28th International Biology Olympiad

July 23-30, 2017
University of Warsick
United Kingdom

Theory 2

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INSTRUCTIONS FOR THE THEORY EXAMINATIONS
理論考試說明

PAPER 2 (理論 2) : 1.30PM - 4.30PM

Instructions 說明

Each paper comprises 46 questions, which will be completed on a computer.
每部分理論共有46個問題，將在電腦上完成。

You MUST answer ALL parts of ALL questions. For multiple-true/false tasks, answer each statement with either 'true' or 'false'. Between none and all of the statements may be true. For calculations, choose the number nearest to the correct answer. You should make your best guess if you are unsure; you will not be penalised for incorrect guesses, but may gain marks.
你必須回答所有問題的所有小題。對於多重是非題，您必須用“對”或“錯”來回答每個敘述。每小題的敘述可能是"對"或"錯，且每小題答案都是獨立，亦即每題的小題可能全對至全錯。作計算時，選擇最接近與計算所得的數值的答案。若不確定答案，你可以猜；答錯會扣分，但答對就得分。

Each correct answer will score 1 mark. Each incorrect or missing answer will score 0 marks.
答對一小題得一分，答錯或未回答者則 0分。

You SHOULD attempt the questions IN ORDER, and come back to any that you cannot answer at first. You can flag these by clicking the flag icon, and see your progress by opening the contents pane on the left-hand side. You may find that ideas explored in earlier questions help you answer later questions.
你應**嘗試依序回答**問題，不會的題目先跳過，回頭再做。你可按下"旗號"的按鍵來標示未答或有疑問的題目，然後再從最左側點選打開各題的內容。你會發現前面的題目可能有助於回答後面的問題。

Some figures can be enlarged by clicking on them.
有些圖可以點選放大。

You can change the language you view the papers in by choosing an option from the top right corner.
你可點選右上角來選擇試題語言版本。

You will need to use the information given to you in each question creatively, but you will never require advanced technical or specialised knowledge.
你應靈活使用每題所給的資訊，但你無法從中獲得進一步或特殊的知識。

You MUST bring this equipment to the exam.
你必須攜帶下列物件進入考場。

- Approved calculator 准許使用的計算機
- Pen/pencil 原子筆/鉛筆
- You will be provided with scrap paper. You MUST NOT bring any paper into, or out of, the exam room. A copy of this document will be available on the first page of each exam.
  你會拿到計算紙，但不能攜帶任何紙張進出考場。此說明將會在每場考試的第一頁聲明。

Regulations 規定

You MUST NOT communicate with ANY other candidate at ANY time, whilst you are in the examination room.
當你在考場的時候，你**絕對不能**和任何其他考生交談。

You MUST NOT open ANY other windows on your computer.
你**不得**在電腦上打開任何其他視窗。

You MUST NOT access ANY information that could unfairly help you whilst the examination is in progress.
不得在考試進行中時試圖獲取**任何**外界的援助。

If you require the assistance of a guide you should raise your hand, and remain facing forward until given further instructions.
如果需要協助，立刻舉手，直到得到進一步指示。

You MUST NOT attempt to leave your computer station without the assistance of a guide.
未經同意，**不得**離開電腦站。

If you experience technical problems, you MUST inform a guide IMMEDIATELY.
如果遇到技術問題，請**務必立即**通知在場協助的人員。

Good luck!

USEFUL SCIENTIFIC DEFINITIONS 有用的學術名詞定義

WT	In all cases, *WT* refers to *wild-type*. Wild-type organisms have not been genetically manipulated, or otherwise chosen for a specific genetic property. 在所有情況下， *WT*是指*野生型* 。野生型生物體沒有被遺傳操作，或是被選擇用於特定的遺傳特性。
Knockout 剔除	*Knockout* refers to an organism which has had specific gene, which is stated in the question, mutated such that no product is produced from it. *剔除*是指曾經具有特定基因的生物體，其在該問題中說明該基因突變，使得不產生相關產物。
Haplotypes 單倍型	A haplotype is a combination of alleles that occur on the same DNA molecule. For example, if genes A, B, C, D, and E are located on the same chromosome, and each gene has two alleles, this genomic region can have many different haplotypes (AbCdE, abcDE, ABCde etc.). If these genes are strongly genetically linked, some haplotypes will occur in the population more often than expected by chance, i.e. specific alleles of one gene will usually co-occur with specific alleles of the linked genes. 單倍型是發生在同一DNA分子上的等位基因的組合。例如，如果基因A，B，C，D和E位於同一染色體上，並且每個基因具有兩個等位基因，則該基因組區域可以具有許多不同的單倍型（AbCdE，abcDE，ABCde等）。如果這些基因具有很強的緊密遺傳關聯，那麼在族群中，有些單倍型會比偶然發生者較常出現，即一個基因的特定等位基因通常與連鎖基因的特定等位基因共存。 Mutations within such a linked region create new haplotypes, descended from the old. Meiotic crossing over within the region breaks existing haplotypes and randomly recombines alleles thus eliminating the association between alleles over time. 在此連鎖區域內的突變會從舊的產生新的單倍型。區域內的減數分裂互換會破壞現有的單倍型，並隨機重組等位基因，從而隨時間消除等位基因之間的關係。
mmHg 毫米汞柱	Millimeters of mercury. Biologists usually use mmHg as the unit for pressure. mmHg are directly proportional to Pascals and cmH2O, but give rounder numbers in most biological situations. 毫米汞柱。生物學家通常使用mmHg作為壓力單位。 mmHg 與 Pascals 和 cmH2O 成正比，但在大多數生物學環境中給出更多的數字。
Partial pressure 分壓 （**PGas**）	Partial pressure measures the pressure that a gas would exert on its surroundings if only that gas was present. Partial pressures are noted as Pgas (e.g. Po2 = partial pressure of oxygen). 分壓測量某氣體在其周圍施加的壓力(當該氣體存在時)。分壓標示為Pgas（例如，Po_2 = 氧的分壓）。 For example, the total pressure of atmospheric air, at sea-level, is 760 mmHg, and oxygen makes up 21 % of all the molecules in atmospheric air. Therefore the partial pressure of oxygen in atmospheric air is Po_2 = 0.21 x 760 = 160 mmHg. 例如，海平面上大氣的總壓為760 mmHg，氧氣佔大氣中所有分子的21％。因此，大氣中氧氣的分壓為Po_2 = 0.21×760 = 160 mmHg。 The partial pressure of a gas in solution, is the partial pressure that the gas would have in air which is in equilibrium with the solution. For example, the partial pressure of oxygen in a glass of water exposed to atmospheric air for a long time will also be 160 mmHg. Hence, partial pressures are used by biologists to predict the rate and direction of gas transfer and equilibrium conditions. 溶液中氣體的分壓是氣體在與溶液平衡的空氣中將產生的分壓。例如，長時間暴露於大氣中的一杯水中的氧分壓也將為160 mmHg。因此，生物學家使用分壓來預測氣體轉移和平衡條件的速率和方向。 Partial pressures are NOT directly proportional to the concentration of the gas in a solution. Concentration depends on partial pressure, solubility, temperature etc. 分壓與溶液中氣體的濃度並非成正比。濃度取決於分壓、溶解度、溫度等。
Expression 表現	Many DNA genes are transcribed to produce RNA, which is translated to produce a polypeptide. This folds, and may be modified, to give a functional protein. Unless stated otherwise, the expression level of a gene describes how much functional protein it is generating through the combined action of these processes.

	許多DNA基因被轉錄以產生RNA，其被轉譯以產生多肽。這種折疊並且可以被改變，以產生功能性蛋白質。除非另有說明，基因的表現程度可代表藉由這些過程的組合作用可產生多少功能性的蛋白質。 Therefore, if expression is increased, more functional protein is being produced. This does not necessarily mean there is increased amounts of protein (it may be degraded quickly). The functional product may also need further steps to become activated. 因此，如果表現增加，則產生更多的功能性蛋白質。這並不一定意味著蛋白質的量增加（可能會迅速降解）。功能性產品還可能需要更多步驟才能被活化。
Arrows 箭頭	In scientific diagrams, arrows are taken to mean *leads to*, *activates*, *becomes,* or simply a label. 在科學圖中，箭頭被認為是指*導向*、*活化* 、*成為*或僅僅是一個標籤。
Flat-headed arrows 平頭箭頭	In scientific diagrams, flat-headed arrows are taken to mean *inhibits*, *blocks*, or *reduces*. 在科學圖中，平頭箭頭表示*抑制* ， *阻止*或*減少* 。

ADAPTING TO THE ENVIRONMENT 適應環境

AMAZON BIOMASS 亞馬遜生物量

Forests sink more than 30% of anthropogenic CO_2, but the way they handle atmospheric CO_2 is changing. This map shows the change in total fixed carbon mass in the Amazon over the last decade. The Amazon rainforest is responding to climate change similarly to most rainforests.
森林降低了人類活動生成之 CO_2 的 30% 以上，但森林對大氣中CO_2的作用方式則在改變中。這張地圖顯示了過去十年亞馬遜的固定碳總量的變化。亞馬遜雨林因應氣候變化的方式，與大多數熱帶雨林類似。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Excluding deforestation, rainforests have shown a net increase in carbon biomass in recent years.
排除森林砍伐的因素，近年來，熱帶雨林的碳生物量呈現淨增加。

B. Increasing UV input, due to a thinning ozone layer, can increase carbon fixation.
由於臭氧層變薄，漸增的UV輸入會使碳固定增加。

C. Increasing atmospheric CO_2 concentration can increase carbon fixation.
增加大氣中的 CO_2 濃度可以增加碳固定。

D. Small increases in temperature increases the rate of photosynthetic enzymes.
溫度的微幅增加會增加光合酵素的速率。

BERMUDAN CORAL 百慕達珊瑚

Oceans also sink more than 30% of anthropogenic carbon dioxide, which dissolves to form an acid that alters calcium carbonate solubility (1). Many marine invertebrates have calcium carbonate skeletons, which form marine sediments and reefs. The British island of Bermuda is a hub for studying coral reefs and sea trenches, so the effect of CO_2 on Bermudan sediments in seawater was measured (2). Five thousand metres below the reefs, marine bacteria fix CO_2 to grow (3).
海洋也降低了人類活動生成之 CO_2 的 30% 以上，其溶解形成可改變碳酸鈣溶解度的酸（1）。許多海洋無脊椎動物都有碳酸鈣骨架，其成為海洋沉積物和珊瑚礁的來源。百慕達的英國島嶼是研究珊瑚礁和海溝槽的適當地點，所以量測在百慕達海水中，CO_2對沉積物的影響（2）。在珊瑚礁以下五千公尺海域中，海洋細菌藉固定CO_2生長（3）。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Anthropogenic carbon dioxide damages invertebrate skeletons.
人類活動生成之 CO_2 損壞無脊椎動物的骨骼。

