：π = 3，亞佛加厥常數爲 6 x 10^{23}，1 bp DNA 分子量爲 660。

a. If the diameter of this spherical cell is 1 μm, what would be the molar concentration of DNA in this cell?

   The volume of a sphere of radius r is $\frac{4}{3}\pi r^3$

   該細菌爲球菌，直徑爲 1 μm，試問該細菌的 DNA 莫耳濃度爲何？

   球的體積公式爲 $\frac{4}{3}\pi r^3$

   Answer: _____Molar

b. If the DNA assumed a conformation as proposed by Watson and Crick, what would be the linear length of the bacterial DNA? Note that the 10 bp of linear DNA has a length of 3.4 nm ?
   該 DNA 結構與 Watson 與 Crick 推論的相同，試問該細菌的 DNA 長度爲何？注意：10 bp 的線性 DNA 長度爲 10 nm。

   Answer: _____metre

c. How many bacterial cells one should take to get 1 mg of DNA?
獲得 1 mg 的細菌 DNA 需要多少的細菌？

Answer: _____

2. (3 points) Smooth endoplasmic reticulum (SER) is mainly concerned with the following functions:
   (3 分) 光滑內質網 (SER) 主要與下列功能有關：
   I. Lipid synthesis 脂質合成
   II. Drug detoxification 藥物解毒
   III. Ca^{++} storage 鈣離子貯存
   IV. Gluconeogenesis 糖類新生作用

   Fill in the following table with a tick mark (√) wherever appropriate and indicate the function/s of SER wherever it is extensively present, by choosing from options I – IV above.
   判斷下列器官或細胞是否具有 SER，並在答案卷中的 SER 普遍存在或 SER 非普遍存在正確位置打鉤 (√)。如果器官或細胞具有 SER 請於功能欄中填入上述功能的代號 I – IV。

	Organ/Cell 器官 / 細胞	SER extensively present SER 普遍存在	SER not extensively present SER 非普遍存在	Function/s (if extensively present) 功能
a.	Adrenal gland 腎上腺			
b.	Sebaceous glands 皮脂腺			
c.	Intestinal villi 腸道絨毛			
d.	Muscles 肌肉			
e.	Liver 肝臟			
f.	Pancreas 胰臟			

3. (2 points) There are various mechanisms by which a cell can commit suicide – a phenomenon known as “apoptosis”. One of the mechanisms is triggered by reactive oxygen species. The outer membrane of mitochondria normally expresses a protein Bcl-2 on its surface. Another protein Apaf-1 binds Bcl-2. Reactive oxygen species cause Bcl-2 to release Apaf-1 and a third protein Bax to penetrate the mitochondrial membrane, releasing cytochrome c. The released cytochrome c forms a complex with Apaf-1 and caspase 9. This complex sequentially activates many proteases that digest cellular proteins. Finally, the cell is phagocytosed.
(2 分) 細胞會有細胞凋亡的現象，誘發該現象會被活性氧分子所驅動。正常細胞粒線體外膜會表現 Bcl-2，Apaf-1 蛋白會與 Bcl-2 結合。當活性氧分子存在時，Bcl-2 會失去與 Apaf-1 蛋白結合，另一種蛋白 Bax 會進入粒線體中，進而釋放細胞色素 c。細胞色素 c 會與 Apaf-1 與 caspase 9 形成複合物。此複合物會活化許多蛋白酶分解細胞蛋白。最終，細胞會被吞噬。

What will be the fate of a cell exposed to reactive oxygen species in the following situations? Choose from the options given on the next page.

當細胞在下列四種狀況下，碰到活性氧分子後，有關細胞的命運，分別自 A – C 選項中，回答下列問題？

Choose from the following options:

A. The cell resists apoptosis.
細胞不會出現細胞凋亡

B. The cell is forced towards apoptosis.
細胞會走向細胞凋亡

C. The fate of the cell cannot be predicted.
細胞命運無法決定

Situation I: The cell receives a signal for inhibition of expression of Apaf-1 protein. _____

狀況一：收到抑制 Apaf-1 表現訊號。

Situation II: The cell expresses low-affinity Bcl-2 proteins. _____

狀況二：細胞表現低結合能力 Bcl-2 蛋白。

Situation III: A competitive inhibitor of Apaf-1 for Bcl-2 binding is added to the cell in excess quantity. _____

狀況三：加入過量的 Apaf-1 蛋白競爭者，該競爭者會與 Apaf-1 搶 Bcl-2。

Situation IV: A chemical which significantly lowers the ratio of Bax to Bcl-2 is added to the cell. _____

狀況四：加入會明顯降低 Bax 蛋白的化學藥劑

4. (3 points) The stoichiometry of aerobic and anaerobic degradation of glucose by yeast are as follows:
(3 分) 下列化學公式是用來測量酵母菌在有氧與無氧條件下利用葡萄糖的劑量基準。

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$
$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

In an experiment, the complete utilization of 0.5 mol of glucose, partly under aerobic and partly under anaerobic conditions, yielded 1.8 mol of CO_2.
實驗中，在兼性條件下 (部分有氧與部分無氧)，消耗 0.5 莫耳的葡萄糖會產生 1.8 莫耳的 CO_2。

a. Calculate the fraction of glucose that is utilized aerobically.
計算有氧條件下利用葡萄糖的比例。
Answer: _____%

b. Calculate the Respiratory Quotient, which is defined as the molar ratio of the CO_2 produced to the O_2 utilized.
計算呼吸商數，該商數是以 CO_2 的生成與 O_2 利用的莫耳比值。
Answer: _____

5. (2.5 points) In order to study the effect of a hormone on the breakdown of a polysaccharide in liver tissue, fresh liver was homogenized in an isotonic buffer system. Part of this homogenate was centrifuged to obtain a clear supernatant and a pellet.

   (2.5 分) 爲了研究荷爾蒙對肝臟中多醣類水解的影響。新鮮的肝臟被置於等張溶液中均質化，部分的均質液經過離心後被分成上清液與沉澱物。

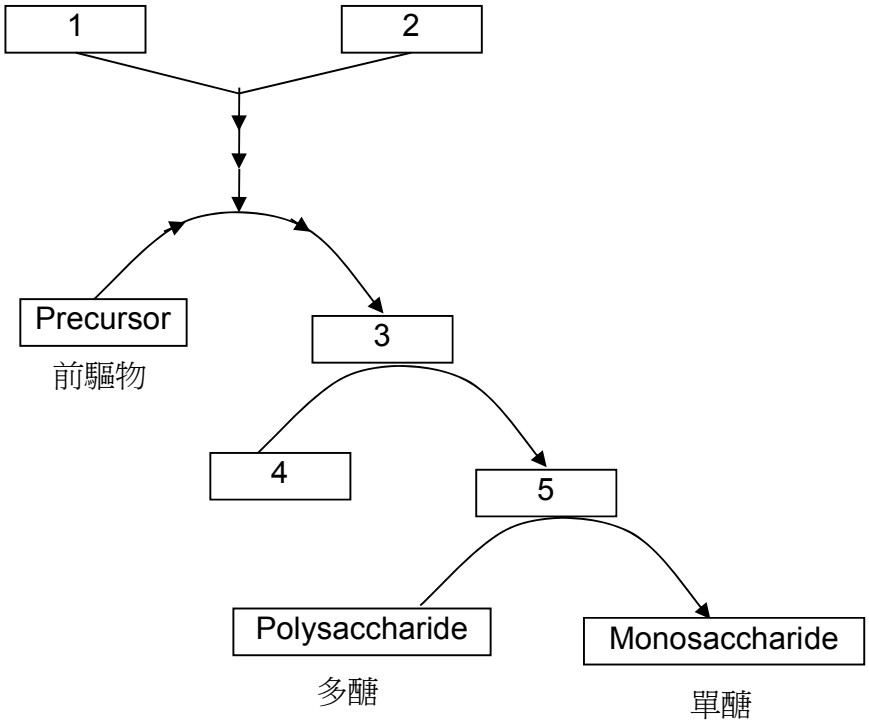
The following experiments were then conducted.

實驗結果分別記錄於下表中。

Experiment 實驗	Reaction mixture 反應混合物	Result 結果	
		Quantity of enzyme 酵素含量	Activity of Enzyme 酵素活性
I	Liver homogenate 肝臟均質液	++++	±
II	Liver homogenate + hormone 肝臟均質液 + 荷爾蒙	++++	++++
III	Supernatant + hormone 上清液 + 荷爾蒙	++++	±
IV	Pellet + hormone 沉澱物 + 荷爾蒙	±	±
V	Supernatant + small quantity of reaction mixture from Experiment IV 上清液 + 少量實驗 IV 中的混合物	++++	++++
VI	Supernatant + small quantity of heated reaction mixture from Experiment IV 上清液 + 少量加熱過的實驗 IV 中的混合物	++++	++++
VII	Supernatant + small quantity of heated pellet + hormone 上清液 + 少量加熱過的沉澱 + 荷爾蒙	++++	±

Complete the signal transduction pathway for the breakdown of the polysaccharide in the following schematic.

完成下列有關多醣類水解的訊息傳遞路徑圖



Options: 選項

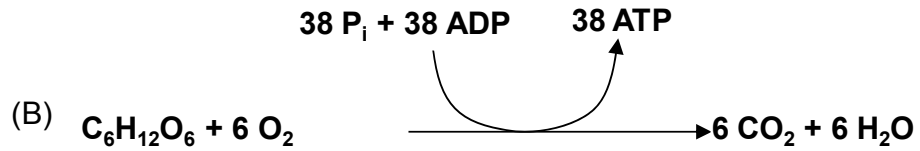
A. Membrane-bound protein 膜包被蛋白
B. Heat-stable molecule 熱穩定蛋白
C. Inactive enzyme 去活化酵素
D. Active cytosolic enzyme 活化態細胞質酵素
E. Hormone 荷爾蒙
F. Organic inhibitor 有機抑制劑
G. Heat shock protein 熱休克蛋白

Fill in the appropriate letters in the table from the options given.

將上述選項答案填入下列表格中。

1	2	3	4	5

6. (4 points) Sugars and fatty acids are important biomolecules that provide energy to the majority of living systems. The estimated utilization of palmitic acid and glucose in the human body is shown in the equation below:
(4 分) 糖與脂肪酸是生物體中提供能量的重要生物分子。棕櫚油酸與葡萄糖在人體內的利用以可以利用下列公式表示：



Answer the following questions: 回答下列問題：
(Atomic weights of H: 1, C: 12 and O: 16) (分子量 H:1，C: 12，O: 16)

I. ATP yield (in moles) per mole of oxygen in Reaction A :_____
反應 A 中，消耗一莫耳氧氣會產生多少莫耳的 ATP

II. ATP yield (in moles) per mole of oxygen in Reaction B:_____
反應 B 中，消耗一莫耳氧氣會產生多少莫耳的 ATP

III. ATP yield (in moles) per gram of fuel in Reaction A: _____
反應 A 中，消耗一公克反應物 (燃料) 會產生多少莫耳的 ATP

IV. ATP yield (in moles) per gram of fuel in Reaction B:_____
反應 B 中，消耗一公克反應物 (燃料) 會產生多少莫耳的 ATP

V. Based on the above reactions, state whether the following statements are true or false by putting tick marks (√) in the appropriate boxes.

依照上述的反應，回答下列問題。正確時在 True 欄位打鉤 (√)，錯誤時在 False 欄位打鉤 (√)。

	True	False
a.		
b.		
c.		
d.		

Statements: 問題

a. Under conditions of mild-intensity exercise and abundance of oxygen, the Respiratory Quotient tends to be < 1.
在輕度運動且氧氣充足條件下，呼吸商數小於 1。

b. High-intensity exercise is primarily fuelled by fat when oxygen concentration is limiting.
氧氣濃度受限下，劇烈運動會優先利用脂肪。

c. Reaction A represents the energy-acquiring process of nervous tissue while Reaction B is more common in skeletal muscles involved in rapid movement.
反應 A 常見於神經組織，反應 B 常見於快速的肌肉運動。

d. Under conditions of hypoxia, the shift of tissue metabolism from fatty acid oxidation to glucose oxidation will yield more ATP.
缺氧環境下，組織的代謝會自脂肪酸氧化移到葡萄糖氧化，以便生成更多的 ATP。

7. (1+1+2=4 points) Leena is a molecular biology student. She purifies two fragments of DNA, 800 and 300 base pairs long. These were obtained from a plasmid after digesting it with *Hin*dIII. Each of these fragments has a single *Eco*RI recognition site.
(1+1+2=4 分) 李娜是一位分子生物學的學生。她以分離了兩段 DNA 片段，大小分別爲 800 與 300 bps。這些片段分別來自受到 *Hind*III 作用後的質體，這些片段中分別有 *Eco*RI 辨認位。

Leena wants to join these two fragments to get a 1.1kb gene as shown in Figure 7.1. She suspects that this gene has a unique protein-coding sequence.
李娜想要將上述兩個片段接合成爲 1.1 kb 的基因 (如下圖所示)。原因是她懷疑該基因有個唯一蛋白質轉譯區。

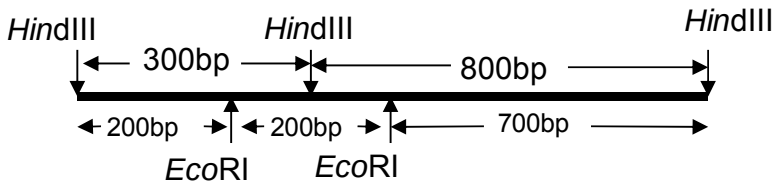


Figure 7.1

She, therefore, mixes the two fragments in the presence of excess DNA ligase in an appropriate buffer and incubates the mixture. She removes an aliquot (a small part of the reaction mixture) after 30 minutes and loads it on an agarose gel to check the results. She is surprised to find many bands along with the expected 1.1kb band (as shown in the figure 7.2) in the gel!

