28th International Biology Olympiad

July 23-30, 2017
University of Warsick
United Kingdom

Theory 1

本中文翻譯版題目無圖片

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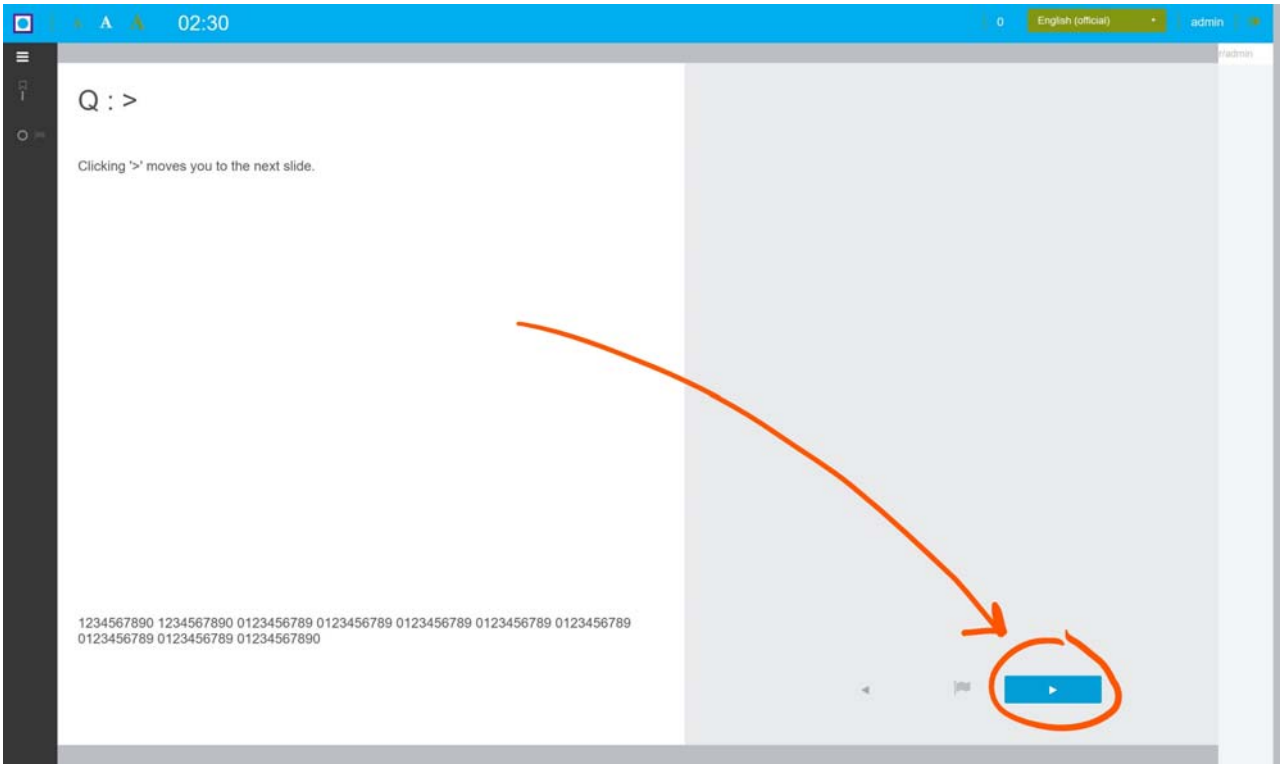
原文版題目(含圖片)及解答

https://www.ibo-info.org/en/info/papers.html

操作簡介

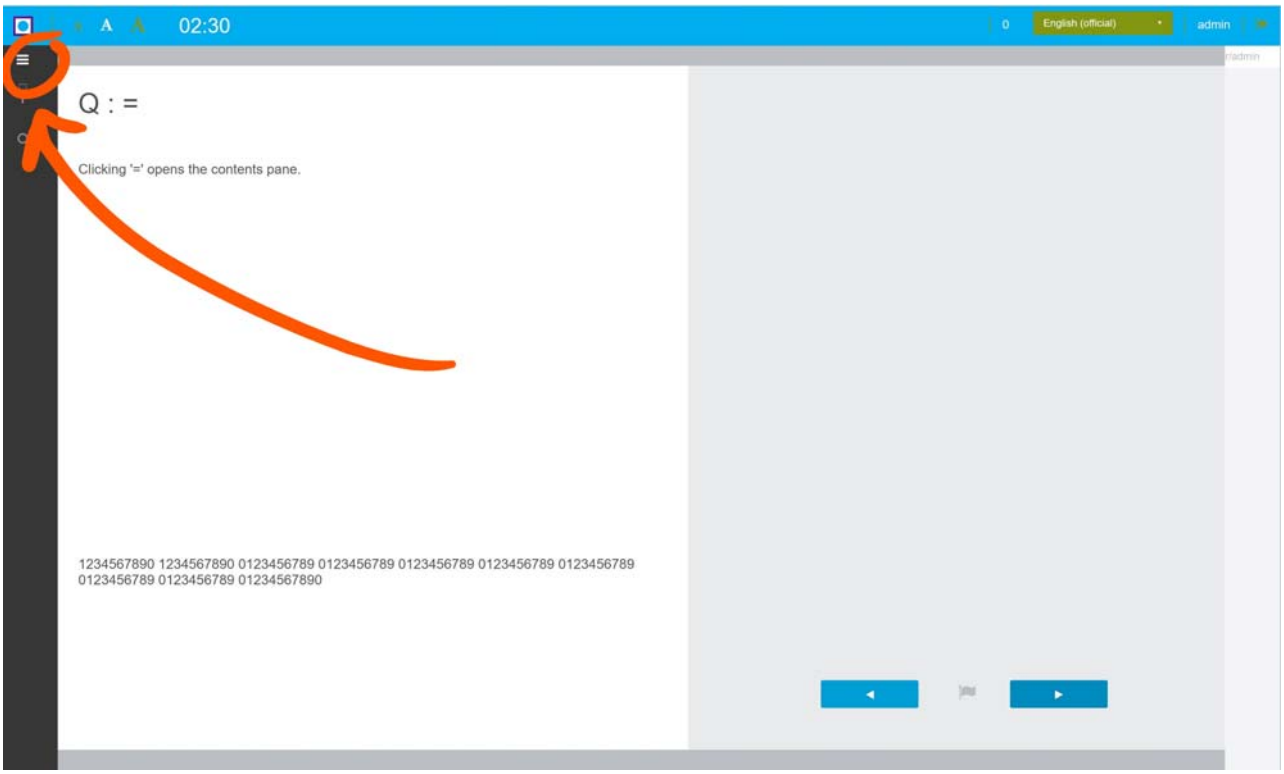
View all the introductory slides before moving to the first question. ***They contain essential and useful information,*** including instructions and useful scientific definitions.
查看所有說明簡介的投影片，然後再轉到第一個問題。 *簡介說明包含必要和有用的訊息，*包括說明和有用的科學定義。

Click '>' to move to the next page.
點擊“>”移動到下一頁。

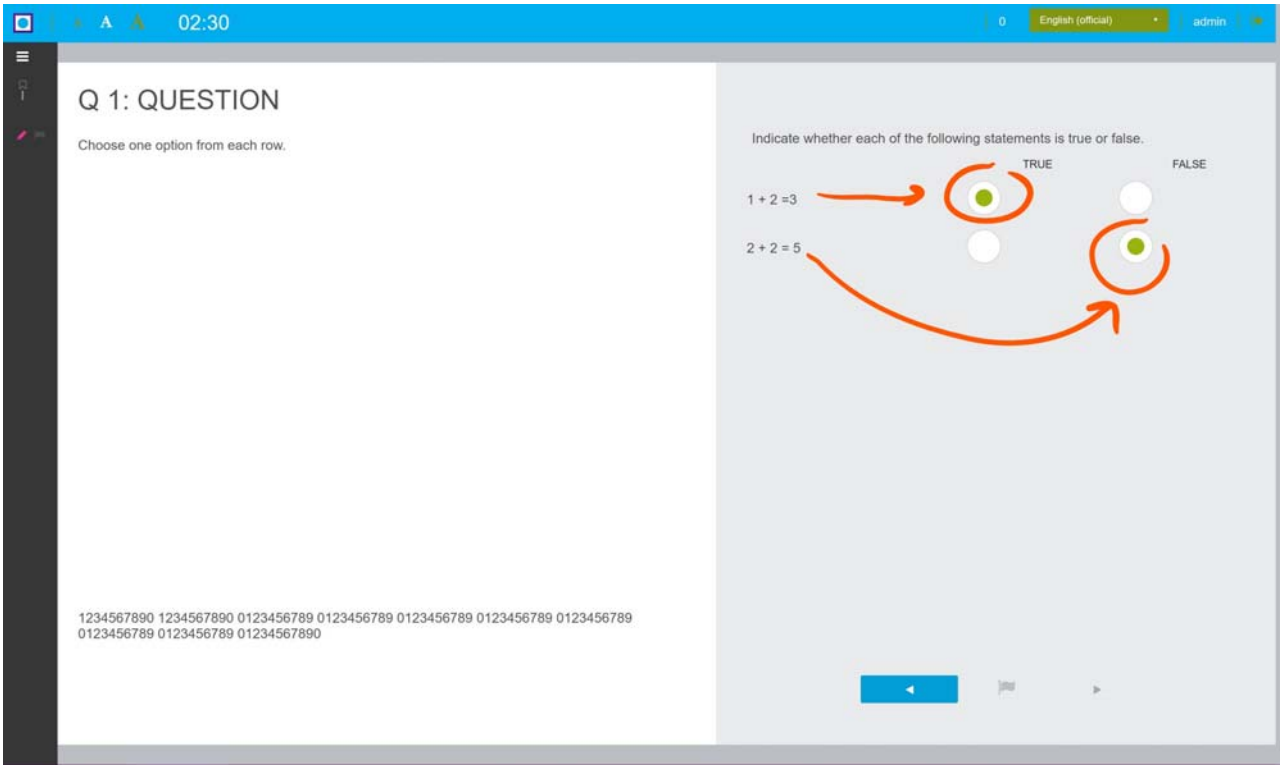


Click the burger to view the contents of the exam. Click it again to close the contents.
點擊左上角"漢堡形"查看考試的內容。再次單擊以關閉內容。

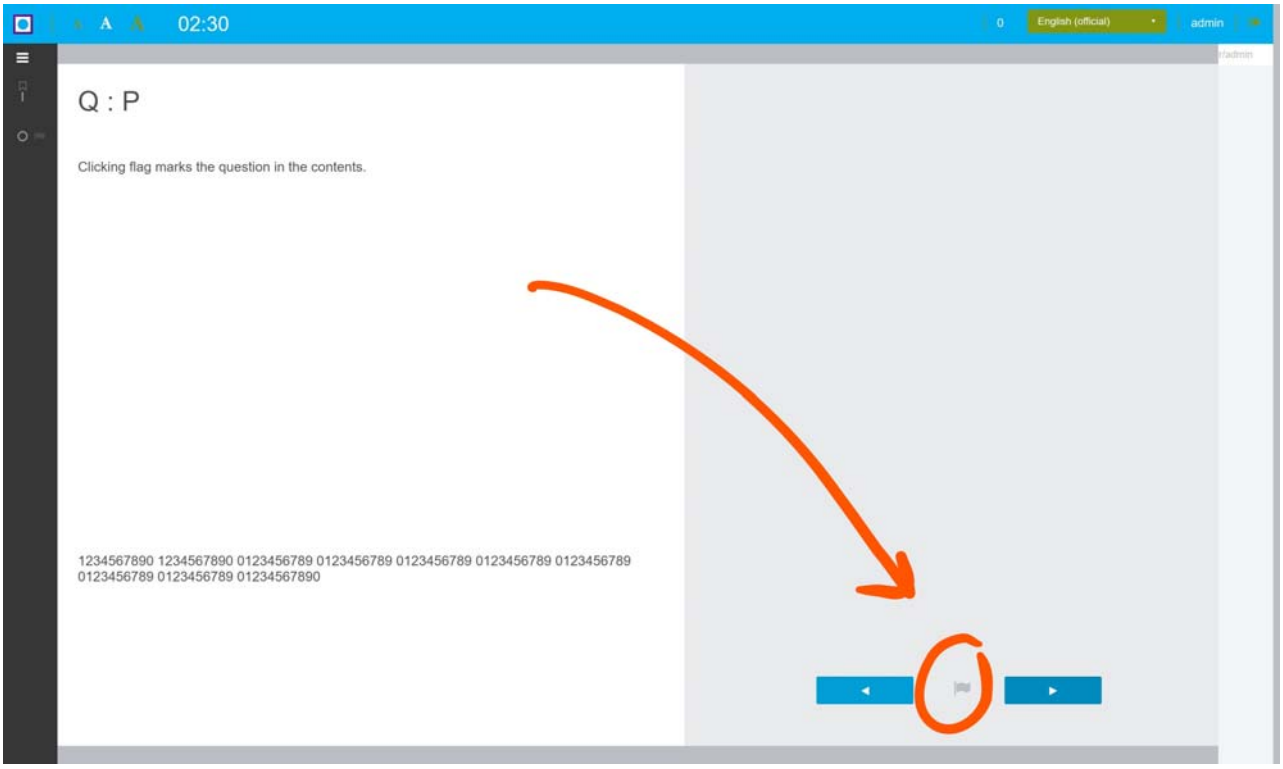
Then click '>'
然後點擊“>”



For all questions, select one option per row. All your answers can be changed at any time during the exam, and will be saved automatically.
對於所有問題，每行選擇一個選項。在考試期間，你可以隨時更改所有答案，它會自動儲存。



