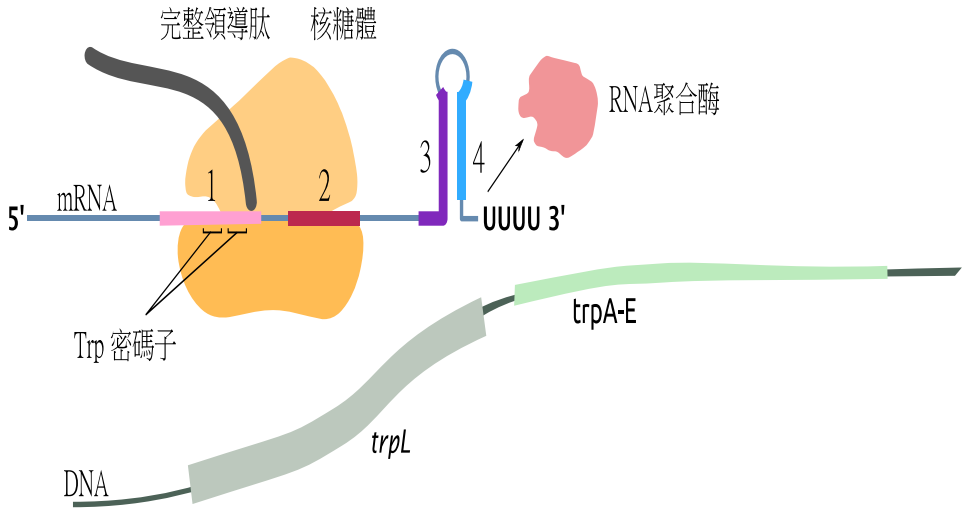
IBO 2013 Theoretical Exam 1

1

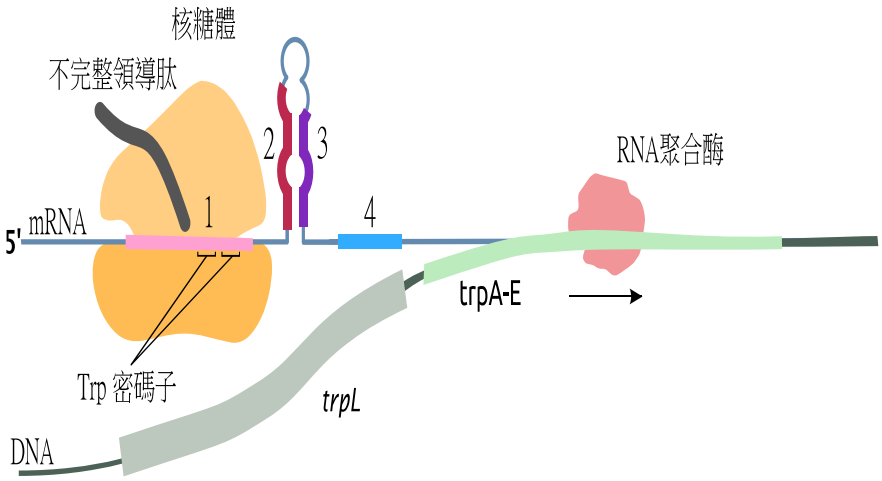
Cell-, molecular- and microbiology

某些細菌擁有調節生產參與色胺酸（Trp）生合成的酵素之額外機制。色胺酸（Trp）操縱組位在實際基因(*trp*A-E)前方，含有領導肽序列（*trp*L），其編碼能合成領導肽。領導肽序列（*trp*L）包含彼此連續的2個色胺酸密碼子。

在色胺酸濃度高時，核糖體轉譯領導肽的mRNA會停坐在終止密碼子上，因而罩蓋住mRNA的片段2，使片段3及4形成環套。環套而後會接上poly-U，而形成RNA聚合酶(RNA　pol)的一個終止信號，使其從DNA上離開。



然而，在色胺酸濃度低時，核糖體會停駐在色胺酸密碼子上，使片段2和3形成環套，整個色胺酸操縱組便可被RNA聚合酶轉錄。



指出下列各敘述的對或錯。

A. 相同的調節機制也適用於真核細胞的核基因中。

B. 當胺基醯tRNA合成酶（可將色胺酸附著在$tRNA^{Trp}$）濃度降低時，*trpA-E*基因的轉錄將會在色胺酸濃度較低時發生去活化。

C. 在刪除編碼領導肽基因中的2個色胺酸密碼子之一以後，*trpA-E*基因的轉錄將會在色胺酸濃度較低時發生去活化。

D. 若某一突變能破壞環套2-3的穩定性，則*trpA-E*基因的轉錄將會在色胺酸濃度較低時發生去活化。

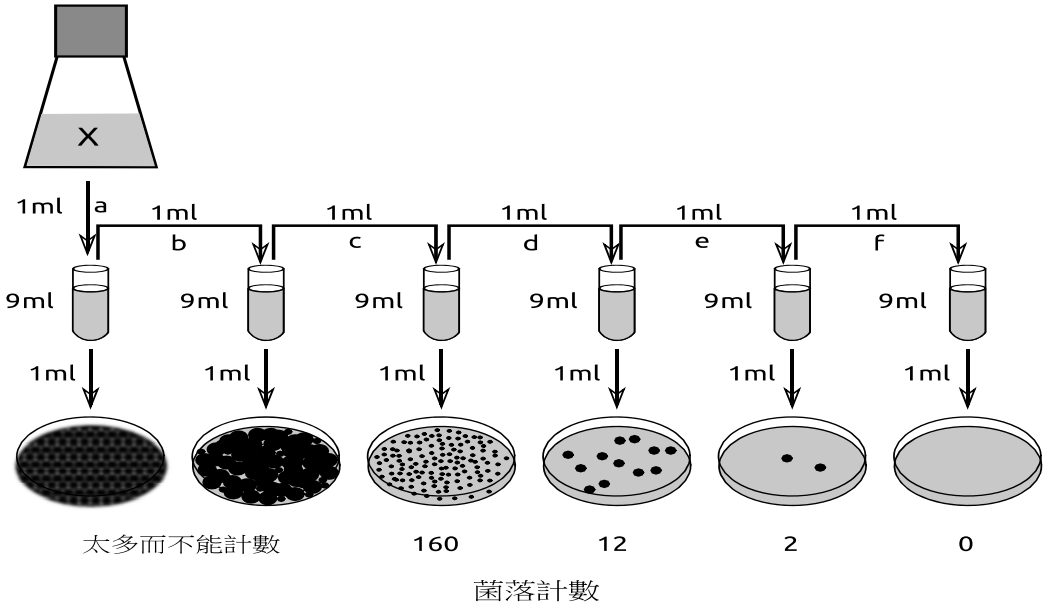
A. False **B.** False **C.** True **D.** True

Original commentary
Correct answers
A *false*
the mechanism works only if the translation begins before the transcription finishes. In eukaryotes, the transcription happens in the nucleus, then the mRNA is exported to the cytoplasm where it is translated and this mechanism cannot work in this form.
B *false*
by reduced concentrations of the tryptophan's aminoacyl-tRNA synthetase, tRNA loaded with tryptophan will be formed slower than in the normal case, so that less tRNA-Trp will be present. To inactivate the transcription of the trpA-E genes, a higher tryptophan concentration than in the normal case is needed.
C *true*
with only 1 Trp codon, a lower concentration of Trp can still allow translation of the leader peptide and therefore inhibit the synthesis of the enzymes.
D *true*
a mutation destabilizing stem loop 1-2 will promote the formation of stem loop 2-3 even at low tryptophan concentrations, inhibiting the transcription of the trpA-E genes.

References
Walsh et al, Biochemistry (1979)

Own commentary

計算液態培養基中的細菌數可用不同方式進行：(1)用細胞計數盤在顯微鏡下計數;(2)用分光光度計測量培養液吸光度後，再推算細菌數(在A_{600} = 1時相當於每毫升$8x10^8$細菌);(3)將培養液稀釋數次，再塗於洋菜培養基上，然後以菌落數(見圖)回推每毫升可形成菌落的細菌數（cfu/ml）。



指出下列敘述是對或錯。

A. 有一 A_{600} = 0.1含細菌的培養液，若其倍增時間為 30 分鐘，不用2個小時細胞數即可增長到 4×10^8 個/ml 。

B. 以洋菜培養基菌落數所估算出的細菌數會比在顯微鏡下計算出的少。

C. 用具有最準確結果的洋菜培養基(由圖中)計算，估計X培養液中含有$1.6x10^5$ cfu/ml。

D. 取圖中的稀釋液f在洋菜培養基上重複多次培養，某些培養基會培育出菌落。

A. True **B.** True **C.** True **D.** True

Original commentary

Correct answers

A *true*

A culture with an OD_{600} = 0.1 and a doubling time of 30 minutes will have an OD_{600} = 0.2 after 30 minutes, 0.4 after 1 hour, and 0.8 after 1:30 hour, therefore it will will reach $4*10^8$ cells/ml in less than 2 hours ($4x10^8$) cells correspond to an OD = 0.5).

B *true*

Counting colonies on plates gives the number of cfu/ml, and only living cells can form colonies, whereas under the microscope, dead cells are also counted.

C *true*

The plate giving the most accurate results is the one with 160 colonies that corresponds to a 1:1000 dilution of the starting culture X. $160*1000 = 1.6x10^5$

D *true*

The dilution f contains 0.16 cells/ml. Statistically, by plating it more than six times, colonies should grow.

Own commentary

在一活的生物體中，細胞通過細胞凋亡(細胞程式性死亡)或壞死(細胞膨脹和爆裂)其中一種方式而死亡。

指出下列敘述正確或錯誤。

A. 未成熟T細胞若辨識自體抗原會誘發該細胞的凋亡。

B. 腸道上皮細胞與基膜(lamina)失去接觸時，會進行細胞凋亡。

C. 進行凋亡中的神經幹細胞表面會顯露出一個促進吞噬的信號。

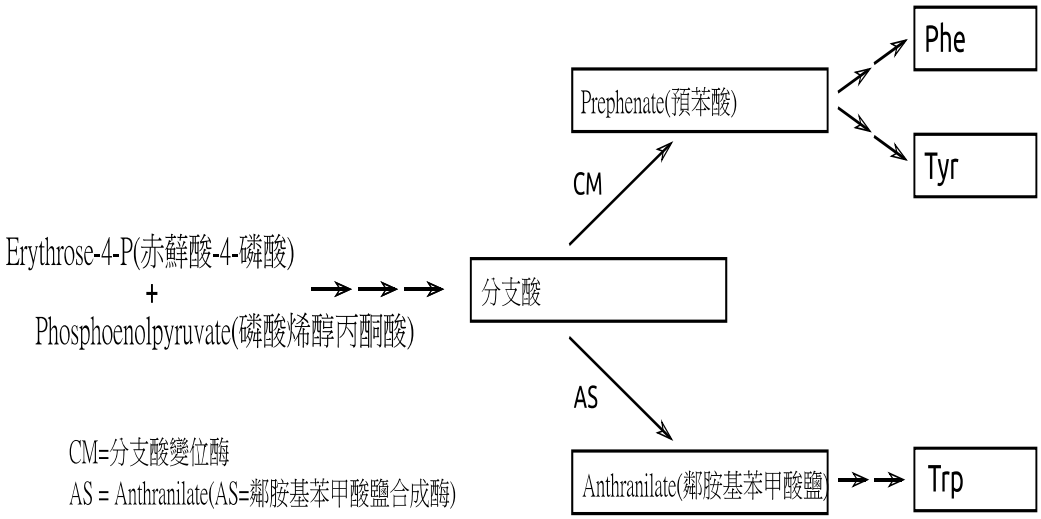
D. 壞死常會誘發發炎的免疫反應。

A. True **B.** True **C.** True **D.** True

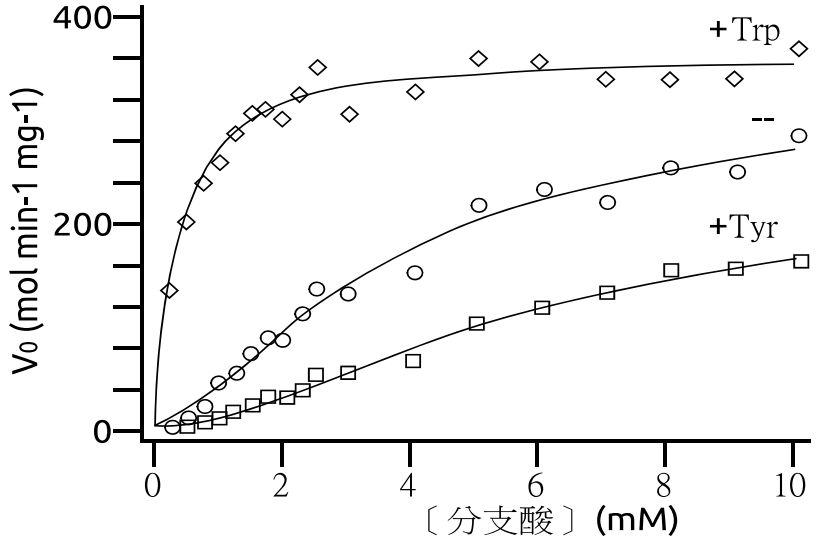
Original commentary
Correct answers
A *true*
T-cells recognizing self antigens need to be killed, this is programmed and occurs through apoptosis
B *true*
In a monolayer epithelium, cells losing contact with the basal lamina lose survival signals and die through apoptosis.
C *true*
Cells undergoing apoptosis are phagocytosed by neighbouring cells. To promote this process, they expose a signal to stimulate neighbouring cells to phagocyte them.
D *true*
During necrosis, when the cell bursts, components which are usually encapsulated within the cell are released in the extracellular space. This induces an inflammatory response.

Own commentary

在此介紹酵母菌細胞中導向芳香族胺基酸合成的分支酸途徑。



在色胺酸存在 (+ Trp)及缺乏(−), 或酪胺酸存在(+ Tyr)的情況下, 估算分支酸變位酶(chorismate mutase, CM)的作用速率。



根據這些結果和途徑示意圖指出下列敘述是對或錯。

A. 色胺酸會增加分支酸變位酶的活性

B. 色胺酸能抑制分支酸(chorismate)的合成, 但酪胺酸不能

C. 高濃度酪胺酸可能會增加色胺酸合成。

D. 預苯酸(prephenate)及鄰胺基苯甲酸鹽(anthranilate)這兩個合成的分支途徑會互相競爭分支酸

A. True **B.** False **C.** True **D.** True

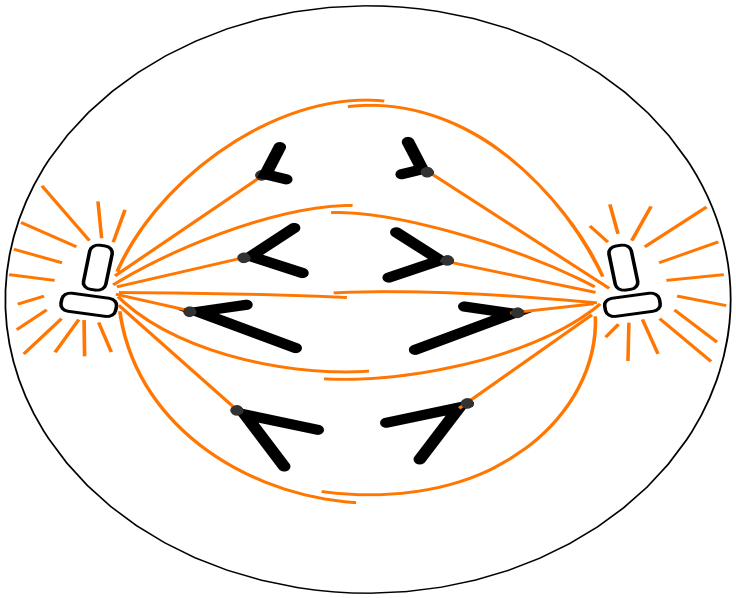
Original commentary
Correct answers
A *true*
Under addition of tryptophane, at the same chorismate concentrations, the speed is higher

B *false*
The synthesis of erythrose-4-P is neither inhibited by tryptophan, nor by tyrosine. It would not make sense that only tryptophan inhibits E4P, since E4P is needed for the synthesis of both tryptophan and tyrosine and their synthesis is regulated differently.
C *true*
When the tyrosine concentration is increased, CM gets slower, and the chorismate will be used by AS instead to produce tryptophane.
D *true*
Both pathway branches have chorismate as a starting point and the positive/negative regulation by Trp/Tyr hints that chorismate is not present in unlimited supply.

