Student Code: _____

20th INTERNATIONAL BIOLOGY OLYMPIAD

Tsukuba, JAPAN 12th – 19th July, 2009

THEORETICAL TEST: PART B

Time available: 150 minutes

GENERAL INSTRUCTIONS

1. Write your 4-digit student code in every student code box.
   請在每一參賽生編號（Student Code）欄，寫下您的四碼編號。

2. The questions in Part B may have more than one correct answer. Fill your all answers in the **Answer Sheet** for Part B. The marks, numbers, or characters to answer questions in Part B vary depending on questions. The ways to answer are indicated along with the questions.

   本卷（Part B）試題可能**不只一個正確答案**，請將所有答案填入答案卷（Answer Sheet）。本卷答題方式視問題而異，或以標示、或以數字或字母作答，各試題就答題有其相關說明。

3. Use pencils and erasers. You can use a scale and a calculator provided.
   答題請用鉛筆及橡皮擦。您可以使用大會提供之測量尺與計算機。

4. Some of the questions may be marked “DELETED”. DO NOT answer these questions.
   被標示爲“刪除”（ “DELETED” ）的問題**請勿作答**。

5. The maximal points of Part B is 108 (points are indicated in each question).
本卷計分共 108（各試題有其計分說明標示）。

6. Stop answering and put down your pencil IMMEDIATELY after the end bell rings.
終止鈴響後請**立即**停止作答並放下您的鉛筆。

GOOD LUCK!!

Cell Biology 細胞生物學

B1. (3 point) On a dry matter basis, is the average proportion of the following elements significantly higher in herbaceous vascular plants or in mammals? For each element mark 'X' in the appropriate box.

以乾重為基礎計算，分別比較下列化學元素在草本維管束植物或哺乳動物的肝眾中所占的平均比率，何者明顯較高？在較高者的空格畫「**X**」。（3 分）

A. Nitrogen 氮

B. Oxygen 氧

C. Calcium 鈣

D. Potassium 鉀

E. Sodium 鈉

F. Phosphorus 磷

B2. (2.5 points) Match each of the following properties of water with a benefit to organisms by putting a letter (A to E) in the appropriate box.

配合題。請將下列『水的特性』與『對於生物好處』進行配對，將「A-E」填入適當空格中：（2.5 分）

Property 水的特性

I. Low light absorption in the visible region 在可見光範圍內，水對光的吸收量低

II. High heat capacity 高的熱容量 (高比熱)

III. High heat of fusion 融合的高熱能 (高熔解熱；高凝固熱)

IV. High heat of vaporization 高蒸散熱

V. Polarity of molecules 分子極性

Benefit to organisms 對於生物好處

A. Biological membranes composed of lipid molecules are thermodynamically stable.
由脂分子組成的生物膜其熱動態性是穩定的

B. Terrestrial plants and animals can cool themselves with minimum loss of water content. 陸生植物及動物可以在水減少量最低的狀況下，達到自我降溫的目的

C. Temperature changes in plants and animals are minimized under fluctuating environmental conditions. 動植物在變動的環境下，溫度的改變極微小

D. Plants can efficiently utilize solar radiation for photosynthesis.
植物可以有效利用光能在光合作用上

E. Plants and animals are protected against freezing at low temperatures.
在低溫下，動植物可受到保護，避免被冰凍

B3. (3 points) A coding region of a gene consists of 735 base pairs without stop codon. Calculate the molecular mass of the protein from this gene. The average molecular mass of the free amino acid in the protein is assumed to be 122. Five disulfide bonds are present in the protein. Show your calculations.

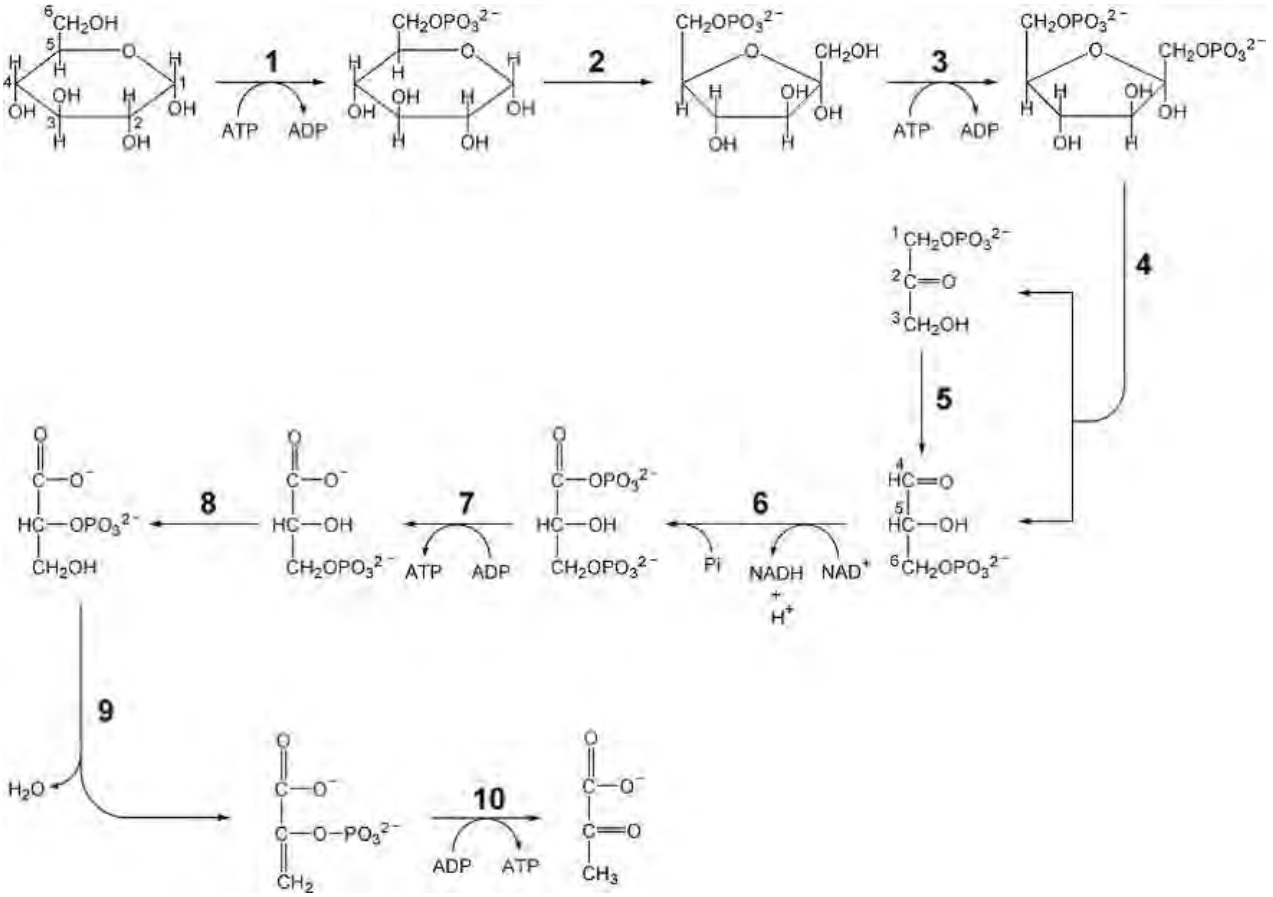
一個基因的編碼區長度爲 735 個鹼基對，其中並無終止密碼。計算該基因轉譯出蛋白質的分子量。本題一個游離的胺基酸平均分子量為 122，該蛋白質含有 5 個雙硫鍵。必須寫出計算式。（3 分）

B4. (3.5 points) Glycolysis is essential for all organisms.

(1) The figure below shows the reactions of glycolysis. The numbers in the figure indicate enzymes which catalyze the reactions. Categorize each enzyme into the “enzyme type” listed below and put each reaction number in an appropriate box. Note that some enzyme types may be missing.

糖解作用在所有生物都是必要的。(3.5 分）

(1) 下圖為糖解作用的反應過程。圖中數字表示催化反應的酵素。將這些參與的酵素分別歸類到下列的酵素類型中。請將圖中代表反應的酵素數字代號 (1 – 10) 配合寫到適當的酵素類型代號 (A – F) 空格中。**請注意，有些酵素類型可能沒有對應的酵素數字代號。**



Enzyme type: 酵素類型

A. Oxidoreductase 氧化還原酶

B. Transferase 轉基酶

C. Hydrolase 分解酶

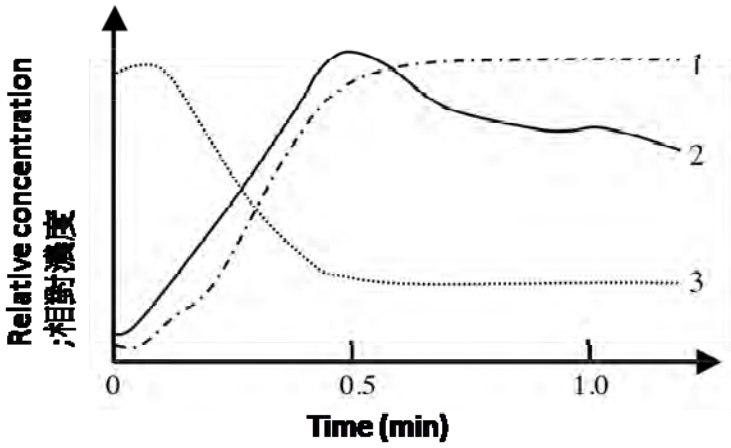
D. Lyase 溶解酶

E. Isomerase 異構酶

F. Ligase 接合酶

(2) A cell culture of muscle cells was incubated in oxygenated medium that was then quickly made anoxic. The concentrations of three compounds which are important in glucose metabolism were measured immediately after oxygen removal (marked as time 0) and shown in the graph below:

（2） 在含氧的培養基中培養肌肉細胞，會迅速消耗氧氣而形成缺氧狀態。當移除氧氣時（圖中 0 處），立刻測定與關葡萄糖代謝相關的三種化合物濃度，其相關濃度變化如下圖：



Match each curve of the graph (1, 2, and 3) with the metabolite whose concentration change it depicts:

請將圖中代謝物濃度曲線 (1, 2, 與 3) 與代表的代謝物 (A, B 與 C) 進行配對

Metabolites: 代謝物

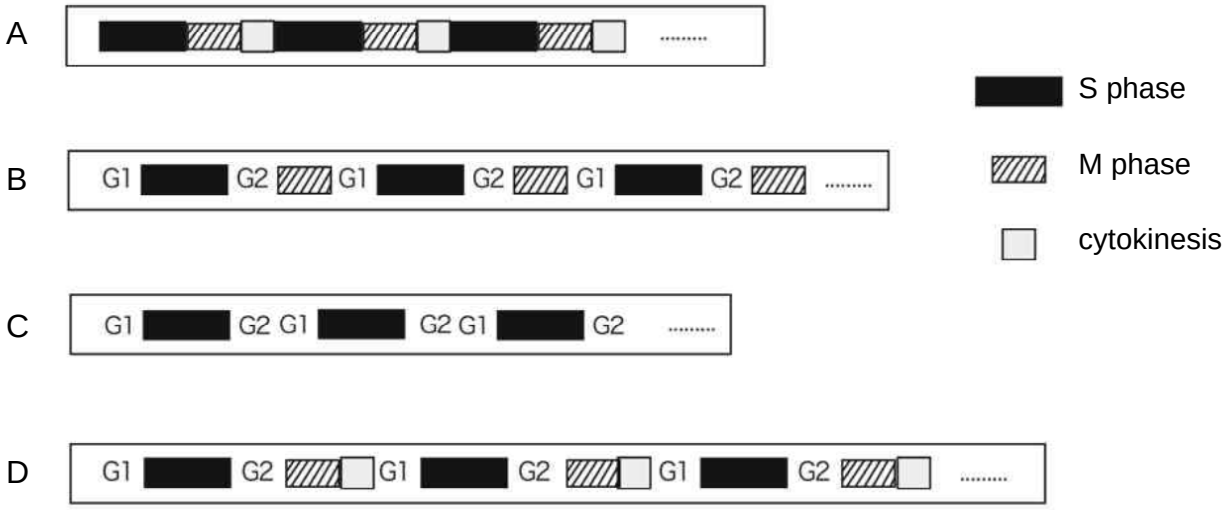
A. Glucose-6-phosphate 葡萄糖-6-磷酸 (G6P)

B. Lactate 乳酸

C. Fructose-1,6-bisphosphate 果糖-1,6-二磷酸

B5. (2 points) Different patterns of cell cycling (A to D) are shown below. Correctly match them with the given cell types they represent.

