Country: _____

Student Code: _____

23rd INTERNATIONAL BIOLOGY OLYMPIAD

8th – 15th July, 2012

SINGAPORE

THEORETICAL TEST – PAPER 2

Write all answers in the **ANSWER SHEET**

將答案寫在答案紙上

Dear Participants

- You have a total of 3 hours (180 minutes) for answering this theory paper.

  你有3個小時可回答本份理論題

- Use the **Answer Sheet**, which is provided separately, to answer all the questions.

  請在答案紙上回答所有問題

- The answers written in the Question Paper will **NOT** be evaluated.

  寫在試卷上的答案將不計分

- Write your answers legibly. **Note that there may be more than one correct/incorrect answer and every cell should be filled.**

  For example:

  請依下列方式作答, 注意: 答案中可能有多於一個正確 /錯誤的, 每個空格都要填寫!

  例如下方所示:

a	b	c	d	e
×	✓	×	×	✓

- 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: 有些題目已被標示為刪除, 請勿作答! 同時也要在看完整個題目後再作答, 因為有些小題會出現在下一頁中。

- The maximum number of points for this paper is 91.8.

  本試題共計 91.8分

- Stop answering and put down your pen IMMEDIATELY when the bell rings.

  當鈴聲響起, 應立即停止作答並放下原子筆

- Your Answer Sheets as well as the Theoretical Test question paper will be collected at the end of the test period.

  最後, 監試人員會來收走試題及答案紙。

Good Luck! ☺

CELL BIOLOGY

1. Four mixtures of microorganisms were collected from different sites around a school and each microbial mixture was inoculated into a medium that contained all essential elements (in the form of ionic compounds) except carbon. The medium was at first clear (i.e., not turbid), and this was left to be cultured with agitation in the dark for 24 h (Stage I). The culture was subsequently continued in bright light for 24 h (Stage II) and then a further 24 h in the dark (Stage III). The turbidity of the four samples was monitored at the end of each stage and the following results were obtained.

   四種微生物的混合物從校園裡的不同地點蒐集而來，並且被培養於含有所有必須之元素（以離子態化合物的形式存在）的培養基（但是此培養基不含有碳源）。培養基一開始時為澄清（亦即：不混濁），接著於黑暗中搖瓶培養 24 小時（狀態一 ，Stage 1）。培養液接著於光亮中持續培養 24 小時（狀態二 ，Stage 2），然後再回復到黑暗中接續培養 24 小時（狀態三 ，Stage 3）。這四個樣品的混濁度，在每一個培養狀態之後都被觀察與紀錄，結果如下：

Sample	End of Stage		
	I	II	III
1	Clear 澄清	Clear 澄清	Clear 澄清
2	Clear 澄清	Slightly turbid 有點混濁	Slightly turbid 有點混濁
3	Slightly turbid 有點混濁	More turbid 較混濁	Very turbid 非常混濁
4	Slightly turbid 有點混濁	Slightly turbid 有點混濁	Slightly turbid 有點混濁

Which of the following organisms are likely to be present in samples 1 to 4? Use a tick (✓) to indicate presence and a cross (×) to indicate absence **in the Answer sheet**. (3.2 points)

在樣品 1 到 4 中含有下列哪些微生物(a-d)。有存在的請打勾(✓)，不存在的請打叉(×)，並寫於答案卷上。(3.2 分)

a. photoautotrophic microorganisms

光合自營微生物

b. chemo-organotrophic microorganisms

化學-有機異營微生物

c. microorganisms that carry cellular storage granules such as inclusion bodies

帶有細胞儲存微粒（例如：內含體 (inclusion bodies)）的微生物

d. microorganisms that carry thylakoid membranes in their cells

其細胞帶有類囊體膜的微生物

2. A rod-shaped bacterial cell is observed to have numerous pili (fimbriae) growing all over its surface. These structures appear to be able to lengthen and shorten. Indicate the correct function(s) (a – d) of these structures with a tick (✓) and incorrect answer(s) with a cross (×). (1 point)

一個桿狀的細菌細胞被觀察到含有許多的線毛（線毛科的桿菌 (fimbriae)）長於其表面。這些結構似乎可以伸長和縮短。指出這些構造的正確功能(請打勾✓)，不正確的答案請打叉(×)。(1 分)

a. recombination 遺傳重組

b. attachment to surfaces 用於貼附於表面

c. active motility in solution 在溶液中的活動能力

d. for defence 用於防禦

3. Two bacterial cells were cross sectioned, and Bacterium A showed a single membrane covering its cell, while Bacterium B is covered by two membranes which are separated by a narrow space containing peptidoglycan material. Identify which bacterium is Gram positive and Gram negative respectively **in the Answer sheet**. (0.4 points)

   兩個細菌細胞被橫切開來，細菌A以單層膜包覆其細胞；然而細菌B被兩層膜所包覆，並且此兩層膜被含有肽聚糖的狹小空間隔開。請於**答案卷**寫出哪一個細菌為革蘭氏陽性菌？哪一個細菌為革蘭氏陰性菌？（0.4 分）

4. Research was conducted to examine the presence of regulator element in the upstream of transcription start site from eukaryotic gene. As a preliminary study, a researcher performed *in silico* analysis by multiple alignment of nucleotide -37 to -26 from 900 different genes. The resulting homology percentage data are shown in the table below.
一個研究用來檢驗真核基因在轉錄起始點上游所存在的調控因子（regulator element）。在初步的研究當中，一個研究人員藉由多重排列 900 個不同基因之-37 到 -26 的核苷酸序列，來執行電腦分析。所得到之基因同源性的百分比數據如下表所示：

		-37 (5')											**-26 (3')**
Base frequency (%) 鹼基出現的頻率	A	21	16	4	91	0	95	67	97	52	41	16	24
	C	23	39	10	0	0	0	0	0	0	9	35	37
	G	28	35	3	0	0	0	0	3	12	40	38	30
	T	28	10	83	9	100	5	33	0	36	10	11	9

4.1. Based on the given data, predict the most likely nucleotide sequence -35 to -29 within the conserved area which is essential for its regulator function. **In the Answer Sheet**, fill the boxes with A, C, T, and G, at the appropriate positions. (1.4 points)
基於上述所給的數據，推測位於-35 到 -29 之保守區域內的最有可能核苷酸序列（並且此序列是其調控因子的功能所必須）。請在**答案卷**上之空格填入A, C, T, 或 G。（1.4 分）

4.2. Deletion of nucleotides -50 to -26 of several genes resulted in dramatically decreased RNA polymerase binding within the gene. Which type(s) of sequence element may be represented by nucleotides -50 to -26? Indicate appropriate answer(s) with a tick (✓) and inappropriate answer(s) with a cross (×) **in the Answer Sheet**. (1.0 point)
刪除數個基因之-50 到 -26 的核苷酸，會顯著地降低 RNA 聚合酶結合至該基因。請指出答案卷上哪些序列的功能特性，可以用來代表-50 至 -26 之核苷酸序列的可能特性。適當的答案請打勾(✓)，不恰當的答案請打叉(×)。(1 分)

5. Hormones regulate physiological processes in various specialised cells. Match the hormones listed below (a – e) with the physiological processes (I – VII) that they regulate. Note: some processes can be regulated by more than one corresponding hormone. (2.8 points)
荷爾蒙調控生理作用於不同的特化細胞中。對應下列之荷爾蒙(a – e)所調控之對應的生理作用(I – VII)。注意！有些作用可以被一個以上的荷爾蒙所調控。（2.8 分）

Hormone 荷爾蒙	Physiological process 生理作用
a. Insulin 胰島素	I. gluconeogenesis 糖質新生作用
b. cortisol 皮質醇	II. glycogenesis 肝糖合成作用
c. glucagon 升糖素	III. glycogenolysis 肝糖分解作用
d. thyroid hormone 甲狀腺素	IV. lipolysis 脂質分解作用
e. epinephrine 腎上腺素	V. lipogenesis 脂質生成作用
	VI. protein catabolism 蛋白質異化作用
	VII. protein anabolism 蛋白質同化作用

6. Which of the following allow(s) cell membranes to remain fluid under cold temperatures? Indicate correct answer(s) with a tick (✓) and incorrect answer(s) with a cross (✗). (0.8 point)
下列哪項允許細胞膜在冷的溫度下仍能保持流動？正確的答案請打勾(✓)，不正確的答案請打叉(✗)。(0.8 分)

a. by using active transport
藉由主動運輸

b. by co-transport of glucose and proton
藉由葡萄糖和氫離子的共同運輸作用

c. by increasing the percentage of unsaturated phospholipids in the membrane
藉由增加細胞膜上不飽合磷脂質的百分比

d. by decreasing the number of hydrophobic proteins in the membrane
藉由降低細胞膜內疏水性蛋白質的數目

7. Cellular abnormality can often lead to manifestation of disease or disorders in our body. Match the following cellular abnormalities (I – V) each with their most likely disorder (a – e). (1.5 points) 細胞的不正常性會導致我們身體顯現出疾病和功能失調。對應下列之細胞不正常性(I – V)和其所造成之最可能的功能失調 (a – e)。(1.5 分)

Cellular abnormalities: 細胞的不正常性

I. altered cellular receptor 變了樣的細胞受體

II. uncontrollable cell division 無法控制的細胞分裂

III. abnormal membrane transport protein 不正常的膜運輸蛋白

IV. enzyme absence 酵素缺失

V. absence of structural protein 結構蛋白的缺失

Disorders: 功能失調

a. A child has chronic respiratory infections; secretions of the gut and lung are thick in this child, and his sweat is altered, with high Na^+ and Cl^- levels.
一位小孩有慢性的呼吸感染症；這位小孩之腸和肺的分泌物是濃厚黏稠的，並且他的汗水變成含有高濃度的鈉離子（Na^+）和氯離子（Cl^-）。

b. A young man has pain in his chest and biopsy test demonstrates presence of abnormal, unspecialized, metastatic cells.
一位年輕人有胸痛。切片檢查顯示有不正常的、未分化的、癌轉移的細胞

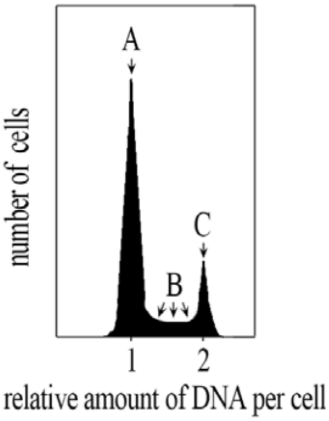
c. A phenotypically normal boy is diagnosed as having androgen insensitivity; his chromosomes are 46, XY.
一位外表型正常的男孩被診斷出對男性荷爾蒙是無感的；但是他的染色體有 46 條且為 XY

d. A young boy has progressive weakness and muscle wasting atrophy of calf muscles.
一位年輕男孩逐漸的虛弱，並且小腿肌肉持續地肌肉萎縮

e. Affected children gradually lose skills and sight; have massive accumulation of lipid in brain cells. Death occurs at young age. There is no treatment.
被影響的孩童逐漸地失去行為能力與視力；其腦細胞有脂肪之大量累積。幼年即會死亡。目前沒有治癒的方法。

8. A replicating cell population was stained with a dye that became fluorescent when bound to DNA. The DNA content of its individual cells was then determined by fluorescence-activated cell sorting (FACS) which is shown in the graph below.

一個複製中的細胞群被一種染劑染色；此染劑結合上 DNA 後可產生螢光。個別細胞之 DNA 含量利用螢光活化細胞分選儀（fluorescence-activated cell sorting, FACS）來測定，結果如下圖：



a. From the graph, which group of cells (A – C) are in the S phase of the cell cycle? (0.9 points)

從此圖可看出，哪一個細胞群（A 至 C）處於細胞週期的 S 時期？(0.9 分)

b. Which group of these cells (A – C) are in the LONGEST phase of the cell cycle? (0.9 points)

哪一個細胞群（A 至 C）處於細胞週期之**最長的**時期？(0.9 分)

Indicate appropriate answer(s) with a tick (✓) and inappropriate answer(s) with a cross (✗).

適當的答案請打勾(✓)，不恰當的答案請打叉(✗)。

9. Phospholipids are a class of lipids that are a major component of all cell membranes as they can form lipid bilayers.

磷脂質是一種脂質，當其形成脂質雙層膜時也是所有細胞膜之主要成份

9.1. Indicate true statement(s) with a tick (✓) and false statement(s) with a cross (✗). (0.8 points)

正確的敘述請打勾(✓)，錯誤的敘述請打叉(✗)。(0.8 分)

a. The hydrophobic tails are oriented towards the interior of the cell membrane.

疏水性的尾部指向細胞膜的內部

b. The fatty acids present in the membrane do not have double bonds.

細胞膜上的脂肪酸不具有雙鍵

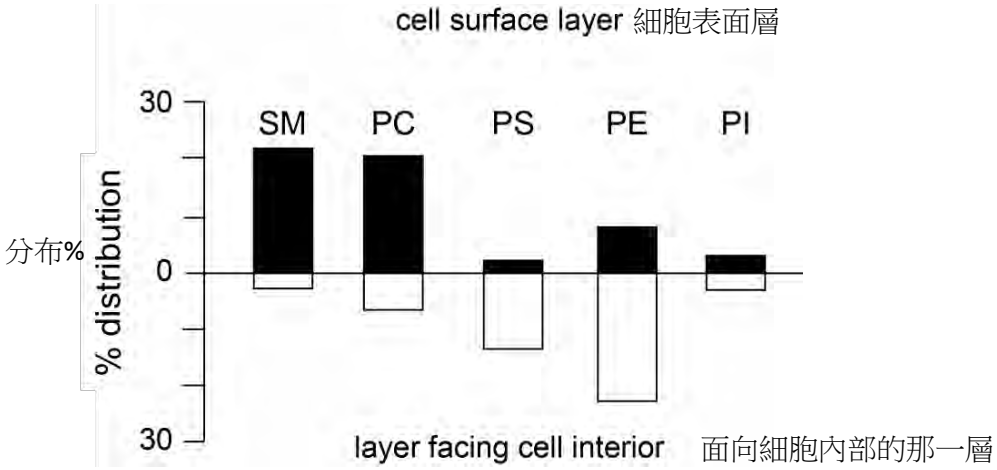
c. Once phospholipids are incorporated they remain in the cell membrane permanently.