References
Schnappauf et al, Biochemistry (1998)

Own commentary

下面示意圖顯示一個雙套的真核細胞在細胞分裂時的某一時期。



指出下列敘述是對或錯。

A. 此示意圖可代表有絲分裂的某一時期

B. 此示意圖可代表第二減數分裂的某一時期

C. 如果微管的運動蛋白(motor protein)被抑制，細胞不能達到此一時期

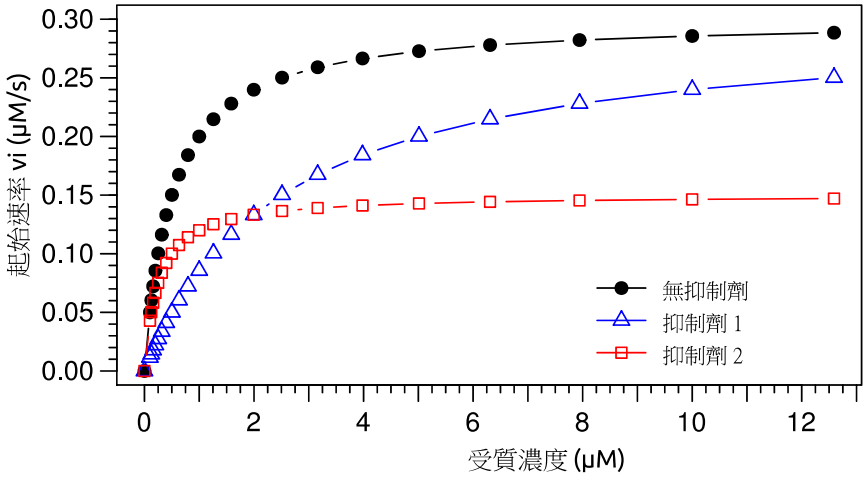
D. 在此一時期，組蛋白基因的轉錄達到高峰

A. False **B.** True **C.** True **D.** False

Original commentary
Correct answers
A *false*
as the chromosomes are different from each other in the picture, they cannot arise from pairs of chromosomes, which would need to be the case for mitosis of a eukaryotic diploid cell.
B *true*
during meiosis II, the 2 chromatids are distributed between daughter cells.
C *true*
to reach anaphase, molecular motors working on microtubule are needed for the expansion of microtubuli
D *false*
in this stage, the DNA is highly condensed and not available to transcription. Furthermore, new histone proteins are particularly necessary during the S-phase where the DNA is duplicated and needs to be packaged, not in the anaphase.

Own commentary

本題評估一酵素對不同抑制劑的敏感度，於酵素濃度為10 nM的情況下，評估不同受質濃度下的產物形成速率。在加入或不加入兩種不同抑制劑的情況下，計算並繪出初始速率v_i (在t = 0 s時)與受質濃度的函數圖。



指出下列敘述是對或錯。

A. 在沒有任何抑制劑的情況下，酵素的 K_M (Michaelis常數)值為 0.15 μM。

B. 抑制劑 1 的效果可因添加更多受質而得到部分補償。

C. 抑制劑2可降低此酵素的最大速率(V_{max}) 。

D. 周轉數(一酵素分子每1秒鐘能處理分子數目的最大值)在抑制劑 2的抑制下約為10-20/s。

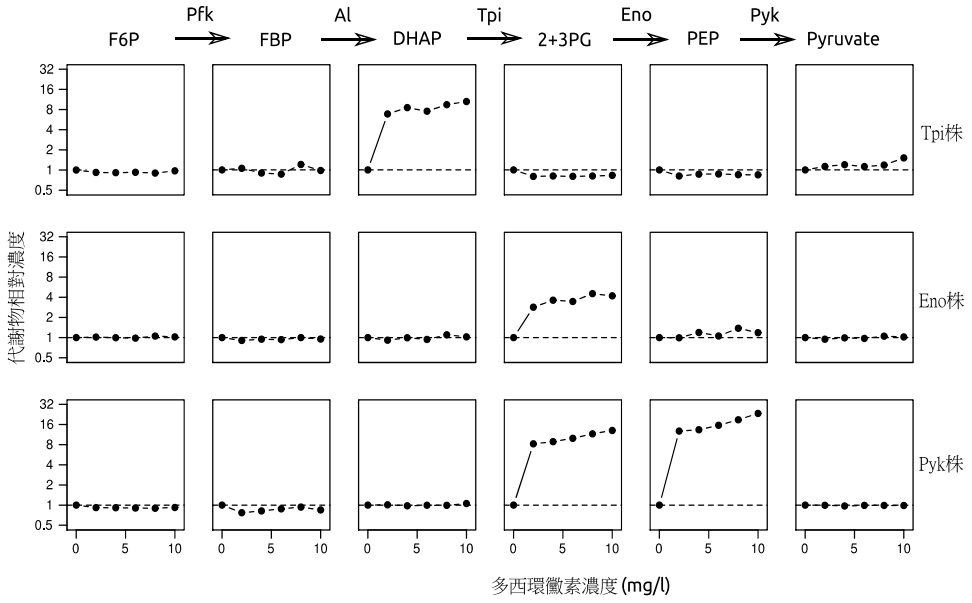
A. False **B.** True **C.** True **D.** True

Original commentary
Correct answers
A *false*
K_m is the [substrate] at which half the maximal velocity is reached, in this case v_{max} is 300 nM/s, $v_{max}/2$ = 150 nM/s, which corresponds to 0.5 μM
B *true*
With inhibitor 1, only the K_M is affected, not the v_{max}. The reaction to proceed at the same speed as without inhibitor if more substrate is added (corresponds to a competitive inhibitor).
C *true*
The v_{max} is reduced (150 nM/s instead of 300 nM/s without inhibitor): corresponds to an uncompetitive inhibitor.
D *true*
$k_{cat} = v_{max}$ / [Enzyme] = (150 nM/s) / (10 nM) = 15/s

Own commentary

三個酵母菌(*Saccharomyces cerevisiae*)株各自被轉殖入含有糖解過程中的一個不同酵素之基因(Tpi, Eno 或Pyk), 因受多西環黴素抑制的啟動子控制故加入多西環素可控制下游相對應酵素的合成。測量各酵母菌株生長在含不同濃度多西環黴素之葡萄糖液中的某些代謝物的濃度, 以不含多西環黴素濃度作標準化。測量數據上方為糖解過程的相關步驟, 代謝物及酶的縮寫如下：

代謝物		酵素	
F6P	果糖 6-磷酸	Pfk	ATP-dependent phosphofructokinase(ATP依賴性磷酸果糖激
FBP	果糖 1,6-二磷酸	Al	Aldolase(醛縮酶)
DHAP	dihydroxyacetone phosphate(二羥丙酮磷酸)	Tpi	Triose phosphate isomerase(磷酸丙酮異構酶)
2+3-PG	2- and 3-phosphoglycerate(2，3-磷酸甘油酸)	Eno	Enolase(烯醇化酶)
PEP	phosphoenolpyruvate(磷酸烯醇丙酮酸)	Pyk	Pyruvate kinase(丙酮酸激酶)



指出下列敘述是對或錯。

A. 調降其中任何一個酶, 都可以打斷整個徑路中的代謝物濃度。

B. 調降其中任何一個酶, 影響其受質濃度比影響其產物濃度更多。

C. 由2+ 3-PG到PEP反應的平衡, 比由FBP到DHAP反應的平衡會更偏向產物方向進行。

D. F6P的濃度預計不受 Al 調降的影響。

A. False **B.** True **C.** False **D.** True

Original commentary
Correct answers
A *false*
even if the substrate of the down-regulated enzyme undergoes a big concentration change, the concentrations of other metabolites stays similar.
B *true*
as seen from the graphs, the metabolite undergoing the biggest change is the substrate of the down-regulated enzyme.
C *false*
down-regulation of Tpi affects strongly (more than 10 fold) the levels of DHAP, its substrate, but the concentration of FBP stays constant, thus the equilibrium of FBP → DHAP is strongly on the side of DHAP. In contrary, down-regulation of Pyk does not only affect the concentration of PEP, its direct substrate, but also of 2+ 3PG, the substrate of the previous enzyme in the pathway, Eno. This means that the increased level of PEP is enough to shift the equilibrium of 2+ 3PG → PEP back to 2+ 3PG, therefore the equilibrium is not as strongly on the side of the glycolytic product than FBP → DHAP.

D *true*
During the reaction of F6P to FBP, ATP is hydrolyzed to phosphorylate F6P. Therefore, the equilibrium is strongly on the side of FBP. Down-regulation of Al would result in an increase of the FBP concentration, but since the equilibrium is strongly on the side of FBP (even more strongly than for the reaction FBP → DHAP), the concentration of F6P will stay unaffected.

References
Fendt et al, Molecular Systems Biology (2010)

Own commentary

有些物質必須從被合成處主動或被動運輸至它們活動的位置。

分別指出下列物質是否是從細胞質運輸到細胞核。

A. tRNAs

B. 組蛋白

C. 核苷酸

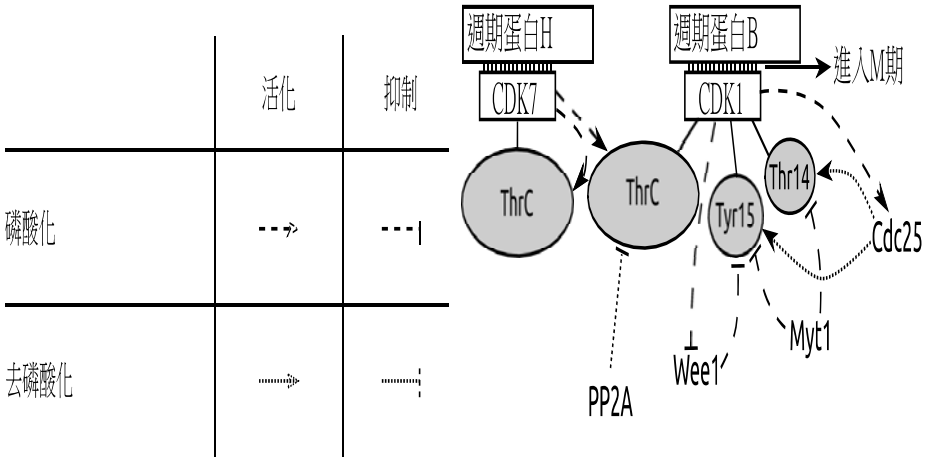
D. ATP合成酶的次單元

A. False **B.** True **C.** True **D.** False

Original commentary
Correct answers
A *false*
tRNAs are synthesized in the nucleus, but need to get to the cytoplasm to be used by the ribosome.
B *true*
Histones are proteins synthesized in the cytoplasm, but need to get to the nucleus to bind to the DNA.
C *true*
Nucleotides are obtained by endo/picocytosis or synthesized in the cytoplasm, but need to get to the nucleus to be used in DNA replication and transcription.
D *false*
The ATP-synthase is a membrane protein synthetised in the cytoplasm (on the ER membrane) and transported to the plasma membrane, but not to the nucleus

Own commentary

細胞週期的進行是由不同的週期蛋白依賴激酶(CDKs)推動，而只有在它結合到各自的週期蛋白並在ThrC（核心羥丁胺酸; core threonine）處磷酸化後才有活性，其他胺基酸的磷酸化或去磷酸化可進一步調節其活性。以下途徑顯示參與進入細胞週期M階段的一些蛋白質。



指出下列各突變是否能活化週期蛋白B/CDK1複體，促使細胞週期進入M期。

A. 減少 Cdc25 去磷酸化活性的突變。

B. 減少 Wee1 磷酸化活性的突變。

C. 使CDK1的ThrC改變為無法磷酸化的纈胺酸之突變。

D. 抑制週期蛋白H結合到CDK7的突變。

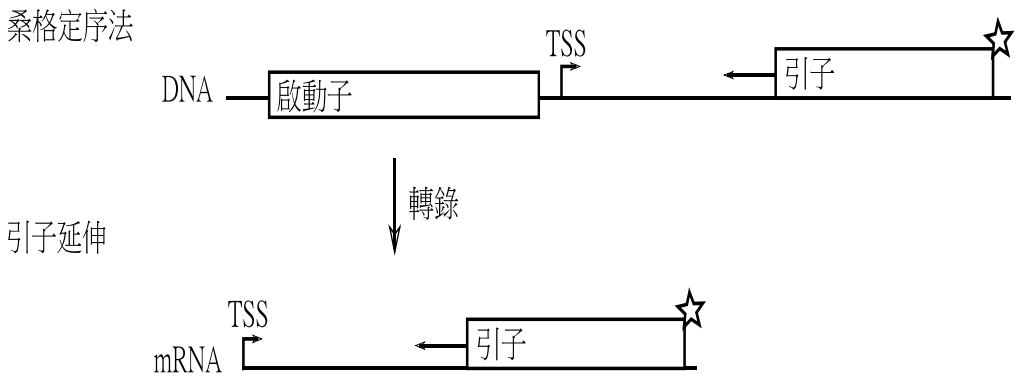
A. False **B.** True **C.** False **D.** False

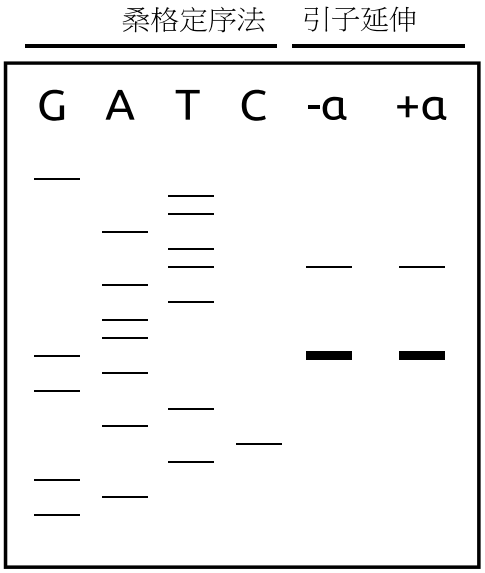
Original commentary
Correct answers
A *false*
Cdc25 by dephosphorylating CDK1 at Tyr15 and Thr14 activates CDK1 (removes the inactivation). By reducing its activity, CyclinB/CDK1 would be less active
B *true*
Wee1 inactivates CDK1 by phosphorylating it at Tyr15.
C *false*
to be active, CDK1 needs to have Thr161 phosphorylated, with a valine at position 161, CDK1 would be always inactive
D *false*
CDK7 needs to be bound to CyclinH and phosphorylated at Thr170 to be active and able to phosphorylate (and therefore activate) CDK1 in complex with CyclinB. This mutation in CyclinH would make it unable to bind CDK7 which would stay in an inactive state.

References
Fussenegger et al, Biotechnol. Prog. (1998)

Own commentary

為確定一個新發現的細菌基因啟動子之轉錄起始位置(TSS), 一個與此基因3' 端互補的放射性標記的引子, 被用於DNA桑格定序法及mRNA的引子延伸。引子延伸(類似cDNA的合成)是指藉重複添加轉錄因子α在被轉錄的mRNA上。





A. 桑格定序法和引子延伸所使用的聚合酶不同。

B. 此基因的mRNAs含有CUCAUGAC序列, 是這些細胞中TSS之後的前8個鹼基。

C. 此基因中含有多個 TSS。

D. 轉錄受轉錄因子α的調控。

A. True **B.** True **C.** True **D.** False

Original commentary
Correct answers
A *true*
For Sanger sequencing, a DNA polymerase is needed, whereas for primer extension, reverse transcriptase is used.
B *true*
The PE lane on the radiography gives the length of the mRNA. The first (most 5') base of the main mRNA corresponds to the fragment from the sequencing with the same length (here: G). The second most 5' base of the mRNAc corresponds from the sequencing one nucleotide shorter (=one band lower on the radiography) than PE (here: A).
C *true*
For this gene, a main and a secondary TSS exist.
D *false*

Transcription in the absence or presence of α produces the same ratio of mRNA starting from the main and the secondary TSS.