A – D 爲不同型式的細胞周期，請與 I – IV 的不同細胞型態進行正確的配對。(2 分)



Cell types 細胞型態

I. Human epithelial cell 人類表皮細胞

II. Sea urchin embryonic cells up to 128-cell stage 128 細胞時期的海膽胚細胞

III. Drosophila salivary gland cell 果蠅唾腺細胞

IV. Plasmodium of slime mold 黏菌的原生質體

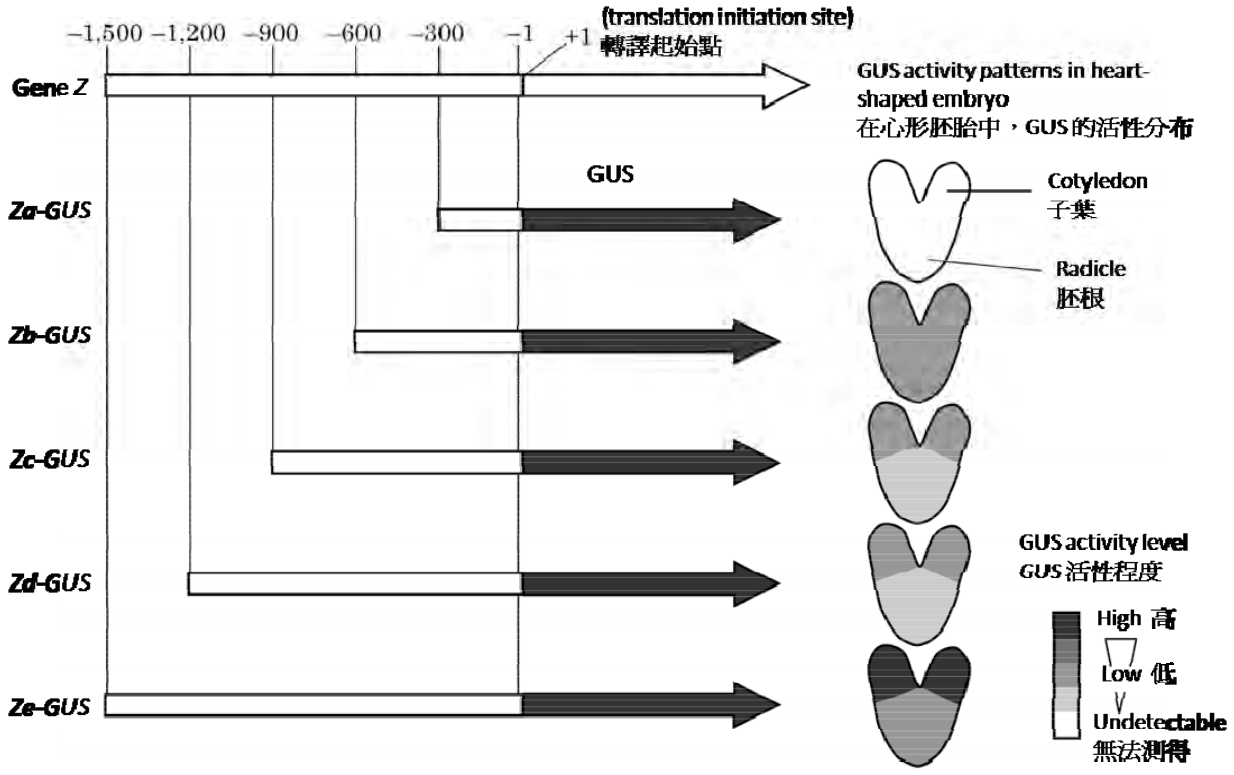
B6. (3 points) A cell suspension of a microorganism was fed with [^{3}H]-labeled uridine and incubated. Cell components were fractionated from these cells and radioactivity in the mRNA fraction was measured, which revealed that 2.5 picomoles of uridine were incorporated into mRNA in 1 x 10^6 cells. Assuming that the base composition of mRNA is random and that the average length of mRNA is 3,000 bases, calculate how many molecules of mRNA were synthesized in each individual cell during incubation.

(Avogadro's number: 6 x 10^{23})

提供具有 [^{3}H] 標示的尿嘧碇 (uridine) 於微生物培養基中，進行細胞培養。分離細胞內容物後，偵測 mRNA 是否具有放射性，實驗顯示 1 x 10^6 細胞的 mRNA 中可偵測到有 2.5 x 10^{-12} picomole 的尿嘧碇具有放射性。假設 mRNA 的核苷酸序列組成是隨機的，且 mRNA 的平均長度爲 3,000 鹼基，請計算在培養過程中，共有多少 mRNA 分子被合成（3 分）

B7. (4 points) From the model plant *Arabidopsis*, 0.3, 0.6, 0.9, 1.2, and 1.5-kbp genomic fragments upstream of the translation start site of gene *Z* were isolated and designated *Za*, *Zb*, *Zc*, *Zd*, and *Ze*, respectively. These fragments were fused to the structural gene of β-glucuronidase (GUS) of *Escherichia coli*. *Arabidopsis* was transformed with the resultant chimeric genes *Za-GUS*, *Zb-GUS*, *Zc-GUS*, *Zd-GUS*, and *Ze-GUS*, and examined for GUS activity by in-situ chromogenic reaction. The following figure schematically shows construction of the chimeric genes and the GUS activity patterns in heart-shaped embryos of the transgenic *Arabidopsis* carrying these chimeric genes.

分離模式植物阿拉伯芥 基因 Z 轉譯起始點上游的基因片段，其大小分別爲 0.3, 0.6, 0.9, 1.2, 與 1.5-kbp，分別標記爲 *Za*, *Zb*, *Zc*, *Zd*, and *Ze*。這些片段分別接上來自大腸菌的 β-葡萄醣醛酸酶 (β-glucuronidase (GUS))，這些重組基因 (chimeric genes) 分別送入阿拉伯芥中，爲了偵測送入的重組基因所表現的 GUS 基因活性，因此進行活體呈色反應 (in-situ chromogenic reaction)，植株分別標記爲 *Za-GUS*, *Zb-GUS*, *Zc-GUS*, *Zd-GUS*, 與 *Ze-GUS*。下圖爲重組基因在阿拉伯芥的 心形胚胎中 GUS 活性反應結果與重組基因的構築輿圖。(4 分)



Based on this result, identify the function of each upstream region of *Z*.

基於上述結果，請將 基因 Z 上游不同大小的 DNA 片段 (I, II, III 與 IV) 與功能 (A - G) 進行配對。

Upstream region 上游區域

I. –1,500 to –1,201

II. –1,200 to –901

III. –900 to –601

IV. –600 to –301

Functions 功能

A. promotes gene expression in a tissue-non-specific manner

基因表現強與組織特異性無關

B. promotes gene expression in cotyledons only

僅在 子葉組織 中有促進基因表現能力

C. promotes gene expression in tissues other than cotyledons only

僅在 非子葉的其他組織 中有促進基因表現能力

D. suppresses gene expression in cotyledons

在 子葉組織 中會抑制基因表現

E. suppresses gene expression in tissues other than cotyledons

在 非子葉的其他組織 中會抑制基因表現

F. little influence on gene expression

基因表現僅受到些微影響

Plant Anatomy and Physiology 植物解剖與生理

B8. (3 points) Deficiency of a particular mineral element in the soil elicits a specific pattern of leaf discoloration in plants (chlorosis), which is related to metabolic roles and mobility (translocation) of the mineral element in the plant. The following describes the deficiency symptoms (leaf discoloration), metabolic roles, and mobility of magnesium (Mg), iron (Fe), and nitrogen (N).

土壤中缺乏某一特定礦物元素會導致植物葉片出現特殊的褪色現象（褪色症），這與該礦物元素在植物代謝上的角色以及移動性（轉運）有關。以下分別描述鎂、鐵及氮等元素缺乏時的病徵（葉褪色情形）、代謝角色以及移動性。

Deficiency symptoms

A. Deficiency of this mineral causes chlorosis initially in young leaves

B. Deficiency of this mineral causes chlorosis initially in old leaves

缺乏時的病徵

A. 缺此元素將導致嫩葉發生褪色症

B. 缺此元素將導致老葉發生褪色症

Mineral mobility

C. This mineral is highly mobile in plants.

D. This mineral is largely immobile in plants.

元素移動性

C. 此元素在植物中的移動很快速

D. 此元素在植物中的幾乎不會移動

Metabolic roles

E. This mineral is involved as a component in the electron transfer system and is also required for the synthesis of some of chlorophyll-protein complexes.

F. This mineral serves as a constituent of many plant cell components including amino acids, nucleic acids, and chlorophyll.

G. This mineral is involved in the activation of various enzymes and serves as a part of the ring structure of chlorophyll.

代謝角色

E. 此元素是電子傳遞系統的組成成分之一，而且也是某些葉綠素-蛋白質複合體合成所必須的成分

F. 此元素是爲植物細胞中組成的要素，包括胺基酸、核酸以及葉綠素等的成分

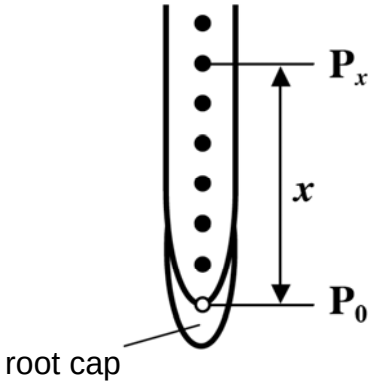
G. 此元素參與了多種酵素的活化，而且是葉綠素環狀結構的一部分

Connect each mineral element to the appropriate descriptions of the above three categories (A or B for Deficiency symptoms; C or D for Mineral mobility; E, F, or G for Metabolic roles).

請將這三種礦物元素分別和上述三類敘述做聯結。（A, B 爲缺乏時的病徵；C, D 爲礦物元素移動性；E, F, G 爲代謝角色）

B9. (3 points) Growing plant roots were analyzed with respect to spatial patterns of cell division and elongation growth. The roots were marked with graphite particles (P) at various positions along the root axis, where *x* was the distance from the root apex just behind the root cap to P_x.

由細胞分裂及增長的空間角度來分析植物根生長的情形。在根軸的不同部位以石墨顆粒進行標示，x 是從根冠內之根尖(P_0)到 P_x 的距離。



For each P_x, the following data were collected.

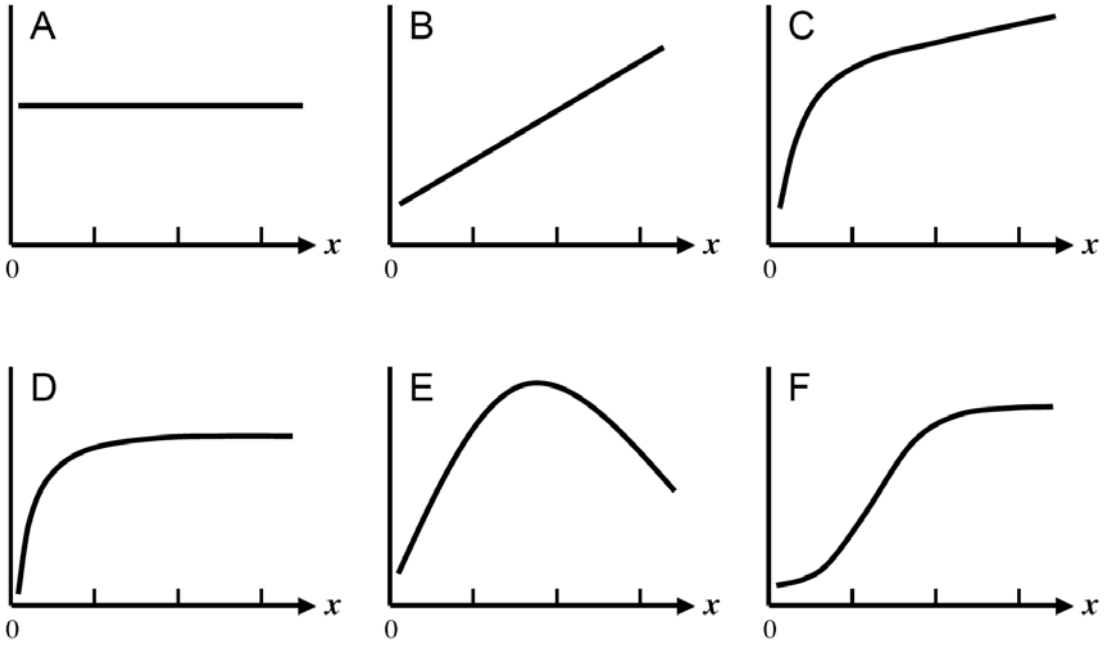
I. Cumulative number of total epidermal cells present between P_0 and P_x
II. Cumulative number of mitotic epidermal cells present between P_0 and P_x
III. Velocity of displacement (movement away) of P_x from P_0

對每一個標示部位 P_x，下列數據是須收集的：

I. P_0 到 P_x 的所有表皮細胞數
II. P_0 到 P_x 的所有分裂的表皮細胞數
III. 增長速率 (P_x 自 P_0 遠移的速率)

When the data are plotted against *x*, what types of profiles do these data sets show? For each data set, choose the most appropriate profile from the followings.

若數據對 x 作圖，數據所出現的圖形各爲何者？請針對每一個數據選出最適當的圖形。



B10. (4 points) Henbane (*Hyoscyamus niger*) is a medicinal plant. Two varieties of this plant, one of which is annual and the other biennial, were characterized for flowering.

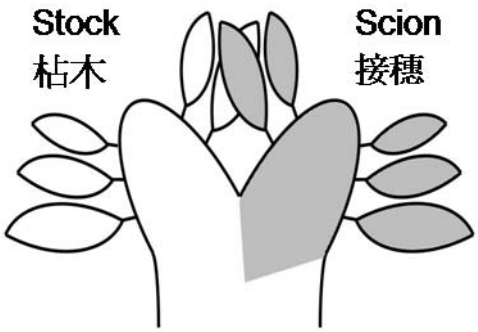
In the first experiment, effects of cold treatment and day length on flowering were examined in the annual and biennial varieties. For this purpose, cold-treated and untreated plants were grown under the short-day condition or the long-day condition. The following table indicates whether the plants flowered or not.

Henbane (*Hyoscyamus niger*) 是一種茄科的藥用植物。根據其開花特徵，可將此植物分成兩個變種，一變種是一年生，另一變種是二年生。在第一個實驗中，分別檢測低溫處理及日照長度，對一年生與二年生變種之開花影響。爲此目的，低溫處理及未處理的植物分別在短日照下或長日照下生長，下表顯示此植物的開花情形。

		Flowering 開花	
Variety 變種	Treatment	Short-day 短日照	Long-day 長日照
Annual 一年生	Cold-treated 低溫處理	No	Yes
	Untreated 未處理	No	Yes
Biennial 二年生	Cold-treated 低溫處理	No	Yes
	Untreated 未處理	No	No

In the second experiment, cold-treated and untreated plants of the annual and biennial strains were grafted as shown in the following figure, and then grown under the long-day condition. Whether the stock and scion flowered or not was recorded. The results of the two types of grafts (#1 and #2) are summarized in the table.