B. The structure of the Bermudan barrier reef is under threat due to changes in seawater chemistry.
由於海水化學的變化，百慕達屏障珊瑚礁的結構受到威脅。

C. The growth of invertebrates contributes to the oceans' ability to sink carbon.
無脊椎動物的生長有助於海洋吸收碳的能力。

D. Bacteria at hydrothermal vents use modified photosynthetic enzymes to fix carbon.
熱噴泉口的細菌利用修飾過的光合酵素來固定碳。

ACIDOSIS 酸中毒

Blood pH must be tightly controlled. To achieve this, the lungs excrete CO_2 from the body and the kidneys alter blood HCO_3^- levels. The blood chemistry of healthy people (H) and people with diseases i, ii, and iii was analysed, and falls in the ranges shown.
血液pH必須嚴格控制。為達此目的，生物利用肺臟呼出CO_2和腎臟調節血液 HCO_3^- 的含量。以下是對健康個體（H）和罹患 i，ii，iii等之病患之血液化學成分分析結果

Indicate whether the following are true, or false
指出下列敘述是正確或錯誤。

A. Disease i makes blood too acidic
疾病 i 使血液過酸。

B. Disease ii involves increased gas exchange in the lungs.
疾病 ii 之肺臟的氣體交換增加。

C. Disease ii involves harmful changes in kidney function
疾病 ii 對腎功能產生有害影響。

D. Vomiting can induce the phenotype seen in iii.
嘔吐可誘導產生類似疾病 iii 之表型。

CARBON MONOXIDE POISONING 一氧化碳中毒

Sir John Kendrew (1917-1997) published the structure of haem-proteins, revealing how oxygen is transported in the blood.
Carbon monoxide is a poisonous gas which can enter the blood via the lungs and alters oxygen transport. In normal air, Po_2 = 100 mmHg in the lungs. After addition of CO, so Pco = 0.4 mmHg, there are equal molar amounts of CO and O_2 in the blood.
約翰·肯德魯爵士（1917-1997）發表了血紅蛋白的結構，揭示了血液中的氧如何運輸。
一氧化碳是一種有毒氣體，可以通過肺進入血液並改變氧的運輸。在一般的空氣中，肺部 Po_2 = 100 mmHg。加入CO後，Pco = 0.4mmHg，血液中的 CO 和 O_2含量相等。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Carbon monoxide increases the affinity ('tightness of binding') of haemoglobin for oxygen.
一氧化碳增加血紅蛋白對氧的親合力（“結合緊密度”）。

B. 0.4 mmHg of carbon monoxide reduces the solubility of oxygen in plasm.
0.4 mmHg的一氧化碳降低了氧在血漿中的溶解度。

C. Carbon monoxide reduces the amount of functional heamoglobin in the blood in physiological conditions.
一氧化碳會降低生理狀態下具有功能的血紅素之含量

Calculate how many fold greater the affinity of carbon monoxide for haemoglobin is compared to the affinity of oxygen for haemoglobin.
請計算一氧化碳對血紅蛋白的親和力是氧氣之多少倍。

A. Choose the nearest relative affinity to the correct answer.
選擇與正確答案最接近的親和度。

ALVEOLAR GASES 肺泡氣體

John Haldane (1892-1962) discovered many mechanisms which control gas exchange and breathing.
The effect of altering the pressure of oxygen or carbon dioxide in air sacs (alveoli) within human lungs on the volume of air breathed every minute was recorded.
Alveolar air, at sea level, usually has Po_2 = 100 mmHg, Pco_2 = 40 mmHg
約翰·哈爾丹（John Haldane）（1892-1962）發現了許多控制氣體交換和呼吸的機制。
結果發現若改變人體內肺泡(alveoli)中氧氣或二氧化碳的壓力會影響每分鐘呼吸的空氣體積。
海平面的肺泡中 Po_2 = 100mmHg，Pco_2 = 40mmHg。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤

A. Increasing blood acidity (lowering pH) increases breathing rate
增加血液酸度（降低pH）會增加呼吸頻率。

B. Breathing rate is determined by the oxygen content of blood in normal conditions
正常情形下，呼吸速率由血液的氧含量決定。

C. At high altitude (atmospheric pressure < 50 % of sea level), falling carbon dioxide pressure in the blood has a greater impact on breathing than falling oxygen pressure.
在高海拔（大氣壓<50%海平面）時，血液中的二氧化碳分壓下降較氧分壓下降對呼吸頻率的影響更大。

D. Total blood oxygen content changes negligibly when alveolar oxygen pressure is increased from 50 mmHg to 150 mmHg.
當肺泡氧壓從50 mmHg增加到150 mmHg時，總血氧含量之變化可忽略不計。

ANIMAL RESPIRATORY SYSTEMS 動物呼吸系統

The gas exchange surfaces, and the direction of respiratory-medium and blood flow, of different animals are sketched. Mammals and birds must use respiratory muscles to drive air to these surfaces, as shown.
下圖描繪不同動物的氣體交換表面，呼吸媒介和血流的方向。哺乳動物和鳥類必須使用呼吸肌來驅動空氣到這些氣體交換表面，如圖所示。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤

A. Mammals require passive diffusion to exchange gases.
哺乳動物需要被動擴散以進行氣體交換。

B. Mammals extract a greater proportion of the air's oxygen than fish extract from water.
哺乳動物自空氣中所獲得的氧比例遠大於魚類自水中所獲得的氧。

C. Air must reach within micrometers of active insect cells.
空氣必須在昆蟲細胞的微米（micrometers)以內，方可維持細胞機能。

D. Bird lungs exchange gas with air for a greater proportion of a breathing cycle than mammals.
鳥肺與空氣進行氣體交換之比例較哺乳動物呼吸週期大。

AIR ROOTS 氣生根

Mangrove trees grow in intertidal flats, and can have vertical roots (pneumatophores) which act like snorkels for the submerged roots. The mechanism through which they facilitate gas exchange was investigated by recording gas pressures, relative to atmospheric air, as pneumatophores are covered and uncovered by the tide.
紅樹林生長在潮間帶，可具有垂直向上的根（呼吸根），它就像是沉水根的浮潛呼吸管一樣。藉由記錄呼吸根被潮汐覆蓋或露出時的氣體壓力，與大氣壓力相比較，來研究它們促進氣體交換的機制。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Air is sucked into roots when pneumatophores are revealed by falling tides.
當呼吸根因潮汐下降而暴露時，空氣被吸入根部。

B. Respiration in the roots contributes to the air pressure changes in the roots.
根部呼吸有助於根部中氣壓的變化。

C. Pneumatophores supply CO_2 for photosynthesis.
呼吸根提供CO_2，以利進行光合作用。

D. Respiration rate in the roots slows when pneumatophores are submerged.
當呼吸根被淹沒時，根中的呼吸速率減慢。

MERISTEM OXYGEN 分生組織的氧

Seagrass grows rapidly from a meristem at its base. However, weak growth and death of entire seagrass meadows, have become common in recent years. The oxygen partial pressure along the diameter of a seagrass stem was recorded at different seawater temperatures and oxygen saturations.
海草可從其基部的分生組織快速生長。然而，近年來已經普遍存在的現象是整個海草床的生長和死亡都很弱。在不同的海水溫度和氧飽和度之下，記錄沿著海草莖直徑的氧分壓。

Atmospheric Po_2 is usually = 160 mmHg.
大氣的Po_2通常 = 160 mmHg。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Rising seawater temperatures could explain the loss of seagrass meadows.
海水溫度升高可解釋為何海草床損失。

B. These experiments were performed in the dark.
這些實驗在黑暗中進行。

C. The meristem has a faster metabolic rate than surrounding tissue.
分生組織具有比周圍組織更快的代謝率。

D. There is more CO_2 in the meristem at 30 ^oC, than at 5 ^oC.
比起在5℃情況下，分生組織在30℃下具有更多的CO_2。

E. The meristem will receive more oxygen in rough ocean conditions than calm ocean conditions.
相較於在平靜的海洋條件下，分生組織在大風浪的海洋中可獲得更多的氧。

PHOTOSYNTHETIC OXYGEN 光合作用的氧

Joseph Priestley (1733-1804) discovered that plants consume CO_2. In this process they produce elemental oxygen, which he also discovered. In chloroplasts, the oxygen-evolving complex loses single electrons when exposed to light. After a specific number of electrons are lost, the complex regains electrons from water to produce oxygen, in a cycle. Consecutive pulses of light were flashed at a solution of chloroplasts, and the amount of oxygen produced from each flash was recorded.
Joseph Priestley（1733年至1804年）發現植物會消耗CO_2。在這個過程中，他也發現植物產生了元素氧。當暴露在陽光下，在葉綠體中的氧衍生(oxygen-evolving) 之複合物會損失游離電子。在丟失特定數量的電子之後，此複合物會在一個循環中從水中重新獲得電子以產生氧。以連續的閃光照射葉綠體溶液，記錄每次閃光所產生的氧量。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. 2 light pulses are sufficient to complete the oxygen-evolving cycle.
2次閃光即足以完成氧衍生之循環。

B. A maximum of 4 electrons is lost by the complex.
複合物最多丟失4個電子。

C. At the beginning of the experiment, most complexes had already lost 1 electron.
在實驗開始時，大多數複合物已經丟失了1個電子。

D. More oxygen is evolved for the same light exposure at the end of the experiment.
在實驗結束時，對於相同的曝光，會有更多的氧被演變。

FRANK-STARLING LAW

William Harvey (1578-1657) discovered that the heart pumps blood around the body in a circuit. Ernest Starling (1866-1927) discovered many of the fundamental properties of the circulatory system, including how cardiac output (the amount of blood pumped in a given time) is controlled. Starling completely removed a beating heart from the body, and attached it to an apparatus that allowed him to alter the pressure of incoming 'venous' (1) or outgoing 'arterial' blood (2). He then measured cardiac output.
Both the left and right-sides of the heart gave similar results.
威廉·哈維（William Harvey，1578-1657）發現，心臟泵送血液循環全身。歐內斯特·斯塔林（Ernest Starling，1866-1927）發現了循環系統的許多重要現象，包括心輸出量（單位時間內心臟泵送的血液量）之調節與控制。 Starling將一跳動中之心臟自個體分離出來，然後放入一特製之生理儀器，可使其改變回心血量（生理狀態下之靜脈回流量）（1)及離心血量（表示動脈離心血量）(2)後，他測量心輸出量在不同狀況下之變化。心臟的左右兩側都有類似的結果。

Indicate whether each of the following statements is true or false, of an *unmanipulated animal*
以一未經處理之動物為例，指出下列敘述是正確或錯誤。

A. Responses to exercise include toning (contraction of smooth muscle) of the veins
對運動的反應包括影響靜脈張力（平滑肌的收縮）。

B. If outflow from the right-side of the heart increases, nervous or hormonal coordination is required for outflow from the left-side of the heart to match it.
如果從心臟右側流出之血量增加，則需要神經刺激或激素的協同作用使心臟左側流出血量也同步增加。

C. The energy required for the heart to beat increases as venous blood pressure increases.
隨著靜脈血壓升高，心臟跳動所需的能量亦增加。

D. In the early stages of heart failure, cardiac output can be maintained if blood volume is increased.
在心臟衰竭的早期階段，血量增加可以維持心輸出量。

PRESSURE-VOLUME LOOPS 壓力及容積迴路

The pressure and volume of beating ventricles can be measured as they change with time.
Recordings (1) and (2) are from the same resting, healthy heart, beating at 60 beats per minute (bpm).
At maximum cardiac output of 28.8 l/min, the maximum ventricular volume doubles, and the minimum ventricular volume halves.
Recordings (3) and (4) are from different diseased hearts.