The flag icon can be used to mark questions in the contents pane.
旗形圖標可用於在左側的內容窗格中標記問題。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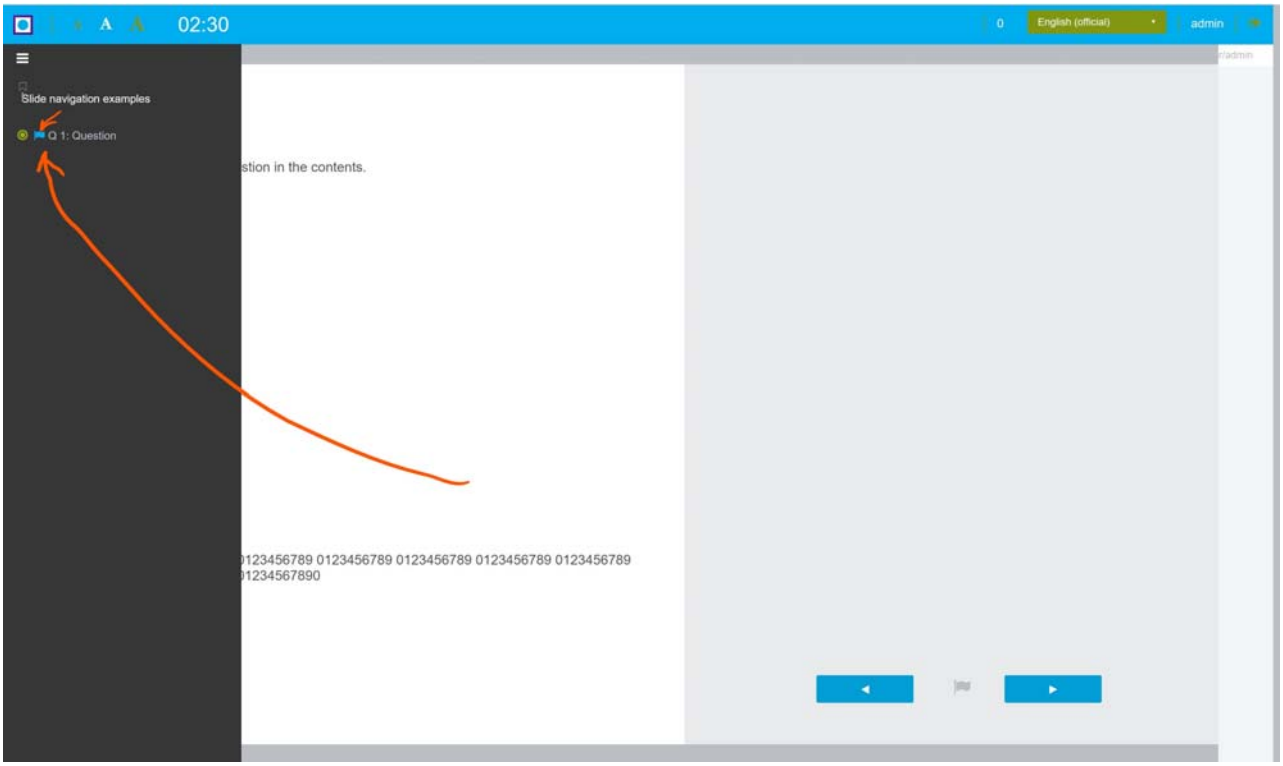
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INSTRUCTIONS FOR THE THEORY EXAMINATIONS
理論考試說明

PAPER 1 (理論 1): 8.30AM - 11.30AM

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, you must 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；答錯不會扣分，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 later to any that you cannot answer. 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.
你可點選右上角處以更換想看試題的語言版本。

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

These terms have featured in IBO exams for many years, but you may not be familiar with their precise definitions.
這些學術名詞已經在IBO考試中出現多年，但你可能不會熟悉他們的精確定義。

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 a specific gene, which is stated in the question, mutated such that no functional 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，使得不產生具功能的產物。
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 cmH_2O, 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 cmH_2O 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 $Po_2 = 0.21 \times 760 = 160$ 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$Po_2 = 0.21 \times 760 = 160$ 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 product 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產物。 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* 。

BLUEPRINTS OF LIFE

生命的藍圖

SEQUENCING 定序

Frederick Sanger (1918-2013) invented protein, RNA and DNA sequencing, and Sir Shankar Balasubramanian (1966-present) invented high-throughput DNA sequencing. The National Health Service is sequencing an unprecedented 100 000 genomes from rare-disease patients, but different sequencing technologies have different merits for this purpose, as described below.
Frederick Sanger發明蛋白質、RNA和DNA的定序，Sir Shankar Balasubramanian發明了高通量DNA定序。國家衛生署正對100000個罕見疾病患者的基因組進行定序，對此目的而言，不同的定序技術各有其優點，如下所述

Technology 技術	Maximum length of sequence fragments which can be read 可讀定序片段的最大長度	Error rate 錯誤率	Total number of bases sequenced per sample per day 每天定序總量
Sanger sequencing Sanger定序	900 bp	1 in 1000 bp 1/1000	900 bp (1 fragment) (1片段)
Illumina machines Illumina機器	200 bp	1 in 100 bp 1/100	$3x10^{11}$ bp (>$1.5x10^{9}$ fragments) (>$1.5x10^{9}$ 片段)
PacificBiosciences machines PacificBiosciences機器	5000 bp	1 in 10 bp 1/10	$4x10^{8}$ bp (>80 000 fragments) (>80 000片段)

Indicate whether each of the following statements is true or false of the 100 000 genomes project.
下列各有關100000基因組計畫的敘述是正確或錯誤

A. Illumina technology is best for finding new Single Nucleotide Variations (mutations to a single base) in the patient genomes.
如果要在病人基因組中找到新變異(單鹼基突變)，Illumina技術是最好的選擇

B. PacificBiosciences technology is best for assessing transcriptional changes by RNA sequencing.
要檢測轉錄時發生的變化，PacificBiosciences技術是RNA定序最好的選擇

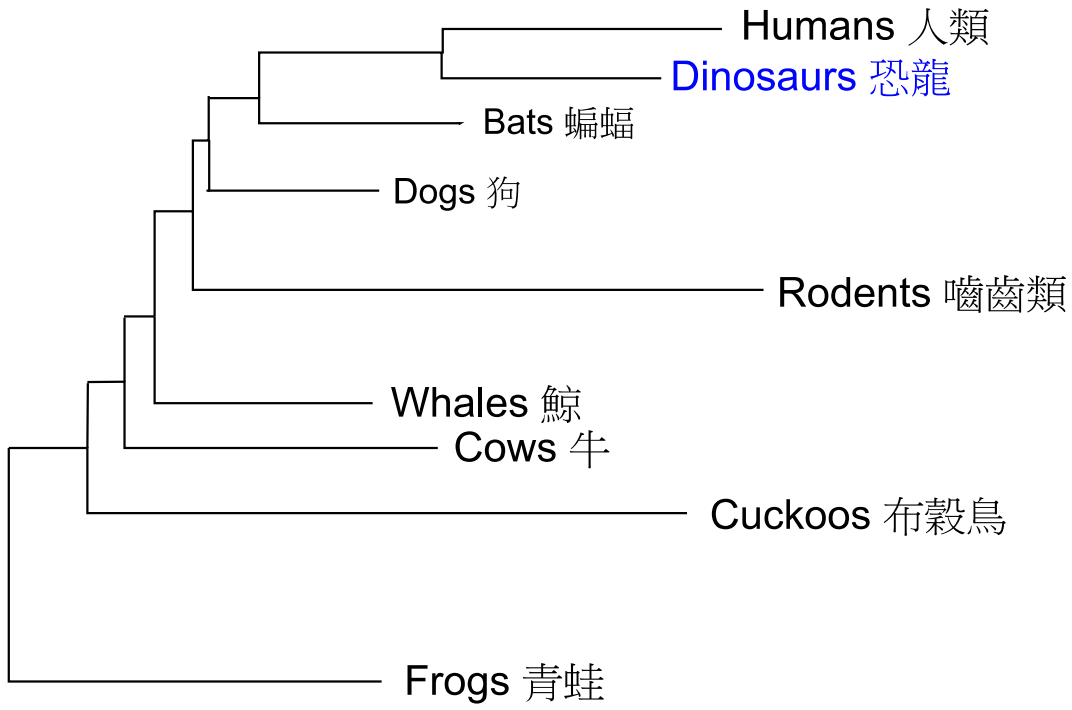
C. PacificBiosciences technology is best for finding rearrangements of chunks of DNA in the patient genomes.
要找到大片段的DNA重組，PacificBiosciences技術是是最好的選擇

D. Sanger sequencing is best for validating sequencing results before using patients' genetic information to guide clinical interventions
當參考病人的遺傳資料來決定臨床處置方式時，Sanger定序法是最好的選擇

ANCIENT DNA 古代 DNA

Mark Thomas (1964-present) read the first DNA sequences from woolly mammoths *(Mammuthus primigenius)*. However, ancient DNA analysis remains difficult, due to degradation, contamination, and polymerase inhibitors found in the samples. Scientists attempted to extract DNA from a dinosaur fossil and analyse the sequence of one specific gene. The following phylogeny was produced after comparing the sequence against other species.

Mark Thomas（1964年至今）從長毛猛獁象（*Mammuthus primigenius*）解讀出第一段DNA序列。然而，由於樣品中發現的降解、污染和聚合酶抑制劑，古代DNA的分析仍然是困難的。科學家試圖從恐龍化石中提取DNA，並分析一個特定基因的序列。以下的系統發生圖 (親緣關係圖) 即是將此序列與其他物種進行比較所得結果。



Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. When working with ancient samples, it is easier to recover DNA sequences from a mitochondrial gene than a nuclear gene of the same length.
在研究操作古代樣品時，從粒線體基因中回收DNA序列比從其他相同長度的細胞核基因還要容易。

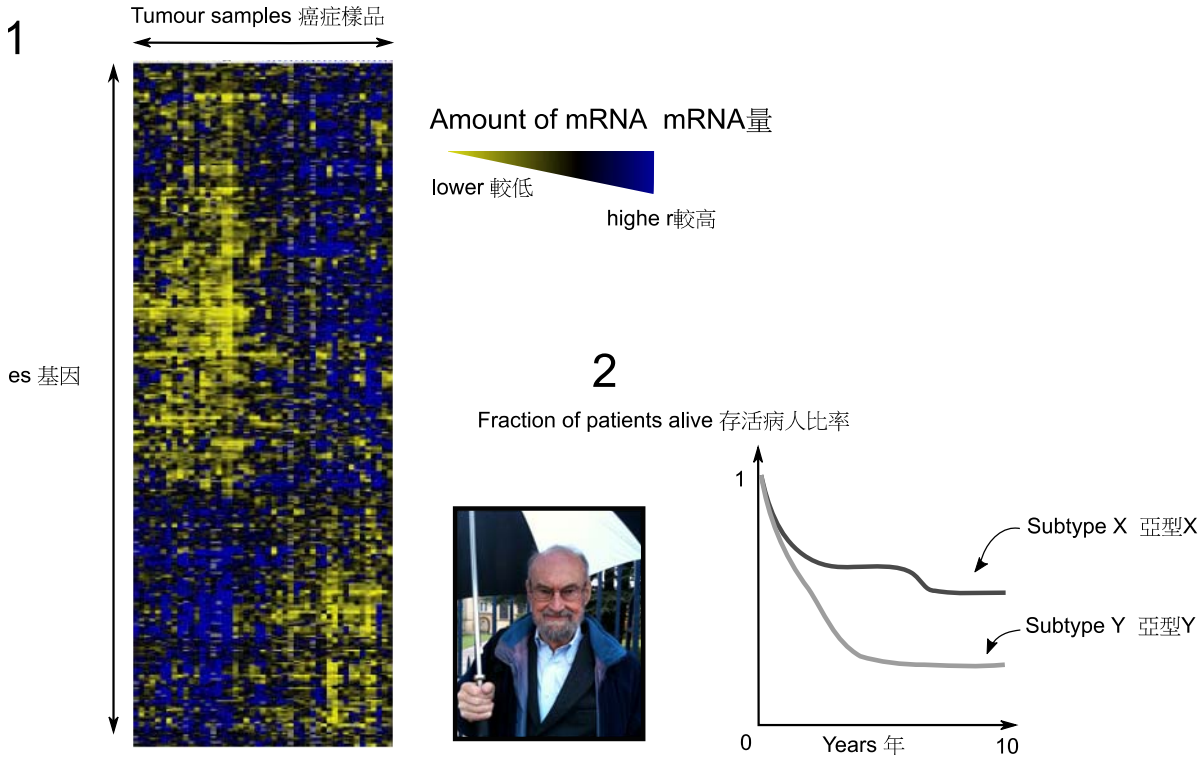
B. It is better to sequence very long DNA fragments from ancient samples, than very short fragments.
相較於非常短的片段，從古代樣品中分離出非常長的DNA片段是比較好的。

C. Adding a DNA fragment of a known sequence could show whether or not samples contain polymerase inhibitors.
添加已知序列的DNA片段可以顯示樣品是否含有聚合酶抑制劑。

D. This dinosaur fossil extract is likely to contain contaminating DNA.
這種恐龍化石的提取物很可能含有遭污染的DNA。

CANCER MICROARRAY癌症微陣列

Sir Edwin Southern (1938-present) invented microarrays to analyse the expression of hundreds of genes simultaneously. A microarray has probes printed onto it which detect a specific complementary mRNA. These probe for mRNAs expressed from across the genome . Diffuse Large B Cell lymphomas (DLBCL) from tens of patients were analysed by microarray (1). Additionally, patient survival rates for two clinical subtypes of DLBCLs were measured (2).
埃德溫爵士（1938年至今）發明了微陣列，用以同時分析數百個基因的表達。微陣列上印有探測特異性互補mRNA的探針，可用以探測從基因組表達的mRNA。利用微陣列分析數十名患有瀰漫性大B細胞淋巴瘤（DLBCL）的病人mRNA表現量（圖1）此外另外收集X及Y兩種DLBCL臨床亞型(subtype)患者的存活率資料（圖2）。



Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. The data rule out patient survival rate being determined by differences in gene expression between DLBCL subtypes

此資料排除病患存活率由DLBCL亞型間的基因表現差異決定

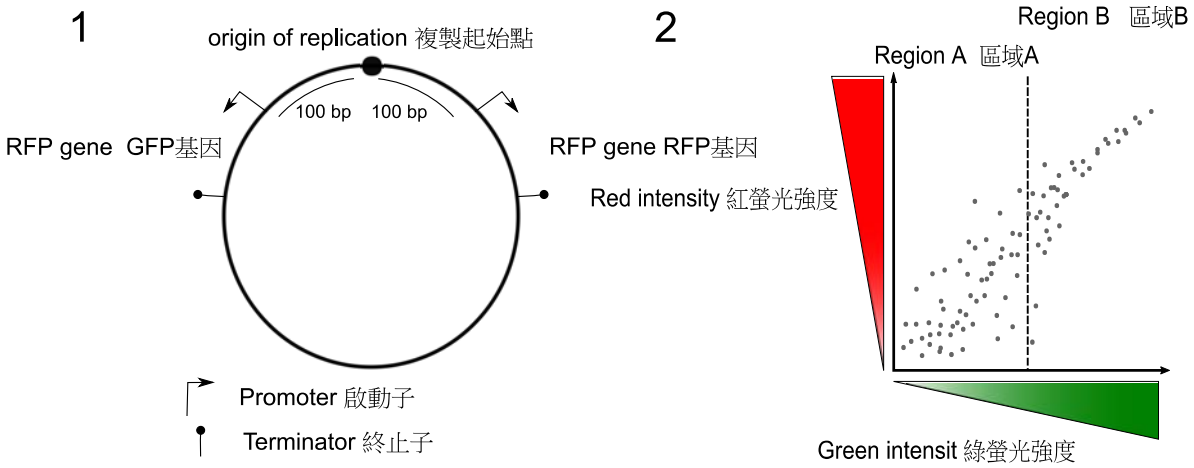
B. Gene expression data suggest there are two major subtypes of DLBCL distinguishable at the molecular level
基因表現數據顯示可以在分子層次分辨兩種DLBCL亞型。

C. Measuring the expression of a single gene is sufficient to distinguish subtypes of DLBCLs.
測量單一基因的表現情形足以區分DLBCL亞型。

D. Each subtype of DLBCL has an equal number of relatively up-regulated versus down-regulated genes compared to other subtypes.
每種DLBCL亞型與其它DLBCL亞型具有相對等數量的上調與下調表現的基因。

GENE EXPRESSION NOISE 基因表現雜訊

A plasmid was inserted into bacteria (1). Red fluorescent protein (RFP) or green fluorescent protein (GFP) are produced from the genes in this plasmid whenever transcription factors bind to their promoters. The red and green gene promoter sequences are identical. Plasmid DNA replication starts at the origin of replication, and replication forks move outwards in both directions at the same speed. Replication occurs whenever replication factors bind to the origin of replication. The red and green fluorescence intensity of individual bacteria was measured (2).
將一質體置入細菌體中（1）。此質體在有轉錄因子結合其啟動子時，質體上的紅螢光蛋白（RFP）或綠螢光蛋白（GFP）基因會表現產生對應蛋白。紅螢光和綠螢光蛋白基因啟動子序列是相同的。質體DNA複製從起始點開始，複製叉以兩個方向向外移動，速度相同。每當複製因子與複製起始點結合時，就會開始複製。可在細菌體中檢測到表現的紅色和綠色螢光強度（2）。



Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. Replicating plasmids have unequal numbers of red fluorescent protein and green fluorescent protein genes.
複製質體具有不等數量的紅色螢光蛋白和綠色螢光蛋白基因。

B. On average, cells in Region A contain more replication factors than those in Region B.
平均而言，區域A中的細胞比區域B中的細胞具有較多的複製因子。

C. On average, cells in Region A contain more transcription factors than those in Region B.
平均而言，區域A中的細胞比區域B中的細胞具有較多的轉錄因子。

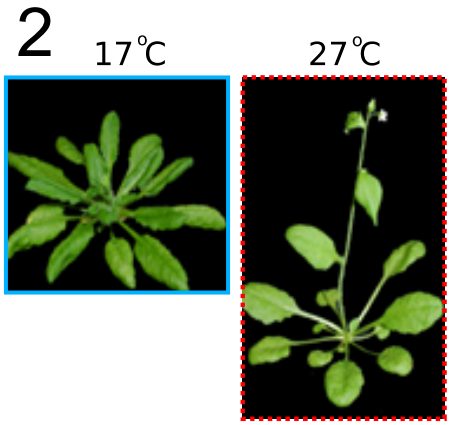
D. Increasing the activity of transcription factors is expected to increase the number of cells containing equal amounts of green fluorescent protein and red fluorescent protein.
增加轉錄因子的活性，預期將增加含等量的綠色螢光蛋白和紅色螢光蛋白細胞之數量。

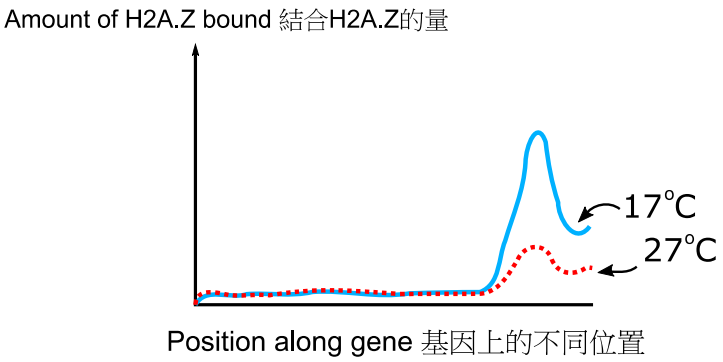
EPIGENETICS OF FLOWERING 開花的表觀遺傳學

Dame Jean Thomas (1942-present) discovered that eukaryotic DNA is tightly wrapped around histone proteins. Sir Adrian Bird (1947-present) helped explain the epigenetic marks of DNA. For example, the classical histone H2A, can be replaced by a variant, H2A.Z.
H2A.Z occupancy on a pro-flowering gene (1) in *Arabidopsis* plants (2) of the same age, at different temperatures, was measured

Dame Jean Thomas發現真核生物DNA纏繞著組蛋白(Histone proteins)，Sir Adrian Bird以此解釋DNA的表觀遺傳標示，例如：一般的組蛋白H2A可以被一種變異的H2A.Z取代。
比較同齡，但生長在不同溫度下的阿拉伯芥，其"前開花基因"(pro-flowering gene)處H2A.Z的含量。

1





Indicate whether each of the following statements is true or false.
回答下列各敘述是正確或錯誤

A. Increasing temperature increases pro-flowering gene expression.
溫度升高會增加前開花基因的表現

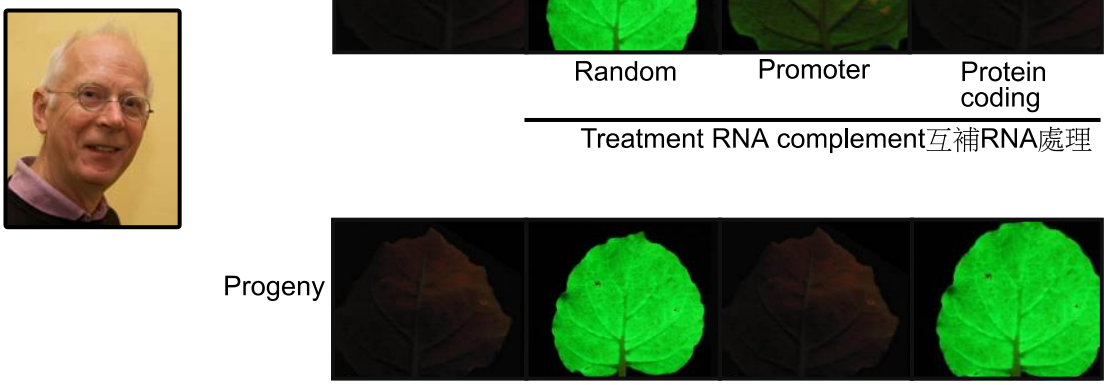
B. H2A.Z enhances gene expression.
H2A.Z增強基因表現

C. Temperature moves the locations to which H2A.Z binds in the genome.
溫度會改變H2A.Z與基因組結合的位置

D. Plants that flower early may have increased H2A.Z occupancy in this gene before flowering.較早開花的植物可能在開花前於此基因處有較多的H2A.Z

GENE SILENCING 基因靜默

Sir David Baulcombe (1952-present) discovered RNA-directed gene silencing.
The gene for green fluorescent protein (GFP) was inserted into plants. The plants were treated with RNAs, which silence GFP, and were then allowed to set seed (the treatment RNAs are not present in the next generation). The treatment RNA sequence was complementary to either the promoter or the protein coding sequences of GFP, or random (non-complementary). The parent plants, their progeny, and controls were imaged under a UV light.
David Baulcombe爵士（1952年至今）發現了RNA指導基因沉默。
將綠色螢光蛋白（GFP）的基因插入植物中。用RNAs處理植物，使其GFP基因沉默，然後使該植物結種子（處理RNAs不會存在於下一代植物細胞中）。此沉默RNA序列與GFP的啟動子或蛋白質編碼序列互補,或隨機（非互補性）互補。以UV光照射處理植物母本(treated plant)，其後代(progeny)和對照組(control)植物並進行成像實驗。



Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. Leaves expressing GFP appear darker under UV light.
在UV光照射下，葉子表現的GFP呈現較暗

B. RNA-directed gene silencing is possible without using treatment RNAs designed to target mRNA.
RNA-引導基因沉默可能不需使用針對目標mRNA的RNAs

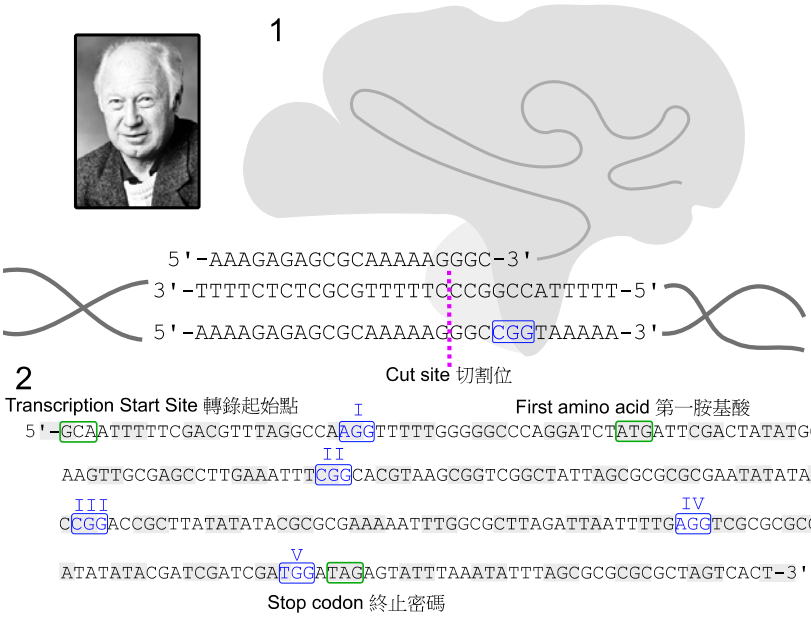
C. Changes in the expression level of genes can be inherited from one generation to the next without mutating the DNA sequence.
基因表現量之改變可能代代相傳，但不會造成DNA突變

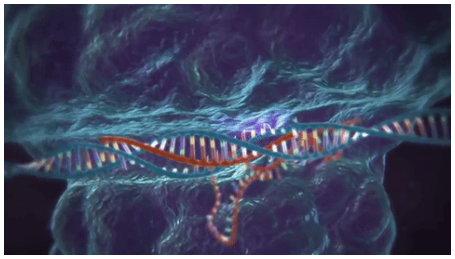
D. Silencing against the protein coding sequence is heritable.
針對蛋白編碼區設計的基因沉默可以遺傳給後代

GENE ENGINEERING 基因工程

Michael Smith (1932-2000) invented site-directed mutagenesis. Recently scientists invented CRISPR-Cas9 technology to carry out mutagenesis more easily.
Cas9 protein from *Streptococcus pyogenes* is guided by a 20bp guideRNA which base-pairs with target DNA. This Cas9 enzyme can only make double strand cuts in DNA three bases upstream from a 5'-NGG-3' site (1). Double strand cuts are attacked by DNA degrading enzymes, and then re-joined. Gene X, which you want to stop from functioning with this enzyme, is shown (2).
An alternative way to knockout genes is to use a pair of modified Cas9's which can only make single strand cuts, and guideRNA's which target adjacent sites.