在第二個實驗中，低溫處理及未處理的一年生與二年生變種植物進行嫁接 (如下圖)，並在長日照條件下生長。記錄枯木與接穗部分是否開花。兩種嫁接 (#1 and #2) 的結果整理如下表。



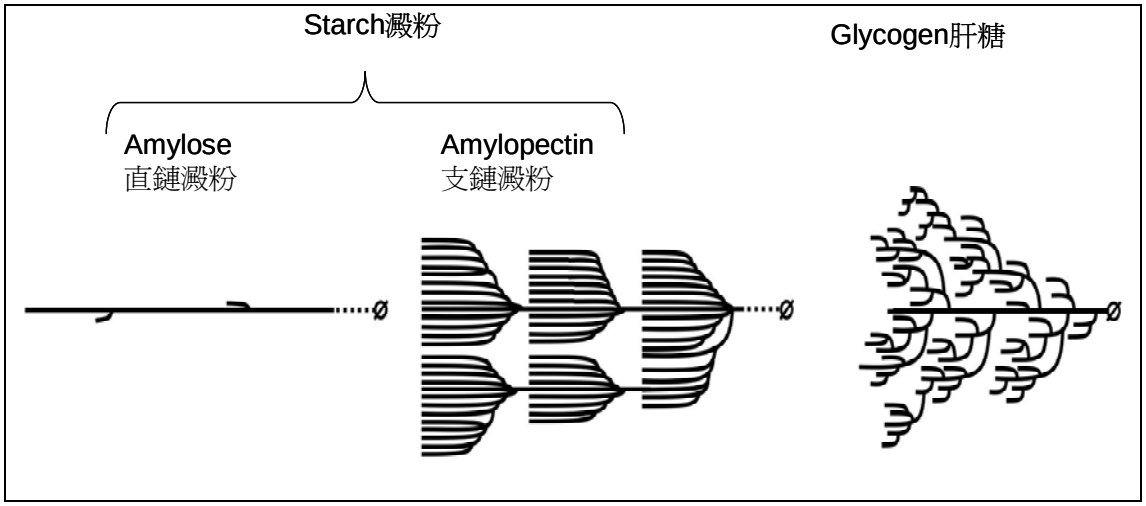
		Strain	Treatment	Flowering
Graft #1 嫁接#1	Stock 枯木	Annual 一年生	Untreated 未處理	Yes
	Scion 接穗	Biennial 二年生	Untreated 未處理	Yes
Graft #2 嫁接#2	Stock 枯木	Biennial 二年生	Cold-treated 低溫處理	Yes
	Scion 接穗	Biennial 二年生	Untreated 未處理	Yes

Assuming the involvement of florigen in flowering of this species, identify the properties of the shoot apical meristems and leaves of the annual and biennial plants, based on the above results. Mark the appropriate boxes with "X" about florigen response (1) and florigen productivity (2).

假設開花激素參與此物種的開花過程，根據以上結果，試判定一年生與二年生植物的莖頂分生組織與葉的性質。在答案紙上表格中，關於開花激素是否有反應(1)以及開花激素是否產生(2)，在適當的空格標示 "**X**"。

B11. (3 points) Plants and animals accumulate starch and glycogen as a storage polysaccharide, respectively. Starch consists of two sorts of large, water-insoluble polymers of glucose, amylose and amylopectin. Amylose is essentially unbranched and linear while amylopectin is highly and regularly branched, which forms branch clusters. Glycogen is also a branched glucose polymer, but unlike amylopectin, it is relatively small and water-soluble. In the glycogen molecule, branches are shorter, irregular, and not clustered.

植物與動物分別以累積澱粉及肝糖爲其儲存的多醣類。澱粉包含有兩種不溶於水的葡萄糖聚合物：直鏈澱粉(amylose)及支鏈澱粉(amylopectin)，直鏈澱粉不分支且成直線；支鏈澱粉具多且有規律地的分支，分支常聚成團。肝糖也是一種分支的葡萄糖聚合物，但不像支鏈澱粉，而是相對較短且爲水溶性，其分支短、不規則、且不聚成團。



回答下列 3 小題

(1) Biosynthesis of starch involves three classes of enzymes: chain elongation enzymes, branching enzymes, and debranching enzymes. *Sugary*, a rice mutant, is deficient in a particular debranching enzyme. The endosperm of this mutant is characterized by the accumulation of glycogen-like polysaccharide instead of amylopectin. In consideration of this information, the role of the wild-type debranching enzyme in starch biosynthesis is:

澱粉的生物合成過程中有三類酵素參與：鏈延長酶、分支酶、去分支酶。水稻突變型 (*Sugary*) 在某去分支酶有缺失，此突變型的胚乳會累積似肝糖的多醣類，而非支鏈澱粉。根據此資訊，野生型的去分支酶在澱粉合成之角色是：

A. to remove all branches from amylopectin to form amylose.
B. to shorten every branch of amylopectin.
C. to regulate the branching pattern of amylopectin.
D. to cut α1 -4 glycosidic bonds of amylopectin.

A. 從支鏈澱粉去除所有分支而形成直鏈澱粉
B. 減短支鏈澱粉的每個分支
C. 使支鏈澱粉的分支型式規律化
D. 切斷支鏈澱粉的 α1 –4 糖苷鍵

(2) The seeds of the *Sugary* mutant of rice are not different from the wild-type seeds in the size and appearance before desiccation which is associated with seed maturation. During desiccation, however, the *Sugary* seeds become shrunk and wrinkled. This phenomenon suggests that before desiccation, as compared with the wild-type seeds, the *Sugary* seeds contain:

在種子成熟過程中所經歷乾燥時期之前，水稻突變型 (*Sugary*) 種子與野生型的大小及外形沒有差別；然而在乾燥時期時，突變型 (*Sugary*) 種子縮小且有皺褶。此現象暗示：與野生型比較，在乾燥之前，突變型 (*Sugary*) 種子含有：

	storage polysaccharide 儲存多醣類	Water 水
A	More 多	Less 少
B	more 多	more 多
C	less 少	more 多
D	less 少	less 少

(3) Bacteria including cyanobacteria accumulate a glycogen-like polysaccharide for storing glucose. Which of the following can reasonably explain the evolution of storage polysaccharides?

細菌及藍綠菌會累積類似肝糖的多醣類以儲存葡萄糖。下列敘述何者可合理解釋多醣類儲存的演化？

The common ancestor of plants and animals could synthesize:

A. both amylopectin and glycogen, but plants have lost the ability of glycogen synthesis during evolution.
B. both amylopectin and glycogen, but animals have lost the ability of amylopectin synthesis.
C. amylopectin but not glycogen, and animals have acquired the ability of glycogen synthesis.
D. glycogen but not amylopectin, and plants have acquired the ability of amylopectin synthesis.

植物與動物的共同祖先能合成：

A. 支鏈澱粉及肝糖，但植物在演化過程中喪失合成肝糖的能力
B. 支鏈澱粉及肝糖，但動物喪失合成支鏈澱粉的能力
C. 支鏈澱粉但非肝糖，但動物獲得合成肝糖的能力
D. 肝糖但非支鏈澱粉，但植物獲得合成支鏈澱粉的能力

B12. (3 points) Soybean roots form nodules when infected by *Rhizobium*. HN is a recessive mutant of soybean that exhibits a hypernodulating phenotype. As shown in Figure 1, the roots of the HN mutant form more nodules than the wild-type (WT) roots, and the shoot growth of the HN mutant is retarded compared to WT. Figure 2 schematically shows the nodulation phenotypes observed in grafting experiments with WT and the HN mutant. In the absence of *Rhizobium*, the HN mutant is not phenotypically different from WT in any aspects.

當黃豆根部感染根瘤菌 (*Rhizobium*) 後，會形成根瘤。一隱性突變型 (HN) 具有形成根瘤過量之表現型，如圖 1 所示，突變型的根比野生型 (WT) 形成較多根瘤；且其莖部生長較野生型遲緩。圖 2 顯示在野生株與突變株中不同部位嫁接，觀察根瘤表現型的結果。在沒有根瘤菌的情況下，野生株與突變株差異很大。

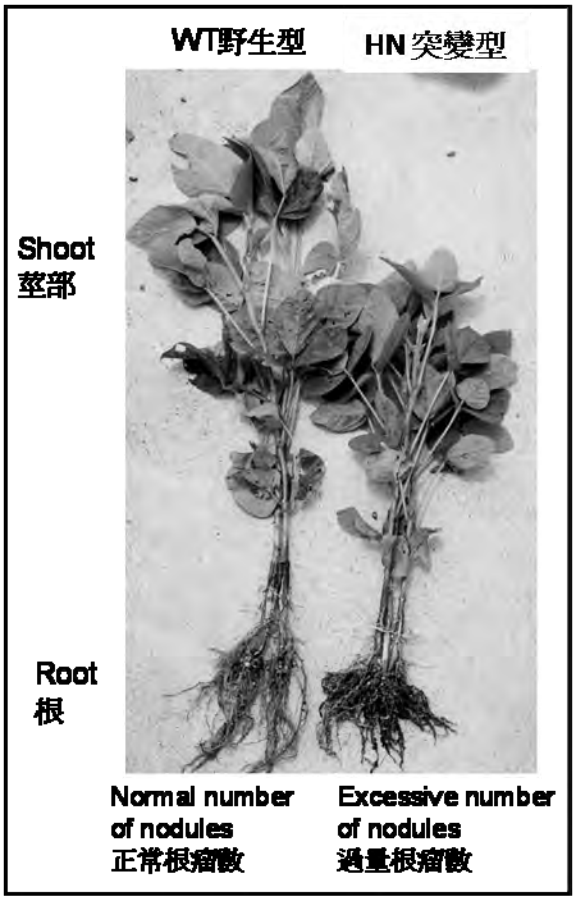


Figure 1

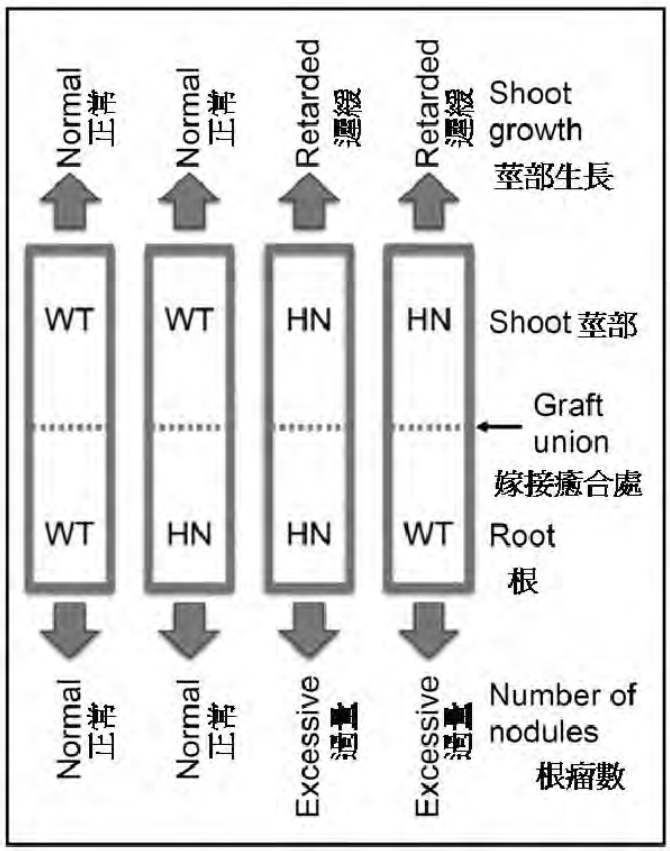


Figure 2

From the above information, what can be reasonably inferred? For each of the following statements, mark “X” in the appropriate box choosing the option in the bracket.

根據上述資訊，何者較合理？在 I, II, III 三個敘述，分別從大括弧中選出正確選項，並在答案卷上對應空格中標示 “**X**”。

I. In the HN mutant, the { A. shoot 莖部 / B. Root 根 } determine the hypernodulation phenotype
由突變株的 判定根瘤過量表現型

II. The shoot of WT { A. positively regulates 可正向調節 / B. negatively regulates 可負向調節 / C. is neutral for the regulation of 與調節無關 } the number of nodules
野生型的莖部 根瘤數

III. In the HN mutant,hypernodulatioris { A. the cause 造成 / B. the result 結果 / C. Independent 無關於 } of retarded growth of the shoot.
在HN突變株，根瘤過量的性狀是 莖部生長遲緩

Animal Anatomy and Physiology

動物解剖與生理

B13. (3 points) Three patients I, II and III show symptoms of low thyroxine levels. Defects are found in the hypothalamus for patient I, in the anterior pituitary for patient II, and in the thyroid for patient III. After thyroid-stimulating-hormone-releasing hormone (TRH) is given to these patients, the concentration of thyroid-stimulating hormone (TSH) before and after (30 min) TRH administration is measured in each patient.

B13（3 分）三位病患 I、II 及 III 均呈現甲狀腺素過低的症狀。病患 I 的下視丘有缺損，病患 II 的腦垂腺前葉有缺損，病患 III 的甲狀腺有缺損。三位病患均被投予 TRH，並分別於投予 TRH 前，以及投藥後 30 分鐘，分別測量他們體內 TSH 濃度如下表

	Before TRH administration 投予 TRH 前	After TRH administration 投予 TRH 後
Healthy person 健康個體	Lower than 10 低於 10	Between 10 and 40 10~40 間
A	Lower than 10 低於 10	Between 10 and 40 10~40 間
B	Between 10 and 40 10~40 間	Higher than 40 高於 40
C	Lower than 10 低於 10	Lower than 10 低於 10

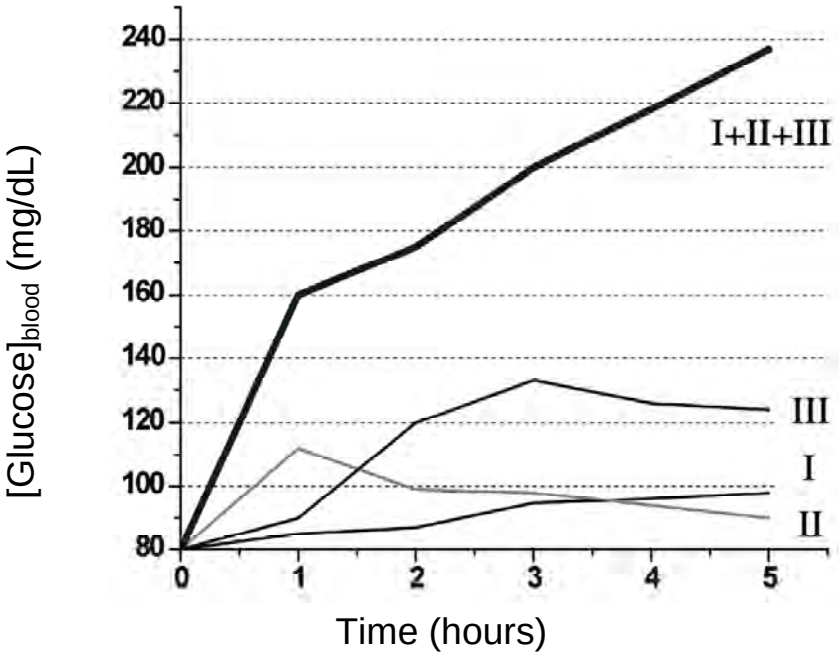
Fill the letter of the appropriate data (A–C) for each patient (I–III).