Own commentary

目前認為血液中高濃度的三酸甘油酯是心臟病的高危險因子，Y受體的致效劑(agonist)S被觀察到可降低三酸甘油酯濃度。

請問如何證實S的作用是專一性地透過Y受體達成？

A. 可藉由活化Y受體基因來使小鼠大量表現Y受體(超過一般生理濃度)

B. 可藉由剔除Y受體基因來使小鼠不表現Y受體(剔除基因)

C. 利用Y受體的專一性拮抗劑(去活性的分子)

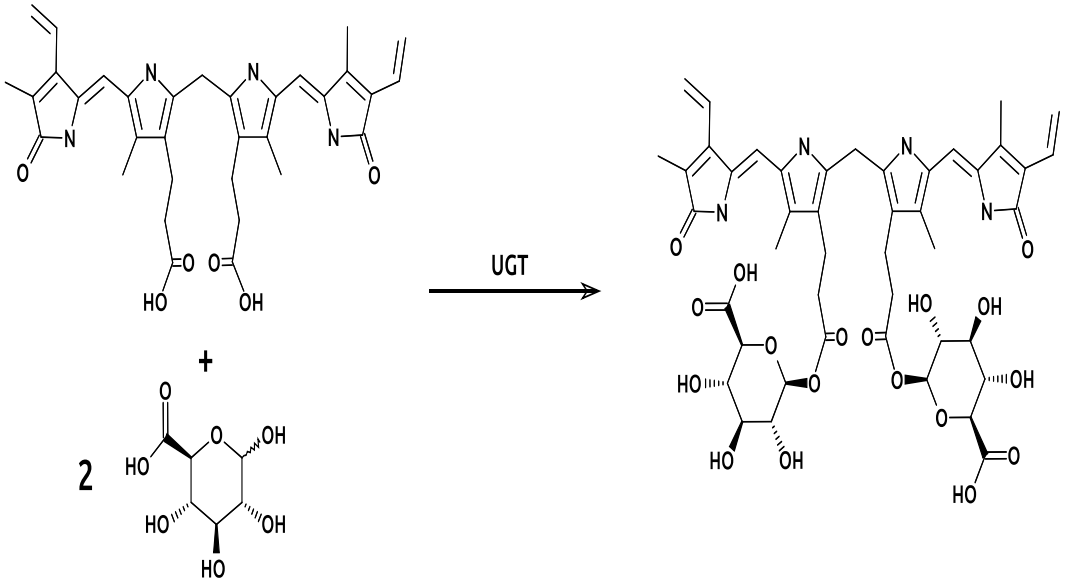
D. 在老鼠體內注射針對S的抗體，使之自血液中移除S

A. False **B.** True **C.** True **D.** False

Original commentary
Correct answers
A *false*
Even if the decrease in triglycerides levels observed would be more important than with wild-type mice, this is not enough to prove that S-Y interaction is either sufficient or necessary for the decrease.
B *true*
If in these mice, triglycerides levels decrease after addition of S, it is not mediated by Y. If no decrease can be observed, the interaction of S and Y is necessary for the decrease in triglycerides levels
C *true*
If Y is inactivated by an antagonist, treatment with S should not decrease triglycerides levels, it shows that S-Y interaction is necessary for the decrease in triglycerides levels. If a decrease would be observed, it would show that S mediates triglycerides levels decrease via an other mechanism.
D *false*
Even if no decrease in triglycerides levels would be observed, this would only prove that S is necessary to decrease triglycerides, but would not prove that it acts via Y.

Own commentary

膽色素(膽紅素)是肝臟透過酵素UGT(見下圖)將血紅素中的血基質(heme)與2個葡萄糖醛酸(glucuronic acid)結合而成的代謝物，此種結合態的膽色素(conjugated bilirubin)是膽汁的一種成分，且會分泌進入小腸。



指出下列各敘述正確或錯誤

A. 與葡萄糖醛酸結合可使膽色素在水中的溶解度增加

B. 若小腸附近的膽管有腫瘤產生而堵塞膽汁的分泌，會導致血液中結合態膽色素量上升。

C. 若基因點突變顯著降低UGT的活性，會導致血液中非結合態膽紅素的濃度下降。

D. 體內結合態膽紅素的濃度增加為瘧疾感染症狀之一。

A. True **B.** False **C.** False **D.** True

Original commentary

Correct answers

A *true*

Glucuronic acid is a hydrophilic molecule, whereas bilirubin is hydrophobic and insoluble in water. Conjugation with glucuronic acid increases its solubility in water.

B *false*

When the bile cannot enter the small intestine, the conjugated bilirubin accumulates in the bile duct and moves back upwards in the intrahepatic bile ducts and enters the blood. As a result the conjugation is reduced or even stops causing an accumulation of unconjugated bilirubin too.

C *false*

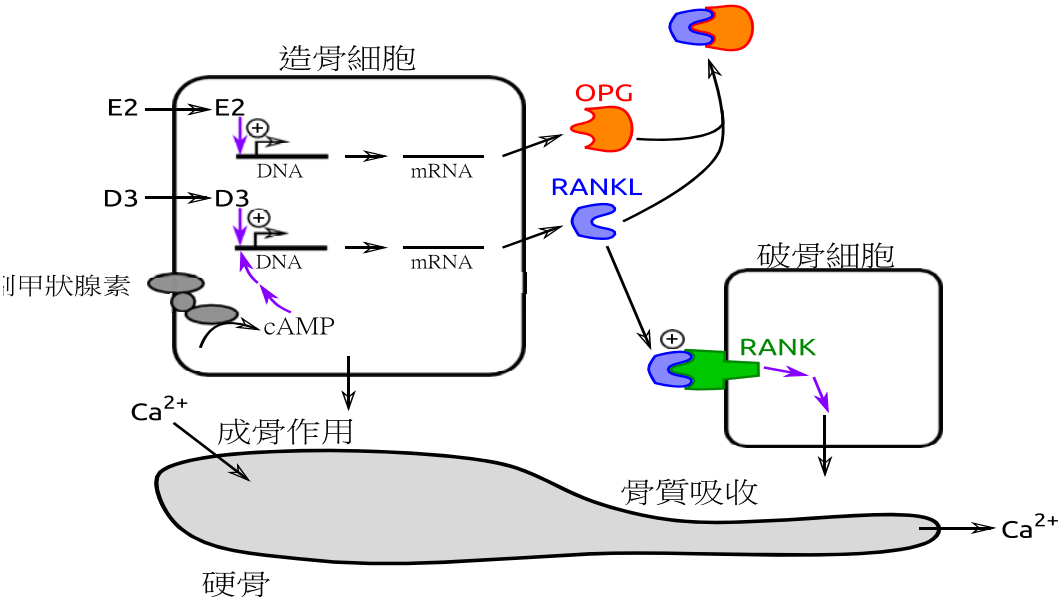
If the UGT is not working properly (like in patients suffering from Morbus Meulengracht), the conjugation of bilirubin is reduced and the level of unconjugated bilirubin is increased.

D *true*

At one stage, *Plasmodium falciparum* reproduces in erythrocytes. These erythrocytes burst when releasing offspring parasites, leading to a liberation of hemoglobin, which in turn increases the level of bilirubin in the blood, which will be conjugated.

Own commentary

造骨細胞分泌新的骨骼基質時，會藉由分泌RANKL活化破骨細胞的RANK受體，以刺激破骨細胞破壞現存骨質，上述過程會受到維生素D3(D3)及副甲狀腺素(PTH)的調節。雌激素(oestrogen, E2)的存在會導致造骨細胞分泌osteoprotegerin (OPG)，OPG會藉由破壞RANKL而抑制上述破骨細胞的作用。



指出下列各敘述正確或錯誤

A. 雌激素替代治療可防止更年期後的骨質吸收作用

B. 副甲狀功能亢進(副甲狀腺功能過度)症狀之一即為骨質流失。

C. D3及E2為親水性分子(hydrophilic)，而PTH為親油性分子(lipophilic)

D. 鈣離子自尿液中流失會導致體內PTH濃度下降

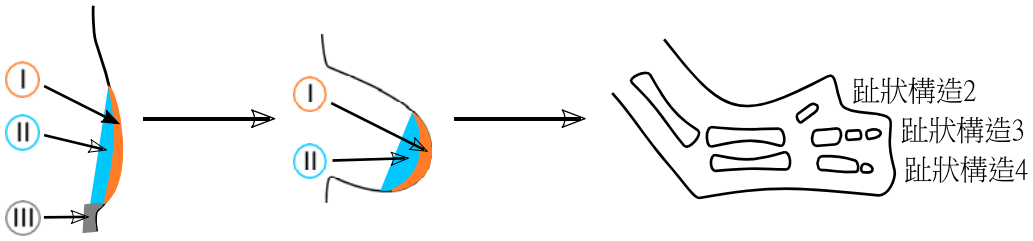
A. True **B.** True **C.** False **D.** False

Original commentary
Correct answers
A *true*
After menopause the estrogen level declines. Estrogen replacement therapy increases OPG levels and prevents thereby RANKL to bind to RANK, which would activate osteoclasts.
B *true*
Loss of bones mass is a symptom of hyperparathyroidism, where increased production of PTH leads to increased levels of RANKL and increased osteoclast activity
C *false*
Estrogen and Vitamin D are lipophilic hormones as shown above they have to cross the cell membrane to operate whereas PTH needs to bind to a extracellular receptor as it is hydrophilic and cannot cross the membrane
D *false*
Renal loss of calcium leads to a decrease of plasma calcium level which causes a elevation of PTH. PTH indirectly activates osteoclasts which resorb bone, process during which calcium is released into the blood. This reestablishes the calcium plasma level.

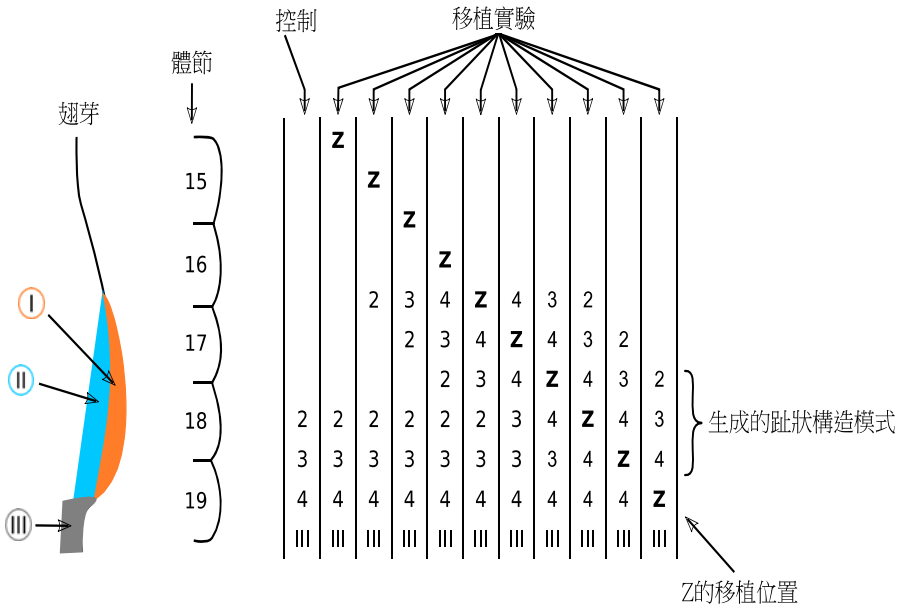
References
Seeman et al, NEJM (2006)
Stavros et al, NEJM (1995)
Weinstein et al, NEJM (2009)

Own commentary

雞的翅膀是從翅芽形成開始發育，並形成含有3趾(digit)的完整構造。



為了研究趾狀構造的發育情形，在發育早期，將左翅芽第3區移植到右翅芽第3區。移植體所形成的趾狀構造形態及相對體節位置列於下圖(以Z表示)。



指出下列各敘述正確或錯誤

A. 第一區與第二區對指狀構造之產生是必要的。

B. 第3區似乎可分泌特殊訊息分子，其濃度會影響趾狀構造的類型

C. 如果將第3區自體節19/20移植到體節17，則體節19的細胞無法形成趾狀構造4。

D. 形成趾狀構造需一系列誘導作用：形成趾狀構造2需由趾狀構造3誘導，而形成趾狀構造3則需由趾狀構造4誘導。

A. True　B. True　C. True　D. False

Original commentary
Correct answers
A *true*
No digits could develop at position of somites 14/15-16 where zone I is absent.
B *true*
A high concentration of the signal (near zone III) leads to formation of digit 4, a middle concentration to digit 3, a low one to digit 2. Grafting a second zone III close enough to the normal one increases the concentration of the signal and promotes the formation of digits 3/4 (see e.g. when Z is grafted at somite 17, the digit pattern posterior of it is 4-3-3-4, without digit 2 being formed.
C *true*
The results suggest that digit number 4 is only formed next to a zone III. In fact, such a transplantation would result in no digit being formed by somite 19.
D *false*
If it was the case, a digit 2 could only be formed next to a digit 3 itself near to a digit 4. As seen when Z is grafted at somites 15 or 15/16, this is not the case, a digit 2 can be formed even in the absence of a digit

3/4 next to it.

References

Tickle et al, Nature (1975)

Own commentary

將神經元培養在純氧環境，且含有類似腦組織成分的體外培養液中。幾分鐘後，加入可阻斷細胞內電子傳遞鏈的氰化物。

指出下16列各敘述正確或錯誤

A. 細胞內鉀離子濃度上升

B. 自發性動作電位產生的機率增加

C. 粒線體膜間腔中的氫離子濃度增加。

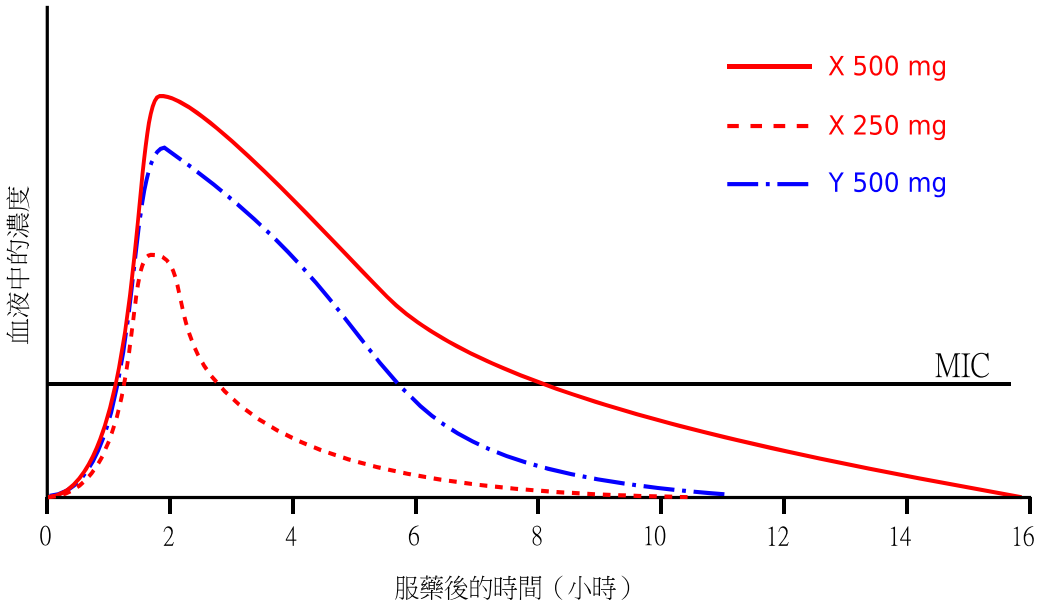
D. 溶液中碳酸氫鹽(bicarbonate)的濃度減少

A. False **B.** True **C.** False **D.** True

Original commentary
Correct answers
A *false*
Addition of cyanide leads to a rapid depletion of ATP in the neuron. As a consequence, the Na^+ / K^+ pump will no longer exchange Na^+ against K^+ inside the cell. Through diffusion, the distribution of ions will be equalized across the cell membrane, and hence the concentration of K^+ will decrease in the cell.
B *true*
With an increase of the membrane potential due to diffusion (see A), the probability of a spontaneous action potential increases.
C *false*
The concentration of H^+ is kept high in the intermembrane space of the mitochondria by the electron transport chain. After blocking this chain, the concentration quickly decreases through the production of ATP at the ATP-synthetase.
D *true*
After adding cyanide, the cell stops emitting CO_2. The CO_2 dissolved as bicarbonate in the solution from before adding cyanide is entering the atmosphere with an extremely low partial pressure of CO_2 (as it was initially pure O_2).