她將上述兩個片段與過量的 DNA 接合酶，適當的緩衝液混作用。經過 30 分鐘的反應後，取出部分的反應物進行瓊脂電泳確認實驗結果。結果發現除了她想要的 1.1 kb 片段外，還出現許多雜帶 (如圖 7.2 所示)。

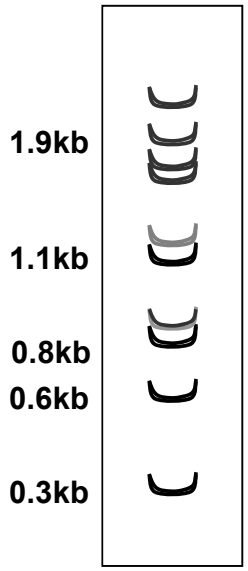


Figure 7.2

I. Which one of the following statements can explain this result?
Put a tick mark (√) in the appropriate box.
下列敘述何者可以解釋實驗結果? 答案正確請打鉤 (√)。

a.	b.	c.	d.

a. The two fragments used for ligation were not sufficiently purified.
兩個片段純化不完全。

b. The multiple bands on the gel are due to the degradation of DNA in the reaction mixture.
出現許多的雜帶來自於 DNA 的降解。

c. The observed band pattern is a result of ligation of randomly-selected fragments.
所能看到的帶型來自於任意選擇接合的結果。

d. DNA ligase did not function, and hence, it led to the random catenation of the DNA molecules.
DNA 接合酶無法作用，因此產生隨意鏈結。

II. If another aliquot of the reaction mixture is removed after 8 hours, which one of the following would be expected?

Put a tick mark (√) in the appropriate box.

經過 8 小時後，重複上述實驗，將會出現下列何種結果。答案正確請打鉤 (√)。

a.	b.	c.	d.

a. Prominent bands of high molecular weight
高分子量位置會出現明顯的帶群。

b. Prominent bands of low molecular weight.
低分子量位置會出現明顯的帶群。

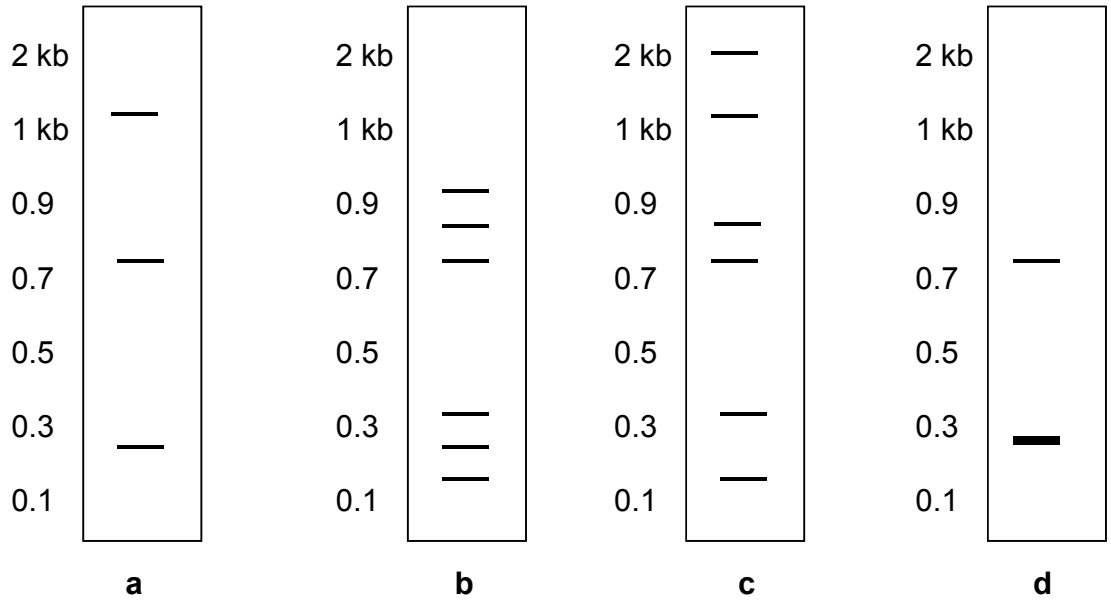
c. Large number of molecules of varying lengths leading to a smearing on the gel.
許多不同長度的帶群會出現，膠體會出現無法辨認的塗汙結果。

d. The gel pattern would remain the same. Only the intensity of bands would increase.
結果相同，僅有強度增加。

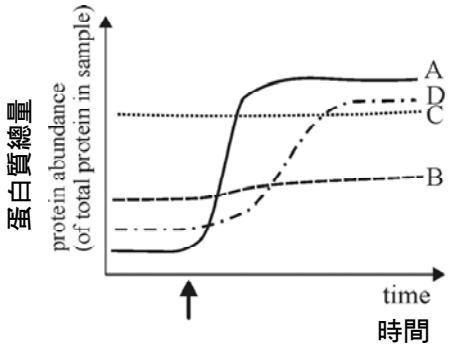
III. Leena is interested in the 1.1kb fragment shown in Figure 7.1. Hence, she elutes the 1.1kb fragment from the gel shown in Figure 7.2 and subjects part of this sample to *Hin*dIII digestion. She obtains the expected pattern with two bands, 800 and 300 base pairs long. To confirm its restriction map, she subjects the remaining sample to complete *Eco*RI digestion. Which pattern of bands would she obtain?
Put a tick mark (√) in the appropriate box.

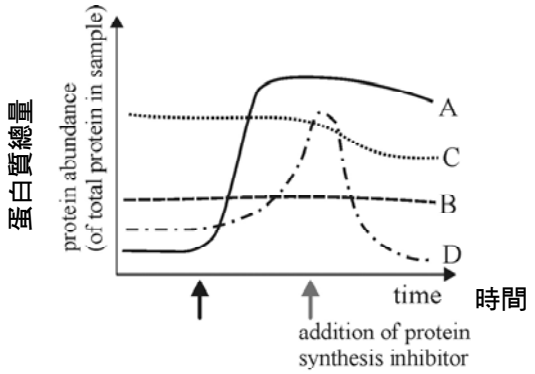
李娜還是對 1.1 kb 片段感興趣。因此，她還是將圖 7.2 中的 1.1 kb 片段萃取出來。經由 *Hin*dIII 作用，她得到期望的 800 與 300 bps 片段。爲了完成限制酶輿圖，上述片段經由 EcoRI 完整作用後，下圖中是應該會的到的結果。答案正確請打鉤 (√)。

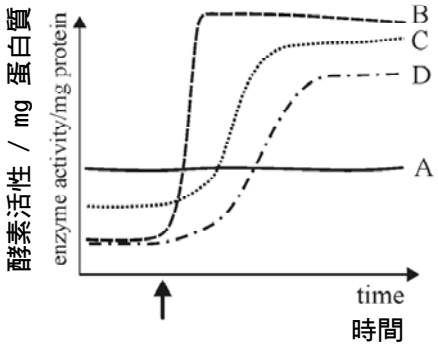
a.	b.	c.	d.

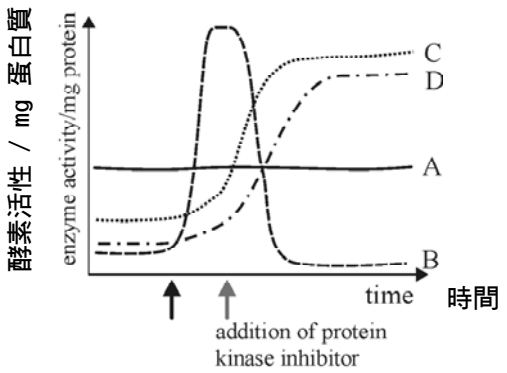


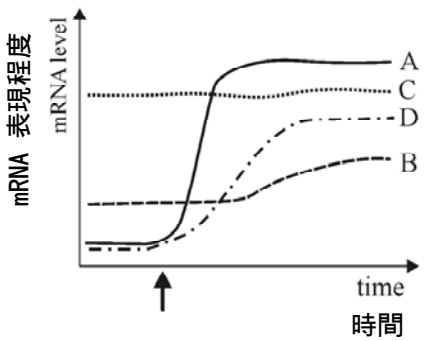
8. (2.5 points) Protein function can be regulated at many levels. By interpreting the graphs below, find out how each of these proteins (A to D) is regulated. They are all enzymes involved in the same physiological process, their activity is induced by the same treatment and their respective activities in a sample can be measured with specific assays. The arrows indicate the beginning of the activating treatment.
(2.5 分) 有許多的方式能調節蛋白質的功能，由下圖中的解釋說明蛋白質 A – D 的調控。所有的酵素反應都在相同的條件下進行。深色箭頭表示反應的起始位置。











Match the proteins A to D with their mode(s) of regulation (I to IV) by putting tick marks (√) in the appropriate boxes.

將蛋白質 A – D 與下列調控模式 (I 到 IV) 配合，在正確的配合位置打鉤 (√)。

I. Post-translational modification, but not phosphorylation
轉譯後修飾，但是缺乏磷酸化

II. Transcriptional regulation
轉錄調控

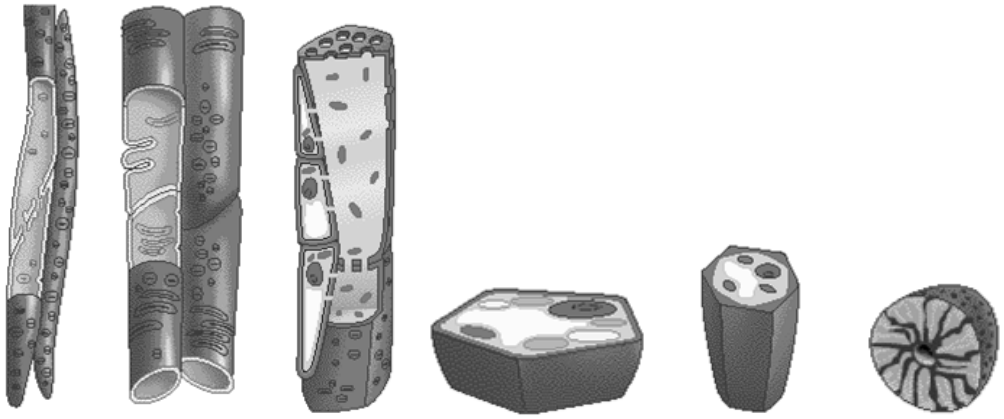
III. Proteasomal degradation and rapid turnover
蛋白酶體降解與快速轉換

IV. Phosphorylation
磷酸化

Protein 蛋白質	Mode of regulation 調節模式			
	I	II	III	IV
A				
B				
C				
D				

PLANT SCIENCES (15 points)

9. (4 points) Study the schematics of the plant tissues/cells shown below and fill in the blank column with appropriate letter/s.
下圖是各種植物組織或細胞的示意圖，在下表空格中填入適當的英文字母代號（一或多個）



A **B** **C** **D** **E** **F**

No.		Answer 答案
I	Cell/s that is/are not alive when functional. 成熟時，是死細胞	
II	Plasmodesmata can be found associated with this/these cell/s. 具原生質絲 的細胞	
III	When you eat potato, you eat the tissue formed of this/these cell/s. 馬鈴薯可食部分的細胞	
IV	Cell/s that harden/s the nut skin. 堅果的堅硬外殼	

10. (1.5 points) On the basis of the photoperiod required for flowering, plants can be described as: 光週期影響開花的情形可將植物分成

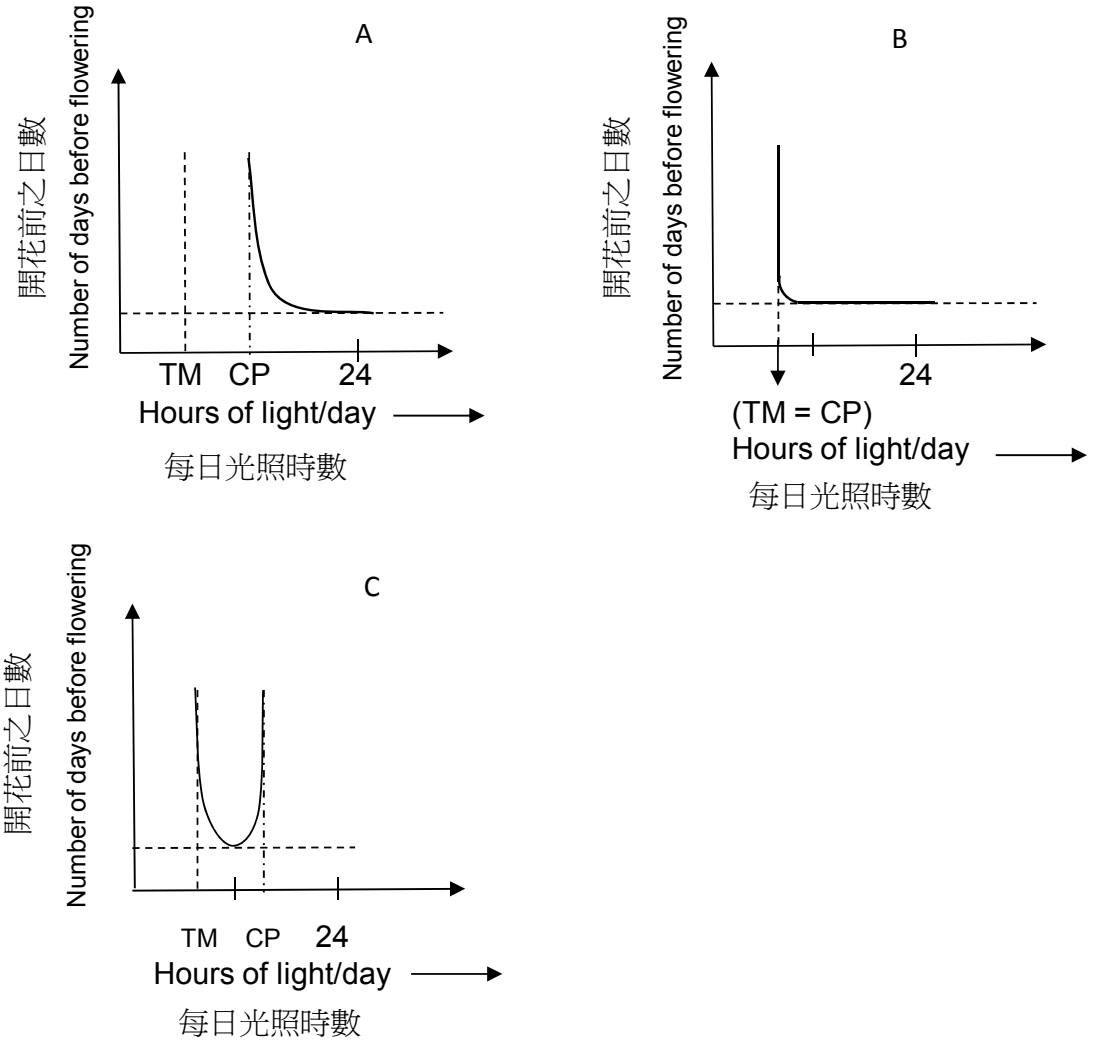
I. Short-day plants 短日照植物

II. Long-day plants 長日照植物

III. Day-length indifferent plants 中性日照植物

The effect of varying light periods on flowering in these three types of plants is depicted in the graphs below, where TM, trophic minimum, is the minimum light that is required to produce the organic matter indispensable to its metabolism and CP is the critical period for flowering.