以字母代號 A, B, C，填入病患代號 I – III 的正確欄位中。

B14. (2.5 points) The graph below shows the blood glucose level after three hormones I, II and III are administered separately or together.

B14.（2.5 分）**此題爲題組，計三小題**

下圖爲單獨或合併投予三種激素 I、II 及 III 所造成血糖濃度的變化



(1) How do you classify these hormones? 這些激素屬於下列哪一種功能？

A. Hypoglycemic 降血糖

B. Hyperglycemic 昇血糖

(2) Choose the type of interaction between these hormones.
這些激素間的交互作用，可歸類爲下列何種關係？

A. Additive 加成作用

B. Antagonistic 拮抗作用

C. Synergistic 協同作用

D. None 無

(3) Pick the three possible hormones that are consistent with the results shown in the graph.根據圖中的結果，這些激素最有可能爲下列那三種？

A. Insulin 胰島素

B. ADH (Vasopressin) 抗利尿激素

C. Adrenalin (Epinephrine) 腎上腺素

D. Renin 腎素

E. Glucagon 升糖素

F. Angiotensinogen 血管收縮素原

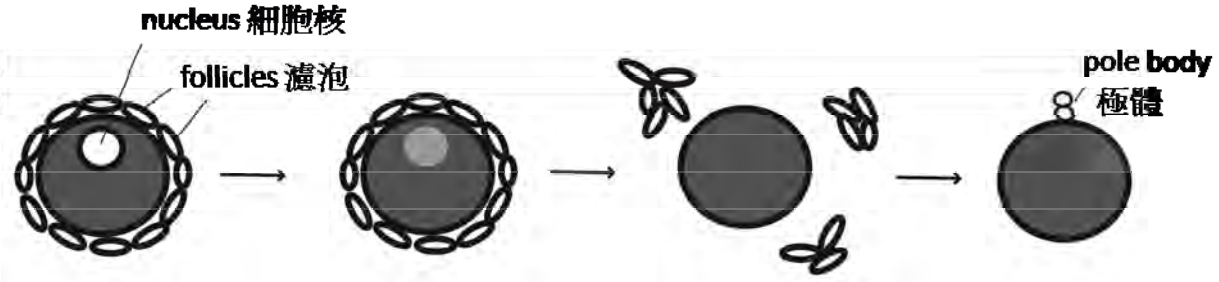
G. Cortisol 糖皮質素

H. Calcitonin 降鈣素

I. Atrial natriuretic peptide 心房鈉泌素

B15. (4 points) The oocytes of a starfish grow within the provided follicle in the gonad. Eventually they cease meiosis at prophase I, and wait as a state of immature eggs. The immature eggs resume meiosis when stimulated and lose their nuclear envelop as shown below.

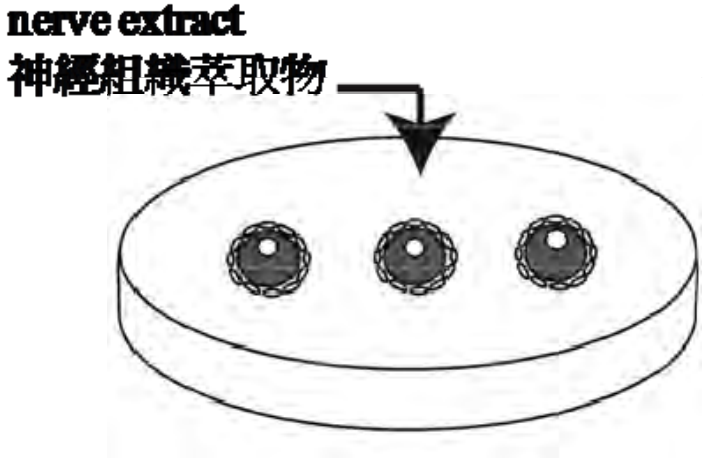
B15（4 分）海星的卵子在生殖腺中的濾泡內成長。卵子會於第一次減數分裂前期停止分裂，而停留在未成熟的狀態。若受到刺激，未成熟的卵子會繼續進行減數分裂，並失去核膜 (如下圖)。



In order to understand the mechanism of this resumption, the following experiments were conducted. 爲了解造成繼續分裂的機制，進行以下實驗。

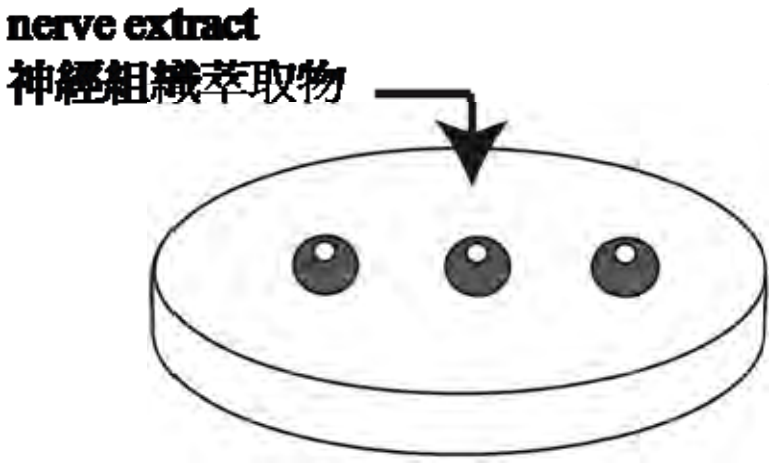
Experiment 1: When extract from the nerve tissue of adult starfish was added to immature eggs surrounded by follicles, meiosis resumed.

實驗1：將取自海星成體的神經組織萃取物，加到被濾泡包圍的未成熟卵上時，減數分裂重新恢復。



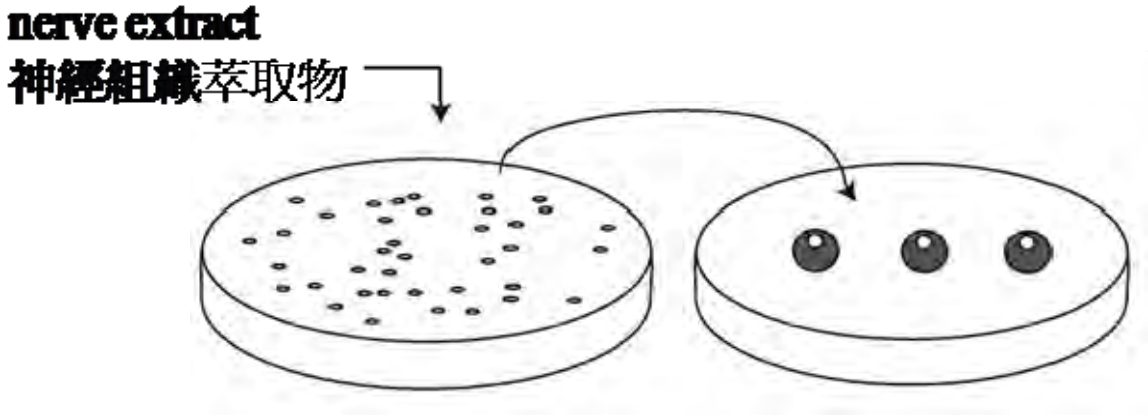
Experiment 2: When extract from the nerve tissue of adult starfish was added to immature eggs from which follicles were removed, meiosis did NOT resume.

實驗2：將取自海星成體的神經組織萃取物加到移除濾泡的未成熟卵上時，減數分裂 不會恢復。



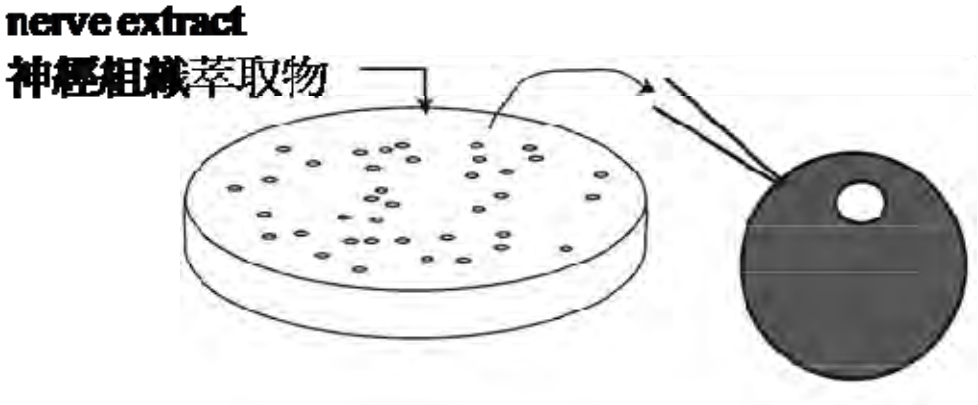
Experiment 3: When extract from the nerve tissue of adult starfish was added to follicles after they had been separated from immature eggs, and subsequently the medium was added to immature eggs without follicles, meiosis resumed.

實驗3：將取自海星成體的神經組織萃取物，先加到分離出來的濾泡中，再將培養液加到未成熟卵上，減數分裂會重新恢復。



Experiment 4: When extract from the nerve tissue of an adult starfish was added to follicles after separated from immature eggs, and the medium was injected to immature eggs without follicles, meiosis did NOT resume.

實驗4：將取自海星成體的神經組織萃取物，先加到分離出來的濾泡中，再將培養液直接注射入未成熟的卵內，減數分裂 **不會** 恢復。



Based on these results, four hypotheses were developed.

根據上述實驗結果，提出四種假說。

Hypothesis 1: The extract from the nerve tissue contains a substance which directly acts on immature eggs causing them to resume meiosis.

假說 1：神經組織的萃取液內含有某種物質，可直接作用在未成熟的卵上，造成減數分裂的恢復。

Hypothesis 2: The extract from the nerve tissue contains a substance which acts on immature eggs to resume meiosis, but the follicle blocks the substance from reaching the immature eggs.

假說 2：神經組織的萃取液中含有某種可使未成熟卵恢復減數分裂的物質，但濾泡阻斷了該物質與未成熟卵的接觸。

Hypothesis 3: The extract from the nerve tissue contains a precursor of a substance that causes meiosis to resume, which is processed by the follicle into an active compound that causes immature eggs to resume meiosis.

假說 3：神經組織的萃取液中具有某種可恢復減數分裂物質的前驅物，需經由濾泡進行處理後，才會形成具活性的物質，使減數分裂恢復。

Hypothesis 4: The extract from the nerve tissue induces follicles to secrete a substance which then acts on the cell surface of an immature egg to cause a resumption of meiosis.

假說 4：神經組織的萃取液可誘使濾泡分泌某種物質，該物質可作用於未成熟卵的表面，使減數分裂重新恢復。

Indicate whether each hypothesis is rejected or not.

分別指出上述哪些假說會被推翻，哪些假設不會被推翻。

B16. (2 points) After the nucleus is removed from a fertilized frog egg, it is re-transferred back into the enucleated egg. In another experiment, the nucleus from a gut epithelial cell is transferred to an enucleated egg. In both cases, the eggs grow well and develop normally into tadpoles.

B16.（2 分）將蛙受精卵中的細胞核移出後，再將細胞核植回去核的卵中。在另一個實驗中，在去核的卵中注入一個腸道上皮細胞的細胞核。上述的兩種實驗中，卵都會發育並長成正常的蝌蚪。

(1) Choose the correct statement from A to E below.

(1)從 A～E 中選出正確的敘述。

During differentiation from fertilized eggs to tadpole gut epithelial cells:

在蛙受精卵分化形成蝌蚪的腸道上皮細胞的過程中：

A. gene expression patterns do not change. 基因表現的模式沒有改變

B. some genes are not expressed, but the genes themselves are not lost during development. 有些基因沒有表現，但基因本身並未在發育過程中喪失。

C. all the genes are expressed. 所有的基因均能表現

D. the amount of proteins does not change. 蛋白質的總量並無變化

E. the amount of RNAs does not change. RNA 的總量並無變化

(2) In the experiment above, frog gut epithelial cells were used. If this experiment were performed in mammals, theoretically almost all cell types can be used as a nucleus donor, but a few cell types cannot. Which of the following cell types is NOT appropriate as a donor cell?

(2)上述的實驗中使用蛙腸道的上皮細胞。如在哺乳類身上進行該實驗，在理論上，所有種類的細胞應該均可作爲核的來源，但實際上有少數細胞是不能的。下列各種細胞中，哪些不適合作爲核的來源。

A. B lymphocyte　B 淋巴球

B. Liver cell　肝細胞

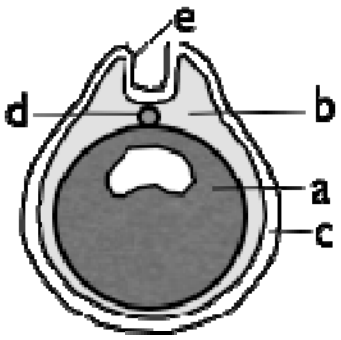
C. Mammary gland cell　乳腺細胞

D. ES (embryonic stem) cell　胚胎幹細胞

E. Cone cell　視錐細胞

B17. (2 points) The figure below represents a cross section of a vertebrate neurula stage embryo.

B17.(2 分)下圖爲脊椎動物胚胎在神經脊時期的橫切示意圖。



(1) The following are statements about the tissues and organs derived from (a), (b), (c) and (d) of the figure. Identify whether each statement is True or False and mark “X” in the appropriate box.

下列是有關圖中(a), (b), (c) ,(d)所分化出來的組織或器官之敘述，請辨認下列敘述是正確或是錯誤，並在適當的欄位中標上“**X**”的記號。

A. Tissues derived from (a) are always associated with those from (b).

分化自(a)的組織常與分化自(b)的組織經常一起出現

B. The developmental fate of (c) sometimes changes.

(c)的分化結果有時會改變

C. (d) differentiates into the backbone (vertebra).

(d)會分化成脊骨（脊椎骨）

D. Most of the circulatory system arises from (b).

大部分的循環系統均分化自(b)

(2) Neural tube arises from (e). The following are statements about the formation and later development of the neural tube. Identify whether each statement is True or False and mark “X” in the appropriate box.