一但磷脂質被嵌入之後，磷脂質將永遠停留於細胞膜中

d. The bilayers are randomly interspersed with proteins.

蛋白質被雜亂無章地散布於此雙層膜

9.2. Mammalian plasma membranes are characterized by the presence of different types of phospholipids (SM, PC, PE, PS and PI). The graph below shows the percentage distribution of each phospholipid across the plasma membrane of human erythrocytes.
哺乳類之細胞膜被鑑定存有不同種類的磷脂質 (分成 SM, PC, PE, PS and PI 這五種)。下圖顯示出穿過人類紅血球細胞膜之每一種磷脂質的百分比分布情形：



Indicate the correct statement(s) with a tick (✓) and incorrect statement(s) with a cross (×). The numbers indicated are approximate figures. (0.8 points)
正確的敘述請打勾(✓)，錯誤的敘述請打叉(×)。圖上標示的數值乃是大概值。(0.8 分)

a. Membranes, in general, can be concluded to be asymmetric.
一般來說，細胞膜可以被認為是不對稱的。

b. 24% of the total membrane phospholipids contain SM and 4% contain PI.
全部膜磷脂質的百分之 24 含有 SM，百分之 4 含有 PI。

c. 80% of the inner total membrane phospholipids contain PE and 16% contain PC.
全部內膜磷脂質的百分之 80 含有 PE，百分之 16 含有 PC。

d. Most PC is confined to the outer surface of the erythrocytes while most of the PE and PS are confined to the inner surface of the erythrocytes.
大部分的 PC 被侷限於紅血球之外表面，然而大部分的 PE 和 PS 則被侷限於紅血球之內表面。

10. In a study of a rice plant, it is found that gibberellins (GA) play an important role in the growth of seedlings. The GA repressor protein (GARP) controls the expression of GA induced genes. This protein contains two domains: (i) regulatory domain (DELLA) and (ii) the repressor domain (GRAS). GA bound to its receptor, attaches to DELLA domain and facilitates association of repressor domain with 'SCF ubiquitin ligase complex'. It results in GARP getting targeted and degraded by proteasome. This leads to GA induced gene expression and seedling growth.
在一個水稻的研究中，吉貝素 gibberellins (GA)被發現在小苗生長時期扮演一個重要的角色。吉貝素抑制蛋白（GARP）控制了吉貝素所誘導之基因的表現。此蛋白質含有兩個區塊（domains）：(i) 調控區塊 (DELLA) 和 (ii) 抑制區塊(GRAS)。吉貝素（GA）結合至其受體之調控區塊 (DELLA)時 ，導致抑制區塊(GRAS)與泛素連接酶複合體（SCF ubiquitin ligase complex）結合。此舉導致 GARP 被標定，並且被蛋白酶體(proteasome)所降解。GARP 被降解後，將導致吉貝素所誘導之基因的表現與小苗的生長。

Based on this information, indicate growth of the seedings with a loss of function mutation in the DELLA domain or the GRAS domain with a tick (✓) under the presence or absence of gibberellins, and use a cross (×) if no growth is predicted **in the Answer Sheet**. (1.2 points)
基於這些訊息，於存在吉貝素gibberellins (GA) 或缺乏不存在吉貝素之狀況下，並搭配DELLA區塊或GRAS區塊有功能缺失時，小苗可生長者請打勾(✓)，沒有生長者請打叉(×)。請於**答案卷**作答 。(1.2 分)

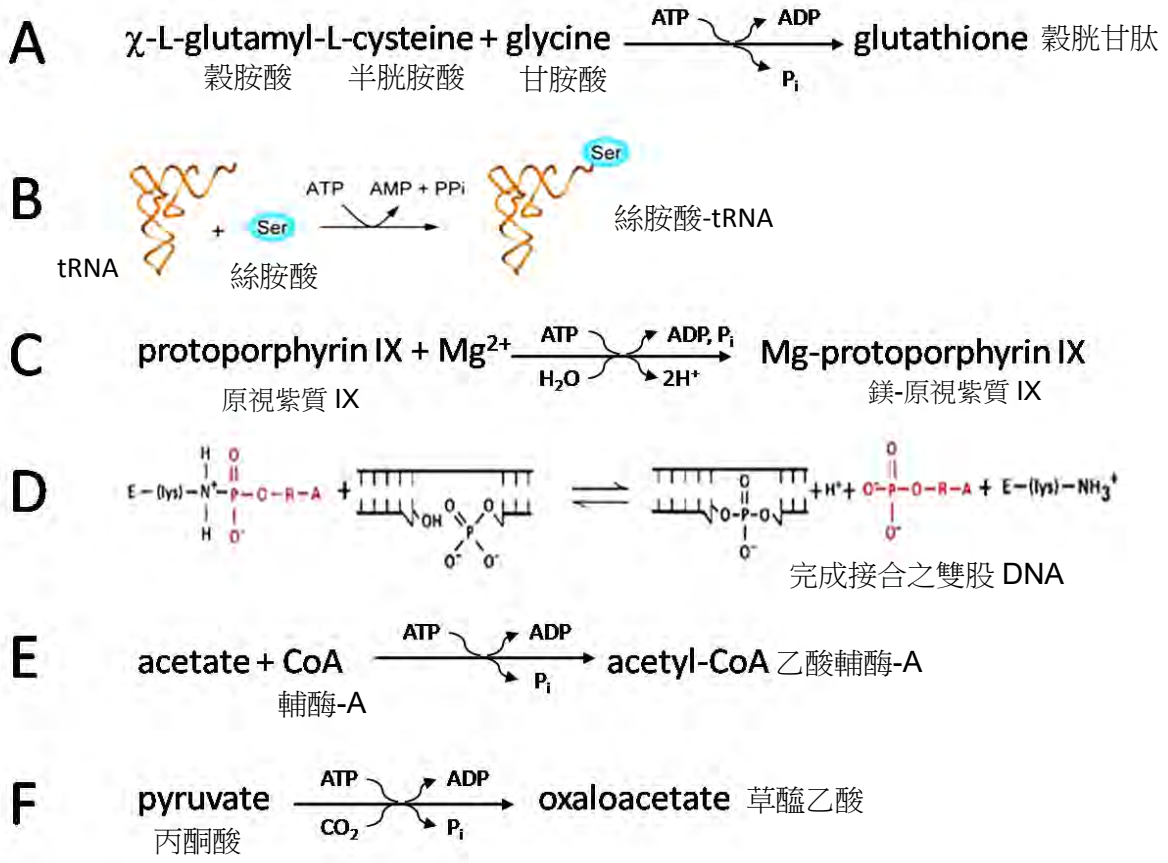
11. The following enzymes (1 – 6) catalyse the formation of the chemical bonds, I to VI.

下列酵素(1 – 6) 催化化學鍵結 (I to VI) 的形成。

Enzyme 酵素	Chemical bond 化學鍵結
1. DNA ligase DNA 接合酶	I. Carbon-oxygen bond 碳-氧鍵
2. magnesium chelatase 鎂離子螯合酶	II. Carbon-sulfur bond 碳-硫鍵
3. acetate-CoA synthase 乙酸輔酶-A 合成酶	III. Carbon-nitrogen bond 碳-氮鍵
4. amino acid-tRNA synthase 胺基酸-tRNA 合成酶	IV. Carbon-carbon bond 碳-碳鍵
5. pyruvate carboxylase 丙酮酸羧化酶	V. Phosphoric ester bond 磷酯鍵
6. glutathione synthase 穀胱甘肽合成酶	VI. Nitrogen-metal bond 氮-金屬鍵

Reactions that the enzymes catalyse are listed below:

酵素催化的反應如下：



Match the enzymes and corresponding enzymatic reactions with the respective bond types. (2.4 points)

以個別的鍵結種類來對應酵素(1-6)及其匹配的酵素反應(A-F) (2.4 分)

PLANT ANATOMY AND PHYSIOLOGY 植物解剖與生理學

12. The cell wall in plants limits cell expansion. Growing cell walls extend faster in acidic conditions and a group of proteins called expansins are key regulators of wall extension during growth. In an experiment, excised cucumber hypocotyls of the same length were subjected to the following treatments (1 – 4) before being attached to an extensometer and the extension of the hypocotyl measured.

植物的細胞壁會限制細胞延伸, 生長中的植物細胞處於酸性條件下可延伸得較快, 且一群稱為延伸酶(expansins)的蛋白質是生長過程中調控細胞壁延伸的關鍵角色。在實驗中, 相同長度的黃瓜下胚軸先以四種不同方式(1 – 4)處理, 再黏接在延伸測量器上, 然後測量下胚軸長度。

	Treatment protocol 處理方式
1	Treated with fusicoccin (a drug which activates H^+-ATPase in the plasma membrane) and placed into a buffer at pH 7 以fusicoccin (一種可活化細胞膜上的酵素H^+-ATPase之藥劑) 處理, 並放在pH 7 的緩衝液中
2	Treated with fusicoccin (a drug which activates H^+-ATPase in the plasma membrane), heated, and placed into a buffer at pH 4.5 以fusicoccin (一種可活化細胞膜上的酵素H^+-ATPase之藥劑) 處理, 加熱並放在pH 4.5 的緩衝液中
3	Heated, then placed in a buffer at pH 4.5 先加熱, 然後放在 pH 4.5 的緩衝液中
4	Heated, then placed in a buffer pH at 4.5 with the addition of an homogenate extracted from a region just behind the growing tip of another cucumber hypocotyls 先加熱, 然後放在 pH 4.5 的緩衝液中, 且該緩衝液中有加入萃取自黃瓜下胚軸(緊鄰生長點)的均質液

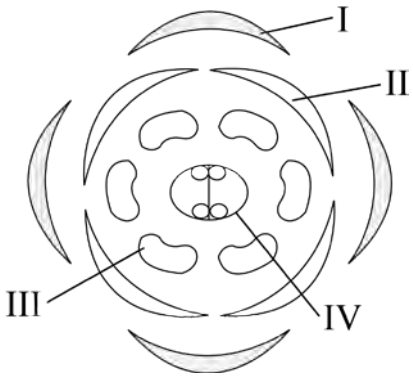
The length of the hypocotyl can either increase or remain the same. Indicate the outcomes with an arrow (↑) for an increase in length and an equal sign (=) for the same length for the different treatments. (1.2 points)

下胚軸的長度可增加或維持不變, 在答案紙上指出各種處理的結果, 以(↑)代表增加; (=)代表維持不變。

13. The ABC model explains how three homeotic genes control floral organ identity:

植物的 ABC 模式用以說明三個同源區基因調控花的各部位之類型:

- activity of gene A alone specifies sepals
  基因 A 單獨作用可特化為萼片
- activity of both gene A and B is required for the formation of petals
  基因 A 及 B 共同作用則特化為花瓣
- activity of genes B and C results in the formation of stamens
  基因 B 及 C 共同作用則會形成雄蕊
- activity of gene C alone specifies carpels
  基因 C 單獨作用可特化為心皮
- gene A and gene C mutually repress each other
  基因 A 及基因 C 則有相互抑制的作用



Indicate what the floral parts (I – IV) develop into in a mutant with a loss of activity of its B gene? Write the resultant outcome **in the Answer Sheet**. (1.2 points)

指出在喪失基因B的突變株之花的各部位(I – IV)會是甚麼構造? 參考下列構造之英文字母, 填在答案紙上之對應部位。

a. sepal 萼片

b. petal 花瓣

c. stamen 雄蕊

d. carpel 心皮

14. Indicate the type of cell division involved in the organ/cell formation and the ploidy of the cells. Use I for mitosis and II for meiosis. (2 points)

在答案紙上的表格中, 指出該器官/細胞形成時會進行的細胞分裂方式以及細胞的染色體套數, 用 **I** 代表有絲分裂; **II** 代表減數分裂。

15. Delves et al. (1986) studied the influence of different organs on nodulation phenotype. To analyze whether shoot or root factors have a regulatory role in the nodule formation, they grafted *wildtype* plant (Bragg cultivar) with two plant mutants (*nts382* and *nts1116*). The grafts were inoculated with *Bradyrhizobium japonicum* strain USDA110 and harvested 9 weeks later. Nodules were picked and counted from each plant and dry weights obtained. The results are summarized in Table 1.

Delves et al. (1986)研究不同器官在腫瘤形成性狀上的影響。為了分析在腫瘤形成過程中, 莖或根的因子是否扮演調控之角色 , 研究人員將兩種突變株(*nts382* and *nts1116*)嫁接在野生型植株(Bragg 栽培種)上, 然後再嫁接株上接種腫瘤菌種 *Bradyrhizobium japonicum* 菌株 USDA110, 並在 9 週後採收。從每棵植株上採取腫瘤並記錄數量及其各別乾重, 結果整理如表 1 所示

Table 1. Supernodulation control by Bragg cultivar

表 1 Bragg 栽培種之超級腫瘤形成控制

嫁接(莖/根)	每株腫瘤數	腫瘤重
Graft (Shoot/Root)	**Nodule No. per Plant**	**Nodule Mass**
		mg dry wt nodule g^{-1} dry wt plant
nts382/nts382	249 ± 90	139 ± 101
nts1116/nts382	71 ± 18	110 ± 5
Bragg/nts382	11 ± 5	2 ± 1
nts382/nts1116	251 ± 46	182 ± 16
nts1116/nts1116	64 ± 6	14 ± 5
Bragg/nts1116	8 ± 3	3 ± 1
nts382/Bragg	182 ± 35	56 ± 28
nts1116/Bragg	48 ± 4	9 ± 2
Bragg/Bragg	8 ± 1	2 ± 1

Indicate correct deduction(s) with a tick (✓) and incorrect deduction(s) with a cross (×). (1.8 points)

判斷下列敘述, 正確以(✓)代表; 錯誤以(×)代表

a. Genetic factors expressed in the shoot are affecting the number of nodules present in the root.

