British Biology Olympiad 2026 Paper 1

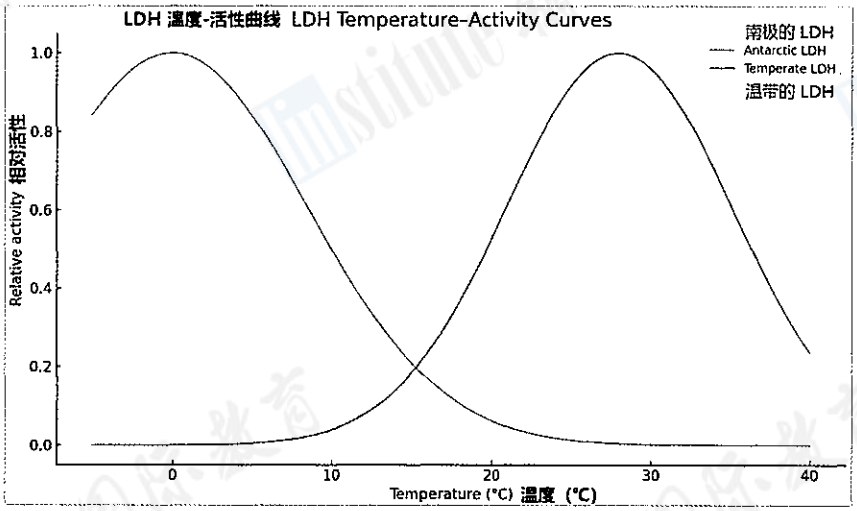
SECTION A — Enzymes & Metabolism 酶与代谢

Lactate dehydrogenase (LDH) is an enzyme that catalyses the conversion of pyruvate to lactate. Different organisms express LDH variants adapted to their thermal environment.

乳酸脱氢酶 (LDH) 是一种催化丙酮酸转化为乳酸的酶，不同生物体会表达适应其热环境的 LDH 变体。

Scientists compared LDH from an **Antarctic fish** and a **temperate fish**. They measured *relative enzyme activity* across a range of temperatures.

科学家比较了来自**南极鱼类**和来自**温带鱼类**的 LDH，并在一定的温度范围内测量了其*相对酶活性*。



A1

LDH temperature activity curves LDH 温度-活性曲线

Problem 1. Antarctic LDH maintains relatively high activity at near-freezing temperatures.

问题 1：南极鱼体内的 LDH 在接近冰点的温度下维持相对较高的活性。

A. TRUE 正确　　B. FALSE 错误

Problem 2. Temperate LDH typically shows its peak activity close to 0°C.

问题 2：温带鱼体内的 LDH 通常在接近 0°C 时表现出峰值活性。

A. TRUE 正确　　B. FALSE 错误

Problem 3. Antarctic LDH shows higher activity than temperate LDH across the entire temperature range.

问题 3：在整个温度范围内，南极鱼体内的 LDH 的活性均高于温带鱼体内的 LDH。

A. TRUE 正确　　B. FALSE 错误

A2

Thermal adaptation of enzymes 酶的热适应性

Problem 4. Cold-adapted enzymes often possess greater molecular flexibility than warm-adapted forms.

问题 4：冷适应酶通常比热适应酶具有更强的分子柔性。

A. TRUE 正确　　B. FALSE 错误

Problem 5. Warm-adapted enzymes generally retain full activity at sub-zero temperatures.

问题 5：热适应酶通常在零摄氏度以下时仍能保持全部活性。

A. TRUE 正确　　B. FALSE 错误

Problem 6. Cold-adapted enzymes frequently lose stability when exposed to warmer conditions.

问题 6：冷适应酶暴露在较温暖环境中时通常会失去稳定性。

A. TRUE 正确　　B. FALSE 错误

Problem 7. Warm-adapted enzymes commonly contain more stabilising interactions such as ionic bonds.

问题 7：热适应酶通常含有更多稳定的相互作用，例如离子键。

A. TRUE 正确　　B. FALSE 错误

A3

Adaptation in Antarctic fish 南极鱼类的适应性

Problem 8. Antarctic LDH is adapted to catalyse reactions efficiently in water near 0°C.

问题 8：南极鱼体内的 LDH 已适应在接近 0°C 的水中高效催化反应。

A. TRUE 正确　　B. FALSE 错误

Problem 9. The temperature optimum of an enzyme cannot evolve under natural selection.

问题 9：酶的最适温度无法通过自然选择进化。

A. TRUE 正确　　B. FALSE 错误

Problem 10. Temperate LDH would perform poorly if expressed in an Antarctic fish.

问题 10：温带鱼体内的 LDH 如果在南极鱼类中表达，其活性将降低。

A. TRUE 正确　　B. FALSE 错误

Problem 11. All vertebrates share identical enzyme temperature optima regardless of habitat.

问题 11：所有脊椎动物的酶的最适温度均相同，与其栖息环境无关。

A. TRUE 正确　　B. FALSE 错误

LDH has a three-dimensional structure including:

LDH 具有三维结构，其中包括：

- an active site, where substrate binds

  一个活性位点，用于结合底物
- a hydrophobic core, stabilising the folded enzyme

  一个疏水核心，用于稳定折叠酶
- surface regions that interact with solvent and other molecules

  与溶剂及其他分子发生相互作用的表面区域

Researchers modeled the structural effects of mutations in cold-adapted and warm-adapted LDH.

研究人员模拟了冷适应和热适应 LDH 中突变产生的结构效应。

Examples include:

包括以下例子：

- replacing a buried hydrophobic residue with a charged one

  将埋藏的疏水残基替换为带电残基
- adding flexible residues (e.g., glycine)

  引入柔性残基（例如甘氨酸）
- altering packing around the active site

  改变活性位点周围的残基堆积

A4

Amino-acid substitution and flexibility 氨基酸置换与柔性

Problem 12. A single amino-acid substitution can be sufficient to alter an enzyme's thermal properties.

问题 12：单个氨基酸置换就足以改变酶的热性质。

A. TRUE 正确　　B. FALSE 错误

Problem 13. All LDH isoforms must share the same amino-acid sequence.

问题 13：所有 LDH 同工酶必须具有相同的氨基酸序列。

A. TRUE 正确　　B. FALSE 错误

Problem 14. Hydrophobic interactions commonly stabilise warm-adapted enzymes.

问题 14：疏水相互作用通常能使热适应酶稳定。

A. TRUE 正确　　B. FALSE 错误

Problem 15. Additional glycine residues may increase enzyme flexibility in cold-adapted LDH.

问题 15：额外的甘氨酸残基可能会增加冷适应 LDH 的酶柔性。

A. TRUE 正确　　B. FALSE 错误

A5

Hydrophobic → charged mutation 疏水 → 带电突变

Problem 16. Replacing a hydrophobic core residue with a charged one can destabilise protein folding.

问题 16：将疏水核心残基置换为带电残基会使蛋白质的折叠态失稳。

A. TRUE 正确　　B. FALSE 错误

Problem 17. Such a substitution could decrease catalytic efficiency.

问题 17：这种替换可能会降低催化效率。

A. TRUE 正确　　B. FALSE 错误

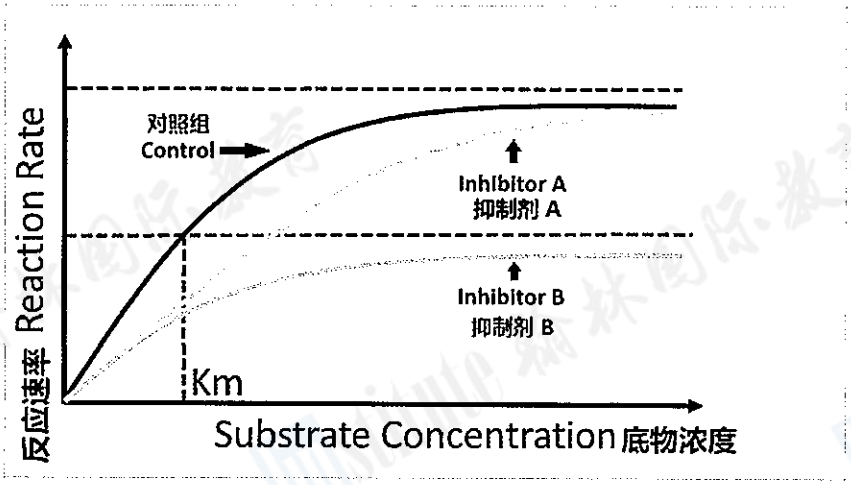
Problem 18. Charged residues are normally favoured in the hydrophobic protein interior.

问题 18：带电残基通常倾向于富集在蛋白质疏水内部。

A. TRUE 正确　　B. FALSE 错误

Scientists investigated two inhibitors of LDH:

科学家研究了两种 LDH 抑制剂：



Vmax is the maximum rate of reaction an enzyme can achieve.

Km is the substrate concentration at which the rate is half Vmax.

Competitive inhibitors usually increase the apparent Km, while non-competitive inhibitors usually reduce Vmax.

Some inhibitors bind at a site other than the active site. These are called allosteric inhibitors.

Allosteric inhibitors may change the enzyme's shape and reduce its activity.

Vmax 是酶能达到的最大反应速率。

Km 是反应速率达到 Vmax 一半时的底物浓度。

竞争性抑制剂通常会增加表观 Km，而非竞争性抑制剂通常会降低 Vmax。

有些抑制剂结合在活性位点以外的部位。这些被称为变构抑制剂。

变构抑制剂可能会改变酶的结构并降低其活性。

A6

Interpreting inhibitor curves 解读抑制曲线

Problem 19. Inhibitor A causes the reaction curve to shift right, indicating a higher substrate concentration is needed to reach the same rate.

问题 19：抑制剂 A 导致反应曲线向右移动，表明需要更高的底物浓度才能达到相同的反应速率。

A. TRUE 正确　　B. FALSE 错误

Problem 20. Inhibitor B causes the maximum reaction rate (Vmax) to fall.

问题 20：抑制剂 B 导致最大反应速率（Vmax）下降。

A. TRUE 正确　　B. FALSE 错误

Problem 21. At high substrate concentrations, the reaction rate with inhibitor A approaches that of the control.

问题 21：在高底物浓度下，加入抑制剂 A 的反应速率趋近对照组的反应速率。

A. TRUE 正确　　B. FALSE 错误

Problem 22. Inhibitor B increases Km.

问题 22：抑制剂 B 使 Km 增加。

A. TRUE 正确　　B. FALSE 错误

A7

Identifying inhibition mechanisms 识别抑制机制

Problem 23. Competitive inhibition can usually be overcome by increasing substrate concentration.

问题 23：竞争性抑制通常可以通过提高底物浓度来克服。

A. TRUE 正确　　B. FALSE 错误

Problem 24. A non-competitive inhibitor can be overcome by adding more substrate.

问题 24：非竞争性抑制剂可以通过增加更多底物来克服。

A. TRUE 正确　　B. FALSE 错误

Problem 25. A decrease in Vmax alone is sufficient evidence that an inhibitor binds at the active site.

问题 25： 仅 Vmax 的降低就足以证明抑制剂结合在活性位点上。

A. TRUE 正确　　B. FALSE 错误

A8

Competitive vs non-competitive inhibition 竞争性与非竞争性抑制

Problem 26. Inhibitor A, which binds at the active site, acts competitively.

问题 26： 抑制剂 A 结合在活性位点，起竞争性抑制作用。

A. TRUE 正确　　B. FALSE 错误

Problem 27. Inhibitor B reduces Vmax because it is non-competitive.

问题 27： 由于抑制剂 B 的非竞争性机制，它会导致 Vmax 降低。

A. TRUE 正确　　B. FALSE 错误

Problem 28. Competitive inhibition reduces Vmax at all substrate concentrations.

问题 28： 竞争性抑制在所有底物浓度下都导致 Vmax 降低。

A. TRUE 正确　　B. FALSE 错误

Problem 29. Non-competitive inhibitors must bind only after the substrate has attached.

问题 29： 非竞争性抑制剂必须仅在底物附着后才能结合。

A. TRUE 正确　　B. FALSE 错误

Different tissues express different LDH isoenzymes:

不同的组织表达不同的 LDH 同工酶：

- **Muscle LDH (LDH-A)** supports anaerobic ATP production.

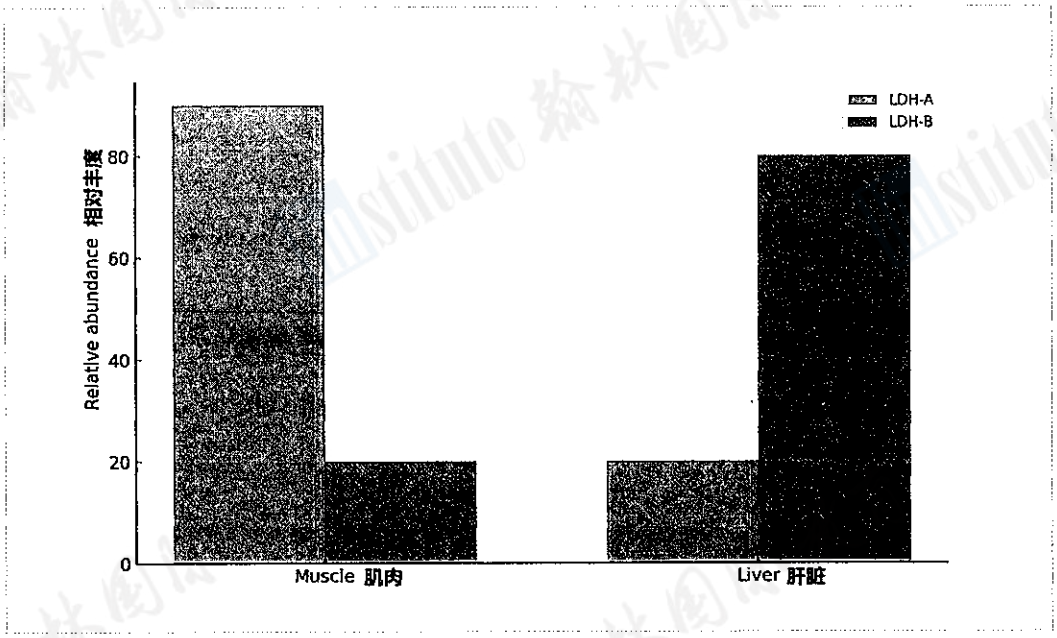
  肌肉 LDH (LDH-A) 支持无氧条件下合成 ATP。

- **Liver LDH (LDH-B)** converts lactate back to pyruvate for further metabolism.

  肝脏 LDH (LDH-B) 将乳酸转化回丙酮酸以进行进一步代谢。

The bar chart shows relative expression of isoenzymes in muscle vs liver.

下方柱状图显示了肌肉与肝脏中同工酶的相对表达量。



A9

Isoenzyme definition 同工酶的定义

Problem 30. Isoenzymes catalyse the same reaction but differ in molecular form.

问题 30： 同工酶催化相同的反应，但在分子形式上有所不同。

A. TRUE 正确　　B. FALSE 错误

Problem 31. Isoenzymes always share identical amino-acid sequences.

问题 31： 同工酶始终具有完全相同的氨基酸序列。

A. TRUE 正确　　B. FALSE 错误

Problem 32. Isoenzymes can differ in their kinetic properties.

问题 32： 同工酶的动力学性质可能不同。

A. TRUE 正确　　B. FALSE 错误

Problem 33. All tissues express the same LDH isoenzymes.

问题 33： 所有组织都表达相同的 LDH 同工酶。

A. TRUE 正确　　B. FALSE 错误

A10

Physiological importance 生理重要性

Problem 34. Muscle LDH helps maintain ATP production during anaerobic conditions.

问题 34：肌肉 LDH 有助于在无氧条件下维持 ATP 的合成。

A. TRUE 正确　　B. FALSE 错误

Problem 35. Isoenzymes prevent tissues adapting to different metabolic demands.

问题 35：同工酶阻碍了组织适应不同的代谢需求。

A. TRUE 正确　　B. FALSE 错误

Problem 36. Isoenzyme diversity is unimportant for physiological function.

问题 36：同工酶的多样性对生理功能并不重要。

A. TRUE 正确　　B. FALSE 错误

Problem 37. Liver LDH can help remove lactate by converting it to pyruvate.

问题 37：肝脏 LDH 能通过将乳酸转化为丙酮酸来帮助清除乳酸。

A. TRUE 正确　　B. FALSE 错误

SECTION B — Ecology, Sampling & Communities 生态学、采样与群落

Ecologists often sample plant or animal communities using quadrats, transects, and mark–release–recapture.

生态学家经常使用样方、样带和标志重捕法来对动植物群落进行抽样调查。

Environmental gradients (e.g., changes in light, moisture, salinity) can influence species distribution.

环境梯度（例如光照、水分、盐度的变化）会影响物种的分布。

Some methods measure:

一些用于测量的方法：

- **species richness** (number of species)

  物种丰富度（物种的数量）

- **species evenness** (relative abundances)

  物种均匀度（相对多度）

- **diversity indices** combining both richness and abundance

  将丰富度与多度二者结合的**多样性指数**

Other sampling approaches estimate:

其他抽样方法用于估算：

- **population size**

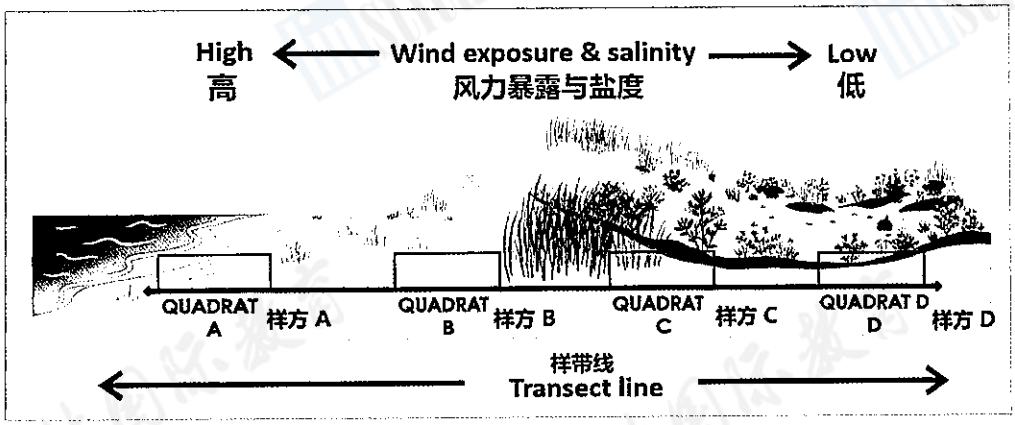
  种群大小

- **patterns of zonation**

  分带模式

- **effects of environmental factors on communities**

  环境因素对群落的影响



B1

Sampling along an environmental gradient 沿环境梯度采样

Problem 38. The species present along a gradient are always evenly distributed.

问题 38：沿梯度分布的物种总是均匀分布的。

A. TRUE 正确　　B. FALSE 错误

Problem 39. Sampling at intervals along a transect helps detect changes in species composition.