心室的壓力和體積會隨時間而變化。
記錄器（1）和（2）來自處於安靜狀態下健康的心臟，其心跳速率每分鐘60下（bpm）。當最大心輸出量為每分鐘 28.8公升(28.8 l / min) 時，心室可容納之最大血量增為原最大心室容量的兩倍，而心室之最小體積可降為原最小心室容量的1/2。
紀錄（3）和（4）來自罹患不同疾病的心臟。

Calculate the cardiac output of the heart measured in (1).
計算（1）中測量的心臟心輸出量。

A. Choose the nearest output to the correct answer.
選擇最接近正確答案的心輸出量。

Calculate the heart rate of the heart measured in (1) when it is generating its maximum cardiac output.
計算在（1）中產生其最大心輸出量時所測得的心跳速率。

A. Choose the nearest rate to the correct answer.
選擇最接近正確答案的心跳速率。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Recording 1 is of the right-side of the heart, recording 2 is of the left-side of the heart.
紀錄器1位於心臟的右側，紀錄器2位於心臟的左側。

B. Recording 3 indicates an aortic (arterial) obstruction.
記錄3表示主動脈（動脈）阻塞。

C. Recording 4 indicates leaky heart valves
記錄4表示心臟瓣膜閉鎖不全。

BLOOD OSMOLARITY 血液滲透壓

Ernest Verney (1894-1967) explained the regulation of urine production. At the indicated time, dogs *(Canis lupus familiaris)* were given *equal volumes* of fresh water, or salty water of the same concentration (osmolarity) as blood, orally or through jugular injection. The volume of urine generated was measured with a catheter.
Ernest Verney（1894-1967）闡釋尿液如何生成。在特定的時間，狗*（Canis lupus familiaris）*被以口服或通過頸靜脈注射等方式給予*等體積*的淡水或與血液相同濃度（滲透壓）的鹽水，狗所產生的尿量用導管測量。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Blood volume is adjusted more quickly than blood osmolarity.
血液體積比血液滲透壓更快地調整。

B. Blood osmolarity receptors are the dominant regulators of urine production.
血液滲透壓受體是尿液產生的主要調節器。

C. Receptors in the gastrointestinal tract regulate the kidneys
在胃腸道受體會調節腎臟。

D. Urine at time X has a higher osmolarity than urine at time Y.
在時間X之尿液滲透壓高於在時間Y所產生之尿液。

ANIMAL NEPHRONS 動物腎元

In kidneys, glomeruli are sieves which filter plasma into nephrons. Nephrons modify this fluid, and reabsorb or excrete it. The volumes of individual glomeruli, leading to two types of nephron, were measured in different animals. In all species, juxtamedullary nephrons are much fewer in number than cortical nephrons, but produce more concentrated urine.
在腎臟中，腎小球是將血漿過濾進入腎元的主要構造。腎元中的濾液，透過再吸收及分泌等作用形成尿液。本實驗量測不同物種腎小球過濾後之液體，分送至近髓質腎元或皮質腎元後之體積。一般而言，所有物種的近髓質腎元遠較皮質腎元少，然而卻產生更多濃縮的尿液 。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Glomerular volume is proportional to body size
腎小球過濾液體之體積與動物體型成正比。

B. Bush Babies *(Galagidae)* live in arid habitats
灌叢嬰猴（*Galagidae*） 生活在乾旱的棲息地。

C. Jerboa *(Dipodidae)* and Bush baby nephron volume distribution has evolved convergently (not inherited from a common ancestor).
跳鼠 （*Dipodidae*）和灌叢嬰猴腎元過濾液體之體積是因其分佈而逐漸演變（不是從共同祖先繼承而來）。

D. In rats *(Rattus)*, the majority of urine is derived from juxtamedullary nephrons.
在大鼠（*Rattus*）中，大多數尿液源自近髓質腎元。

RENAL FILTRATION 腎臟之過濾作用

Inulins are inert polysaccharides which cannot cross cell membranes. Inulins were infused into a human vein at a constant rate of 0.2 moles per minute. After infusion is stopped, a total of 25 moles of inulins were collected in the urine.
菊糖是不能穿過細胞膜的多醣體。將菊糖以 0.2莫耳/分鐘 的定速注入靜脈中。輸注停止後，可在尿液中收集總共 25莫耳 的菊糖。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Rate of inulin secretion is proportional to its concentration in blood.
菊糖分泌速度與其在血液中的濃度成比例。

B. A drug which freely passes through cell membranes will be lost in urine at a faster rate than inulins, when at the same concentration in blood.
當血液中濃度相同時，可自由通過細胞膜的藥物將比菊糖更快出現在尿液中。

Calculate the volume of plasma that the kidneys filter per minute.
計算腎臟每分鐘過濾的血漿體積。

A. Choose the volume closest to the correct answer.
選擇最接近正確答案的血漿體積。

Calculate the total extracellular fluid volume of this person.
計算這個人的細胞外液總體積。

A. Choose the volume closest to the correct answer.
選擇最接近正確答案的體積。

SALT MARSHES 鹽沼

Most of the best farmland, including the English fens, is low lying and threatened by rising sea levels. *Spartina patens* and *Typha angustifolia* are marsh plants. To investigate the effect of seawater exposure on these species, they were planted in saltwater marshes and freshwater marshes, with and without neighboring plants (1), or in greenhouses at six salt concentrations (2).
大多數最好的農地，包括英國的沼澤，都是低窪地，受到海平面上升的威脅。 大米草〈*Spartina patens* 〉 及水蠟燭〈*Typha angustifolia* 〉是沼澤植物。為了研究海水入侵對這些物種的影響，這兩種植物被種在鹽水沼澤和淡水沼澤中，有和沒有鄰近的植物（1），或在六個不同鹽濃度的溫室內（2）。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. *Spartina patens* is more salt-tolerant than *Typha angustifolia.*
大米草〈*Spartina patens* 〉比水蠟燭〈 *Typha angustifolia* 〉更耐鹽 。

B. *Spartina patens* physiology is better adapted for saltwater exposure than freshwater exposure.
大米草〈*Spartina patens* 〉對鹽水的生理適應性優於對淡水的適應性。

C. *Spartina patens* will become more common as sea-levels rise. .
當海平面上升海水入侵後，大米草〈*Spartina patens* 〉的分佈將更普遍。

D. The distribution of *Typha angustifolia* in habitats with graded salinity is determined by competition.
水蠟燭〈*Typha angustifolia* 〉在不同鹽度棲地中的分佈是由競爭所致。

ANTARCTIC FISH 南極魚

The *Royal Research Ship Sir David Attenborough* and submarine *Boaty McBoatface* will explore British Antarctica. Life here exists below the freezing temperature of usual fish, which is determined by their osmolarity (1). Salt accounts for the majority of blood's osmolarity. Fish are therefore prone to freezing, which usually occurs by the expansion of pre-existing ice crystals in the water. Some Antartic fish reduce their freezing point by > 2 ºC by secreting antifreeze proteins into the blood (2). Additionally, fish must have an appropriate cell membrane chemistry, to prevent their membranes from becoming too rigid at low temperatures (3).
皇家研究船長大衛·阿登伯勒爵士和潛艇*Boaty McBoatface*將探索南極的英國領域。這裡的生命生存在一般魚類的水溫冷凍環境以下，取決於他們的滲透壓（1）。血液中所產生的滲透壓以鹽為主，因此，魚容易凍結，這通常是由於水中預先存在的冰晶的膨脹而發生的。一些南極的魚通過將抗凍蛋白分泌到血液中來降低其凝固點達> 2 ºC（2）。此外，魚必須具有適當的細胞膜化學性質，以防止其膜在低溫下變得太硬（3）。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Fish staying at great depth under floating ice shelves need to produce antifreeze proteins.
生活在浮冰層下極深度海域的魚需要生產防凍蛋白質。

B. The anti-freeze proteins function mainly by increasing the osmolarity of the fish.
抗凍蛋白主要通過增加魚的滲透壓而起作用。

C. Antarctic fish have increased expression of phospholipid desaturases.
南極魚類增加了去飽和磷脂酶的分泌。

D. Antarctic fish have better temperature sensors and dynamic responses to temperature than temperate fish.
南極魚具有比溫帶魚更好的溫度感受器和對溫度變化更敏銳的反應。

CYANOBACTERIA EVOLUTION 藍細菌的演化

Scientists are uncertain how Natural Selection shapes genome size, gene number, physiological flexibility and other important features in response to environmental pressures. Ecological and genetic characteristics of four species of marine cyanobacteria are listed in the table. *Prochlorococcus* are the most abundant cyanobacteria on earth. The *Prochlorococcus* lineage evolved from *Synechococcus*.
科學家不確定基因組大小、基因數、生理彈適性及反應環境壓力的其他重要特徵是如何經由天擇形成的。表中列出了四種海洋藍細菌的生態和遺傳特徵。*原綠球菌*是地球上最多的藍細菌。*原綠球菌*是從*聚球藍細菌*演化而來。