神經管分化自(e)。下列爲有關神經管形成及發育過程的敘述，請辨認下列敘述是正確或是錯誤，並在適當的欄位中標上“**X**”的記號。

A. Cells in the wall of neural tube later differentiate into glial cells as well as nerve cells (neurons).

神經管壁的細胞日後會分化成神經膠細胞及神經細胞 (神經元)

B. Lumen in the neural tube is later completely occluded.

神經管的管腔部分日後會完全被填滿

C. Almost all nervous tissue derived from neural tube is central nervous system.

幾乎所有來自神經管的神經組織會構成中樞神經系統

D. The retinal pigment epithelium in the eye derives from optic vesicle formed from the neural tube.

源自神經管的視泡會變成眼球內視網膜上皮中的色素細胞

B18. (3 points) For intracellular infectious bacteria and viruses to successfully invade a cell, they must bind to receptors on the cell surface. HIV, specifically infects helper T cells, which express the CD4 molecule, but not CD8 on their cell surface, making it possible to distinguish helper T cells from other lymphocytes. Thus, CD4 is hypothesized to be a receptor for HIV.

B18. (3 分) 造成細胞內感染的細菌和病毒，必須與細胞表面的受體結合，才能成功侵入細胞。HIV 能專一性感染輔助性 T 細胞，因爲該細胞表面有 CD4 分子，而沒有 CD8。此特性可使輔助性 T 細胞與其他淋巴球區分。因此，有假說認爲 CD4 是 HIV 的受體。

(1) Which two of the following experiments would confirm this hypothesis?

下列實驗中哪兩個可確認此假說？

Experiments that examine whether: 實驗以檢測是否：

A. an antibody against CD4 added to a co-culture system of CD4-positive T cells and HIV can inhibit HIV infection of T cells

加入抗 CD4 的抗體，與具 CD4 的 T 細胞和 HIV 共同培養，可抑制 HIV 感染 T 細胞。

B. an antibody against CD8 added to a co-culture system of CD8-positive T cells and HIV can inhibit HIV infection of T cells

加入抗 CD8 的抗體，與具 CD8 的 T 細胞和 HIV 共同培養，可抑制 HIV 感染 T 細胞。

C. an antibody against HIV added to a co-culture system of CD4-positive T cells and HIV can inhibit HIV infection of T cells

加入抗 HIV 的抗體，與具 CD4 的 T 細胞和 HIV 共同培養，可抑制 HIV 感染 T 細胞。

D. forced expression of the CD4 gene in HIV-resistant CD4-negative T cells causes a recovery of susceptibility to HIV infection

在不會被 HIV 感染的 T 細胞 (無 CD4 表現) 中，強行表現 CD4，可使該 T 細胞恢復對 HIV 的感受性。

E. forced expression of the CD8 gene in HIV-resistant CD8-negative T cells causes a recovery of susceptibility to HIV infection

在不會被 HIV 感染的 T 細胞 (無 CD8 表現) 中，強行表現 CD8，可使該 T 細胞恢復對 HIV 的感受性。

(2) It is known that HIV cannot infect mice, although the mouse has CD4-positive helper T cells, because mouse CD4 cannot bind to HIV. To study further the mechanism of HIV infection in human cells, the following experiments were carried out, and the results are as follows:

已知 HIV 不會感染小白鼠，雖然小白鼠輔助性 T 細胞也具有 CD4，這是因爲小白鼠形式的 CD4 不能與 HIV 結合。爲研究 HIV 感染人體細胞的機制，進行下列實驗，獲得以下結果：

1. When the human CD4 gene is expressed in mouse T cells, HIV can bind to the cells but cannot infect them.

   當人體的 CD4 基因在老鼠的 T 細胞上表現時，HIV 可與細胞結合但不能感染。

2. When human chemokine receptor (CXCR4) is expressed in addition to human CD4 in mouse cells, HIV is able to infect the cells.

   在已經表現人類 CD4 的老鼠細胞中，額外表現人體化學增活素受體（CXCR4），HIV 可感染該細胞。

3. When human CD4 and CXCR4 genes are expressed in mouse cells and the cells are cultivated in the presence of SDF-1a, a ligand of CXCR4, infection by HIV is perturbed.

   當人體的 CD4 和 CXCR4 基因在小白鼠細胞內表現，並將細胞培養於含有 SDF-1a (SDF-1a 是 CXCR4 的配體) 的環境中，HIV 感染細胞的過程會受到干擾。

Which of the following sentences states the correct conclusion based on the above experiments?

基於上述實驗結果，下列敘述何者 **正確**？

A. If CXCR4 is expressed in mouse cells, CD4 is not required for the infection of HIV.
若小白鼠的細胞表現 CXCR4，則 HIV 感染細胞時不需要 CD4

B. Human CD4 is required for the binding with HIV, and the binding is enhanced by the SDF-1a ligand.
HIV 與細胞結合需要人類的 CD4 協助，而該作用會被 SDF-1a 配體的增強

C. Even if human CD4 is expressed in mouse T cells, CXCR4 is required for binding of HIV to the T cells.
即使小白鼠的 T 細胞表現了人體的 CD4，HIV 仍需要 CXCR4 才能與 T 細胞結合

D. Human CD4 is required for the binding with HIV, but infection of HIV into cells requires help of CXCR4.
HIV 與細胞結合時，需要人體 CD4 的協助，而 HIV 感染細胞時則需要 CXCR4

B19. (3 points) The majority of humans have erythrocytes that express the Rh (Rhesus) antigen on their cell surface, but some are negative for the Rh antigen.

An Rh-negative woman marries to a heterozygous Rh-positive man and has three children.

B19. (3 分)大部分人體的紅血球可以表現 Rh（恆河猴）抗原於細胞表面，但有些人的 Rh 抗原則是陰性的。

某 Rh 陰性的婦女和某異型合子 Rh 陽性的男人結婚並育有 3 個小孩。

(1) What is the probability that all three of their children become Rh-positive?

3 個小孩全部都是 Rh 陽性的機率是多少？

A. 1

B. 1/2

C. 1/4

D. 1/8

E. 0

(2) In which combination below could the second child suffer from hemolytic disease?

在下列組合中，何者會造成第 2 個小孩罹患溶血症？

	First child	Second child
A.	Rh-positive	Rh-negative
B.	Rh-negative	Rh-positive
C.	Rh-negative	Rh-negative
D.	Rh-positive	Rh-positive

(3) Which molecules or cells are mainly involved in causing hemolytic disease in the fetus and newborn infant in case of Rh blood group antigen-incompatibility? Choose TWO correct options from A to F.

在 Rh 血型的抗原不相容性上，哪些主要的分子或細胞參與導致胎兒及新生兒溶血症的發生？請從 A~F 中，選擇 **2** 個正確的選項。

A. T cells T 細胞

B. IgM antibody IgM 抗體

C. Complement 補體

D. Interferon gamma γ 干擾素

E. IgG antibody IgG 抗體

F. Perforin 穿孔素

Ethology 行爲學

B20. (3 points)

(1) Foraging honeybees usually perform a waggle dance (Figure 1) when they find an attractive food source 100 m or more away from their hive. The duration of the waggle dance indicates the distance to the food source.

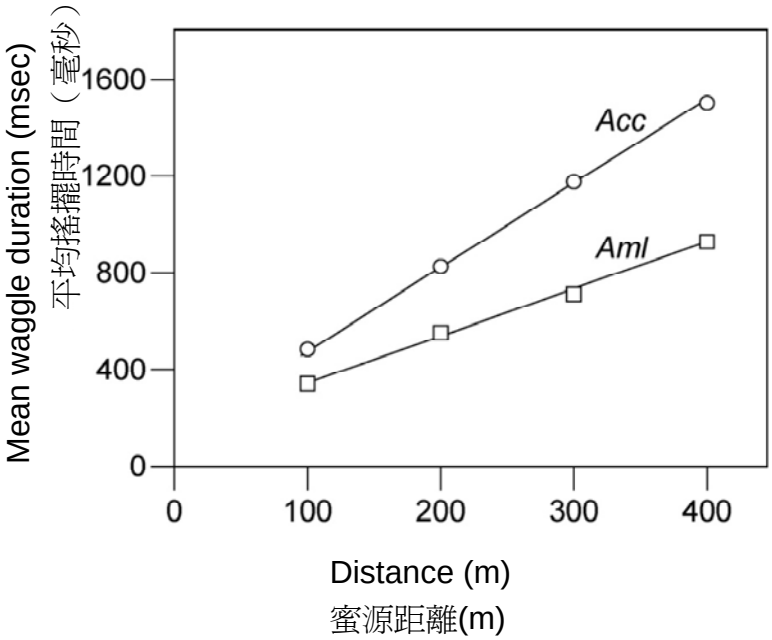
蜜蜂搜索離巢 100 公尺以上距離蜜源時，會用其跳搖擺舞時間的長短來顯示蜜源距離，如圖一。

The duration of the waggle dance was studied in two honeybee species, *Apis cerana cerana* (*Acc*) and *Apis mellifera ligustica* (*Aml*), when food was placed at varying distances from the hives and the data shown in the graph below.

圖二表示 Acc 和 Aml 兩種蜜蜂跳搖擺舞所發的平均時間與蜜源距離的關係。

Figure 1

Figure 2



What were the distances (m) indicated when the average duration of the waggle dances of *Acc* and *Aml* both lasted 800 msec? Answer the distance for each species from the following numbers.

Acc 和 Aml 兩種蜜蜂跳搖擺舞所花時間爲 800 毫秒時，根據下列數據回答其蜜源距離。

130 160 190 220 250 280 310 340 370 400

(2) Mixed colonies of *Acc* and *Aml* were successfully established by introducing *Aml* pupae into *Acc* colony and *vice versa*. The young individuals of both species were accepted by the colony members of the other species. When the same experiment (Figure 2) was performed on the mixed colonies, the introduced *Acc* and *Aml* workers each showed exactly the same patterns that these species had shown earlier.

將 Acc 和 Aml 兩種蜜蜂混合飼養，可成功將一方蜂蛹置入對方蜂窩內孵化，並爲對方蜜蜂所接受。而在異巢孵化長大的蜜蜂，仍然可以表現出圖二中與自己同種蜜蜂相同的行爲。

In the final experiment, food was placed at 400, 500 and 600 m, all in the same direction, and the introduced *Aml* bees trained to forage at the food source 500 m away. When these bees recruited *Acc* bees from the hive, the latter were found to forage at the food site exactly 500 m away. This was also seen when the reverse experiment was done with *Acc* bees recruiting *Aml* bees.

訓練異巢長大的 Aml 蜜蜂去搜索離巢 500m 遠的蜜源，結果發現 Aml 蜜蜂在 Acc 蜜蜂巢內所跳搖擺舞，仍可使 Acc 蜜蜂正確找到蜜源。此實驗於兩者角色互換時，所得結果亦同。

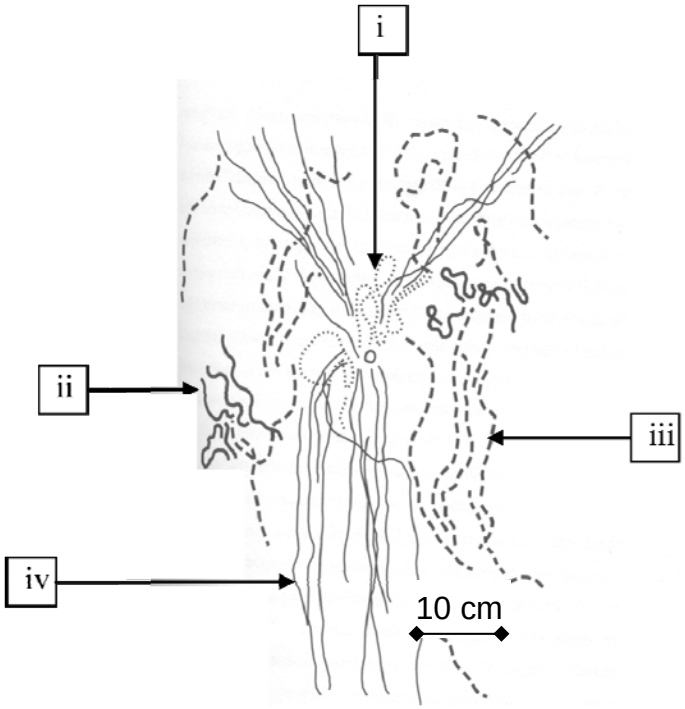
From these experiments, what can we conclude about the transfer of the encoded and decoded information between the actor and receiver bees, respectively?

由這些實驗結果，找出表演者（編碼）及接受者（解碼）獲得資訊來源的方式。

	Encoded information (the actor) 資料編碼（表演者）	Decoded information (the receiver) 資料解碼（接受訊息者）
A.	genetically determined 基因決定	genetically determined 基因決定
B.	genetically determined 基因決定	socially learnt 社會學習
C.	socially learnt 社會學習	genetically determined 基因決定
D.	socially learnt 社會學習	socially learnt 社會學習

B21. (2 points) Red harvester ants (*Pogonomyrmex barbatus*) are social insects and live in underground colonies, in which various functions are carried out by different groups of ants. Below is a picture of one such ant colony. The open circle in the center is the nest entrance. The four types of lines (i to iv) indicate paths followed by different groups of these ants. Match the appropriate groups (A to D) with these lines:

紅色的收穫螞蟻是群居的社會性動物，其利用不同類群的螞蟻來完成不同的功能。下圖是某一螞蟻聚落的圖示，圖中空心圓爲巢穴的出口，四種不同線條則是不同功能類群螞蟻活動的路徑。請找出下列不同功能群的螞蟻(A to D)相對應的活動線條(i to iv)。



Groups:

A. Foragers 搜索食物的螞蟻。
B. Patrollers 巡邏的螞蟻。
C. Nest maintenance ants 巢穴維護的螞蟻。
D. Midden workers or refuse pile sorters (those who pile fecal matter outside the nest) 清理糞便及垃圾的螞蟻

B22. (2 points) In birds, there are many ways of singing. This is caused by the fact that brain regulates the action of the syrinx (vocal organ of birds). In a certain species of birds, two kinds of vocalization can be recognized: longer **songs** produced by males in the breeding season, and other simpler **calls** heard outside the breeding season.