问题 39：沿样带进行间隔采样有助于监测物种组成的变化。

A. TRUE 正确　　B. FALSE 错误

Problem 40. Random quadrats always provide more information than transects for studying gradients.

问题 40：对于研究梯度，随机样方总是比样带提供的信息更多。

A. TRUE 正确　　B. FALSE 错误

B2

Quadrats and percentage cover 样方与覆盖度百分比

Problem 41. Percentage cover is always more accurate than counting individuals.

问题 41：覆盖度百分比始终比个体计数更准确。

A. TRUE 正确　　B. FALSE 错误

Problem 42. Percentage cover estimates can be subjective.

问题 42：覆盖度百分比的估算可能具有主观性。

A. TRUE 正确　　B. FALSE 错误

Problem 43. Quadrats cannot be used in communities with overlapping plant layers.

问题 43：样方不能用于存在植物层重叠的群落。

A. TRUE 正确　　B. FALSE 错误

B3

Interpreting quadrat data 解读样方数据

Problem 44. Quadrat placement has no effect on the accuracy of results.

问题 44：样方的放置对结果的准确性没有影响。

A. TRUE 正确　　B. FALSE 错误

Problem 45. Quadrat size must be appropriate for the organisms being studied.

问题 45： 样方的大小必须与所研究的生物相适配。

A. TRUE 正确　　B. FALSE 错误

Problem 46. Quadrat sampling allows estimation of species frequency.

问题 46： 样方抽样可用于估算物种频度。

A. TRUE 正确　　B. FALSE 错误

Problem 47. More quadrats generally increase reliability of abundance estimates.

问题 47： 增加样方数量通常可提升多度估算的可靠性。

A. TRUE 正确　　B. FALSE 错误

B4

Simpson's Diversity Index 辛普森多样性指数

Problem 48. Simpson's Index cannot be affected by changes in the abundance of a dominant species.

问题 48： 辛普森指数不会受到优势物种多度变化的影响。

A. TRUE 正确　　B. FALSE 错误

Problem 49. A higher Simpson's Index suggests greater diversity.

问题 49： 辛普森指数值越高，表明群落多样性越大。

A. TRUE 正确　　B. FALSE 错误

Problem 50. Simpson's Index incorporates both species richness and abundance.

问题 50： 辛普森指数同时反映物种丰富度与多度。

A. TRUE 正确　　B. FALSE 错误

B5

Effects of Competition on Niches and Distribution 竞争对生态位和分布的影响

Problem 51. Competition between species can reduce the area in which a species is able to survive and reproduce.

问题 51： 物种间的竞争会缩小某个物种的生存繁殖区域。

A. TRUE 正确　　B. FALSE 错误

Problem 52. Competition can prevent two species from maintaining identical niches.

问题 52：竞争可以阻止两个物种维持完全相同的生态位。

A. TRUE 正确　　B. FALSE 错误

Problem 53. The competitive exclusion principle states that identical niches promote stable coexistence.

问题 53：竞争排斥原理指出，相同的生态位会促进稳定的共存。

A. TRUE 正确　　B. FALSE 错误

B6

Zonation and environmental gradients 分带与环境梯度

Problem 54. Zonation can occur where environmental conditions change across space.

问题 54：环境条件发生空间变化的地方，可能会出现分带现象。

A. TRUE 正确　　B. FALSE 错误

Problem 55. Transect data can reveal patterns of zonation.

问题 55：样带数据可以揭示分带模式。

A. TRUE 正确　　B. FALSE 错误

Problem 56. Biological interactions can contribute to patterns of zonation.

问题 56：生物相互作用有助于形成分带模式。

A. TRUE 正确　　B. FALSE 错误

Problem 57. Zonation patterns may differ between locations even when environmental gradients are similar.

问题 57：即使环境梯度相似，不同地点的分带模式也可能不同。

A. TRUE 正确　　B. FALSE 错误

B7

Niche concepts 生态位概念

Problem 58. A species' niche includes its role and requirements in the ecosystem.

问题 58：一个物种的生态位包括其在生态系统中的作用和对资源的需求。

A. TRUE 正确　　B. FALSE 错误

Problem 59. Niches are defined only by abiotic variables.

问题 59：生态位仅由非生物因素定义。

A. TRUE 正确　　B. FALSE 错误

Problem 60. Niche breadth may change depending on resource availability.

问题 60：生态位宽度可能会随资源可用性的变化而改变。

A. TRUE 正确　　B. FALSE 错误

Problem 61. Two populations of the same species may occupy different niches.

问题 61：同一物种的两个种群可能占据不同的生态位。

A. TRUE 正确　　B. FALSE 错误

B8

Primary vs secondary succession 原生演替与次生演替

Problem 62. Primary succession proceeds more quickly than secondary succession.

问题 62：原生演替的进展速度比次生演替更快。

A. TRUE 正确　　B. FALSE 错误

Problem 63. Secondary succession occurs after disturbance where soil remains.

问题 63：次生演替发生在干扰后仍有土壤残留的地方。

A. TRUE 正确　　B. FALSE 错误

Problem 64. Primary succession begins on surfaces lacking soil.

问题 64：原生演替始于缺乏土壤的表面。

A. TRUE 正确　　B. FALSE 错误

Problem 65. Secondary succession never results in a climax community.

问题 65：次生演替永远不会形成顶极群落。

A. TRUE 正确　　B. FALSE 错误

B9

Human impacts on ecosystems 人类对生态系统的影响

Problem 66. Habitat management cannot influence ecological succession.

问题 66：栖息地管理无法影响生态演替。

A. TRUE 正确　　B. FALSE 错误

Problem 67. Conservation efforts may increase habitat diversity.

问题 67：保护工作可以增加栖息地多样性。

A. TRUE 正确　　B. FALSE 错误

Problem 68. Human activities can alter species diversity.

问题 68：人类活动会改变物种多样性。

A. TRUE 正确　　B. FALSE 错误

Problem 69. Human activity always reduces species richness.

问题 69：人类活动总是降低物种丰富度。

A. TRUE 正确　　B. FALSE 错误

B10

Mark－release－recapture 标志重捕法

Problem 70. Mark－release－recapture can estimate population size.

问题 70：标志重捕法可以用于估算种群大小。

A. TRUE 正确　　B. FALSE 错误

Problem 71. The method assumes marked individuals mix randomly with unmarked ones.

问题 71：该方法假设被标记的个体与未标记的个体随机混合。

A. TRUE 正确　　B. FALSE 错误

Problem 72. Marking always increases mortality.

问题 72：标记总是会增加死亡率。

A. TRUE 正确　　B. FALSE 错误

Problem 73. All species are suitable for mark – release – recapture studies.

问题 73：标志重捕法适用于研究所有物种。

A. TRUE 正确　　B. FALSE 错误

B11

Interpretation of sampling data 抽样数据的解读

Problem 74. Diversity indices reveal the ecological mechanisms behind differences.

问题 74：多样性指数揭示了差异背后的生态机制。

A. TRUE 正确　　B. FALSE 错误

Problem 75. Communities with similar diversity indices may differ in species composition.

问题 75：具有相似多样性指数的群落，其物种组成可能存在差异。

A. TRUE 正确　　B. FALSE 错误

Problem 76. Diversity indices can help compare ecological communities.

问题 76：多样性指数可用于不同生态群落之间的比较。

A. TRUE 正确　　B. FALSE 错误

Problem 77. Higher species richness does not always indicate higher diversity.

问题 77：物种丰富度更高并不总是意味着物种多样性更高。

A. TRUE 正确　　B. FALSE 错误

SECTION C — Oxygen Transport Proteins 氧气运输蛋白

Haemoglobin (Hb) and myoglobin (Mb) differ in structure and oxygen-binding behaviour.

血红蛋白 (Hb) 和肌红蛋白 (Mb) 在结构和氧结合行为上存在差异。

A graph is provided showing:

提供的图表显示：

- **Adult Hb**: sigmoidal (cooperative) curve

  成人 Hb： 呈 S 形曲线（表现出协同效应）。

- **Fetal Hb**: left-shifted, higher affinity at a given pO_2

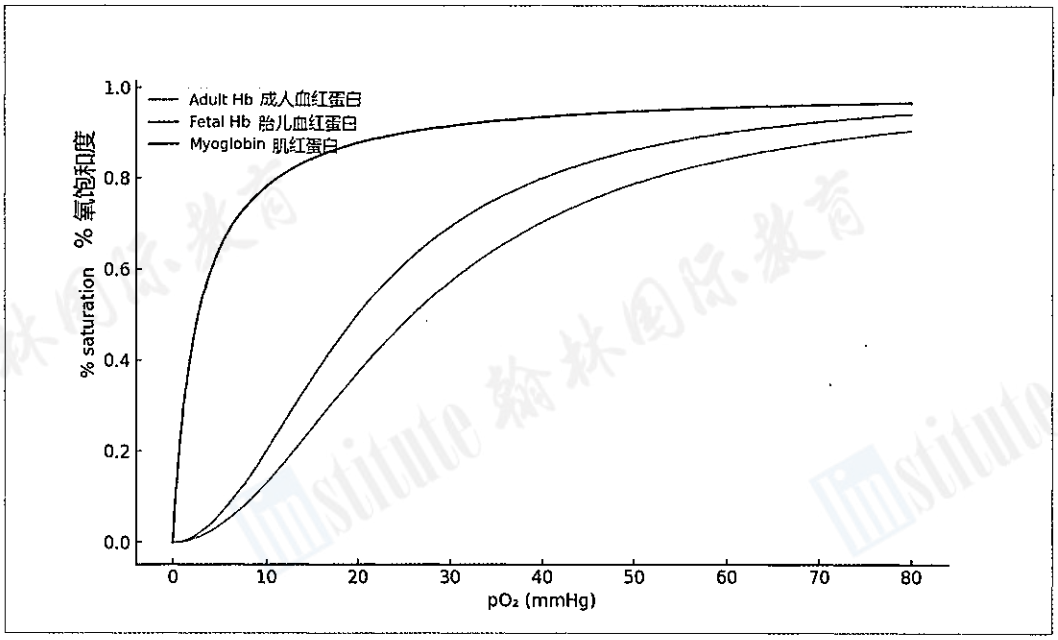
  胎儿 Hb： 曲线左移，在给定的氧分压（pO_2）下具有更高的亲和力。

- **Myoglobin**: hyperbolic curve, high affinity even at low pO_2

  肌红蛋白： 呈双曲线型，即使在低氧分压（pO_2）下也具有高亲和力。

These curves illustrate how structure relates to oxygen binding and release.

以下曲线图阐明了分子结构如何影响氧的结合与释放。



C1

Interpreting oxygen dissociation curves 解读氧解离曲线

Problem 78. The steep portion of the haemoglobin dissociation curve indicates cooperative binding.

问题 78：血红蛋白解离曲线的陡峭部分表明存在协同结合效应。

A. TRUE 正确　　B. FALSE 错误

Problem 79. The plateau region of the haemoglobin curve reflects minimal change in saturation with increasing pO_2.

问题 79：血红蛋白曲线的平台区反映了随着 pO_2 增加，氧饱和度变化极小。

A. TRUE 正确　　B. FALSE 错误

Problem 80. At very high pO_2, haemoglobin typically unloads oxygen rapidly.

问题 80：在极高的 pO_2 下，血红蛋白通常会迅速释放氧气。

A. TRUE 正确　　B. FALSE 错误

C2

Physiological roles of the different oxygen-binding proteins 不同氧结合蛋白的生理作用

Problem 81. Myoglobin is primarily responsible for transporting oxygen from the lungs to tissues.

问题 81：肌红蛋白主要负责将氧气从肺部运输到组织。

A. TRUE 正确　　B. FALSE 错误

Problem 82. Fetal haemoglobin supports oxygen uptake from maternal blood in the placenta.

问题 82：胎儿血红蛋白支持胎盘从母体的血液摄取氧气。

A. TRUE 正确　　B. FALSE 错误

Problem 83. Adult haemoglobin unloads oxygen more readily than myoglobin during normal tissue respiration.

问题 83：在正常的组织呼吸过程中，成人血红蛋白比肌红蛋白更容易释放氧气。

A. TRUE 正确　　B. FALSE 错误

Problem 84. Myoglobin helps maintain oxygen supply in muscle when pO_2 falls during intense activity.

问题 84：当剧烈活动导致肌肉中的 pO_2 下降时，肌红蛋白有助于维持氧气供应。

A. TRUE 正确　　B. FALSE 错误

C3

Structural basis of binding behaviour 结合行为的结构基础

Problem 85. Cooperative binding causes haemoglobin to maintain high affinity even at low pO_2.

问题 85：协同结合使血红蛋白即使在低 pO_2 下也能维持高亲和力。

A. TRUE 正确　　B. FALSE 错误

Problem 86. Myoglobin changes its oxygen affinity in response to binding at adjacent subunits.

问题 86：肌红蛋白通过相邻亚基的结合来改变其氧亲和力。

A. TRUE 正确　　B. FALSE 错误

Problem 87. Haemoglobin's quaternary structure allows subunits to influence one another's oxygen binding.

问题 87：血红蛋白的四级结构使各亚基能够相互影响对氧的结合。

A. TRUE 正确　　B. FALSE 错误

C4

Bohr effect and physiological triggers 波尔效应与生理触发机制

Problem 88. Rising CO_2 in active tissues generates carbonic acid, lowering pH.

问题 88：活跃组织中 CO_2 浓度升高生成碳酸，从而导致 pH 值降低。

A. TRUE 正确　　B. FALSE 错误

Problem 89. A reduced pH stabilises the low-affinity form of haemoglobin.

问题 89：pH 值降低稳定了血红蛋白的低亲和力构象。

A. TRUE 正确　　B. FALSE 错误

Problem 90. Increased CO_2 causes haemoglobin to bind oxygen more tightly.

问题 90： CO_2 增加导致血红蛋白与氧气的结合更紧密。

A. TRUE 正确　　B. FALSE 错误

Problem 91. The Bohr effect promotes oxygen unloading where metabolic activity is high.

问题 91： 在代谢活跃区域，波尔效应可促进氧气释放。

A. TRUE 正确　　B. FALSE 错误

The three-dimensional haem pockets in haemoglobin and myoglobin include specific amino acids that:

血红蛋白和肌红蛋白中的三维血红素口袋包含特定的氨基酸，它们的作用包括：

- hold the haem group in place

  将血红素基团固定到位

- influence oxygen affinity

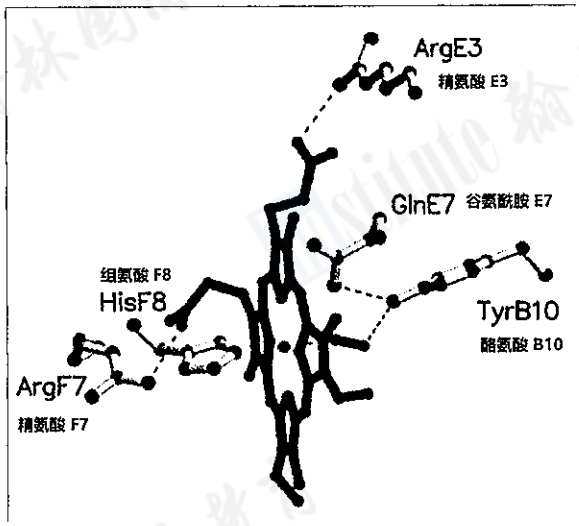
  影响氧亲和力

- stabilise the folded protein

  稳定折叠后的蛋白质

The following structural diagram highlights amino-acid residues located close to the haem group in a globin protein.

下方的结构图突出显示了珠蛋白中位于血红素基团附近的氨基酸残基。



From Geuens, E., Hoogewijs, D., Nardini, M. *et al.* Globin-like proteins in *Caenorhabditis elegans*: *in vivo* localization, ligand binding and structural properties. *BMC Biochem* 11, 17 (2010). https://doi.org/10.1186/1471-2091-11-17

C5

Structural changes near the haem 血红素附近的结构变化

Problem 92. Any mutation near the haem will increase oxygen affinity.

问题 92： 血红素附近的任何突变都会增加氧亲和力。

A. TRUE 正确　　B. FALSE 错误

Problem 93. Changes to HisF8 can impair anchoring of the haem group.

问题 93： 改变组氨酸（HisF8）可能会削弱血红素基团的锚定。

A. TRUE 正确　　B. FALSE 错误

Problem 94. A bulky substitution at TyrB10 could disturb the haem pocket and alter oxygen binding.

问题 94： 在酪氨酸（TyrB10）处进行大体积的氨基酸置换可能会干扰血红素口袋，并改变氧结合。

A. TRUE 正确　　B. FALSE 错误

C6

Functional consequences of altered haem environment

血红素环境改变的功能后果

Problem 95. Mutations that disrupt the haem pocket can alter how readily haemoglobin binds or releases oxygen.

问题 95： 破坏血红素口袋的突变会导致血红蛋白结合或释放氧气的难易度改变。

A. TRUE 正确　　B. FALSE 错误

Problem 96. Introducing a charged residue near the haem may reduce oxygen-binding efficiency.

问题 96： 在血红素附近引入带电残基可能会降低氧结合效率。

A. TRUE 正确　　B. FALSE 错误

Problem 97. All mutations near the haem decrease oxygen affinity.

问题 97： 血红素附近的所有突变都会降低氧亲和力。

A. TRUE 正确　　B. FALSE 错误

C7

Evolutionary consequences of haemoglobin mutation 血红蛋白突变的进化后果

Problem 98. Protein stability is unaffected by changes to amino-acid sequence.

问题 98：蛋白质稳定性不受氨基酸序列变化的影响。

A. TRUE 正确　　B. FALSE 错误

Problem 99. Harmful haemoglobin mutations may decrease survival and reproduction.

问题 99：有害的血红蛋白突变可能会降低存活率和繁殖率。

A. TRUE 正确　　B. FALSE 错误

Problem 100. Mutations cannot influence an organism's tolerance to environmental extremes.

问题 100：突变不能影响生物体对极端环境的耐受性。

A. TRUE 正确　　B. FALSE 错误

Problem 101. Some haemoglobin mutations are advantageous only under particular environmental conditions.

问题 101：某些血红蛋白突变仅在特定的环境条件下才是有利的。

A. TRUE 正确　　B. FALSE 错误

C8

Comparing functional characteristics of myoglobin and haemoglobin

比较肌红蛋白和血红蛋白的功能特征

Problem 102. Myoglobin facilitates intracellular oxygen storage within muscle fibres.

问题 102：肌红蛋白有利于肌肉纤维内进行细胞内氧气储存。

A. TRUE 正确　　B. FALSE 错误

Problem 103. Haemoglobin's quaternary structure makes it well suited for oxygen transport rather than intracellular storage.

问题 103：血红蛋白的四级结构使其更适合氧气运输，而不是细胞内储存。

A. TRUE 正确　　B. FALSE 错误

Problem 104. Myoglobin is effective at maintaining oxygen supply during periods of short-term hypoxia.

问题 104：肌红蛋白在短期缺氧期间能有效维持氧气供应。

A. TRUE 正确　　B. FALSE 错误

Problem 105. Haemoglobin is better suited than myoglobin for storing oxygen inside muscle cells.