	Synechococcus *聚球藻*	***Prochlorococcus*** *原綠球菌* ***eNATL***	***Prochlorococcus*** *原綠球菌* ***eMED4***	***Prochlorococcus*** *原綠球菌 eMIT*
Depth at which found 發現深度	Very deep 很深	Deep 深	Shallow 淺	Shallow 淺
Region in which found 發現的地區	Global 全球	Global 全球	Poles 波蘭人	Equator 赤道
Ability to tolerate low nutrient conditions 耐低營養條件能力	Cannot tolerate 不能容忍	Can tolerate 可以容忍	Can tolerate 可以容忍	Can tolerate 可以容忍
Ability to tolerate high light exposure 耐高光照能力	Cannot tolerate 不能容忍	Cannot tolerate 不能容忍	Can tolerate 可以容忍	Can tolerate 可以容忍
Ability to tolerate high temperatures 耐高溫能力	Cannot tolerate 不能容忍	Cannot tolerate 不能容忍	Cannot tolerate 不能容忍	Can tolerate 可以容忍
Genome size （mB） 基因組大小	2.4	1.87	1.66	1.71
Number of genes in genome 基因組中的基因數量	2700	2100	1900	1700

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. A species requires more genes to specialise to a new habitat.
一物種需要更多的基因以特別適應於新棲地。

B. *Prochlorococcus* species can tolerate low nutrient conditions because they have more genes with which they can utilise their environment.
*原綠球菌*種類可耐受低營養的條件，因它們具有更多可利用環境的基因。

C. Intense equatorial sunshine drove the evolution of light tolerance.
赤道強烈的陽光驅動光耐受性的演化。

D. Measuring genome size can be used to estimate the number of genes *Prochloroccous* has.
測量基因組大小可用以估計*原綠球菌*基因的數目。

REPRODUCTION & EVOLUTION 生殖與演化

ORGANISM SCALING 生物個體大小

Archibald Hill (1886-1971) invented the field of biophysics, which can use simple geometric equations to predict how the anatomy of large and small animals differs.
(1) Organisms exchange substances across a surface area. These substances are used to supply a volume of tissue.
(2) The maximum force a muscle can generate is proportional to the number of muscle fibres contracting in parallel.
(3) The maximum force a column can withstand is proportional to its cross-sectional area.
希爾（1886-1971）是生物物理學領域先鋒，用簡單的幾何方程來預測大小動物解剖的結構如何不同。
（1）生物經由表面交換物質，用以支持一定量的組織。
（2）一肌肉可產生的最大力量與平行收縮的肌纖維數目成正比。
（3）一圓柱狀物可承受的最大力與其橫截面積成正比。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Increasing an organism's mass 8 times approximately halves its surface area to volume ratio.
將生物體的質量增加 8 倍，使其表面積與體積的比例減半。

B. Diffusion rates are more likely to be inadequately low for large animals than small animals.
大型動物的擴散率可能比小型動物更不足。

C. Larger animals can carry heavier objects, compared to their body weight, than small animals.
以牠們的體重比較，較大的動物比小動物可攜帶更重的物體。

D. A cat's *(Felis silvestris catus)* bones are disproportionately thick, as a ratio of their body size, when viewed alongside an elephant's *(Elephantidae)* skeleton.
將貓（*Felis silvestris catus*）骨骼與大象（*Elephantidae*）骨骼一起觀察時，其骨骼厚度對體型大小比會呈現不成比例地厚。

MUSCLE ANATOMY 肌肉解剖

Hugh Huxley (1924-2013) proposed the sliding filament theory of muscle contraction. Myosin can bind actin filaments, then change conformation, tugging on actin. Skeletal muscle myosin can only generate tension on actin by this change of conformation, and releases actin immediately once it is complete. During each cycle of binding, myosin hydrolyses one ATP molecule.
赫胥黎（1924-2013）提出了肌肉收縮的肌絲滑動理論。肌凝蛋白可與肌動蛋白結合，改變構形，牽拉肌動蛋白。肌凝蛋白與肌動蛋白一旦結合後，肌凝蛋白就會水解一個ATP使肌動蛋白分開，周而復始，而這也是骨骼肌產生力量之主要來源。

Myosin is found as two alternative forms; MYH-I or MYH-II. Individual muscle fibres either contain MYH-I, or MYH-II, but individual muscles contained a mix of fibre-types. The mix of fibre-types in different mammal species (dots) was measured. MYH-II cycles more quickly than MYH-I.
肌肉細胞(肌纖維)內之肌凝蛋白主要有兩種; MYH-I 或 MYH-II。但肌束或肌肉則可能同時含有具 MYH-I 或 MYH-II 的肌肉細胞。以下實驗測量不同哺乳動物（以點表示）中肌肉中 MYH-1 及 MYH-2 之肌纖維含量。請記住，一般而言， MYH-II 比 MYH-I 更快地完成肌動週期循環。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Human muscles contract more quickly than chimp *(Pan)* muscles when opposed by the same load
相同負重時，人類肌肉的收縮速度比黑猩猩（*Pan*）的肌肉收縮速度快。

B. A muscle fibre generates more force when it is shortening rapidly, compared to when its shortening is resisted by a load
肌肉因負重而收縮時，收縮速度越快，產生的力量越多。

C. Chimps generate a greater proportion of the ATP in their muscles aerobically, compared to humans
與人類相比，肌肉在有氧狀態下，黑猩猩在肌肉中產生更高比例的ATP。

D. The most recent common ancestor of humans and chimps is likely to have had muscles more similar to humans' than chimps'.
人類和黑猩猩最近之共同祖先的肌肉可能更類似人類而非黑猩猩。

E. A tensed muscle that is *not* shortening, does *not* consume ATP.
處於緊繃狀態下之肌肉， 如*不*收縮 便*不*消耗ATP。

DINOSAURS 恐龍

Mary Anning (1799-1847) developed the concept of prehistoric life, by collecting fossils. Richard Owen (1804-1892) coined the term d*inosaurs*, whilst Thomas Huxley (1825-1895) used fossils to show birds *(Aves)* evolved from, and are, dinosaurs *(Dinosauria)*. Until last year, scientists believed the dinosaur phylogeny was as shown in (1). In 2017, British scientists analysed many more fossils and produced a new tree (2) based on hundreds of characteristics, including those shown. For birds, the characters are representative of ancestral birds.
瑪麗安寧（1799-1847）藉由收集化石開發了史前生活的概念。理查德·歐文（1804-1892）創造了恐龍名詞 d*inosaurs* ，而托馬斯·赫胥黎（1825-1895）使用化石顯示鳥類（*Aves*）演化自恐龍，並且也是恐龍 。直到去年，科學家認為恐龍的親緣關係(phylogeny)如（1）所示。 2017年，英國科學家分析了更多的化石，並根據數百種特徵，包括所示的特徵，建構了一個新的演化樹狀圖（2）。對於鳥類來說，這些特徵是古鳥的代表。

Indicate whether each of the following statements is more likely to be true under dinosaur phylogeny (1), or phylogeny (2).
指出在恐龍親緣關係（1）或親緣關係（2）之下，以下各項是否更有可能是真實的。

A. Some sauropods (*Sauropoda*; the group farthest left in each tree) were feathered.
一些蜥腳類（ *Sauropoda* ; 此群體在每一樹狀圖中左側最遠方）具有羽毛。

B. Bird-like hips evolved multiple times (convergence)
鳥形臀部的特徵重複演化多次（趨同演化）。

C. Exclusive carnivory evolved multiple times.
完全肉食性重複演化多次。

D. The earliest dinosaurs evolved in the Southern hemisphere.
最早的恐龍在南半球產生。

DIGESTIVE SYSTEMS 消化系統

Dame Jane Goodall (1934-present) discovered that great apes *(Hominidae)* use tools, to access more nutritious food, and hunt for meat. Bears *(Ursidae)* exhibit similar behaviour, but giant pandas *(Ailuropoda melanoleuca)* only eat bamboo. These different animals have gut anatomies which reflect their diets, as shown. Sketches have been enlarged to similar sizes to allow comparison. Dogs *(Canis lupus)* represent a typical carnivore, Rhinos *(Rhinocerotidae)* a typical herbivore.
珍古德爵士（1934年至今）發現，猿猴（*Hominidae*）使用工具，以獲取更多營養的食物，並獵食肉類。熊（*Ursidae*）表現出類似的行為，但大熊貓（*Ailuropoda melanoleuca*）只吃竹子。這些不同的動物具有反映其飲食的腸道解剖結構，如圖所示。下圖將不同物種臟器以相似大小呈現，以利比較。狗（*Canis lupus*）代表典型的食肉動物，犀牛（*Rhinocerotidae*）代表典型的食草動物。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Humans invest more energy in digestion to acquire nutrients than chimpanzees *(Pan)* do.
人類在吸收養分的消化過程中，會比黑猩猩 *(Pan)* 消耗更多的能量。

B. Chimpanzees eat more meat and fruits than orangutans *(Pongo)*.
黑猩猩比紅毛猩猩 *(Pongo)*吃更多的肉和水果。

C. Giant panda digestive systems extract most of the nutrients present in Bamboo.
大熊貓消化系統吸取竹子中存在的大部分營養物質。

D. Food passes more rapidly through orangutans than through humans.
食物通過紅毛猩猩消化道比通過人類消化道更快。

PREHISTORIC BRITONS 史前英國人

Stonehenge was built in the late Neolithic (Stone age; ~ 3000 BC) on what was Europe's most important trade route, between Cornwall and the Eastern Mediterranean. In the Early Bronze age (~ 2500 BC), the Beaker phenomenon swept across Europe, and many peoples began producing characteristic pottery (1). To discover whether British people bought and made Beaker pots, or Britain was invaded by a people that did, remains from different sites were genome sequenced. The average proportion of alleles originating from different populations (colours) in the genomes of Neolithic, Beaker and Late Bronze Age individuals was compared (2).
巨石陣是建於新石器時代晚期（石器時代，公元前3000年），歐洲最重要的貿易路線是康沃爾郡和東地中海之間。在青銅時期（公元前2500年），燒杯陶現象橫掃歐洲，許多人開始生產特色陶器（1）。要了解英國人是否製作及買賣燒杯壺，還是外來的人所製，需收集不同地點遺物做基因組測序。比較新石器時代，燒杯期和後青銅器時期人類基因組成中（顏色）平均等位基因組的比例（2）。

Rs4988235(T) is an allele of the gene for the enzyme lactase which causes it to be produced into adulthood. Its frequency in British people through time was measured (3). Lactose is a sugar in milk.