Own commentary

抗生素的作用效果主要取決於作用時間及濃度，亦即抗生素劑量、服藥間隔及細菌排出抗生素的量。抗生素X與Y會對人體產生毒性且都會被腎臟排泄，但抗生素Y還會透過肝臟的細胞色素複合物(cytochrome complexes)代謝而分解。抗生素X會導致離子可自由通過細菌細胞膜，而Y會抑制細胞分裂時細胞壁的合成。下圖顯示健康人服用500 mg X或250 mg Y後，其體內抗生素X(紅色)與Y(藍色)的平均濃度，同時本圖也顯示培養於試管內的細菌若被抑制生長時，所需的最低濃度(MIC，黑色實線)。



指出下列各敘述正確或錯誤

A. 若想安全治療腎功能低下的病患，抗生素X的服藥間隔須延長。

B. 增加抗生素X的劑量至每天500 mg，則延長服藥間隔一倍時間即可防止抗生素X累積，並確保其血液中的濃度在MIC之上。

C. 若病患服用的水果含大量細胞色素複合物的抑制劑(如葡萄柚)，則必須增加抗生素Y的投藥量。

D. 維持血液抗生素X的濃度高於MIC(即細菌被抑制生長時，所需的最低濃度)，比維持血液抗生素Y的濃度高於MIC更重要。

A. True **B.** False **C.** False **D.** False

Original commentary
Correct answers
A *true*
Drug X is eliminated only renally and thus in renal insufficient patients, the consideration of the risk of accumulation of drug X is important. By increasing the intake interval, the kidney has more time to eliminate the drug and hence the risk of accumulation is reduced.
B *false*
As shown in the graph a dosage of drug X of 250 mg causes blood concentration higher than MC only for 2–3 h but a dosage of drug X of 500 mg causes blood concentration higher than MC for approx. 8 h, meaning more than double of a dosage of 250 mg and meaning the interval has to be more than doubled.
C *false*
Substances inhibiting the cytochrome complexes (e.g. grapefruit) leads to slower inactivation/excretion of drug Y and hence patients treated with this drug have to be given lower dosages or asked to increase the intake intervals to prevent accumulation and intoxication.
D *false*
As bacteria cell division is a continuing process and bacteria divide not simultaneously the concentration of drug Y has to be as a therapeutic level (higher than MC). A change in the membrane permeability of ions causes rapid bacterial damage and death consecutively.

References
Tulane University; MIC & Time- vs Concentration-Dependent Killing

Own commentary

根據是否直接影響激素的分泌，內分泌功能失調可歸納為3種

- 原發性內分泌失調直接透過代謝或發育影響激素分泌。
- 次級內分泌失調會改變促激素(tropic hormones)的分泌，這些促激素能作用在其他腺體
- 三級內分泌失調主要影響下視丘的功能。

指出下列各敘述正確或錯誤

A. 病患體內腎上腺皮質素(可體松;cortisol)及促腎上腺皮素(ACTH)增加，與皮釋素(CRH)濃度下降等現象，表示應為原發性內分泌系統失調。

B. 甲狀腺促素(TSH)過量分泌為原發性內分泌系統失調。

C. 因腫瘤導致體內皮質素濃度大幅上升可視為原發性或次級內分泌系統失調。

D. 若因腫瘤導致產生二級內分泌系統失調，則血液中相對應之釋放激素(releaseing hormone)濃度會受到影響。

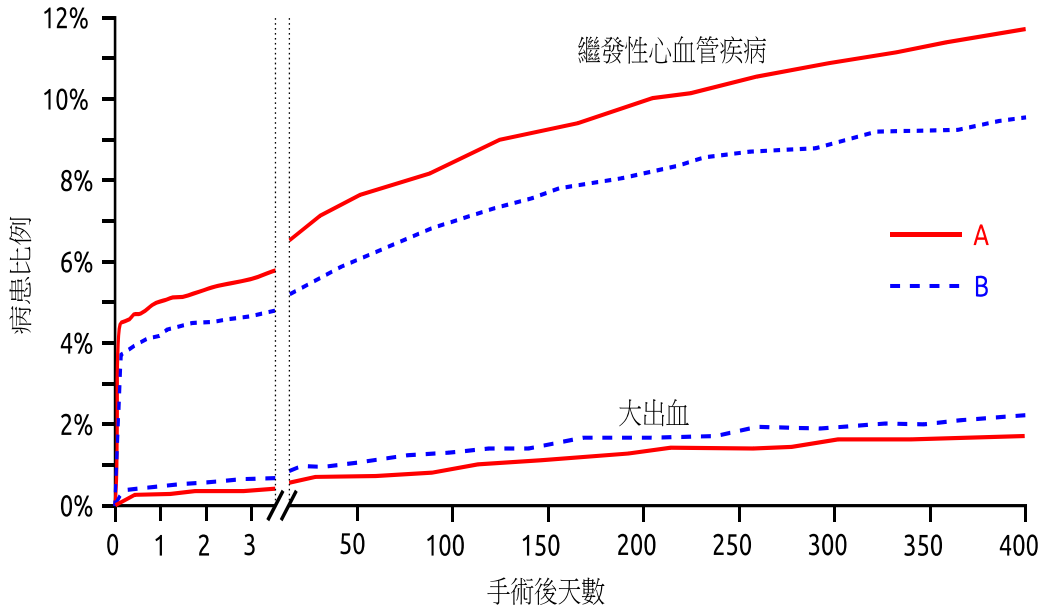
A. False **B.** True **C.** True **D.** True

Original commentary
Correct answers
A *false*
The most likely explanation is a secondary dysfunction leading to an overproduction of ACTH, which in turn leads to an elevated Cortisol level and, due to feedback, an decreased CRH level.
B *true*
Due to feedback interactions, a primary underproduction leads to an increase in the corresponding tropic hormone.
C *true*
A hormone-producing tumor of the adrenal gland as a primary dysfunction elevates the cortisol. The same is caused secondary due a overproduction of ACTH causing a stimulation of the adrenal gland. The latter results in a overproduction of cortisol.
D *true*
A secondary dysfunction affects the tropic hormone through a feedback mechanism.

References
Campbell Biology

Own commentary

目前已知冠狀動脈手術後必須有效抑制血小板凝集，以降低術後併發症的風險。以13608位病患進行臨床試驗，以測試A與B兩種競爭性抑制劑對心肌梗塞的治療效果。下圖顯示服用A與B兩種藥物後在手術後400天內罹患繼發性心血管疾病(如中風)的病患比例，同時，本圖亦顯示兩種藥物處理後，病患在術後400天內發生大出血的比例。



下列各項敘述正確或錯誤

A. 本研究顯示抑制劑B可有效降低病患罹患二度心血管意外的風險，但不會降低大出血之風險。抑制劑A則無上述效果

B. 本研究顯示如果以較便宜的抑制劑A取代抑制劑B三天後，病患罹患繼發性心血管疾病的風險會上升。

C. 將抑制劑B取代抑制劑A，則3天內所有冠狀動脈手術的患者罹患繼發性心血管疾病的風險將較原抑制A使用組顯著下降10%。

D. 建議在重複本研究的實驗時，要新增1個投予安慰劑的控制組

A. True **B.** True **C.** True **D.** False

Original commentary
Correct answers
A *true*
Inhibitor B does indeed decrease the risk of a secondary cardiovascular incident, but at the same time increases the risk of a major bleeding.
B *true*
The study suggests that patients treated with inhibitor B have a reduced risk of a secondary cardiovascular incidence even after day 3. This can be read from the figure since the absolute difference in the fraction of patients with a secondary cardiovascular incident is increasing from day 3 to day 400. If there were no difference in the effects after day 3, the risk to suffer a secondary cardiovascular incident in the following 397 days would be the same in both treatments. Hence the number of patients with such an incident between days 3 and 400 can be calculated as n*(1−f(3))*r where f(3) is the fraction at day 3, n the total number of patients and r the rate. The total fraction of patients at day 400 is then given by f(400)=(f(3)*n + (1−f(3))*n*r)/n = f(3)+ (1−f(3))*r=f(3)*(1−r)+ r. The absolute difference at day 400 is thus (fA(3)*(1−r)+ r) − (fB(3)*(1−r)+ r)=(1−r)*(fA(3)−fB(3)), which is always smaller than fA(3)−f(B(3) unless r=0. But note that the students do not need to make these calculations but just realize that the absolute difference increases.
C *true*
To calculate the reduction in the total amount of affected patients, one need to compute the reduction from 5.8% to 4.9% of all patients, which is a reduction by 1−4.9/5.8=15.5%. Note that the exact numbers the students read off the graph do not matter, as to get a reduction of less than 10%, the student would need to misread the percentage of inhibitor A to be 9% or more.

D *false*
Given the known reduction in the risk of complications when inhibiting platelet aggregation it would not be ethical not to give some patient any platelet inhibitor. In addition, the use of a placebo could only reaffirm the beneficial use of such an inhibitor but not add value to the comparison between inhibitors A and B.

References
Wiviott et al, NEJM (2007)

Own commentary

血紅素為一種可運輸氧氣的蛋白質，與氧氣的結合程度隨所在器官而有所差異。

下列各項敘述是正確或錯誤

A. 相同氧分壓狀態下，胎兒血紅素的氧飽和度較母體血紅素的飽和度高。

B. 當細胞進行劇烈的無氧糖解作用時，血紅素與氧氣結合能力降低。

C. 就血紅素與氧氣的結合程度而言，需進行深度潛水的哺乳類比已適應高緯度的哺乳類為佳。

D. 血紅素運送氧的能力較血青素(與氧非協同性結合，為節肢動物用以運送氧的蛋白質)為佳

A. True **B.** True **C.** False **D.** True

Original commentary

Correct answers

A *true*

This is an adaptation of the fetal hemoglobin to recruit oxygen from the maternal blood.

B *true*

Cells relying heavily on anaerobic glycolysis recycle their NADH by fermenting lactate, which increases the acidity of the blood in the vicinity. In a more acidic environment, hemoglobin changes its conformation, which in turn reduces its affinity for oxygen (Bohr effect). This is an effective way to release oxygen where it is needed most.

C *false*

The opposite is true. Mammals that are deep divers need hemoglobin that releases most of the oxygen in the blood. Mammals adapted to high altitude, in contrast, need to fill their hemoglobin with oxygen in the lungs even at low partial pressure, and hence have hemoglobin with higher affinity.

D *true*

The cooperativity between the different hemoglobin subunits allow for a larger difference in affinity between the place of oxygen uptake and oxygen release (a sigmoid dissociation curve).

Own commentary

B型肝炎病毒包含HBs、HBc 、 HBe等抗原，而其中HBs多用以製造疫苗，而 HBe僅見於某些特定病毒株。下表顯示在某些患者體內所測得的病毒抗原與抗體，存在以(+)表示，而不存在以 (-)表示。問號（？）表示沒有進行該測試。

病患	HBs	HBc	HBe	Anti-HBs IgG	Anti-HBs IgM	Anti-HBc IgG	Anti-HBe IgG
P1	−	−	?	+	?	−	?
P2	−	−	−	+	−	+	+
P3	+	?	+	−	+	−	?
P4	+	?	?	?	?	+	+
P5	?	−	−	−	+	−	?

下列各項敘述是正確或錯誤

A. 病患1之前曾注射B肝疫苗，但後來不曾被B肝病毒感染。

B. 病患2已成功抵禦B肝病毒感染。

C. 病患3與病患4最近曾遭B肝病毒感染。

D. 病患5最近已施打過疫苗。

A. True **B.** True **C.** True **D.** True

Original commentary
Correct answers
A *true*
Since vaccination is done using HBs, a vaccinated person is producing anti-HBs IgG after several weeks. A Hepatitis infection, however would also lead to anti HBc and often anti-HBe antibodies, which were not found in P1.
B *true*
While no antigens were found, P2 produces IgG against all three antigens, even those not used in vaccination.
C *true*
The antigen HBe was found in P3, which is a good indication that the virus is present. In addition, the immune system of P3 started its first response by producing IgM antibodies. Since P4 shows anti-HBc and anti-HBe IgG, he or she must have been infected at one point. The presence of HBs strongly suggest that the infection is still in progress since the only alternative would be a very recent vaccination, which is unlikely to be applied to an already immunized person.
D *true*
The presence of anti-HBs IgM suggest a recent and exposure to HBs. However, since HBc and HBe antigens are not present, the likely source of exposure was a recent vaccination.

Own commentary

2013年IBO參賽者即將攀登Niederhorn山，在搭登山纜車快速上山(400公尺上升至2000公尺)之前與之後，及下山後3小時左右測定參賽者的生理參數，並與待在Niederhorn山上超過連續2個月的高山牧羊人之生理參數相互比較。這些參賽者在此高度下應會出現換氣過度及脫水等症狀。

下列各項敘述正確或錯誤

A. 初登山頂的IBO參賽者之心跳速率應比上山前高。

B. 高山牧羊人血液的pH值應比初登山頂的IBO參賽者血液之pH值高。

C. IBO參賽者下山前的尿液pH值應比剛上山時的pH值為高。

D. 有些IBO參賽者登上山頂時，其體內的血紅素濃度應會暫時增加。

A. True **B.** False **C.** True **D.** True

Original commentary

Correct answers

A *true*

The hypoxemia due to the lower partial concentration of oxygen will be compensated by an increased heart and respiratory rate .

B *false*

The blood pH is tightly controlled and is not expected to change substantially. If any change is observed, then the pH of the IBO participant is expected to increase due to hyperventilation, followed by a rapid reduction in the carbondioxyde concentration in the blood.

C *true*

Due to hyperventilation, the carbondioxyde concentration in the blood is decreased rapidly. To prevent an increase of the blood pH, the body excretes basic metabolites through the urine, leading to an increase of the urine pH.

D *true*

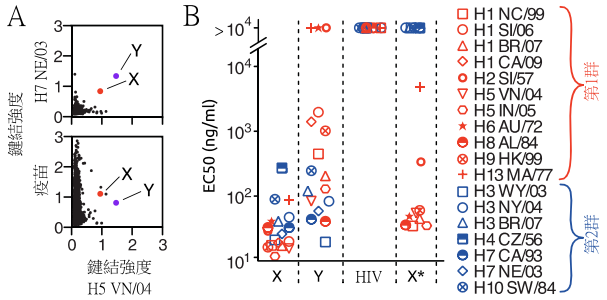
To avoid an increase of the blood pH (see answer to C), the kidney excretes basic metabolites, often leading to dehydration, which is followed by an increase of the hemoglobin concentration in the blood. What is more hyperventilation (especially on high altitudes) leads to dehydration, too.

References

Campell Biology

Own commentary

流感病毒的抗原(Hemagglutinin; HA)快速演化對發展有效治療流感形成重大挑戰，為了發展可有效對抗多種病毒株的抗體，科學家自注射過疫苗的人體中分離出13000個漿細胞，並誘發其產生抗體。這些抗體經過多種流感病毒抗原 (H5 VN/04、 H7 NE/03 及上述兩種抗原的混合疫苗) 測試，並量測其鍵結強度 (如圖A所示) 。其中兩種抗體X及Y，與來自第1群(紅色)及第2群(藍色)的流感病毒發生作用，進一步分析其達到半數最大鍵結飽和度時所需的最小濃度(EC50，見圖B)。為了相互比較，科學家也測量抗HIV的抗體及抗體X*的EC50。X*抗體是由原產生X抗體的漿細胞經突變後，逆轉所有表現的突變性白血球所產生。



下列各項敘述正確或錯誤

A. 流感疫苗所產生的免疫反應主要藉由不同種抗體媒介。

B. 抗體Y可有效對抗來自第2群的病毒株，但對來自第1群病毒株較無效果。

C. 抗體X所產生的廣泛性免疫力應源自體突變。

D. 注射抗體X可對抗多種流感病毒株，且效果可延續數年。

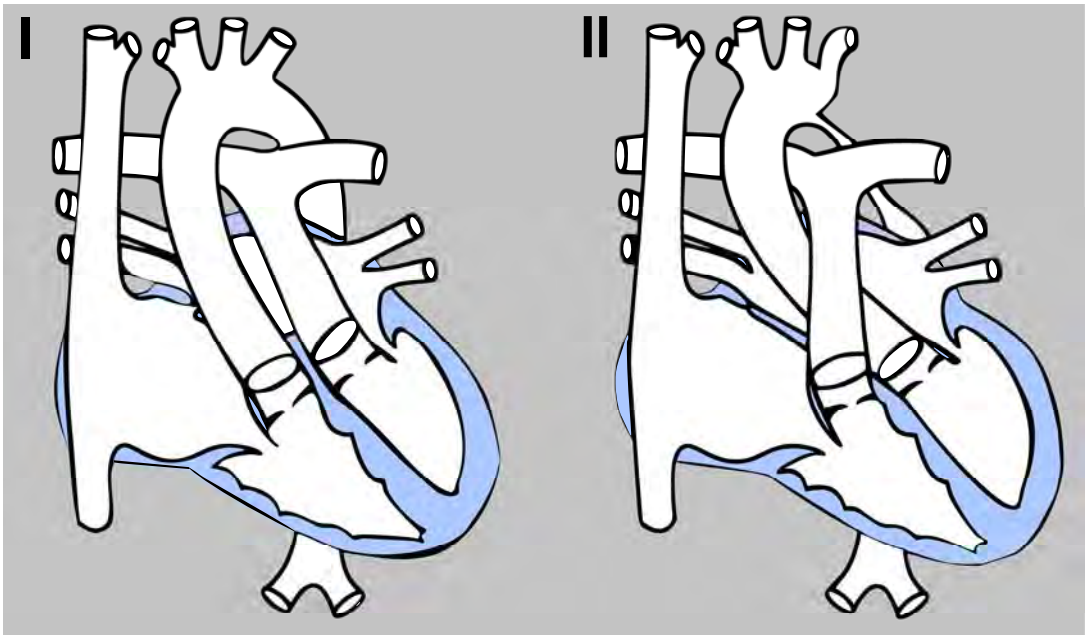
A. True **B.** True **C.** True **D.** False

Original commentary
Correct answers
A *true*
As can be seen in the lower panel of figure A, there are a large number of plasma cells producing antibodies against the HA present in the vaccine.
B *true*
This can be seen in figure B where antibody Y does not bind all group 1 HA better than the control antibody against HIV.
C *true*
Since the germ line copies of all genes do not concur immunity, the difference between X and X* antibodies must be due to somatic mutations that occurred in the cell line leading to the plasma cell producing X. Note that somatic mutations and rearrangements are common in antibody producing cells, a likely adaptation to deal with a wider range of antigens.
D *false*
While an injection of antibody X concurs passive immunity against a wide range of influenza strains, it does not provide active immunity. Therefore, immunization will not last for more than a couple of weeks or maximally month.