鳥類有不同的鳴唱方式，此係藉由腦來調節鳴管（鳥類發聲器官）所導致的結果。有種鳥類會發出兩種不同鳴聲：生殖時期的雄鳥發出較長歌聲以及生殖季節以外的簡易短叫聲。

(1) If the young chicks of such birds are reared in an environment without sound, adult birds cannot produce the exact longer songs. Which of the following is the most appropriate as explanation of the above statement?

如將此鳥之幼鳥飼養在無聲的環境中，則成鳥均不能產生明確的長歌聲。下列敘述中，何者最適解釋此一現象？

A. In an environment without sound, differentiation between males and females cannot be attained.無聲環境下，雌雄差異不易產生。

B. The song is a mode of behavior which is determined by learning after hatching. 鳴唱行爲是由後天學習的一種行爲模式。

C. In an environment without sound, imprinting of the gene responsible for the song cannot occur. 無聲環境下，鳴唱基因無法受印痕的影響而表現。

D. In an environment without sound, the auditory sense cannot develop. 無聲環境下，聽覺系統無法發育。

(2) Although chicken and quail are closely related, their calls are different. An experiment was carried out in which the presumptive brain region of 5-day-old white chicken embryo was substituted by that of a brown quail embryo of the same age. Then the host chicken embryo was incubated. The hatched chicken had some brown parts in its brain, which indicates that these parts were derived from quail. The calls of this chicken were more similar to that of quail rather than that of chicken. Which of the following is the most appropriate conclusion deduced from the experiment?

雞與鵪鶉二者關係雖然很近，叫聲卻不同。將 5 天大的小雞胚胎上控制發育爲腦組織的部分，用相同位置的棕色鵪鶉胚胎腦組織取代，小雞胚胎孵化後的腦會出現棕色部分，顯示此部分是由鵪鶉胚胎腦組織衍生而來。當此小雞長大後，會發出鵪鶉的叫聲，而不是雞的叫聲。以此實驗結果推論，下列哪些結論最爲適宜？

I. Calls are species-specific and are determined genetically.
叫聲是因種而異，且由基因決定

II. Calls are determined after hatching.
叫聲是孵化以後才決定

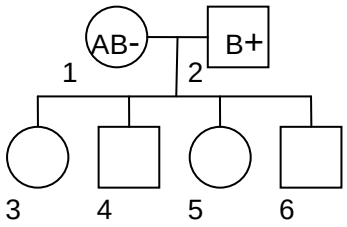
III. Calls are determined by the structure of the syrinx.
叫聲是由鳴管的構造來決定

A. Only I 只有 I
B. Only II 只有 II
C. Only III 只有 III
D. I and II I 和 II
E. I and III I 和 III
F. II and III II 和 III

Genetics and Evolution 遺傳和演化

B23. (4 points) In an experiment on the members of a family with the pedigree shown below, blood plasma and blood cells from different individuals were mixed in pairs to test the presence (p) or absence (a) of coagulation. In this pedigree AB- means that the phenotypes of individual 1 (mother) are AB type and Rh negative (Rh^-), and B+ means that the phenotypes of individual 2 (father) are B type and Rh positive (Rh^+).

（4 分）下圖爲某一家族的族譜。在一項實驗中，將不同家族成員的血漿和血球兩兩混合配對，以測試血液凝固情形，若凝固爲(p)，不凝固爲(a)。在族譜中，AB-代表成員 1（母親）的表現型爲 AB 型及 Rh 陰性，B＋代表成員 2（父親）的表現型爲 B 型及 Rh 陽性。



The results of this experiment are shown below. A blank box in this table indicates a combination that was not tested in this experiment.

此實驗結果如下，空白的欄位代表在此實驗中並未測試該組合。

Plasma donor
血漿捐贈者

Cell donor 血球捐贈者	1	2	3	4	5	6
1		p	a	p		p
2	p		a			p
3	p	p		p	p	p
4	a	a	a		p	
5	p	p				
6	a	p		p	a	

(1) What are the phenotypes of individual 6?

成員6的表現型爲何？

A. A type and Rh^+ A型及Rh陽性

B. A type and Rh^- A型及Rh陰性

C.B type and Rh^+ B型及Rh陽性

D.B type and Rh^- B型及Rh陰性

E. AB type and Rh^+ AB型及Rh陽性

F. AB type and Rh^- AB型及Rh陰性

(2) Which member of this family is probably homozygous with respect to both the ABO blood group and the Rh loci?

這個家族中哪個成員的ABO血型和Rh血型的基因型，兩者皆爲同型合子

A. Individual 2 成員2

B. Individual 3 成員3

C. Individual 4 成員4

D. Individual 5 成員5

E. Individual 6 成員6

B24. (4 points) In maize a single locus determines the color of the seed; allele *A* results in colored seeds, and allele *a* in colorless seeds. Another locus determines the shape of the seeds; allele *B* results in a smooth shape of the seeds, and *b* in wrinkled seeds.

(4 分)在玉米有一個單一的基因座決定種子的顏色；等位基因 A 造成有顏色的種子，等位基因 a 則造成沒有顏色的種子。另外一個基因座決定種子的形狀；B 造成平滑種子，b 則是皺縮種子。

In a crossbreeding between the plant that grew from a colored and smooth seed and the plant that grew from a colorless and wrinkled seed, the offspring were documented as:

將有色平滑種子的植株與無色皺縮種子植株進行交配，得到如下子代：

376 had colored and smooth seeds 376 株具有有色平滑種子

13 had colored and wrinkled seeds 13 株具有有色皺縮種子

13 had colorless and smooth seeds 13 株具有無色平滑種子

373 had colorless and wrinkled seeds 373 株具有無色皺縮種子

(1) What are the genotypes of the parents?

親代的基因型爲何？

A. *AABb* x *aaBb*

B. *AaBb* x *aabb*

C. *AAbb* x *aaBB*

D. *AaBb* x *AaBb*

E. *aabb* x *AABB*

(2) What is the frequency of recombinants?

重組的發生頻率爲何？

A. 0.335%

B. 1.68%

C.3.35%

D.6.91%

E. 48.52%

(3) Three loci C, D and E are located on the same chromosome in this order. Using similar experiments to the above, we found that the frequency of recombinants between C and D is 10% and that between D and E it is 20%. Assuming that crossing over occurs randomly on the chromosome, what is the expected frequency of recombinants between C and E?

同一染色體上的三個基因座依 C、D 和 E 的順序排列。使用類似上述之實驗，發現 C、D 之間的重組頻率爲 10%，D、E 之間爲 20%。假設染色體的互換是隨機發生的，則 C、E 間的預期重組頻率爲何？

B25. (3 points) The evolutionary distance is defined as the number of nucleotide substitutions per nucleotide site between two DNA sequences, and the evolutionary rate is defined as the number of nucleotide substitutions per nucleotide site per year. We sampled two DNA sequences from two species (one sequence from each species), and found that the evolutionary distance between the two sequences is 0.05. We assume that the evolutionary rate is 10^{-8}.

演化距離被定義爲在兩不同 DNA 序列中，每一核苷酸位置被其他核苷酸取代的數目。演化速率則定義爲每年每一核苷酸位置被其他核苷酸取代的數目。我們從兩個物種中選取了兩段 DNA 序列（每種各一段），發現此兩段序列間的演化距離爲 0.05。假設演化速率爲 10^{-8}，則

(1) How many years ago did the two sequences diverge?

此兩段序列在多少年前分化？

(2) What is the relationship between the divergence time between the two **sequences** (T1) and the divergence time between the two **species** (T2) in general?

一般情況下，兩段序列間的分化時間(T1)和兩個物種的分化時間(T2)的關係爲何？

A. T1 < T2

B. T1 = T2

C. T1 > T2

B26. (3 points) Preproinsulin is the primary product of the insulin gene, and consists of 4 major parts: signal, B-chain, C, and A-chain peptides. After several modifications including removal of the signal and C peptides, insulin is obtained.

(3 分)前胰島素原是胰島素基因的初級產物，主要由 4 個部分組成：訊息肽、B 鏈、C 鏈以及 A 鏈等胜肽。經過去除訊息胜肽和 C 胜肽等多次的修飾作用後，才可生成胰島素。

(1) Which of the following peptides is responsible for the transport of polypeptide into the endoplasmic reticulum?

下列哪一個胜肽負責把多胜肽送入內質網？

A. A-chain peptide A 鏈胜肽

B. B-chain peptide B 鏈胜肽

C. C peptide C 胜肽

D. signal peptide 訊息肽

(2) Comparisons of amino acid sequences among mammals show that the sequence similarity between species varies substantially among the peptides. Which of the following is the most likely explanation?

比較哺乳動物之間的胺基酸序列，結果顯示物種之間序列的相似性，具有不同程度上的明顯差異。下列何者爲最好的解釋？

A. directional selection 方向性天擇（選汰）

B. frequency-dependent selection 頻率相關的天擇

C. overdominant selection (heterozygote advantage)
過顯性天擇（異型合子優勢）

D. purifying selection (selection against deleterious mutations)
純化天擇（對抗缺失性突變的天擇）

(3) Which peptide is likely to differ the most among mammals?

哪一個胜肽在哺乳動物之間差異最大？

A. A-chain peptide A 鏈胜肽

B. B-chain peptide B 鏈胜肽

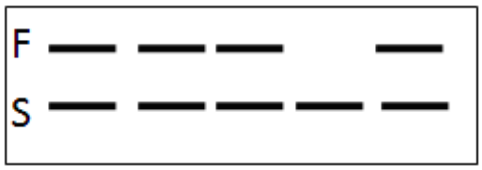
C. C peptide C 胜肽

D. signal peptide 訊息胜肽

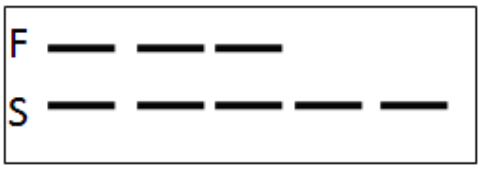
B27. (4 points) In order to quantify genetic diversity of an endangered plant species, genetic variation in subpopulations (I–IV) was examined at the protein level. Subpopulation I is the largest in this species, and the number of individuals in all other subpopulations II, III and IV are each 1/7 of that in subpopulation I. In each subpopulation 5 individuals were sampled. The diagram below shows the results of proteins separated by gel electrophoresis. The band pattern in each lane, which consists of alleles *F* and/or *S*, represents the genotype of each individual at a certain locus.

(4 分)爲定量瀕臨絕種植物物種的基因歧異度，針對不同子群間(I–IV)的基因變異，來進行蛋白質的分析。子群 I 爲該物種數量最多的子群，其餘三個子群(II–IV)均只有子群 I 數量的 1/7。自每一子群中各取五個個體進行分析。下圖爲各子群蛋白質電泳分析的示意圖，每一樣本中的條帶分別代表了基因座 F 及/或基因座 S （F and/or S），而其 F 與 S 的組合，分別代表了不同的表現型。

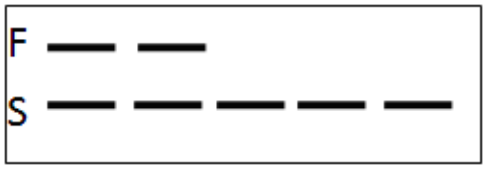
Subpopulation **I** 子群 I



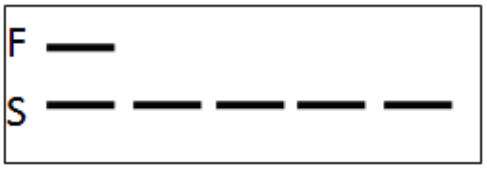
Subpopulation **II** 子群 II



Subpopulation **III** 子群 III



Subpopulation **IV** 子群 IV



(1) Estimate the frequency of *F* in this species.

試估算該物種中出現 F 基因的頻率。

(2) Which subpopulation is thought to be the most isolated group?

上述哪一個子群爲最孤立的子群。

(3) After several generations, we found that the frequency of *F* changed substantially in subpopulations II, III and IV, compared with that of subpopulation I. What is the most likely explanation?

經過數代以後，我們發現相較於子群 I 而言，子群 II、III 及 IV 中 F 基因出現之頻率變化較爲顯著。下列何者爲最合理的解釋？

A. Genetic drift 基因漂流

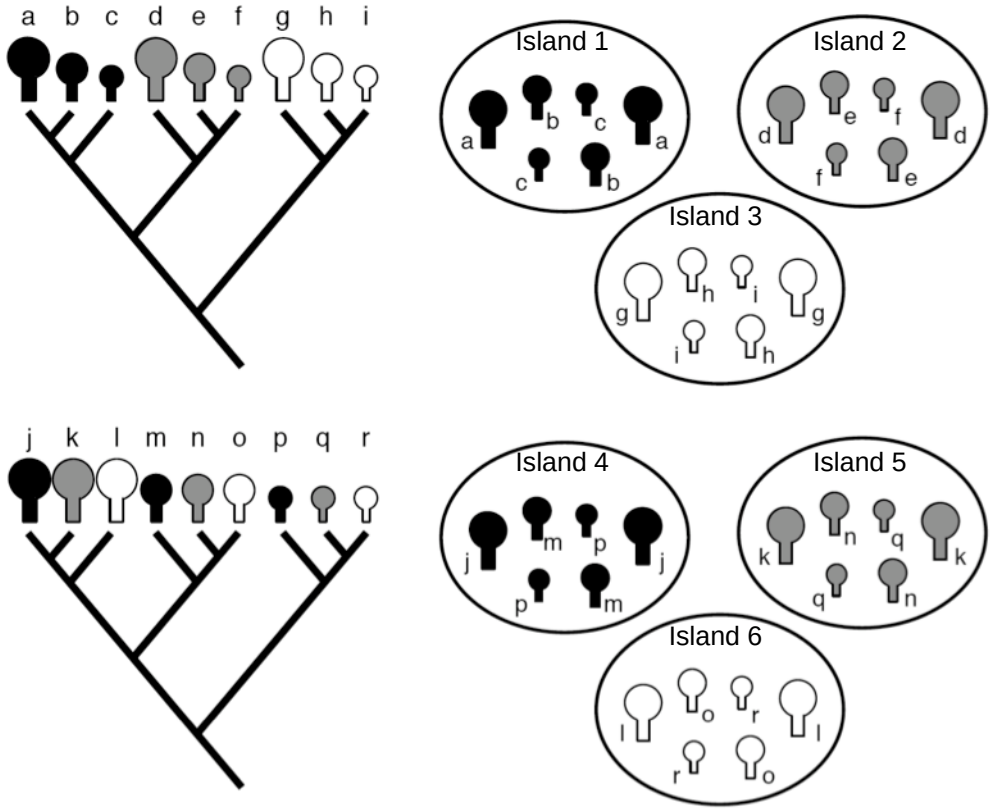
B. Migration 物種遷移

C.Mutation 突變

D.Natural selection 天擇

B28. (3 points) Islands are considered as “experimental sites” for biological evolution and community assembly. The diagram below shows two phylogenetic trees, each consisting of 9 species (a–i and j–r) and community assemblies on 6 islands. Phenotypic traits of the species are represented by size and color.