Michael Smith (1932-2000)發明定點突變.近年來科學家更發明CRISPR-Cas9 技術使基因突變更容易進行。
Streptococcus pyogenes 細菌的 Cas9 可由一個 20 bp 引導RNA的導引而與標的DNA鹼基互補, Cas9 酵素只會針對位於 5'-NGG-3'位點上游 3 bp序列進行雙股DNA切割 (圖1),切割的雙股DNA會被DNA降解酶攻擊再被重新接合,圖2為欲利用此酵素將基因X功能剔除時，DNA序列設計示意圖。
另一可將基因功能剔除的方式是利用修飾的 Cas9's 可執行單股DNA切割,並利用引導RNA之幫助以攻擊鄰近的DNA標的序列





Select the guideRNA sequence that will direct Cas9 to site I.
選擇可導引Cas9到第一位點的引導RNA序列

A. You have five guideRNA sequences to choose from:
有5種引導RNA序列供你選擇
1 = 5'-ATTTTTCGACGTTTAGGCCA-3'-3'
2 = 5'-AUUUUUCGACGUUUAGGCCA-3'
3 = 5'-AUAAAACGUGCAAAUCCGGU-3'
4 = 5'-UUUGCACGUUUAGGCCAAGG-3'
5 = 5'-UUUUUGGGGGCCCAGGAUCU-3'

Select the best available NGG site to target gene X to stop it functioning.
請選擇可使標的基因 X 失去功能的最佳NGG位點

A. NGG site

Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. Using the pair of modified Cas9s and guideRNAs increases off-target damage to other genes.
利用修飾的Cas9s及引導RNAs增加其他基因之脫靶傷害

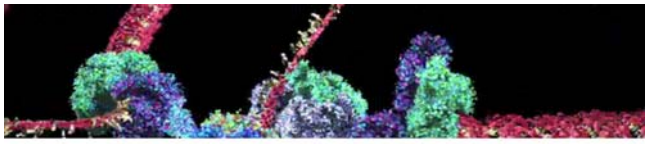
B. The *Streptococcus pyogenes* genome has more NGG sites than expected by chance.
*Streptococcus pyogenes*基因組中具有更多於預期的NGG位點

C. If the gene has no GG sequences, Cas9s from other species should be investigated for alternatives.
如果基因不具有GG序列,則可選用其他物種之Cas9s

REPLICATION FORK 複製叉

X-ray crystallography, invented at the Royal Institution, was used by Sir Francis Crick (1916-2004) and Rosalind Franklin (1920-1958) to discover the structure of DNA, and predict the mechanism of its replication. Building on their work, this is the current predicted structure of an *E. coli* DNA replication fork, which moves along DNA at 1000 bp/s.
i = Tube shaped clamp, which pulls on one DNA strand.
ii = Topoisomerase, which makes temporary cuts in one phosphodiester backbone.
iii = Single-stranded DNA binding protein.
iv = Different polymerases.

克里克（1916-2004）和羅莎琳富蘭克林（1920-1958)利用皇家學會發明的X射線晶體繞射，發現DNA的結構，及預測DNA的複製機制。依據他們的工作，以下為當前所預測的大腸桿菌 DNA複製叉結構，DNA複製叉會以1000bp / s速度沿著DNA移動。
i = 管狀的夾子，掛在DNA的一條鏈上。
ii = 拓撲異構酶，可在一個磷酸二酯骨架上做暫時的切割。
iii =單鏈DNA結合蛋白。
iv =不同的聚合酶。



Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. Antibiotics which poison topoisomerase cause DNA ahead of the fork to become over twisted.
對拓撲異構酶有毒性的抗生素會造成複製叉前面的DNA過度扭曲。

B. An activity of polymerase complex X is to replace ribonucleotide uracil, with deoxyribonucleotide thymidine.
聚合酶X的活性之一是用去氧核糖核苷酸胸腺嘧啶取代核糖核苷酸尿嘧啶。

C. Enzyme i is preferentially loaded at G/C rich (A/T poor) sequences.酶 i 會優先加載於富G / C（A / T少)的序列上。

D. Protein iii assists complementary base pairing.
蛋白質iii幫助互補鹼基的配對。

SPLICING 剪接

Sir Richard Roberts (1943-present) discovered the fundamental structure of genes using adenovirus genomes. Under an electron microscope, Roberts identified Adenoviral DNA and RNA strands. Eukaryotic mRNA was later found to be missing parts (introns) of the genes, because the RNA sequence was rearranged by splicing.
理查羅伯茨爵士（1943-至今）發現使用腺病毒基因組的基因基本結構。在電子顯微鏡下，羅伯茨辨識出DNA和RNA鏈。後來發現在真核細胞的基因，其mRNA會失去部分的序列（內含子），RNA序列因剪接而重組。

Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. Each adenovirus RNA is transcribed from the same DNA strand for the whole RNA.
每一個腺病毒RNA都是從同一股DNA轉錄出完整RNA。

B. Adenovirus mRNA remains bound in a DNA-RNA hybrid duplex for a period of time.
腺病毒的mRNA會以DNA-RNA混合雙鏈體的形式存在一段時間。

C. Transcription requires helicase activity (separates the two DNA strands).
轉錄需要解旋酶的活性（以分離兩條DNA鏈）。

D. mRNA splicing in these Adenovirus genes uses a similar mechanism to typical Eukaryotic splicing.
腺病毒中的mRNA剪接使用的機制與典型真核細胞剪接的機制類似。

DYSTROPHIN 抗肌肉萎縮蛋白

Muscular Dystrophy is caused by alterations to *DYSTROPHIN* (1). This is a very large gene, and its length affects the biology and diagnosis of Muscular Dystrophy.
RNA polymerase moves along DNA at 30 bp per second.
DNA polymerase has an error rate of 10^{-8} mistakes per base.
Repair systems later correct 99% of mistakes.
Sir Alec Jeffreys (1950-present) invented DNA fingerprinting (RFLPs) whereby *DYSTROPHIN* exons may be amplified by PCR, treated with DNA-cutting enzymes (endonucleases), and separated on an agarose gel, according to length in bp (2).
肌肉營養不良症由抗肌肉萎縮蛋白基因（1）的改變引起。這是一個非常大的基因，其長度影響肌肉營養不良的生物學和診斷。

RNA聚合酶以每秒30bp的速度沿著DNA移動。

DNA聚合酶每個基因的錯誤率為10^{-8}個錯誤。
後由修復系統修正其中99%的錯誤。

傑福瑞爵士（1950-至今）發明DNA指紋圖譜（RFLP），通過PCR擴增抗肌肉萎縮蛋白基因外顯子，以DNA切割酶（核酸內切酶）處理後，根據其bp的長度（2）在瓊脂凝膠上分離。

Calculate how long *DYSTROPHIN* transcription takes.
計算抗肌肉萎縮蛋白基因轉錄所需的時間。

A. Select the nearest time to the correct answer.
選擇最接近正確答案的時間。

Calculate how many cell divisions you expect to occur before a new *DYSTROPHIN* allele (sequence variant) is created.
計算在產生抗肌肉萎縮蛋白新的*DYSTROPHIN* 等位基因 (序列不同) 之前，你期待會發生多少次細胞分裂。

A. Choose the nearest number to the correct answer.
選擇最接近正確答案的數字。

Calculate how far away, in base pairs (bp), the following features are from the start of the primer 1a binding site. Select the correct answer for each.
以多少鹼基對（bp）來計算從引子1a結合位置的起點到下列項目的距離。為每個項目選擇正確答案。

A. Primer 1b binding site.
引子1b結合位置。

B. Endonuclease cut site
核酸內切酶切位點

C. Primer 2 binding site.
引子2結合位置。

Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. *DYSTROPHIN* is on the X chromosome.
抗肌肉萎縮蛋白基因位在X染色體上。

B. Muscular Dystrophy is dominant.
肌肉營養不良症是顯性的。

C. DYSTROPHIN protein could be made in bacteria with a 20 kb plasmid.
抗肌肉萎縮蛋白可以用20kb質體由細菌製成。

D. Many muscular dystrophy patients have new (*de novo*) causal mutations.
許多肌肉營養不良症患者是因為有新的（*de novo*）基本突變。

FLY EYES 果蠅眼睛

William Bateson (1861-1926) founded the discipline of modern genetics. Reginald Punnett (1875-1967) created a technique to predict the frequency of phenotypes with Mendelian inheritance, but Edith Saunders (1865-1945) noticed some combinations of traits were not inherited in a Mendelian fashion. To investigate this phenomenon, the genetics of fly *(Drosophila)* traits can be analysed. A fictional *Drosophila* species was crossed according to the following sceme:
William Bateson (1861-1926) 建立了現代遺傳學的學科領域，Reginald Punnett (1875-1967)發展出孟德爾遺傳模式表現型的預測技術，但 Edith Saunders (1865-1945)注意到有一些性狀的遺傳並不依循孟德爾模式。為探討此現象，可以研究果蠅*(Drosophila)*性狀的遺傳。假設一種虛構的果蠅物種，相關基因及雜交方式如下：

WT flies have red-eyes (1) produced by mixing brown and cinnabar pigments.
A mutation in the *white* gene gives white eyes (2).
A mutation in the *cinnabar* gene gives cinnabar eyes (3).
A mutation in the *brown* gene gives brown eyes (4).
WT flies have functional wings (5),
whilst mutations in the *vestigial* gene lead to vestigial wings (6).
White is carried on the X-chromosome. The genes *brown-cinnabar-vestigial* are carried on the same chromosome, in that order.
Males with white-eyes are crossed to females with white-eyes and vestigial wings. All offspring (F1) are red-eyed females, or white-eyed males . No F1 flies had vestigial wings.
The F1 females are mated to a male that has white-eyes and vestigial wings. The female F2 flies from this cross are counted.

野生型紅眼是由棕色和辰砂色色素混合(圖中1)
white 基因突變導致白眼(圖中2)
*cinnabar*基因突變導致辰砂色眼(圖中3)
brown 基因突變導致棕眼(圖中4)
野生型果蠅有正常翅(圖中5)
*vestigial*基因突變造成殘翅(圖中6)
*white*基因位於X染色體上，而 *brown-cinnabar-vestigial* 基因依此順序位於同一條染色體上
白眼雄果蠅與白眼殘翅雌果蠅交配，所有F1子代都是紅眼雌果蠅或白眼雄果蠅，沒有殘翅
F1雌果蠅與白眼殘翅雄果蠅交配，F2子代中的雌果蠅表現型和數量如下

F2 (female) phenotype **F2(雌性) 表型**	**Number of F2 females** **F2雌性個體數**
White eyed, normal wings 白眼，正常翅	500
Red eyed, vestigial wings 紅眼，殘翅	500
Red eyed, normal wings 紅眼，正常翅	50
White eyed, vestigial wings 白眼，殘翅	50
Brown eyed, vestigial wings 棕眼，殘翅	5
Cinnabar eyed, normal wings 辰砂眼，正常翅	5

Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. The gene *vestigial* is on the X chromosome.
*vestigial*基因位於X 染色體上

B. The gene *brown* is essential for making the brown pigment.
brown 基因對合成棕色色素是必須的

C. Mutations to *white* disrupt the products of both *cinnabar* and *brown.*
*white*基因的突變破壞 *cinnabar* 基因和 *brown*基因的產物

Calculate the genetic distance, in cM, between the brown, cinnabar and vestigial genes. Choose the nearest distance to the correct answer for each.
計算brown, cinnabar, vestigial 間的遺傳距離，以cM為單位，計算後所得，與下列數值比較，選擇最接近者為答案

A. *Brown* to *cinnabar.*

B. *Brown* to *vestigial.*

C. *Cinnabar* to *vestigial.*

BUILDING AND GROWING

PROTEIN EVOLUTION蛋白演化

Experiments found that CwiM is a regulator of *Mycobacteria tuberculosis* cell wall formation. The length (1) and number (2) of WT and CwiM knockout cells were assessed. Amino-acid sequence similarity analysis suggests that CwiM is homologous to zinc-dependant enzymes (3).
實驗顯示CwiM是結核菌細胞壁形成的重要調節因子,野生型及CwiM基因剔除細胞用菌體長度(1)及菌數(2)加以評估,胺基酸序列分析顯示CwiM與鋅依賴性酵素的序列很相似(3)

Indicate whether each of the following statements is true or false:
下列敘述何者正確或錯誤。

A. CwiM is likely to be zinc-dependent.
CwiM可能具有鋅依賴性

B. CwiM increases cell survival rate.
CwiM增加細胞存活率

C. CwiM very likely plays a role in cell elongation in *M. smegmatis*.
CwiM在 M. smegmatis很可能具有使細胞延長的功能

D. Cell elongation is required for survival.
細胞延長對生存為必要的

ACETYLATION 乙醯化

Sir Edwin Southern (1938-present) invented a method to visualise specific biomolecules, by separating them according to size, transferring them to a membrane and using specific probes for them. Protein modifications, including acetylation can be visualised in a similar way (Western blotting). WT *Salmonella* had their proteins extracted, and acetylation of a metabolic enzyme was investigated after treatment with purified enzymes pat or cob (1). The role of pat and cob in *Salmonella* growth was assessed in knockout cells (2).
埃德溫爵士（1938年至今）發明了一種可將特定生物分子根據其大小分離，將之轉移到膜上並使用特定的探針加以偵測的方法。包括乙醯化在內的蛋白質修飾也可用類似的方式 (西方墨點法) 來檢測。 將野生型*沙門菌*蛋白萃取後，用純化的酶pat或cob（圖1）處理後, 可用以研究代謝酶的乙醯化。在基因剔除細胞中評估pat和cob對*沙門氏菌*生長的作用 (圖2）。

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

A. Cob adds acetyl groups to proteins.
cob將乙醯基加到蛋白質上

B. More pat treated protein than cob treated protein was used in this analysis.
在此分析中加入的pat處理蛋白較cob處理蛋白多

C. Peak growth rate is equal whether *Salmonella* are feeding on glucose or citrate.
不論沙門氏菌養在葡萄糖或檸檬酸中其最高峰生長速率相同

D. Growth on citrate is initially slow because it takes time for cells to reduce pat activity.
長在檸檬酸中最初生長較慢因其細胞需時間來降低pat活性