References
Corti et al, Science (2011)

Own commentary

下圖顯示2種常見於新生兒的先天性心臟病



下列各項敘述正確或錯誤

A. 在圖示的心臟病I中，肺動脈血液的氧飽和度高於冠狀動脈

B. 在心臟病I中，利用外科手術將主動脈及肺動脈置換，可有效改善血液循環。

C. 在圖示的心臟病II中，冠狀動脈的血壓比正常個體為高

D. 在圖示的心臟病II中，利用外科手術將下腔靜脈及肺靜脈置換，可有效改善血液循環。

A. True **B.** True **C.** True **D.** False

Original commentary

Note
In the heart Malformation I, the aorta comes out of the right ventricle (instead of the left one) and the pulmonary artery out of the left ventricle (instead of the right one). In Malformation II, the aorta is narrowed.

Correct answers
A *true*
This is true because there is no connection between the pulmonary blood circulation and the systemic one.
B *true*
As mentioned in the “answer note” the origins of the aorta and pulmonary artery are swapped.
C *true*
The narrowing of the isthmus of the aorta causes an increased resistance at this location leading to a reduced flow downwards the aorta which increases the blood flow in the arteriae of the upper extremities and the head/brain. The latter increases the blood pressure consecutively.
As a second mechanism the decreased blood flow in the aorta descendens/aorta abdominalis and in the flow renal arteries consecutively. As a physiological mechanism the kidney rises the circular blood pressure to try to increase the renal blood flow.
D *false*
The suggested operation does not change the patients problem. What is more it would create the same separation of the pulmonary and systemic circulation as in Malformation I.

References
Universitätsklinikum Bonn; D-Transposition der großen Arterien
Universitätsklinikum Bonn; Aortenisthmusstenose

Own commentary

在某一海生褐藻 (*Phaeophyta*)群集的各物種中，具有2型多細胞生活個體。

- 1) 高大且生長快速型，會明顯受到環境的季節性變化而導致高死亡率。
- 2) 小型且生長緩慢型，對季節性變化較不敏感，且死亡率低。

這些物種都有單倍體及二倍體的世代交替，同形(isomorphic)的物種之單倍體及二倍體世代皆為高大型；然而異形(heteromorphic)的物種則因不同倍體世代而異。

判斷下列每個敘述的真偽。

A. 同形的物種所占的比例可能增加，且對季節性變化較敏感。

B. 在異形的物種中，高大且生長快速的生活個體型可出現在生長較多的季節。

C. 異形的物種多為一季(冬季/夏季)僅有1個世代。

D. 在這些藻類中，來自二倍體親代的所有單倍體子代，其基因親緣相近程度比來自單倍體親代的所有二倍體子代還遠。

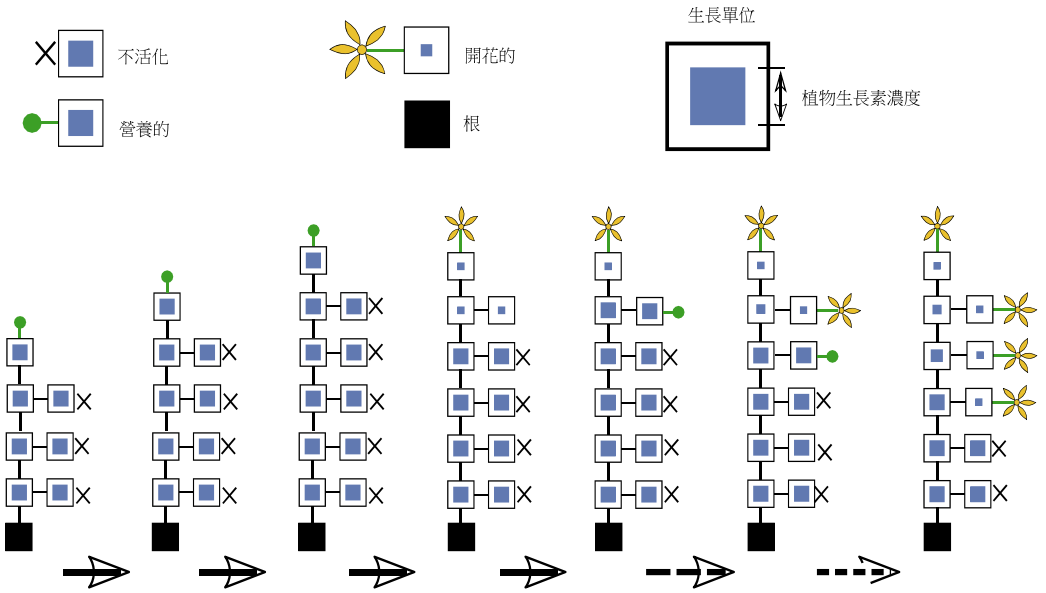
A. False **B.** True **C.** True **D.** True

Original commentary
Correct answers
A *false*
The description of the small life form is giving a hint that it is adapted to endure a tougher, less productive season (winter). A species with the tall and fast growing form alone will have an increasing handicap in regions with a more intense winter compared to heteromorphic species more adapted to endure a tough season.
B *true*
As the tall life form is adapted to fast growth during summer, it will be more competitive during summer as compared to individuals with the small life form present during summer.
C *true*
The small life form is adapted to outlive the unproductive winter - during summer the small life form would implicate a loss of productivity. On the same time, the tall life form would be very vulnerable during winter and most likely not survive. So heteromorphic species only make one new generation at the end of each season.
D *true*
Haploid plants derive from spores which are products of a meiosis and have only one parent. Therefore siblings share half of their genome in average. Diploid plants derive from a zygote out of two gametes, resulting themselves from a meiosis of their parents. All gametes from each parent are genetically identical, as are the full siblings among each other.

References
Bessho et al, Evolutionary Ecology Research (2009)

Own commentary

植物的生長單位稱為metamers(如圖所示)，其源自營養構造的分生組織。每個metamer包括一段莖及一個芽，這個芽最初為不活化狀態，但可活化而成為一分生組織(營養芽)。此營養芽可轉化為開花的分生組織(花芽)。營養芽及花芽可產生植物生長素，並可將植物生長素持續向下運送至較下方的metamers。下圖顯示一植物的不同年齡階段以至開花，並顯示在每個metamer中的植物生長素濃度。



根據所觀察到的植物生長素濃度，判斷下列每個敘述的真偽。

A. 只有在植物生長素超過其作用所需的最小濃度時，才會活化分生組織。

B. 頂端轉化成開花階段時，會失去其頂端優勢。

C. 高濃度的植物生長素可誘導花的發育。

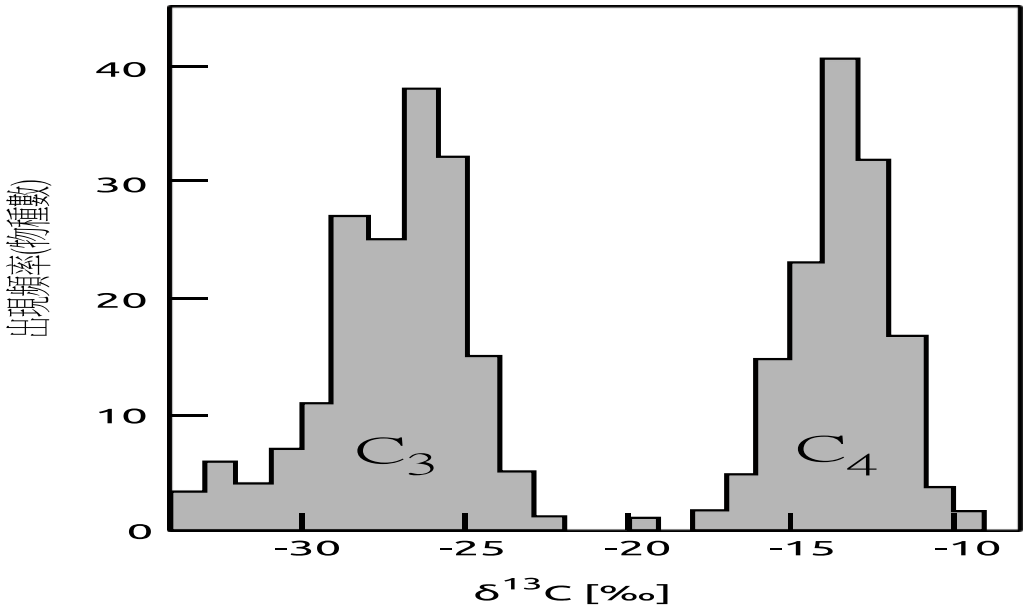
D. 來自不同生長單位頂端的植物生長素對其下方生長單位的影響具累積效應。

A. False **B.** True **C.** False **D.** True

Original commentary
Correct answers
A *false*
The opposite is true, below a certain threshold the apical dominance is lost and the uppermost inactive meristem is activated.
B *true*
A metamer turning into a flower is reducing its production of auxin, so the concentration of auxin sinks in the subsequent metamer and falls under the threshold needed to suppress meristem activation.
C *false*
If this was true, all meristems would turn into a flowers.
D *true*
The residual auxin from all four flowering apices accumulates along the stem and prevents the subsequent metamer from being activated. /br>
References
Przemyslaw et al, PNAS (2009)

Own commentary

空氣中含有2種碳的穩定碳同位素^{12}C 及 ^{13}C，但^{12}C的含量是^{13}C的100倍以上。多種代謝過程多偏好^{12}C而排斥^{13}C，導致^{13}C在生物體內的比例較在空氣中者少。　　理論值與觀測值的相對差異為$\delta^{13}C$，當此數值更負，即表示有較強的排斥情形。圖中顯示$\delta^{13}C$值在具C_3及C_4代謝的不同植物種類之分布。



判斷下列每個敘述為正確或錯誤。

A. 相較在CO_2分壓較低的情況下，當CO_2分壓較高時，RuBisCO對^{13}C的排斥較強。

B. 對^{13}C的排斥程度而言，將CO_2固定為草醯乙酸的反應比CO_2與RuBisCO的反應更強。

C. 以牛肉中的^{13}C含量而言，在瑞士山區吃草的牛可能比在中非草原的牛低。

D. 可根據其重量來區別由甘蔗(C_4)或甜菜(C_3)所純化出來的糖。

A. False **B.** False **C.** True **D.** True

Original commentary
Correct answers
A *false*
Actually the opposite is true. The aim of the C_4 metabolism is to increase the partial pressure of CO_2 for RuBisCO to increase the proportion of the carboxylase reaction compared to the oxigenase reaction. The higher partial pressure is actually the reason of weaker discrimination of ^{13}C in C_4 plants.
B *false*
This reaction is the first fixation step in C_4-plants which are less discriminative than C_3 plants.
C *true*
C_4 plants are much more present in tropical ecosystems than in temperate or cold ecosystem. The isotope ratio is reported upwards in the food chain to herbivores and predators.
D *true*
As ^{13}C is slightly heavier than ^{12}C, the mean weight of a sugar molecule from cane is slightly higher.

Own commentary

多數植物的種子在萌發前較能抵抗逆境。為印證此說法，以小麥種子來進行以下四個實驗處理。

處理	浸泡	培養	移至潮濕紙上，並置於室溫下培養。
A	室溫下5小時	5 h; -20°C	+
B	室溫下5小時	5 h; 30°C	+
C	-	5 h; 4°C	+
D	-	5 h; 50°C	+

判斷種子在下列各種處理下，是否可發芽?

A. A處理

B. B處理

C. C處理

D. D處理

A. False **B.** True **C.** True **D.** True

Original commentary
Correct answers
A *false*

B *true*

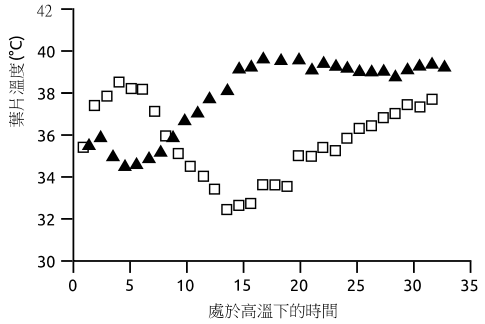
C *true*

D *true*

References
Campbell Biology, 9th ed., p. 84-85 and figure 5.22 ("What determines protein structure?") and pages 807ff. and figure 39.11 ("Seed Development, Form, and Function").

Own commentary

下圖顯示兩組豆科植物(*Phaseolus vulgaris*)在遠紅光及高溫下的葉片溫度變化。在實驗前，一組植物(空心方形)處於水分充足之下，而另一組(三角形)則處於乾旱逆境下3天。



根據此結果，判斷下列敘述正確或錯誤。

A. 在暴露於高溫8分鐘後，乾旱逆境下的植物比控制組有較多氣孔仍維持打開。

B. 兩組植物調控氣孔開閉的能力會隨時間而減弱。

C. 高溫15分鐘後，乾旱逆境植物的葉片，其所吸收與所釋出的熱量大致相同。

D. 植物須在避免水分喪失及避免過熱之間取得平衡。

A. False **B.** False **C.** True **D.** True

Original commentary
Note
If stomata are open, transpiration increases and therefore leaf temperature decreases (through evaporative cooling). The opposite is true for closing of stomata.

Correct answers
A *false*

B *false*

C *true*

D *true*

References
Reynolds-Henne et al, Environmental and Experimental Botany et al (2009)
Campbell, Biology (9th ed.) page 778 ("Effects of Transpiration on Wilting and Leaf Temperature").

Own commentary

將新鮮分離出的葉綠囊（類囊體）懸浮液置於陽光下培養，並藉由DCPIP來測量希爾反應(光解作用)的速率。DCPIP會在光系統I中被還原，且其顏色會從藍色變成無色。

判斷下列每個對實驗處理的修改，是否會明顯降低反應速率?