Rs4988235(T)是產生乳糖酶的等位基因，其在成體會產生。測量歷代其在英國人中之頻度分佈（3）。乳糖是牛奶中的糖。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. A large proportion of Beaker people in Britain were native British people.
英國的大部分燒杯陶期人都是英國本地人。

B. Beaker people in Britain mostly replaced non-Beaker people.
英國的燒杯陶期人大多數取代非燒杯陶期的人。

C. From this data, it can be concluded that modern Britons are very genetically distinct from bronze age Britons.
從這些數據可以得出結論，現代英國人與青銅時代英國人有非常不同的遺傳特性。

Estimate the proportion of modern Britons able to digest milk in adulthood.
估計現代英國人在成年時能夠消化牛奶的比例。

A. Choose the nearest proportion to the correct answer.
選擇與正確答案最接近的比例。

TURTLES 海龜

British Territories in the Atlantic, Indian, Mediterranean and Pacific Oceans are vast new marine reserves which Green turtles *(Chelonia mydas)* and Hawksbill turtles *(Eretmochelys imbricata)* inhabit (1). Sex determination in turtles depends on the temperature of the nest, as shown for Chagos Archipelago hatchlings (2). Sandtemperature in turn depends on the nest site (3). The majority of breeding occurs in peak breeding season, but a scarcity of males reduces breeding rates.
大西洋，印度，地中海和太平洋的英屬領土有眾多的新海洋保護區，有綠蠵龜（*Chelonia mydas*）和玳瑁（*Eretmochelys imbricata*）居住（1）。龜的性別取決於巢穴的溫度，如Chagos群島孵化的幼體（2）所示。沙的溫度因巢的所在地區不同而異（3）。大多數繁殖發生在繁殖季高峰期，但雄性稀少造成繁殖率降低。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Ascension produces an excess of female turtles.
亞森松島產生過多的雌龜。

B. The Chagos Archipelago produces a roughly balanced sex ratio of Hawksbill hatchlings.
查戈斯群島玳瑁幼體孵化的性別比例大致平衡。

C. Chagos island turtle breeding will be less disrupted by global warming, than Ascension island turtle breeding.
Chagos島海龜的繁殖比亞松森島海龜的繁殖受到全球暖化的影響相對較少。

D. Conservationists should protect heavily shaded nest beaches as a priority.
環保人士應優先考量保護較深色的沙灘。

TESTES HISTOLOGY 睪丸組織學

Robert Hooke (1635-1703) popularised microscopy in his famous book *Micrographia*, and invented the term 'cells'. Analysing the size and shape of cells indicates their identity, whilst the appearance of their nucleus can indicate how transcriptionally active a cell is, or whether it is dividing. Specific junctions between cells allow internal substances to be transferred between them, or external substances to be trapped behind them. Testes have a distinct appearance under electron microscopes, as shown. Germ cells (which could pass their genetic material to the next generation) may undergo meiosis, and gradually adopt a morphology specialised for motility: these mature sperm are released into the centre of fluid filled tubes, in a process that happens in continuous waves.

Robert Hooke以他的著作Micrographia 推廣顯微鏡的使用，並發明了細胞一詞。分析細胞的大小和形狀可辨認它們的身份，而細胞核的外觀顯示其轉錄活性如何，或者是否正在分裂中。細胞間的特定構造讓物質可以在它們之間傳輸，或是將外部物質阻擋在外。
睪丸在電子顯微鏡下有特別的外觀，如圖所示。生殖腺細胞可進行減數分裂，產生之子細胞逐漸轉化變成為適合運動的形態：這些成熟的精子不斷的被釋放到充滿流體的管中心。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Cell i helps prevent autoimmunity against testes-specific antigens.
細胞 i 協助阻絕對睪丸專一抗原的自體免疫。

B. Cell ii is a diploid (has two copies of each chromosome) germ-line cell.
細胞 ii 是二倍體的生殖腺細胞。

C. Cell iii facilitates transport of sex hormones (testosterone).
細胞 iii 促進性激素(睪固酮)的運送。

D. Cell iv is using unique histones (DNA-binding proteins) to super-compact DNA.
細胞 iv 有特殊的組蛋白(histones)去超緊包固DNA。

FLOWER SCENTS 花香

Flowers produce volatile fragrances from their petals to attract pollinators, but only once they have become fertile. Some volatile molecules diffuse through petal-cell (pictured) membranes into the air.
鮮花從花瓣中產生揮發性的香味以吸引傳粉者，但只有在這些花是可孕的時候才有花香。圖中可見一些揮發性分子通過花瓣細胞膜，進而擴散到空氣中。

The ABC superfamily of transmembrane transporters use ATP to pump substances out of cells. These include multi-drug resistance pumps that export many foreign chemicals from bacterial, plant and cancer cells. To investigate whether ABC transporters pump some volatile fragrances into the air, scientists generated several testable hypotheses.
跨膜運輸蛋白的ABC超家族利用ATP來將物質送出細胞。這些包括抗多種藥的幫浦，此類幫浦可送出來自細菌、植物和癌細胞的外來化學物質。為了調查ABC運輸蛋白是否將一些揮發性香味送入空氣中，科學家們提出了幾個可測試的假設。

Indicate whether each of the following hypotheses is likely to be true or false if ***ABC transporters are indeed involved in fragrance***.
如果***ABC運輸蛋白確實參與花香味的作用***，指出下列各假說是正確或錯誤。

A. An ABC transporter which is most highly expressed in budding flowers, compared to open flowers, is the one involved in fragrance emission.
相較於盛開的花，在花苞中最高度表現的ABC運輸蛋白是參與花香排放的蛋白。

B. Plant strains which express ABC transporters at high levels in their flowers are more fragrant, compared to strains which express ABC transporters at low levels in their flowers.
相較於在花中ABC運輸蛋白表現量低的植物株，在花中ABC運輸蛋白表現量高的植物株會更香。

C. There is a higher concentration of volatile fragrances inside petal cells when ABC transporters are blocked.
當ABC運輸蛋白被阻斷時，花瓣細胞內揮發性香料濃度較高。

D. Altering ABC transporter function has a greater effect on the emission of small volatile molecules, than large volatile molecules.
改變ABC運輸蛋白的功能，對小的揮發性分子造成的影響較大的揮發性分子更大。

ABC MODEL OF FLOWERING　ABC 花模式

Arabidopsis flowers are formed incorrectly when the *pistillata*, *apatela2* or *agamous* genes are knocked-out, as shown. Genes which determine the identity of parts of an organism are called homeotic selectors (or HOX genes in animals). HOX genes expressed more posteriorly (towards the anus) tend to repress those expressed more anteriorly (towards the head).
如圖所示，當*pistillata*，*apatela2* 或 *agamous* 基因被踢除時， 阿拉伯芥的花形成會不正常。決定生物體部位確切性的基因稱為同源區選擇子 (homeotic selectors)（或在動物中的HOX基因）。 HOX基因更向後端表現（posteriorly，朝向肛門）傾向於抑制更向前端的表現（anteriorly，朝向頭部）。

(1) shows a WT fruit fly *(Drosophila melanogaster)* head, and one which has the *antennapedia* mutation. (2) shows a typical decorative rose with an *agamous* phenotype.
下圖中（1）顯示了WT果蠅的頭，其中一個具有觸角突變 (*antennapedia*)。（2）顯示典型的具有*agamous*表型的觀賞用玫瑰花。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Homeotic selector genes tend to have small and simple promoters compared to other genes.
與其他基因相比，同源區選擇子基因傾向於具有小而簡單的啟動子。

B. *PISTILLATA* expression is necessary for cells to determine they should become part of a flower.
*PISTILLATA*表現是細胞確定它們應該成為花的一部分所必需的。

C. Expression of *AGAMOUS* causes floral meristems to stop growing after four whorls.
*AGAMOUS*的表現會導致花的分生組織在形成四輪花器之後停止生長。

D. The *antennapedia* mutation is a loss of function, or knock-out, mutation.
antennapedia 突變是功能喪失 (或剔除) 的一種突變。

E. All these genes are first expressed once a cell is specialising/differentiating into its final role.
一旦細胞 特化/分化 成其最終角色，所有這些基因會首先表現。

COURTING FLIES 果蠅求偶

Sexual orientation in *Drosophila* matings (male with female, versus male with male, versus female with female) can be controlled by the gene with female, versus male with male, versus female with female) can be controlled by the gene *fruitless*. *Fruitless* mRNA is cut (spliced) in multiple ways to give two forms, FRUITLESS-A and FRUITLESS-B.
果蠅交配中的性取向（雄性與雌性，雄性與雄性，雌性與雌性）可以由*fruitless* 的基因控制。
將 *fruitless*基因產生 mRNA以多種方式阻隔，得到兩種型態，即 FRUITLESS-A 和 FRUITLESS-B。

The sexual development and sexual orientation of WT and *fruitless* knockout flies, and flies which express either FRUITLESS-A or FRUITLESS-B, were studied.
利用野生型〈WT〉、無*fruitless*基因表現者〈*fruitless*基因被剔除〉、FRUITLESS-A 及 FRUITLESS-B 等不同基因型態之果蠅個體，研究牠們的性發育和性取向。

Genotype of fly 果蠅基因型	**Male** 雄性		**Female** 雌性	
	Appearance of fly 果蠅外觀	Fly mates with 交配對象	Appearance of fly 果蠅外觀	Fly mates with 交配對象
WT 野生型	Male 雄性	Females 雌性	Female 雌性	males 雄性
fruitless* knockout** ***fruitless 基因不表現	Male 雄性	Males and females雄性和雌性	Female 雌性	males 雄性
FRUITLESS-A only	Male 雄性	Females雌性	Female 雌性	Females雌性
FRUITLESS-B only	Male 雄性	males 雄性	Female 雌性	Males 雄性

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. *Fruitless* controls the development of appearance in flies. .
*Fruitless*基因控制果蠅外觀的發育。

B. FRUITLESS-A causes flies to court females.
FRUITLESS-A基因會使果蠅對雌性個體求偶。

C. FRUITLESS-B has a role in determining the sexual orientation of female flies.
FRUITLESS-B在雌性果蠅性取向時扮演決定性角色。

D. FRUITLESS-A and FRUITLESS-B perform the same role in male and female flies.
FRUITLESS-A and FRUITLESS-B對雄性及雌性果蠅皆扮演相同的角色。

MASTER DEVELOPMENTAL REGULATORS 發育關鍵調控因子

Sir John Gurdon (1933-present) took differentiated cells from tadpoles (1) or frogs (2, 3), and transferred their nuclei to enucleated eggs. These eggs were allowed to develop (1, 2), or the nuclei were passaged through more enucleated eggs (3). He was able to artificially clone animals*(Xenopus laevis)* for the first time.