(3 分)島嶼被認爲是生物演化和群集組成的 “實驗地”。下圖有兩個親緣關係樹，每個關係樹各有 9 個物種(a–i and j–r)及在 6 個島上的群集組成。這些物種的性狀以大小和顏色來表示。



Which of the following explanations are responsible for the mechanisms of community assembly on these islands? Choose THREE correct options from A to H.

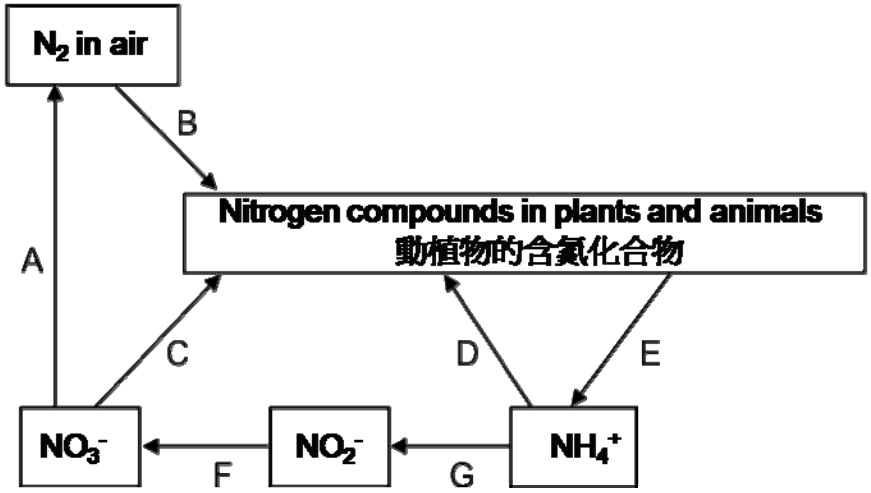
以下那些解釋可以說明，這些島嶼上的群集組成受到何種機制的影響？請從 A 到 H 中選出三個正確的答案。

Options 選項	Islands 島嶼	Evolutionary and genetic structure of species 物種的演化與遺傳結構	Ecological interactions between species 物種間的生態交互作用
A	1, 2, 3	Phylogenetically closely related 親緣上緊密相關	Competitive exclusion in descendent species 後代物種發生競爭排斥現象
B	1, 2, 3	Adaptive radiation 輻射適應	Niche specialization in descendent species 後代物種發生生態地位（niche）特化
C	4, 5, 6	Adaptive radiation 輻射適應	Niche overlap in descendent species 後代物種生態地位重疊
D	4, 5, 6	Sympatric speciation 同域種化	Niche specialization with competitive interaction 具有競爭關係的生態地位特化
E	4, 5, 6	Phylogenetically distant species 親緣相距遙遠的物種	Niche specialization with competitive interaction 具有競爭關係的生態地位特化
F	1, 2, 3	Often seen in oceanic islands rather than land-bridge islands 常見於海洋島嶼而非與大陸相連的島嶼	
G	4, 5, 6	Often seen in isolated island rather than those close to the mainland 常見於孤離的島嶼而非靠近大陸的島嶼	
H	1, 2, 3 vs 4, 5, 6	The community on 4, 5 and 6 are more sensitive to the invasion by an alien species than that on 1, 2 and 3 群集 4、5、6 比群集 1、2、3 對外來種入侵更爲敏感	

Ecology 生態學

B29. (3 points) The following diagram shows the cycle of nitrogen compounds in an ecosystem.

下圖是生態系中含氮化合物的循環



(1) In which of the processes do NOT bacteria participate? Choose TWO from A to G.

圖中哪些過程沒有細菌參與？由 A 至 G 中選出兩項

(2) Which of the processes may include a symbiotic relationship between a species of plant and a species of bacterium?

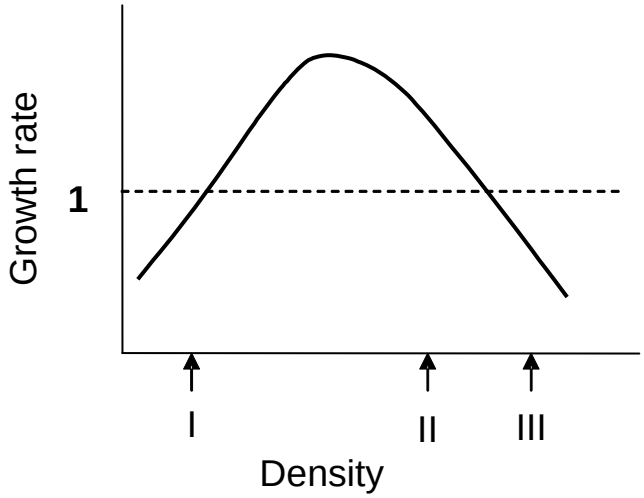
圖中哪一過程包含某種植物與某種細菌的共生關係？

(3) Which of the processes do farmers want to inhibit in agricultural land?

農夫會想要在農田中抑制住圖中的哪一過程？

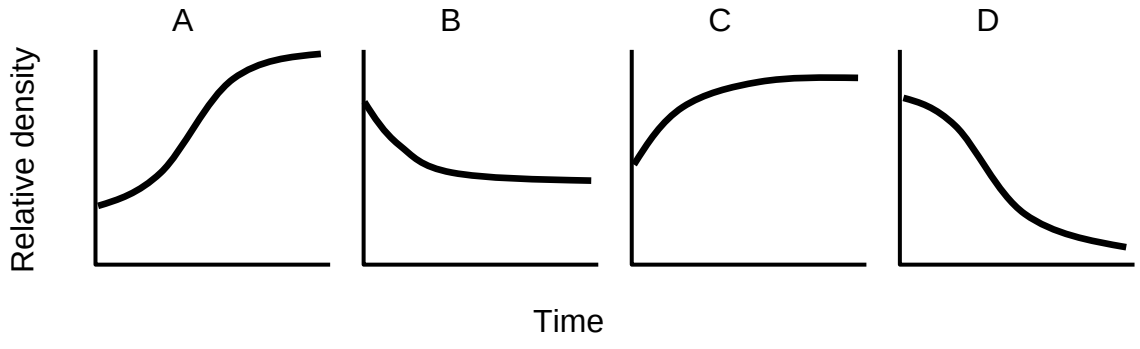
B30. (3 points) The relationship between population density (N_t) and population growth rate ($R = N_{t+1} / N_t$) in a certain animal species is shown below.

下面是某種動物的族群密度(N_t)及族群成長速率($R = N_{t+1} / N_t$)的關係圖



Choose from the following graphs the appropriate population growth patterns that would be obtained if the population is at the densities (I, II, III) shown in the graph above. Note that the y-axis in A to D is relative density that cannot be compared to the absolute density in the figure.

由下面圖中選出族群密度分別在上圖Ⅰ、II、III 時所對應的族群生長類型。注意 A 到 D 圖中的 y-軸爲相對密度而非上圖中的絕對密度。



B31. (2.5 points) Competitive exclusion among species is regulated by various ecological factors. Identify whether the following statements are True or False about this process, and mark “X” in the appropriate boxes.

Competitive exclusion:

A. is intense among species with similar ecological niches.
B. is occasionally interrupted by environmental disturbances.
C. is promoted by species succession.
D. is alleviated by habitat segregation among species.
E. occurs because of keystone species.

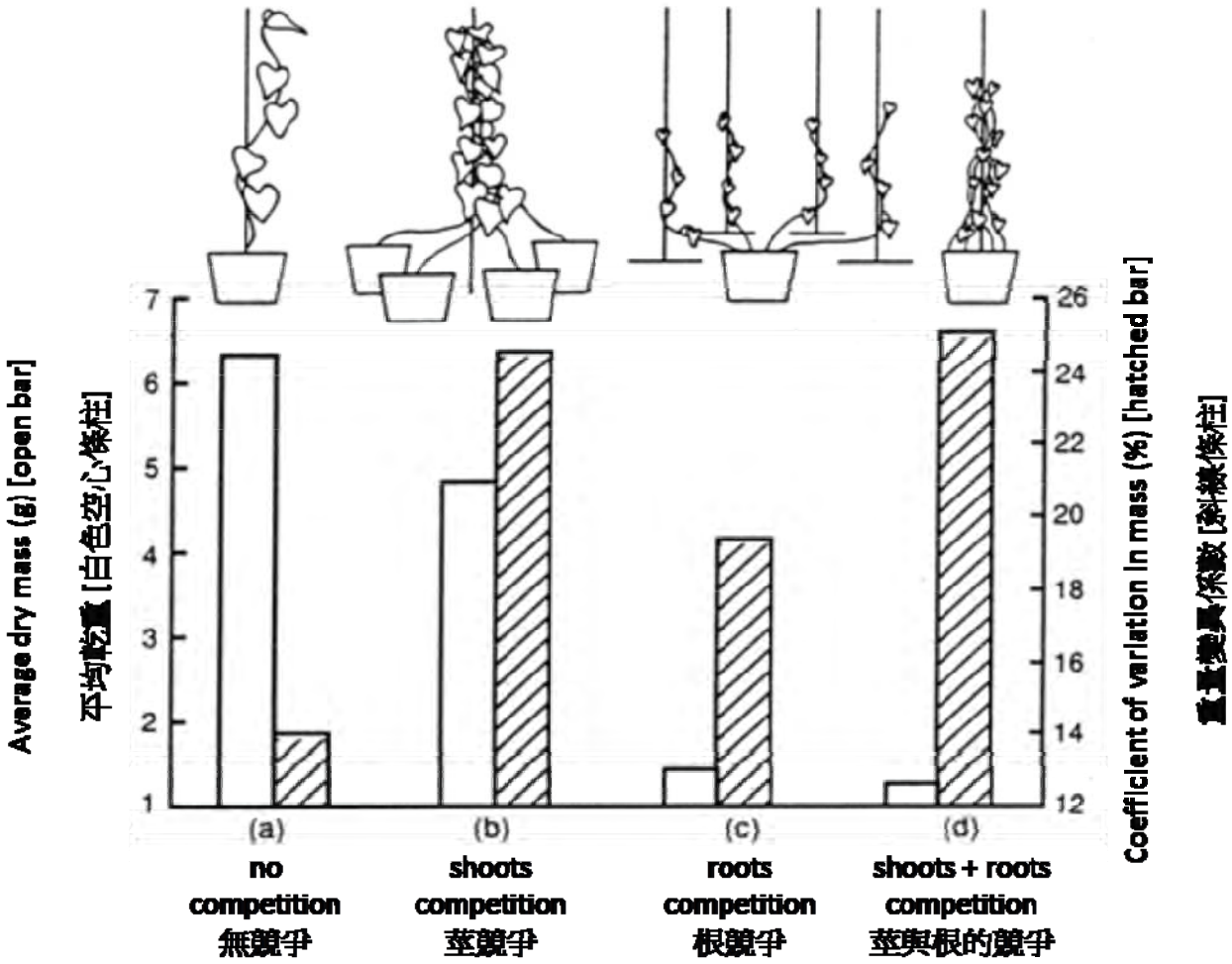
B31. (2.5 points)物種間的競爭排斥會受許多生態因子調控。判斷下列有關競爭排斥的描述是否正確，**“是”**或**“非”**都要在適當欄位中劃**“X”**。

競爭排**斥**：

A. 在生態地位 (niche) 相似的物種之間強烈
B. 偶爾會因環境干擾而被中斷
C. 起因於物種的消長
D. 會因物種棲地的分隔而減緩
E. 是因有關鍵物種而發生

B32. (3 points) The diagram below shows the results of an experiment on the vine *Ipomoea tricolor*, in which root competition and shoot competition were separated. The average dry mass is indicated by open bars, and the coefficient of variation (ratio of standard deviation / mean) of mass among plants is indicated by hatched bars. Identify whether the following statements are True or False about the competition mode of this plant species, and mark "X" in the appropriate boxes

下圖顯示用一種爬藤植物 *Ipomoea tricolor* 爲材料所做的實驗結果，實驗中區分根的競爭與莖的競爭。柱狀圖中的白色空心條柱爲植物的平均乾重，斜線條柱則爲植物重量間的變異係數(標準差與平均的比值)，判斷以下對此競爭的三個描述是否正確，在**"是"**或**"非"**的適當欄位劃 **"X"**。



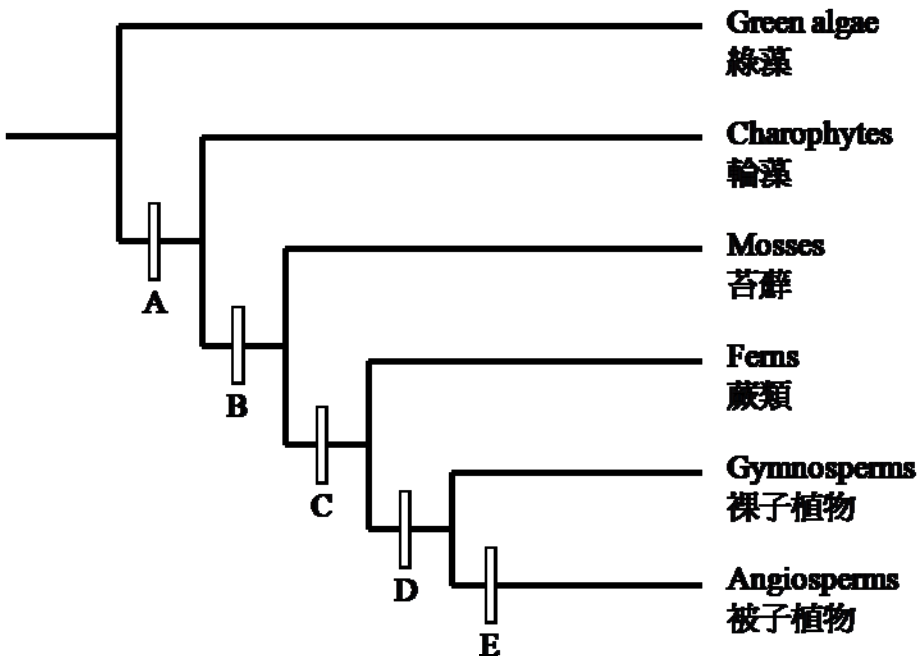
A. Competition for light has more influence on the average mass than competition for soil nutrients.
B. Under conditions of competition, individual plants have stronger potential to monopolize soil nutrients over others than they can monopolize light.
C. When grown individually, soil nutrients constitute a limiting factor for growth, but light does not.