问题 105：血红蛋白比肌红蛋白更适合在肌肉细胞内储存氧气。

A. TRUE 正确　　B. FALSE 错误

C9

Adaptations of diving mammals 潜水哺乳动物的适应性特征

Problem 106. Diving mammals have unusually high concentrations of myoglobin with enhanced stability.

问题 106：潜水哺乳动物拥有浓度异常高的肌红蛋白，且该肌红蛋白的稳定性更强。

A. TRUE 正确　　B. FALSE 错误

Problem 107. Their myoglobin can remain soluble at very high intracellular concentrations.

问题 107：它们的肌红蛋白可以在极高的细胞内浓度下保持可溶性。

A. TRUE 正确　　B. FALSE 错误

Problem 108. Diving mammals rely primarily on haemoglobin for long-term oxygen stores during dives.

问题 108：潜水哺乳动物在潜水期间主要依靠血红蛋白进行长期的氧气储存。

A. TRUE 正确　　B. FALSE 错误

Problem 109. Myoglobin in diving mammals releases oxygen only when pO_2 is high.

问题 109：潜水哺乳动物的肌红蛋白仅在高 pO_2 条件下释放氧气。

A. TRUE 正确　　B. FALSE 错误

SECTION D — Phylogenetics & Evolutionary Relationships
系统发育学与进化关系

The following cladogram shows the evolutionary relationships among six species (A–F). No branch lengths are to scale.

下方的演化支序图显示了六个物种（A–F）之间的演化关系。分支长度不按比例绘制。

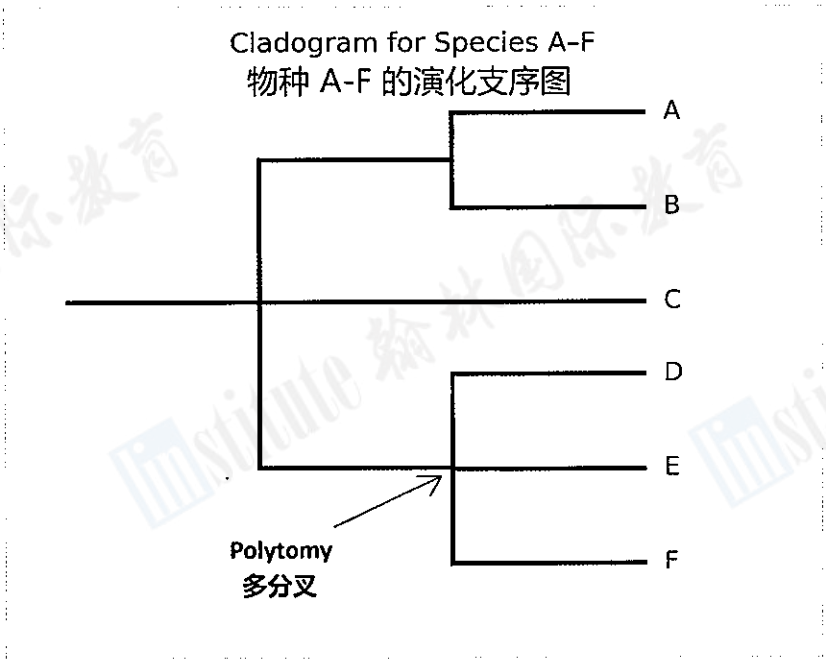


Fig. D1　图 D1

D1

Inferring relationships from Fig.D1　　根据图 D1 推断亲缘关系

Problem 110. Species A and B share a more recent common ancestor with each other than with species C.

问题 110：物种 A 和 B 彼此之间拥有的共同祖先，比它们与物种 C 的共同祖先更近。

A. TRUE 正确　　B. FALSE 错误

Problem 111. Species drawn nearer the left side of the tree are more primitive.

问题 111：绘制在进化树偏左侧的物种更原始。

A. TRUE 正确　　B. FALSE 错误

Problem 112. The horizontal spacing between the tips reflects evolutionary relatedness.

问题 112：进化树末端之间的水平间距反映了演化亲缘关系。

A. TRUE 正确　　B. FALSE 错误

Problem 113. Species E and F form a clade that excludes species D.

问题 113： 物种 E 和 F 形成一个不包含物种 D 的演化支。

A. TRUE 正确　　B. FALSE 错误

D2

Understanding branching order 理解分支顺序

Problem 114. Two species drawn close together must be sister taxa.

问题 114： 图中位置靠近的两个物种必然是姐妹群。

A. TRUE 正确　　B. FALSE 错误

Problem 115. Rotating branches around a shared node does not alter relationships.

问题 115： 围绕共享节点旋转分支不会改变关系。

A. TRUE 正确　　B. FALSE 错误

Problem 116. Species C diverged before the lineage that produced species D, E, and F.

问题 116： 物种 C 的分化早于产生物种 D、E 和 F 的谱系。

A. TRUE 正确　　B. FALSE 错误

D3

Mapping a derived trait 映射衍生性状

A derived trait X is present in species D, E, and F but absent in A, B, and C.

一个衍生性状 X 存在于物种 D、E 和 F 中，但不存在于物种 A、B 和 C 中。

Problem 117. Species A and B most likely lost trait X independently.

问题 117： 物种 A 和 B 最可能独立丢失了性状 X。

A. TRUE 正确　　B. FALSE 错误

Problem 118. Multiple independent origins of trait X are less parsimonious than a single gain.

问题 118： 与性状 X 多次独立起源相比，单次获得更符合简约性原则。

A. TRUE 正确　　B. FALSE 错误

Problem 119. Trait X is ancestral to all six species.

问题 119：性状 X 是所有六个物种的共同祖先性征。

A. TRUE 正确　　B. FALSE 错误

Problem 120. The most parsimonious explanation is that trait X evolved once in the ancestor of D–F.

问题 120：最符合简约性原则的解释是：性状 X 在类群 D–F 的共同祖先中只演化了一次。

A. TRUE 正确　　B. FALSE 错误

D4

Homoplasy refers to similarity not due to recent common ancestry.

同塑性是指并非源于近期共同祖先的相似性。

Trait Y is present in species B and F but absent from their close relatives on the tree.

性状 Y 存在于物种 B 和 F 中，但不存在于它们进化树上的近亲物种中。

Problem 121. Convergent evolution could explain this pattern.

问题 121：趋同演化可以解释这种模式。

A. TRUE 正确　　B. FALSE 错误

Problem 122. The pattern demonstrates recent shared ancestry of B and F.

问题 122：该模式证明了 B 和 F 有最近的共同祖先。

A. TRUE 正确　　B. FALSE 错误

Problem 123. A trait reversal in other lineages is another possible explanation.

问题 123：其他谱系中的性状逆转是另一种可能的解释。

A. TRUE 正确　　B. FALSE 错误

Problem 124. Homoplasy refers only to convergence, not reversals.

问题 124：同塑性仅指趋同，不包括逆转。

A. TRUE 正确　　B. FALSE 错误

D5

Molecular vs morphological evidence 分子证据与形态学证据

Problem 125. If two trees disagree, one of them must be incorrect.

问题 125：如果两棵进化树不一致，则其中一棵必定是错误的。

A. TRUE 正确　　B. FALSE 错误

Problem 126. A single shared mutation is enough to demonstrate close relatedness.

问题 126：单个共有突变足以证明密切的亲缘关系。

A. TRUE 正确　　B. FALSE 错误

Problem 127. Conflicting datasets may reflect variation in evolutionary rates.

问题 127：相互冲突的数据集可能反映了演化速率的差异。

A. TRUE 正确　　B. FALSE 错误

Problem 128. Morphological and molecular trees may differ due to convergent traits.

问题 128：形态学进化树与分子进化树的差异，可能是由趋同性状造成的。

A. TRUE 正确　　B. FALSE 错误

D6

Interpreting branch lengths in the cladogram provided

解释所附分支图中分支长度的含义

Problem 129. Branch length does not represent time.

问题 129：分支长度不代表时间。

A. TRUE 正确　　B. FALSE 错误

Problem 130. Branch spacing is determined by layout, not evolutionary distance.

问题 130：分支间距由布局决定，而非演化距离。

A. TRUE 正确　　B. FALSE 错误

Problem 131. Longer branches indicate faster evolutionary rates.

问题 131：更长的分支表示更快的演化速率。

A. TRUE 正确　　B. FALSE 错误

D7

Ancestry misconceptions 谱系演化误解

Problem 132. All extant species are equally distant from the root.

问题 132：所有现存物种到进化树根部的距离是相等的。

A. TRUE 正确　　B. FALSE 错误

Problem 133. Species closer to the root are less evolved.

问题 133：越靠近根部的物种进化程度越低。

A. TRUE 正确　　B. FALSE 错误

Problem 134. No living species is the direct ancestor of another living species.

问题 134：没有任何现存物种是另一个现存物种的直接祖先。

A. TRUE 正确　　B. FALSE 错误

Problem 135. A species can evolve directly into another extant species.

问题 135：一个物种可以直接进化成另一个现存物种。

A. TRUE 正确　　B. FALSE 错误

D8

Sister taxa 姐妹群

Problem 136. Sister taxa must share similar ecological niches.

问题 136：姐妹群必须共享相似的生态位。

A. TRUE 正确　　B. FALSE 错误

Problem 137. In Fig. D1, species E and F are sister taxa.

问题 137：在图 D1 中，物种 E 和 F 是姐妹群。

A. TRUE 正确　　B. FALSE 错误

Problem 138. Sister taxa share an immediate common ancestor.

问题 138：姐妹群共享一个直接的共同祖先。

A. TRUE 正确　　B. FALSE 错误

Problem 139. Sister taxa always diverge at the earliest point in the tree.

问题 139： 姐妹群总是在进化树的最早分化节点上分化。

A. TRUE 正确　　B. FALSE 错误

D9

Reconstructing ancestral traits 重建祖先性状

Trait Z appears in A, B, C, and D, but not in E or F.

性状 Z 出现在 A、B、C、D 中，但未出现在 E 或 F 中。

Problem 140. The distribution proves that trait Z evolved twice.

问题 140： 该分布证明性状 Z 独立演化了两次。

A. TRUE 正确　　B. FALSE 错误

Problem 141. Trait mapping cannot help infer where Z evolved.

问题 141： 性状映射无法帮助推断 Z 的演化位置。

A. TRUE 正确　　B. FALSE 错误

Problem 142. Trait Z may be ancestral if it is present in early-diverging lineages.

问题 142： 如果性状 Z 存在于早期分化的谱系中，它可能是祖先性征。

A. TRUE 正确　　B. FALSE 错误

Problem 143. Loss of trait Z in E and F is consistent with the tree.

问题 143： 性状 Z 在 E 和 F 中丢失符合该进化树。

A. TRUE 正确　　B. FALSE 错误

D10

Genetic distance 遗传距离

Problem 144. Smaller genetic distances often indicate closer relationships.

问题 144： 较小的遗传距离通常表明亲缘关系更近。

A. TRUE 正确　　B. FALSE 错误

Problem 145. Large distances may reflect long divergence or high mutation rates.

问题 145： 距离较大可能反映了较长的分化时间或较高的突变率。

A. TRUE 正确　　B. FALSE 错误

Problem 146. Equal genetic distances always imply the same branching pattern.

问题 146： 相等的遗传距离总是意味着相同的分化模式。

A. TRUE 正确　　B. FALSE 错误

Problem 147. Genetic distance alone is sufficient to determine precise branching order.

问题 147： 仅凭遗传距离就足以确定精确的分支顺序。

A. TRUE 正确　　B. FALSE 错误

D11

Polytomies (one is labelled on the cladogram) 多分叉（图中已标出）

Problem 148. All descendant species in a polytomy necessarily diverged simultaneously.

问题 148： 多分叉中的所有后代物种必然是同时分化的。

A. TRUE 正确　　B. FALSE 错误

Problem 149. Polytomies may reflect rapid radiations.

问题 149： 多分叉可能反映了快速辐射演化。

A. TRUE 正确　　B. FALSE 错误

Problem 150. A polytomy represents uncertainty about branching order.

问题 150： 多分叉代表了分支顺序的不确定性。

A. TRUE 正确　　B. FALSE 错误

Problem 151. Polytomies occur only when morphological data are unavailable.

问题 151： 多分叉仅在缺失形态学数据时发生。

A. TRUE 正确　　B. FALSE 错误

SECTION E — Speciation & Reproductive Isolation
物种形成与生殖隔离

STIMULUS 1 — Gene Flow Between Diverging Populations

材料 1 — 分化种群间的基因流

Two populations (X and Y) occupy partially different habitats.

两个种群（X 和 Y）占据部分不同的栖息地。

Gene flow measurements reveal:

基因流测量显示：

- **Strong gene flow from X → Y**

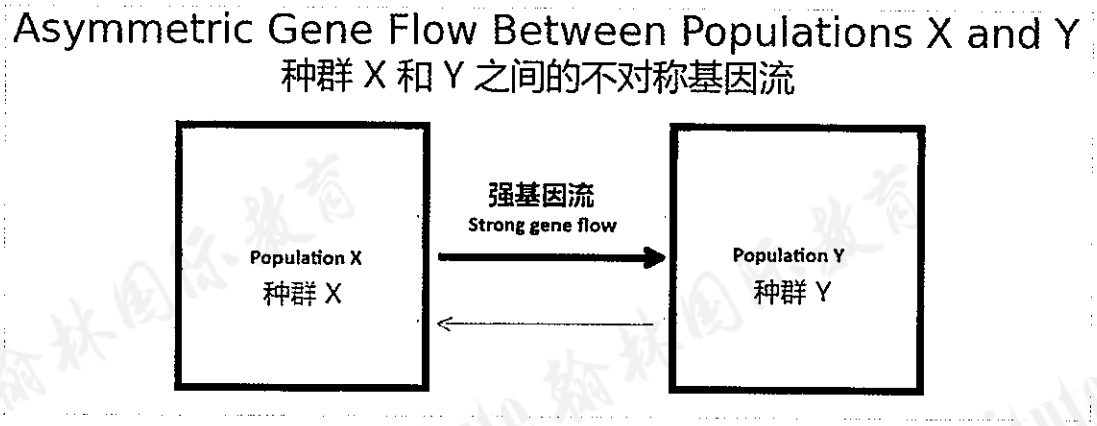
  从 X → Y 的强基因流

- **Weak gene flow from Y → X**

  从 Y → X 的弱基因流

Allele frequencies are beginning to diverge.

等位基因频率开始出现分化。



E1

Barriers to gene flow 基因流的障碍

Problem 152. Habitat differences can reduce opportunities for individuals to meet and mate.

问题 152：栖息地差异会减少个体相遇和交配的机会。

A. TRUE 正确　　B. FALSE 错误

Problem 153. Hybrid inviability is a prezygotic barrier.

问题 153：杂种不活是一种合子前隔离。

A. TRUE 正确　　B. FALSE 错误

Problem 154. Mechanical isolation occurs when reproductive structures are incompatible.

问题 154：当生殖结构不匹配时会发生机械隔离。

A. TRUE 正确　　B. FALSE 错误

E2

Modes of speciation 物种形成的模式

Problem 155. Sympatric speciation can occur even when populations live in the same area.

问题 155：即使种群生活在同一区域，同域物种形成也有可能发生。

A. TRUE 正确　　B. FALSE 错误

Problem 156. Reduced gene flow between neighbouring habitats is typical of parapatric speciation.

问题 156：相邻栖息地之间基因流减少是邻域物种形成的典型特征。

A. TRUE 正确　　B. FALSE 错误

Problem 157. Allopatric speciation requires gene flow to be zero at all times.

问题 157：异域物种形成要求基因流在任何时候都为零。

A. TRUE 正确　　B. FALSE 错误

E3

Divergent selection and reinforcement 分歧性选择与强化作用

Problem 158. Reinforcement causes hybrid fitness to increase over time.

问题 158：强化作用导致杂种适应度随时间增加。

A. TRUE 正确　　B. FALSE 错误

Problem 159. Divergent ecological selection can contribute to reinforcement.

问题 159：分歧性生态选择可以促进强化作用。

A. TRUE 正确　　B. FALSE 错误

Problem 160. If hybrids are fitter than parents, reinforcement is unlikely to occur.

问题 160：若杂种的适应度高于亲本，那么强化作用将不太可能发生。

A. TRUE 正确　　B. FALSE 错误

E4

Genetic divergence 遗传分化

Problem 161. Natural selection cannot promote divergence if any gene flow occurs.

问题 161：如果存在任何基因流，自然选择就无法促进分化。

A. TRUE 正确　　B. FALSE 错误

Problem 162. Divergence can occur at some genes even when others remain similar.

问题 162：即使其他基因保持相似，某些基因仍可以发生分化。

A. TRUE 正确　　B. FALSE 错误

Problem 163. Divergence requires large population sizes to accumulate differences.

问题 163：分化需要庞大的种群规模来积累差异。

A. TRUE 正确　　B. FALSE 错误

Problem 164. Reduced gene flow allows genetic drift to cause allele frequencies to diverge.

问题 164：基因流减少使得遗传漂变能导致等位基因频率发生分化。

A. TRUE 正确　　B. FALSE 错误

E5

Predicting future speciation 预测未来的物种形成

Problem 165. High gene flow can slow or prevent divergence between populations.

问题 165：高基因流可以减缓或阻止种群间的分化。

A. TRUE 正确　　B. FALSE 错误

Problem 166. Divergence can proceed only if both populations evolve in identical habitats.

问题 166：只有当两个种群在完全相同的栖息地进化时，分化才能发生。

A. TRUE 正确　　B. FALSE 错误

Problem 167. Persistent asymmetric gene flow may slow, but not prevent, divergence.

问题 167：持续的不对称基因流可能会减缓分化，但不会阻止分化。

A. TRUE 正确　　B. FALSE 错误

Problem 168. Increasing ecological differences may lead to stronger reproductive barriers.

问题 168：逐渐增加的生态差异可能导致更强的生殖隔离。

A. TRUE 正确　　B. FALSE 错误

Researchers are investigating reproductive isolation between two closely related species, **Species M** and **Species N**.

研究人员正在调查两个亲缘关系很近的物种——**物种 M** 和**物种 N** 之间的生殖隔离。

Although the species overlap in part of their range, hybridisation is rare in natural populations. To understand the barriers to gene flow, scientists carried out controlled crosses in the laboratory.

尽管两物种在其分布区的部分区域存在重叠，但在自然种群中杂交现象却很罕见。为了解基因流的障碍，科学家在实验室进行了受控杂交实验。

They measured two outcomes:

他们测量了以下两个指标：

1. Hybrid viability 杂种存活率

The percentage of offspring that survive to adulthood.

指子代能存活至成年的百分比。

2. Hybrid fertility 杂种生育力

Whether surviving hybrids are capable of producing viable gametes.

存活的杂种是否能够产生可育的配子。

The results are shown below:

结果如下：

Cross Type **杂交类型**	**Offspring Survival (%)** **后代存活率**	**Fertile?** **是否可育?**
M × M	95%	Yes 是
N × N	92%	Yes 是
M × N	60%	No 否
N × M	55%	No 否

E6

Hybrid viability, fertility, and asymmetry 杂种存活率、生育力与不对称性

Problem 169. Hybrid sterility is a form of postzygotic reproductive isolation.