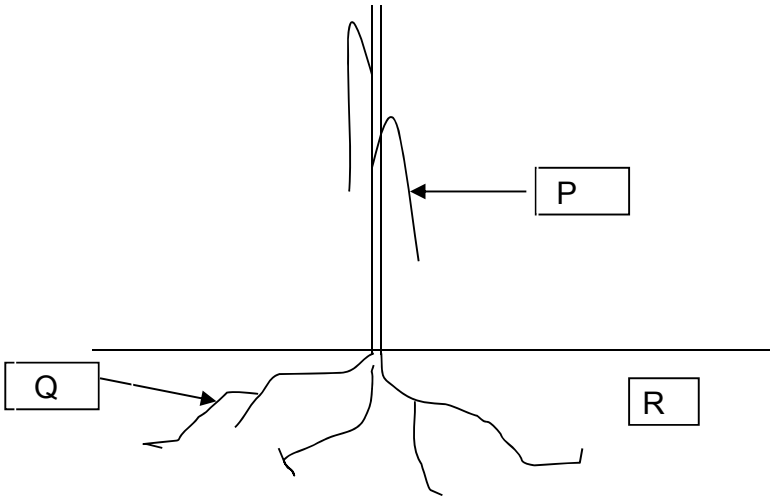
下圖是此三類植物在不同光照下的開花情形。其中 TM(trophic minimum)是指產生誘導開花之有機物質所需的最小光量，CP 是指開花所需之臨界日照。



Choose a plant type (I, II or III) for each of the three graphs and fill in the table.
判斷此三圖分別爲哪一類植物（填入 I, II or III）

Graph	Plant type
A	
B	
C	

11. (2 points) (A) A mesophyte was planted in soil with high salt concentration and watered. It showed wilting. Assign the appropriate values of water potentials to the regions marked P, Q, and R in the schematic representation of this plant.
(A) 一棵中生植物種在高鹽的土壤中，並澆水，結果出現凋萎，在下面示意圖中，標示出 P, Q, 及 R 水勢可能爲下列的三個選項（於圖下方的負數值），分別將適當數值填入答案表格中。



Choose from the options given below and fill in the table:

−1 atm

−5 atm

−8 atm

Region	Water potential 水勢
P	_____ atm
Q	_____ atm
R	_____ atm

(B) Which of the following remedial measures will completely reverse wilting in this plant? Put a tick mark (√) in the appropriate box.

下列哪種處理可使植物之凋萎完全回復正常？在適當空格中打鉤

a. Increasing environmental humidity.

增加環境濕度

b. Irrigation to flush out the excess salts.

增加灌溉以沖掉多餘的鹽

c. Applying wax on the surface of leaves.

在葉表面塗蠟

d. Placing the plant in shade.

把植物放在陰暗中

a.	b.	c.	d.

12. (4 points) A few characteristics of some organisms are listed in the table. Put a tick mark (√) against the appropriate organisms.
下表爲某些生物的特徵，在適當的對應空格中打鉤

	Chlamydomonas 單胞藻	Cyano-Bacteria 藍綠菌	Green-sulphur bacteria 綠色琉化菌	Purple-sulphur bacteria 紫色琉化菌
Phototrophic autotrophs 光合作用自營生物				
Photosystem II absent 沒有光系統 II				
Respiratory enzymes located on plasma membrane 呼吸酵素位於細胞膜				
Chlorophyll *a* as the major photosynthetic pigment 光合作用之主要色素爲葉綠素 *a*				

13. (3.5 points) The total respiration (R) of a young growing plant is described by the following expression: 生長中的幼小植物的總呼吸量(R)如下公式所示

$$R = 0.27\ P + 0.015\ W,$$

where P is the total amount of glucose produced per day and W is the average mass of the plant.

其中 P 是一天所產生的葡萄糖總量，W 是植物的平均重量

Of the processes listed below, some influence the factor 0.27 of the above equation whereas the others do not.

下列過程中，有些會影響公式中的因子 0.27 的數值，有些不會。

1. Movement of water within the cells
   細胞內的水分移動
2. Reduction of nitrate (NO_3^-) ions to ammonium (NH_4^+) ions
   硝酸離子 (NO_3^-) 還原成銨離子 (NH_4^+)
3. Uptake of K^+ ions through the plasma membrane of endodermal cells
   鉀離子會經由內皮細胞膜吸收
4. Uptake of CO_2 in cells of palisade parenchyma
   柵狀組織細胞內的 CO_2 吸收
5. Opening and closing of stomata
   氣孔開閉
6. Lengthening of a polypeptide chain
   多肽鏈長度增加
7. Absorption of light by chlorophyll *a*
   葉綠素 *a* 對光的吸收

Indicate with a tick mark (√) in the appropriate column in the table below, which of these processes do or do not affect the factor 0.27.

在下表中適當空格中打鉤，表示該過程會影響或不影響因子 0.27 的數值

Process	Does Affect 會影響	Does not Affect 不影響
1		
2		
3		
4		
5		
6		
7		

ANIMAL SCIENCES (18 points) 動物學 (18 分)

14. (2 points) The tidal volume is defined as the volume of air entering the lungs in a single inspiration, which is approximately equal to the volume exhaled during subsequent expiration on normal quiet breathing. Exchange of gases with the blood occurs in the alveoli of lungs. In the conducting airways (e.g. trachea), which also contain a volume of air, no exchange takes place. The space within these airways is called the anatomic dead space. Thus the volume of fresh air entering the alveoli during each inspiration equals the tidal volume minus the volume of air in the anatomic dead space. The total volume of fresh air entering the alveoli per minute is called the alveolar ventilation and is expressed in ml/min; it varies directly with the respiration rate.

    潮氣容積是平常靜態時一次吸進入肺中的空氣容積，大約與接下來的呼氣容積相等。肺中的氣體交換是在肺泡處進行，氣管中也含一定容量的空氣，但無氣體交換發生，此空間稱爲解剖上的死腔(dead space)。因此每次吸氣，新鮮空氣進入全部肺泡的容積，等於潮氣容積減去解剖上的死腔。每分鐘進入肺泡新鮮空氣的全部體積稱爲肺泡通氣量 (ml/min)，會隨呼吸速率改變。

Consider the hypothetical breathing patterns of three individuals A, B and C: 若有 A, B, C 三個體在理論上的呼吸量如下：

Individual 個體	Tidal volume 潮氣容積 (ml/breath)	Frequency 頻率 (breaths/min)	Anatomic dead space 解剖上的死空間 (ml/breath)
A	800	12	600
B	500	16	350
C	600	12	200

Which of the following holds true about the alveolar ventilation of these three individuals?

有關此三個體的肺泡通氣量 (ml/min)，下列何者正確？

a. B has considerably greater alveolar ventilation than C.
   B 大於 C
b. A has considerably greater alveolar ventilation than C.
   A 大於 C
c. C has considerably greater alveolar ventilation than B.
   C 大於 B
d. A has considerably greater alveolar ventilation than B.
   A 大於 B

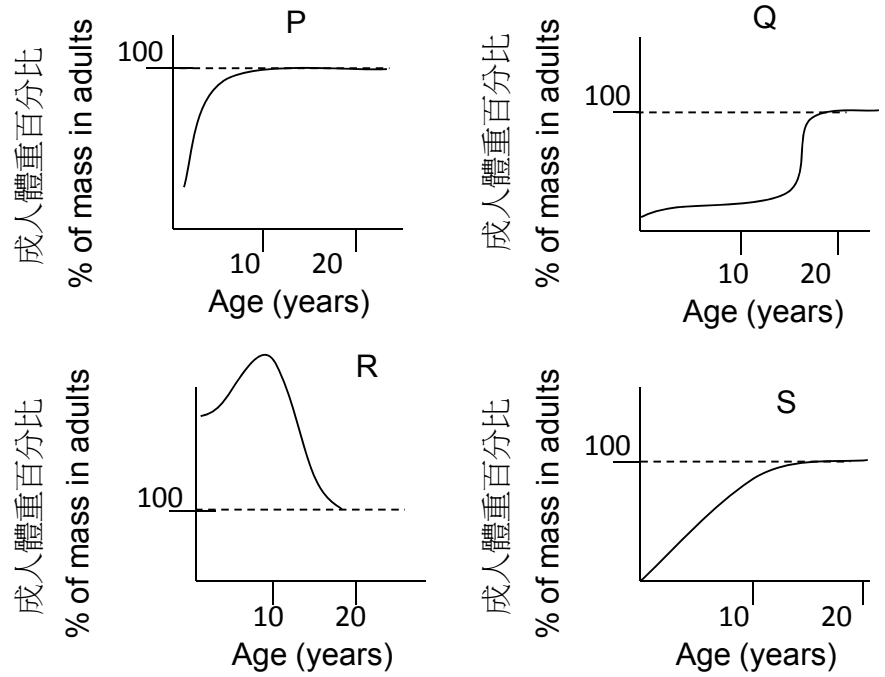
Put a tick mark (√) for the correct statement(s) in the appropriate box of the table.

在表格的正確中位置打鉤(√)。

a.	b.	c.	d.

15. (2 points) The relative growth rates of four organs of the human body are shown in the following graphs.

下方圖示人體四種器官相對生長率



Match the graphs with the organs by putting a tick mark (√) in the appropriate box of the table.

將上列各圖與器官配對，在下表正確位置打鉤(√)。

	P	Q	R	S
Liver 肝				
Brain 腦				
Thymus 胸腺				
Gonads 生殖腺				

16. (2 points) A few statements regarding the respiratory processes in vertebrates are given below:

下列爲有關脊椎動物呼吸過程的陳述：

a. Amphibians use negative pressure to force air into the lungs.

兩生類用負壓使氣體進入肺

b. Reptiles, birds, and mammals use positive pressure to force air into the lungs.

爬蟲類、鳥類、哺乳類用正壓使氣體進入肺

c. Lungs of amphibians and mammals are incompletely ventilated during each breathing cycle.

在每一次呼吸週期中，兩生類及哺乳類的肺換氣不完全

d. Lungs of birds are completely ventilated during each breathing cycle.

鳥類的肺在每次呼吸週期中完全換氣

Mark whether each statement is true or false by putting a tick mark (√) in the appropriate box of the table.

將各陳述的**對**及**錯**在下表中打鉤(√)。

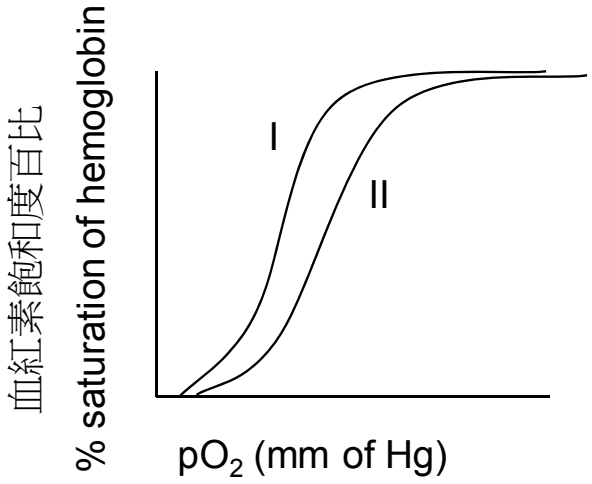
	True	False
a.		
b.		
c.		
d.		

17. (2 points) The oxygen saturation of hemoglobin when plotted versus pO_2 is sigmoid and this is conventionally referred to as the oxygen dissociation curve. Many parameters such as pH, pCO_2, temperature, and metabolic activity of the cell affect the oxygen dissociation curve.