在莖部表現的遺傳因子會影響根中的腫瘤數目

b. Genetic factors expressed in the root are affecting total nodule mass.

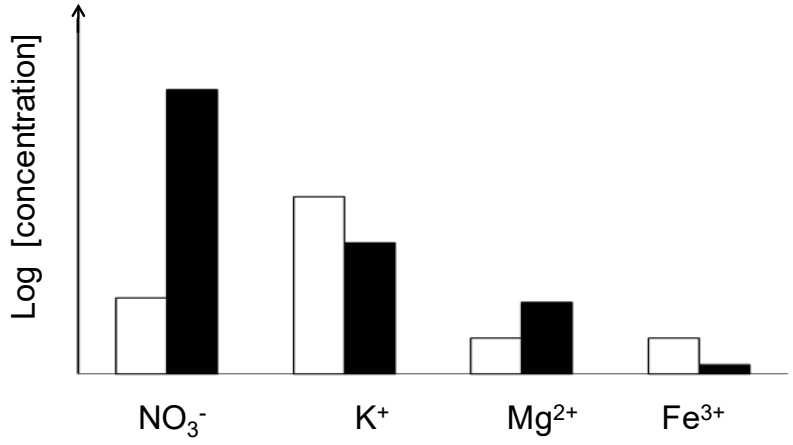
在根部表現的遺傳因子會影響總腫瘤重量

c. Grafts are compensating an increased number of nodules with a lower mass per nodule.

嫁接可補償而使腫瘤數增加, 且每個腫瘤的重量下降

16. The bar chart shows the concentrations of various minerals in the nutrient solution (☐) and in the root cells (■) after 2 weeks of plant growth. Based on the graph given below, indicate appropriate answer(s) with a tick (✓) and inappropriate ones with a cross (×) **in the Answer Sheet**. (2.4 points)

下圖顯示多種礦物離子在植物生 長 2 週後, 其分別存在於營養液(☐)及根部細胞(■)中的濃度。據此資 訊**在答案紙上**填入適當答案, 以(✓)代表; 不適當者, 以(×)代表



17. Chemical Z, produced in germinating barley (*Hordeum)* seeds plays a role in the α-amylase synthesis by the aleurone layer cells. To investigate the role of Z more closely, the promoter of the α-amylase gene was fused with the gene for β-glucuronidase (enzyme producing blue product with certain substrate). The transgenic plants were then tested under various conditions for the presence of blue color in the aleurone layer cells, upon addition of the β-glucuronidase substrate. The results are shown in the table below:

Z 是在萌發中的大麥(*Hordeum)*種子所產生的化學物質, 其參與糊粉層細胞中的 α-澱粉酶合成過程。為進一步探討扮演的角色,將 α-澱粉酶基因的啟動子接合在 β-葡萄糖酸酶 (β-glucuronidase; 是一種可與某些受質作用而產生藍色產物之酵素) 的基因上, 然後將此轉基因植株在不同處理下, 經由加入 β-葡萄糖酸酶的受質之後, 拿來檢測糊粉層細胞中是否呈現藍色, 結果如下表所示。

Experimental condition 實驗處理	Aleurone layer cells with blue colour 糊粉層細胞呈現藍色
Normal seed 正常種子	Present 有
Seed with embryo removed 去除胚的種子	Absent 無
Seed without embryo + Z 無胚種子並外加 Z	Present 有
Isolated protoplasts of aleurone layer cells 自 糊粉層細胞分離出的原生質體	Absent 無
Isolated protoplasts of aleurone layer cells + Z 自 糊粉層細胞分離出的原生質體並外加 Z	Present 有

Indicate correct deduction(s) about Z with a tick (✓) and incorrect deduction(s) with a cross (×). (1.0 points)

指出下列有關 Z 的推論為正確(以✓表示), 或錯誤(以×表示)

a. It is likely to be a transcription factor for the α-amylase gene in barley.

它可能是大麥 α-澱粉酶基因的一種轉錄因子

b. It is produced in the aleurone layer.

它在糊粉層中產生

c. It is produced in the embryo.

它在胚中產生

d. It is produced in the pericarp.

它在果皮中產生

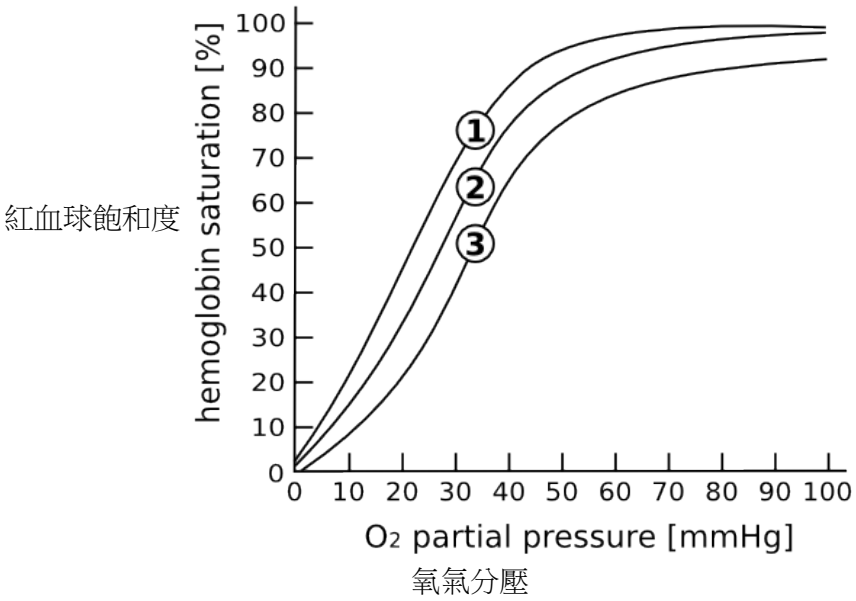
e. It is likely to be ethylene.

它可能是乙烯

ANIMAL ANATOMY AND PHYSIOLOGY

18. The O_2-affinity curve for human haemoglobin at the physiological blood-pH of 7.4 is represented by (2). Under various conditions, the curve would shift towards (1) or (3). Indicate the appropriate curve (1 or 3) under the conditions listed in the table **in the Answer Sheet**.

下圖中 (2) 代表人類血紅素在血液pH 7.4 時的O_2-親合曲線，在不同狀況下曲線會調向(1)或(3) ，請以在答案卷表中的狀況來決定究竟是何者(1 或 3)。(2 分)



19. Tom ran after a snatch thief and caught him after a 80m chase. Which of the following biochemical pathways was important in his muscles during the chase? Indicate the correct answer with a tick (✓) and incorrect answers with a cross (×). (1 point)

湯姆經 80 公尺的追逐抓住搶賊，下列何種生化途徑在追逐時對他的肌肉是重要的？下列答案中對的打鉤(✓)，錯的打叉 (×) (1 分)

a. fatty acid oxidation 脂肪酸氧化

b. glycolysis 糖解作用

c. gluconeogenesis 糖質新生作用

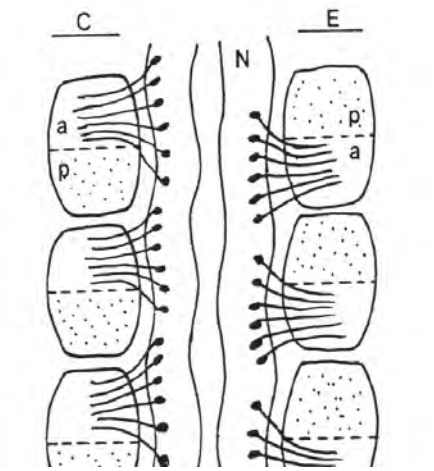
d. glycogenolysis 肝糖分解作用

e. proteolysis 蛋白分解

20. The schematic drawing below was traced from the horizontal section of a chick embryo showing the axon outgrowth pattern of the motorneurones after an experimental manipulation. N is the neural tube which will normally develop into the spinal cord. The segmented structures flanking the neural tube are the somites which will contribute to the muscles and vertebrae development. Somites are subdivided into anterior (a) and posterior (p) segments.

The control side (C) has somites in the original orientation whereas the experimental side (E) has some somites surgically rotated. The objective of the experiment was to determine if the outgrowth pattern of the motor axons is dependent on the orientation of the somites.

下方簡圖描繪一雞胚的水平切面，顯示運動神經元在實驗操作後其軸突的生長形式。N 為在脊索內正常發育的神經管，其側面分節的構造為原椎節，可發育為肌肉及脊椎，原椎節可再細分為前段(a)及後段(p)。控制組(C) 為原來原椎節的排列方向，在實驗組(E)中有幾個原椎節方向經手術旋轉，實驗目的是要瞭解運動神經元軸突的生長形式是否由原椎節排列方向所決定



Based on the above figure, indicate correct deduction(s) with a tick (✓) and incorrect deduction(s) with a cross (✗). (2 points)

根據上圖將正確的推斷打鉤(✓)，錯的打叉 (✗) (2 分)

a. The axons grow out of the neural tube regardless of the orientation of the somites.

不拘原椎節的排列方向，軸突均能由神經管長出

b. The axons preferentially grow through the anterior segment of the somite.

軸突偏好生長經過原椎節的前段

c. The axons preferentially grow through the posterior segment of the somite.

軸突偏好生長經過原椎節的後段

d. The segmented axon outgrowth pattern is an intrinsic property of the motor neurons.

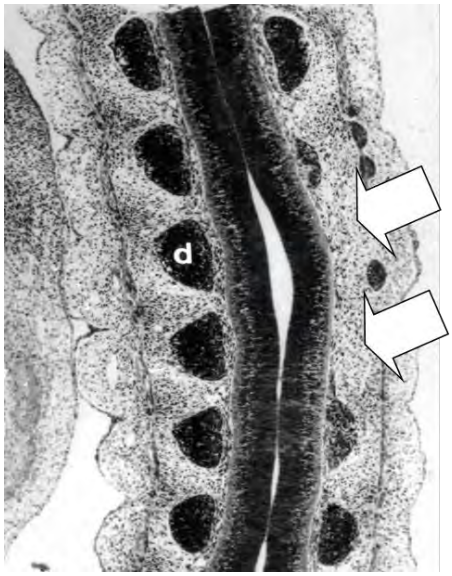
分節的軸突生長類型是運動神經元的內在特質

e. The somite segmentation pattern determines the motor axon segmentation pattern.

原椎節的分節類型可決定運動神經元軸突的分節類型

21. Dorsal root ganglia are formed by neural crest cells migrating away from the neural tube during embryo development. The crest cells forming the ganglia differentiate into sensory neurones. In an experiment, a two-day old chick embryo had the anterior of two somites surgically removed (arrowed) and allowed to develop until the dorsal root ganglia (d) had formed in day 5. In the image below, the right side of the embryo was the experimental side (E) and the control side (C) is to the left. Note the 'ganglia' scattered on the E side of the embryo (next to the arrows).

背根是神經嵴細胞在胚胎發育時由神經管遷移出而形成的，形成神經節的神經嵴細胞分化為感覺神經元。在實驗中，一個兩天大的雞胚中有兩個原椎節的前段以手術移除(箭頭)，並容許發育至第 5 天背根神經節(d)形成。下圖中胚胎右側為實驗組(E) 、左側為對照組(C) ，注意 '神經節' 散布在胚胎的 E 側(箭頭旁)。



Based on the image above, indicate correct deduction(s) with a tick (✓) and incorrect deduction(s) with a cross (✗). (1.6 points)

根據上圖，正確的推論打鉤(✓)、錯的打叉 (✗) (1.6 分)

a. The ganglia segmentation pattern is secondary to the somites segmentation.

神經節分節的分化層次 次於原椎節的分節

b. The ganglia segmentation is dependent on the presence of the anterior part of the somite..

神經節的分節決定於有原椎節前段的存在

c. Ectopic ganglia formed possibly because of somites lacking the anterior segments disrupted the normal crest cell migration pathway.

異位性神經節的形成，有可能因為原椎節缺乏前段會干擾神經堵細胞的正常遷移途徑

d. The somites can regenerate after surgical interference.