问题 169：杂种不育是合子后生殖隔离的一种形式。

A. TRUE 正确　　B. FALSE 错误

Problem 170. Asymmetry in hybrid outcomes can reflect maternal or cytoplasmic effects.

问题 170：杂交结果的不对称性可能反映了母体或细胞质效应。

A. TRUE 正确　　B. FALSE 错误

Problem 171. Differences between M×N and N×M crosses must result from prezygotic barriers.

问题 171：M×N 和 N×M 杂交之间的差异必定是由合子前隔离造成的。

A. TRUE 正确　　B. FALSE 错误

E7

Species concepts 物种概念

Problem 172. Hybrid sterility proves that two species must share identical morphology.

问题 172：杂交不育证明两个物种必须具有相同的形态。

A. TRUE 正确　　B. FALSE 错误

Problem 173. The phylogenetic species concept emphasises unique evolutionary history.

问题 173：系统发育物种概念强调独特的进化历史。

A. TRUE 正确　　B. FALSE 错误

Problem 174. Under the biological species concept, hybrid sterility supports species status.

问题 174：在生物学物种概念下，杂交不育支持物种地位。

A. TRUE 正确　　B. FALSE 错误

Problem 175. The morphological species concept depends only on hybrid fertility.

问题 175：形态学物种概念仅取决于杂种能育性。

A. TRUE 正确　　B. FALSE 错误

Two species (P and Q) inhabit different parts of a woodland:

两个物种（P 和 Q）栖息在同一林地的不同区域：

- **P** in shaded forest edges

  P 分布于阴凉的森林边缘

- **Q** in sunny open areas

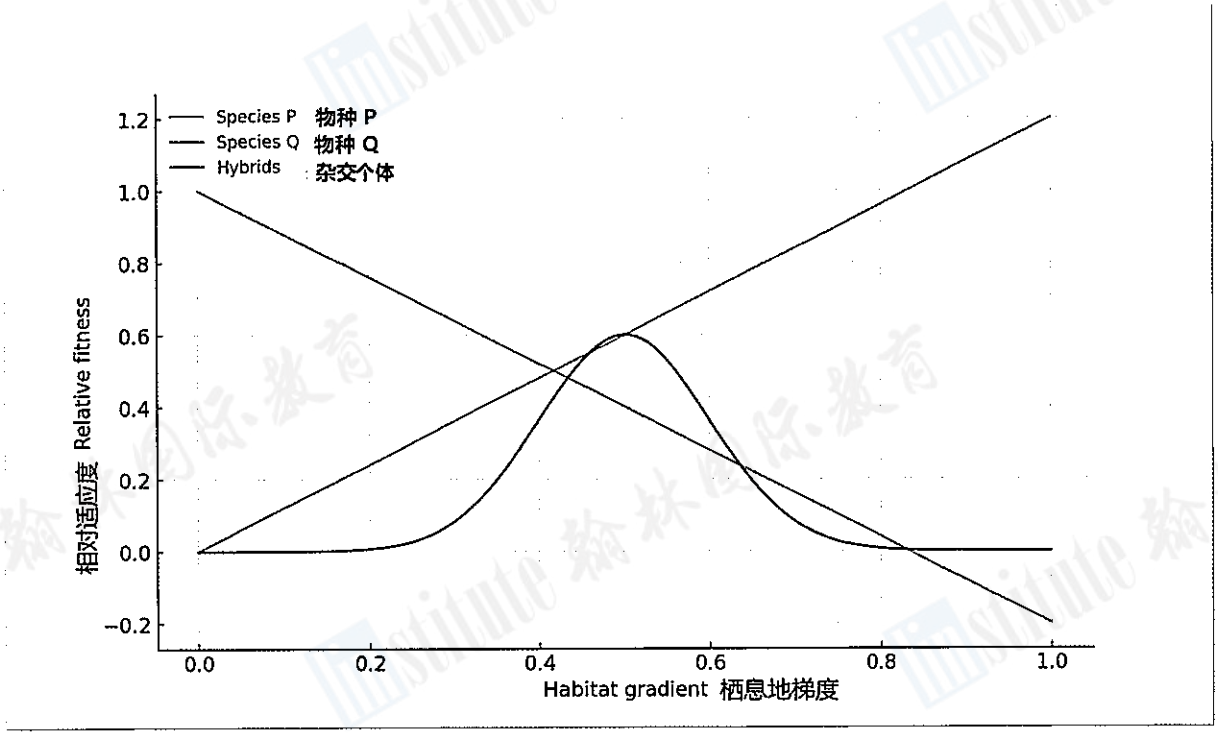
  Q 在阳光充足的开阔地带

Hybrids occur mainly where these habitats meet. Their **fitness is intermediate**, highest in the transitional ecotone.

杂交个体主要出现在这些栖息地交汇的地方。它们的**适应度介于两者之间**，在过渡生态区中达到最高。

The following graph shows the relative fitness of Species P, Species Q, and their hybrids across an environmental gradient.

下图显示了沿环境梯度物种 P、物种 Q 及其杂交个体的相对适应度。



E8

Hybrid zones 杂交带

Problem 176. A hybrid zone may persist if hybrids survive best where the parent habitats meet.

问题 176：如果杂交个体在亲本栖息地交汇处生存力最强，则杂交带可能会持续存在。

A. TRUE 正确　　B. FALSE 错误

Problem 177. A hybrid zone always means the populations have only just begun to diverge.

问题 177：杂交带总是意味着种群才刚刚开始分化。

A. TRUE 正确　　B. FALSE 错误

Problem 178. A hybrid zone can exist even if hybrids are not fitter than either parent species.

问题 178：即使杂交个体的适应度不高于任一亲本物种，杂交带也可以存在。

A. TRUE 正确　　B. FALSE 错误

E9

Gene flow between species through hybridisation 通过杂交进行的物种间基因流

Problem 179. Genes can move from one species to another if hybrids mate back with a parent species.

问题 179：如果杂交个体与某一亲本物种回交，基因可以从一个物种转移到另一个物种。

A. TRUE 正确　　B. FALSE 错误

Problem 180. Gene transfer between species can sometimes transfer beneficial alleles.

问题 180：物种间的基因转移有时可以转移有益的等位基因。

A. TRUE 正确　　B. FALSE 错误

Problem 181. Gene transfer between species cannot occur when hybrids are completely sterile.

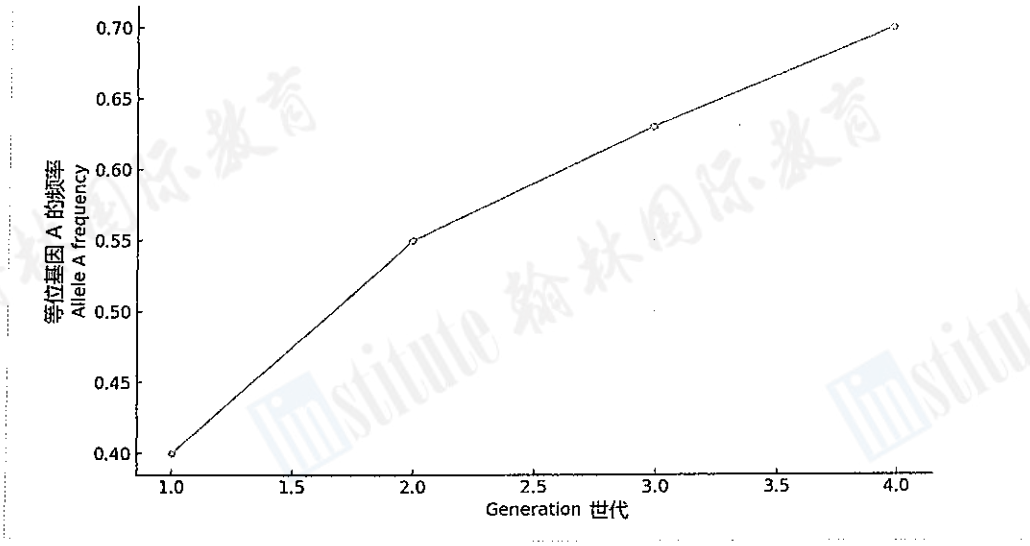
问题 181：当杂交个体完全不育时，物种间的基因转移无法发生。

A. TRUE 正确　　B. FALSE 错误

SECTION F — Population Genetics & Natural Selection
群体遗传学与自然选择

The following graph shows changes in the frequency of allele A over four consecutive generations in a population.

下图显示了一个种群中等位基因 A 的频率在连续四个世代中的变化。



F1

Interpreting allele frequency change 解读等位基因频率变化

Problem 182. An increase in allele A from 0.40 to 0.70 indicates evolutionary change.

问题 182：等位基因 A 的频率从 0.40 增加到 0.70，表明发生了进化改变。

A. TRUE 正确　　B. FALSE 错误

Problem 183. Allele A is likely being favoured by selection.

问题 183：等位基因 A 很可能受到了选择的有利影响。

A. TRUE 正确　　B. FALSE 错误

Problem 184. The increase must be due to mutation alone.

问题 184：这种增加必然仅由突变引起。

A. TRUE 正确　　B. FALSE 错误

F2

Hardy – Weinberg equilibrium assumptions 哈迪-温伯格平衡的假设

Problem 185. Hardy – Weinberg equilibrium assumes rapid environmental change.

问题 185：哈迪-温伯格平衡假设环境发生快速变化。

A. TRUE 正确　　B. FALSE 错误

Problem 186. In Hardy – Weinberg equilibrium, allele frequencies change each generation.

问题 186：在哈迪-温伯格平衡中，等位基因频率每一代都在变化。

A. TRUE 正确　　B. FALSE 错误

Problem 187. Hardy – Weinberg equilibrium assumes no natural selection.

问题 187：哈迪-温伯格平衡假设没有自然选择。

A. TRUE 正确　　B. FALSE 错误

F3

Selection vs drift 选择与漂变

Problem 188. Genetic drift produces predictable directional changes in large populations.

问题 188：遗传漂变在大种群中会产生可预测的定向变化。

A. TRUE 正确　　B. FALSE 错误

Problem 189. Genetic drift is more likely in small populations.

问题 189：遗传漂变在小种群中发生的可能性更大。

A. TRUE 正确　　B. FALSE 错误

Problem 190. A steady directional increase in an allele over several generations often suggests selection.

问题 190：一个等位基因在数代内呈现稳定的定向增加，通常暗示存在选择作用。

A. TRUE 正确　　B. FALSE 错误

A population declined from **10,000 → 200 individuals** after an extreme storm. Allele frequencies changed substantially in the survivors.

一场极端风暴后，一个种群从 **10,000 个个体**减少到 **200 个个体**。幸存者中的等位基因频率发生了显著变化。

A schematic shows:

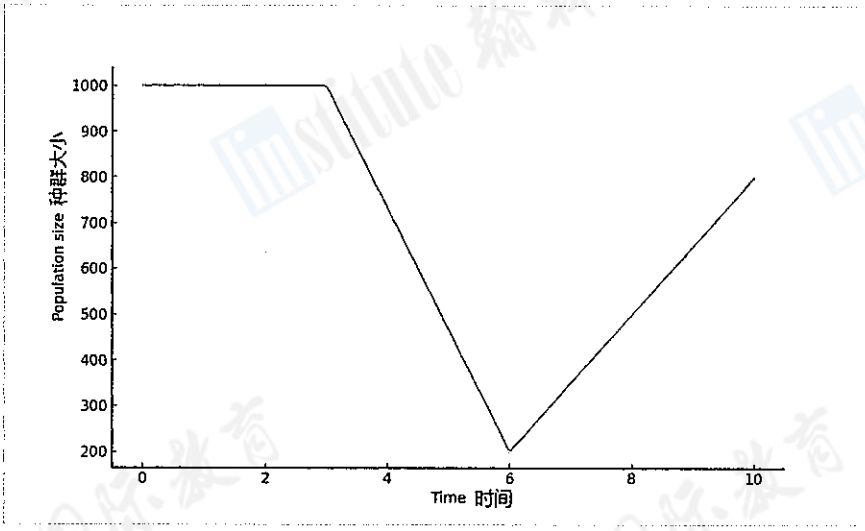
示意图显示：

- Population crash　　种群骤减
- Reduced variation　　遗传变异减少
- Gradual recovery in numbers, not in diversity

  个体数量逐渐恢复，但遗传多样性未恢复

The following graph shows a population before, during, and after the storm.

下图展示了风暴前、中、后的种群情况。



F4

Effects of Population Bottlenecks 种群瓶颈效应的影响

Problem 191. A severe reduction in population size can cause large random shifts in allele frequencies.

问题 191：种群规模的严重缩减会导致等位基因频率发生大幅度的随机漂变。

A. TRUE 正确　　B. FALSE 错误

Problem 192. Bottlenecks prevent natural selection from acting.

问题 192：瓶颈效应阻碍了自然选择的作用。

A. TRUE 正确　　B. FALSE 错误

Problem 193. Bottlenecks always increase genetic diversity.

问题 193：瓶颈效应总是增加遗传多样性。

A. TRUE 正确　　B. FALSE 错误

Problem 194. Rare alleles are more likely to be lost during a bottleneck.

问题 194：在瓶颈期间，稀有等位基因更容易丧失。

A. TRUE 正确　　B. FALSE 错误

F5

Drift and Genetic Variation After Bottlenecks 瓶颈效应后的遗传漂变与遗传变异

Problem 195. Genetic diversity may remain low even after the population size recovers.

问题 195：即使种群规模恢复后，遗传多样性仍可能保持在较低水平。

A. TRUE 正确　　B. FALSE 错误

Problem 196. All allele frequency changes during a bottleneck must be caused by natural selection.

问题 196：瓶颈期间所有的等位基因频率变化必然是由自然选择引起的。

A. TRUE 正确　　B. FALSE 错误

Problem 197. Drift becomes weaker in very small populations.

问题 197：在非常小的种群中，遗传漂变会减弱。

A. TRUE 正确　　B. FALSE 错误

Problem 198. Loss of genetic variation can reduce the population's future adaptive potential.

问题 198：遗传变异的丧失会降低种群未来的适应潜力。

A. TRUE 正确　　B. FALSE 错误

A small group of 25 individuals colonises a new island.

一个由 25 个个体组成的小群殖民了一个新岛屿。

Allele C is present at high frequency in the new population but was rare in the original one.

等位基因 C 在新种群中频率很高，但在原种群中很罕见。

For F6-F8.

针对 F6-F8。

F6

Founder effect basics 奠基者效应基础

Problem 199. Founder effects require natural selection to occur.

问题 199：奠基者效应需要自然选择才能发生。

A. TRUE 正确　　B. FALSE 错误

Problem 200. Founder effects can lead to rapid genetic drift.

问题 200：奠基者效应可能导致快速的遗传漂变。

A. TRUE 正确　　B. FALSE 错误

Problem 201. Founder effects may increase the frequency of rare alleles.

问题 201：奠基者效应可能会提高某些稀有等位基因的频率。

A. TRUE 正确　　B. FALSE 错误

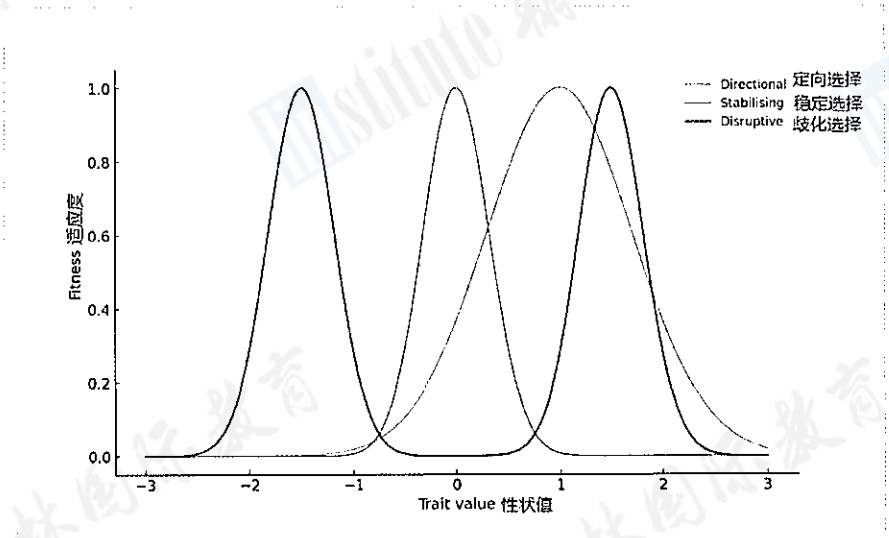
Problem 202. The allele frequencies in the founders may differ greatly from the source population.

问题 202：奠基者的等位基因频率可能与源种群有很大差异。

A. TRUE 正确　　B. FALSE 错误

The diagram shows three distinct patterns of selection acting on a quantitative trait:

图表显示了作用于数量性状的三种不同的选择模式。



F7

Patterns of natural selection 自然选择的模式

Problem 203. Directional selection favours individuals at one extreme of the phenotype range.

问题 203：定向选择倾向于表型范围某一极端的个体。

A. TRUE 正确　　B. FALSE 错误

Problem 204. Stabilising selection reduces phenotypic variation around the mean.

问题 204：稳定选择减少围绕均值的表型变异。

A. TRUE 正确　　B. FALSE 错误

Problem 205. Disruptive selection favours intermediate phenotypes over extremes.

问题 205：歧化选择倾向于中间表型而非极端表型。

A. TRUE 正确　　B. FALSE 错误

Problem 206. Stabilising selection increases phenotypic variance around the mean.

问题 206：稳定选择会增加均值附近的表型方差。

A. TRUE 正确　　B. FALSE 错误

F8

Comparing modes of selection 比较选择模式

Problem 207. Directional, stabilising, and disruptive selection all alter the fitness of different phenotypes.

问题 207：定向、稳定和歧化选择都改变了不同表型的适应度。

A. TRUE 正确　　B. FALSE 错误

Problem 208. Stabilising and disruptive selection have opposite effects on variation.

问题 208：稳定选择和歧化选择对变异的影响相反。

A. TRUE 正确　　B. FALSE 错误

Problem 209. Directional selection often reduces genetic variation when selection pressure is consistent.

问题 209：当选择压力持续存在时，定向选择通常会减少遗传变异。

A. TRUE 正确　　B. FALSE 错误

Problem 210. All three modes of selection shift the population mean.