CORK 木栓

Cork oak *(Quercus suber)* produces suberin, a highly resistant material, from fatty acids, and uses it to reinforce the cell walls of cork. The expression of genes specific to cork tissue was measured across the year, and the genes were grouped into biosynthetic enzymes, or chaperone proteins. Sir Hugh Pellham (1954-present) discovered chaperones, which assist other proteins to fold properly.
軟木橡樹（*Quercus suber*）從脂肪酸產生高抗性的材料，木栓質，並用於加強木栓層的細胞壁。Hugh Pellham 爵士（1954年至今）經由測量木栓組織之特定基因的表現在一年內的變化，並將基因區分為生物合成酵素相關或伴護蛋白(chaperone proteins)相關，他發現了可幫助其他蛋白質正確折疊的伴護蛋白。

Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. Cork tissue grows fastest in late spring.
木栓組織在春末生長最快。

B. The enzymes produce hydrophilic molecules.
這些酵素可產生親水性分子。

C. Increased expression of chaperones may allow cork to continue growing, despite higher temperatures.
儘管在更高的溫度之下，伴護蛋白的表現增加可使木栓層繼續生長。

QUININE BIOSYNTHESIS 奎寧的生物合成

The UK has undertaken to cure 1 billion cases of neglected tropical diseases, and develop new treatments, from 2017-2022. Quinine-like drugs are useful treatments for several diseases, but their synthesis by *Cinchona* trees requires many steps. Enzymes I and II were seen to catalyse a range of substrates into a range of stereoisomers, reversibly.
英國已經進行治療被忽視的熱帶疾病多達10億個案例，並將從2017年至2022年開展新的治療。奎寧類的藥物對幾種疾病的治療是有用的方法，但它們從金雞納樹(*Cinchona*)的合成需要許多步驟。酵素 I 和 II 能催化一系列的受質轉變成一些立體異構體，且此反應為可逆的。

Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. Overexpressing enzyme I may increase quinine synthesis.
酵素 I 過度表現會增加奎寧的合成。

B. Modifying enzyme II may change the ratio of quinine:quinidine in plants.
修飾酶 II 會改變植物中 quinine:quinidine 的值。

C. Nitrogen uptake in the roots may increase if enzyme II is overexpressed.
如果酵素 II 過度表現，則根中的氮吸收可會增加。

D. Trees containing the largest amount of quinine, also contain the largest amount of quinidinone.
含有最大量奎寧的樹也會含有最大量的 quinidinone。

DAY-NIGHT CYCLES 晝夜週期

Cytokinin is a plant hormone involved in stress signalling, which may affect responses to day-night cycles.
細胞分裂素是涉及逆境訊息傳遞的植物激素，它會影響對晝夜週期的反應。
Arabidopsis plants were grown under 8 hours light / 16 hours dark for 12 days, then four different light / dark regimes for one cycle. Patches of cell death were measured in leaves after this.
阿拉伯芥植物在 8小時光照 / 16小時黑暗 條件下生長12天，然後在四種不同的 光照/黑暗 條件下生長一個晝夜週期。此後在葉片中測量細胞死亡的斑塊。

Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. Increased light exposure is the major cause of cell death in cytokinin receptor knockouts in this experiment.
增加的光照是造成本實驗中細胞分裂素受體缺失的細胞死亡的主要原因。

B. A condition of 12 h light and 12 h dark will lead to a high percentage of cells dying in cytokinin receptor knockout plants.
12小時光照和12小時黑暗的條件將導致在細胞分裂素受體缺失植物中有高百分比的死亡細胞。

C. Cytokinin increases leaf stress.
細胞分裂素增加葉片的逆境。

D. Cytokinin helps adjust expression of circadian clock related genes.
細胞分裂素有助於調節晝夜節律性相關基因的表現。

OAK GALLS 橡樹蟲癭

Dame Ottoline Leyser (1965-present) showed that auxin is a plant hormone with roles in environment-development interactions. For example, English oak *(Quercus robur)* is attacked by gall wasp larvae *(Cynipidae)*, which cause tumorous galls to grow.
Dame Ottoline Leyser（1965年至今）指出植物生長素是一種在環境與發育交互作用中具多種角色的植物激素。例如，*Quercus robur* 受到癭蜂幼蟲（*Cynipidae*）攻擊，而引起了瘤狀蟲癭的生長。

Auxin can cause tumour growth, but auxin is degraded by oxidation (1). Plants use the enzyme PPO to control oxidation of phenolic chemicals (2), but auxin is *not* a phenolic compound.
植物生長素可引起腫瘤生長，但植物生長素卻因氧化而降解（1）。植物使用酵素 PPO 來控制酚類化學物質的氧化（2），但植物生長素*不是*酚類化合物。

Different chemical fractions (based on mass) were taken from galls and mixed with auxin and an oxidising agent. Auxin oxidation rate was then measured. Only fractions 6 and 17 contained mostly phenolic compounds (3).
從蟲癭中萃取出不同分子量的化學成分，並與植物生長素和一種氧化劑混合。然後測量植物生長素的氧化速率。只有分餾物 6 和 17 是主要含有酚類化合物者（3）。

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

A. Auxin activity is high in galls.
蟲癭中的植物生長素的活性高。

B. Compounds in fractions 6 and 17 are oxidised more easily than auxin.
分餾物 6 和 17 中的化合物比植物生長素更容易被氧化。

C. Phenolic compounds are responsible for oxidising auxin in galls.
酚類化合物負責氧化蟲癭中的植物生長素。

D. Secretion of auxin-like compounds by these gall wasp larvae is necessary to drive gall formation.
藉由這些癭蜂幼蟲分泌類似植物生長素的化合物是驅動蟲癭形成所必需的。

E. An upregulation of PPO in galls, compared to healthy tissue, could explain these results.
相較於健康組織，蟲癭中的PPO短暫而適度的增加表現可以解釋這些結果。

GROWTH PLATES 生長板

Growth hormone (GH) is secreted by the brain, and can stimulate the liver to secrete insulin-like growth factor 1 (IGF1).
Bones, formed from chondrocytes, elongate from terminal growth plates as animals grow.
生長激素（GH）由大腦分泌，可以刺激肝臟分泌類胰島素生長因子1（IGF1）。
骨骼由骨細胞組成，隨著動物成長可自生長板增生。
(1) A healthy, active growth plate. All the growth plates injected with GH activated.
（1）健康活化的生長板：生長板因注射GH而活化。

(2) GH was injected into rat growth plates in combination with IGF1 inhibitors.
（2）將GH與IGF1抑製劑共同注射進入大鼠生長板。

(3) All GH was inhibited in a rat.
（3）所有GH在大鼠體中被抑制。

(4) GH injected into a rat growth plate with a liver specific IGF1 knockout.
（4）將GH注射IGF1基因剔除鼠之生長板中。

(5) GH was added onto stem cells in a dish
（5）將GH加入含有幹細胞之培養皿中

Indicate whether each of the following statements is true or false
下列敘述何者正確或錯誤。

A. Mutations in *GH* can lead to dwarfism.
*GH*突變可導致侏儒症。

B. IGF1 is necessary for chondrocytes to enlarge.
IGF1是軟骨細胞生長(enlarge)所必需的。

C. Injecting IGF1 would lead to bone elongation, even if GH is absent.
即使GH不存在，注射IGF1會導致骨骼伸長。

D. IGF1 is produced by chondrocytes, as well as the liver.
IGF1由軟骨細胞以及肝臟產生。

SHOOT BRANCHING 莖的分支

The *RMS1* gene encodes a signalling protein which is altered in modern crops. Its activity can be studied by grafting together seedlings from different plants, and monitoring their growth.
在現代作物中，*RMS1*基因編碼會改變訊息傳遞蛋白。此蛋白之活性可藉由將來自不同植物的幼苗嫁接，並監測其生長來研究。

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

A. RMS1 activity increases shoot branching.
RMS1活性增加莖的分支。

B. The signal produced by *RMS1* travels towards the shoot tip rather than towards the roots.
由*RMS1*產生的訊息會朝向莖頂移動，而不是朝向根。

C. RMS1 activity in the root is sufficient to give WT plant architecture.
根中的RMS1活性足以賦予WT植物的結構。

D. RMS1 activity in the root is necessary to give WT plant architecture.
根中 RMS1 的活性對於WT植物的結構是必要的。

SLIT COMM ROBO

In *Drosophila* embryos, developing neurons (red) grow along two columns parallel to the midline. Some traverse the midline and some do not, creating a ladder. Midline cells secrete a protein, called Slit, which is detected by the receptor, Robo. Comm, a transcription factor, controls Robo expression. To investigate how this guides neurons, WT (1), *Robo* knockout (2), *Comm* knockout (3), and *Comm* overexpression (4) flies were dissected.

下圖顯示在*果蠅*胚胎中，發育中的神經元（紅色）平行於中線的兩個體節生長。有些神經元會穿過中線，有的則否，外型類似階梯狀。中線細胞分泌一種稱為Slit的蛋白質，其受體為Robo。 而Comm為一種控制Robo表達之轉錄因子。為了研究Robo及 C omm如何引導神經元，科學家利用下列四種果蠅：野生型WT(1)， R*obo*基因剔除果蠅(2)， *Comm* 基因剔除果蠅(3) 和*Comm*過度表現(4)來研究 *Comm*的表現，結果如下圖。

Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. Neurons cross the midline more often in *Comm* knockout flies, than WT flies.
相較於野生型，*Comm* 基因剔除果蠅中其神經元更常見越過中線。

B. Neurons are repelled when they detect Slit.
當神經元偵測到Slit存在時，會互相排斥

C. Comm acts to increase Robo expression
Comm會促進Robo之表現

D. Neurons increase Comm expression once they cross the midline.
神經元一旦跨越中線，會增加Comm表現。

TURING PATTERNS 圖靈模式

Alan Turing (1912-1954) famously invented the fields of computer science and artificial intelligence. Turing also published equations explaining spontaneous pattern formation in biology.
Dark zebrafish *(Danio rerio)* stripes are formed by collections of dark cells (melanophores), whilst brown stripes are produced by collections of lighter cells (xanthophores). To investigate whether zebrafish stripes are a Turing pattern, pigmented cells were surgically removed (dashed regions), and the appearance of melanophores from precursor cells was measured a fortnight later. The scale bar in the bottom right corner is 1 mm.
艾倫圖靈（1912-1954）在計算機科學和人工智能領域享譽盛名。然而圖靈在生物學相關領域也發表體表模式生成之相關著作。
黑斑馬魚*（Danio rerio）*條紋主要由黑暗細胞（黑色素細胞）的聚集形成，而棕色條紋織成主要是由較淺色之細胞（xanthophores）聚集而產生。為了調查斑馬魚條紋是否呈現圖靈模式，首先利用外科手術取出色素細胞（虛線區域），兩週後測量自前驅細胞分化而來之色素細胞的表現。右下角的刻度尺為1 mm。

Indicate whether each of the following statements is true or false
下列敘述何者正確或錯誤。

A. Melanophore formation is stimulated by other melanophores immediately next to the precursor cells.
黑色素細胞之生成主要是受剛自前驅細胞分化而來之黑色素細胞的刺激。

B. Precursor cells from different stripes are predetermined to become either melanophores or xanthophores.
來自不同條紋的前趨細胞已確定未來成為黑色素細胞或淺色細胞。

C. Melanophore formation is stimulated by other melanophores >0.5 mm from the precursor cells.
黑色素細胞之生成主要受來自前趨細胞且> 0.5mm的黑色素細胞所刺激。

D. Melanophore formation is stimulated by xanthophores >0.5 mm from the precursor cells.
黑色素細胞之生成主要受來自前趨細胞且> 0.5mm的淺色細胞所刺激。

RESPONDING TO THE WORLD 回應世界

CELL PROTEIN ATLAS 細胞蛋白圖譜

The location of proteins in a cell affects their function by determining which molecules they interact with. A collaboration of scientists in Sweden and Cambridge used microscopy to map the location of >12 000 human proteins in numerous cell types. In the diagram below, solid bars around the circumference represent all the different types of protein within each organelle, and lines are drawn between the same type of protein in different organelles.
蛋白質在細胞中的位置可決定與其作用的分子，進而影響其功能。瑞典和劍橋的科學家合作，使用顯微鏡來繪製> 12000個人類蛋白質在不同細胞類型中的位置。下圖中，沿圓周周圍的實心條表示各種胞器中所有不同類型的蛋白質，而在不同胞器中的同類蛋白質之間則繪線條相連。

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

A. Most proteins are found only in a single organelle.
大多數蛋白質僅在單一胞器中發現。

B. Most mitochondrial proteins are found only in the mitochondria.
大多粒線體蛋白質僅在粒線體中發現。

C. Most proteins that are found in multiple organelles are spread homogeneously through the cell.
大多數蛋白質能在多個胞器中發現，且在細胞中均勻分佈。

CALCIUM SIGNALLING 鈣的訊息傳遞

Jean Hanson (1919-1973) discovered how muscles contract. Contraction is triggered by a build up of calcium in the cytoplasm, which is actively removed during relaxation. Calcium diffuses through plasma membrane channels (1), or endoplasmic reticulum membrane channels (2).
(1, purple) Plasma membrane channels, opened by depolarisation, pore width = 1 atom
(2, orange) ER channels, open by binding calcium on cytoplasmic face, pore width = 100s of atoms
The concentrations of the major biological ions in different compartments are shown.