原椎節經手術移除後仍可再生

22. Combining the observations and deductions derived from **Questions 20** and **21**, it is quite obvious that the anterior segment of the somites are conducive for the outgrowth of motorneurones and the migration of neural crest cells. Indicate valid inference(s) with a tick (✓) and invalid inference(s) with a cross (×). (1.5 points)

綜合**第 20 及 21 題**的觀察與推論，原椎節的前段明顯有助於運動神經元的生長及神經堵細胞的遷移。將有效的推論打鉤(✓)、無效的打叉 (×) (1.5 分)

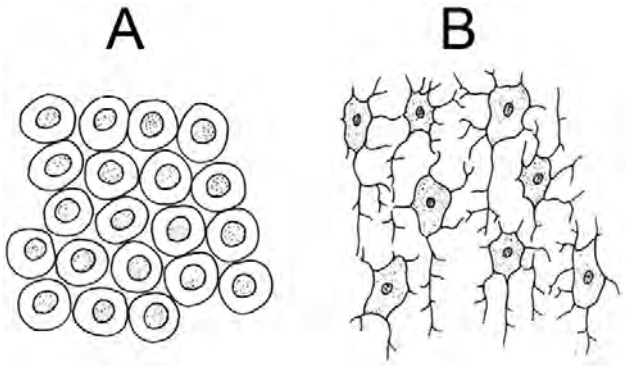
a. The anterior segments of the somites are likely to express extracellular matrix molecules that guide the axons and the crest cells.
原椎節的前段可能會表現能引導軸突與神經堵細胞的細胞間質分子

b. The molecules expressed in the anterior segments of the somites are likely to be adhesive proteins for contact inhibition.
原椎節前段所表現的分子可能是引起接觸性抑制的黏附蛋白

c. The posterior segments of the somites may produce repulsive molecules that axons and crest cells avoid.
原椎節的後段可能產生使軸突及神經堵細胞迴避的排斥分子

23. A transverse section through the spinal cord is examined under high magnification of the microscope. Indicate which figure (A or B: not drawn to scale) corresponds to grey and white matter respectively. (0.6 points)

將一脊索橫切的切片在高倍顯微鏡下檢查，指出灰質與白質分別能以下方何圖 (A 或 B：未依比例放大) 代表



24. Blood glucose concentration is regulated by homeostasis. Indicate the concentrations at which the following responses are elicited. Use a tick (✓) and a cross (×) for high and low blood glucose concentrations respectively. (1.2 points)

血糖濃度由恆定作用調控，指出下列情況中的血糖濃度。分別用打鉤(✓)代表血糖濃度高，打叉(×)代表血糖濃度低。(1.2 分)

a. detected by α-cells in islets of Langerhans

蘭氏小島中 α-細胞所測得

b. increase in insulin secretion

胰島素分泌增加

c. convert glycogen to glucose

肝糖轉化為葡萄糖

d. speeds up rate of glucose uptake by cells from blood

加速細胞從血液對葡萄糖的吸收率

e. promotes fat synthesis

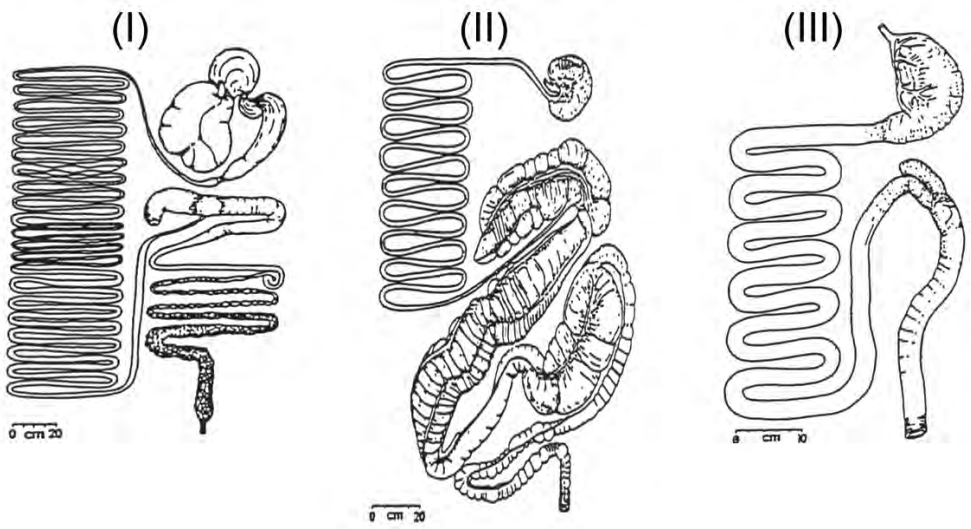
促進脂質合成

f. stimulates formation of glucose from amino acids

刺激由氨基酸形成葡萄糖

25. Match the digestive systems (I – III) with the corresponding animal feeding adaptation (a – c). (1.5 points)

將下列消化系統((I～ III)與動物的攝食適應(a ~ c)作配對 (1.5 分)



a. carnivore with limited post-gastric fermentation

胃後有限發酵的肉食動物

b. herbivore with extensive post-gastric fermentation

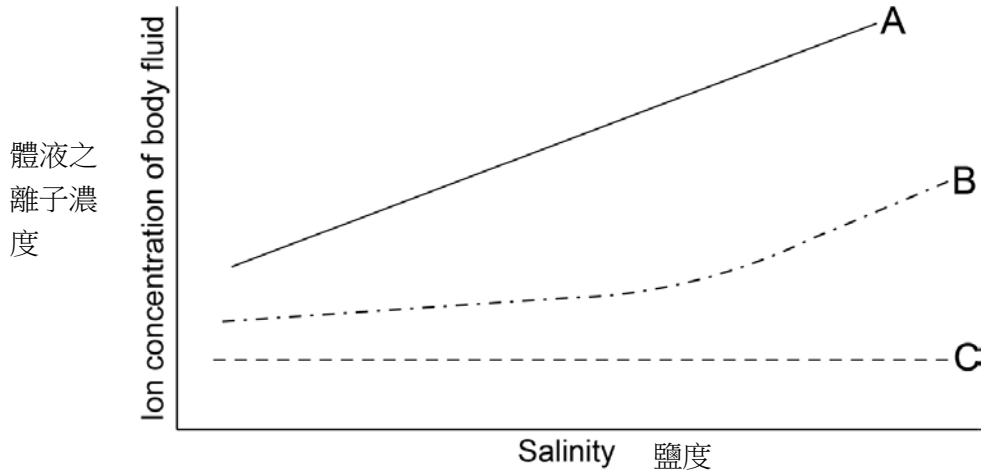
胃後大量發酵的植食動物

c. herbivore with extensive pre-gastric fermentation

胃前大量發酵的植食動物

26. The graph below shows the different responses of marine animals to salinity changes.

下圖顯示三種海洋動物對鹽度變化的不同反應



An extremely heavy and sustained week-long rainfall resulted in the salinity at a river mouth to fall from 28 ppt to 8 ppt. This caused many soft-bodied intertidal organisms to die. Which group of organism survived best? Write your answer **in the Answer Sheet**. (1 point)

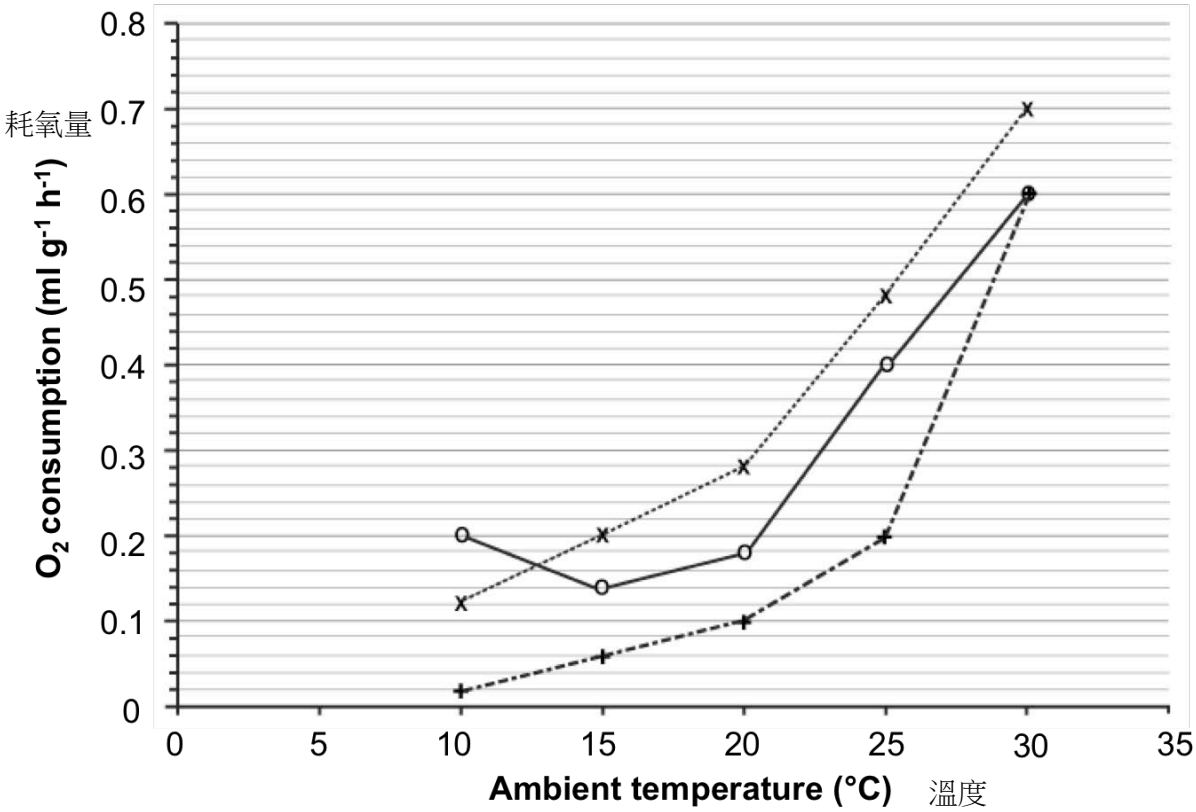
持續一週的極端大雨使河口的鹽度由 28 ppt降至 8 ppt，導致許多潮間帶軟體生物的死亡。請問哪一群的生物存活的最好。將你的答案寫在**答案卷**上 (1 分)

27. Q_{10} values are often used to describe the effects of temperature on the rate of many reactions involved in biological processes. The Q_{10} value is the ratio of the velocity constants k_1 (at t + 10 °C) and k_2 (at t °C), [k_1/k_2].

Q_{10}值常被用來描述溫度對許多生化過程的反應，Q_{10}值為速率常數k_1(在 t + 10 °C時)與k_2(在 t°C時)的比例 [k_1/k_2]

27.1. Using the data on the oxygen consumption of the three organisms below, calculate the Q_{10} values for temperature intervals of (i) 10 – 20 °C, (ii) 15 – 25 °C, and (iii) 20 – 30 °C. (3.6 points)

用下列三種生物耗氧量的資料計算：(i) 10 – 20 °C，(ii) 15 – 25 °C，及(iii) 20 – 30 °C三溫度間距的Q_{10}值(3.6 分)



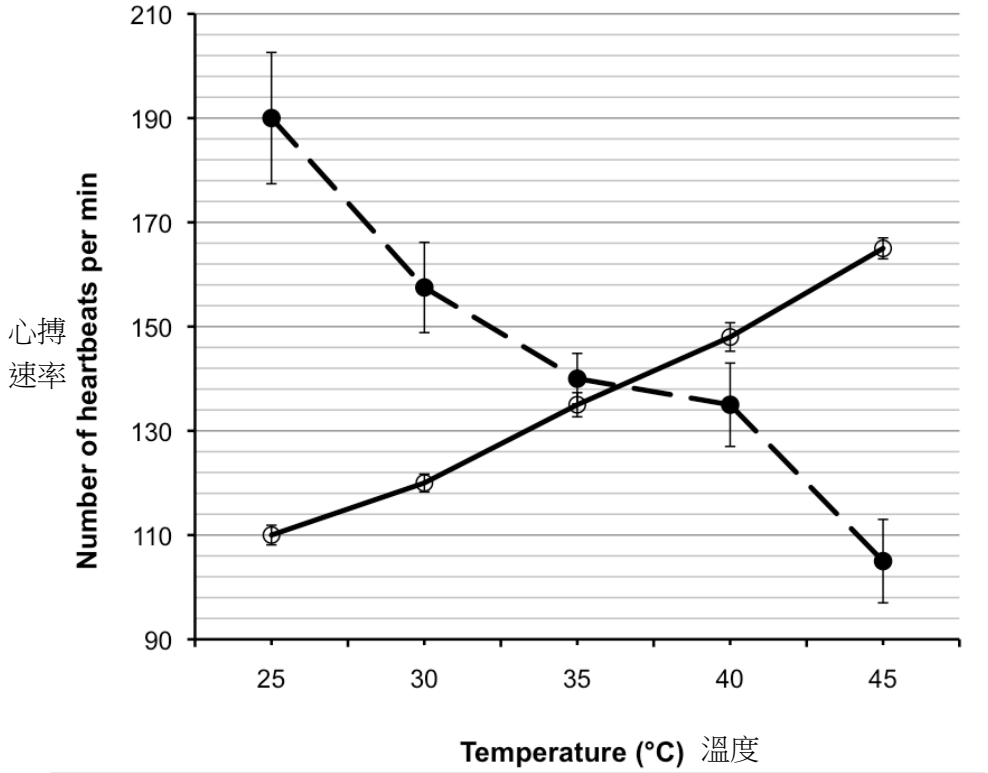
Note: A: --- X--- B: — O — C: -·-·- +-·-·-

27.2. Classify the organisms (A – C) as ectotherm(s) or endotherm(s). (0.9 points)

A～ C 三者分別為 外溫動物 或 內溫動物 (0.9 分)

28. Ghost crabs (*Ocypode ceratophthalmus*) are common on tropical shores, with the adults being nocturnal (staying in their burrows in the day) and the juveniles, diurnal in activity behaviour. Adult crabs generally excavate burrows higher up the shore than juveniles. Heart beat rates of juvenile and adult ghost crabs were measured at various temperatures.

鬼蟹(*Ocypode ceratophthalmus*) 在熱帶海岸為常見種，成體為夜行性(白天穴居)、幼體則為日行性，成體在海岸挖穴的位置通常比幼體的高。在不同溫度下測量鬼蟹成體及幼體心搏速率



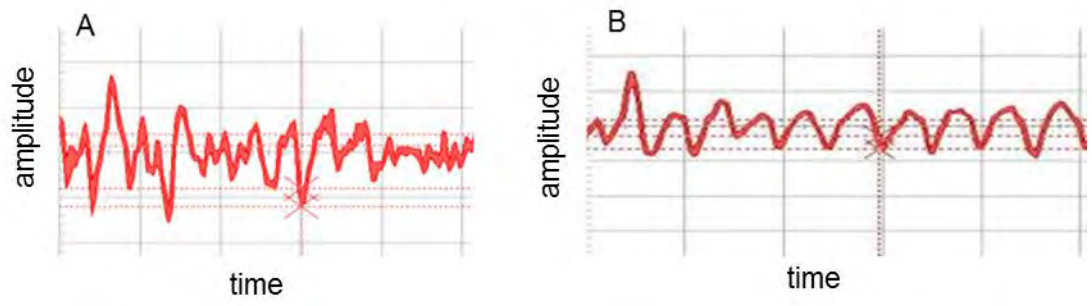
● juvenile crabs 幼蟹； ○ adult crabs 成蟹

28.1. Graphs (A – D) below represent the trend of typical physiological response of organisms to temperature change as measured by Q_{10} values. Identify the correct graph for the two stages of crab development. (1 point) (1 分)

下方圖(A – D)為溫度變化下生物典型的生理反應所測的Q_{10}值，選出能代表此二個蟹期的圖

28.2. The heart beat patterns of the crabs at 30 °C over a period of 5 s are shown in the figure below. Match the patterns with the correct stage of crab development. (1 point)

下圖為蟹在 30 °C 心搏 5 s 的模式，將此二圖與蟹的二發育期配對 (1 分)



28.3. Indicate correct statement(s) with a tick (✓) and incorrect statement(s) with a cross (✗). (1.6 points)

下列敘述正確的打鉤(✓)，錯誤的打叉 (✗) (1.6 分)

a. As heart rate and metabolic rate are strongly correlated, this study provides evidence that smaller organisms have higher basal metabolisms regardless of temperature.