A. 競爭光要比競爭土壤營養物對植物平均乾重的影響更大
B. 在競爭狀態下，某些植物體競爭土壤營養物的壟斷能力較其競爭光的壟斷能力強
C. 植物在獨自生長時，土壤營養物是生長的限制因子，光則不是

Biosystematics 生物系統分類

B33. (3 points) At which branches A to E in this phylogenetic tree of green plants were the traits I to VI listed below acquired?

在此綠色植物親緣關係樹中，下面 I 到 VI 的性狀分別是由 A 到 E 的哪一分支獲得？



I. Pollen 花粉

II. Tracheid 管胞或假導管

III. Cuticle 角質層

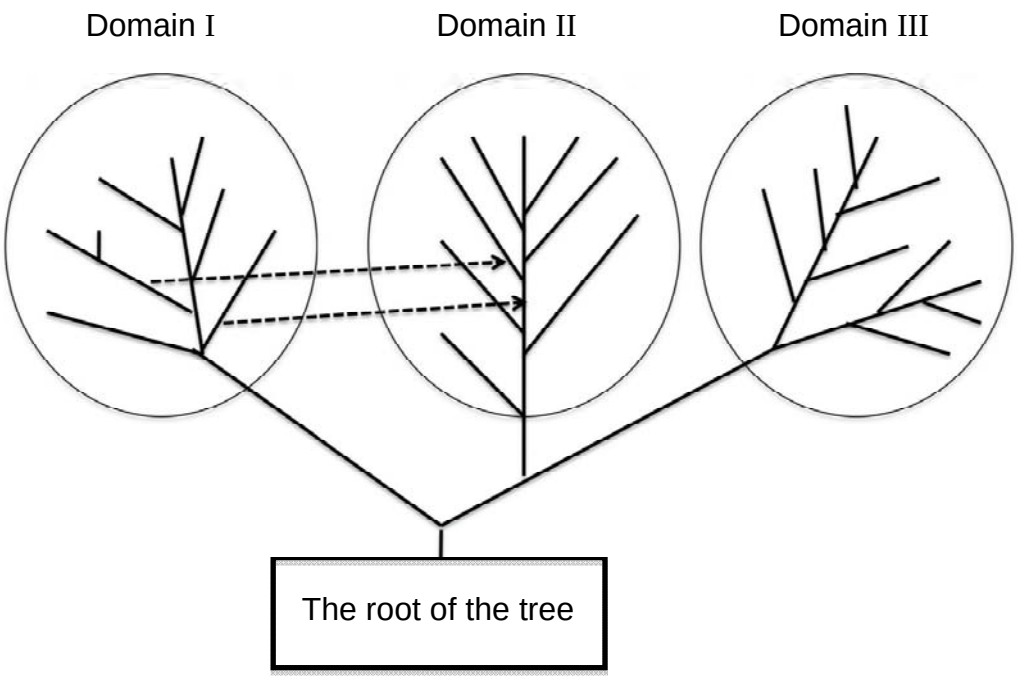
IV. Seed 種子

V. Carpel 心皮

VI. Multicellular embryo 多細胞的胚

B34. (5 points) The universal phylogenetic tree based on molecular sequencing analysis shows three major groups of living organisms as shown below. Woese proposed the concept of three domains in living organisms in the 1990s based on such a tree.

根據分子序列分析得到的親緣關係樹，顯示生物有如下三大類群。Woese 根據此在 1990 年代提出生物三域的概念。



(1) What was the molecule used for the construction of the universal phylogenetic tree? What was the benefit of this molecule for the universal tree? Choose the combination of the molecule and benefit.
用來建立此親緣關係樹的分子爲何？此分子的優點爲何？
請自下表中選出正確答案。

	Molecule 分子	Benefit 優點
A	Ribosomal protein 核糖體蛋白	Low substitution rate of amino acid sequences 低胺基酸序列置換率
B	Ribosomal protein 核糖體蛋白	High substitution rate of amino acid sequences 高胺基酸序列置換率
C	Ribosomal RNA 核糖體 RNA	Low substitution rate of nucleotide sequences 低核苷酸序列置換率
D	Ribosomal RNA 核糖體 RNA	High substitution rate of nucleotide sequences 高核苷酸序列置換率
E	Globin 球蛋白	Low substitution rate of amino acid sequences 低胺基酸序列置換率
F	Globin 球蛋白	High substitution rate of amino acid sequences 高胺基酸序列置換率
G	Transfer RNA tRNA	Low substitution rate of nucleotide sequences 低核苷酸序列置換率
H	Transfer RNA tRNA	High substitution rate of nucleotide sequences 高核苷酸序列置換率

(2) The two broken arrows indicate hypothesized endosymbiotic events whereby members of Domain I became endosymbionts of Domain II. What are the two organisms that were involved in these events, what did they become in the cells of Domain II and what is their current biological function in the Domain II organisms?
兩條虛線箭頭顯示假想的內共生事件。在此 Domain I 的成員成爲 Domain II 的內共生體。哪兩類生物會參與此一事件？他們分別變成 Domain II 細胞中的何種構造，他們現在在 Domain II 生物體內的功能爲何？

	Domain I	Domain II	Function
Older symbiosis 先發生的			
Newer symbiosis 後發生的			

Domain I	Domain II	Biological function 生物功能
1. Cyanobacteria 藍綠菌 2. Chlorella 綠球藻 3. Gram-negative respiratory bacteria 格蘭氏陰性呼吸菌 4. Gram-positive fermentative bacteria 格蘭氏陰性發酵菌 5. Spirochaeta 螺旋體 6. Virus 病毒	1. Mitochondria 粒線體 2. Respiratory chain 呼吸鏈 3. Flagella 鞭毛 4. Chloroplast 葉綠體 5. Chlorophyll 葉綠素 6. Nuclear 細胞核	1. Photosynthesis 光合作用 2. Nitrogen fixation 固氮作用 3. Glycolysis 糖解作用 4. Respiration 呼吸作用 5. Conjugation 接合作用 6. Movement 運動

(3) Which of the following corresponds to domains I, II or III?

Domain I, II, 與 III 分別爲下列何者

A. Archaea 古細菌

B. Bacteria 真細菌

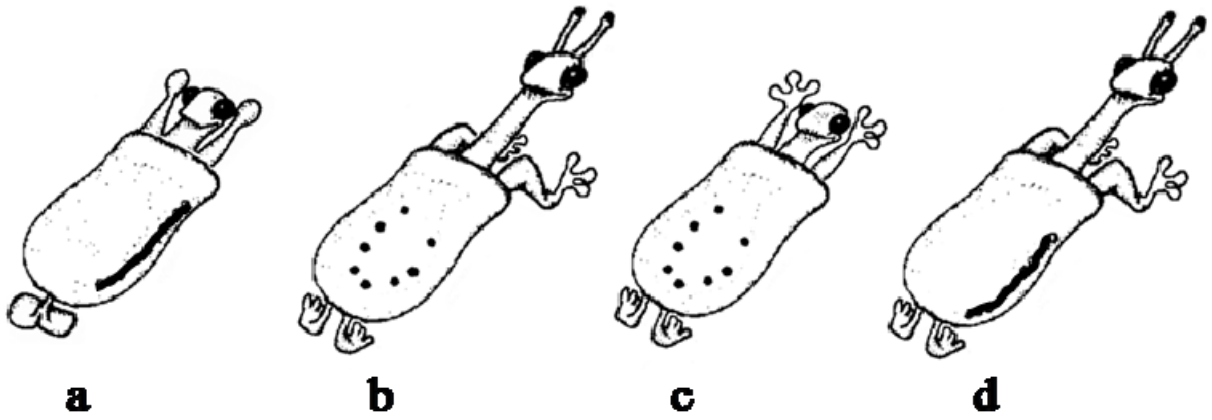
C. Eukarya 真核生物

B35. (4 points) Joseph Camin, a taxonomist, invented artificial non-existing creatures, the *Caminalcules*, for his students. Below are depicted four different Caminalcules.

有一位分類學家 Joseph Camin 爲他的學生創造出人造的虛擬生物 Caminalcule，以下爲四種不同的 Caminalcule

Take a close look at the following four Caminalcules:

仔細觀察下列四種 Caminalcule

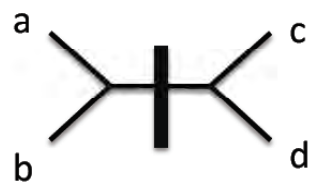


(1) For these four Caminalcules, choose an appropriate cladogram by focusing upon the following characteristics. The most likely tree should be the one where the largest number of characters can be mapped in the internal branch.

針對此四種 Caminalcule，依據下列特徵選擇一個最適當的支序圖 (親緣關係樹)。最有可能的數狀圖應該四部分支標示最多特徵>

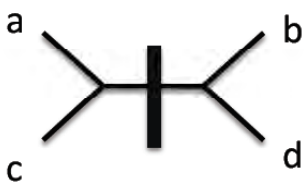
1. Antenna 觸角
2. Belly spots 腹點
3. Elbow 肘
4. Fingers 趾
5. Neck 頸
6. Spots at the side 側線
7. Posterior legs 後肢

A



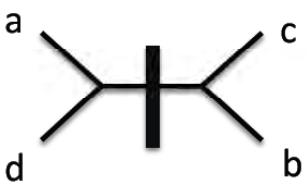
Internal branch

B



Internal branch

C



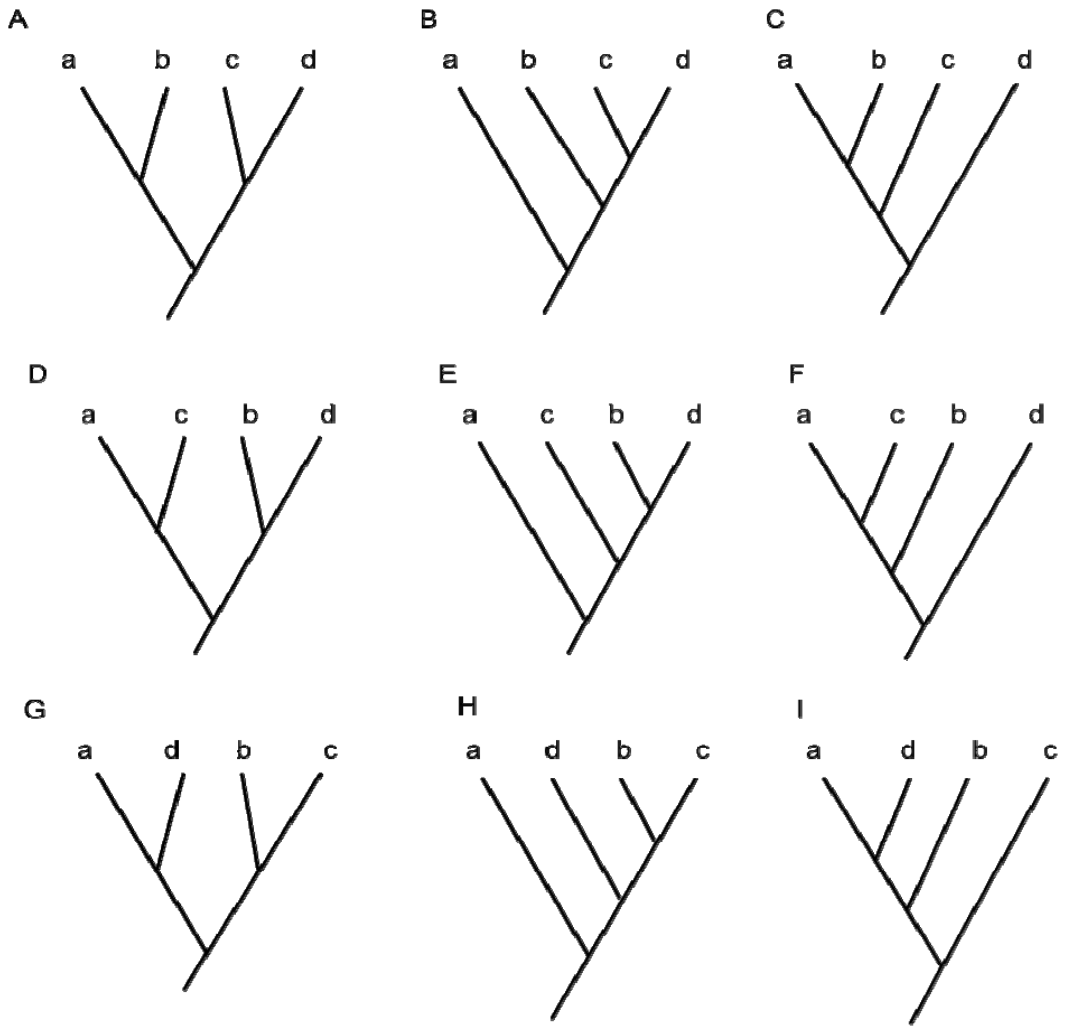
Internal branch

(2) Choose characteristics from the list in question (1) which presumably evolved convergently (independently lost or acquired) in two species of the four.

在問題 (1) 的特徵中，有哪些特徵是在四個種類中的兩種呈現趨同演化 (獨立獲得或失去)？

(3) Assuming that “Caminalcule a” is a sister taxon of the other species, choose an appropriate rooted tree from the following.

假設 Caminalcule a 是其他三種的姊妹類群，從下列各圖中選出最適當且有根的樹狀圖。



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