血紅素的氧飽和可對 pO_2 作成 S 曲線，一般稱作氧-血紅素解離曲線，許多變因如細胞的 pH、pCO_2,、溫度及新陳代謝的活性均會影響氧-血紅素解離曲線。

Two such curves, I and II, are depicted in the following graph

圖示兩條曲線：I 及 II 如下：



Determine whether the curves could represent the sets of conditions given below. Put a tick mark (√) in the appropriate boxes in the table.

決定兩條曲線是否代表下列情況，在下表中正確位置打鉤(√)。

Set	Condition	True	False
A	Curve I. Normal blood pH and Curve II. Acidosis 曲線 I 正常 pH ；曲線 II 酸中毒		
B	Curve I. 40°C and Curve II. 30°C 曲線 I 40°C；曲線 II 30°C		
C	Curve I. Elephant hemoglobin and Curve II. Cat hemoglobin 曲線 I 大象的血紅素；曲線 II 貓的血紅素		
D	Curve I. Fetal hemoglobin and Curve II. Maternal hemoglobin 曲線 I 胎兒血紅素；曲線 II 母體血紅素		

18. (2 points) Given below are the data on breathing rate, heart rate and body temperature of four different mammals A, B, C, and D.
下表所示爲 A、B、C、D 四不同哺乳動物的呼吸、心跳及體溫

Animals 動物	Breathing rate (inhalations/min) 呼吸速率(次/分)	Heart rate (beats/min) 心跳速率(下/分)	Body temperature 體溫 (°C)
A	160	500	36,5
B	15	40	37,2
C	28	190	38,2
D	8	28	35,9

Study the data and rank these animals in descending order of surface area per unit volume as well as the total volume of blood by filling in the boxes with appropriate letters (A to D).
研讀資料，將這些動物單位體積的表面積及血液的總體積用適當的字母(A 到 D)，依降階排列填入格中：

Surface area per unit volume of the body (身體每單位體積的表面積)

□ > □ > □ > □

Total volume of blood in the body (體內血液的總體積)

□ > □ > □ > □

19. (5 points) In order to find out the nature of factors involved in humoral immunity, three groups of mice were immunized according to the scheme below:
為明白體液性免疫中不同因子的影響，將三組小鼠依下列步驟免疫：

Immunization scheme
免疫時程

1	Mice 小鼠	→		Isolate serum **(S1)** after 2 weeks 兩周後採血清 (S1)
2	Mice 小鼠	→	Immunized with pathogen P 病原體 P 免疫	→ Isolate serum **(S2)** after 2 weeks 兩周後採血清 (S2)
3	Mice 小鼠	→	Immunized with pathogen Q 病原體 Q 免疫	→ Isolate serum **(S3)** after 2 weeks 兩周後採血清 (S3)

Using sera from the above immunization schemes, the following experiments were conducted to test the response of these sera towards pathogens P or Q:
用依上述步驟所獲之血清進行下列實驗，以測試血清對病原體 P 或 Q 的反應

No.	Experiment 實驗
I	Serum S1 → Add pathogen P or Q → No lysis of pathogen P or Q 血清S1→加病原體P或Q→病原體P或Q的溶解不發生
II	Serum S2 → Add pathogen P → Lysis of pathogen P 血清 S2→加病原體 P→病原體 P 的溶解
III	Serum S3 → Add pathogen Q → Lysis of pathogen Q 血清S3→加病原體Q→ 病原體Q的溶解
IV	Serum S2 → Add pathogen Q → No lysis of pathogen Q 血清S2→加病原體Q→病原體Q的溶解不發生
V	Serum S3 → Add pathogen P → No lysis of pathogen P 血清 S3→加病原體 P→病原體 P 的溶解不發生
VI	Serum S2 → Heat at 55°C for 30 min → Add pathogen P→ No lysis of pathogen P 血清S2→55°C加熱到30分鐘→加病原體P→P的溶解不發生
VII	Serum S3 → Heat at 55°C for 30 min → Add pathogen Q → No lysis of pathogen Q 血清S3→55°C加熱到30分鐘→加病原體Q→Q的溶解不發生
VIII	Serum S2 → Heat at 55°C for 30 min → Add serum S1 → Add pathogen P → Lysis of pathogen P 血清S2→55°C加熱到30分鐘→加血清S1→加病原體P→P 的溶解不發生
IX	Serum S2 → Heat at 55°C for 30 min → Add serum S1 heated at 55°C for 30 min → Add pathogen P → No lysis of pathogen P 血清S2→55°C加熱到30分鐘→加入55°C加熱過30分鐘的血清S1→加病原體P→P的溶解不發生
X	Serum S2 → Heat at 55°C for 30 min → Add serum S3 → Add pathogen P → Lysis of pathogen P 血清S2→55°C加熱到30分鐘→加血清S3→加病原體P→病原體P 的溶解

Answer the following questions:

回答下列問題：

(A) If serum S3 is heated at 55°C for 30 min, and mixed with serum S1, which of the following pathogen would it lyse?
若將血清 S3 加熱到 55°C 30 分鐘，再與血清 S1 混合，何種病原體會溶解？

a. Only P
b. Only Q
c. P and Q both
d. Neither P nor Q

Put a tick mark (√) in the appropriate box.
在下表的正確格子中打鉤(√)

a.	b.	c.	d.

(B) If serum S2 is heated at 55°C for 30 min, and mixed with serum S3, which of the following pathogen would it lyse?

若將血清 S2 加熱到 55°C 30 分鐘，再與血清 S3 混合，何種病原體會溶解？

a. Only P
b. Only Q
c. P and Q both
d. Neither P nor Q

Put a tick mark (√) in the appropriate box.

在下表的正確格子中打鉤(√)

a.	b.	c.	d.

(C) Which of the following statements are TRUE or FALSE for the above experiment?
由上述實驗分別判斷下列何敘述爲對或錯？

a. The lysis of pathogen requires only one component, which is heat-labile.
病原體的溶解只需要一種成分，加熱可破壞這種成分

b. The lysis of pathogens requires at least two components. One component is induced by the pathogen, while the other is non-inducible and is pathogen non-specific.
病原體的溶解最少需要兩種成分，一種成分是病原體誘發出來的，另一種是非誘發的且對病原體無專一性

c. The pathogen-induced component is heat-labile whereas the non-specific component is heat-stable.
病原體誘發出來的成分對熱不穩定，無專一性的成分則對熱穩定

d. The pathogen-induced component is heat-stable whereas the non-specific component is heat-labile.
病原體誘發出來的成分對熱穩定，無專一性的成分對熱不穩定

e. The pathogen-specific components cannot function if present together.
對病原體專一的成分若與病原體放在一起就無作用

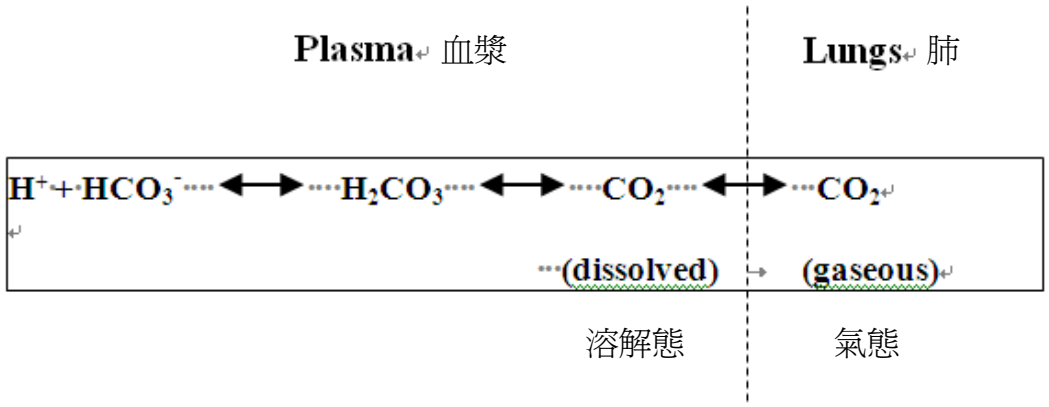
f. The non-specific component has to be derived from the same mice in which the pathogen-specific component would be induced.
無專一性的成分必須與病原體專一成分在同一隻小鼠中誘發

Put a tick mark (√) in the appropriate boxes.

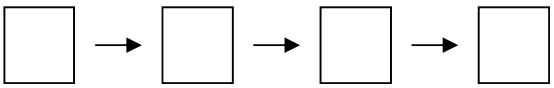
在下表的正確格子中打鉤(√)

Options	True	False
a.		
b.		
c.		
d.		
e.		
f.		

20. (3.5 points) In air-breathing animals, bicarbonate ions present in the blood play an important role of buffering. Various equilibria that occur in lungs and plasma are shown below.
在呼吸空氣的動物，血液中的碳酸氫根離子扮演重要的酸鹼質緩衝角色。下面顯示在肺與血漿中不同的平衡式：



Indicate the events that will occur in sequence as a result of following activities by filling in the boxes with the appropriate numbers I to VI of the given options:
若一個人有下列的活動或動作，把會發生的事件，用 I 到 VI 中適當的數字依次填在空格中。

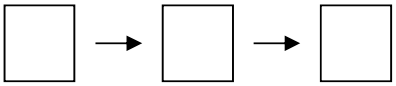


A. A person is hyperventilated as a result of rapid breathing.

一個人因爲快速呼吸而產生過度的通氣

A person continues vigorous exercise:

一個人連續激烈運動



Options:

選項

I. Decrease in plasma carbon dioxide concentration

血漿中二氧化碳濃度降低

II. Decrease in blood bicarbonates

血液中碳酸氫根離子降低

III. Acidosis

酸中毒

IV. Increase in blood bicarbonates

血液中碳酸氫根離子增加

V. Increase in exhalation of carbon dioxide

二氧化碳的呼出增加

VI. Alkalosis

鹼中毒

GENETICS AND EVOLUTION (20.5 points)

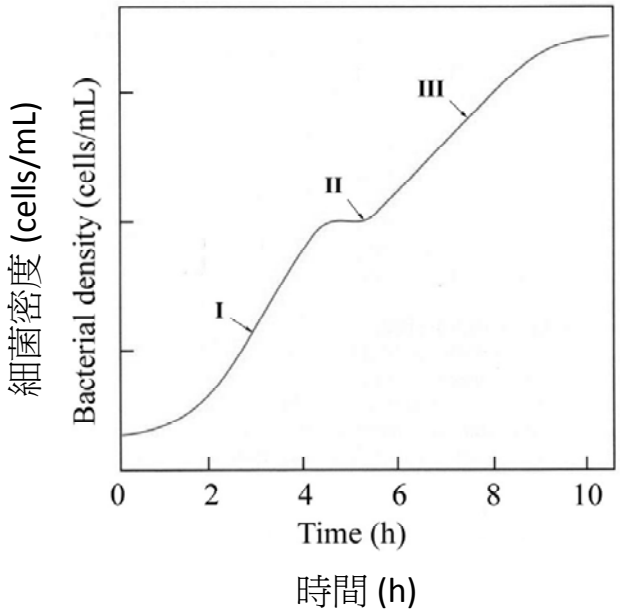
21. (2 points) Cystic fibrosis is an autosomal recessive trait. If parents who are both carriers for this gene have 3 children, what is the probability that exactly two will be phenotypically normal?

囊性纖維病變是一種隱性體染色體病變，若父母皆爲此基因的攜帶者， 他們生三個小孩其中兩個的表現型爲正常的機率爲何？

Answer: _____

22. (2 points) *E. coli* cells were grown in a medium containing glucose and lactose, and a growth curve was obtained which is shown below.

大腸桿菌在含有葡萄糖及乳糖的培養基中生長，其生長曲線如下圖。



Fill in the table using tick marks (√) to indicate which of the listed events would predominate during the three phases of growth (I to III).

下列各現象在 I 至 III 三個時期中的哪一個時期最明顯？ 各(√)一個

	I	II	III
Lactose hydrolysis by β-galactosidase 乳糖被β-galactosidase 水解			
Reduction of *lac* repressor's affinity for the *lac* operator *lac* 抑制子對 *lac* 操作子的親和力的降低			
Binding of the CAP-cAMP complex to the *lac* promoter CAP-cAMP 複合體連接在 *lac* 啓動子上			
Utilization of glucose 葡萄糖的利用			

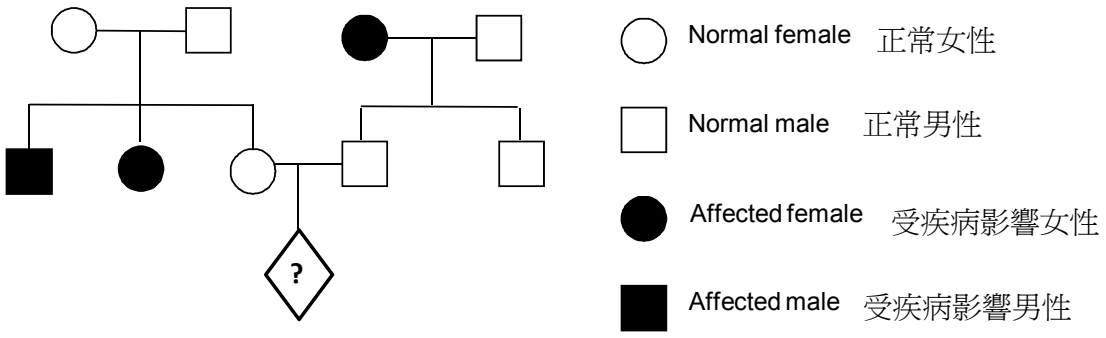
23. (2 points) In a small tribal population, the frequencies of two alleles *A* and *a* at a particular locus were 0.3 and 0.7, respectively. However, not all the individuals with genotype *aa* could live up to the reproductive age and the relative fitness of this genotype was found to be 0.9. The remaining genotypes had a relative fitness of 1.
在小族群中，某對偶基因 *A* 及 *a* 的頻率分別爲 0.3 及 0.7，但並非所有的 *aa* 個體均可存活至繁殖期，基因型 *aa* 的相對適存率爲 0.5，其他基因型則可達 1。