心搏率與代謝率高度相關，本研究提供證據說明不論溫度小型生物的基礎代謝率較高

b. The higher heart rates of juvenile crabs are compensated by more heat lost via the proportionately larger surface area to volume ratio.

幼蟹有較高的心搏率，以補償因表面積對體積的比率較大而散失較多的熱

c. Adult crabs show endogenous nocturnal activity as they are not so heat tolerant, preferring to stay in their burrows during the day.

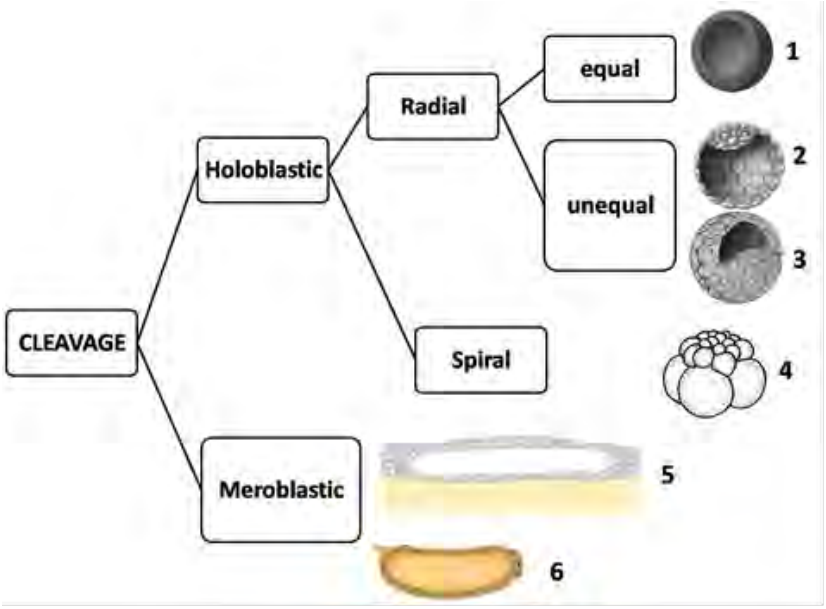
成蟹顯示內生的夜行行為，牠們對熱不太能容忍，白天偏愛留在穴中

d. Physiological responses to thermal stress remain constant as ghost crabs mature.

在 鬼蟹的成熟過程中，對熱壓力的生理反應則一直未變

29. The types of cleavage pattern and blastulas (1 – 6) for some animal embryos are shown below:

下圖為某些動物胚胎的卵割及囊胚形式(1 – 6)



29.1. Match the cleavage patterns and blastulas (1 – 6) with the corresponding animals. Indicate P for protostome and D for deuterostome. (1.2 points)

將卵割類型及囊胚(1 – 6)與動物配對，以 P 代表前口動物、D 代表後口動物 (1.2 分)

29.2. Identify the main factor that influences the cleavage. (1.0 points)

請辨識出影響卵割的主要因子(1.0 分)

a. the ratio of the egg cytoplasm to nucleus

卵細胞的質核比

b. the thickness of the egg membrane

卵膜的厚度

c. the amount of the yolk content

卵黃的含量

d. the overall volume of the zygote

合子的總體積

ETHOLOGY

30. Vervet monkeys (*Cercopithecus aethiops*) warn fellow monkeys by producing unique warning signals according to the type of predators such as eagles, leopards and snakes. Depending on the type of signals, monkeys in the group choose the appropriate method to escape. A newborn Vervet monkey is capable of producing all of these signals but it does not know which signal should be used in each case. If a baby monkey produces the signal for eagles when a sparrow is flying over, adult monkeys look up at the sky and then ignore the signal. However, if an eagle is indeed hovering, the entire group joins in the warning. Sometimes, baby monkeys are punished by their mothers for producing wrong signals.

絨猴警告同伴危險時，會依據天敵的型態如老鷹、豹以及蛇而產生不同的警訊；猴群中的猴子則根據不同的警訊而採取不同的逃避方式。新生幼猴能發出各種警訊，但不知道何種場合該發出何種警訊。如一隻麻雀飛過，使新生幼猴發出老鷹飛過時的警訊，成猴抬頭往上空探視後即不予理會。但如果真是老鷹在空中盤旋，則整群猴皆加入警戒。有時，新生猴群因發出錯誤的警訊而遭到母猴的懲罰。

Which of the following learning types are associated with the warning signal development in baby monkeys? Indicate the correct answer(s) with a tick (✓),incorrect conclusion(s) with a cross (×) **in the Answer Sheet**. (0.8 points)

下列所列何學習方式是與新生幼猴所發展出警訊的能力有關？在**答案卷**上，正確者請打勾(✓)， 錯誤者請打叉(×)。(0.8 分)

a. Imprinting 印痕

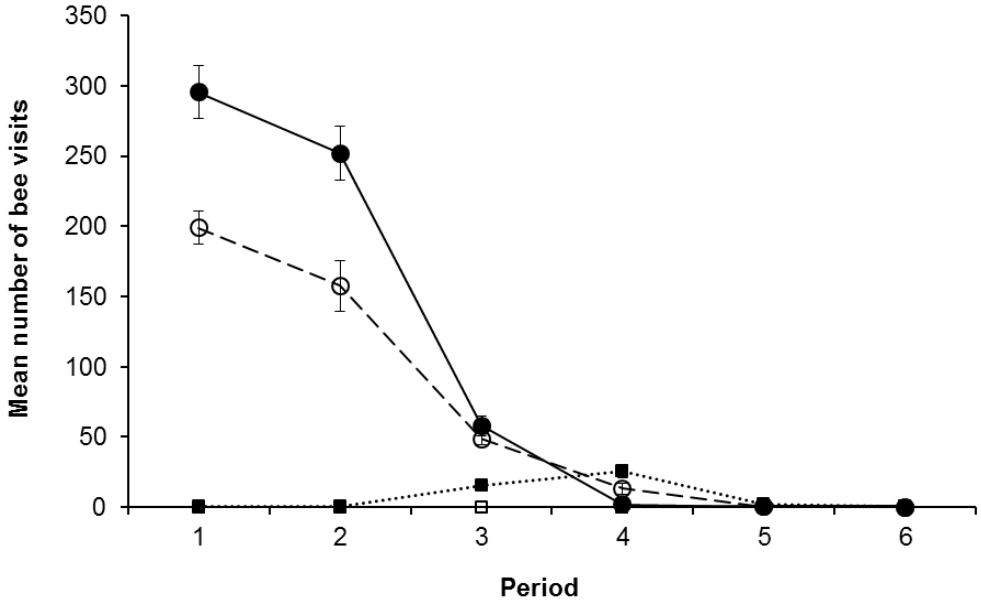
b. associative learning 關聯學習

c. problem solving 解決問題

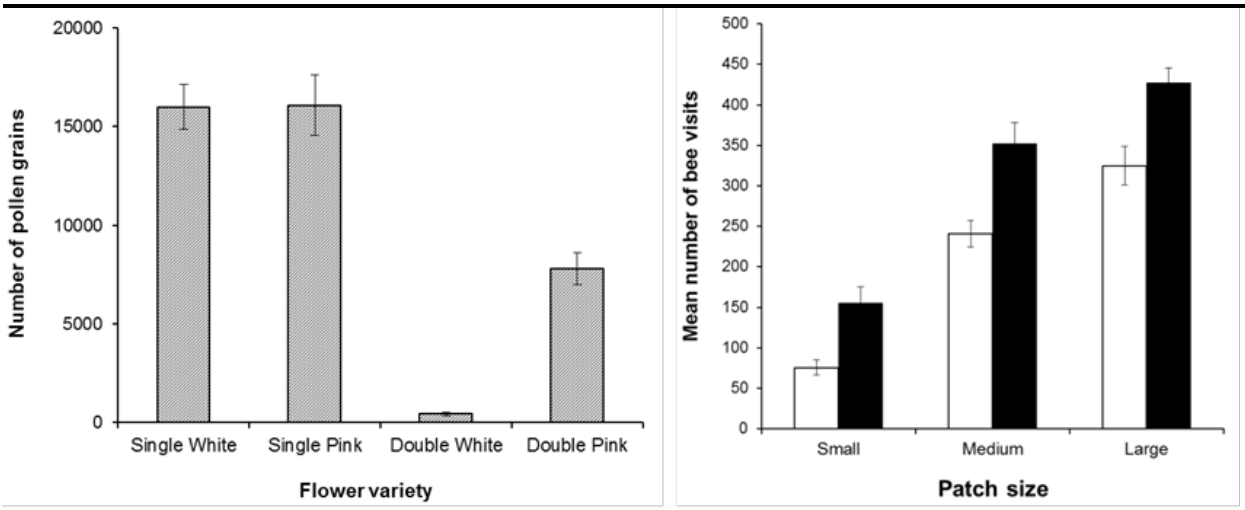
d. social learning 社會學習

31. The Asian honey-bee, *Apis cerana* is the primary pollinator of *Portulaca grandiflora*. Bees' pollination of four flower varieties of *P. grandiflora*: white flowers (single and double-petalled) and pink flowers (single and double-petalled), was studied. Bees' visitations to the four flower varieties at six observation periods of half hour duration from 0930 h to 1230 h were recorded. Pollen production per flower in the four flower varieties was determined. Three different floral patch sizes (small, medium, and large: 20, 40, and 80 flowers respectively) placed at a distance of 1.5 m apart from each other, were presented to the bees.

亞洲蜜蜂 *Apis cerana* 為 *Portulaca grandiflora* 植物主要的授粉者。針對此種植物所有的 4 種不同變異型態 (白花單瓣及重瓣，粉紅花單瓣及重瓣) 與授粉關係進行研究，從 09:30 至 12:30 每半小時為期進行六個時段的觀察，計錄蜜蜂至此 4 型花的造訪次數。4 型植物每朵花的花粉量皆有紀錄。研究者設置三種不同的花叢(小、中及大：分別為 20, 40, 及 80 朵花)，各叢間距 1.5 公尺來觀察蜜蜂對他的利用。



○---- Single white, ●—— Single pink, □—— Double white, ■····· Double pink



說明：Number of pollen grain 花粉粒數量； Mean number of bee visits 蜜蜂平均造訪次數

Indicate correct conclusion(s) about the honey bees' behaviour with a tick (✓) and incorrect conclusion(s) with a cross (×). (2 points)

下列有關蜜蜂行為的敘述，若正確者請打勾(✓)， 錯誤者請打叉(×)。(2 分)

a. *Apis cerana* preferred the single-petalled *Portulaca grandiflora* flowers regardless of observation period.
Apis cerana 喜歡單瓣花(*Portulaca grandiflora*)不因觀察時段不同而有差異

b. Pink flowers were always preferred over white flowers as they had more pollen grains for the bees to harvest.
粉紅花總是好過白花受到蜜蜂的青睞，因粉紅花有較多的花粉提供蜜蜂使用

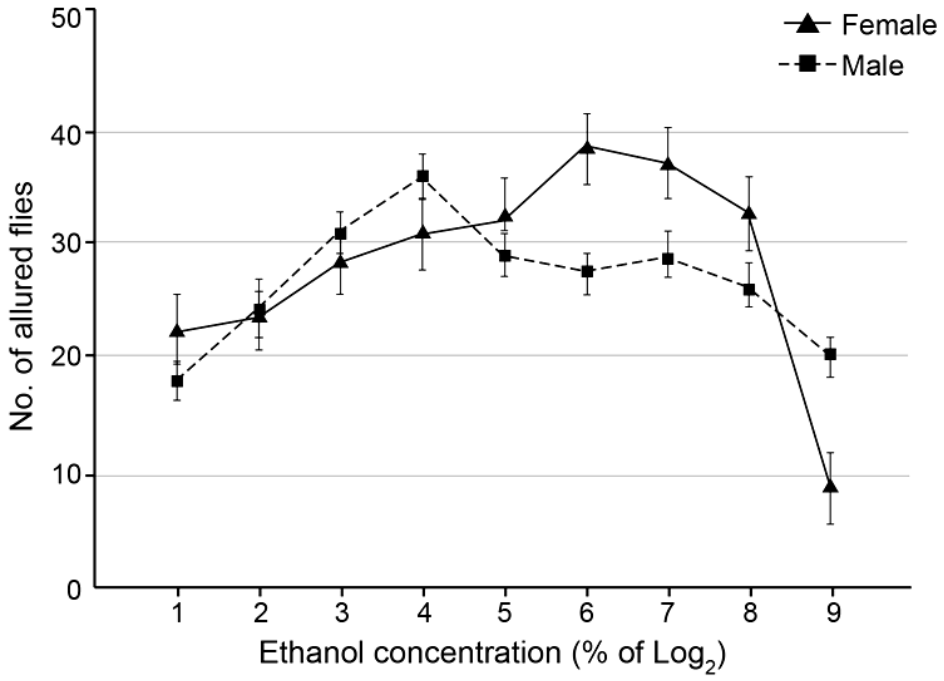
c. Flower colour provide an indirect cue to reward size.
花的顏色提供了與獎勵大小(reward size)有關的間接線索

d. Pollinators did not respond to diminishing rewards but floral patch size influenced their foraging patterns significantly.
授粉者對逐漸減少的獎品沒有反應，而花叢大小卻顯著地影響牠們的覓食型態

e. Larger floral patch size provided stronger advertising signals and the promise of larger rewards.
較大的花叢提供較強的吸引效力及保證較強的獎勵

32. Fruit flies usually find food by following the odour of ethanol produced from fruits. The fruit also serves as the place for male and female flies to mate and reproduce. The graph below shows the relationship between the number of allured flies and the concentration of ethanol.