Jean Hanson（1919-1973）發現肌肉如何收縮。肌肉收縮主要是由細胞質內鈣離子所造成，而肌肉舒張是由於透過主動運輸將鈣離子移除。鈣離子主要透過細胞膜上鈣離子通道(1)及內質網上鈣離子通道擴散(2)進入細胞質。
（1, 紫色）細胞膜去極化使細胞膜上鈣離子通道開啟，孔道大小僅供1個原子進出
（2, 橘色）內質網上鈣離子通道主要透過鈣離子與其細胞質側之結合來開啟，孔道大小可供100 原子進出
下列數據顯示細胞內不同區域之鈣離子濃度

Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. Peak calcium flow into the cytoplasm is greater from the intracellular than extracellular stores.
相較之下，從細胞內胞器流入細胞質中之鈣離子之尖峰值遠比細胞外流入細胞內更多。

B. Cytosolic calcium has to be moved against an electrical and chemical gradient to be returned to the endoplasmic reticulum.
細胞質鈣離子必須同時抵抗電濃度梯度及化學濃度梯度，以返回內質網。

C. Muscle performance is improved by artificially expressing channel (2) on the plasma membrane.
如果在肌肉上利用人工方式大量表現內質網上鈣離子通道（2）會改善肌肉的性能。

D. Peak calcium flow is greater in high frequency muscle than to low frequency muscle.
受高頻刺激的肌肉，其鈣離子流動之最高值，大於受低頻刺激的肌肉

ACTION POTENTIAL PROPAGATION 動作電位傳播

Sir Alan Hodgkin (1914-1998) and Sir Andrew Huxley (1917-2012) explained how action potentials occur and spread.
(i) Resting neurons have a negative voltage (membrane potential) across their membrane (more negative inside than outside).
(ii) If the potential becomes less negative, ion channels open, making the voltage become positive.
(iii) Channels shut in a time dependent fashion.
(iv) Channels cannot re-open until the membrane returns to the resting negative voltage.
(v) As one section of membrane becomes positive, electrical currents make adjacent sections less negative.
Artificial action potentials can be triggered and measured in a giant neuron which runs the length of worms. A stimulating pair of electrodes are placed close to each other, against the worm, and a voltmeter placed further along is used to record the passing action potential. The trace from setup (1) is shown. Other setups (2, 3 & 4) were also tested.

艾倫·霍奇金爵士（1914-1998）和安德魯·赫克斯利爵士（1917-2012年）的研究闡述了動作電位之生成及傳播。
（i）靜止期之神經元之細胞膜之膜電位呈現負值:膜內較膜外為負。
（ii）如果膜電位負電性變小(less negative)，會打開離子通道使膜電位變為正值。
（iii）離子通道之關閉有時間性
（iv）直到膜回到原靜止膜電位，離子通道才能重新打開。
（v）當膜的一個部分變為正時，電流使得相鄰部位的負值降低(less negative)。

可在蠕蟲的巨型神經元中觸發和量測動作電位。將一對互相靠近的刺激電極放置在蠕蟲上用以刺激產生動作電位並可利用電壓計量測其大小。裝置(1)之實驗結果顯示於下圖，也測試其他裝置（2,3和4）所產生之電位變化。

Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. If the voltmeter electrodes are swapped in setup (1), action potentials can still be measured.
如果在裝置（1）中交換伏特計及電極的位置，仍然可以測得動作電位。

B. Action potentials can still be measured in setup (2).
可以在裝置（2）中測量到動作電位。

C. Action potentials can still be measured in setup (3).
可以在裝置（3）中測量到動作電位。

D. Measured action potentials will have a larger magnitude (reach a higher voltage) in setup (4) than setup (1).
在裝置（4）中，測量的動作電位將比裝置（1）的大（達到更高的電壓）

SYNAPTIC INFORMATION PROCESSING 突觸信息處理

Sir John Eccles (1903-1997) and Sir Charles Sherrington (1857-1952) discovered the different roles of synapses, which dictate how neurons respond to stimulation from each other.
Neurons 1, 2 and 3 were artificially fired, and their ability to initiate an action potential at point 4 was assessed.

約翰·埃克爾斯爵士（1903-1997）和查爾斯·舍林頓爵士（1857-1952）發現了突觸的不同作用，了解神經元如何因應刺激產生反應。
神經元1,2,3已由人為方式激發，他們對point4產生動作電位的能力分析如下

Indicate whether each of the following statements is true or false.
下列敘述何者正確或錯誤。

A. Simultaneous stimulation from neurons (1) and (3) can fire (4).
同時刺激神經元(1)及神經元(3)可誘發點(4)產生電位變化

B. Neuron (2) stimulates neuron (1).
神經元(2)可刺激神經元(1)。

C. The potential of (4) becomes more negative when (2) alone fires.
若只有刺激神經元(2)，反而會使點(4)之電位變得更負。

D. If (3) was fired twice in quick succession, (4) would fire.
若神經元(3)快速兩次被活化，會激活點(4)

RECEPTOR INFORMATION PROCESSING 受體信息處理

Whilst Lewis Wolpert (1929-present) hypothesised graded responses to signals control animal development, Sir John Gurdon (1933-present) was the first scientist to relate the number of activated receptors to different cell responses.
Whilst Lewis Wolpert (1929-present)提出在動物發育調控過程的訊號反應是漸層作用的,而 Sir John Gurdon (1933-present) 是第一位科學家探討活化態受體數目與不同細胞反應間的關係

The neurotransmitter acetylcholine can produce a graded response, but if the inhibitor BCM is above the critical concentration (>X mM), a cell's response to acetylcholine is significantly below maximal at all acetycholine concentrations.
Each acetylcholine receptor has one binding site for the neurotransmitter acetylcholine.
神經傳導物質乙醯膽鹼能產生漸層反應,但假設其抑制劑BCM劑量超過其關鍵濃度(> mM), 則細胞對乙醯膽鹼的反應會顯著低於最高強度,不論乙醯膽鹼的濃度為何, 每個乙醯膽鹼受體具有一神經傳導物質乙醯膽鹼結合位

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

A. BCM is a competitive inhibitor of the acetylcholine receptor (binds in the same way as acetylcholine).
BCM是一種乙醯膽鹼受體的競爭型抑制劑 (其與受體結合方式和乙醯膽鹼相同)

B. Increasing the number of acetylcholine receptors increases cells' sensitivity to acetylcholine.
乙醯膽鹼受體數目增多會增加細胞對乙醯膽鹼的敏感度

C. Individual receptors produce 50 % of their maximal signal when treated with 1 mM acetylcholine.當以 1 mM 乙醯膽鹼處理時,每個受體會產生其最大訊號的50%

Calculate the minimum proportion of receptors which, when fully active, are sufficient to generate the maximal response.
請計算當被完全活化時可產生最大反應的最少受體百分比

A. Choose the nearest proportion to the correct answer.
請選擇最接近的正確百分比選項

DRUNK FLIES 醉蠅

he most important signalling pathways of development and cancer were discovered by epistasis analyses in fruit-flies *(Drosophila melanogaster)*. Such screens also showed the protein encoded by the Arouser gene mediates signals along the Epidermal growth factor receptor (Egfr) pathway in neurons. *Arouser* knockout flies are unusually sensitive to ethanol (get drunk easily).
透過對果蠅（*Drosophila melanogaster*）上位基因的分析，發現發育和癌症最重要的信號路徑。這種篩選也顯示由醒酒基因編碼的蛋白質可調節控制神經元表皮生長因子受體（Egfr）途徑的信號。 醒酒基因剔除的果蠅對乙醇非常敏感（易醉）。

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

A. Wild type Arouser facilitates alcohol tolerance.
野生型的醒酒基因有助於對酒精的耐受性。

B. Blocking Egfr activity increases alcohol sensitivity.
阻止Egfr 的活性會增加對酒精的敏感性。

C. Over-expression of *Akt* in *arouser* knockout flies increases alcohol sensitivity.
醒酒基因剔除的果蠅*Akt* 會過度表現而增加對酒精的敏感性。

D. Socially isolating *arouser* knockouts makes them more like WT flies.
在社群上隔離醒酒基因剔除的果蠅會使它們更像野生型果蠅。

OPTOGENETICS 光遺傳學

Tim Bliss (1940-present) discovered that stimulating a neuron sensitises it to future stimulation, and that this is a basis of long term memory. This can occur because stimulation leads to transcription of ion channel genes. One of these channels was fused to a light sensitive protein, which allows it to be activated by fiber-optic implants, and cloned into mice.
蒂姆·布利斯（Tim Bliss，1940年至今）發現，刺激神經元會使其對未來的刺激更加敏感，這是長期記憶的基礎。主要是因為刺激會導致離子通道基因的轉錄。光敏蛋白可被特殊光纖活化，可將光敏蛋白質與這些離子通道結合，並植入到小鼠體內。

The mice were treated as follows:
(1) Transcription of this channel was blocked in every cell, until adult mice were first shown a particular, non-threatening stimulus.
(2) Transcription of this channel was re-blocked in every cell.
(3) Mice were given an electric shock, causing them to freeze. In a subset of mice, electrocution was accompanied by a flash of fiber optic light to the brain.
(4) Mice were shown the non-threatening stimulus again.
上述基因轉殖小鼠按下列步驟處理(如圖)：
（1）對離子通道之轉錄被阻斷的成年老鼠給予一特定但不具威脅性之刺激。
（2）這個離子通道之轉錄又被阻斷。
（3）小鼠受到電擊，導致產生呆滯行為(freezing)。然而在一小部分小鼠中，伴隨著光纖對腦部之刺激導致觸電。
（4）小鼠再次處於不具威脅性之刺激。

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 freezing behaviour in (4) is explained by mice forming an association between flashing lights and electrocution.
圖中(4)呈現之呆滯行為可解釋為小鼠已將閃光及觸電產生連結

B. The same neurons are activated by electric shock and fiber optic lights.
電極和光纖活化相同神經元。

C. Flashed mice have a false memory of the non-threatening stimulus.
接受光纖照射的小鼠對非威脅性刺激建立了錯誤的記憶。

D. Control mice are likely to freeze if they are shown the electric shock apparatus after the experiment.
對照組的老鼠如果在實驗後給予電擊刺激，則也有可能產生呆滯的反應。

BURROWING MICE 洞穴老鼠

Sir Francis Galton (1822-1911) invented the field of behavioural genetics.
Burrowing mouse *(Juscelinomys)* burrows have quantifiable features, including presence or absence of an escape tunnel (1) and length of the entrance tunnel (2).
Species A and Species B were crossed. The first generation of the cross (F1), were back-crossed (BC) with Species A.
In BC mice, there is no correlation between entrance tunnel length and the presence or absence of an escape tunnel.
弗朗西斯·加爾頓爵士（1822-1911）發明了行為遺傳學領域。
挖洞鼠（*Juscelinomys*）洞穴具有可量化的特徵，包括逃生隧道（1）的存在與否以及入口隧道（2）的長度。
物種A和物種B雜交，其第一子代（F1）與物種A進行了反交（BC）。
在BC小鼠中，入口隧道長度與逃生隧道的存在與否之間沒有相關性。

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

A. Entrance tunnel length is determined by a single locus (gene).
入口隧道長度是由單個基因座（基因）決定。

B. Alleles for the presence of an escape tunnel are dominant to those for absence of an escape tunnel.
具有逃生隧道的等位基因對於沒有逃生隧道的基因而言是顯性的。

C. F1 hybrids can be distinguished from Species A and Species B by looking at their burrows.
F1雜交種可以藉由觀察它們的洞穴來區分物種A和物種B.

D. Genes determining entrance tunnel length and the presence or absence of escape tunnels are close to each other in the genome.
決定入口隧道長度的基因和逃生隧道存在與否的基因，在基因組中是彼此靠近的。

TRAVELLING SALES-BEES
旅行中的推銷員 --蜜蜂

Radar, invented in the UK, was used to track the flight of English bees *(Apis mellifera)*. To investigate how bees forage, the following experiment was performed:
雷達是在英國發明的，用於跟踪英國蜜蜂（*Apis mellifera*）的飛行。為了研究蜜蜂飼料，進行以下實驗：

(1) Fake flowers were filled with syrup, and the bees were released from a nest-box.
（1）將糖漿注入假花中，蜜蜂從巢箱中釋放出來。

(2) Bees were given time to build experience of the setup.
（2）讓蜜蜂對設計的設施有一段接觸的經驗。

(3) Syrup was removed from one flower, leaving it empty, and placed in another..Syrup was removed from one flower, leaving it empty, and placed in another.
（3）將糖漿從其中一朵花中取出放在另一朵花中，原花朵不再注入糖漿。

(4) Bees were allowed to build experience of the new set up. Representative flights are shown (a & b).
（4）讓蜜蜂對於新設立的環境建立接觸的經驗。圖（a&b）顯示兩隻蜜蜂的飛行概況。

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

A. Bees continually attempt to optimise the shortest route to harvest syrup from the flowers.
蜜蜂不斷嘗試找出最適合之最短路線來收穫假花中的糖漿。

B. Experienced bees do not search for new flowers unless the environment changes.
有經驗的蜜蜂除非環境改變，否則不會去尋找新的花朵。

C. Bees exhibit signs of confusion if they encounter unexpected features on their route.
蜜蜂會顯示出困惑的跡象，如果牠們在路上遇到意想不到的事物。

D. Bees visit all the nutritious flowers within range of their nest.
蜜蜂會探訪巢區內所有具糖漿的花朵。

MEMES

Rchard Dawkins (1941-present) invented the idea of memes, and Sir Frederic Bartlett (1886-1969) showed previous knowledge alters the processing of new stimuli. Bartlett asked British people to reproduce a drawing of Native American masks from memory. This was passed to a new person to memorise and reproduce, and the reproduction passed on, several times in succession (1). This study has been repeated recently (2). Representative reproductions are shown.