Sir John Gurdon（1933年至今）從蝌蚪（1）或青蛙（2,3）中取出已分化細胞，將其核轉移到去核卵。並使這些卵發育（1,2），或將這些核在去核卵中經更多次繼代培養（3）。他是第一個以人為方式將動物*（爪蟾屬）*複製的科學家。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Gurdon proved adult cells contain all the DNA required by the fetus.
Gurdon證明成年細胞含有胎兒所需的所有DNA。

B. Cytoplasmic factors are sufficient to regulate cell type
細胞質因子足以調節細胞類型。

C. The most powerful (irreversible) regulators of cell type are turned on early in development.
細胞類型的最有力(不可逆的) 調控因子在發育早期就表現了。

D. Factors which determine cell type can take a long time to act on some genes.
決定細胞類型的因子需要很長時間才能對某些基因起作用。

VARIEGATED PLANTS 雜色植物

Four o'clock plants (*Mirabilis jalapa*) can have a mix of white and green patches on their leaves, so they appear variegated - a picture showing the different colours of branches possible, but not necessarily the usual pattern of these branches, is shown (1). Variegated plants were grown, and flowers on green, white or variegated branches were fertilised by pollen from green, white or variegated branches. The progeny had the following phenotypes.
紫茉莉（ *Mirabilis jalapa* ）可以在其葉子上混合白色和綠色的斑塊，因此它們出現雜色 - 下圖 (1) 顯示具有不同顏色的分枝可能形式，但不一定是這些分枝的常見形式。栽種雜色植物，然後在綠色、白色或雜色分枝上的花，以綠色、白色或雜色分枝的花粉來受粉。其後代具有下列不同表現型。

Phenotype of branch bearing seed 具種子的分枝之表現型	**Phenotype of branch bearing pollen** 具花粉的分枝之表現型	**Phenotype of offspring plant** 子代植株的表現型
White	White	White
White	Green	White
White	Variegated 雜色	White
Green	White	Green
Green	Green	Green
Green	Variegated	Green
Variegated	White	White, green, or variegated
Variegated	Green	White, green, or variegated
Variegated	Variegated	White, green, or variegated

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Chloroplasts can be transmitted through pollen during Four o'clock plant reproduction.
紫茉莉生殖時，葉綠體可透過花粉傳遞下去。

B. During cell division as a plant grows, each daughter cell has the same composition of alleles.
植物生長時，在細胞分裂期間，每個子細胞具有相同的等位基因組成。

C. Egg cells in a variegated flower can contain different chloroplasts with distinct genomes.
雜色花中的卵細胞可含有具有不同基因組的不同葉綠體。

D. Older branches of a variegated four o'clock plant are more likely to be all white, or all green, than younger branches.
一棵雜色紫茉莉中，老分枝比年輕分枝更有可能是全白或全綠。

體外受精 （IN VITRO FERTILIZATION IVF）

Sir Robert Edwards (1925-2013) invented *in vitro* fertilisation (IVF) and Sir Douglas Turnbull developed '3 parent IVF': the nuclear DNA of a mother and father are transferred into an enucleated oocyte from a second female. The ethicist Baroness Mary Warnock (1924-present) has enabled the UK to pioneer the safest and most advanced reproductive medicines, to combat genetic diseases such as Leigh syndrome.
羅伯特·愛德華茲爵士（1925-2013）發明了體外受精（IVF）；道格拉斯·特恩布爾爵士（Sir Douglas Turnbull）發明了 "3個親源之IVF"：將來自母親和父親的核DNA結合後送入來自第二個女性之去核卵母細胞中。倫理學家瑪麗·沃諾克（Mary Warnock）女爵（1924年至今）使英國具有最安全和最先進的生殖醫學，以抵抗如Leigh等遺傳疾病。

Leigh syndrome is caused by mutations to the mitochondrial gene *COX2*. Mitochondrial DNA (mtDNA) in the muscles typically has the following distributions.
Leigh症候群導因於粒線體基因*COX2*的突變。下列實驗顯示肌肉中的粒線體DNA（mtDNA）之分佈。

Sample 樣品	**% of mtDNA which is WT** **粒線體DNA為** **野生型之比例**	**% of mtDNA which is *COX2*mutant** **粒線體DNA為** ***COX2*突變體之比例**
Healthy mother of healthy child 擁有健康孩子的健康母親	100	0
Healthy mother of Leigh's child 擁有罹患Leigh氏症孩子的健康母親	30-50	50-70
Healthy child 健康孩子	100	0
Leigh's child Leigh氏症孩子	< 20	> 80

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤

A. 30% of fully functional mitochondria is sufficient to prevent Leigh's disease.
30%的功能完整的粒線體便足以防止Leigh氏症。

B. The father of a Leigh's child should be screened for *COX2* mutant mtDNA
Leigh氏症小孩的父親應做*COX2*突變體mtDNA篩檢。

C. If only a small amount of cytoplasm is accidently transferred with the nuclear DNA, the three-parent IVF child is safe from Leigh syndrome.
如果只有少量的細胞質被意外地與核DNA一同轉殖，透過三親源IVF而來的小孩應不致罹患Leigh氏症。

D. Rapidly dividing tissues are typically more affected by mtDNA mutations than slowly dividing tissues.
快速分裂的組織通常比慢速分裂組織更容易受mtDNA突變的影響。

E. Sampling a cell from an early IVF embryo could determine whether the foetus will develop Leigh syndrome when implanted.
從早期IVF胚胎取樣細胞分析，可確認胚胎植入後日後是否會罹患Leigh氏症。

GRAFTING 嫁接

In nature, different plant species can graft together. An experiment was done where shoots from species A were grafted onto roots of species B. Plant chloroplast and nuclear genomes were independently transformed with different antibiotic resistance genes (Kan and Spec). Single cells from the shoot, root, and graft junction were excised, then grown on agar with antibiotics. Surviving cells are grown into adult plants. Plant phenotype is denoted by its colour.
在本質上，不同的植物物種可以嫁接在一起。實驗中，將來自物種A的莖嫁接到物種B的根上。植物的葉綠體和細胞核基因組中被獨立轉殖了不同的抗生素抗性基因（Kan 和 Spec）。切除來自莖、根和嫁接接合處的單一細胞，然後用含有抗生素的瓊脂作培養。存活的細胞最後長成成熟植株。植物的表現型由其顏色來表示。

Indicate whether each of the following statements is true or false?
指出下列敘述是正確或錯誤。

A. Chloroplasts can travel the complete length of the plant.
葉綠體可在植物的全體長中運行。

B. Genomes can be transferred between species.
基因組可以在物種之間轉移。

C. Plants which grow on the agar plates from (1) can cross with their parents.
圖（1）中，在培養基上生長的植物可與他們的父母反交。

D. Plants which grow on the agar plates from (2) can cross with their parents.
圖（2）中，在培養基上生長的植物可與他們的父母反交。

HUMAN EMBRYOLOGY人類胚胎學

Sir Martin Evans (1941-present) was the first person to culture Embryonic Stem Cells (ESCs)(from a mouse). It is now known that the following transcription factors:
Sir Martin Evans (1941-present) 是第一位培養小鼠胚幹細胞(ESCs)的人,下列為目前已知的轉錄因子
- OCT4 determines ESCs to become epiblast,
OCT4決定胚幹細胞形成上胚層
- GATA6 determines ESCs to become extra-embryonic endoderm,
GATA6決定胚幹細胞形成胚外內胚層
-CDX2 determines ESCs to become epiblast.
CDX2決定胚幹細胞形成表上胚層
In all previously known animals, OCT4 and GATA6 are found only in the inner cell mass, and block the transcription of one-another, until cells adopt one fate. Additionally, no known animal cells express all three markers at the same time. However, closely related species can have quite different embryos. Hence, in 2016 English scientists grew human embryos *in Vitro* for a record breaking 14 days, and stained them for these transcription factors. Arrows mark the same point on each image.
在過去已知動物中,OCT4及GATA4只在內細胞團(inner cell mass)中存在, 且彼此拮抗,直到細胞分化命運已定,此外, 沒有已知的動物細胞同時表現此三種標記基因. 然而, 極近似物種可能具有極不同的胚胎,因此, 在2016年英國科學家破記錄的在試管中將人類胚胎培養了14天,且將其以抗體免疫染色顯現這些轉錄因子,在下圖中以箭頭同點標定

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. OCT4 and GATA6 repress one-another to differentiate the inner cell mass in humans.
OCT4 and GATA6彼此拮抗使人類內細胞團分化。

B. OCT4 is not found outside the inner cell mass in humans.
人類內細胞團以外的細胞無OCT4。

C. Human yolk sac cells are typical of previously known animal yolk sac cells.
人類卵黃囊細胞就是過去已知的動物卵黃囊細胞。

D. Cells expressing OCT4 may adhere more strongly to one another, than to other cell types.
表現OCT4的細胞彼此間的黏附性強於其與他類細胞間的黏附性。

E. It can be concluded from these images that a population of GATA6 expressing cells switch their fate after day 8.
從這些圖像中可得的結論為一群表現GATA6的細胞在8天後改變其分化走向。

DOMESTICATION 馴化

Plants have a plastic developmental body plan, built up of simple units. *Brassica oleracea* is the progenitor for many domesticated *Brassica* crops. During domestication of each crop different units were selected.
植物具有可塑性的生長發育方式，由簡單的部位成長。 *Brassica oleracea* 是許多馴化的甘藍油菜的祖先。在每個作物馴化期間，選擇了不同的部位。

Identify which single unit was selected for during domestication in each crop.
指出在每一個作物的馴化過程中選擇植物的哪一個部位。

A. Brussel sprouts 芽菜甘藍
B. Cauliflower 白花菜
C. Kale 羽衣甘藍
D. Kohlrabi 大頭菜
E. Broccoli 綠花椰菜

DISEASE & DECAY 疾病與衰弱

THE CELL CYCLE 細胞週期

The major ways by which the cell-cycle is regulated in all eukaryotes were discovered by British scientists. In humans, Cyclins (discovered by Sir Tim Hunt; 1943-present) are transcribed at specific cell-cycle stages, and bind cyclin-dependent kinases (CDK; discovered by Sir Paul Nurse; 1949-present), to coordinate division. Protein-53 (p53; discovered by Sir David Lane; 1952-present) is activated by a huge array of post-translational modifications, which allows it to exert diverse effects. p53 can exert these effects even when its activity is reduced by half, but each p53 monomer is only active when bound to three other functional p53 monomers in a homotetramer. p53 is mutated in the majority of cancers ever sequenced.
真核生物細胞週期的主要調控機制是由英國科學家發現，人類在不同的細胞週期階段，會有特定的的週期素(Cyclins, 由Sir Tim Hunt發現)被轉錄表現，週期素會和週期素激酶(CDK, 由Sir Paul Nurse發現)結合，並活化CDK，去控制細胞分裂。
蛋白質53(p53, 由Sir David Lane)必須藉由很多不同的轉譯後修飾，始能有多樣的功能
即使p53的活性降到一半，依然能發揮功效。
一個p53單體必須和另外三個正常的p53結合成同形四聚體(homotetramer)才有功能。
在大多數的的癌症中，都有突變p53。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤

A. Tumours which have lost p53 activity have higher mutation rates than tumours which have p53 activity.
失去p53活性的腫瘤的突變率比具正常p53的腫瘤突變率要高

B. Single celled organisms, such as yeast *(Saccharomyces)*, possess equally powerful regulators like p53.
單細胞生物，如酵母菌，也具有與p53完全一樣功效的調控蛋白

C. Treatments which deliver more p53 to cells, would reduce the division of healthy cells.
若讓細胞內的p53量增加，則會減少健康細胞的分裂

D. Both alleles of p53 are usually mutated in cancer.
通常癌細胞的二個p53等位基因都是突變型

E. *P53* knockout mice *(Mus musculus)* show an overgrowth of bone-marrow cells.
剔除p53的老鼠會有骨髓細胞過度生長現像

METASTASIS 腫瘤轉移

Different types of primary tumours give rise to secondary tumours at different rates, and in characteristic places. (The primary organ is where the primary tumour occurs, the secondary organ is where the secondary tumour develops). To understand why, healthy mice *(Mus musculus)* were injected with cells from skin cancers which spontaneously developed in different mice: Arrow thickness = relative proportion of mice exhibiting the symptom.
(1) Cells from the primary tumour were injected into the heart.
(2) Cells from the primary tumour were injected into the tail vein.
(3) Cells from a secondary tumour were injected into the heart.
In (1, 2 & 3) cancer cells were recovered from the lymph of 100% of the injected mice within hours.
In (4), cells from primary tumours were injected into the heart, and cells recovered from homogenised brain or lung were serially passed through fresh mice.

不同類型的初級腫瘤轉移成二級腫瘤的速率不同、位置不同(初級腫瘤所在處是初級器官，二級腫瘤所在處是二級器官)，為了解原因，將不同小鼠*(Mus musculus)* 自發性的皮膚癌細胞，注射到健康小鼠(如圖)，圖中箭頭寬度= 小鼠出現症狀的相對比例。
(1) 將初級腫瘤癌細胞注射到心臟
(2) 將初級腫瘤癌細胞注射到尾巴血管
(3) 二級腫瘤癌細胞注射到心臟
在(1, 2, 和3)的實驗中，注射後數小時內，在被注射小鼠的淋巴中，100%都發現癌細胞。
(4) 將初級腫瘤癌細胞注射到心臟, 然後將其腦或肺部的細胞磨碎，並接續注射到其他小鼠。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤

A. The pattern of secondary tumours can be accurately predicted simply by how close different organs are to the primary tumour.
只要視器官位置與初級腫瘤是否接近，便可預期二級腫瘤出現模式

B. Crossing the blood vessel wall, in the secondary organ, is the limiting step in the formation of secondary tumours from circulating cancer cells.
在二級器官中，通過血管壁是自循環的癌細胞到形成二級腫瘤過程中的限制步驟

C. Cells of a new secondary tumour evolve over time to thrive in the secondary organ.
新的二級腫瘤的細胞可以演變到在二級器官中繁盛增生

D. Cancer evolves as it spreads to seed new secondary tumours more efficiently.
癌細胞散播新的二級腫瘤較有效率

APOPTOSIS 細胞凋亡

Sir Alastair Currie (1921-1994), Sir John Sulston (1942-present) and colleagues discovered how cells can commit controlled suicide (apoptosis).
Sir Alastair Currie (1921-1994), Sir John Sulston (1942-present)等人及其同事們發現細胞如何進行程式控制性自殺(細胞凋亡)

Apoptosis is executed by Caspase enzymes. Cyclohexamide (CH), which inhibits ribosomes, was used to induce apoptosis in cells treated with the hormone bone morphogenetic protein-9 (BMP9). To measure the number of apoptotic cells after treatment, inactive luciferase substrate, and the light-emitting enzyme luciferase, were added.
細胞凋亡由Caspase enzymes執行. 核糖體抑制劑Cyclohexamide (CH)可用以誘導BMP9賀爾蒙處理細胞的凋亡. 加入釋放冷光的Luciferase受質或失活型受質可用以偵測並定量經處理後凋亡細胞的數目。

Calculate the % change in luminescence caused by BMP9 treatment, compared to no BMP9 treatment. Adjust values to take the blank measurement into account.
請計算出因BMP9處理後的冷光百分比之改變,請將空白控制組數值考量並矯正測定值
請利用空白控制組的數值校正測定值

A. Choose the nearest change to the correct answer.
請選出與答案最接近的選項

Indicate whether each of the following statements is true or false.
請指出下列各敘述為對或錯

A. BMP9 treatment causes an increase in apoptosis.
BMP9 處理增加細胞凋亡

B. A large excess of both inactive substrate and luciferase is required to give a linear luminescence signal in response to caspase activity.
加入過量的失活型受質及luciferase，可使caspase活性反應的冷光訊號呈線性關係

C. Caspase gene expression is increased during apoptosis.
在細胞凋亡的過程中，Caspase基因表現會增加

KREBS CYCLE 克氏循環

Sir Hans Krebs (1900-1981) uncovered the major biochemical pathway of mitochondria.
The Krebs cycle was artificially modified in a free prokaryote to maximise lysine production.

Sir Hans Krebs (1900-1981) 發現一種粒線體中的主要生化路徑。
在獨立生長的原核細胞中,克氏循環經人為修飾,使其lysine胺基酸產量達到最高

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Blocking the final step of threonine synthesis leads to an unregulated increase in lysine synthesis.
阻斷 threonine 生合成的最後步驟會造成 lysine 生合成的提升

B. Increasing ID activity increases lysine synthesis.
增加 ID 活性會增加 lysine 生合成

C. Making PEPC insensitive to malate/aspartate increases lysine synthesis.
使 PEPC 對 malate/aspartate 不敏感會增加 lysine 生合成

D. Increasing PEPCK activity increases lysine synthesis.
增加 PEPCK 活性會增加 lysine 生合成

ELECTRON TRANSPORT CHAIN 電子傳遞鏈

Peter Mitchell (1920-1992) discovered how mitochondria produce ATP.
Electrons are harvested from succinate, malate and ascorbate (vitamin C), and drawn onto oxygen. Complexes I-IV sequentially harness their energy to pump protons across mitochondrial inner membranes (1).
The oxygen saturation of a suspension of mitochondria, treated with substrates and the poisons potassium cyanide (KCN), rotenone or antimycin A (AA) at the indicated points, was measured over time (2)

Peter Mitchell 發現粒線體如何產生ATP.
由琥珀酸、蘋果酸和抗壞血酸(維生素C)處獲得電子，最後交與氧。複合體 I-IV 依序以獲得的能量用於使氫離子通過粒線體內膜(圖中1)。
將粒線體懸浮液，在指定的時間點加入受質和不同的毒物：氰化鉀(KCN)、魚藤酮(rotenone)、或抗黴素A(antimycin A, AA)，檢測氧的量。(圖中2)

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Rotenone inhibits complex I.
魚藤酮抑制複合體 I

B. Antimycin A inhibits cytochrome C.
抗黴素A抑制細胞色素C

C. Cyanide poisoning can be treated with malate.
氰化鉀中毒可以用蘋果酸解毒

D. Oxygen consumption is increased by poisons which introduce pores to mitochondrial membranes.
以造成粒線體之膜破洞的毒物處理後，氧的消耗量會增加

ELITE RUNNERS 精英跑者

In the last few games, team GB has used sport science to finish second in Olympic and Paralympic medal tables.
英國代表隊已經運用運動科技在過去的幾場比賽中，在奧運和殘奧獎牌中排名第二。
The running velocity of different gold-medal 100m sprinters is presented (1)
不同比賽獲100米金牌的短跑運動員的跑步速度如（1）
Phosphocreatine, which is present in the cytoplasm of muscle, buffers ATP levels in a one-step reaction (2). Glycolysis generates a few ATP by converting glucose to pyruvate. Mitochondria generate dozens of ATP by converting pyruvate to CO2.
存在於肌肉細胞質中的磷酸肌酸藉著一步化學反應來保持細胞中ATP的濃度（2）。糖解藉由將葡萄糖轉化為丙酮酸而產生一些ATP，粒線體則將丙酮酸轉化為CO_2，在此過程中產生數十個ATP。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Faster sprinters metabolise more muscle glycogen to CO_2 than slower sprinters.
較快的短跑運動員其肌肉中肝醣代謝成CO_2的速率比較慢的短跑運動員為快。

B. The kinetics of their glycolytic enzymes are an essential determinant of which medals these sprinters win.
他們的糖解酶的動力學是這些短跑運動員獲勝的重要決定因素。

C. Creatine, as a dietary supplement, would enhance the performance of Usain Bolt (Jamaica's 100 and 200 m winner) more than Paula Radcliffe (Britain's record breaking marathon runner).
作為膳食補充劑的肌酸對於增加Usain Bolt（牙買加的100和200米冠軍）的表現效果大於其對Paula Radcliffe（英國創紀錄的馬拉松運動員）的效果。

D. Glycolysis becomes the main energy source of these sprinters after ~ 70 meters.
約70米後，糖解作用成為這些短跑運動員的主要能量來源。

MENDELIAN RANDOMISATION 孟德爾式隨機法

Sir Richard Doll (1912-2005) invented statistical methods to prove smoking causes human disease. Mendelian randomisation was invented to investigate more subtle behaviours, such as the health impacts of alcohol (1) and high density lipoproteins (HDLs; 'good' cholesterol) (2). An underlying genotype, inferred to cause a behaviour, is identified, and its correlation with disease is assessed. White British people were recruited for this study.
Sir Richard Doll 發明了統計方法以證明吸菸引起人類疾病。孟德爾式隨機法可以用來探討較複雜的行為，例如酒精對健康的衝擊(圖中1)，和高密度脂蛋白(HDLs，好膽固醇)(圖中2)。在行為背後控制的基因已被發現，它與疾病間的相關性也被評估，白種英國人被徵求參與此研究