问题 210：所有三种选择模式都会改变种群均值。

A. TRUE 正确　　B. FALSE 错误

British Biology Olympiad 2026 Paper 2

Q1 Animal learning 动物的学习

These are some types of learning in animals:

以下是动物的几种学习类型：

a. Observational learning - acquiring skills or behaviours by observing another individual

观察学习——通过观察其他个体来习得技能或行为

b. Habituation – learning to ignore neutral stimuli that are presented repeatedly

习惯化——学会忽视反复出现的中性刺激

c. Classical conditioning – associating an existing response with a novel neutral stimulus

经典条件反射——将已有的反应与新的中性刺激关联

d. Operant conditioning – associating an existing behaviour with a reward or punishment resulting in the behaviour being performed more or less frequently

操作性条件反射——将已有的行为与奖励或惩罚关联，从而使该行为出现频率增加或减少

e. Latent learning – learning information without immediate reinforcement or motivation, which may affect later behaviour

潜在学习——在没有即时强化或动机的情况下学习信息，且这些信息可能影响后续行为

f. Imprinting – a rapid learning process that occurs during a specific developmental phase of life leading to strong, often irreversible, behavioural adaptations (e.g. a gosling learning to recognise and follow the first moving object it sees)

印记学习——在生命特定发育阶段发生的快速学习过程，会形成强烈且通常不可逆的行为适应（例如：雏鹅学会识别并跟随它看到的第一个移动物体）

g. Insight learning – finding a solution to a problem or novel situation through reasoning and experience, without trial and error

顿悟学习——通过推理和经验找到问题或新情境的解决方案，而非通过试错

Questions: 问题：

What type of learning does the following demonstrate? (each learning type could be present multiple times or not at all) (5 marks)

下列案例分别体现了哪种学习类型？（每种学习类型可以重复选择或者不选）（5 分）

Problem 211. When *Octopus cyaneus* inserted an arm up a tube breaking the water surface they were rewarded. Over time they performed this action more often.

问题 211：当*蓝章*将一条腕足沿管道向上伸出水面时，会得到奖励。随着时间推移，它们更频繁地进行这一行为。

A. a B.b C. c D. d E. e F. f G. g

Problem 212. In one study, *Octopus vulgaris* learnt to choose one of two objects that differed only in colour by watching another octopus select that object.

问题 212：一项研究中，*普通章鱼*通过观察另一只章鱼选择特定物体，学会了在两个仅颜色不同的物体中选出同一个物体。

A. a B.b C. c D. d E. e F. f G. g

Problem 213. When a plastic model of a lobster was presented outside a tank 15 seconds at the beginning of each minute, over time *O. vulgaris* reduced their inspection of the model.

问题 213：每分钟起始时刻，在水箱外展示龙虾塑料模型（持续 15 秒），一段时间后，*普通章鱼*对该模型的探查行为减少。

A. a B.b C. c D. d E. e F. f G. g

Problem 214. Octopuses can learn to discriminate between objects soaked in different concentration KCl solutions when given a reward for choosing the higher concentration.

问题 214：当选择高浓度氯化钾（KCl）溶液浸泡的物体可获得奖励时，章鱼能学会区分不同浓度氯化钾溶液浸泡的物体。

A. a B.b C. c D. d E. e F. f G. g

Problem 215. Octopuses explore new areas and can remember the locations of burrows and hiding spots when they are needed later.

问题 215：章鱼会探索新区域，并能记住洞穴和藏身点的位置，以备后续需要时使用。

A. a B.b C. c D. d E. e F. f G. g

Indicate if each of the following statements is true or false: (3 marks)
判断下列说法是否正确：（3 分）

Problem 216. The fact that many octopuses live mostly solitary lives means that they are incapable of observational learning.

问题 216：许多章鱼主要过独居生活，这意味着它们无法进行观察学习。

A. TRUE 正确　　B. FALSE 错误

Problem 217. *Thaumoctopus mimicus* being able to mimic the body form and swimming gait of many other species (e.g. lionfish, sea snake and flatfish) demonstrates observational learning.

问题 217：*拟态章鱼* 能够模仿多种其他物种的体型和游泳姿态（如狮子鱼、海蛇和比目鱼），这体现了观察学习。

A. TRUE 正确　　B. FALSE 错误

Problem 218. Octopuses remembering productive foraging grounds demonstrates latent learning.

问题 218：章鱼能记住高产觅食地，这体现了潜在学习。

A. TRUE 正确　　B. FALSE 错误

Q2 Octopus behaviour 章鱼的行为

Octopuses' arms are involved in nearly all their behaviours such as locomotion, prey capture, den construction, postural camouflage, mimicry, signalling, and reproduction. They exhibit high levels of independence, dexterity and flexibility. This is facilitated by their extensive peripheral nervous system and muscular hydrostatic arms.

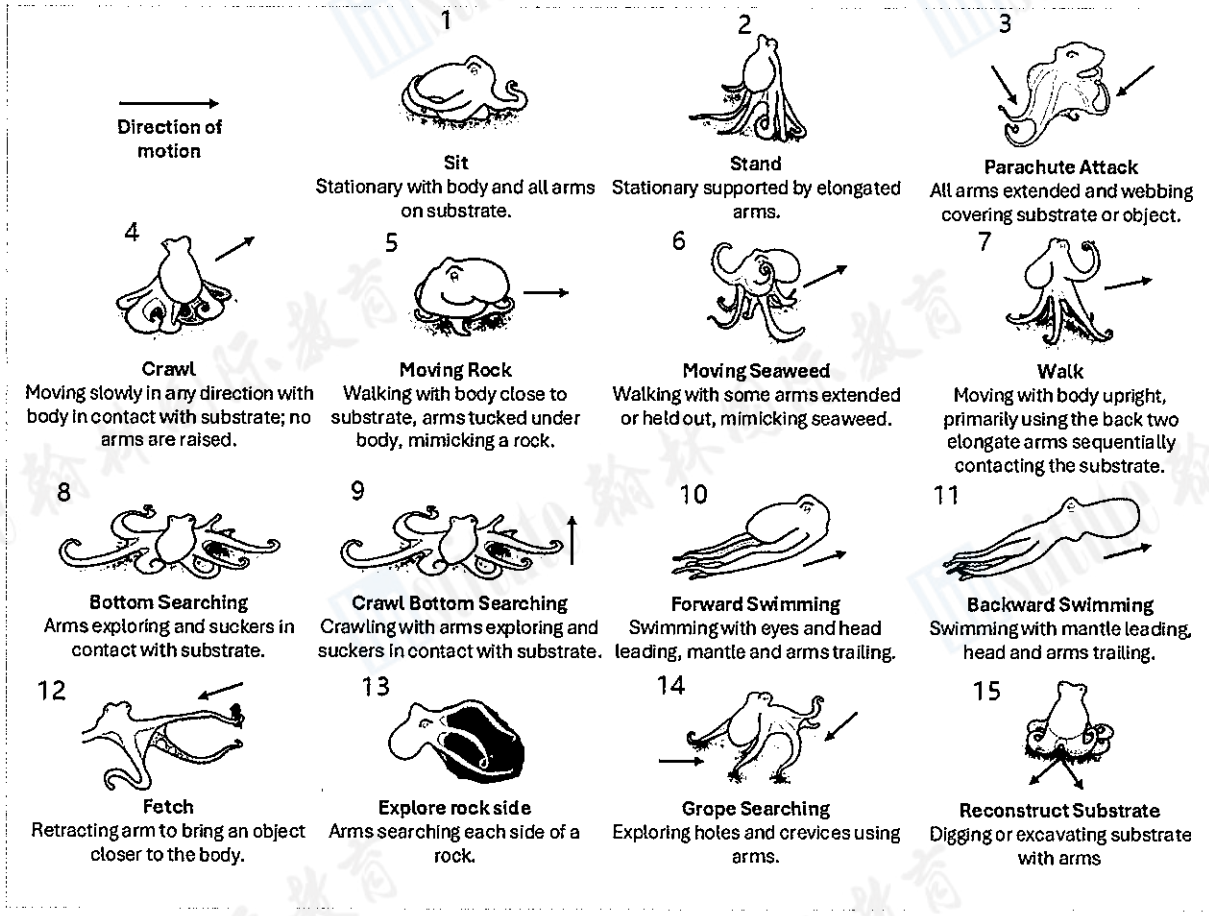
章鱼的腕足几乎参与其所有行为，例如运动、捕食、筑巢、姿态伪装、拟态、信号传递和繁殖。它们展现出高度的自主性、灵活性和适应性，这得益于章鱼发达的外周神经系统，以及以及具有肌肉性静水骨骼结构的腕足。

Octopuses eat a wide range of animals that live in a range of areas, including the surface of rocks, rocky crevices, and in/on the seabed. They are often solitary with minimal social interaction outside of mating.

章鱼的猎物种类繁多，这些猎物栖息于多种区域，包括岩石表面、岩石缝隙以及海床内或海床上。章鱼通常独居，除交配外几乎无社交互动。

Below are some common behaviours that are involved in states such as locomotion, foraging, threatening and escaping.

以下是一些常见的行为，这些行为多与运动、觅食、威胁和逃跑等生命活动状态相关。



J. Bain, based on Bennice, C.O., Buresch, K.C., Grossman, J.H.et al.Octopus arm flexibility facilitates complex behaviors in diverse natural environments.Sci Rep15, 31875 (2025). https://doi.org/10.1038/s41598-025-10674-y.

Identify the behaviours exhibited in each of the following images: (2 marks)

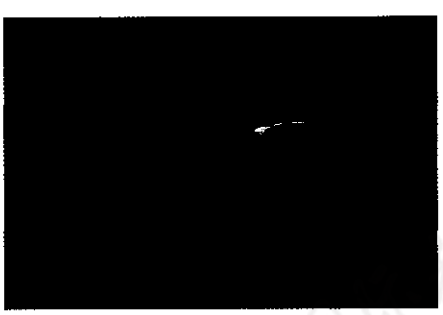
识别下列各图中章鱼表现出的行为：（2 分）

Please fill in the corresponding behavior numbers (1-15) from the figure in the blanks below.

请在以下横线填写图中对应的行为序号（1-15）。

Problem 219. This octopus is moving: _____

问题 219：该章鱼正在移动：_____



NOAA, Public domain, via Wikimedia Commons

Problem 220. This octopus is static: _____

问题 220：该章鱼处于静止状态：_____

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An ethogram is a tool commonly used by animal behaviour scientists to keep track of and analyse behaviours of an animal. Specific behaviours that have been identified in an animal species in previous studies are included selectively in an ethogram depending on the research question being explored. Typically, a single focal animal is observed for a certain amount of time, and the specific behaviour that the animal exhibits at every pre-determined time interval (e.g. every 30 seconds) is marked on the ethogram.

行为图谱是动物行为学家常用的工具，用于记录和分析动物的行为。研究人员会根据具体的研究问题，从该物种已知的行为库中选择性地筛选出相关行为纳入图谱。通常，研究人员会对单个焦点动物进行一定时间的观察，并每隔一段预先设定的时间（例如 30 秒），将动物表现出的特定行为记录在行为图谱中。

Here are some possible research questions about octopus behaviour:

以下是关于章鱼行为的几个可能的研究问题：

A. Do octopuses spend longer moving by crawling or swimming?

章鱼爬行移动和游泳移动的时间哪个更长？

B. What proportion of time do octopuses spend foraging?

章鱼用于觅食的时间占比多少？

C. Which foraging behaviours precede parachute attacks in octopuses?

章鱼在进行伞状攻击前会表现出哪些觅食行为？

Below is an incomplete ethogram (two behaviours are missing - denoted by i. and ii.) constructed using the behaviours from figure 1. The behaviours (columns) are ordered by relevance to the research question (most relevant on the left), and only the most relevant behaviour is recorded at a time, even if more than one behaviour is observed occurring simultaneously.

下方是一份不完整的行为图谱（其中两个行为缺失，标记为 i. 和 ii.），该图谱基于图 1 中的行为构建。行为（列）按与研究问题的相关性排序（最相关的在左侧）；即使观察到多种行为同时发生，同一时间也仅记录最相关的一种行为。

Time / minutes 时间 / 分钟	Parachute Attack 伞状攻击	Grope Searching 触探	Explore Rock Side 岩侧探查	i.	Bottom Searching 底部探查	ii.	Fetch 抓取	Crawl 爬行	Moving seaweed 拟藻移动	Moving Rock 拟岩移动	Other 其他
0.0								x			
0.5						x					
1.0						x					
1.5					x						
2.0											x
2.5											x
3.0				x							
3.5				x							
4.0	x										
4.5											x
5.0											x
5.5											x
6.0										x	
6.5										x	
7.0			x								
7.5		x									
8.0		x									
8.5			x								
9.0		x									
9.5									x		
10.0									x		

Questions: 问题：

Problem 221. The ethogram has varying suitability for investigating different research questions. Order the questions from highest to lowest suitability. Mark the answer sheet in sequence from top to bottom. (2 marks)

问题 221：该行为图谱对不同研究问题的适配性存在差异，请按适配性从高到低对上述研究问题排序。填涂答题卡时，按照从上往下的顺序分别涂卡。**（2 分）**

_____，_____，_____

Problem 222. For research question B, which 2 unused behaviours from figure 1 should be in columns i. and ii.? (answers can be in either order) (2 marks)

问题 222：针对研究问题 B，图 1 中哪两个未使用的行为应填入 i. 和 ii. 列？（答案顺序可互换）**（2 分）**

_____，_____

Indicate if each of the following statements is true or false: (3 marks)

判断下列说法是否正确：（3 分）

Problem 223. The individual was definitely never observed exhibiting the fetch behaviour over this period.

问题 223：在此期间，该个体肯定从未被观察到表现出抓取行为。

A. TRUE 正确　　B. FALSE 错误

Problem 224. The individual might have been observed swimming during this period.

问题 224：在此期间，该个体可能被观察到表现出游泳行为。

A. TRUE 正确　　B. FALSE 错误

Problem 225. The individual might have been observed exhibiting the grope searching behaviour at 7.0 minutes.

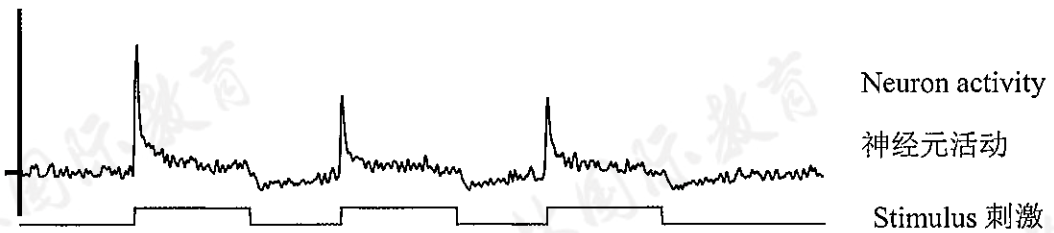
问题 225：在 7.0 分钟时，该个体可能被观察到表现出触探行为。

A. TRUE 正确　　B. FALSE 错误

Q3 Circuit motifs 神经回路模体

Many neurons involved in sensory circuits of the nervous system are wired together such that the output neuron spikes only when the stimulus *changes* in intensity. For example, shown below is the activity of a neuron that spikes only when the stimulus is switched on. Such a neuron is known as an 'ON-response neuron':

神经系统感觉回路中的许多神经元以特定方式连接，使得输出神经元仅在刺激强度发生*变化*时才产生动作电位。例如，下图显示了一个仅在刺激开启时才产生动作电位的神经元活动。这种神经元被称为“ON-响应神经元”：



Journal of Neuroscience 13 April 2016, 36 (15) 4325-4338; DOI: 10.1523/JNEUROSCI.3887-15.2016, CC-BY

This way of encoding information about the stimulus is far more energy-efficient than a 'rate-coding' neuron, one which simply spikes more frequently when stimulus intensity is high and slower when stimulus intensity is low.

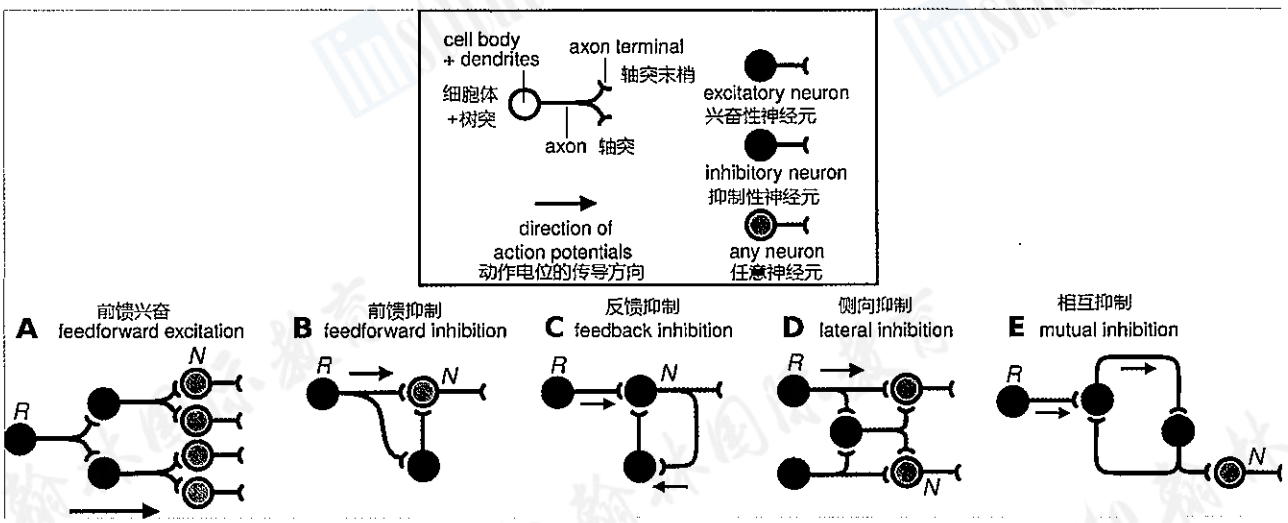
这种刺激信息编码方式，比“频率编码神经元”的能量效率高得多。后者仅在：刺激强度高时放电更频繁，刺激强度低时放电频率降低。

An ON-response neuron can be produced downstream of a rate-coding neuron through surprisingly simple circuits. Take neuron '*R*', a *rate-coding* sensory neuron that is responding to a stimulus suddenly switching from off to on. Assume no other neurons are receiving a stimulus.

通过出奇简单的回路，可以在一个频率编码神经元的下游产生一个 ON-响应神经元。以神经元“*R*”为例，它是一个*频率编码*感觉神经元，此时正对一个突然从关闭转为开启的刺激做出响应。假设没有其他神经元接受该刺激。

Problem 226. Which of the following neuron circuits could produce an 'ON-response' in the downstream neuron labelled '*N*'? *(There may be more than one.)* (5 marks)

问题226：下列哪些神经元回路可以在标记为“*N*”的下游神经元中产生“ON-响应”？ *（本题为多项选择题）*（5分）



Q4 LHON disease 遗传性视神经病变

Leber hereditary optic neuropathy (LHON) is a rare genetic disease that can cause visual loss due to optic nerve degeneration. LHON is maternally inherited and primarily affects young males. Prior to the degeneration of retinal ganglion cells and optic atrophy, high levels of reactive oxygen species (ROS) accumulate within these cells. Whole-tissue sequencing data indicated missense mutations in patients' samples, with 90% of patients having mutation patterns at the same three loci.