What is the expected percentage of heterozygotes among newborns in the next generation?
在下一代中，異型合子所佔百分比爲何？

Answer: _____%

24. (2 points) In the following pedigree, the probability that the individual marked as ◊ will be affected is:

由下面族譜圖中計算個體◊會受疾病影響的機率爲何？



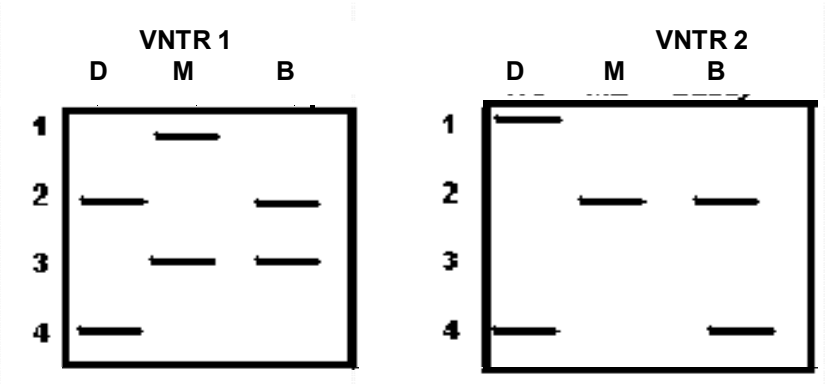
Answer: _____

25. (2 points) If two heterozygotes (*Aa*) mate, what is the minimum number of offspring they should have such that the probability of at least one offspring having genotype *aa* is greater than 90%?
兩個異型合子(*Aa*)交配，最少要生多少個子代，才能使至少有一個 *aa* 子代之機率大於 90%？

Answer: _____

26. (2 points) A celebrity has been named in a paternity suit. The defendant (labeled D in the autoradiogram), the mother (labeled M), and the baby (labeled B) have each been typed for two loci VNTR1 and VNTR2, as shown in the autoradiograms below. Each of these VNTR loci has four alleles. For VNTR1, the frequencies of the alleles 1, 2, 3, and 4 in the general population are 0.2, 0.4, 0.3, and 0.1, respectively. For VNTR2, the frequencies of alleles 1, 2, 3, and 4 are 0.1, 0.1, 0.2, and 0.6, respectively.

下圖爲一親本案例的檢驗結果：被告 (D；父)、母親(M)、孩子(B)，VNTR1 的四個對偶基因 1, 2, 3, and 4 之頻率分別是 0.2, 0.4, 0.3, and 0.1；VNTR2 的四個對偶基因 1, 2, 3, and 4 之頻率分別是 0.1, 0.1, 0.2, and 0.6。



a. Do the autoradiograms indicate that D could be the father of the baby B?
Put a tick mark (√) in the appropriate box.
上圖是否顯示 D 是孩子 B 的父親？在適當的空格打鉤(√)

Yes	No

b. What is the probability that another male in the general population could be the father of the baby B?
孩子 B 的父親另有其人的機率爲何？

Answer: _____

27. (2 points) In some populations, inbreeding takes place amongst first cousins. Inbreeding leads to a reduction in the frequency of heterozygotes and is measured as the inbreeding co-efficient, F, where

有些族群中會有近親交配，近親交配會降低異型合子的頻率，其影響數值爲近親係數(F)，公式如下

$$f_{\text{observed}}^{\text{heterozygotes}} = f_{\text{expected}}^{\text{heterozygotes}} \times (1 - \text{F})$$

(異型合子觀測值)　　(異型合子理論值)

The symbol f denotes frequency. f 代表頻率

If F = 1 (complete inbreeding), the population consists entirely of homozygotes.

若 F = 1（全部都是近親交配），族群個體都是同型合子

In a population of 150 individuals, the observed numbers of MN blood group genotypes are: 60 *MM*, 36 *MN*, 54 *NN*.

有一族群的個體數爲 150，MN 血型之基因型之觀測值爲：**60** *MM*, **36** *MN*, **54** *NN*

a. Calculate F. 計算 F 值爲多少？

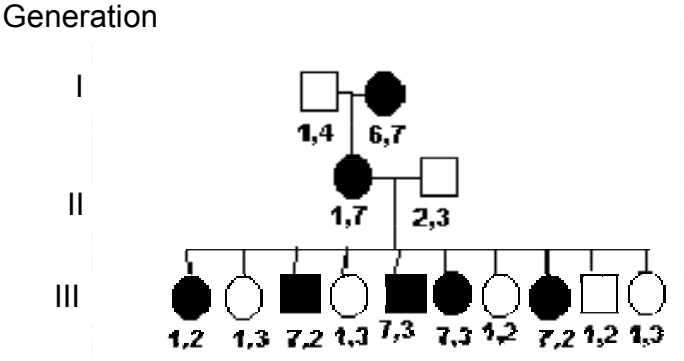
Answer: _____

b. If, for another population of the same species, the allelic frequencies remain the same but the value of F is half of that calculated in a, what will be the frequency of the heterozygotes (*MN*) observed in this group?

若在同物種的另一族群中，基因頻率維持相同，但 F 值是上題的 1/2，計算 *MN* 的頻率應爲多少？

Answer: _____

28. (2 points) The transmission pattern of a disease caused by an autosomal dominant gene is shown in the following pedigree:
下方族譜顯示一個由體染色體顯性基因引起的疾病之傳遞情形。

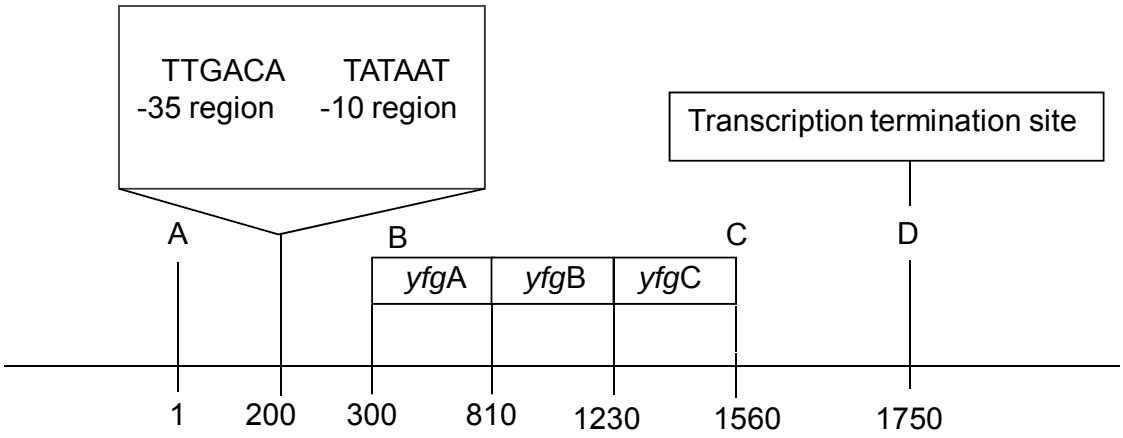


Each family member has been typed for a seven-allele microsatellite polymorphism. Based on the genotypes in Generation III, calculate the recombination frequency between the disease and microsatellite loci.
每個家族成員下方之數字代碼代表其多型性微衛星之基因型。根據第三代的基因型，計算該疾病與此微衛星基因座之間的重組頻率。

Answer: _____

29. (2 points) The figure given below depicts a region of double stranded DNA, in a bacterium, containing a polycistronic operon with three of your favorite genes *yfgA*, *yfgB* and *yfgC*, as shown. The positions of certain bases in the nucleotide sequence around *yfg* operon, with respect to position A are marked in the figure.
下圖爲某細菌雙股 DNA 的片段，帶有一個具 *yfgA*, *yfgB* and *yfgC* 三基因的多基因段操縱子，*yfg* 操縱子之 A 的周圍之某些核苷酸鹼基序列位置如圖所示。

The *yfg* operon



Length of DNA in base pairs

Answer the following questions: 回答下列問題

I. What is the expected minimum number and length of the transcript(s) from this operon?

由此操縱子所轉錄出的產物最少數目及長度爲何？

a. A single transcript of 1260b

具 **1260** 個核苷鹼基的單一轉錄產物

b. A single transcript of 1450b

具 **1450** 個核苷鹼基的單一轉錄產物

c. A single transcript greater than 1451b but less than 1550b

範圍在 **1451** 與 **1550** 個核苷鹼基之間的單一轉錄產物

d. Three transcripts of 330b, 420b and 510b

分別具 **33**0、**420** 及 **510** 個核苷鹼基的三段轉錄產物

Put a tick mark (√) in the appropriate box. 在一個適當空格上打鉤**(√)**

a.	b.	c.	d.

II. From the above figure, calculate the maximal expected mass of the YfgA protein is _____ kDa.

(Assume the mass of an amino acid to be 110 Da)

由上面圖中計算出 YfgA 蛋白質的最大分子量應爲 _____ kDa

(一個氨基酸的分子量以 110 Da 計算)

30. (2.5 points) The map distance between two genes on a chromosome can be calculated using the frequency of crossing over between them. In case of a genetic cross involving three genes, the crossover (CO) classes of progeny can be categorized as

染色體上兩基因間之距離可由兩者之互換率來計算。在三個基因間的遺傳互換中，子代中的互換(CO)類型可分爲下面三種：

(i) Single crossover I (SCO I), 單次互換 I (SCO I)

(ii) Single crossover II (SCO II), 單次互換 II (SCO II)

(iii) Double crossover (DCO). 兩次互換 (DCO)

DCO requires the simultaneous occurrence of the two SCOs.

兩次互換(DCO)須有兩個單次互換同時發生

Among the progeny of a test cross, the number of non-crossovers (NCO) is the highest followed by SCO I and II. The DCO is the least frequent.

試交的子代中，無互換(NCO)的數值最高，SCO I and II 次之，DCO 最少。

A *Drosophila* fly, heterozygous for alleles *p*, *q* and *r*, when crossed with a homozygous recessive fly, had the following progeny:
異型合子與同型合子的果蠅交配所得之子代數目，如下表所示：

(p^+, q^+, and r^+ indicate wild-type alleles whereas *p*, *q*, and r indicate the mutant alleles.)
p^+, q^+, and r^+代表野生型；*p*, *q*, and r 代表突變型

Genotype	Number of progeny
$p\ q^+\ r$	375
$p^+q\ r^+$	355
$p\ q\ r$	50
$p^+\ q^+\ r^+$	45
$p^+\ q^+\ r$	75
$p\ q\ r^+$	85
$p\ q^+\ r^+$	8
$p^+\ q\ r$	7
	Total = 1000

The middle gene is the one that has altered position in the DCO classes compared to that in the NCO classes.

中間基因(middle gene)是指 DCO 類型中改變的位置

(A) Which is the middle gene in the given cross? Put a tick mark (√) in the appropriate box.

哪一個是中間基因？在適當空格中打鉤(√)

p	
q	
r	

(B) Assuming 1% crossover as one map unit (mu), calculate the distance between *p*, *q*, and *r*.

將 1%的互換訂爲一個單位(mu)，分別計算 *p*, *q*, and *r* 之間的距離

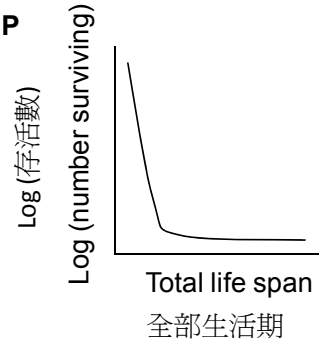
Distance between ***p*** and ***q***	_____ mu
Distance between ***p*** and ***r***	_____ mu
Distance between ***q*** and ***r***	_____ mu

ECOLOGY (16.5 points)

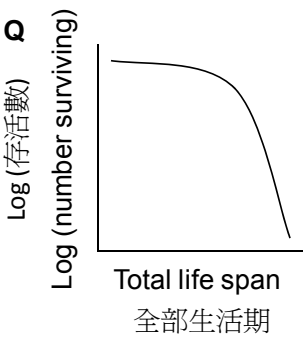
31. (1.5 points) Consider a population of r-selected insects in the early part of its growth season. Choose the appropriate growth curve at this stage, survivorship curve and current age structure (from each pair of graphs) that represents this population and put the corresponding letter in the boxes below.