Indicate, *based on this study*, whether each of the following statements is true or false.
根據此研究，指出下列各敘述是正確或錯誤。

A. Compared to not drinking any alcohol, consuming small amounts of alcohol is beneficial to health.
與完全不飲酒相比，少量飲酒有益健康

B. Drugs which raise HDL are expected to reduce cardiovascular disease.
能提高HDL的藥，期待也可減少心血管疾病

C. If people with the genotype *aa*, who happen to consume no alcohol for religious reasons, have a high risk of cardiovascular disease, it should be concluded alcohol contributes to disease directly.
若一人之基因型是aa，不飲酒，但是有心血管疾病風險，據此可以說，酒精直接造成疾病

D. If the allele *a* is found to be more common in Scotland, and *A* in Wales, the conclusions of a UK wide study will be strengthened.
如果 *a* 等位基因在蘇格蘭較普遍，而 *A* 等位基因主要在威爾斯，則擴大至全英國各區的研究結果會更顯著

REDQUEEN HIV 無敵的HIV病毒

Dame Amanda Fisher discovered many properties of the HIV.
HIV has two states. It can remain dormant within cells or can be active, replicating and producing viral proteins. In 2016, the National Health Service announced a new treatment, which awakens dormant HIV and kills active HIV. Many recipients are preliminarily cured.
Dame Amanda Fisher發現許多HIV的特性。HIV具兩種型態，其可在細胞中潛伏，或維持活躍的複製並製造病毒蛋白。在2016年，National Health Service 發布一種新的治療方法可以喚醒潛伏的HIV病毒，且殺死活躍型HIV，許多接受治療的病人在治療之初都痊癒。

Three patients (1, 2, & 3) contracted HIV at time 0, and remained untreated. Each month, blood samples were taken from each patient. Antibodies and virus were separately extracted from the samples. Antibodies from each time point were mixed with viruses from each time point, and the infectiousness of the antibody-treated virus was measured.
三位感染HIV且未接受治療的病人(1, 2 & 3)，由在圖上標示時間 0 處開始每個月採集每位病人的血液樣品，並從樣品中分別萃取抗體及病毒。將每次抽血所得之抗體與萃取的病毒混合後，進行抗體處理病毒之感染力檢測。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. In the first month of infection, patients suppress circulating HIV.
在感染的第一個月，病人抑制血液中循環的HIV

B. Patients' antibodies will be more effective against awakened dormant virus, than currently active virus.
相較於正活躍的病毒，病人的抗體較能有效對抗被喚醒的潛伏態病毒

C. Patient 2 developed AIDS last.
病人2 最慢發展成免疫缺陷症候群

D. The virus evolved most rapidly in patient 3.
在病人3中病毒演化最快

E. The immune system is better at targeting cells infected with inactive virus than active virus.
與被活躍病毒感染的細胞相比, 免疫系統比較會攻擊被不活躍病毒感染的細胞

ANTIBIOTIC RESISTANCE 抗生素耐性

Sir Alexander Fleming (1881-1955) discovered antibiotics, but humanity's biggest killers are now mostly resistant to them.
In one pathogen, antibiotics are degraded either by intracellular enzymes, or by enzymes released into the surrounding environment. A strain susceptible to antibiotics was labelled red, and a resistant strain was labelled yellow. Equal amounts of susceptible and resistant bacteria were mixed and seeded as a dense lawn on plates. These were treated with drug A or B at different concentrations, and grown for a period of time. The colour of the remaining cells was photographed.
弗萊明（1881-1955）發現抗生素，但今天人類最大殺手大多已能抵抗抗生素。
對一病原體而言，抗生素可能被細胞內酶或釋放到周圍環境中的酶降解。對抗生素敏感的菌株標記為紅色，抗性菌株標記為黃色。將易感的與抗性的細菌等量混合並緻密的接種在培養盤上。用不同濃度的藥物A或B處理這些細菌，並生長一段時間後，將留下的細菌顏色拍照。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. This species of bacteria expresses the target of Drug B.
這種細菌會表現藥物B攻擊的目標。

B. When there is no drug, the plates will become increasingly yellow, and less red, with time.
當沒有藥物時，培養盤顏色會變得越來越黃，隨時間推移紅色就越來越少。

C. Resistance to Drug A involves an extracellular enzyme
對藥物A 的抗藥性涉及細胞外酶。

D. Plasmids carrying genes for antibiotic resistance are more likely to spread when resistance uses extracellular enzymes, than when it uses intracellular enzymes.
抗性菌株若使用細胞外酶，其攜帶抗生素抗性基因的質體會比使用細胞內酶時更容易散播。

PRIONS 普利昂蛋白

John Griffith (1928-1972) explained the biology of prion diseases. Prions are proteins which have folded incorrectly into a more stable form. When a prion comes into contact with its correctly folded counterpart, it catalyses this protein to also re-fold into a prion. Prion build-ups, which resist proteolysis, damage the brain, and in the 1990s millions of cattle *(Bos taurus)* in the UK had to be destroyed to prevent prions from spreading.
格里菲斯(1928-1972）解釋了普利昂病的生物學。 Prions是經不正確折疊而成為更穩定形式的蛋白。當prion與正確折疊的蛋白質接觸時，它會催化該蛋白質也折疊成prion。Prion不會分解，累積後卻會損害大腦，在20世紀90年代，英國有數百萬隻牛（*Bos taurus*）必須被焚燬，以防prion的擴散。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. At the start of disease, prions accumulate exponentially.
疾病開始時，prion呈指數級累積。

B. Animal prion diseases may spread to humans
動物prion疾病可能傳給人類。

C. Cattle with some genetic variants may be protected from prion diseases.
具有一些遺傳變異的牛可被保護免受prion疾病的侵襲。

D. Banning animal protein supplements in livestock diets is an effective way to reduce prion diseases.
禁止在牲畜飲食中添加動物蛋白補充劑是減少prion疾病的有效途徑。

TUBERCULOSIS DRUGS 結核病藥物

Mycobacterium tuberculosis The UK runs the biggest collaborations to screen for new antibiotics for tuberculosis. Molecules X and Y were found, which binds to the active site of a *Mycobacterium tuberculosis* enzyme.Dashed lines indicate hydrogen bonds.
Molecule Z was also found to inhibit the enzyme, by binding a site other than the active site.
英國經營結核病抗生素新藥篩選最大合作案。發現分子X和Y 均能與結核分枝桿菌酶的活化位結合, 虛線表示氫鍵。而分子Z也能抑制酶卻是結合在活化位之外的部位。

Indicate whether each of the following statements are true or false.
指出下列敘述是正確或錯誤。

A. Molecule X binds to the enzyme's active site reversibly.
分子X 能可逆性的結合在酶的活化位。

B. Molecule Y could have been found in a screen for molecules which increase the temperature at which the enzyme denatures.
分子Y可能為被篩選出的分子，因其可增加使酶變性的溫度。

C. Molecule X binds to the active site more tightly than molecule Y.
分子X比分子Y更能緊密結合在活化位。

D. Molecule Z is a better drug candidate if the substrate concentration is usually very high.
如果受質濃度通常很高，則分子Z是更好的候選藥物。

VACCINATION AND EPIDEMIOLOGY 疫苗接種和流行病學

Edward Jenner (1749-1823), the inventor of immunology, pioneered modern vaccination. Jenner noticed milkmaids exposed to cowpox did not catch smallpox. Jenner injected pus from a cowpox infection (top), into a boy, who became mildly ill. Jenner later injected the boy with pus from a smallpox victim (bottom), and the boy did not become ill (1). Smallpox was usually spread through the respiratory tract, was highly contagious, and quite deadly, but, due to vaccination, is now the only human pathogen to have been driven extinct.
免疫學發明人詹納（1749-1823）是現代疫苗接種的先峰。詹納注意到暴露於牛痘的女傭不會得天花。詹納給一個男孩注射由感染牛痘產生的膿液（上），而使他輕度生病。詹納再給這男孩從天花受害者產生的膿液（下），男孩並沒有生病（1）。天花通常經呼吸道傳播，傳染性高又會致命，但由於疫苗接種，現在是唯一被滅絕的人類病原體。

John Snow (1813-1858) invented epidemiology. Snow mapped the occurrence of cases in Victorian London during the first Cholera pandemic, and saved many lives (2). In 1961, the current seventh global Cholera pandemic began in Indonesia.
史諾（John Snow，1813-1858）是流行病學的先峰。在維多利亞時代的倫敦發生第一次霍亂大流行，史諾以地圖追蹤病例發生點，挽救了許多生命（2）。第七次全球性霍亂大流行在1961年起源於印尼。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. Smallpox and Cowpox share some amino-acid sequences on their surface.
在天花和牛痘表面有些胺基酸序列相同。

B. People often contracted smallpox more than once.
人們常不只一次感染天花。

C. Snow ended the Cholera outbreak by removing the handle from the Warwick Street water pump.
史諾藉著去除華威街水井幫浦的手柄終結了霍亂的疫情。

D. Smallpox remains viable outside of the host for longer than Cholera.
天花在宿主體外存活的時間比霍亂要長。

E. Smallpox lingers in isolated communities longer than Cholera.
在孤立的社區中，天花病情拖延時間長於霍亂。

HAEMOPHILIA 血友病

Robert Macfarlane (1907-1987) explained the biochemistry of blood clotting, and discovered the cause of haemophilia B, which causes fatal bleeding.
Queen Victoria's son, Prince Leopold, was the first European noble to develop haemophilia B, but it quickly devastated European royal lines. An incomplete family tree is shown.
Robert Macfarlaneu研究血液凝集的生物化學，發現會引起出血致死的B型血友病的原因。Victoria女王的兒子，Leopold王子是第一個罹病的歐洲貴族，但很快地血友病開始蹂躪歐洲王室，這裡有一個不完整的譜系圖

Based on this tree, calculate the probability that Alexis would have died from haemophilia if he survived the Russian revolution.
依據此譜系圖，如果Alexis 沒有死於俄國革命，計算Alexis會死於血友病的機率。

A. Choose the nearest probability to the correct answer.
選擇最接近正確答案的機率。

Indicate whether each of the following statements is true or false.
指出下列敘述是正確或錯誤。

A. In this family, haemophilia B could have originated from a new (*de novo*) mutation during meiosis in Queen Victoria's oocytes.
在此家庭中，B型血友病是源自 Victoria 女王的卵母細胞在減數分裂時發生的新突變。

B. Clotting factor activity is reduced by more than half in these haemophiliacs.
在這些病人中凝血因子的活性低於原本正常的一半。