A. 將溶液溫度由20 °C提高至30 °C。

B. 在加入葉綠囊之前，先移除存放葉綠囊的緩衝液中的溶解性氣體。

C. 加入DCMU，它是一種可與光系統II結合的殺草劑。

D. 加入2,4-D，它是一種殺草劑，作用為人工合成的植物生長素。

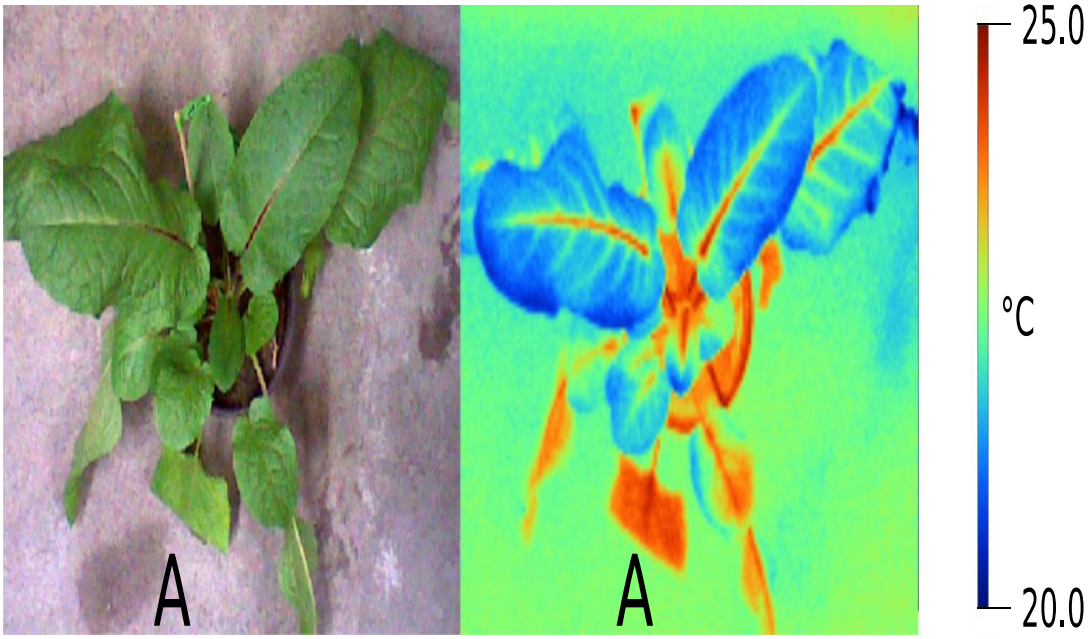
A. False **B.** False **C.** True **D.** False

Original commentary
Correct answers
A *false*
Temperature remains in the physiological optimum and the rate is expected to increase with temperature.
B *false*
No oxygen nor CO_2 is needed for electron transport chain.
C *true*
If the electron transport chain is interrupted, DCPIP will not be reduced and the suspension will not turn colourless.
D *false*
Auxin has no effect on electron transport chain.

References
Campbell Biology, 9th ed., p. 193-194 (electron transport chain).

Own commentary

遠紅光攝影照片可用以檢視植物表面的溫度。下圖為植物照片及其對應的遠紅光照片。



根據此圖，判斷下列每個敘述為正確或錯誤。

A. 新葉由於生長在老葉的陰影下，故此植物的新葉較老葉涼。

B. 在具高代謝活動的植物部位比低代謝處的溫度較高。

C. 葉脈的蒸散作用顯著較葉片低。

D. 葉片A的溫度高顯示此植物開始面臨乾旱逆境。

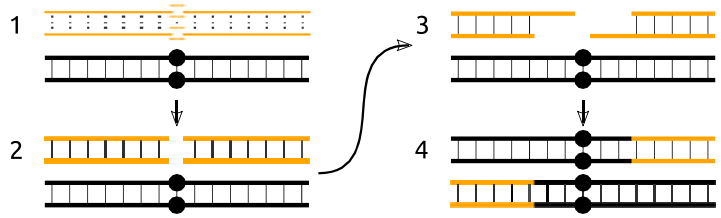
A. False **B.** False **C.** True **D.** False

Original commentary
Correct answers
A *false*
Younger leaves are actually warmer than older leaves because they are transpiring less. The really old leaves in senescing state are warmer, but do not provide shade.
B *false*
While metabolism may indeed increase the temperature of plant parts, this is usually a negligible factor. In addition, the hottest parts of the plant (shoot and veins) are actually not those parts with the highest metabolism. Those would rather be leaves producing starch, actively growing meristems and roots (which are not visible). Finally, non-metabolizing structures such as the pot, the substrate or the small pole with a tag get equally warm as the hottest parts of plants.
C *true*
The temperature of leaf veins is higher than that of the leaf blade because their transpiration is very low.
D *false*
Leaf A is senescing and thus not transpiring any more. Other leaves are healthy and transpiring, hence the reason cannot be that the plant is suffering from drought stress.

References
Campbell, Biology (9th ed.)page 778 ("Effects of transpiration on wilting and leaf temperature")

Own commentary

依據目前確認的基因重組分子模式所述(如下圖)，基因重組起始於一條染色分體發生雙股斷裂(DSB)，接著從斷裂點由5'向3'移除一段單股DNA，隨著重組過程的進行，DSB斷裂區段失去的遺傳訊息會被修補，修補DSB斷裂區段時，原來失去的訊息會依照同源染色分體上的遺傳訊息重建。



考慮某基因的二個等位基因，A和B，發生DSB的機率分別為rA和rB。在一隔離的大族群中，原本等位基因A和等位基因B具相同頻率。

判定下列各敘述是否正確

A. 如果rA是rB的2倍，則等位基因A的頻率改變，在rB=0.05時會比在rB=0.01時要快

B. 如果rB很大，rA小很多，則等位基因A的頻率會以線性模式趨向固定(等位基因頻率=1)

C. 如果rA=rB，則即使族群很小，等位基因A的頻率都會維持恒定不變

D. 除非有其他的機制影響，否則這種基因重組在族群中會逐漸降低

A. True **B.** False **C.** False **D.** True

Original commentary

Note

It should be clear from both the figure and the text that the allele initiating the DSB is not transmitted, which leads a bias in transmission in heterozygotes if the probabilities rA and rB are different.

Correct answers

A *true*

The larger the recombination rate, the more often the described mechanism can actually play. Hence the allele frequency changes more rapidly.

B *false*

While such a setting will lead to a rapid increase in allele A, the increase cannot be linear because the process depends on the frequency of heterozygous individuals, which become rapidly rare as the frequency of A approaches 1. Thus, the frequency of A is expected to increase asymptotically.

C *false*

In the case of rA=rB, this mechanisms will not necessarily lead to a change. However, due to genetic drift, an allele frequency is never expected to remain constant, unless the population is extremely (infinitely) large.

D *true*

This mechanism effectively leads to a reduction in the recombination rate since alleles with a lower recombination rate are favored.

Own commentary

在雌果蠅(*Drosophila melanogaster*)中，卵母細胞(oocyte)位於母體的營養細胞(nurse cells)和濾泡細胞(follicle cell)之間，營養細胞和濾泡細胞提供胚發育所需的養分、蛋白質和mRNA。有一基因所產生的mRNA會被運送到卵母細胞，此基因的一個突變 X會導致胚胎畸形且無法存活。

判定下列各敘述正確或錯誤

A. 如果此突變是顯性的，則突變X異型合子雄果蠅和野生型的雌果蠅交配所生的雌性子代可以存活

B. 如果此突變是顯性的，則不會觀察到存活的突變X同型合子個體

C. 如果此突變是隱性的，則對於突變X異型合子母親，只有雌性胚胎是畸型

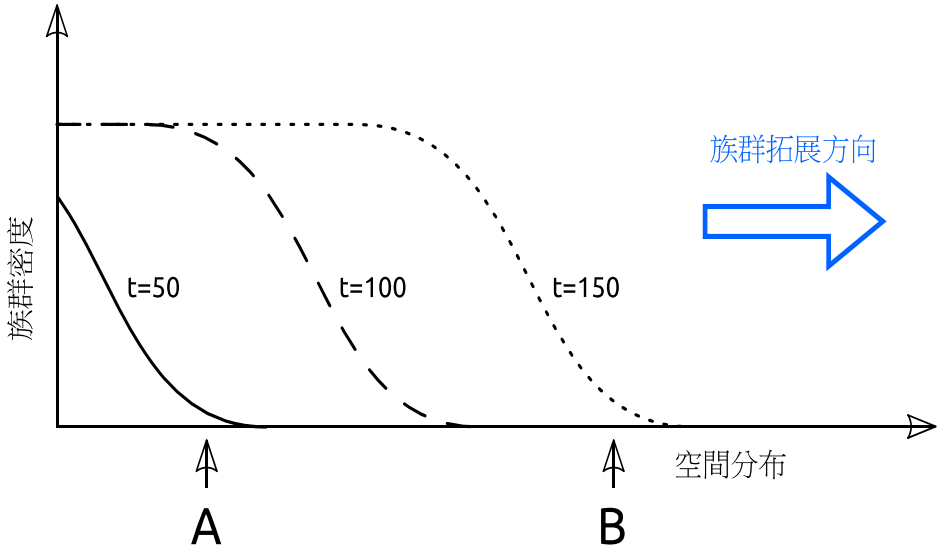
D. 如果此突變是隱性的，二個突變X異型合子的個體雜交產生F1子代，其F2中有1/6是突變X同型合子

A. True **B.** True **C.** False **D.** True

Original commentary
Correct answers
A *true*
Female with a mutation in a maternal effect gene are viable, even if they are sterile.
B *true*
To be homozygous for the mutation, an individual need to receive a mutant allele from each parent, however, females with a dominant mutation are sterile and therefore cannot transmit the mutation to offspring.
C *false*
If the mutation is recessive, all offspring of a heterozygous mother will be viable.
D *true*
To be homozygous for the mutation, an individual need to receive a mutant allele from each parent. In the F1 of a cross between heterozygotes, the genotypes are distributed 1:2:1. Males can give the mutant allele with a probability of 1/2, however, the homozygous mutant female are sterile, therefore, only heterozygous females, representing 2/3 of the fertile females can give the mutant allele to their offspring, this with a probability of 1/2. The final probability of being homozygous in the F2 is 1/2 * 2/3 * 1/2 = 1/6.

Own commentary

假設有個一維均質棲地，其承載力（負荷量）為K。此棲地只有1種一年生植物在時間點t=0時位於下圖最左位置，在每一世代有m=0.01 比例的種子會散播至鄰近地點，而1−m比例的種子會留在原地，下圖呈現這種植物在不同世代 (t)的空間分布和族群密度的關係



判定下列各敘述是否正確或錯誤

A. 使m值倍增的突變會讓族群拓展速率增快

B. t=100的族群中，若在A位置出現單一個增益突變，則在此族群中此突變一定會變成固定(等位基因頻率=1)

C. t=50時在A位置出現的中性突變會比t=150時在B位置出現的中性突變具較高的機率變成固定(等位基因頻率=1)

D. t=150時，若發生一個有害但非致死的突變，則其發生在B位置的存留時間會比發生在A位置的存留時間為久

A. True **B.** False **C.** True **D.** True

Original commentary
Correct answers
A *true*
The speed of the expansion is primarily dependent on the growth rate and, up to a limit, on the migration rate. If the migration rate is very small (as is the case here), it will, on average, take multiple generations until the next deme is colonized. Hence, an increase in the migration rate does lead to an increased colonization speed.
B *false*
The most likely fate of every mutation appearing in a population is that it is lost by genetic drift.
C *true*
While both mutations have the same probability to become common at their receptive positions, a mutation that becomes common at position B will have a very low probability to become common at position A. In contrast, a mutation that becomes frequent at position A is likely contributing to the newly colonized demes and will thus have a higher chance to get fixed in the whole population.
D *true*
Since the population density will increase rapidly at Position B, selection is very weak and genetic drift is not efficient in losing new alleles. In contrast, both drift and selection are acting more strongly on a new mutation at position A since the population is large and stable in size. Hence, a deleterious mutation is much more likely to persist in the population when appearing at position B than when appearing at position A.

Own commentary

一種紅色真菌的顏色是由代謝過程將一前驅色素經過數種中間產物的轉換而得。研究此代謝過程時發現了4種突變菌種（Ⅰ－Ⅳ），各具不同顏色。下表是這些突變菌種單倍體的顏色，以及彼此間交配後產生之單倍體子代的顏色

菌種或交配組合	顏色			
	紅色	灰褐色	黃色	粉紅色
野生型	X			
Ⅰ		X		
Ⅱ		X		
Ⅲ			X	
Ⅳ				X
Ⅰx 野生型	X	X	X	
Ⅱx Ⅲ	X	X	X	X
Ⅱx Ⅳ		X		X
Ⅲx Ⅳ	X		X	X

判定下列各敘述是否正確

A. 至少有4個基因參與此代謝途徑

B. 菌種Ⅰ至少有2個與此代謝過程相關的基因發生突變

C. 在此代謝過程中，轉換粉紅色素的酵素作用在轉換灰褐色素的酵素之前

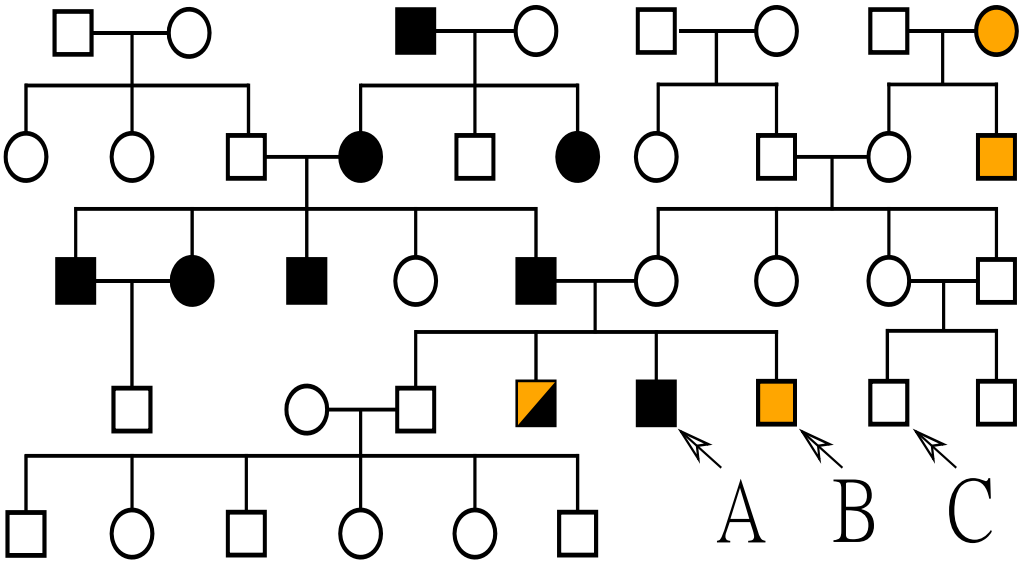
D. 菌種Ⅰ和菌種 IV交配後可得到紅色子代

A. False **B.** True **C.** False **D.** True

Original commentary
Correct answers
A *false*
In this pathway, 3 steps catalyzed by a total of 3 enzymes are enough to explain the results.
B *true*
Crossing I (beige) with the wild-type produces, besides beige and red (wild-type) offspring, also yellow offspring which can only be explained if strain I is mutant both for the enzyme metabolizing the beige intermediate and the one transforming the yellow one. Since strain I appears beige, it also means that the yellow pigment is situated further downstream in the pathway as the beige one.
C *false*
Crossing II (beige) with IV (pink) does not produce any red (wild-type) offspring, this means that at least one of the two strains is mutant for both alleles. Crossing III (yellow) with IV (pink) does not produce beige offspring. Since we know from B that beige is upstream of yellow, this can only be explained if IV is only mutant for the gene metabolizing the pink intermediate, therefore strain II is mutant both for the enzyme metabolizing beige and the one metabolizing pink. Since II appears beige and not pink, the beige intermediate is upstream of the pink one.
D *true*
Offspring can only be red if between the 2 parents, at least one copy of each gene is wild-type. We know from B that I is mutant only for the enzymes converting yellow and beige and from C that IV is only mutant for the enzyme converting, therefore red (wild-type) offspring can be observed when crossing I and IV.

Own commentary

下圖是一個有關遺傳性疾病X(黑色)和遺傳性疾病Y(橘色)的譜系，其中3個男性（A，B 和 C）是遺傳諮詢的對象。在族群中遺傳性疾病X非常稀少，而遺傳性疾病Y的致病等位基因頻率為 6%



以最可能的遺傳模式判定下列各敘述是否正確

A. 個體B一定是疾病X致病等位基因的帶原者

B. 個體C不可能是疾病Y致病等位基因的帶原者

C. 如果個體A與一個無血緣關係的正常女性將有一個兒子，這個兒子得到疾病X的機率是50%

D. 如果個體B與一個無血緣關係的正常女性將有一個兒子，這個兒子得到疾病Y的機率 > 5.65%

A. False **B.** True **C.** True **D.** True

Original commentary
Note
Mode of inheritance disease X
Since two affected individuals have a healthy son, disease X must be dominant and since both males and females are affected, it cannot be Y-linked. Finally, since we know that the disease is extremely rare and thus most likely absent in the family of the mother of A and B, the disease must be autosomal then an X-linked disease can not be inherited from father to son (individual A).