有一個正在增長中的 r-策略之昆蟲族群，由下列圖示中選擇可代表此昆蟲族群生長曲線、存活率曲線、及年齡結構圖，將選取之字母填於下表。

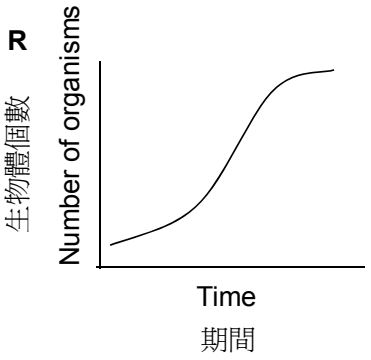
P



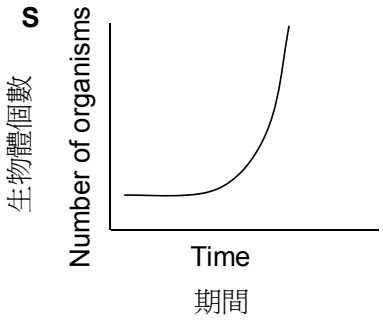
Q



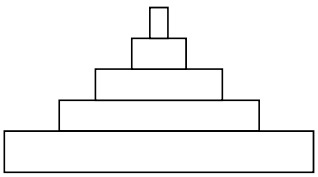
R



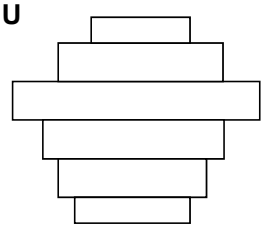
S



T



U



rowth curve 生長曲線	Survivorship curve 存活率曲線	Age structure 年齡結構

32. (3 points) Nitrogen, as a mineral nutrient, has the greatest effect on plant growth. Atmosphere contains nearly 80% nitrogen gas (N_2), yet plants have to be provided ammonium salts or nitrates as fertilizers for optimum growth and yield. Certain nitrogen-fixing bacteria (rhizobia, cyanobacteria, etc.) can convert atmospheric N_2 into ammonia using nitrogenase by the following reaction:

$$N_2 + 8\ e^- + 8\ H^+ + 16\ ATP \longrightarrow 2\ NH_3 + H_2 + 16\ ADP + 16\ P_i$$

Such bacteria can be used as biofertilizers in agriculture. In soil, ammonia is protonated to ammonium (NH_4^+). This, in turn, is converted to nitrate (NO_3^-) and then to N_2 gas by the action of nitrifying and denitrifying bacteria, respectively. Plants require nitrogen mainly in the form of nitrate, which is exported from roots to shoots, reconverted to ammonium and assimilated as amino acids.

氮爲礦物性營養鹽，對植物生長影響最大，大氣中含有約 80%的氮氣，但只有銨鹽及硝酸鹽可被吸收，某些固氮菌(根瘤菌、氰化菌)能藉氮化酵素將 N_2 轉爲 NH_3，,這些細菌在農業上可做爲生物肥料，在土壤中 NH_3 先轉爲銨鹽(NH_4^+)，再轉爲硝酸鹽，再藉脫氮菌轉爲 N_2 釋出至空氣。植物吸收硝酸鹽，由根運送至莖，轉換成氨及胺基酸。

(A) Plants do not themselves fix N_2, because:植物本身不固氮是因爲：

a. it is easily available from the soil.氮容易由土壤中獲得
b. they lack the nitrogenase enzyme complex.植物缺乏氮化酵素
c. the process has a very high requirement of ATP per mole of N_2 fixed.固氮過程須消耗大量 ATP
d. hydrogen evolved in the process is deleterious to plants.固氮過程產生的氫會對植物造成傷害

Put a tick mark (√) in the appropriate box.對的選項打鉤

a.	b.	c.	d.

(B) Processes related to nitrogen conversion to different chemical forms in the soil, carried out by the nitrogen-fixing bacteria, nitrifying bacteria and denitrifying bacteria can be, respectively, described as:
氮轉換過程中，固氮菌、硝化菌及脫氮菌所進行的反應類型,分別爲下列何者？

a. reduction, oxidation and oxidation.還原、氧化、氧化
b. reduction, oxidation and reduction. 還原、氧化、還原
c. reduction, reduction and oxidation. 還原、還原、氧化
d. oxidation, oxidation and reduction. 氧化、還原、氧化

Put a tick mark (√) in the appropriate box. 對的選項打鉤

a.	b.	c.	d.

(C) Based on the given information, which type of soil bacteria will NOT be beneficial for plants?

由所提供的資料，土壤中的細菌對植物生長無利：

a. Nitrogen-fixing bacteria 固氮菌
b. Nitrifying bacteria 硝化菌
c. Denitrifying bacteria 脫氮菌
d. ~~Nitrifying and denitrifying bacteria 硝化菌及脫氮菌~~

Put a tick mark (√) in the appropriate box. 對的選項打鉤

a.	b.	c.	~~d.~~

33. (2 points) The relationship between members of different species is termed as interspecific relationships. Some such relationships are listed below. -
不同種類的個體間的關係稱爲種間關係(interspecific relationships)，某些種間關係如下：

1. Mosses (A) grow on the trunks and branches of trees (B).
蘚苔(A)生長在樹幹及樹枝(B)上

2. A female moth (A), the only pollinator, arrives at a *Yucca* flower (B) with a ball of Y*ucca* pollen. She places her pollen ball on the stigma and then lays eggs in some, but not all, of the ovules. Offspring development kills the seeds on which they feed. If too many seeds are killed, the fruit is aborted by the plant, killing the developing moth larva.
一種雌蛾(A)是龍舌蘭(Y*ucca)*花(B)的特有傳粉者，她將花粉球放於花的柱頭，而後將卵產於部分子房中(並非全部)。幼蟲發育期間靠種子維生，若過多的種子被吃，則植物提早落果而殺死在內的幼蟲

3. *Wolbachia*, a rickettsia-like bacterium (A) infects some insects (B). The infected males are either killed or develop as females, leading to distorted sex ratios (female bias) in the population.
Wolbachia 是像立克次體的細菌(A)會感染一些昆蟲(B)，被感染的雄性可能死亡，亦可能發育爲雌體，造成族群中性別比例的改變(雌性過多)

4. Certain plants (A) attract ants (B) through extra-floral nectaries to deter herbivores.
某種植物(A)藉由其花蜜吸引螞蟻(B) 以保護其不被草食動物覓食

Indicate in the table given below whether the species (A and B) involved in each of these are benefited (indicate by +), harmed (indicate by –) or not affected (indicate by 0). Identify also the type of interaction by choosing from the options I to VII given below.

上述 AB 物種間的關係如有利則以”＋”表示，有害則以”－”表示，沒有影響則以”0”表示。由其下所提供的 7 種交互作用選擇正確者填入下列方格中：

Options: 選項

I. Amensalism 無利並存

II. Commensalism 片利共生

III. Competition 競爭

IV. Mutualism 互利共生

V. Parasitism 寄生

VI. Predation 掠食

~~VII. Proto-cooperation 先期合作~~

Number	A	B	Type of interaction 交互作用類型
1.			
2.			
3.			
4.			

34. (4 points) Mathematical models can be applied to many aspects of predator behavior.In a simple mathematical model, it is assumed that a predator can feed on two prey species, Prey1 and Prey2 and that it captures and consumes every prey it encounters. For this predator, the variables T_s, N_1, N_2, E_1, E_2, T_{H1}, and T_{H2} are defined as follows:

數學模式可用於解釋許多與掠食有關的行爲，在一簡單數學模式中，假如掠食者會掠食兩種獵物：獵物 1 及獵物 2，掠食者遇到獵物時即會獵食。針對此掠食行爲的相關因子 T_s, N_1, N_2, E_1, E_2, T_{H1}, and T_{H2} 定義如下：

T_s: Total time spent searching for the prey species

尋找獵物所花的總時間

N_1: Number of Prey1 encountered per unit time

單位時間遇到獵物 1 的數量

N_2: Number of Prey2 encountered per unit time

單位時間遇到獵物 2 的數量

E_1: Energy gained from a single Prey1

由獵物 1 所得的能量

E_2: Energy gained from a single Prey2

由獵物 2 所得的能量

T_{H1}: Handling time needed for each Prey1. This includes time required for capturing and consuming the prey.

捕捉及食用獵物 1 所需的操作時間

T_{H2}: Handling time needed for each Prey2

捕捉及食用獵物 2 所需的操作時間

(A) Once a prey has been captured, the profitability (calories gained per unit time) of each prey species for the predator is, respectively:在獵物被捕後，掠食者從不同獵物的獲利率(單位時間內獲得的卡路里)分別爲何？

a. $\frac{E_1}{T_{H1}}$ and $\frac{E_2}{T_{H2}}$

b. $\frac{E_1}{T_{H1}+T_{H2}}$ and $\frac{E_2}{T_{H1}+T_{H2}}$

c. $\frac{E_1}{N_1 T_{H1}}$ and $\frac{E_2}{N_2 T_{H2}}$

d. $\frac{E_1}{T_{H1}+T_{H2}+T_S}$ and $\frac{E_2}{T_{H1}+T_{H2}+T_S}$

Put a tick mark (√) in the appropriate box 在對的選項打鉤

a.	b.	c.	d.

(B) The total energy gain E for the predator will be:

掠食者所獲得的總能量 (E)爲：

a. $E = (E_1 + E_2)T_S$

b. $E = E_1N_1 + E_2N_2$

c. $E = (E_1N_1 + E_2N_2)T_S$

d. $E = \frac{E_1N_1 \times E_2N_2}{T_S}$

Put a tick mark (√) in the appropriate box. 在對的選項打鉤

a.	b.	c.	d.

(C) The total time (T) spent to gain the total energy E will be:

獲得總能量所需花費的總時間 (T) 爲

a. $T = T_S + T_S(N_1T_{H1} + N_2T_{H2})$

b. $T = T_S + T_{H1} + T_{H2}$

c. $T = 1 + N_1T_{H1} + N_2T_{H2}$

d. $T = T_S + N_1T_{H1} + N_2T_{H2}$

Put a tick mark (√) in the appropriate box. 在對的選項打鉤

a.	b.	c.	d.

(D) In one situation, the following data were obtained:

下表是某種情形下所獲得的資料

T_s = 60 minutes

Prey1 獵物 1	Prey2 獵物 2
N_1 = 2/min	N_2 = 5/min
T_{H1} = 10 min	T_{H2} = 20 min
E_1 = 1000 cal	E_2 = 700 cal

Which of the following hypothesis does the above mathematical model support?上列數學模式支持下列何種假說？

a. The predator should specialize on Prey1 as it leads to a better rate of energy gain.此掠食者必須專注獵物 1 才可獲得較佳的能量效率(能量 / 時間)

b. The predator should specialize on Prey2 as it leads to a better rate of energy gain. 此掠食者必須專注獵物 2 才可獲得較佳的能量效率(能量 / 時間)

c. The predator should not specialize on one particular prey as a combination of both prey species is more beneficial 掠食者不應專注捕食某一種獵物，因掠食者捕食兩種獵物的好處大於只捕食其中任一種獵物

d. The predator should specialize on both prey species as any one of them may be likely to be unavailable in future. 掠食者應專注捕食兩種獵物，也許其中任何一種有可能於未來無法獲得

Put a tick mark (√) in the appropriate box. 在對的選項打鉤

a.	b.	c.	d.

35. (6 points) A female gall fly (*Eurosta solidaginis*) typically lays a single egg in the bud of some plants. After the egg hatches, the larva burrows its way through the bud and produces a tumor-like structure called a gall. Larvae inside these galls present a very nutritious food source for many birds.
一隻雌癭蠅(*Eurosta solidaginis*) 通常在一些植物的芽上產一個卵，在蛋孵化後，幼蟲在芽間穿梭活動且形成蟲癭(gall)，此類蟲癭爲許多鳥種提供特別營養的食物

(A) After observing some galls, a student proposed a hypothesis that birds choose larger galls in preference to smaller ones. In order to gather the data to test this hypothesis, she conducted a survey of one such site and measured the widths of disturbed (fed on by the birds) as well as undisturbed galls. The results are as follows:
一位學生在觀察後提出鳥喜好大型蟲癭的假說，她在一處進行調查，測量有被鳥取食及沒有被鳥取食的蟲癭大小(mm)，其結果如下：

Disturbed galls 被取食的蟲癭		Undisturbed galls 沒被取食的蟲癭	
Gall number	Width (mm)	Gall number	Width (mm)
1.	12	1.	18
2.	15	2.	15
3.	30	3.	22
4.	20	4.	12
5.	23	5.	20

You need to put this hypothesis to test. (Some of the required statistical formulae as well as the Student-t and Chi-square probabilities are provided in the **Annexure** at the end of Part B-Question Paper.)

你須測試此假說(某些需要統計測試，公式及 t 與卡方分布（Chi-square）的機率表列在本卷最後的附錄(**Annexure**)處)

I. Which of the following is the correct null hypothesis?

下列何者爲正確的虛無假說？

a. The birds do not choose galls of smaller size.

鳥不選擇小型的蟲癭

b. The birds do not choose galls of larger size.

鳥不選擇大型的蟲癭

c. The birds do not choose galls based on size.

鳥不根據蟲癭的大小來作選擇

d. The birds do not choose galls of smaller size in preference to larger size.

鳥喜歡較大的蟲癭，不選擇較小的

Put a tick mark (√) in the appropriate box. 在適當空格中打鉤

a.	b.	c.	d.

II. The test that you will require to do is:

此一實驗需用之統計分析是

a. Student's t test　t－測試

b. Chi-square test　卡方分析

c. Both Student's t test and chi-square test　t 及卡方皆需用

d. Either Student's t test or chi-square test　t 或卡方分析都可

Put a tick mark (√) in the appropriate box　在適當空格中打鉤

a.	b.	c.	d.

III. The degree/s of freedom is/are: Answer:_____

自由度爲？

IV. The value/s of the statistic/s (up to two decimal points):

所得之統計值（算至小數點兩位）

Answer: _____

V. Mark the correct interpretation:

選擇正確的敘述

a. At $p < 0.05$, the null hypothesis can not be rejected.

在 $p < 0.05$ 時，不能拒絕虛無假說

b. At $p < 0.05$, the null hypothesis is rejected.

在 $p < 0.05$ 時，拒絕虛無假說

Put a tick mark (√) in the appropriate box 在適當空格中打鉤

a.	
b.	