Leber 遗传性视神经病变（LHON）是一种罕见的遗传性疾病，可因视神经退行性变导致视力丧失。该病为母系遗传，且主要影响年轻男性。在视网膜神经节细胞发生退化及视神经萎缩发生之前，细胞内会积累高水平的活性氧（ROS）。全组织测序数据显示，患者样本中存在错义突变，其中 90% 的患者在相同的三个基因位点上出现突变。

Problem 227. Not all carriers of LHON manifest symptoms. How would you explain this maternally inherited trait which primarily affects young males? (2 marks)

问题 227：并非所有 LHON 携带者都会表现出症状。如何解释这种母系遗传且主要影响年轻男性的性状？（2 分）

A. Nuclear DNA mutation but the symptom onset is triggered by LH-surge (LH is Luteinizing hormone)

核 DNA 突变，但症状发作由促黄体生成素激增触发（LH 即促黄体生成素）

B. Mitochondrial DNA mutation but the symptom onset is influenced by environment and X-linked trait

线粒体 DNA 突变，但症状发作受环境和 X 连锁性状影响

C. Mutation happens on Y-chromosome, but the symptom onset is influenced by mitochondria

突变发生在 Y 染色体上，但症状发作受线粒体影响

D. Mutation happens on X-chromosome, but the symptom onset is influenced by cytoplasmic ATP level

突变发生在 X 染色体上，但症状发作受细胞质 ATP 水平影响

Problem 228. What does the mutation primarily affect? (1 mark)

问题 228：该突变主要影响以下哪一过程？（1 分）

A. Cellular respiration 细胞呼吸

B. Mitosis 有丝分裂

C. Sodium-potassium pump activation 钠-钾泵激活

D. Acetylcholine release 乙酰胆碱释放

Problem 229. High levels of ROS leads to: (1 mark)

问题 229：高水平的活性氧（ROS）会导致：（1 分）

A. Apoptosis 细胞凋亡

B. Increased cell-to-cell communication 细胞间通讯增强

C. Rapid cell division 细胞快速分裂

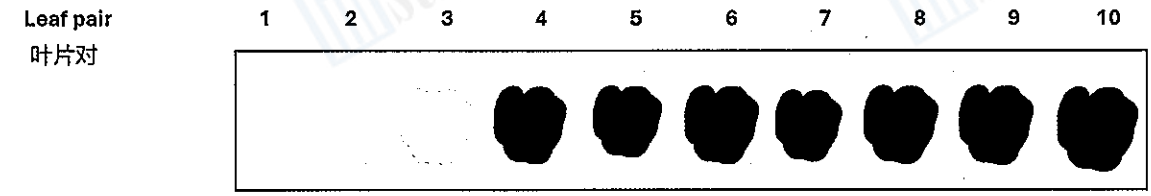
Q5 Novel plant protein kinase 新型植物蛋白激酶

A team of researchers has identified a novel plant protein named Protein A, coded for by gene a. Structural analyses indicate that Protein A belongs to the family of Ca^{2+}/calmodulin-regulated protein kinases. However, unlike typical plant Ca^{2+}-dependent protein kinases, Protein A lacks both the auto-inhibitory region and EF-hand motifs, which accounts for its Ca^{2+}-independent behaviour. The research group subsequently aimed to elucidate the regulatory pathway that governs Protein A activity, potentially operating in place of the canonical Ca^{2+}-mediated mechanism.

某一组研究人员鉴定出一种由基因 a 编码的新型植物蛋白，命名为蛋白 A。结构分析表明，蛋白 A 属于 Ca^{2+}/钙调素调节的蛋白激酶家族。然而，与典型的植物 Ca^{2+}依赖性蛋白激酶不同，蛋白 A 同时缺乏自身抑制区（auto-inhibitory region）和 EF 手形基序（EF-hand motifs），这解释了其不依赖 Ca^{2+}的特性。该研究组随后致力于阐明调控蛋白 A 活性的通路，该通路或可替代经典的 Ca^{2+}介导机制发挥作用。

Following is some experimental data relating to Protein A.

以下是与蛋白 A 相关的部分实验数据：

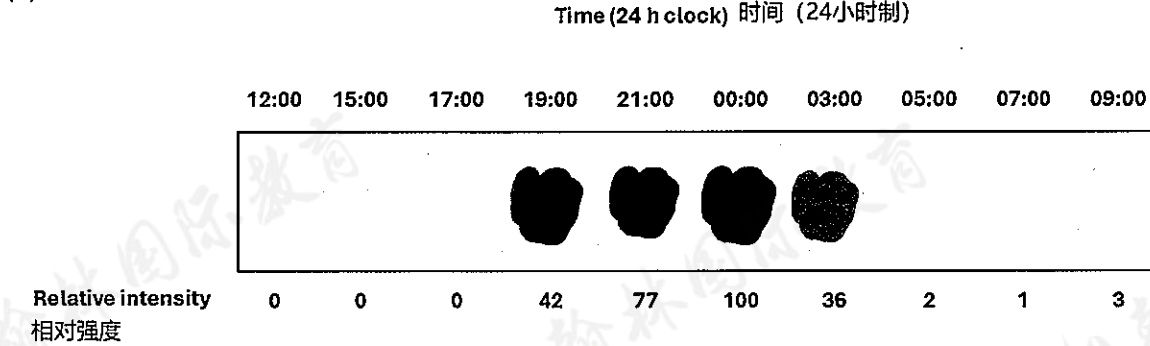


Leaf pair 叶片对	1	2	3	4	5	6	7	8	9	10
Relative intensity 相对强度	0	8	13	49	70	64	59	76	79	100
Nocturnal malate accumulation (mM) 夜间苹果酸积累量（单位：mM）	-6	15	39	55	54	46	46	59	43	45

Figure 1: The phosphorimage shows hybridisation of gene a cDNA to blots of RNA from leaves of different ages, numbering from the youngest leaf pair down the stem. The numbers below the phosphorimage show the relative intensities of the bands. The malate content of cell sap was measured at the end of the night (08:00 h)and the end of the day (16:00 h). The data are presented as the differences between these values.

图1：该磷屏成像图显示了基因a的cDNA与来自不同叶龄叶片（按叶片对从上到下、从最年轻开始编号）RNA印迹的杂交结果。成像图下方的数字显示了条带的相对强度。细胞液的苹果酸含量在夜间结束时（08:00）和白天结束时（16:00）进行了测定，图中数据以这两个时间点的测量差值呈现。

(a)



Time (24 h clock) 时间（24小时制）	12:00	15:00	17:00	19:00	21:00	00:00	03:00	05:00	07:00	09:00
Relative intensity 相对强度	0	0	0	42	77	100	36	2	1	3

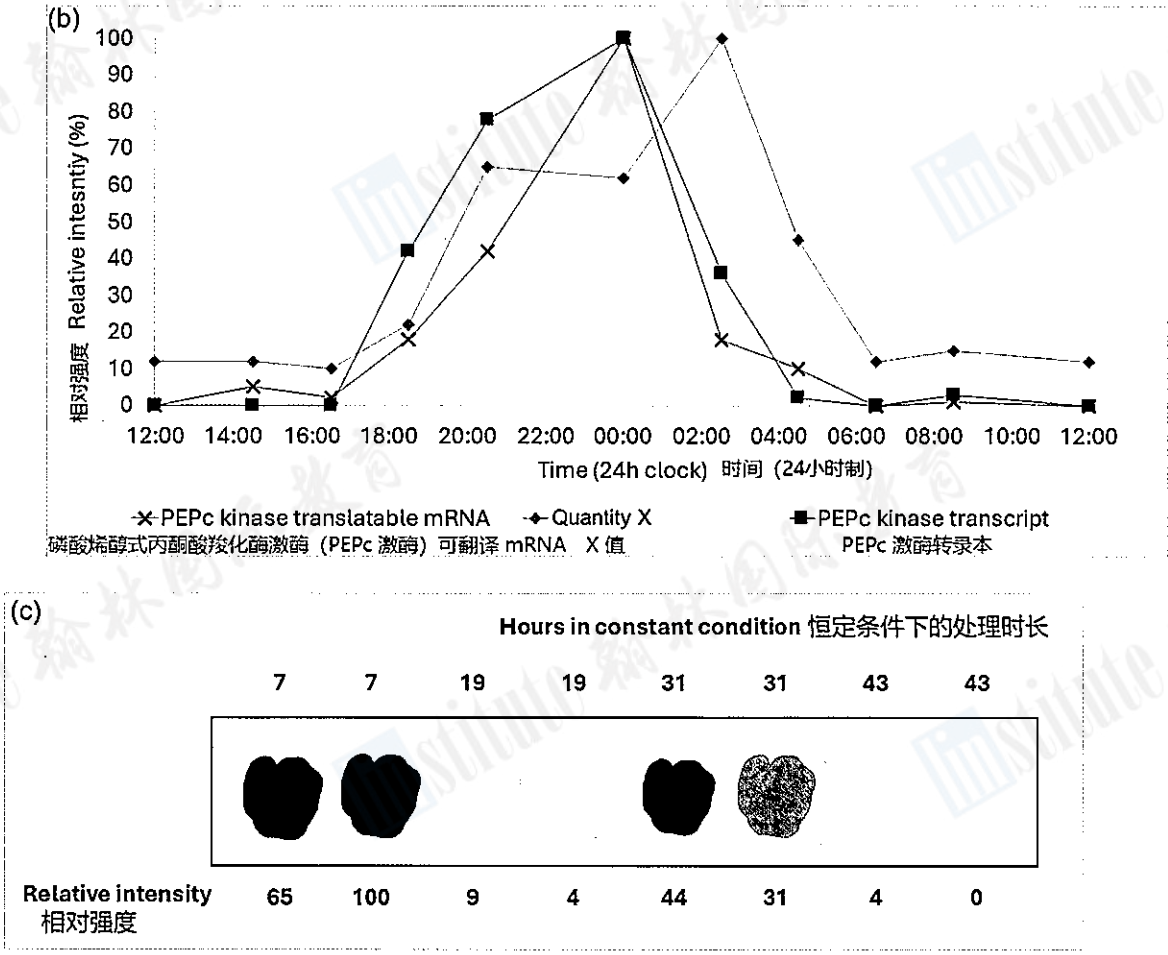


Figure 2: (a) Phosphorimage showing hybridisation of cDNA of *gene a* to blots of leaf RNA throughout the normal diurnal cycle, photoperiod 08.00–16.00; the numbers below the phosphorimage show the relative intensities of the bands.

图 2：（a）磷屏成像图显示，在正常昼夜周期内（光照周期为 08:00-16:00），*基因 a* 的 cDNA 与叶片 RNA 印迹的杂交结果；成像图下方的数字代表条带相对强度。

(b) The quantitative data from (a) are shown with the amounts of PEPc kinase translatable mRNA, quantity X and PEPc kinase transcript under identical conditions. This plot shows that the level of Protein A transcripts increased and decreased over the diurnal cycle in parallel with the level of its translatable mRNA.

(b) 来自 (a) 的定量数据，以及相同条件下 PEPc 激酶的可翻译 mRNA 量、X 值以及 PEPc 激酶转录本水平。此图表明，蛋白 A 转录本的水平在昼夜周期中与其可翻译 mRNA 的水平同步增减。

(c) Phosphorimage showing hybridisation of cDNA of *gene a* to blots of RNA from duplicate leaves kept in constant conditions (continuous darkness, CO_2-free air at 15°C). Constant conditions commenced at zero time, corresponding to the end of a normal day.

(c) 磷屏成像图显示，*基因 a* 的 cDNA 与在恒定条件（持续黑暗、15°C 无 CO_2 的空气）下培养的重复叶片 RNA 印迹的杂交情况。恒定条件于零时启动，此时对应一个正常光照周期结束。

A diurnal cycle is a 24-hour cycle often driven by environmental cues.

昼夜周期是一个 24 小时周期，通常由环境信号驱动；

A circadian cycle is a 24-hour cycle driven by an internal clock, persisting in the absence of external signals.

昼夜节律周期是一个 24 小时周期，由内在生物钟驱动，在缺乏外部信号时仍能持续存在。

Using the figures and information provided here, indicate whether the following statements are true (T), false (F) or cannot be determined from these data (C). (5 marks)

根据提供的图表和信息，判断下列说法正确（T）、错误（F）或无法通过这些数据确定（C）。（5 分）

Problem 230. Protein A lacks the property to act as a kinase enzyme.

问题 230：蛋白 A 不具备激酶功能。

A. TRUE 正确　　B. FALSE 错误　　C. Cannot be determined 无法确定

Problem 231. Transcription of Protein A is under circadian control.

问题 231：蛋白 A 的转录受生物钟调控。

A. TRUE 正确　　B. FALSE 错误　　C. Cannot be determined 无法确定

Problem 232. Older leaf contains more Protein A by leaf volume.

问题 232：较老的叶片按体积计算含有更多蛋白 A。

A. TRUE 正确　　B. FALSE 错误　　C. Cannot be determined 无法确定

Problem 233. More efficient transcription process in older leaf is responsible for this hybridisation pattern.

问题 233：较老叶片中更高效的转录过程是形成该杂交模式的原因。

A. TRUE 正确　　B. FALSE 错误　　C. Cannot be determined 无法确定

Problem 234. Less efficient protein degradation pathway in older leaf is responsible for this hybridisation pattern.

问题 234：较老叶片中效率较低的蛋白降解途径是形成该杂交模式的原因。

A. TRUE 正确　　B. FALSE 错误　　C. Cannot be determined 无法确定

Problem 235. In Figure 2 (b), identify quantity X. (2 marks)

问题 235： 图 2（b）中的 X 值代表什么？（2 分）

A. tRNA level in leaf cell

叶细胞中的 tRNA 水平

B. Total DNA level of the bulk tissue

整体组织的总 DNA 水平

C. Hybridisation of 3'-non-translated sequences of gene a transcript

基因 a 转录本 3' 非翻译区的杂交信号

D. Activity of Protein A

蛋白 A 的活性

Problem 236. Increased protein A activity leads to increased carbon fixation. In which habitat would you expect to find species where photosynthetic genes are under post-translational control by protein A? (1 mark)

问题 236： 蛋白 A 活性增强会提高碳固定效率。下列哪种栖息地中会找到其光合作用基因受蛋白 A 翻译后控制的物种？（1 分）

A. High altitude 高海拔地区

B. Grassland 草原

C. Drought zone 干旱地区

D. Flooded area 洪涝地区

Q6 Drought resistance of plants 植物的抗旱性

The transpiration stream is the transport of water and dissolved minerals from roots to leaves through the xylem vessels, driven by the equilibration of water potential.

蒸腾流是指水分和溶解的矿物质受水势差驱动，通过木质部导管从根部运输到叶片的过程。

Under normal conditions the xylem forms an uninterrupted water column, allowing efficient transport; however, drought conditions can disrupt this stream. Drought stress decreases the pressure in the water stream (increasing the tension), which can lead to cavitation – where air is pulled into a conduit through a pit and rapidly expands, filling the conduit and causing an embolism.

正常条件下，木质部会形成连续的水柱，从而实现高效运输；但干旱环境会破坏该运输过程。干旱胁迫会降低水流压力（增大张力），进而引发空化现象 —— 空气通过纹孔被吸入导管后迅速膨胀，最终填满导管并形成栓塞。

In some plants, xylem embolism causes irreversible damage and cannot be repaired. It is observed that some plants can repair embolisms, but the mechanism is unknown. Repair could involve the generation of positive pressure in the xylem to dissolve the gas, allowing it to diffuse away.

部分植物的木质部栓塞会造成不可逆损伤，无法修复；但研究发现，有些植物能够修复栓塞，其机制尚不明确。修复过程可能涉及在木质部内产生正压，使气体溶解并扩散排出。

Problem 237. Which part of the plant is most vulnerable to cavitation? (1 mark)

问题 237：植物的哪个部位最易发生空化现象？（1 分）

A. Roots 根

B. Stem 茎

C. Leaves 叶

Problem 238. Which adaptations could help prevent cavitation?

（There may be more than one.） (2 marks)

问题 238：下列哪些适应性特征有助于防止空化发生？*（本题为多项选择题）*（2 分）

A. A larger water potential gradient between the soil and leaves of the plant.

土壤与植物叶片的水势梯度更大。

B. More positive root pressure.

更高的根压。

C. Decreased porosity of pit membranes.

纹孔膜孔隙度降低。

D. Wider leaf xylem vessels.

叶片木质部导管更粗。

Indicate if each of the following statements are true or false: (4 marks)
判断下列说法是否正确：（4 分）

Problem 239. Herbaceous plants are more likely to be able to repair embolisms than woody plants.
问题 239：草本植物比木本植物更有可能修复栓塞。

A. TRUE 正确　　B. FALSE 错误

Problem 240. Gravity has a significant effect on water potential in all plants.
问题 240：重力对所有植物的水势都有显著影响。

A. TRUE 正确　　B. FALSE 错误

Problem 241. Embolism repair is likely to involve active transport of minerals out of the xylem.
问题 241：栓塞修复可能涉及矿物质主动运输出木质部的过程。

A. TRUE 正确　　B. FALSE 错误

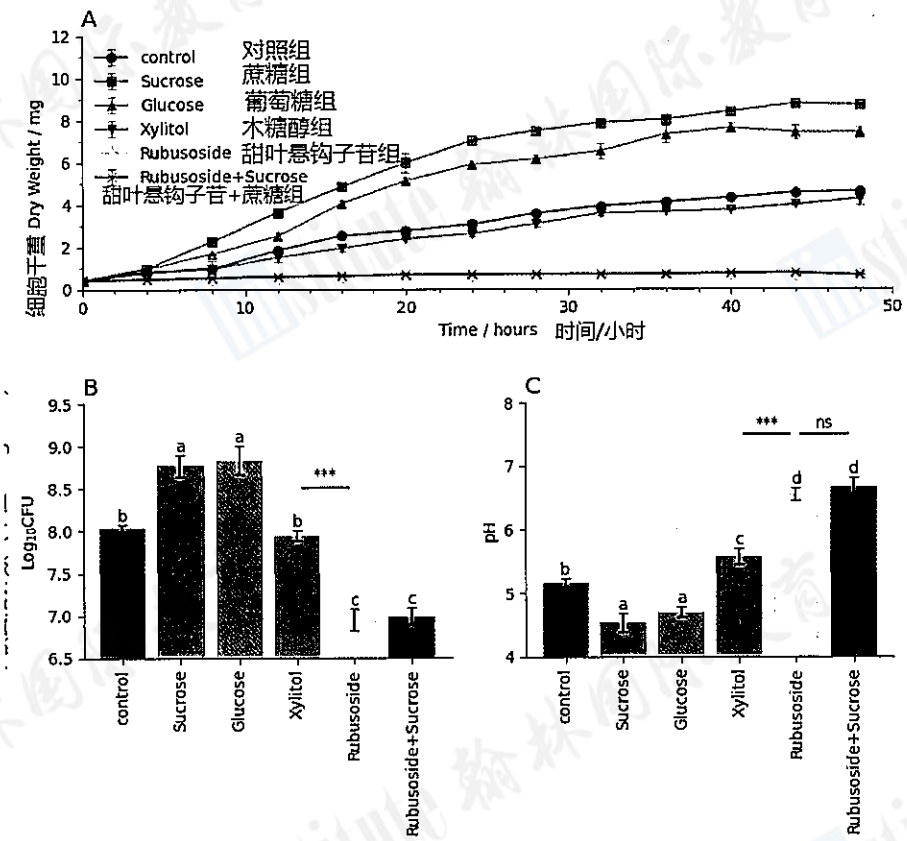
Problem 242. Reducing xylem connectivity is likely to be an effective adaption to drought.
问题 242：降低木质部的连通性可能是植物应对干旱的有效适应性特征。

A. TRUE 正确　　B. FALSE 错误

Q7 Sweetener 甜味剂

Intake of glucose and sucrose accelerates the development of tooth decay in children. *Scardovia wiggsiae* (*S. wiggsiae*) is a potential pathogen of early childhood caries (ECC). Research has demonstrated that rubusoside, a sweetener that does not cause tooth decay, inhibits the pathogen *Streptococcus mutans* (*S. mutans*). Research was done to investigate the effects of rubusoside on metabolism of *S. wiggsiae*.