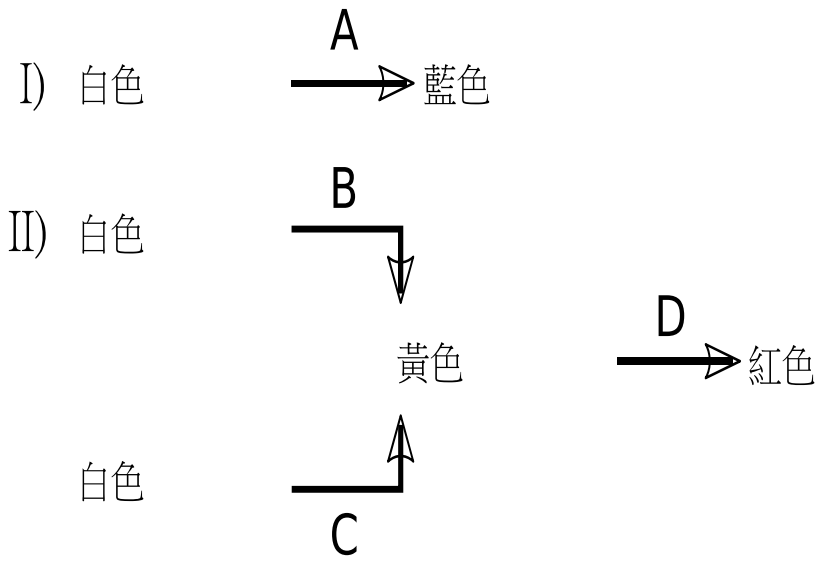
Mode of inheritance of disease Y
Dominant inheritance can be excluded because two healthy individual have an affected son (individual B). Autsomal recessive is unlikely because the father of individuals A and B has healthy parents, grand parents, uncles, aunts and siblings. Hence the most likely mode of inheritance is X-linked recessive.

Correct answers
A *false*
Given a dominant inheritance of disease X, individual B cannot be a carrier of this disease. Note that it is enough to realize that the disease must be dominant but not to distinguish between autosomal or gonosomal to answer this questions.
B *true*
A male cannot be carrier of a X-linked recessive disease.
C *true*
Since the disease is dominant, individual A will pass on the affected allele in 50% of the cases.
D *true*
While individual B will pass on his Y-chromosome and hence not the disease causing allele, the probability that the mother will pass it on is non zero. Given the allele frequency of 6% in the population and given that the mother is healthy, she is a carrier with a probability of (2*0.06*0.94)/(1-0.06*0.06) = 11.32%, in which case she has a probability of 50% to transmit the disease causing allele. Hence, the probability to have an

affected son is 5.67%. A common mistake is to assume the probability that the mother is a carrier to be 2*0.06*0.94*0.5 = 5.64%, and hence to ignore the fact that we already know that the mother is not affected.

Own commentary

一種植物有幾個不同的自交純品系，各具不同的隱性突變。野生型的紫色花是由2個生化合成路徑分別產生的紅色和藍色色素混合而成。如下圖所示，這2個合成途徑 (I 和 II) 需要基因A-D所產生的酵素，合成途徑中無色的中間產物都以白色"white"表示。



判定下列各敘述是否正確

A. 如果所有參與基因都不具連鎖關係，一個紅花純品系和一個藍花純品系雜交後，預測F2有<25%的個體會開紅花

B. 若將一個紫花純品系和一個黃花純品系雜交後，再將其 F1回交黃花純品系親代，得到160個黃花子代、40個紅花子代、40個綠花子代和160個紫花子代，則基因A和D在同一染色體上，相距20 cM

C. 如果B基因距A基因比距C基因近；A基因距C基因比距B基因近，B基因一定位於A基因和C基因之間

D. 如果B基因和C基因相距28.5 cM，將2個紫花自交純品系雜交後所得之F1紫花個體彼此雜交，而F2中有藍花的個體，則藍花個體的頻率應少於5%.

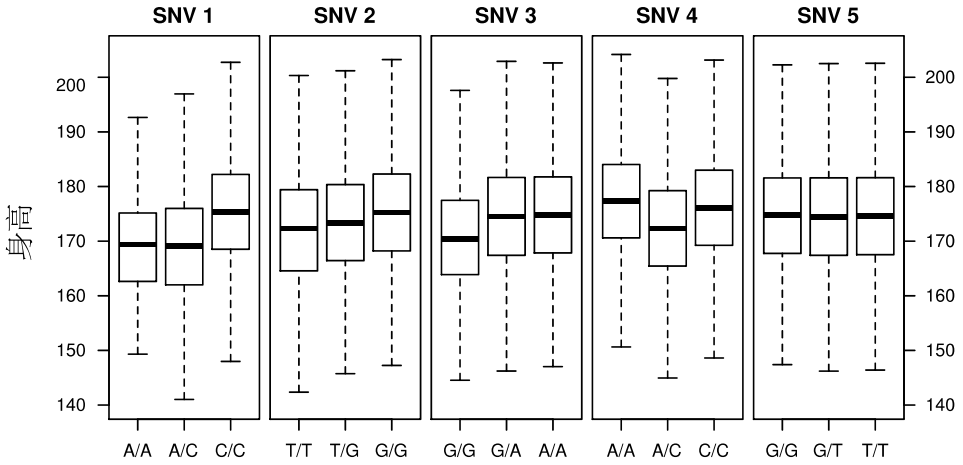
A. True **B.** True **C.** False **D.** True

Original commentary
Correct answers
A *true*
A red inbred line is homozygous for a loss of function mutation in gene A (genotype aaBBCCDD). A blue inbred line is homozygous for a loss of function mutation both in gene B and gene C (genotype AAbbccDD), as otherwise the plants turn green. The F1 of such a cross has the genotype AaBbCcDD. F2 individuals with red flowers must be homozygous for a (which they are with probability 1/2*1/2=1/4) and may not be homozygous for both b and c at the same time, which they are with probability 1-(1/2)^4=15/16. The total frequency of red individuals among the F2 is thus 1/4*15/16=15/64=23.9%. However, note that the red inbred line might also be homozygous for either b or c, in which case the F1 individuals have genotypes AabbCcDD or AaBbccDD. In this setting, the probability that an F2 individual is not homozygous for both b and c is reduced to 1-(1/2)^2=3/4, and hence the frequency of red F2 individuals would be 1/4*3/4=3/16=18.75%. So independent of the assumptions, the frequency is always < 25%.
B *true*
Yellow inbred lines must be homozygous for loss of function mutations a and d. In a back-cross setting with an individual homozygous for A and D (as the purple inbred line must be), the genetic distance can easily be computed as the frequency of non-parental phenotypes (green and red) among the progeny (see Campbell chapter 15). Thus, the distance is 80/400=20cM.
C *false*
From them stem we know that B and C are linked. We further know that B is closer to A than to C. This

leaves us with the orders A–B–C or B–A–C. Since A is closer to C than to B, only B–A–C remains (or C–A–B read from the other side).
D *true*
The only possible inbred purple genotypes that result in a purple F1 but some blue F2 when crossed are AAbbCCDD and AABBccDD. Under this setting, the F1 is AABbCcDD, and hence purple. A blue F2 individual has then the genotype AabbccDD, which requires a recombination to happen in both F1 parents (from the haplotypes AbCD and ABcD to AbcD and ABCD). This occurs with probability 0.285 (since the two genes B and C are 28.5 cM apart). After recombination, the needed haplotype is transmitted with a 50% chance. Hence the total probability for an F2 individual to be blue is $(0.285*0.5)^2=2.03\%$.

Own commentary

想找到與特定性狀相關的基因，有一常用的策略是用統計方法去分析表現型和單核苷變異(SNV)間是否有關聯性的存在，這需要大樣品個體數和大量的SNV。下圖是一個實驗計畫的結果，目的是研究身高和5個SNV位置間的關係，樣品取自瑞士20,000個逢機個人樣本



判定下列各敘述是否正確

A. SNV1和SNV3與影響身高的基因連鎖，SNV2則無

B. 如果族群中SNV4的C等位基因頻率從50% 降到30%，則此族群的平均身高會增加

C. 因為此族群的身高中位數是175 cm，所以SNV1的A等位基因頻率一定低於30%

D. 這些結果足以說明大部分的身高變異是由遺傳所決定

A. True **B.** True **C.** True **D.** False

Original commentary

Correct answers

A *true*

All three SNVs seem to be linked to a gene with an allele affecting body height. The difference to SNV 2 is only that the pattern observed at SNVs 1 and 3 is very likely due to the effect of a dominant-recessive locus in close proximity since the heterozygous genotype results in a very similar phenotype as one of the homozygous genotypes, but the pattern observed at SNV 2 is best explained with incomplete dominance.

B *true*

If the frequency of the C allele decreases from 50% to 30, the number of heterozygous individuals decreases from 50% to 42%, and hence the average body height is expected to increase.

C *true*

SNV 5 has no effect on body height, and hence gives a direct estimate of the average height in the population (about 175 cm). If the A allele at SNV 1 has a frequency of 30%, the frequency of the dominant C/C genotype is only 49%, which is not possible since the average height for this genotype had then to be > 180cm to obtain a population average of 175cm. Higher allele frequencies of A would even make it worse. Note: the true allele frequency in the example is 7%.

D *false*

All SNVs together can explain only 10% of the variation. The students are not able to calculate this value from the data. However, they are able to judge that SNVs 1 through 4 each explain about 5cm max, which makes about 20cm difference between the most extreme genotypes ([A/A, T/T, G/G, A/C] vs [C/C, G/G, A/A, A/A]). However, the body height in the populations spans a multiple of this difference. Hence the conclusion from this data that a majority of the variation s genetically determined is false. But note that in fact body height in humans is 60-80% heritable, yet one needs different data to show this.

Own commentary

貓的某一個基因位有2種等位基因(A, a), 在一族群中, 有1300隻貓是AA, 7400 隻貓是異型合子 Aa, 1300 隻貓是 aa。

判定下列各敘述是否正確

A. 此族群中等位基因A的頻率是0.5

B. 在哈-溫平衡的情況下, 應當只有6000隻貓對此基因是異型合子

C. 如果此族群被隔離, 且逢機交配, 則預期下一代會達哈-溫平衡

D. 此族群不符哈-溫平衡的原因是同型合子的個體不孕

A. True **B.** False **C.** True **D.** False

Original commentary
Correct answers
A *true*
The frequency of allele A is given by (2*1300+ 7400)/(2*(1300+ 7400+ 1300))=10000/20000=0.5.
B *false*
Under Hardy-Weinberg, 2*p*q=2*0.5*0.5=5000 cats are expected to be heterozygous.
C *true*
A population is always in the Hardy-Weinberg equilibrium after only a single generation of random mating.
D *false*
If only heterozygous individuals were fertile, the allele frequency would indeed be 0.5. However, the offspring would still be expected to be heterozygous in only 50% of the cases.

Own commentary

為釐清3種蠅類(*Lauxaniidae*)的親緣關係，以這3種的18S RNA及細胞色素氧化酶基因的核苷酸序列資料來分析。圖中的小點代表其核苷酸與第1條序列(*Minettia*)相同；橫線則代表有1或多個鹼基對之刪除或插入情況。

根據這些數據，判斷下列每個敘述為正確或錯誤。

A. 細胞色素氧化酶的基因其累積突變情形比18S RNA基因為快。

B. 從演化來看，*Minettia*的序列較*Lauxiana* 或 *Lyciella*保守。

C. *Minettia*的細胞色素氧化酶序列較*Lauxiana* 及 *Lyciella*兩者皆長8個核苷酸，由此可知，後兩者的親緣最近。

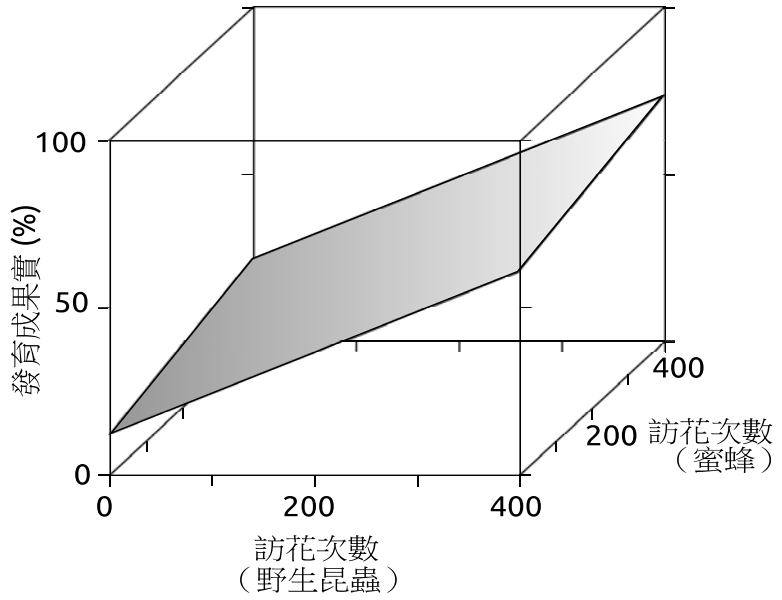
D. 18S RNA及細胞色素氧化酶的單一核苷酸取代，表示*Minetti, Lauxiana* 及 *Lyciella* 間的不同親緣關係。

A. True **B.** False **C.** False **D.** False

Original commentary
Correct answers
A *true*
Cytochrome oxidase has13 point mutations and 4 deletions, 18S RNA has 6 point mutations and 1 deletion.
B *false*
Minettia was arbitrarily chosen as reference to align the other two species and do not mean that it is the most primitive one.
C *false*
Between Lyciella and Minettia is only one deletion, Lauxiana has 3 independent deletions compared with Minettia and Lyciella.
D *false*
False, 18S RNA and cytochrom oxidase do show the same general topology of the genetic tree.

Own commentary

櫻桃樹（*Prunus avium*）的花可藉飼養的家蜂及野外的昆蟲如野生蜂或大黃蜂來授粉，要研究這些授粉者授粉的成果（樹上的花發育成果實的比例），研究者針對全球的櫻桃樹進行研究，選擇在一標準化的時間內觀察家蜂及野生昆蟲訪花的次數。所得的結果，可由下圖的線性模式表示。



請指出下列敘述正確或錯誤。

A. 當家蜂及野生昆蟲完全不存在時，櫻桃樹不結果實。

B. 家蜂傳粉的效率比野生昆蟲高，只需較少的訪花次數就能增加結實。

C. 要產生最大的結實率，果農被建議在家蜂訪花時，限制野生昆蟲的造訪。

D. 獨立生長於充滿花朵庭院的櫻桃樹，其結實量多於獨立生長於麥田中間的櫻桃樹。

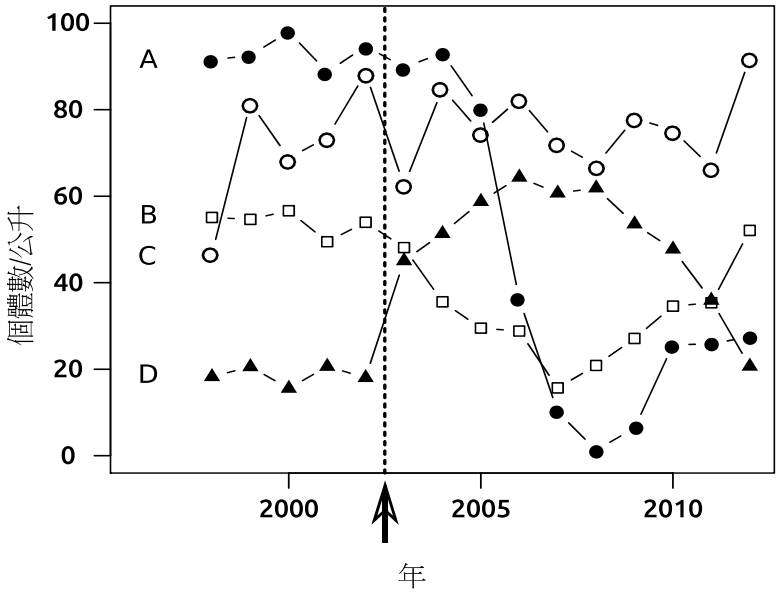
A. False **B.** False **C.** False **D.** True

Original commentary
Correct answers
A *false*
The regression predicts that about 10% of cherries would still be pollinated. This might be due to wind pollination or self-pollination.
B *false*
The slope of wild bees~fruit set is steeper than the one for honey bees, thus wild insects are more efficient.
C *false*
Both regressions (domestic bees~fruit set and wild insect~fruit set) are linear. Wild pollinators enhance fruit set regardless of the abundance of domestic honey bees.
D *true*
In a flower-rich backyard the density of both wild pollinators and domestic bees is expected to be higher than in a monoculture of wheat because the backyard is likely to offer a more breeding sites and a more diverse flowers spectrum to feed on.