(B) After observing more sites, another student came up with a hypothesis that patches with high density of galls are foraged more than those with low density. To test this hypothesis, he surveyed six patches. The results are as follows:

另一個學生又在其他多處進行觀察後，又提出了一個假說：鳥在蟲癭密度高的地方有較多的覓食。要測試此一假說，他調查了 6 處，結果如下：

Gall description 蟲癭概況描述	Site I	Site II	Site III	Site IV	Site V	Site VI	Total
Density 密度	High	Low	High	High	Low	Low	
Foraged 被取食	15	6	10	14	7	8	60
Undisturbed 沒有被取食	5	3	7	8	7	9	39
Total	20	9	17	22	14	17	99

I. The null hypothesis will be: 此虛無假說將是：

a. The birds do not choose galls in less dense areas.
在蟲癭密度低的地方，鳥對蟲癭不做選擇

b. Density of galls is not more important than the size of the gall.
蟲癭密度的高低並不比蟲癭的大小更重要（兩者一樣重要）

c. Choosing of galls by birds is independent of the gall density in the patch.
鳥選擇蟲癭與該地的蟲癭密度無關

d. Choosing of galls by birds is not dependent on the size of galls but on the density of the patch. 鳥選擇蟲癭與蟲癭大小無關，但與該地的蟲癭密度有關

Put a tick mark (√) in the appropriate box. 在適當空格中打鉤

a.	b.	c.	d.

II. To test the hypothesis, the test that will be required is:

要驗證此假說，所需用的統計分析爲

a. Student's t test　t－測試

b. Chi-square test　卡方分析

c. Both Student's t test and chi-square test　t 及卡方皆需用

d. Either Student's t test or chi-square test　t 或卡方分析都可

e. Put a tick mark (√) in the appropriate box. 在適當空格中打鉤

a.	b.	c.	d.

III. The degree/s of freedom is/are: _____

自由度爲？

IV. The value/s of the statistic/s (up to two decimal points):

統計值（到小數點兩位）

_____

V. Based on the value you obtain, the correct interpretation is:

選擇正確的敘述

a. At $p < 0.05$, the null hypothesis can not be rejected.

在 $p < 0.05$ 時，不能拒絕虛無假說

b. At $p < 0.05$, the null hypothesis is rejected.

在 $p < 0.05$ 時，拒絕虛無假說

Put a tick mark (√) in the appropriate box　在適當空格中打鉤

a.	
b.	

ETHOLOGY (11 points) 動物行爲

36. (2 points) In a population of prey animals, most individuals are solitary and stay well apart from others. But some mutant types arise that search out others, use them as shields against predators and take away fitness from the solitary types by making them more conspicuous to their predators. Let the fitness payoff for a solitary individual living in a population consisting of only solitary types be P. But when a solitary individual is found and used by a social type, the solitary animal loses some fitness (B) to the social type. There is also an additional cost C to being social in terms of the time required to find a solitary individual to hide behind and that arising from the resulting increased conspicuousness to predators. When two social types interact, assume that they each have an equal chance of hiding behind the other when the predator attacks. A game theory diagram summarizes these interactions as follows:

在一獵物的族群中，大多數的個體是獨居的，個體間相互遠離。但有些突變的個體出現，牠們會尋找同伴，以牠們當作肉盾來防禦掠食者，並因由於有突變者的靠近而變得顯目，造成獨居者被捕獲的機率增加，導致其適應度 (fitness)減少。假設 P 爲獨居個體在一全爲獨居性個體的族群中之適應度，但當獨居性個體被發現，並被群居性個體(social type，即前述之突變種)利用時，相對於群居性個體而言，此獨居個體會損失一些適應性(以 B 代表)。但群居也有一些額外的代價(Cost，以 C 代表)，其一爲尋找同類個體當肉盾需要花時間；另一爲形成群體後，對掠食者形成更顯著的目標。故當兩種不同類型（獨居及群居）同時存在時，若有掠食者出現，牠們有相同的機會躲藏在彼此的後面(即利用彼此當肉盾)以躲避掠食者的攻擊。根據遊戲(博弈)理論，將此兩種不同類型的個體之相互作用列於下表：

Payoff for 獲利的對象	In presence of	
	Solitary 獨居性	Social 群居性
Solitary 獨居性	P	P – B
Social 群居性	P + B – C	P + B/2 – B/2 – C = P – C

(A) If B is greater than C, what behavioral type will predominate in the population over time?

若 B 大於 C，在一段時間後，哪類的行爲類型將會在族群中佔優勢？

a. Solitary 獨居性

b. Social 社會性

Put a tick mark (√) in the appropriate box. 在適當空格中打鉤

a.	
b.	

(B) The average fitness payoff of a prey

就任一獵物個體而言，在下列兩情形下，其平均的獲利分別爲何？

(i) when it enters a population composed entirely of solitary types and

當牠進入一全屬獨居性個體組成的族群

(ii) when it enters a population composed entirely of social types

would, respectively, be:

當牠進入一全屬群聚性個體組成的族群

a. P – B/2 – C/2, P + B/2 – C/2
b. P – B/2, P + B/2 – C
c. P + B/2 – C/2, P – B/2 – C/2
d. P + B/2, P – B/2 – C

Put a tick mark (√) in the appropriate box. 在適當空格中打鉤

a.	b.	c.	d.

37. (3 points) Game theory models have been borrowed from economics and often applied to behavioral ecology in order to understand the strategies that animals use against each other while competing for resources. In a Hawk-Dove game, for example, in which there were two kinds of competing individuals, Hawks and Doves, with different behavioral strategies, John Maynard Smith suggested the following pay-offs:
遊戲理論的模式係源自經濟學，常用於行爲生態學中來解釋動物個體間爲競爭資源而產生的策略，例如在鷹與鴿的遊戲理論中，有 2 種類型的競爭個體：鷹型與鴿型，各有其不同的行爲策略。John Maynard Smith 建議下列的利益分配：

Winner 獲勝	+50
Injury 受傷	-100
Loser 失敗	0
Display 展示	-10

(A) Assuming that (a) Hawks always win against Doves, (b) Hawks win on half the occasions when they meet other Hawks but suffer injury during the other half, (c) Doves always display when they meet other Doves, but win on only half of these occasions, and (d) Doves never display to Hawks, what would be the average pay-off to the attacker in different fights as listed in the following matrix?
假設(a)鷹與鴿相遇，鷹總是獲勝；(b)鷹與鷹相遇，有一半獲勝的機會，但亦有一半受傷的機會；(c) 鴿與鴿相遇，總是互相展示，但只有一半獲勝的機會，(d)鴿從不向鷹展示。下列之矩陣中，就一攻擊者而言，牠面對不同的對手時，其平均的獲利爲何？

		Opponent 對手	
		Hawk 鷹	Dove 鴿
Attacker 攻擊者	Hawk 鷹		
	Dove 鴿		

(B) An Evolutionary Stable Strategy (ESS) is one that will always win against any other strategy and can never be invaded by another when it occurs in a population. Evaluate whether the following statements are true or false given the pay-offs for the Hawk and Dove strategies listed above.

演化上的穩定策略(ESS)爲在族群中的一種策略，對其他策略而言，此策略總是會贏，決不會有機會被其他策略取代。根據上述鷹及鴿的策略，判斷下列敘述之真僞：

a. Hawk is an ESS and when all individuals in a population play this strategy, a mutation to Dove can never be successful.

鷹是一種演化上的穩定策略(ESS)，當一族群中所有的個體皆採用此策略時，突變爲鴿策略者不可能成功

b. Dove is an ESS and when all individuals in a population play this strategy, a mutation to Hawk can never be successful.

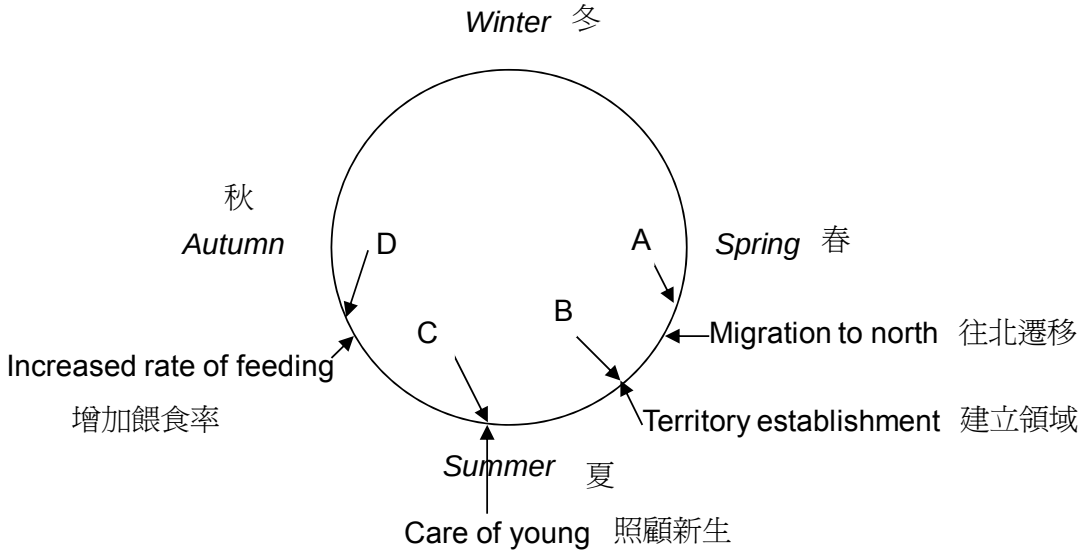
鴿是一種演化上的穩定策略(ESS)，當一族群中所有的個體皆採用此策略時，突變爲鷹策略者不可能成功

Put a tick mark (√) in the appropriate box. 在適當空格中打鉤

Statement	True 真	False 僞
a.		
b.		

38. (2 points) White crown sparrows that live in temperate regions show a complex annual cycle of behavior.

住在溫帶地區的白冠雀，下圖顯示出其在一年中有不同的行爲表現



Match physiological changes (I to V) in these birds with the appropriate points in the behavioral cycle (A to D). Choose from the following options and fill in the table given below with the appropriate numbers:

選配此鳥種之生理變化(I to V)與其一年中不同行爲的表現(A to D)對應，選擇下列的選項，將羅馬數字填入下表中

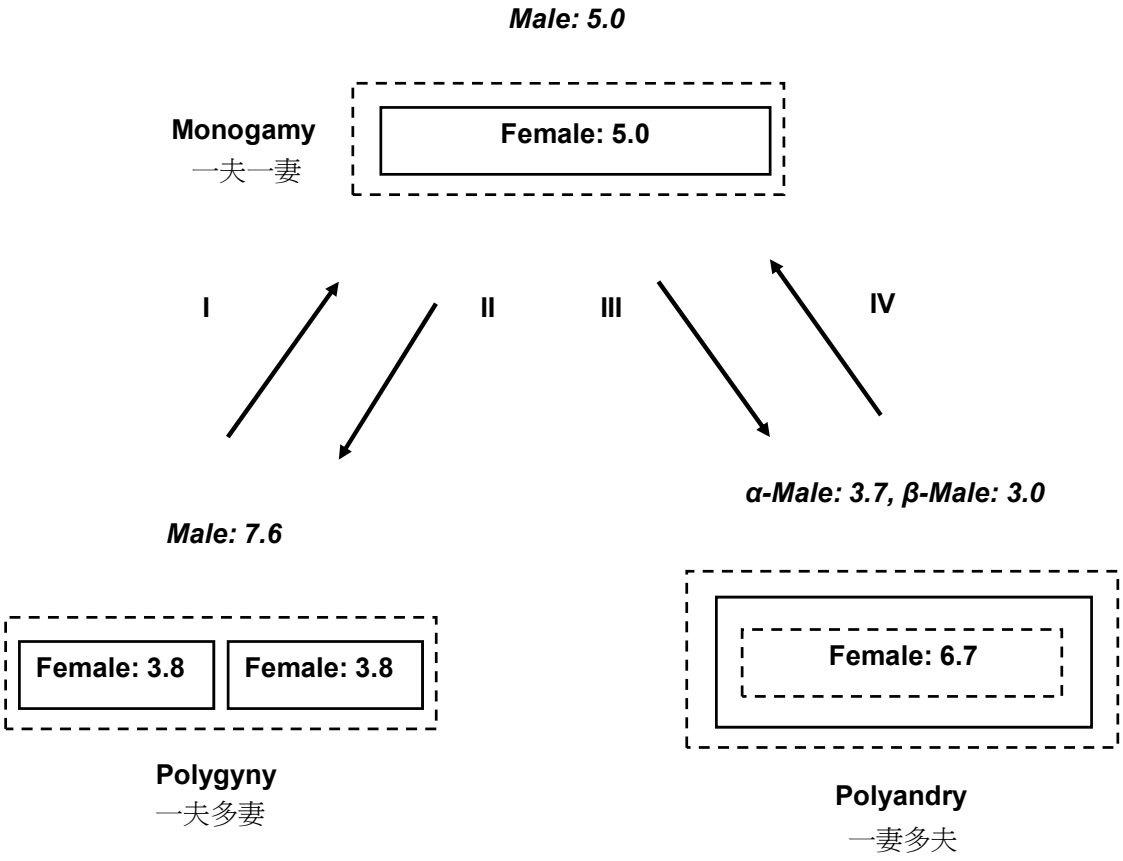
Options: 選項

I. Molting 換羽
II. Gonadal regression 卵巢萎縮
III. Gonadal development 卵巢發育
IV. Fat deposition 脂肪堆積
V. Hibernation 冬眠

Points in the behavioral cycle 一年中的行爲表現	Physiological changes 對照之生理變化
A	
B	
C	
D	

39. (4 points) The dunnock is a common bird of the British Islands. The females of this species establish territories represented by solid lines in the figure below, which may be defended by one or two (α and β) unrelated males (dashed lines). The numbers in the figure refer to the average number of young raised per season by males and females in the different mating combinations. The arrows indicate the directions in which the behaviour of the males and females encourage changes in the mating system.