果蠅藉著水果所發出的酒香(酒精)來尋找食物，水果也成為果蠅雌雄個體交配及繁殖的場所。下圖顯示酒精濃度與被吸引果蠅數量的關係：



說明：No. of allured flies 被吸引的果蠅數量

Based on the graph, indicate the correct statement(s) with a tick (✓) and incorrect statement(s) with a cross (×). (1 point)

根據上圖，下列敘述若正確者請打勾(✓)， 錯誤者請打叉(×)。(1 分)

a. The male/female ratio in the number of flies occupying the food source varies depending on the ethanol concentration.

飛往食物的果蠅，其 雄/雌 比例受到酒精濃度的影響

b. The number of mating animals would be the lowest when ethanol concentration is 9.

當酒精濃度為 9 時，交配的果蠅數量將是最低的

c. The competition between males would be most severe when ethanol concentration is 7.

當酒精濃度為 7 時，雄性間的競爭最激烈

d. The number of laid eggs would be the highest when ethanol concentration is around 6 and 7.

當酒精濃度為 6 和 7 時，果蠅所產的卵將是最多的

e. The number of attracted flies would be the highest when ethanol concentration is 8.

當酒精濃度為 8 時，受到吸引的果蠅是最多的

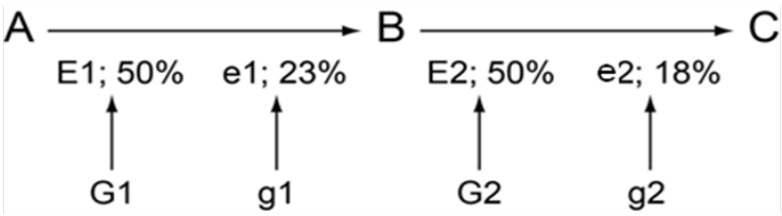
GENETICS AND EVOLUTION 遺傳學和演化

33. A two-step metabolic pathway in a diploid organism has the following components:

Gene 1 (G1) encodes enzyme E1 that converts substrate A to product B. Its mutant allele g1 produces a defective e1 that has 46% activity of normal E1. Similarly, gene 2 (G2) encodes the enzyme E2 that converts the metabolic intermediate B to the product C, while its mutant allele g2 produces a defective enzyme e2 with 36% activity of normal E2. For both enzymes, each allele contributes 50% towards the protein pool in the cell and both reactions have the same rate in a wild-type cell.

在一個二倍體生物中，有一個二步驟代謝過程，包含以下要件：

Gene 1 (G1)表現酵素 E1，E1 將受質 A 轉化為中間產物 B，突變等位基因 g1 產生的缺失酵素只有 46% 的正常 E1 效能；Gene 2 (G2) 表現酵素 E2，E2 將中間產物 B 轉化為產物 C，突變等位基因 g2 產生的缺失酵素只有 36% 的正常 E2 效能。對任一酵素而言，每一個等位基因貢獻其 50% 的酵素總量。此二步驟的反應速率相同。



In the F_2 progeny of a cross between G1G1g2g2 and g1g1G2G2 individuals, what fraction is expected to show an elevated level of the metabolic intermediate B? (2 points)

將G1G1g2g2 個體和g1g1G2G2 個體交配後，在其F_2子代中，會增加(累積)中間產物B的個體比例為何？(2 分)

34. In a particular breed of dogs, the hairless condition is produced by the heterozygous genotype. Normal dogs are homozygous recessive. Puppies homozygous for the H allele are usually born dead with abnormalities of the mouth and absence of external ears. If the average litter size at weaning is 6 in matings between hairless dogs, what would be the average expected number of hairless and normal offspring at weaning for matings between hairless dogs and between hairless and normal dogs? (1.8 points)

在一特定品種的狗中，無毛性狀為 Hh 異結合型，正常有毛狗為隱性同結合型 hh，顯性同結合型 HH 的幼犬通常出生時已死亡，其口和耳皆不正常。如果無毛狗和無毛狗交配，產下的所有幼犬中，平均只有 6 隻小狗可以長到斷奶，其中會有幾隻無毛狗？幾隻正常有毛狗？若是無毛狗和正常有毛狗交配產下的幼犬，到斷奶時，平均會有幾隻無毛狗？幾隻正常有毛狗？(1.8 分)

35. There are two types of red-green colour blindness – deuteranopia and protanopia, governed by two linked loci on the X chromosome. Among 18,121 Norwegian children examined in a study, 9049 were males, of which, 725 were males with colour blindness, 551 had deuteranopia and 174 had protanopia. Of the 40 females with colour blindness, 37 had deuteranopia and 3 had protanopia.

df	χ^2
1	3.841
2	5.991
3	7.815
4	9.488
5	11.070

Table: χ^2 values for $\alpha = 0.05$

人類紅-綠色盲有二種：deuteranopia 和 protanopia，由位於 X 染色體上的二個不同基因所控制。一個針對 18,121 位挪威孩童的調查顯示：在 9049 位男童中，725 有色盲，其中 551 位是 deuteranopia，174 位是 protanopia；40 位色盲女童中，37 位是 deuteranopia，3 位是 protanopia 。

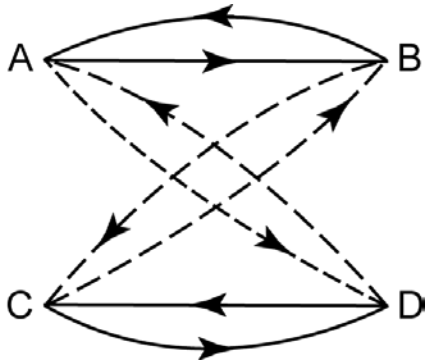
Estimate the allele frequencies for deuteranopia (independent of protanopia) from the data on males. Use these values to test the phenotypic distribution in females for compatibility with the Hardy Weinberg equilibrium (HWE) using the χ^2 test.

Indicate compatibility with HWE with a tick (✓) and incompatibility with a cross (×). (4.0 points)

請由男孩的資料中估算deuteranopia的等位基因頻率(不考慮protanopia)，並依據所得之等位基因頻率，使用χ^2 test去檢測女孩的色盲表現型頻率分布是否符合哈-溫平衡，符合請畫勾(✓)，不符合請畫叉(×)。

36. The diagram below presents the patterns of clan membership for a kinship group of Native Americans. The diagram shows the conditions of marriage and the way the clan of the father determines the clan of the children. The broken lines point from the father's clan to the clan of his children and the solid lines point from a man's clan to the clan of a potential wife.

下圖是一個美國原住民部落內的氏族關係，圖中呈現的是婚姻限制條件，以及父親和他的小孩氏族之間的關係。圖中的虛線方向表示父親的氏族決定孩子的氏族；實線方向表示一個男人，他的妻子應具有的氏族為何。



The pattern of clan membership between the four clans A, B, C and D.

部落中的四種氏族 A, B, C 和 D 之間的關係

A disease X, that is prevalent in this clan community, is a dominant sex linked trait and is carried on the Y chromosome. Answer the following questions relevant to disease transmission between the four clans.

一種流行於部落中的疾病 X，是由位於一個 Y 染色體上的顯性等位基因造成，請回答下列有關此疾病在四種氏族間傳遞關係的問題。

36.1. Maska of clan D has disease X.–After two generations both including sons, indicate the clans that will be affected if only Maska carried the disease, with a tick (✓) and non-affected clans with a cross (×). (2 points)

Maska 的氏族為 D，他有疾病 X，經過二個世代的生殖繁衍，其中包括他的兒子和孫子。這時有哪些氏族會受此疾病影響？受影響的請打勾(✓)，不受影響的請打叉(×) 。(2 分)

36.2. What is the probability of Tala (clan A) and Yonato (clan B) having a son with disease X in clan D if Yonato's father had disease X? (2 points)

若 Yonato (氏族 B)的父親有疾病 X，則 Tala (氏族 A) and Yonato(氏族 B) 的兒子(氏族 D) 有疾病 X 的機率是多少？(2 分)

37. A number of nutritional mutant strains were isolated from wild-type red bread mold *Neurospora crassa* that responded to the addition of certain supplements in the culture medium by growth (+) or no growth (0). Given in the Table below are the responses for single-gene mutants.

從紅麵包黴菌 *Neurospora crassa* 中分離出數個營養需求突變體，這些突變體在外加不同特定營養補充物後的生長情形紀錄於下表中，(+)代表生長，(0)代表不能生長。

Strain 突變種	Supplements added to minimal culture medium 外加營養補充物				
	Citrulline	Glutamic semialdehyde	Arginine	Ornithine	Glutamic acid
A	+	0	+	0	0
B	+	+	+	+	0
C	+	0	+	+	0
D	0	0	+	0	0

37.1. Indicate the sequence (1 – 5) of the five metabolites within the metabolic pathway **in the Answer Sheet**. (1.5 points)

在答案卷上用(1 – 5)指出以上五種營養補充物在代謝途徑的生成先後順序。(1.5 分)

37.2. Indicate the strain that is blocked at each of the four steps in the metabolic pathway **in the Answer Sheet**. (1.2 points)

在答案卷上指出相對應各代謝步驟被中斷的突變菌種。(1.2 分)

38. Given that A^1A^1 = lethal, A^1A^2 = gray, A^2A^2 = black, B^1B^1 = long hair, B^1B^2 = short hair, B^2B^2 = very short hair (fuzzy), and parents that are $A^1A^2B^1B^2$.

A^1A^1 = 致死，A^1A^2 = 灰色，A^2A^2 = 黑色，B^1B^1 = 長毛，B^1B^2 = 短毛， B^2B^2 = 極短毛 (毛絨)，而親本基因型是 $A^1A^2B^1B^2$.

38.1. What is the fraction of adult offspring that is expected to be gray and fuzzy? (1 point)

在成年的子代中，灰色毛絨個體所佔比例為何？(1 分)

38.2. In the case when fuzzy is also a lethal trait, what is the fraction of adult progeny expected to be black and short? (1 point)

若毛絨性狀也會致死，則成年的子代中，黑色短毛個體所佔比例為何？(1 分)

39. You are given the following number of F_1 flies.

設有下列數目的各種果蠅

	Male 雄	Female 雌	Total 總計
wild type 野生正常型	80	60	140
mutant 突變體	30	30	60

If the mutation was inherited via a simple autosomal recessive mode, what is the most likely parental genotype? Indicate the correct answer(s) with a tick (✓) and incorrect answer(s) with a cross (×). (1 point)

如果此突變性狀為單純的體染色體隱性遺傳，這群果蠅的親本之基因型最可能為下列哪一種？對的請打勾(✓)，錯的請打叉(×)。(1 分)

a. w w X w+w+

b. w+w X w+w

c. w+w X w w

d. w+w X w+w+

e. w+ w+ X w+ w+

40. If a paternal chromosome has alleles L, M, and n and the maternal chromosome has l, m, and N. Which of the following chromosomes could possibly be produced as a result of a single crossing over? Indicate the correct answer(s) with a tick (✓) and incorrect answer(s) with a cross (×). (1 point)

如果個體內來自父本的染色體，其上的等位基因是 L, M, 和 n，而來自母本染色體上的等位基因是 l, m, 和 N。則下列哪些染色體(等位基因組合)可以因為單次染色體互換而得到？對的請畫勾(✓)，錯的請畫叉(×).。

I. LMN

II. LMn

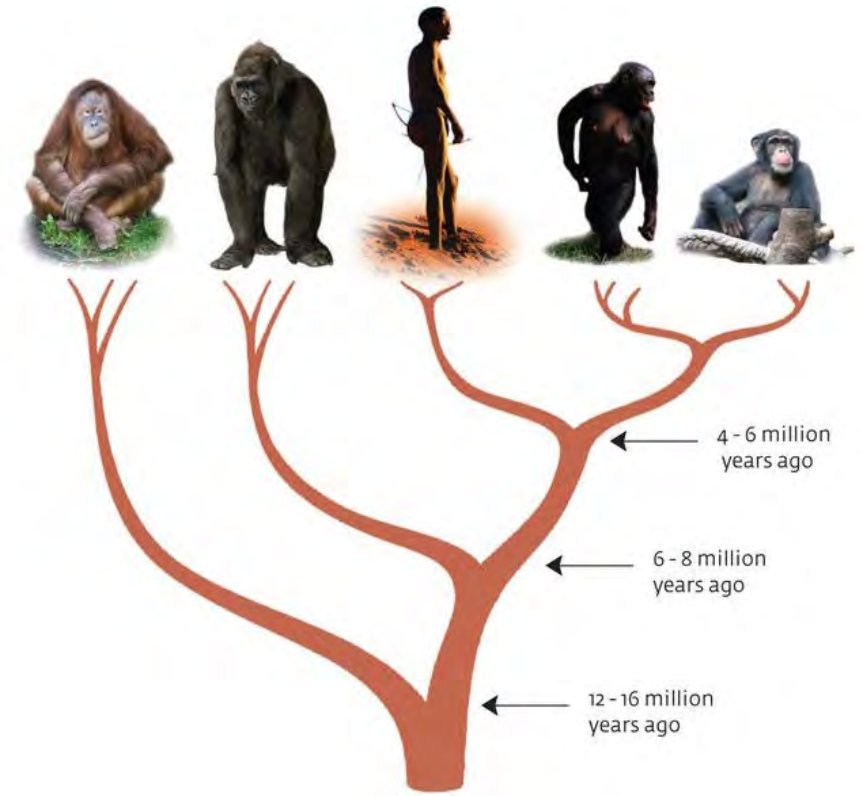
III. LmN

IV. Lmn

V. lmn

41. The closest living relative of human (*Homo sapiens*) is widely considered to be the chimpanzee (*Pan troglodytes*) and bonobo (*Pan paniscus*). Together with the orangutans (*Pongo pygmaeus* and *P. abelii*) and gorilla (*Gorilla gorilla* and *G. beringei*) they form the subfamily Homininae. This evolutionary relationship can be presented as shown below.