摄入葡萄糖和蔗糖会加速儿童形成龋齿。*韦格斯卡多维亚菌*（*Scardovia wiggsiae*，*S. wiggsiae*）是幼儿龋齿（ECC）的潜在致病菌。研究表明，甜叶悬钩子苷（一种不会导致龋齿的甜味剂）能抑制*变形链球菌*（*Streptococcus mutans*，*S. mutans*）这一致病菌。本研究旨在探究甜叶悬钩子苷对*韦格斯卡多维亚菌*代谢的影响。



Redrawn from Wang, P., Ma, R., Ma, D. et al. Effect of rubusoside, a natural sucrose substitute, on the metabolism of Scardovia wiggsiae: a novel potential cariogenic pathogen. BMC Biol 23, 262 (2025). https://doi.org/10.1186/s12915-025-02321-9

Fig. 1: Effects of rubusoside, sucrose + rubusoside, xylitol, glucose, and sucrose on the cell growth of *S. wiggsiae* in an anaerobic environment at 35 °C. Dynamic dry weight of cells at 48 h (**A**), quantitative statistics of plate colony counts (**B**), pH value at 48 h (**C**). Values are presented as mean ± SD. Different letters represent significant differences among treatments. Statistical significance is marked with asterisks: ns, not significant; *, P<0.05; **, P<0.01; ***, P<0.001.

图 1：在 35°C 厌氧环境下，甜叶悬钩子苷、蔗糖 + 甜叶悬钩子苷、木糖醇、葡萄糖及蔗糖对*韦格斯卡多维亚菌*细胞生长的影响。（**A**）48 小时细胞动态干重；（**B**）平板菌落计数定量统计；（**C**）48 小时 pH 值。数据以“平均值 ± 标准差（mean ± SD）”表示，不同字母代表处理组间存在显著差异；统计显著性用星号标记：ns 表示无显著差异；*，P<0.05；**，P<0.01；***，P<0.001。

Indicate if the statements are true or false: (4 marks)
判断下列说法是否正确：（4 分）

Problem 243. Rubusoside has potential applications in the food industry.

问题 243：甜叶悬钩子苷在食品工业中具有潜在应用价值。

A. TRUE 正确　　B. FALSE 错误

Problem 244. Glucose had significantly increased CFU compared to sucrose.

问题 244：与蔗糖相比，葡萄糖显著增加了菌落形成单位（CFU）。

A. TRUE 正确　　B. FALSE 错误

Problem 245. Sucrose always has a significant promoting effect.

问题 245：蔗糖始终具有显著的促生长作用。

A. TRUE 正确　　B. FALSE 错误

Problem 246. From this data you can conclude that rubusoside will have an inhibitory effect on S. wiggsiae in the presence of all sugars.

问题 246：根据该数据可得出结论：在所有糖类存在的情况下，甜叶悬钩子苷均会对韦格斯卡多维亚菌产生抑制作用。

A. TRUE 正确　　B. FALSE 错误

Problem 247. What accurately describes the effect of Xylitol on growth of *S. wiggsiae*? (1 mark)
问题 247：下列哪项准确描述了木糖醇对*韦格斯卡多维亚菌*生长的影响？（1 分）

A. Inhibitory 抑制作用
B. Promoting 促进作用
C. Not statistically significant 无统计显著性

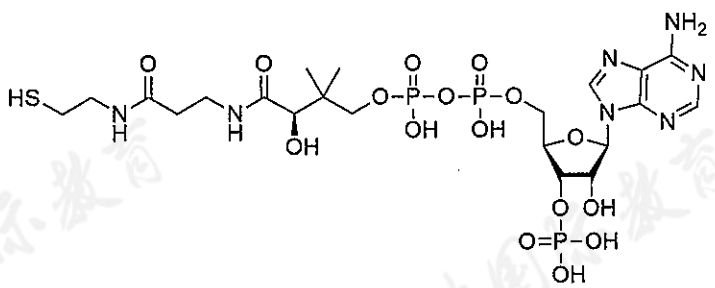
Problem 248. In the control group, which period had the largest average rate of growth of dry mass? (1 mark)
问题 248：对照组中，哪个时间段的细胞干重平均增长率最大？（1 分）

A. 0h – 8h　0 小时–8 小时
B. 8h – 12h　8 小时 - 12 小时
C. 12h – 20h　12 小时 - 20 小时
D. 20h – 40h　20 小时 - 40 小时

Q8 Structure and Biosynthesis of Coenzyme A
辅酶 A 的结构与生物合成

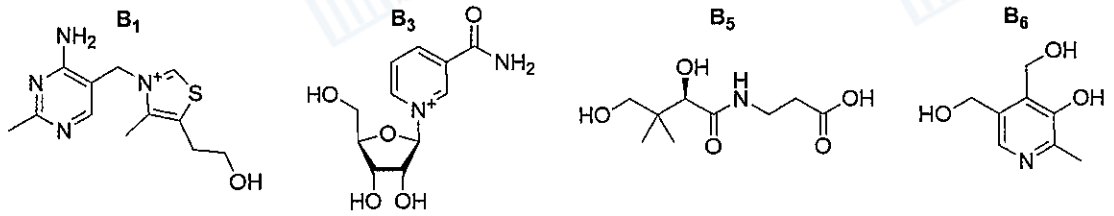
Coenzyme A (CoA) is an essential cofactor in all living organisms. Shown below is the chemical structure of CoA.

辅酶 A（CoA）是所有生物体内必需的辅因子，其化学结构如下图所示。



The biosynthesis of CoA requires one of the following B vitamins.

辅酶 A 的生物合成需要以下某种 B 族维生素作为原料。



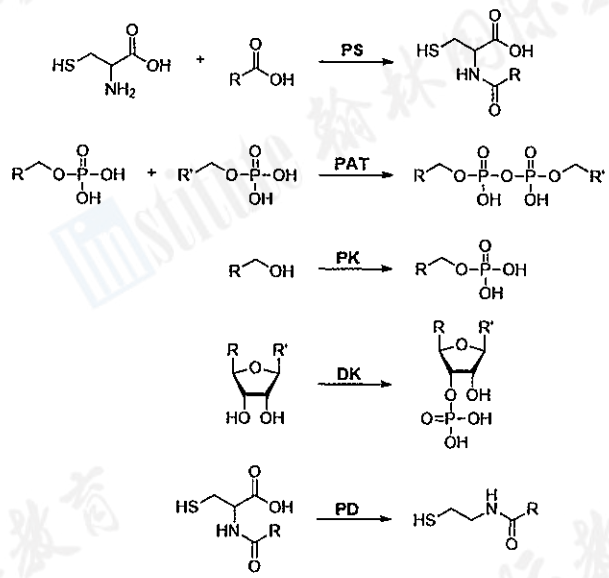
From this vitamin, CoA is synthesised via five enzymes (PS, PAT, PK, DK, PD) that each catalyse a different reaction. The five enzymatic steps, in order, are as follows.

以该维生素为起始物质，辅酶 A 通过五种酶（PS、PAT、PK、DK、PD）催化合成，每种酶催化不同的反应。这五个酶促步骤的顺序如下：

1. The vitamin is phosphorylated by ATP. 该维生素被 ATP 磷酸化；
2. A three-carbon fragment is installed. 引入一个三碳片段；
3. The molecule is decarboxylated. 该分子发生脱羧反应；
4. Adenosine monophosphate (AMP) is installed. 引入单磷酸腺苷（AMP）；
5. The sugar part of the molecule is phosphorylated by ATP. 该分子的糖基部分被 ATP 磷酸化。

The reaction that each enzyme catalyses is shown below. They are not in order.

下图展示了每种酶催化的反应（反应未按上述顺序排列）。



Questions：问题：

Problem 249. Which B vitamin is required for the biosynthesis of CoA? (2 marks)
问题 249：辅酶 A 的生物合成需要哪种 B 族维生素？（2 分）

A.B_1　　B.B_3　　C.B_5　　D.B_6

Problem 250. How many condensation reactions occur during the biosynthesis of CoA? (2 marks)
问题 250：辅酶 A 的生物合成过程中发生了多少次缩合反应？（2 分）

_____

Problem 251. Order the five enzymes for the biosynthesis of CoA. (5 marks)
问题 251：请按顺序排列辅酶 A 生物合成所需的五种酶。（5 分）

_____，_____，_____，_____，_____

Indicate if the statements are true or false: (3 marks)　判断下列说法是否正确：（3 分）

Problem 252. In step 2, the three-carbon fragment is an amino acid.
问题 252：步骤 2 中，引入的三碳片段是一种氨基酸。

A. TRUE 正确　　B. FALSE 错误

Problem 253. The sugar part of CoA is glucose.
问题 253：辅酶 A 的糖基部分是葡萄糖。

A. TRUE 正确　　B. FALSE 错误

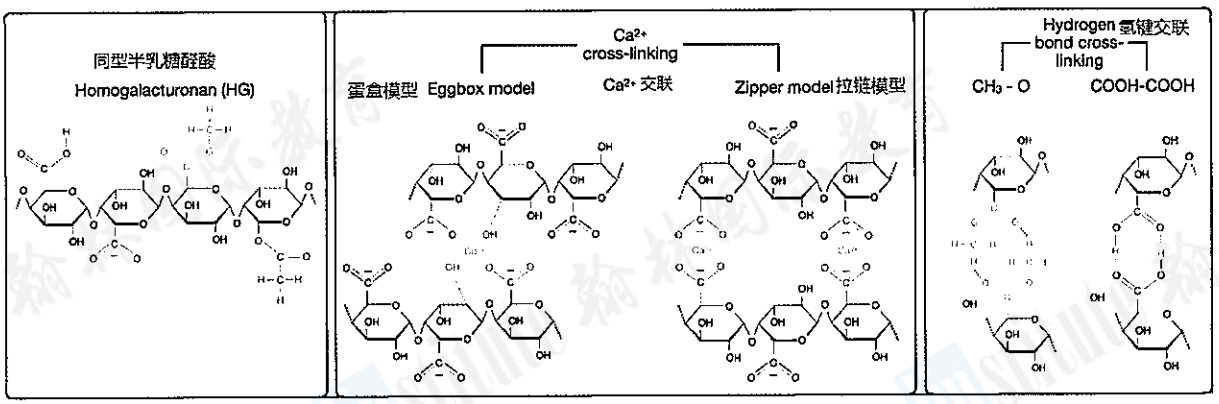
Problem 254. The nucleotide part of CoA is adenine.
问题 254：辅酶 A 的核苷酸部分是腺嘌呤。

A. TRUE 正确　　B. FALSE 错误

Q9 Membrane porosity 膜孔隙率

Along with cellulose, pectins are a major component of plant cell walls. The properties of plant cell walls are significantly affected by the extent of pectin chain crosslinking, including their porosity. Several mechanisms for cross-linking of the most abundant pectin domain, homogalacturonan, are shown below. Carboxyl groups in homogalacturonan have a pKa of around 3.6.

除纤维素外，果胶是植物细胞壁的主要成分之一。果胶链的交联程度会显著影响植物细胞壁的特性，其中包括孔隙率。下图展示了最丰富的果胶结构域 —— 同型半乳糖醛酸（homogalacturonan）的几种交联机制。同型半乳糖醛酸中羧基的 pKa 约为 3.6。



Obomighie et al., 2025, CC BY 4.0

Problem 255. Order the following cross-links from strongest to weakest. Mark the answer sheet in sequence from top to bottom. (2 marks)

问题 255：将以下交联方式按从强到弱的顺序排列。填涂答题卡时，按照从上往下的顺序分别涂卡。（2 分）

A. Ca^{2+} cross linking. Ca^{2+}交联

B. CH_3-O cross-linking. CH_3-O 交联

C. COOH-COOH cross-linking. COOH-COOH 交联

Indicate if the following statements are TRUE or FALSE: (2 marks)

判断下列说法是否**正确**：（2 分）

Problem 256. Homogalacturonan will have stronger crosslinks under acidic conditions than alkaline conditions.

问题 256：同型半乳糖醛酸在酸性条件下形成的交联比碱性条件下更强。

A. TRUE 正确　　B. FALSE 错误

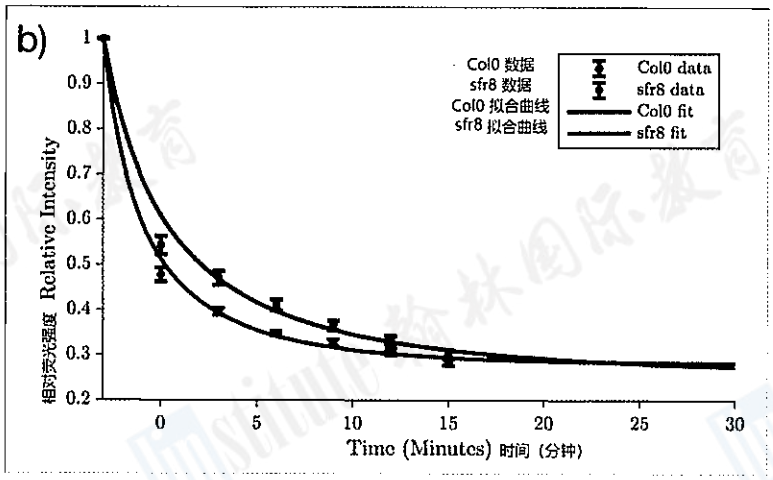
Problem 257. Fluidity of pectin domains will be greater in absence of Ca^{2+}.

问题 257：缺乏 Ca^{2+} 时，果胶结构域的流动性会更高。

A. TRUE 正确　　B. FALSE 错误

Membrane porosity was investigated by measuring the ability of relatively large fluorescence quenching molecules (which prevent light being emitted from the excited fluorophore) to traverse the cell wall. The plasma membranes of wild type (Col0) and mutant (*sfr8*) plant cells, which have a mutation in the *mur1* gene influencing pectin cross-linking, were labelled with a fluorescent marker. A quencher molecule was then introduced and the decrease in fluorescence measured over time.

研究人员通过检测较大的荧光淬灭分子（可阻止受激发的荧光团发光）穿过细胞壁的能力，探究了膜孔隙率。野生型（Col0）和突变体（*sfr8*）植物细胞的质膜均用荧光标记物标记，其中 *sfr8* 突变体的 *mur1* 基因发生突变，该基因会影响果胶交联。随后引入淬灭分子，并测量随时间变化的荧光强度下降情况。



Obomighie et al., 2025, CC BY 4.0

Indicate if the following statements are true or false: (5 marks)
判断下列说法是否正确：（5 分）

Problem 258. Col0 cell walls are likely to have a larger mean pore size.

问题 258： Col0 的细胞壁可能具有更大的平均孔径。

A. TRUE 正确　　B. FALSE 错误

Problem 259. Pectin cross-linking is reduced in sfr8 mutants.

问题 259： sfr8 突变体的果胶交联程度降低。

A. TRUE 正确　　B. FALSE 错误

Problem 260. Sfr8 mutants are likely to be more vulnerable to fungal disease.

问题 260： sfr8 突变体可能更易受真菌性病害的侵袭。

A. TRUE 正确　　B. FALSE 错误

Problem 261. Sfr8 mutants will have a higher rate of CO_2 diffusion into mesophyll cells due to increased cell wall porosity.

问题 261： 由于细胞壁孔隙率增加，Sfr8突变体的二氧化碳向叶肉细胞扩散的速率会更高。

A. TRUE 正确　　B. FALSE 错误

Problem 262. Given that boron cross-links between pectin chains bring them closer together, a mutant with fewer boron cross-links will also have fewer Ca^{2+} cross-links.

问题 262：已知硼介导的果胶链交联会使果胶链相互靠拢，因此硼交联较少的突变体，其 Ca^{2+} 交联也会更少。

A. TRUE 正确　　B. FALSE 错误

Q10 Extra-terrestrial life 地外生命

It has been speculated that extra-terrestrial life could use a solvent other than water. There are many different compounds which may be used instead; the properties of some of these are listed in the following table:

有推测认为，地外生命可能使用水以外的物质作为溶剂。存在许多可能被用作溶剂的不同化合物；下表列出了一些此类化合物的性质：

Solvent 溶剂	Melting Point at 1 atm pressure /°C 1 个标准大气压下熔点 /°C	Boiling Point at 1 atm pressure /°C 1 个标准大气压下沸点 /°C	Heat Capacity /J mol^{-1} K^{-1} 摩尔热容 / J mol^{-1} K^{-1}
Water 水	0	100	75
Hydrogen sulphide 硫化氢	-85	-59	34
Ammonia 氨	-78	-33	81
Methane 甲烷	-183	-161	53

Another unique property of water is that it expands when it freezes.

水的另一独特性质是结冰时会膨胀。

Indicate if each of the following statements is true or false: (3 marks)
判断下列说法是否正确：（3 分）

Problem 263. An organism with ammonia would be better at maintaining a constant internal temperature than one with the other solvents.

问题 263：以氨为溶剂的生物，比以其他溶剂为介质的生物更擅长维持恒定的体内温度。

A. TRUE 正确　　B. FALSE 错误

Problem 264. Freezing would be more likely to damage the membranes of water-based cells than those using alternative solvents.