References
Garibaldi et al, Science (2013)

Own commentary

2003年春天的一次意外事件，造成大量肥料流入瑞士的一個小湖中。下圖顯示在此事件發生前後幾年當中，每年8月所測得的4種浮游生物的豐富度。此意外事件以箭頭表示。



請指出下列各敘述是正確或錯誤。

A. 當意外事件發生後，物種C的族群密度快速下降。

B. 肥料對物種A很可能具毒性。

C. 物種D比物種B或C都更適合做為生物指標。

D. 在此意外事件發生的10年內，此群集內的物種相對密度已重新建立。

A. False **B.** False **C.** True **D.** False

Original commentary

Correct answers

A *false*

The decline in density of species C after the accident is in the range of its normal annual fluctuation. A causal relation with the accident is very unlikely.

B *false*

Zooplankton has short generation times. If the fertilizer itself were poisonous, the effect would be a drastic reduction already within the first two years after the accident.

C *true*

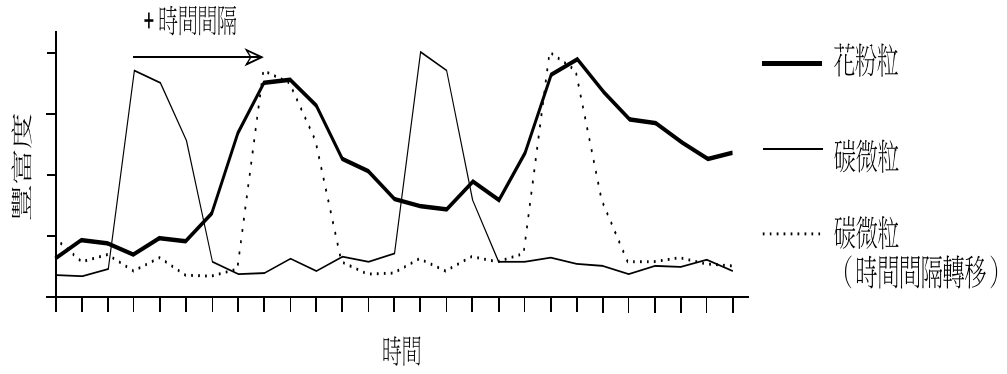
After the accident, species A and D show drastic and stable shifts in population densities. Those shifts are much bigger than the stochastic fluctuation before and some years after the accident and therefore seem to be reliable. The shift in population density of species B is much smaller. Species C does not seem to react at all.

D *false*

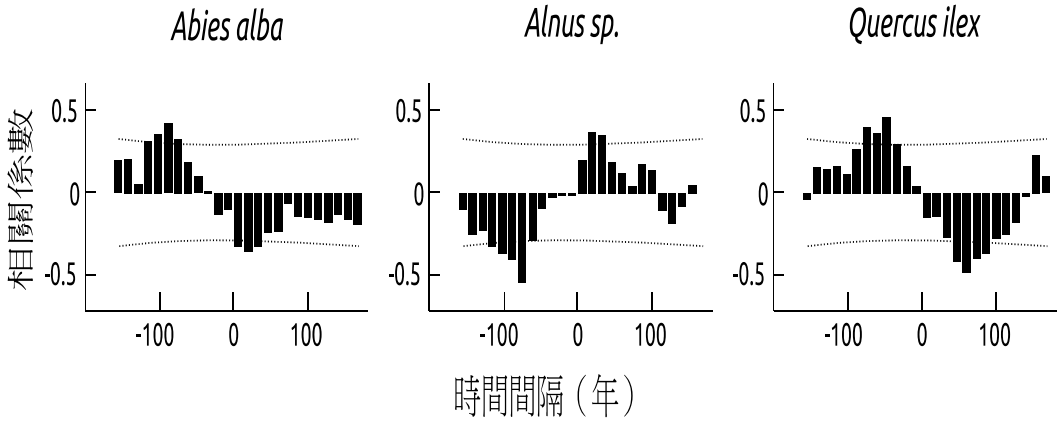
After 10 years, species is likely to still have a much smaller density than before the accident. During the years 7–9 after the accident, no significant increase in population density happened.

Own commentary

為了研究火災對於森林生態系所造成的影響，研究人員自地中海的湖中距今近6000年前的沈積物取得不同層面的切片，檢視其中的碳微粒（小於10μm）及3種樹種的花粉粒數量。由於森林生態系對外界刺激產生的反應常要在許多年後才能顯現，「碳微粒」與「一種樹的花粉粒」兩者間的豐富度相關性在火災發生前後，以不同的時間間隔來進行分析。例如：下圖中的假想樹種在火災發生許多年後，達到最高的豐富度。因此，藉著某一特定時間間隔的轉移，碳微粒與花粉粒的相關性將達到最高。



下圖顯示3種樹種碳粉粒與花粉粒的分析結果。其中，*Abies alba*種晚近在當地絕跡。相關係數超過閾值（虛線）時，具統計上α=0.05的顯著水準。



請指出下列各敘述是正確或錯誤。

A. 火災事件頻率的增加，可能造成*Abies alba*樹種滅絕。

B. *Alnus*樹種的花粉粒與碳微粒的關係所呈現的模式，可歸因於火災的煙刺激了花產生更多的花粉粒。

C. 目前地中海森林中優勢的*Quercus ilex*樹種，可歸因於它對週期性火災具有容忍力。

D. *Abies*樹種花粉粒豐富度受到火災事件的影響，快於*Quercus*樹種。

A. True **B.** False **C.** False **D.** True

Original commentary
Correct answers
A *true*
According to the data shown the amount of Abies pollen is negatively correlated with the amount of charcoal for a few decades after a fire. Therefore the species seems not to be tolerant to fire. An increase of frequency of fires will lead to successive regression of this species.
B *false*
The positive correlation between charcoal and pollen approximately 20-40 years after fire event cannot be explained by a reaction of individual flowers or even trees to fire stimulus. The period of increased pollen

production lasts several decades what is much too long for being explained by a punctual stimulus.
C *false*
As it is for Abies, Quercus seems to be less present during the period after a fire event. The recent dominance must have other reasons than tolerance to fire.
D *true*
The negative correlation to fire events is significant after a time lag of about 10–15 years in Abies, but only after about 40 years in Quercus.

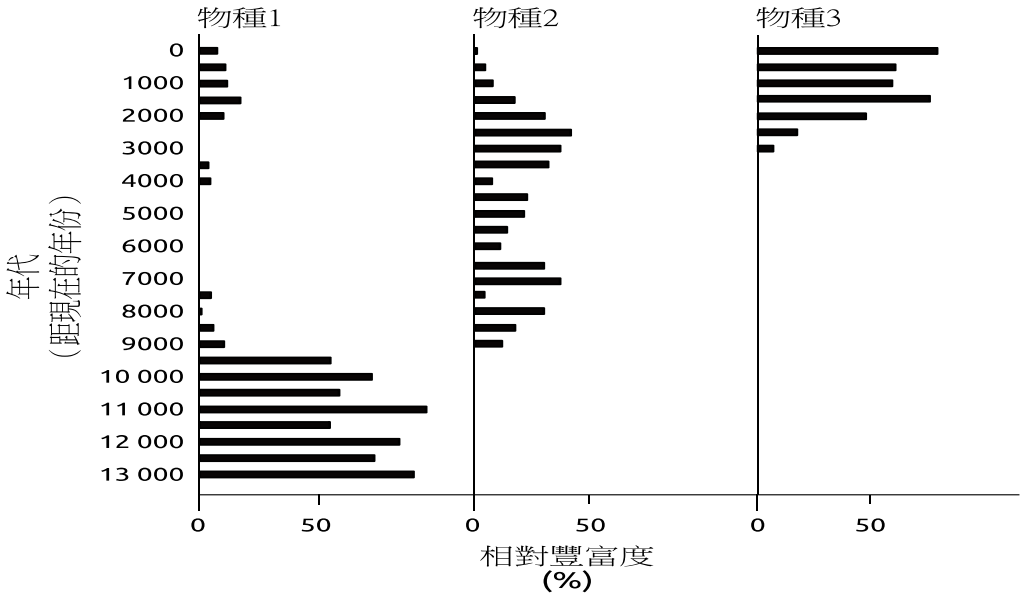
References
Colombaroli et al, Journal of Ecology (2007)

Own commentary

許多搖蚊類的物種（不會叮咬的蚊蚋）僅會在特殊的生態環境中大量出現，下列是在瑞士常見的3種搖蚊類。

	最佳的營養狀態	7月平均氣溫	附近最常見的植披
物種1	貧養化	7.1 - 12.9 °C	高山寒帶草原
物種2	中度營養化	9.3 - 17.6 °C	混生林
物種3	高度營養化	10.7 - 19.2 °C	農地

在湖沈積物中的搖蚊類化石，可用來重建湖畔周邊環境過去的氣候及生態狀況。在一個瑞士的小湖內，其沈積層中所有搖蚊類的頭鞘及數量皆已鑑定並記錄。下圖為前述所列3個搖蚊物種在每層沈積物中出現的相對豐富度。



請指出下例各敘述是正確或錯誤。

A. 自9000年前開始，人類就對該處有影響。

B. 自2000年前至今，可能有一個間歇性的寒冷氣候。

C. 物種3作為環境營養條件的指標性，優於作為平均氣溫的指標性。

D. 物種2豐富度的波動，可用Lotka-Volterra模式（掠食者及被掠食者間的競爭及消長模式，模式中包括吃蟲的天敵）來解釋。

A. False **B.** True **C.** True **D.** False

Original commentary
Correct answers
A *false*
The apparent increase in temperature and change of vegetation type at about 9000 years BP coincides with the end of the last ice age, when alpine vegetation was replaced by forests. However, human impact seems to be clearly indicated by appearance of species 3, whose optimal niche is in human made farmland that appeared about 3000 years BP.
B *true*
Since 2000 years, species 1 reappears in the sediment after an absence of several thousand years. It is the same species that was predominant at the end of the ice age. This indicates that the average temperature fell below a maximal level for this species.
C *true*

The sediment of the past 2000 years show that Species 3 is able to live in abundance at the same place as species 1, which has a much different temperature range. Therefore it is not a very good indicator species for temperature. But species 3 seems to be very closely linked to human farming activity, and predominates since the decline of forest indicated by species 2.
D *false*
Interactions between predators and prey show fluctuation periods of several years at maximum (insects are short living), but will not be visible on a time scale of several hundreds of years.

References
Heiri et al, Palaeogeography, Palaeoclimatology, Palaeoecology (2003)

Own commentary

支序分析是一種根據個體形質的有無及分子特徵，來建構個體間演化關係的研究方式。為了讓此支序分析正確可行，必須符合下列3項假設。

- 在一個譜系中，特徵隨著時間改變。
- 任何兩個個體的配對，具有共同的祖源。
- 演化譜系呈兩叉分支。

請指出下列各敘述是否與前述假設完全相符（是），或至少與其中一假設不符（否）。

A. 利用刺絲胞的有無可用來進行支序分析，以重建後生動物的譜系關係。刺絲胞是刺絲胞動物（例如：海葵）所具有的複雜細胞。有些海蛞蝓會藉由攝取海葵，來獲得刺絲胞並納入體內以為防衛之用。

B. 支序學可用來重建生態上鮮明的植物物種的親緣關係，這些物種其一是由兩個不同的親種進行雜交所產生。

C. 支序學可用來建構源自於偏僻島嶼的一種通才型雀鳥所產生的2種雀的親緣關係。這些物種的嘴喙長度與深度、踝骨及羽色有所不同。

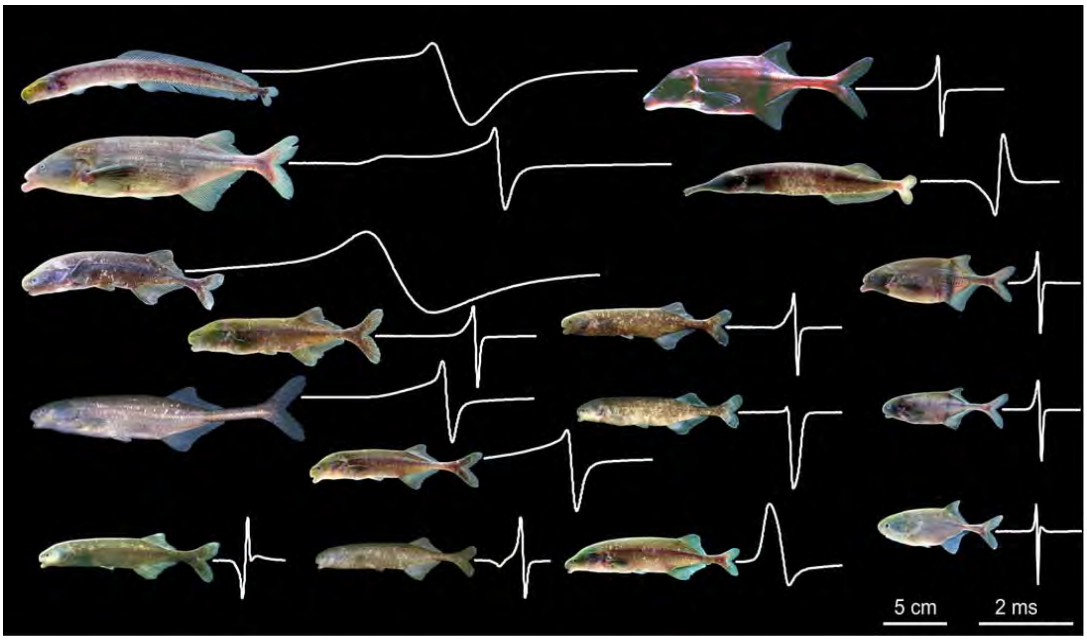
D. 支序學可用來建構地衣多細胞真核類的親緣關係。地衣是綠藻或藍綠菌與真菌形成的共生體。

A. False **B.** False **C.** True **D.** False

Original commentary
Correct answers
A *false*
Although both taxa have nematocysts, this trait cannot be used to put both of them in a distinct clade within metazoa, as sea slugs do not produce nematocyst themselves. In regard of this trait the evolutionary lineages do not split in bifurcating manner.
B *false*
Here, evolutionary lineages do not split in bifurcating manner, but the origin of one lineage is the fusion of two initially separated lineages.
C *true*
This example is in agreement with all assumptions.
D *false*
Lichen behave functionally a single organism, but consists of two independent organisms with a completely different phylogenetical background. Therefore the principle of splitting lineages in bifurcating manner is violated.

Own commentary

象鼻魚科（*Mormyridae*）的魚類以具有測定目標位置及藉由發電器官（EOD）產生微弱電場進行溝通的能力而聞名。牠們也可偵測到同科其他魚種所發出的電波。下圖顯示16種居住於中非雨林流域的象鼻魚類的身體外形、相對體型大小及溝通時發出的波形（白線）。



請指出下列各敘述是正確或錯誤。

A. 象鼻魚顯示了專以捕食其他體型大小相似魚種為生之魚類的典型特性。

B. 象鼻魚顯示了下列魚類的典型特性：藉由共同的視覺警告信號（繆氏擬態; Müllerian mimicry），並會發出電流警告天敵。

C. 象鼻魚顯示了生活在高度渾濁水域或夜行性為主之魚類的典型特性。

D. 象鼻魚顯示了藉由非視覺線索來吸引配偶之魚類的典型特性。

A. False **B.** False **C.** True **D.** True

Original commentary

Note

Since the students cannot be expected to know these fish, the question focuses on testing if the students can think of typical features of fish of a specific lifestyle, and are then asked to check if the *Mormyridae* show such features. This gets us around asking the students to judge the life style of *Mormyridae*.

Correct answers

A *false*

Fish specialized on preying other fish of similar size typically have a relatively large mouth with large conical teeth, both absent from all species of *Mormyridae*.

B *false*

If Müllerian mimicry would be important to reduce pressure from predators, all shown Mormyrids should show very similar, extremely contrasting colours most likely in combination of yellow and black or orange/red and black. In contrast, all shown *Mormyridae* are of dull / camouflage color. Furthermore, *Mormyridae* do not produce harmful electric shocks which could be used as an anti-predation behavior (mentioned in the text).

C *true*

Mormyridae live in turbid water and are mostly nocturnal. They have very small eyes compared to body size what indicates that vison is limited and seems to play a minor role for these fish. Large eyes are common in diurnal fish species that live in clear water. The complex systems for object localization and communication via the generation and reception of weak electric fields are very useful for nocturnal fish in turbid water.

D *true*

All *Mormyroiadea* are of dull color and have impaired vision. Hence, a system to attrackt mates using non-visual cues is highly expected. In addition, the electric signals produced vary greatly between species and are used to attract mates. /br>

References
Hopkins, Electroreception (1986)

Own commentary