Richard Dawkins 提出memes的想法，而Sir Frederic Bartlett 提出先備的知識會改變對新刺激的處理。Bartlett要受測者人依據看過後的記憶畫出美國原住民的面具，給另一人看，然後再畫出，如此重製過程連續進行數次如圖中1，最近這個研究被重新做一次如圖中2，其中代表性的結果在此呈現

Indicate whether each of the following statements is more true of Bartlett's experiment (1) or the repeat experiment (2).
回答下列敘述是對Bartlett的實驗(1)較適切，或是對新重複的實驗(2)較符合

A. Memories tended to simplify the original object.
記憶傾向簡化原本物件

B. Objects tended to be remembered as more similar to familiar objects than is actually the case.
被記憶的物體容易被記成較熟悉的相似形像，而非真實形像

C. The participants of the study were instructed to focus on making accurate reproductions.
參與實驗的人曾被教導要專心畫出正確複製

D. Memories included features not present on the actual object.
記憶包含不存在於真實物件中的特徵

THE PITUITARY GLAND 腦下垂體

The hypothalamus is the central regulator of homeostasis, whilst diverse hormones from the posterior and anterior pituitary glands orchestrate most bodily functions. To investigate how these three structures coordinate their actions in rats *(Rattus norvegicus)*, each was electrically stimulated, and the effect on hormone secretion from both pituitary glands was observed (1). Secondly, whole rat pituitary glands were transplanted to locations with different blood supplies, to reveal why they usually receive blood from hypothalamic veins (2).
下視丘是體內恆定的調節中樞，而來自腦垂腺後葉和前葉的多種激素支配身體大部分的功能。為了研究大鼠（*Rattus norvegicus*）中這三種結構如何協調其作用 ，電刺激這三種結構，並且觀察腦垂腺對激素分泌的影響（1）。其次，將全腦垂腺移植到不同血液供應處，以揭示其為什麼通常從下視丘之靜脈接受血液（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. The hypothalamus controls secretion of hormones from both pituitary glands.
下視丘控制腦垂腺前後葉分泌激素。

B. Hypothalamic blood specifically has factors necessary for the survival of the anterior pituitary.
下視丘血液中具有維繫腦垂腺前葉生存所必需的因子。

C. Hypothalamic neurons innervate the posterior pituitary.
下視丘的神經元支配腦垂腺後葉。

D. Hypothalamic hormones cause the posterior pituitary to secrete hormones.
下視丘分泌之激素引起腦垂腺後葉分泌激素。

OBESE MICE 肥胖小鼠

Sir Frederick Banting (1891-1941) and John Macleod (1876-1935) discovered insulin and invented modern diabetes treatment. This inspired similar investigations into body weight homeostasis and obesity: two mouse *(Mus musculus)* lines (obese; Ob, & diabetic; Db) have identical over-eating phenotypes. Each is deficient for a single, but different, gene. Damaging the arcuate nucleus in the brain, which is the structure soley responsible for regulating the sensation hunger, produces a similar phenotype. Mice were joined surgically, allowing a small amount of blood to flow between them, and then observed.
弗雷德里克·班廷爵士（1891-1941）和約翰·麥克勞德（John Macleod）（1876-1935）發現胰島素並發明了現代糖尿病治療的方法。這也激發了對體重恆定和肥胖的相關研究：兩種不同品系老鼠（*Mus musculus*）系（肥胖鼠，簡稱Ob，糖尿病鼠;簡稱 Db）都呈現過度飲食的表型。雖然老鼠都呈現過度飲食，但分別缺損的是不同的基因。弓狀核主要調節體內飢餓的感覺，所以破壞大腦中的弓狀核也會有過度進食的現象。將不同小鼠利用手術連接，允許少量血液在它們之間流動，然後觀察其反應，並請依照實驗結果，回答下列問題。

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

A. Surgical connection allows mice to freely share nutrients.
手術之連結允許老鼠自由地分享營養物。

B. Db mutants overproduce an appetite suppressing substance.
Db突變鼠將會大量產生食慾抑制物質。

C. The products of genes Ob and Db act in the same pathway.
基因Ob和Db的產物作用在相同的路徑。

D. The WT product of gene Ob promotes a pathway which activates the arcuate nucleus.
野生型小鼠（控制組）體內基因Ob的產物可活化弓狀核。

E. Some cases of human obesity can be treated by administering a hormone.
可以藉由施打激素治療一些人類肥胖的病例。

SHARING THE WORLD 分享世界

EUTROPHICATION 水體優養化

The use offertiliser s, and release of sewage, have altered the balance of nitrogen and phosphorus based nutrients in the environment. Additionally, nitrogen oxides from pollution dissolve in rain to form acids. Growing algae incorporates an average of 16 nitrogen atoms per phosphorus atom, and eutrophication occurs when algal decomposition depletes oxygen. In 1957, the River Thames was declared 'biologically dead', without oxygen, but is now among the world's healthiest major rivers. Phosphorus availability (1), and nitrogen:phosphorus molar ratio (2) was measured across Northern Europe.
使用肥料和排放污水，改變了環境中氮及磷營養鹽的平衡。此外，來自污染物的氮氧化物在雨中溶解形成酸。生長的藻類藉著每個磷原子平均與16個氮原子結合，當藻類死亡分解時消耗大量氧氣，形成缺氧環境，則會產生優養化現象。在1957年，泰晤士河因缺氧被宣佈為“生物死亡”，但現在是世界上最健康的主要河流之一。在歐洲北部各地測量磷的可利用率（1）和氮：磷的摩爾比（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. The risk of eutrophication would be much lower if European farmers reduce phosphate, but not nitrogen, fertiliser use.
如果歐洲農民減少磷酸鹽的使用，而不是減少氮肥及肥料的使用，優養化的風險將會降低許多。

B. Nitrogen oxide pollution increases the risk of eutrophication around Great Britain.
氮氧化物的污染會增加英國境內優養化的風險。

C. Based on nutrient levels, British waters contain most of Europe's large, energetic fish species.
從營養量而言，英國海域包含絕大多數的歐洲大型、好鬥的魚種。

D. European rivers are more polluted with phosphate than nitrogen.
歐洲河流磷酸鹽的汙染比氮嚴重。

E. Nutrient levels allow algae to grow quicker along the East coast of Denmark, than the West.
營養鹽的濃度使得藻類在丹麥東海岸比西海岸更快地生長。

ELISA 酵素鍵結免疫吸附分析

John Marrack (1886-1976) discovered the biochemistry of antibody-antigen interactions. These can be harnessed to detect pesticides contaminating sample water:
約翰·馬拉克（John Marrack，1886-1976）發現抗體 - 抗原反應的生化作用。其可用來檢測水樣品中汙染的殺蟲劑：
1) Wells are coated in the pesticide.
1）將殺蟲劑塗到樣品槽中。
2) A very small amount of antibody against the pesticide is mixed with sample water, and then the mix is transferred to the wells.
2）將非常少量的殺蟲劑抗體與樣品水混合，然後將混合物轉移到樣品槽中。
3) The wells are washed with clean water several times.
3）用乾淨的水清洗樣品槽數次。
4) An enzyme that produces a blue pigment, which is attached to a secondary antibody that binds the first antibody, is added.
4）加入二級抗體與第一種抗體結合。二級抗體上鍵結有會產生藍色素的酵素

Different antibodies (X, Y & Z) can be used for this process.
不同的抗體（X，Y和Z）可用於此步驟。

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

A. To test for atrazine specifically, antibody Y should be used.
要測定atrazine的特異性要用抗體Y

B. All these pesticides probably have the same mechanism of action.
所有這些殺蟲劑的作用機轉相同

C. All these antibodies could come from the same mouse injected with atrazine.
這些抗體可來自同一隻注射過atrazine的小鼠

D. Darker blue wells contained water which was more contaminated with pesticide.
水樣品中汙染的殺蟲劑越多其產生的藍色素顏色越深

MADAGASCAR 馬達加斯加

The Royal Botanic Gardens, Kew, is responsible for the millennium seed bank, including archiving the 70% of Madagascan plant species that are threatened with extinction. The shape of a plant phylogeny can be used to prioritise species for conservation.
皇家植物園Kew負責千年種子庫，其中包括70%的受到滅絕威脅的馬達加斯加的植物種類。植物系統演化的圖譜可用於判別需優先保育植種的選取。

The tree fern (*Cyatheales*) phylogeny is typical of plants (1).
樹蕨（ *Cyatheales* ）系統演化是植物的典型（1）。
The chance of plants being at risk of extinction is related to the age of the species (the length of its branch on a phylogeny) (2).
植物面臨滅絕危機與物種的年齡（其分支在系統演化中的長度）有關（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. The vast majority of Madagascan species are likely found nowhere else.
絕大多數的馬達加斯加種類都不可能在其他地方找到。

B. The age of Madagascan species accounts for their unusually high extinction risk categorisations.
馬達加斯加物種的年齡顯示了該地屬於超乎尋常高的滅絕風險特質。

C. Globally, Kew should focus on collecting seeds from old species.
就全球觀點而言，英國皇家Kew植物園應該集中在收集古老植種的種子。

D. Failure to bank any Madagascan seeds will result in a greater loss of evolutionary history and genetic diversity than failure to bank African species.
未收集馬達加斯加植種的物種對物種演化和遺傳多樣性所造成的損失將大於未收集非洲物種的種類。

WINDFARMS 風電場

The UK is extending the world's largest offshore windfarm in the North Sea. However, disruption to wind patterns, and other effects, causes difficulties for birds. Several windfarms were previously built in the habitats of red grouse (*Lagopus lagopus scotica*), snipe (*Gallinago gallinago*), skylark (*Alauda arvensis*), curlew (*Numenius sp.*), and meadow pipit (*Anthus pratensis*).The population density of these species was compared to undisturbed habitats before, during and after windfarm construction.

英國正在北海擴建世界上最大的海上風電場。然而，風型的改變以及其他的影響對鳥類造成困擾。之前有幾座風電場建立在紅松雞（ *Lagopus lagopus scotica* ），田鷸（ *Gallinago gallinago* ），雲雀（ *Alauda arvensis* ），大杓鷸（ *Numenius sp* ）和草鷚〈*Anthus pratensis* ）的棲地上。這些鳥種族群的密度在這些風電場施工前、施工中及施工完成後，與未受干擾之棲地進行比較。

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 process of windfarm construction reduces the red grouse population.
風電場在建設過程中使紅松雞的族群減少。

B. Of the species studied, finished windmills are only dangerous to curlews.
在研究的物種中，興建完成後的風電廠只有對大杓鷸產生影響。

C. The study windfarm is located in better red grouse habitat than the control site.
本研究所選的風電場所在之環境對紅松雞而言，與對照組所處環境相比是較好的棲地。

D. An environmental change, other than windfarm construction, is harming the snipe population.
除了風電場之建設外，環境變化正在危害田鷸的族群。

POPULATIONS 族群

The world's longest conservation efforts have restored the populations of many native British species, but several aliens are also thriving.
世界上最久的保育工作已經恢復了許多英國本土種類的種群，但是幾種外來種也在大量繁殖。
(1) Rabbits *(Oryctolagus cuniculus)* were introduced to Great Britain ~ 2000 years ago by the Romans.
（1）兔子（*Oryctolagus cuniculus*）由羅馬人引進到英國～2000年前。
(2) A pair of Parakeets *(Psittacula krameri)* was released into London by Jimi Hendrix.
（2）吉米·亨德里克斯（Jimi Hendrix）將一對長尾小鸚鵡（*Psittacula krameri*）野放到倫敦。
(3) Native Peregrine Falcons *(Falco peregrinus)* nest in London, which as Europe's largest city, provides ample nest sites and prey, including parakeets.
（3）倫敦是歐洲最大的城市，它提供了本地的游隼（*Falco peregrinus*）許多築巢地點及獵物，包括長尾小鸚鵡。

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

A. Myxomatosis resistance in British rabbits arose around 1950.
英國兔子對粘液病毒的抵抗性約在1950年代顯現。

B. Peregrine falcons are effective biocontrols for the parakeet population.
游隼是對長尾小鸚鵡種群有效的生物防治。

C. Removing rabbits from the UK would help conservation of native species such as Peregrines.
將兔子從英國移除有助於保護本地種類，如游隼。

SEA URCHINS 海膽

Sea urchins *(Echinoidea)* are a major food source of otters*(Enhydra lutris)*. Sea urchin populations tend to explode where sea beds have been damaged by human activities. Sea urchins, limpets (*Patella vulgata*) and seaweeds can live together. Seaweed coverage was measured in an experimental area where the populations of urchins and limpets was artificially controlled.