一般認為黑猩猩(*Pan troglodytes*)和侏儒猩猩(*Pan paniscus*)是與人類(*Homo sapiens*)演化關係最接近的存活物種。此三者和紅毛猩猩(*Pongo pygmaeus* and *P. abelii*)及大猩猩(*Gorilla gorilla* and *G. beringei*)共同形成 Homininae 亞科，他們的演化關係可以下圖呈現：



41.1. The phylogenetic tree demonstrating the evolutionary relationship of the higher primates is cnstructed using molecular data and is considered to be reliable because:

此譜系樹說明了靈長類的演化關係，其建立的基礎是分子的資料，並被認為是可信的。下列的理由中，對的請打勾(✓)，錯的請打叉(✗)。(0.8 分)

a. DNA mutations and polymorphisms can be readily identified and analyzed.

DNA 突變及多型性容易被辨識和分析

b. DNA sequences can be converted into protein sequences for comparative analysis.
DNA 序列可以被轉換成蛋白質序列進行比較分析

c. the availability of large amount of molecular data permits rigorous computational analyses to be conducted.
因為有大量的分子資料，可以進行精密的電腦分析。

d. physically intact and unfragmented genomic DNA can be recovered after millions of years.
完整無斷裂的基因組 DNA 在經過數百萬年後，依然可以被找到。

Indicate true statement(s) with a tick (✓) and false statement(s) with a cross (✗). (0.8 point)

41.2. Most of the oldest fossils belonging to the subfamily Homininae are found in the African continent. This is similarly reflected by the living species, with orang utans being the only species not found in Africa. This observation of fossil distribution supports the:
大部分屬於 Homininae 亞科的最古老化石都是在非洲被發現，而現存屬於此亞科的物種除紅毛猩猩外皆存在於非洲。這些有關化石分布的觀察支持下列何者？對的請打勾(✓)，錯的請打叉(✗)。(0.8 分)

a. "Out of Africa" hypothesis whereby the first human beings evolved in Africa and subsequently migrated to other continents.
“遠離非洲”假說：第一個人類是在非洲演化出後，再遷移至其他大陸。

b. "Out of Asia" hypothesis as the oldest living species, the orang utans, are found only in South-East Asia.
“遠離亞洲”假說：最古老的現存物種 - 紅毛猩猩，只在東南亞被發現。

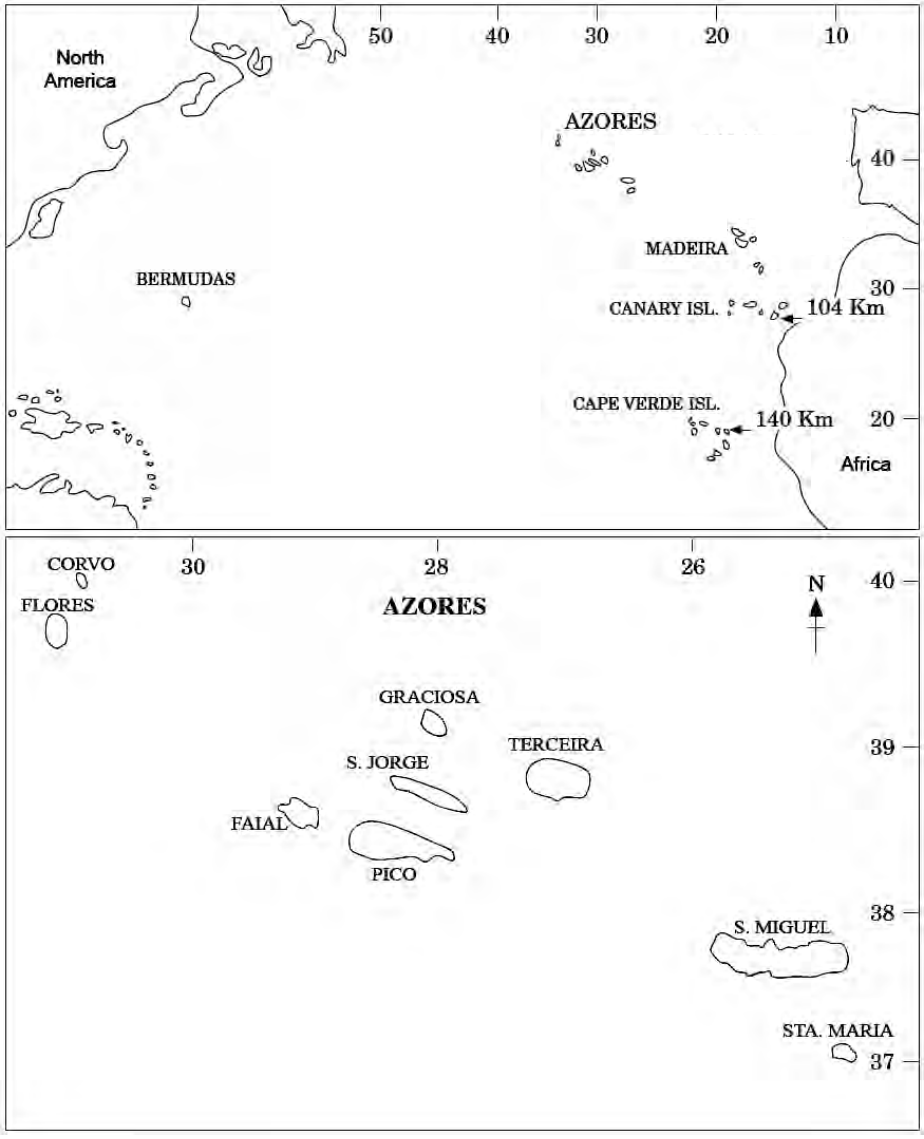
c. "multi-centric origin" hypothesis.
“多元起源”假說。

Indicate true statement(s) with a tick (✓) and false statement(s) with a cross (✗). (0.8 point)

ECOLOGY

42. Borges and Brown (1999) studied the arthropod species richness in three islands (Pico, Santa Maria and Terceira), in the Azorean archipelago. The figure below shows the location of the islands with respect to major land masses, Africa and Europe (in the east) and North America (in the west).

Borges and Brown (1999) 在亞述群島中的 3 島(Pico, Santa Maria and Terceira) 進行節肢動物多樣性(species richness)的研究。下圖顯示這些島與主要大陸：非洲及歐洲(在東方)及美洲(在北方)的相對位置。



Some other characteristics of the islands are given in the table below.

下表顯示此 3 島的一些特性

Island	Altitude (m) 高度(公尺)	Geological age (Myr) 地質年齡(百萬年)	Distance from mainland(km) 與大陸的距離(公里)
Pico	2351	0.037 – 0.300	1866
Santa Maria	587	8.12	1585
Terceira	1023	0.300 – 2	1770

42.1. Match the following x axes with the correct graphs (I to IV). (2.4 points)

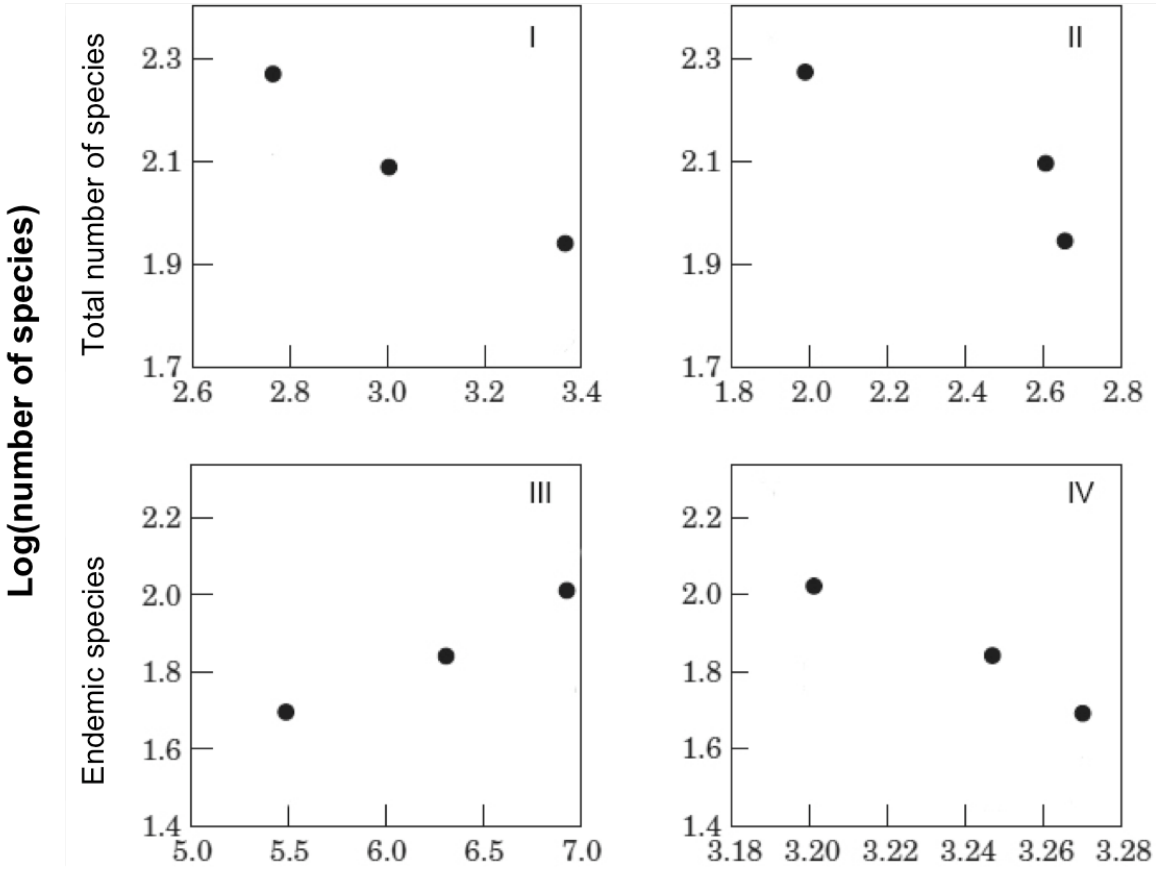
選擇下列提供的 X 軸的單位與下圖(I 至 IV)相對應(2.4 分)

a. Log_{10}(area in km^2)

b. Log_{10} (altitude in m)

c. Log_{10} (distance from mainland in km)

d. Log_{10} (geological age in years)



說明：Endemic species 特有種

42.2. Estimate from the graphs, the number of endemic species (to the nearest whole number) in the three islands. (1.2 points)

由圖估計此三島上所具有的特有種數量(至最近的整數) (1.2 分)

42.3. From the data indicate correct conclusion(s) that can be drawn from the study with a tick (✓) and incorrect conclusion(s) with a cross (✗). (1.5 points)

由上資料顯示，下列敘述若正確者請打勾(✓)， 錯誤者請打叉(✗)。(1.5 分)

a. Diversity was greater on the island with the lowest maximum altitude and decreased with increasing altitude.

生物多樣性在高度最低(lowest maximum altitude)的島上最大，其隨島的高度增加而減少

b. Results of this study support the species-area hypothesis.

此項研究的結果支持物種-面積假說

c. Isolation alone cannot be used to explain the species richness patterns found in the arthropod assemblage in the three islands.

僅是隔離無法說明節肢動物在此三島多樣性的型態

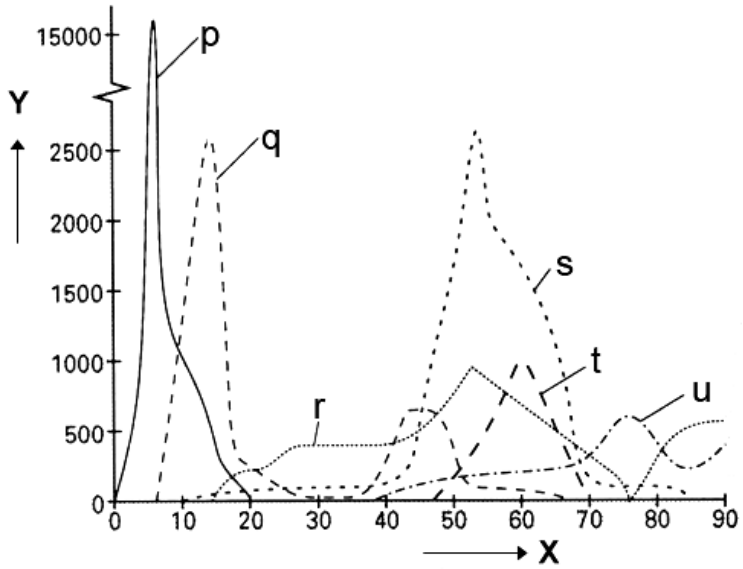
d. Species richness patterns in these islands are influenced by both ecological and evolutionary factors.

在此些島上物種多樣性的型態是受到生態及演化因子的影響

e. MacArthur and Wilson's Theory of Island Biogeography is fully supported by the results of this study.