问题 264：相比使用替代溶剂的细胞，结冰更容易损伤水基细胞的膜结构。

A. TRUE 正确　　B. FALSE 错误

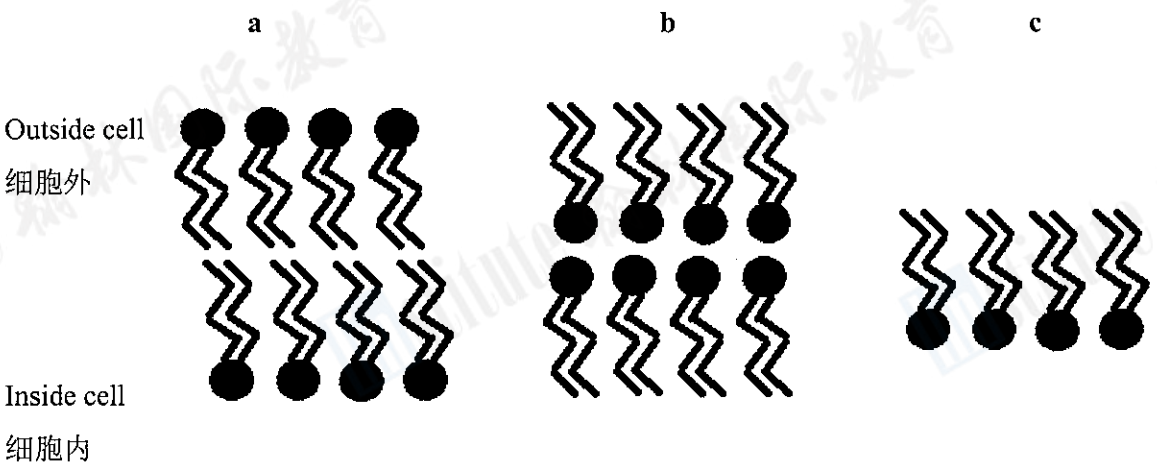
Problem 265. Organisms living on another planet (with similar pressure to Earth) and using a different solvent would be likely to have a slower rate of metabolism compared to terrestrial life.

问题 265：生活在另一颗行星（压力与地球相似）并使用不同溶剂的生物，其代谢速率很可能比地球生命更慢。

A. TRUE 正确　　B. FALSE 错误

The following diagrams show potential cell boundaries using a molecule with a hydrophilic head and hydrophobic tail:

下图展示了潜在的细胞边界结构，该结构由“亲水头部 + 疏水尾部”的分子构成：



Problem 266. Imagine a single-celled organism that uses water as an internal solvent and lives in a sea of a non-polar solvent such as methane. Which of these could be used as a cell boundary in this organism? (1 mark)

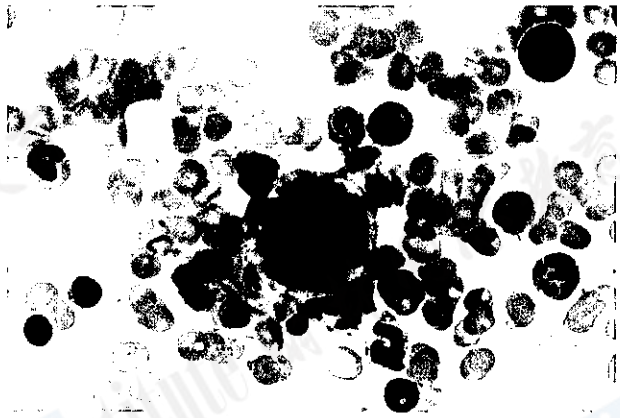
问题 266：假设存在一种单细胞生物，其体内溶剂为水，却生活在以甲烷这类非极性物质为溶剂的海洋环境中。上图中哪种结构可作为该生物的细胞边界？（1 分）

A. a　　B. b　　C. c

Q11 Polyploidy 多倍体

Human megakaryocytes (MK) are polyploid, with a single large multilobulated nucleus and a DNA content of up to 64n. This arises from undergoing endomitosis, in which several stages of mitosis are omitted. MKs produce blood platelets which are necessary for normal clotting.

人类巨核细胞（MK）为多倍体，具有单个大型多叶核，DNA 含量最高可达 64n。其形成源于核内有丝分裂（endomitosis），该过程中省略了有丝分裂的多个阶段。巨核细胞负责产生维持正常凝血功能所需的血小板。



Ed Uthman from Houston, TX, USA, CC BY 2.0, via Wikimedia Commons

Problem 267. MKs are derived from the differentiation of hematopoietic stem cells. Which of the following correctly describes the stem cells? (1 mark)

问题 267：巨核细胞由造血干细胞分化产生。下列哪项正确描述了该干细胞的特性？（1 分）

A. Totipotent 全能性

B. Multipotent 多能性

C. Unipotent 单能性

Indicate if the following statements are true or false: (7 marks)
判断下列说法是否正确：（7 分）

Problem 268. When endomitotic replication is unregulated, the risk of arterial blockage is reduced.

问题 268：当核内有丝分裂复制失调时，动脉阻塞的风险会降低。

A. TRUE 正确　　B. FALSE 错误

Problem 269. Patients with reduced bleeding time will have a larger mean MK nuclear content.

问题 269：出血时间缩短的患者，其巨核细胞的平均核物质含量更高。

A. TRUE 正确　　B. FALSE 错误

Problem 270. Cell cytoplasmic volume decreases as DNA content increases.

问题 270：随着 DNA 含量增加，细胞质体积会减小。

A. TRUE 正确　　B. FALSE 错误

Problem 271. Endomitosis in MKs produces highly polyploid cells with increased biosynthetic demand.

问题 271：巨核细胞的核内有丝分裂会产生生物合成需求增加的高度多倍体细胞。

A. TRUE 正确　　B. FALSE 错误

Problem 272. Polyploidisation requires less energy than mitosis.

问题 272：多倍体化比有丝分裂所需能量更少。

A. TRUE 正确　　B. FALSE 错误

Problem 273. Lower ploidy MKs are more differentiated.

问题 273：倍性较低的巨核细胞分化程度更高。

A. TRUE 正确　　B. FALSE 错误

Problem 274. MKs found in the lungs are more likely to be capable of phagocytosis and antigen presenting of pathogens than MKs found in the bone marrow.

问题 274：肺部中的巨核细胞，比骨髓中的巨核细胞更可能具备吞噬病原体和呈递抗原的能力。

A. TRUE 正确　　B. FALSE 错误

Problem 275. How are the spindle poles likely to be positioned in the MK during endomitosis compared to in a normal cell in mitosis? (1 mark)

问题 275：与处于有丝分裂过程的正常细胞相比，巨核细胞在核内有丝分裂期间，纺锤体的位置可能如何？（1 分）

A. Further apart. 距离更远

B. Closer together. 距离更近

C. Same position. 位置相同

In a recent study (Murphy et al., 2025), the concentration of cell-free DNA (cfDNA) in plasma was measured in mice with depleted platelets, due to immune thrombocytopenic purpura (ITP), and with normal platelet count. Mice with severely depleted platelets displayed an increase in the concentration of cfDNA in plasma.

在近期的一项研究中（Murphy et al，2025），研究人员检测了两类小鼠血浆中的游离 DNA（cfDNA）浓度：一类是因免疫性血小板减少症（ITP）导致血小板减少的小鼠，另一类是血小板计数正常的小鼠。结果显示，血小板严重匮乏的小鼠，其血浆 cfDNA 浓度升高。

Problem 276. Which two of the following statements are correct? (2 marks)

问题 276： 下列哪两项说法正确？（2 分）

A. DNA is stored in platelets.

血小板中储存有 DNA。

B. When the Y-chromosome is detected in maternal platelets, this is likely due to the transfer of fetal blood cells across the placenta.

若在母体血小板中检测到 Y 染色体，可能是胎儿血细胞通过胎盘转移所致。

C. Injection of healthy mice with anti-platelet antibodies would increase cfDNA concentration in plasma.

向健康小鼠注射抗血小板抗体，会升高其血浆中 cfDNA 的浓度。

D. Injection of healthy mice with anti-platelet antibodies would decrease MK number.

向健康小鼠注射抗血小板抗体，会减少其巨核细胞数量。

Indicate if the following statements are true or false: (4 marks)
判断下列说法是否正确：（4 分）

Problem 277. DNA in platelets and cfDNA will both be degraded by DNase.

问题 277： 血小板中的 DNA 和 cfDNA 均会被脱氧核糖核酸酶（DNase）降解。

A. TRUE 正确　　B. FALSE 错误

Problem 278. Platelets have a small number of mitochondria per cell.

问题 278： 每个血小板中含有少量线粒体。

A. TRUE 正确　　B. FALSE 错误

Problem 279. Given that the mitochondrial genome is ~16,500bp, long DNA fragments found in platelets are more likely to map to the mitochondrial genome than the nuclear genome.

问题 279： 已知线粒体基因组全长约 16500 个碱基对，因此血小板中发现的长 DNA 片段更可能匹配到线粒体基因组，而非核基因组。

A. TRUE 正确　　B. FALSE 错误

Problem 280. Overall, most DNA fragments found in platelets will map to the mitochondrial genome.

问题 280： 总体而言，血小板中发现的大多数 DNA 片段会匹配至线粒体基因组。

A. TRUE 正确　　B. FALSE 错误

Q12 Phylogenetic trees 系统发育树

Phylogenetic trees are a graphical representation of the evolutionary relationships between taxa. Maximum parsimony the principle of creating the tree that has the fewest evolutionary changes possible.

系统发育树是直观呈现各类群进化关系的图形化工具。最大简约法是构建出进化演变次数最少的系统发育树的原则。

Lichen are symbiotic associations primarily between a fungus and a photosynthetic partner (algae or cyanobacteria), with recent research indicating multiple other species are also present. Classification of lichen is based on the classification of the fungus.

地衣是主要由真菌与光合共生伙伴（藻类或蓝细菌）形成的共生体，近期研究表明，地衣中还存在多个其他物种。地衣的分类以其共生真菌的分类为依据。

Cladonia is a common genus of lichens. Some morphological components of a typical *Cladonia* are:

石蕊属（Cladonia）是一类常见的地衣属，其*典型形态*结构包括：

Squamules – leaf like structures that grow close to the substrate.

鳞叶：叶状结构，紧贴基质生长。

Apothecia – often brightly coloured fruiting bodies which produces sexual spores.

子囊盘：通常是颜色鲜艳的子实体，可产生有性孢子。

Podetia – upright structures that carry the fruiting bodies.

柄状体：支撑子实体的直立结构。

Scyphus – a widened, usually concave portion of the podetium.

杯状体：柄状体上一处膨大且通常呈凹陷状的部分。

Table 1 shows the variation in characteristics of 7 species of lichen in the *Cladonia* genus.

表 1 展示了*石蕊属* 7 个物种的特征差异：

Characteristic 特征	*i* ***Cladonia firma*** *坚石蕊*	*ii* ***Cladonia portentosa*** *畸瘤石蕊*	*iii* ***Cladonia squamosa*** *鳞片石蕊*	*iv* ***Cladonia polydactyla*** *多指石蕊*	*v* ***Cladonia callosa*** *痴石蕊*	*vi* ***Cladonia scabriuscula*** *粗皮石蕊*	*vii* ***Cladonia rangiformis*** *鹿角石蕊*
Basal squamules (Present or Absent) 基生鳞叶（有 / 无）	Present 有	Absent 无	Present 有		Present 有	Absent 无	Present 有
Podetium branched (highly branched or little/no branching) 柄状体分枝情况（高度分枝 / 少量分枝 / 不分枝）	little/no branching 少量分枝 / 不分枝	highly branched 高度分枝	little/no branching 少量分枝 / 不分枝		little/no branching 少量分枝 / 不分枝	highly branched 高度分枝	highly branched 高度分枝
Apothecia colour (red, brown) 子囊盘颜色（红色 / 棕色）	Brown 棕色	Brown 棕色	Brown 棕色	Red 红色	Brown 棕色	Brown 棕色	Brown 棕色
Scyphi on top of podetia (present or absent) 柄状体顶端的杯状体 （有 / 无）	Absent 无	Absent 无	Present 有		Present 有	Absent 无	Absent 无
Apothecia located on Scyphi (present or absent) 子囊盘位于杯状体上（有 / 无）	Absent 无	Absent 无	Present 有		Absent 无	Absent 无	Absent 无
UV fluorescent (positive: blue-white, positive: white, or negative) 紫外荧光 （阳性：蓝白色 / 阳性：白色 / 阴性）	Negative 阴性	Positive: blue-white 阳性：蓝白色	Positive: white 阳性：白色	Negative 阴性	Positive: white 阳性：白色	Negative 阴性	Negative 阴性

Figure 1: *Cladonia polydactyla* 图 1：*多指石蕊*

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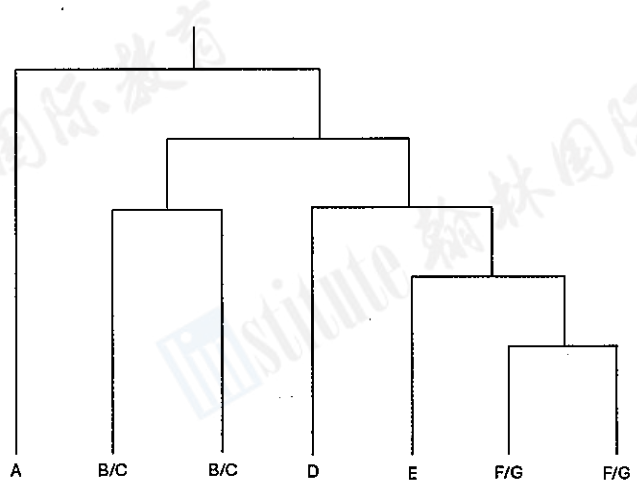
Questions: 问题：

Problem 281. Fill in the table for *Cladonia polydactyla* using Figure 1. (4 marks)
问题 281：结合图 1（*多指石蕊，Cladonia polydactyla*），由上到下补全上表中该物种的特征信息。（4 分）

_____，_____，_____，_____

Here is the structure of an unscaled phylogenetic tree for the species in the table above:
下图为上表中 7 个物种的未标度系统发育树框架：



Assuming that *Cladonia polydactyla* has the same characteristics of the common ancestor of all 7 species, complete the phylogenetic tree using the principle of maximum parsimony. B and C can be given in either order, as can F and G. (7 marks)

Please fill in the corresponding serial numbers of the characteristics in the figure (i, ii, iii, iv, v, vi, vii).

假设*多指石蕊*具有这 7 个物种共同祖先的全部特征，请依据最大简约性原则完成该系统发育树的构建。其中 B 与 C 的位置可互换，F 与 G 的位置也可互换。（7 分）

请填写图中对应的特征序号（i, ii, iii, iv, v, vi, vii）。

Problem 282. 问题 282： A. _____

Problem 283. 问题 283： B. _____

Problem 284. 问题 284： C. _____

Problem 285. 问题 285： D. _____

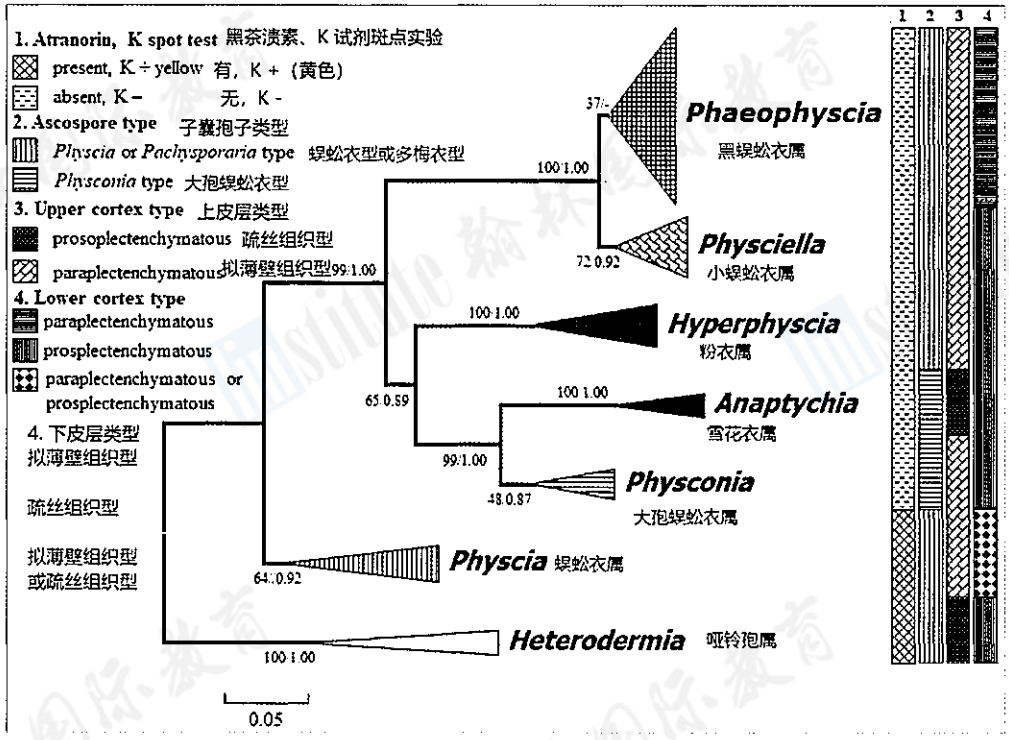
Problem 286. 问题 286： E. _____

Problem 287. 问题 287： F. _____

Problem 288. 问题 288： G. _____

Here is a phylogenetic tree of some different genera of Lichen. Assume the principle of maximum parsimony has been used to create it, with Heterodermia having the same features as the common ancestor. The tree

以下是一些不同属地衣的系统发育树。假设其构建使用了最大简约法原则，且哑铃孢属具有与共同祖先相同的特征。



Indicate if the following statements are true or false: (3 marks)
判断下列说法是否正确：（3 分）

Problem 289. The tree contains exactly one character reversal.

问题 289：该系统发育树恰好包含一次性状逆转。

A. TRUE 正确　　B. FALSE 错误

Problem 290. No traits evolved more than once.

问题 290：没有任何性状演化过一次以上。

A. TRUE 正确　　B. FALSE 错误

Problem 291. *Hyperphyscia* is more related to *Anaptychia* than it is to *Physciella.*

问题 291：粉衣属（*Hyperphyscia*）与雪花衣属（*Anaptychia*）的亲缘关系，比其与小蜈蚣衣属（*Physciella*）更近。

A. TRUE 正确　　B. FALSE 错误

These are three types of groups of taxa:

分类单元的类群分为以下三类：

a. Monophyletic – contains a common ancestor and all its descendants
单系群（Monophyletic）—— 包含一个共同祖先及其所有后代；

b. Paraphyletic – contains a common ancestor but not all its descendants
并系群（Paraphyletic）—— 包含一个共同祖先，但不包含其所有后代；

c. Polyphyletic – does not contain the common ancestor of the taxa
多系群（Polyphyletic）—— 不包含该类群所有分类单元的共同祖先。

Assign the following groups solely based on the above tree: (5 marks)

仅依据上述系统发育树，判断下列类群分别属于哪一类。（5 分）

Problem 292. *Phaeophyscia* and *Physciella*

问题 292：*黑蜈蚣衣属 与小蜈蚣衣属*

A. a　　B. b　　C. c

Problem 293. All atranorin producing lichen.

问题 293：所有产生黑茶渍素的地衣

A. a　　B. b　　C. c

Problem 294. All lichen with *Physconia* type ascopores

问题 294： 所有具有*大孢蜈蚣衣型子囊孢子*的地衣

A. a　　B. b　　C. c

Problem 295. All lichen with a prosoplectenchymatous upper corex

问题 295： 所有具有疏丝组织上皮层的地衣

A. a　　B. b　　C. c

Problem 296. All lichen that can have a paraplectenchymatous lower cortex

问题 296： 所有可能具有拟薄壁组织下皮层的地衣

A. a　　B. b　　C. c