海膽（*Echinoidea*）是水獺 *(Enhydra lutris)* 的主要食物來源。海底常因人類活動而受到破壞，使海膽族群暴增。海膽、鑰孔螺和海藻可共同生存。在實驗區對海膽和鑰孔螺進行人工控制，並針對海藻覆蓋率進行測量。

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

A. Limpets affect seaweed growth when sea urchins are present.
當海膽存在時，鑰孔螺會影響海藻生長。

B. Sea urchins have a bigger effect on seaweed than limpets have on seaweed.
海膽對海藻的影響比鑰孔螺對海藻的影響要大。

C. Sea urchins help damaged seabeds recover.
海膽幫助受損的海床恢復。

D. Increasing the number of otters increases ocean primary productivity.
增加水獺數量增加了海洋初級生產力。

CUCKOOS 杜鵑

The Island of Great Britain is a critical hub for migrating birds, from as far away as Canada and South Africa, due to its mild climate and well preserved habitats.
由於氣候溫和，保存良好的棲息地，英國島嶼是遷徙鳥類的重要樞紐，包括遠自加拿大和南非來的候鳥。

Cuckoos *(Cuculus canorus)* are one migratory species which has seen its population decline in recent years. Therefore, many cuckoos had trackers attached to them, and were monitored over several years. Their Autumn migration routes are shown (1). A roughly equal number of birds took the Eastern and Western routes through Africa. Points at which tracked birds died are shown.
杜鵑（*Cuculus canorus*）是一種近年來族群減少的候鳥物種。因此，許多杜鵑被標放追蹤器，進行好幾年的監測。他們的秋季遷徙路線如（1）所示。鳥群遷徙到非洲的路線，穿過東邊和西邊路線的數量大致相當。跟踪標放的鳥，記錄到死亡地點。

The change in cuckoo populations in different regions of Great Britain, and the migration route which these populations take are shown (2).
在英國不同地區杜鵑種群的變化以及這些種群的遷徙路線可由（2）顯示。

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

A. Conditions for birds migrating along the western route have changed in recent years.
近年來，沿西線遷徙的鳥類環境概況發生了變化。

B. Crossing the Sahara desert is the biggest challenge for migrating cuckoos.
穿越撒哈拉沙漠是遷移杜鵑的最大挑戰。

C. Mortality rates during migration have an important impact on the population sizes of cuckoos in different parts of Britain.
遷移期間的死亡率對英國不同地區的杜鵑族群量有重要影響。

D. These data would be consistent with Summer conditions within Britain, before migration begins, determining mortality rates during migration.
這些資料與英國夏天遷移開始前的環境狀況是一致的，決定了杜鵑遷移期間的死亡率。

WILDCATS 山貓

Lynx *(Lynx lynx)* may be reintroduced to Great Britain in 2017, after being hunted to extinction 1300 years ago. Scottish wildcats (*Felis silvestris grampia*) are Britain's only remaining endogenous cat species, and are distinguished from wildcats (remaing endogenous cat species, and are distinguished from wildcats (*Felis silvestris silvestris*) by their larger size, thicker fur, and unique hunting technique. Feral domestic cats (*Felis silvestris catus*) are also present in Scotland.
Lynx 山貓（*Lynx lynx*）可能於2017年被重新引入英國，在1300年前被狩獵滅絕。蘇格蘭野貓（ *Felis silvestris grampia* ）是英國唯一存在的本地貓科動物，與野貓（ *Felis silvestris silvestris* ）的區別在於它們的體型更大，毛皮更粗糙及獨特的狩獵技巧。野生家貓（ *Felis silvestris catus* ）也出現在蘇格蘭。

Motion-sensitive cameras in 347 Scottish locations captured 200 000 images, and volunteers used these to identify wildcats, feral cats, and hybrid cats by their markings.cats by their markings.
利用在蘇格蘭地區347個不同點所設置的對移動敏感的相機所拍攝的20萬張影像，志願者利用各貓種間不同的特性來分辨野貓、野生家貓和混種貓。

In one year they found 10 different Scottish wildcats. In the next year, they found 9 different Scottish wildcats, one of which had the same markings as a cat photographed in the preceding year.
在一年中，他們發現了10隻不同的蘇格蘭野貓。第二年，他們發現9隻不同的蘇格蘭野貓，其中之一與前一年拍攝的貓相同。

Additionally, they estimated that there were about 500 feral cats, and 300 hybrid cats in the area.
此外，他們估計在該地區大約有500隻野生家貓，以及300隻混種貓。

Estimate how many Scottish wildcats there are in Scotland.
估計蘇格蘭有多少蘇格蘭野貓？

A. Choose the nearest number to the correct estimate.
選擇最接近的正確估計值。

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

A. Neutering feral cats would help prevent the Scottish wildcat population becoming less fit over time.
結紮野生家貓將有助於防止蘇格蘭野貓種群隨著時間的變化，降低其適應性。

B. Vaccinating feral cats would be an effective way to prevent transmissible disease in Scottish wildcats.
對野生家貓進行防疫接種，將是防止疾病在蘇格蘭野貓族群中傳播的有效途徑。

C. Two species which have coexisted in the same region for thousands of years, are more likely to interbreed than two species which have recently come into contact but are equally genetically divergent.
在同一地區共同存在數千年的兩種物種比最近接觸但同樣具有遺傳差異的兩種物種更有可能發生雜交。

SOIL BACTERIA 土壤細菌

Sequencing of ribosomal RNA genes (rDNA), which have very low diversity within families, reveals the identity and relative abundance of bacterial families in different soils.
核糖體RNA基因(rDNA)在相同科的細菌中多樣性很低，而rDNA測序卻揭示了在不同土壤中細菌科的身份辨識和相對豐度。
Bacteriovoracaceae and *Bdellovibrionaceae* are predatory bacteria. Each has a different maximum growth rate in optimal conditions.
Bacteriovoracaceae and *Bdellovibrionaceae* 兩科是掠食性細菌。各具有不同的最佳條件及最大生長速率。
Haliangiaceae 和 *Koribacteraceae* 兩科則是非掠奪性的細菌。

指出下列敘述是正確或錯誤。

A. *Bdellovibrionaceae* and *Bacteriovoracaceae* occupy different niches.
*Bdellovibrionaceae*和*Bacteroeoracaceae*佔據不同的區位。

B. *Bacteriovoracaceae* is an important predator of *Haliangiaceae*.
*Bacteriovoracaceae*科是*Haliangiaceae*科細菌的重要捕食者。

C. *Bacteriovoracaceae* and *Koribacteraceae* might occupy different habitats.
Bacteriovoracaceae 和 *Koribacteraceae* 科細菌可能有不同的棲地。

D. rDNA sequencing could be used to assess the abundance of individual *Bacteriovoracaceae* species.
rDNA 定序可用來評估*Bacteriovoracaceae*個別物種的豐度。

HAPLOTYPE NETWORK 單倍型網絡

A haplotype network shows the evolutionary relatedness of haplotypes, and the proportion of individuals from a specific population with each haplotype. The 1000 genomes project, coordinated by the European Bioinformatics Institute in England, allows a global human haplotype network to be produced.
單倍型網絡可以顯示單倍型的演化相關性，以及來自具有每個單倍型的特定族群的個體之比例。由英國歐洲生物資訊學研究所來負責協調的1000個基因組計畫，製作出一個全球人類單倍型網絡，如下圖。

The circles represent one haplotype, each from the same locus.
圓圈代表一個單倍型，各自來自相同的基因座。

The colours represent different populations by geographic location.
不同顏色代表依地理位置區分的不同族群。

The lines represent an evolutionary link between two haplotypes.
這些線代表兩個單倍型之間的演化連結。

Denisovans are a non-human subspecies of the genus *Homo*. Tibetans are an Asian population, closely related to their neighbours across most of their genome.
丹尼索瓦人(Denisovans) 是智人屬 (*Homo*) 的非人類亞種。

Tibetans are an Asian population, closely related to their neighbours across most of their genome.
西藏人是亞洲族群，其與鄰近族群的大部分基因組有密切相關。

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 British are more related to the Finnish than the British are to Yorubians at this locus.
以此基因座而言，英國人與芬蘭人的親緣比起英國人與優魯班人的關係更近。

B. Tibetans have a higher genetic diversity than Han Chinese at this locus.
以此基因座而言，西藏人比漢族具有更高的遺傳多樣性。

C. The Yorubian people are found in Africa.
優魯班人在非洲被發現。

D. Tibetan ancestors interbred with Denisovans after leaving Africa.
西藏人的祖先在離開非洲之後，與丹尼索瓦人雜交。

EVOLUTIONARY GENETICS 演化遺傳學

Charles Darwin's (1809-1882) discovery was united with Mendelian genetics by Sir Ronald Fisher (1890-1962) and John Haldane (1892-1964). Equations then allowed biologists to predict evolution, including the evolution of complex traits like behaviour, and quantitative traits like height.
Sir Ronald Fisher 和 John Haldane 將達爾文的發現和孟德爾的遺傳學結合。之後，生物學家利用數學程式可以預測演化，包括一些複雜的性狀，像是行為；以及數量性狀，如身高

Symbol 符號	Definition 定義
r	The relatedness of two individuals 二個體間的相關性
n_i	The number of alleles the two related individuals share 二相關個體所具有的共同等位基因數目
n_p	The number of alleles shared on average between two members of the population 族群中二個體間所具有的共同等位基因的平均數目
Nt	The total number of alleles in the genome 基因組成中等位基因的總數
w	Inclusive fitness 總適應度
D	Direct fitness: the number of offspring an individual has, multiplied by the relatedness (r) of each of those offspring to the individual. 直接適應度：一個體的子代數目乘上各子代和此個體的相關性
I	Indirect fitness: the number of offspring an individual's relative has, multiplied by the relatedness (r) of each of those offspring to the individual. 間接適應度：一個體親人的子代數目，乘上各子代和此個體的相關性
C	The cost an individual's behaviour has to the number of offspring that it can produce. 一個體產生子代數所付出的代價
B	The benefit an individual's behaviour has to the number of offspring that a relative can produce. 一個體因親戚所產生的子代數目而獲得之利益
g	Genetic value of an individual: the value a quantitative trait would have, if no environmental influences acted on it. 一個體之遺傳價值：在沒有環境影響下，一數量性狀值
Δ_s	The change, between generations, due to natural selection. 親代和子代間，因天擇造成之改變
$\beta_{w,g}$	The correlation between fitness (w) and genetic value (g). 適應度(w)和遺傳值間的相關性
var(g)	The variance in genetic value (g) in a population 族群內遺傳值的變方

Rule for adaptive behaviours/traits 適應性行為/表徵的規則	Equation 方程式
Relatedness 相關性	$\mathbf{r = (n_i - n_p) / N_t}$
Inclusive fitness 總適應度	$\mathbf{w = D + I}$
Hamilton's rule 漢米爾頓規則	$\mathbf{C < r\ B}$
Price equation 普萊士方程式	$\mathbf{\Delta_s\ g = \beta_{w,g}\ var(g)}$

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

A. Spiteful behaviours (cost to the actor and recipient) exist when actors are more related to recipients than expected by chance.
當主動者和接收者之間相關性較高時，損人不利己的行為(主動者和接收者皆會付出代價)會比隨機發生時要高

B. These equations predict alleles exist which produce a recognisable trait (e.g. appearance or pheromones) and also cause altruism towards unrelated individuals with that trait.
這些方程式預測產生可辨認的表徵(外表和費洛蒙)的等位基因是存在的，同時，對具這些表徵的無相關個體也會有利他表現

C. These equations predict stress responses in some organisms include purposeful increases in mutation rate.
這些方程式預測一些物種的逆境反應，包括有目的的增加突變率

D. Naked mole rat *(Heterocephalus glaber)* colonies of many adults, with a single breeding pair, can be explained by inclusive fitness.
裸鼴鼠的群落中,有很多成鼠，但只有一對生育鼠，這可以用總適合度來解釋

E. Natural selection acts more quickly when aphids are in their sexual lifecycle, than asexual lifecycle.
自然淘汰在蚜蟲有性生活週期中的作用比在其無性生活週期中較快

BUTTERFLY EYESPOTS 蝴蝶眼斑

To investigate the evolution of butterfly eyespots, their mean size and colour was measured in each generation. Butterflies were split into 4 groups based on the colour (width of the golden ring) ratio (1), or size ratio (2), of their top and bottom eyespots. The most extreme butterflies in each group were bred together, and this was repeated with each successive generation.
為研究蝴蝶眼斑的演化，量測每一代眼斑的大小和顏色。依據上下翅面的眼斑顏色(金環寬度)比(1)，或是大小比(2)，可將蝴蝶分為4群。將每一群中最極端的蝴蝶養在一起，每一代皆如此。

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

A. Top:bottom eyespot colour ratio has greater genetic variation than top:bottom eyespot size ratio.
正面：底面眼斑顏色比的遺傳變異性比正面：底面眼斑大小比要大

B. Simply selecting for top eyespots which are more golden will produce bottom eyespots which are more golden.
對正面眼斑選拔更多金色，也會讓底面的眼斑更金

C. Many relatives of this species have very different top:bottom eyespot size ratios.
這種蛾的相近種具有非常不同的正面/底面比

D. Eyespot size would remain constant if random butterflies of this experimental population were mated.
如果族群中的蝴蝶隨機交配，則族群眼斑大小會維持固定

INDUSTRIAL MELANISM 工業化後的黑變症

The light-coloured form of the English peppered moth *(Biston betularia)* was replaced by a melanic (dark) form, as camouflaging lichens disappeared due to pollution during the industrial revolution. Clean air, lichens and light moths have now returned.
To discover the genetic basis of this, hundreds of moths were genotyped and haplotypes were determined. Melanism was due to a dominant mutation in the *cortex* gene. *Cortex* mRNA is cut (spliced) into two forms, Cortex-1A and Cortex-1B. Cortex mRNA abundance was measured.
在工業革命時期，因為汙染，導致偽裝地衣的消失，進而使得淺色的英國斑點蛾被深色的斑點蛾取代。現在乾淨的空氣，地衣和淺色斑點蛾又回來了。為發現這變化的遺傳基礎，將數百隻的斑點蛾做基因型鑑定，決定其單倍型(haplotypes)，黑變症是由於在 *corte*x 基因發生的顯性突變造成。*Cortex* mRNA經由RNA剪接，可以得到二種型，Cortex-1A 和 Cortex-1B. 對Cortex mRNA的量進行量測。

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

A. There is a greater diversity of haplotypes in the population close to the melanic *cortex* allele, than further away.
在族群中，靠近深色cortex等位基因處的單倍型多樣性會較大，遠離則降低。

B. *Cortex-1A* is more likely to be driving melanism than *Cortex-1B*.
Cortex-1A比Cortex-1B 較有可能是控制黑變症的原因

C. The expression data are consistent with the melanic phenotype being dominant.
表現量的資料和深色表現型是顯性的現像是一致的

D. The light form has reappeared because of Cortex-1A and Cortex-1B. Cortex mRNA (reversion).
淺色蛾的再出現，是因為回復突變所致