此研究結果可完全支持 MacArthur 及 Wilson 所提出的島嶼生態假說

43. Daniel boiled water and hay in a beaker for some time, and left it uncovered for some days. During that period only heterotrophic bacteria were found in the beaker. He then added a few drops of ditch water and covered it loosely. The water from the ditch only contained heterotrophic unicellular organisms (no bacteria or fungi). Daniel regularly determined the size of the populations of the different species (p – u) present in the beaker over a period of time.
Daniel 將燒杯內的水及乾草燒滾了一段時間，將其曝露在空氣中數日。在此期間，只有異營性的細菌出現在燒杯中。其後，他加了幾滴溝水並將燒杯蓋上，但仍留下空隙，所用的溝水只有異營性的單細胞生物(無細菌或真菌)。Daniel 定期檢視在一段時間中燒杯裡的不同物種(p–u)的族群變化。



X = Time (days); Y = number of individuals per ml at water surface

Looking at the results, some of Daniel's students claimed that in the beaker:
看到這些結果，有些 Daniel 的學生聲稱在燒杯內

I. competition is likely to occur
競爭可能會發生

II. succession is taking place
消長是正在進行

III. total biomass is increasing in the period between Day 40 to Day 50
在 40 至 50 天之間整體生物量是在增加中

Some other students even went on to predict that:

其他一些學生甚至更進一步預測

IV. the number of dividing bacteria will decrease to zero

分裂的菌種，其數量將減至 0

V. the number of the other dividing heterotrophic unicellular organism will decrease to zero

其他分裂的異營性單細胞生物，其數量將減至 0

VI. a climax stage will develop, comprising bacteria and other heterotrophic unicellular organisms, in a stable natural equilibrium

將發展至極相，包括細菌及其他異營性單細胞生物，形成一穩定的自然平衡

Indicate correct statement(s) with a tick (✓) and incorrect statement(s) with a cross (×). (1.2 points)

指出敘述正確者請打勾(✓)， 錯誤者請打叉(×)。(1.2 分)

44. Increasing concentration of carbon dioxide (a greenhouse gas) has been linked to global climate change. Carbon dioxide can be removed from the atmosphere and deposited in a reservoir in order to either mitigate or defer global warming and avoid dangerous climate change. The removal process includes carbon dioxide uptake from the atmosphere by all chlorophyllous plants, through photosynthesis. Indicate correct statement(s) concerning the amount of carbon “stored” per unit area in different ecosystems with a tick (✓) and incorrect statement(s) with a cross (×). (1 point)

二氧化碳(一種溫室氣體)的濃度增加，已被認為與全球氣候改變有關。二氧化碳可由大氣中移除，存入庫藏，來因應或減緩全球暖化並避免危險的氣候變遷。移除過程包括二氧化碳由大氣中經所有葉綠素植物的光合作用來吸取。考慮碳量於不同生態體系所貯存之單位面積，下列敘述正確者請打勾(✓)， 錯誤者請打叉(×)。(1 分)

a. net primary productivity (NPP) (or net carbon absorption rate) of coniferous forests ＞ temperate forests ＞ tropical forests

松林之淨初級生產力(NPP)(或淨碳吸收率) ＞溫帶森林＞熱帶森林

b. carbon stocks (the amount of carbon stored) of coniferous forests ＞ temperate forests ＞ tropical forests

松林之碳匯(碳貯存量) ＞溫帶森林＞熱帶森林

c. net primary productivity (NPP) of temperate grasslands ＞ savannas (grasslands with scattered trees) ＞ tundra

溫帶草原之淨初級生產力(NPP) ＞大草原(草原上有稀林)＞凍原

d. net primary productivity (NPP) of secondary forests ＞ climax forests or old growth forests

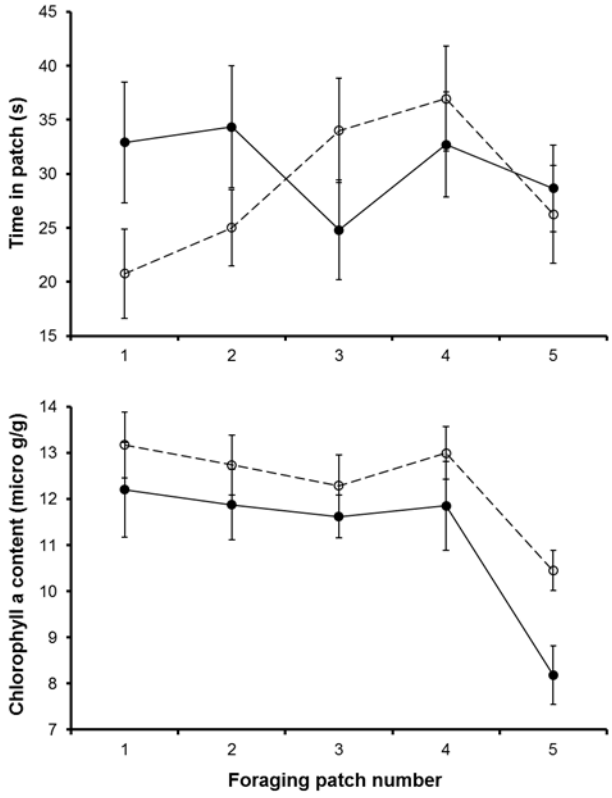
次級森林之淨初級生產力(NPP) ＞極相

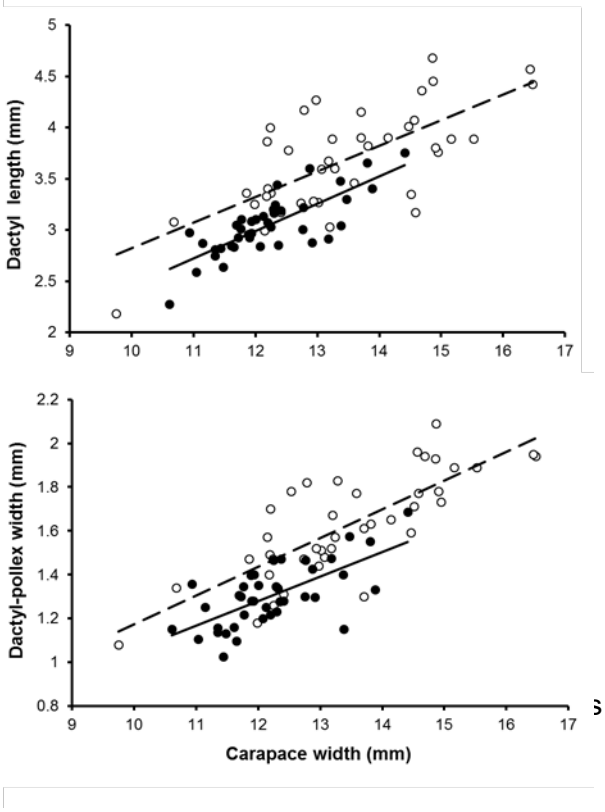
e. as compared to other ecosystems, coral reefs have very high net primary productivity, and their contribution to global production of biomass is large

如與其他生態系相較，珊瑚礁具有非常高的淨初級生產力，他們對全球生物量生產的貢獻很大

45. Male fiddler crabs have an enlarged cheliped (the major cheliped) to attract mates and defend territories. However, the major cheliped is useless for foraging; hence males are left with only one feeding appendage – the minor cheliped. Many strategies have been proposed by researchers to explain how male fiddler crabs compensate for this apparent disadvantage. A student conducted a study to investigate some of these strategies. She videotaped the foraging bouts of males and females on the first five patches of sediment upon first emergence at low tide. Sediment samples from these five patches were collected after the crabs have vacated the patch and chlorophyll a content in these samples was determined. Various dimensions of the feeding cheliped in males and females were also compared. The mean number of scoops per second for the two sexes was determined from the videotapes: females, 2.39 ± 0.08 scoops; males, 1.60 ± 0.06 scoops.

雄性招潮蟹具有膨大的螯足(大螯)，用以吸引配偶及防衛領域，但此大螯在覓食上卻毫無效用，故雄性只能用另一螯足來覓食，該螯足亦稱副螯。研究者提出許多策略來解釋雄性招潮蟹如何克服此項明顯的缺失。一位學生針對這些策略進行研究，她在退潮時選擇最先出現的 5 處沉積物區塊，對其間雌雄個體的覓食回合進行錄影。在蟹離開後，收集此 5 處的沉積物樣本，並對其內所含之葉綠素 a 之含量進行分析。雌性和雄性用以覓食的螯足其空間使用的變化亦加以比較。雌雄每秒平均掘食的次數藉由錄取的影像來分析：雌性 2.39 ± 0.08 次掘食；雄性 1.60 ± 0.06 次掘食。





● Females (實線)　○ Males (虛線)

Indicate correct conclusion(s) that can be drawn from the student's study with a tick (✓) and incorrect conclusion(s) with a cross (×). (2.4 points)

由學生研究所獲得的結果，下列敘述正確者請打勾(✓)， 錯誤者請打叉(×)。(2.4 分)

a. Male fiddler crabs do not compensate for the one-feeding-cheliped-handicap by feeding at a faster rate than females.

雄性招潮蟹的掘食速率並沒有比雌性快，以補償其只有一隻覓食螯足的缺陷

b. There is sexual dimorphism in the minor cheliped.

副螯在雌雄間呈現性別二型性

c. In general, male fiddler crabs compensate for the one-feeding-cheliped-handicap by staying for a longer period of time in a foraging patch.

一般而言，雄性招潮蟹在覓食區塊停留較久，以補償其只有一隻覓食螯足的缺陷

d. Male fiddler crabs generally leave a foraging patch at a higher threshold of chlorophyll a content than females.

一般而言，雄性招潮蟹離開覓食區塊時，該處葉綠素 a 含量較雌性離開時的含量為高

e. Males compensate for the one-feeding-cheliped-handicap by having larger scoops of sediment per lift of the cheliped.

雄性招潮蟹藉每次掘食較大量的沉積物，來補償其只有一隻覓食螯足的缺陷

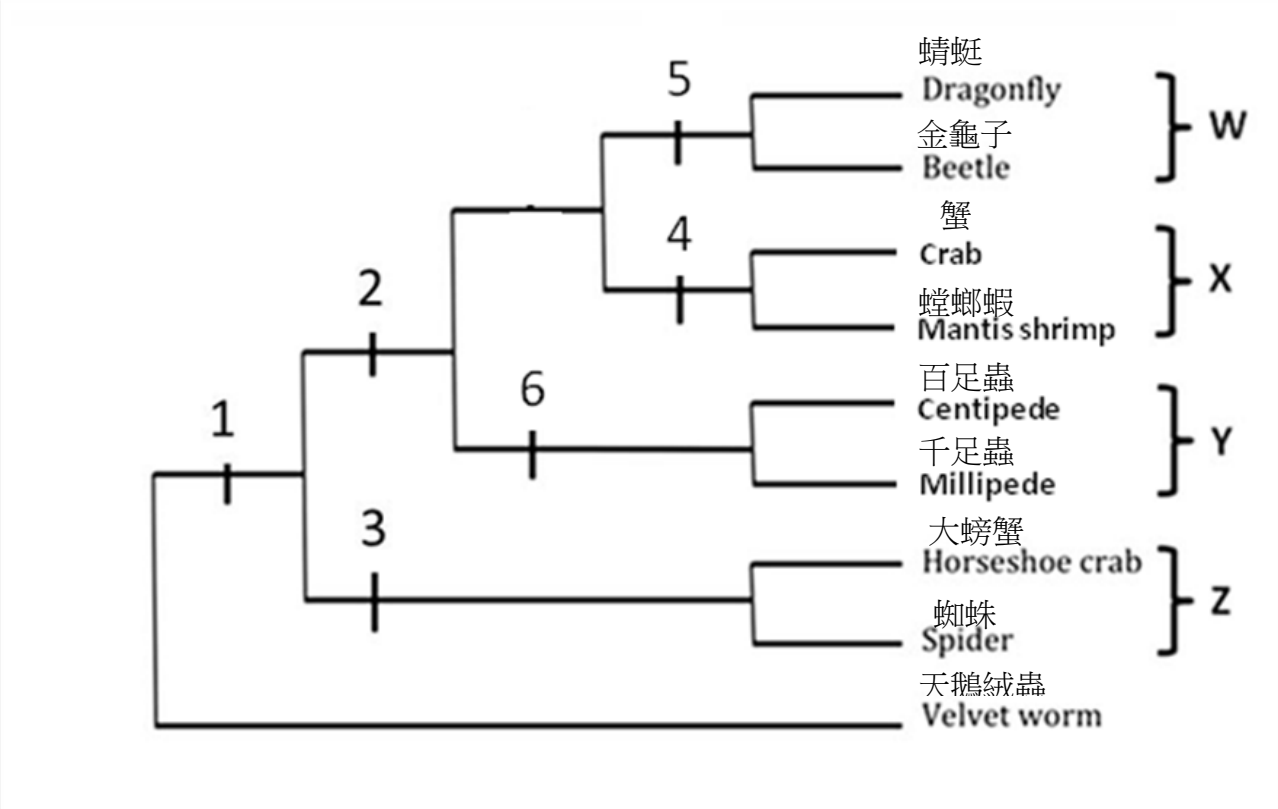
f. Results of this study do not support the principles of the optimal foraging theory.

此一研究的結果不支持最佳覓食理論(optimal foraging theory)

BIOSYSTEMATICS 生物系統分類

46. Morphological characters (1 – 6) shared by two or more organisms and their recent common ancestor are shown in the cladogram below.

下面的支序圖顯示出被兩個或多個物種所共享的形態特徵 (1 – 6)，以及他們最近的共同祖先



46.1. Which of the morphological characters (1-6) are the synapomorphies for the corresponding taxonomic groups indicated **in the Answer Sheet**. (1.2 points)

哪些形態特徵(1-6)是答案卷上所指類群的共享裔徵?

46.2. Identify the taxonomic groups (W – Z) in the table provided **in the Answer Sheet**. (1.2 points)

由答案卷所提供之表格來判斷出W – Z的類群

46.3. Based on your knowledge of these organisms and groups, match the morphological characters listed below (I – VI) among the labelled morphological characters from 1 to 6. (1.2 points)

依據你對這些生物和類群的了解，由標示的形態特徵（1 到 6）來配對出下列 I 到 VI 之形態特徵。

I. body organised into head, and elongated (and segmented) trunk; numerous pairs (> 12 pairs) of legs
身體分成頭和延長的（及具體節的）軀幹；具有多對的腳（大於 12 對）

II. body organised into head, thorax, and abdomen; three pairs of legs (from thorax)
身體分成頭、胸部和腹部；從胸部長出三對腳

III. jointed/segmented appendages
具關節/分段的附肢

IV. antennae (one or more pairs); mandibles (chewing mouthparts)
一或多對的觸角；具顎（咀嚼用的口器）

V. two pairs of antennae; biramous (two branches) appendages
兩對的觸角觸鬚；雙叉的附肢

VI. no antennae; no mandibles
沒有觸角觸鬚；沒有顎

46.4. Classify the groups listed below (I – IV) according to their respective phylogenetic origins **in the Answer Sheet**. (1.2 points)

根據他們對應之親緣關係起源（列於**答案卷**），來分類下列的類群(I 到 IV)。(1.2 分)

I. W and X

II. X and Y

III. Y and Z

IV. W, X, Y, and Z

END OF PAPER