Dunnock(一種雀)是英國常見的鳥，雌鳥建立領域顯示在下圖的實線範圍，其可能由 1 或 2 隻(α and β)，無親緣關係的雄性來防衛（虛線範圍），下圖爲在不同的交配組合下，每季雌雄個體所養育的平均幼鳥數，圖中箭頭所示之方向爲雌及雄鳥打算改變其婚配制度的取向。



(A) Identify the specific individuals, which would attempt to change the mating system in the directions shown by the arrows.

由箭頭的方向找出特別的個體，其有打算改變婚配制度之意向。

a. I: Male, II: Female, III: Female, IV: β-Male
b. I: Female, II: Male, III: β-Male, IV: α-Male
c. I: Female, II: Male, III: Female, IV: α-Male
d. I: Male, II: Female, III: α-Male, IV: β-Male

Put a tick mark (√) in the appropriate box. 在適當空格中打鉤

a.	b.	c.	d.

(B) Which of the following statements are true? 下列敘述何者爲真？

I. The benefit of polygyny to males is the increased amount of food brought for the chicks by two females instead of one.
一夫多妻制對雄性的好處是帶回巢餵幼鳥的食物增加，因爲會有 2 隻雌鳥（而非 1 隻雌鳥）帶食物回巢餵幼鳥

II. The cost of polygyny to females is shared male care because the contribution of the male's feeding efforts is essential for the survival of the chicks.
對雌鳥而言，一夫多妻制的缺點是單隻雄鳥照顧多隻雌鳥的子代，其結果造成每隻雌鳥的幼鳥受到雄鳥照顧之機會減少，尤其是本種雄鳥餵食幼鳥對幼鳥之存活相當重要

III. The cost of polyandry to females is the aggression that often results between the two males who have mated with her.
對雌鳥而言，一妻多夫制的缺點是 2 隻與雌鳥交配的雄性間常會發生敵意的行爲

IV. The cost of polyandry to males is shared paternity.
對雄鳥而言，一妻多夫制的缺點是不能確定子代與牠的親緣關係

a. I and II
b. II and III
c. I and IV
d. II and IV

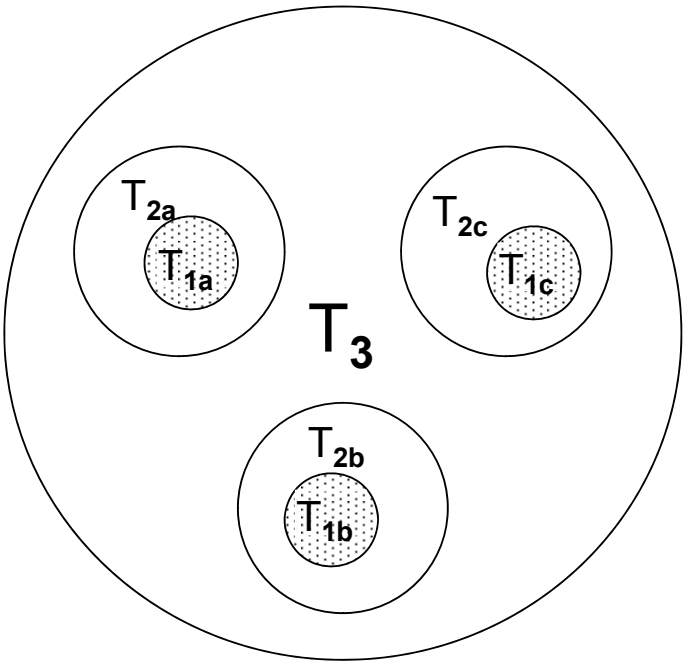
Put a tick mark (√) in the appropriate box. 在適當空格中打鉤

a.	b.	c.	d.

BIOSYSTEMATICS (13)

40. (2 points) The schematic diagram below represents group-in-group relationships. The **T_3 taxon**, represented by the largest circle, includes three **T_2 taxa**. Each of these three **T_2 taxa** has one **T_1 taxon**, represented by circles filled with dots; the dots represent individuals.

下圖中的圓圈顯示群在群中的關係，**T_3** 分類群代表最大的圓圈，其包括 3 個含有 **T_2** 分類群的圓圈；每一個 **T_2** 圈內有一分類群，以具有小點的圓圈代表，每一點代表一個體。



According to above scheme, assign the correct taxa from the options given below to each of the circles. Fill in your answers by writing the appropriate number in the table. Points will be awarded only if the entire table is correctly filled. 根據上圖，將下列所提供之各種分類群的選項，選擇適當的選項，將其數字填入下表中。**只有整表完全填寫且都答對才計分**。

Options:選項

I. Annelida 環節動物門
II. Lepidoptera 鱗翅目
III. Polychaeta 多毛綱
IV. Mollusca 軟體動物門
V. Orthoptera 直翅目
VI. Insecta 昆蟲綱
VII. Arthropoda 節肢動物門
VIII. Crustacea 甲殼綱
IX. Gastropoda 腹足綱
X. Arachnida 蜘蛛綱
XI. *Lumbricus* (earthworm) 蚯蚓屬
XII. *Hirudo* (leech) 水蛭屬
XIII. *Gryllus* (cricket) 蟋蟀屬
XIV. *Unio* (freshwater mussel) 淡水貽貝屬
XV. *Euscorpias* (scorpion) 蠍子屬
XVI. *Daphnia* (water flea) 水蚤屬

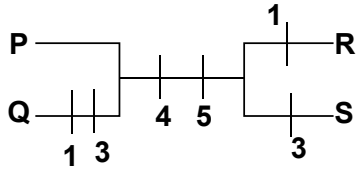
Taxon 分類群	Option/s 選項
T3	
T2a	
T1a	
T2b	
T1b	
T2c	
T1c	

41. (2 points) The sequence of a pentanucleotide DNA segment of four species P, Q, R and S are given.
四個物種 P, Q, R and S 的 DNA 序列如下

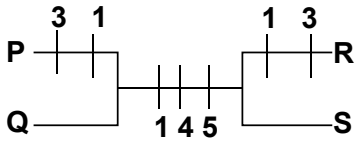
Species 物種	Sequence site 序列				
	1	2	3	4	5
P	A	G	T	T	C
Q	C	G	A	T	C
R	C	G	T	A	T
S	A	G	A	A	T

The most parsimonious phylogenetic classification of these species would be:
此四種之最簡單的系統親緣關係爲何？

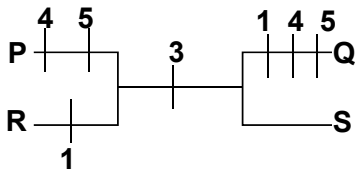
a.



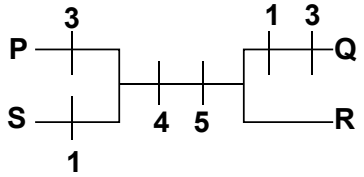
b.



c.



d.

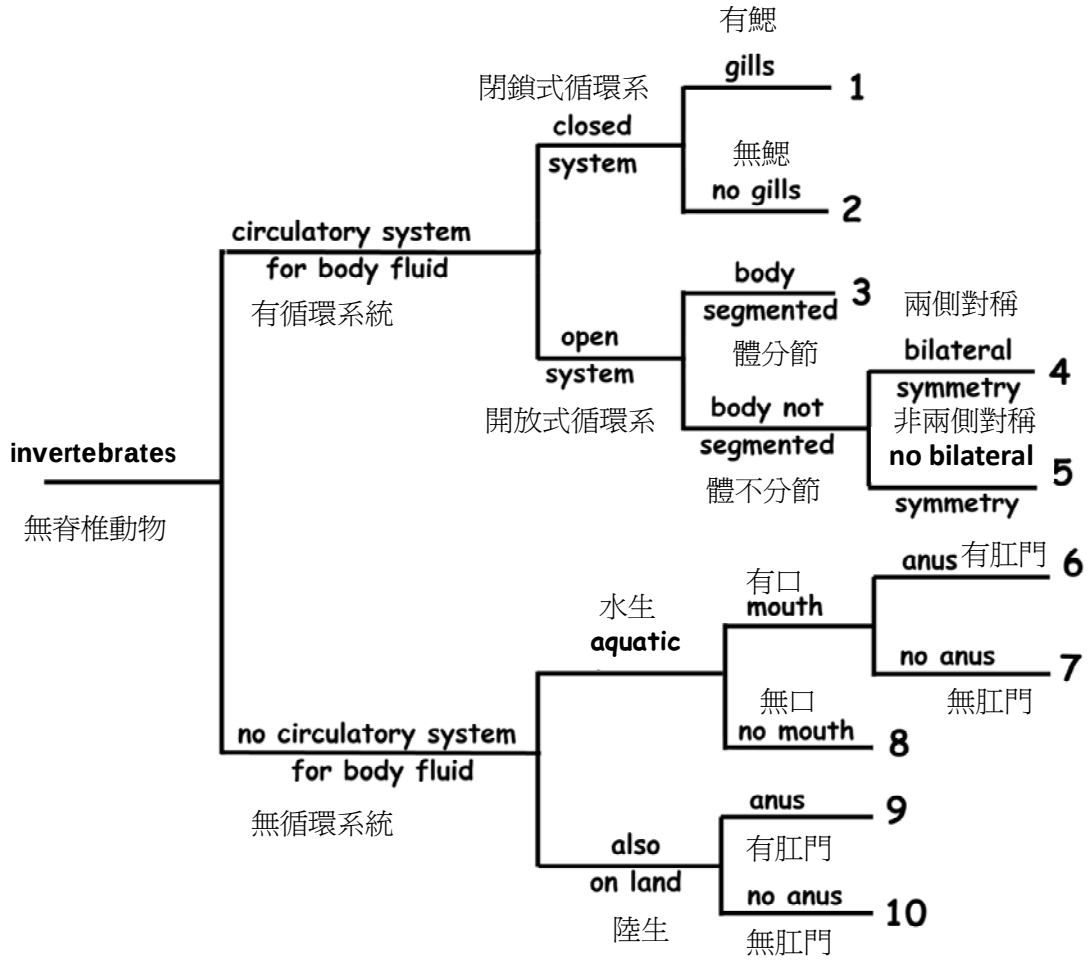


Put a tick mark (√) in the appropriate box. 在適當空格中打鉤

a.	b.	c.	d.

42. (5 points) A classification chart based on certain characteristics of invertebrates is shown below:

下圖爲根據無脊椎動物的某些特徵所製作之分類圖



Fill in the appropriate numbers from the classification chart against the respective groups in the table below:

針對下表所列的分類群，請由上述分類圖選取適當之數字，填入下表中。

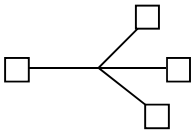
Group 分類群	Number 數字	Group 分類群	Number 數字
Annelida (Earthworms) 環節動物門（蚯蚓）		Mollusca (Land snails) 軟體動物門（陸生蝸牛）	
Arthropoda (Crayfishes) 節肢動物門（龍蝦）		Mollusca (Squids) 軟體動物門（烏賊）	
Cnidaria (Jellyfishes) 刺絲胞動物門（水母）		Nematoda (Roundworms) 線形動物門（蛔蟲）	
Echinodermata (Starfishes) 棘皮動物門（海星）		Platyhelminthes (Tapeworms) 扁形動物門（絛蟲）	
Mollusca (Bivalvia) 軟體動物門（二枚貝）		Porifera (Sponges) 海綿動物門（海綿）	

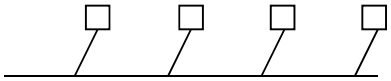
43. (4 points) The genetic distances between four species are provided in a matrix below. The numbers represent the percentage differences between each pair of species.
四個物種的遺傳距離如下列矩陣所示。其中的數字代表兩物種間的差異百分比。

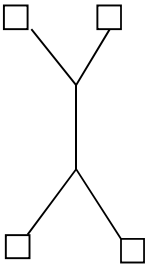
	A	B	C	D
A	-	-	-	-
B	5	-	-	-
C	13	14	-	-
D	15	16	6	-

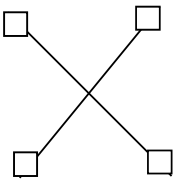
(A) Which of the following tree structures represents the matrix data most appropriately? (Squares in the figure represent species and the lengths of the lines approximate the genetic distance between them.)

下列哪個樹狀圖結構最能適切地代表矩陣中的數據？（樹狀圖中的方格代表物種，分枝的長度相當於彼此間之遺傳距離）

a. 

b. 

c. 

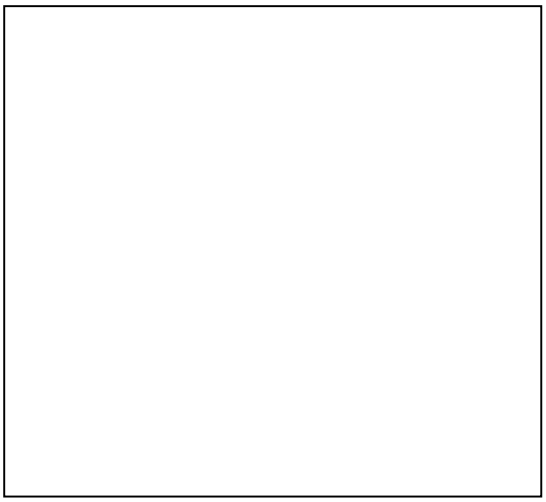
d. 

Put a tick mark (√) in the appropriate box. 在適當空格中打鉤

a.	b.	c.	d.

(B) Based on the answer selected in the previous question and using the data given in the matrix, construct the tree that correctly shows the genetic relatedness of the four species, where the numbers on the lines should approximate the genetic distance between them..

根據上題所選的答案及利用矩陣中的數據，建構一個樹狀圖以正確顯示出四物種之遺傳親緣關係，並在分枝上註記其長度數值(即其遺傳距離)。



********** END OF PART B **********