

高中自然領域

雙語教學資源手冊 生物科英語授課用語

A Reference Handbook for **Senior High School** Bilingual Teachers in the
Domain of **Natural Sciences (Biology)**: Instructional Language in English

〔 高中一年級 〕





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★主題一 細胞的構造與功能★

Cell Structure and Function

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■ 前言 Introduction

本章節首先藉由講解細胞學說的建立與發展，讓我們了解形成「學說」的科學歷程，也了解「細胞學說」的內容與其重要性。接著 1-1「細胞的構造」介紹了細胞的構造與其所對應的功能，我們可以根據細胞核的有無，將細胞分為原核細胞與真核細胞，而真核細胞又可以分為動物細胞與植物細胞。在 1-2「細胞與能量」我們了解到生物體都需要能量以維持生命現象，生物透過光合作用與呼吸作用相互配合，可以直接或間接從光能中獲得能量，並透過「能量貨幣」—ATP 與 ADP 之間的能量轉換，以及細胞內的代謝作用，使生物體獲取生理作用所需的能量。1-3「細胞週期與細胞分裂」說明細胞需要依賴細胞分裂與分化，才能得以展現生長與繁殖的生命現象，使生命存續。在細胞分裂中最重要兩種分裂方式分別為「有絲分裂」以及「減數分裂」，有絲分裂為細胞進行分裂後，會產生兩個相同細胞的過程；而減數分裂則是一種可以讓細胞染色體數目減半的分裂方式。藉由了解人體生殖細胞的形成過程，以及細胞分化對多細胞生物體的重要性，讓我們能感受生命誕生的奧妙，進而珍惜生命。

1-1 細胞的構造

Cell Structure

■ 前言 Introduction

有生命的個體會表現出生命的特性，由細胞學說我們可以了解到，細胞是生物體構造與功能的基本單位。大部分的生物體是由多細胞聚集而成的，因此組成一個多細胞生物各種細胞具有多種的形態，其形態與功能密切相關，不同形態的細胞能夠彼此分工合作，共同完成完整的生命現象；另一方面，單細胞生物則是由單一細胞表現出所有的生理功能。細胞是由許多化學分子所形成的，主要有水、礦物質、醣類、蛋白質、脂質和核酸等，而細胞內部又具有各種細微構造，在構造與功能的配合下，進行多種生理作用與化學反應，表現出各種生命特性。我們能夠依據細胞核的有無及細胞質內構造的差異，將細胞分為原核細胞與真核細胞。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
organelle	胞器	cell theory	細胞學說
semiautonomous organelle	半自主胞器	cytosol	細胞質液
smooth endoplasmic reticulum	平滑內質網	plasma membrane	細胞膜
protein	蛋白質	cytoplasm	細胞質
endoplasmic reticulum	內質網	cell nucleus	細胞核
phospholipid	磷脂質	eukaryotic cell/ eukaryote	真核細胞／ 真核生物

Golgi apparatus	高基氏體	centriole/ centrosome	中心粒／中心體
nuclear membrane	核膜	central vacuole	中央液泡
ribosome	核糖體	lysosome	溶體
nucleoplasm	核質	chromatin	染色質
nucleoli	核仁	rough endoplasmic reticulum	粗糙內質網
nucleic acid	核酸	prokaryotic cell/ prokaryote	原核細胞／原核生 物
stroma	基質		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ Some _____ exist _____; some exist _____.

例句：Some ribosomes exist in cytoplasm; some exist on the surface of endoplasmic reticulum.
有些核糖體分布於細胞質內，有些則分布於內質網表面。

❷ The common basic organelles in _____ includes _____, _____, and _____.

例句：The common basic organelles in eukaryote includes plasma membrane, cytoplasm, and cell nucleus.

真核細胞共同的基本構造為細胞膜、細胞質及細胞核。

③ _____ is able to _____, in order to _____.

例句：The plasma membrane **is able to** separate the cell from external environment, and selectively letting materials passing in and out, **in order to** maintain the basic work of physiological function.

細胞膜可以區隔細胞內外的環境，並選擇性地讓物質進出細胞，以利細胞內生理作用的正常進行。

④ There is/are _____ outside _____ of _____.

例句：**There are** cell walls **outside** the plasma membranes **of** algae, fungus and plants.

藻類、真菌和植物細胞在細胞膜外，有細胞壁包覆。

⑤ According to _____, we can divide _____ into _____ and _____.

例句：**According to** whether there are cell nucleus and the differences of the cytoplasm structure in cells, **we can divide** cells **into** prokaryotic cells **and** eukaryotic cells.

依據細胞核的有無及細胞質內構造的差異，可以將細胞分為原核細胞與真核細胞。

⑥ _____ are made up of _____.

例句：All organisms **are made up of** cells.

生物體皆由細胞所構成。

■ 問題講解 Explanation of Problems**☞ 學習目標 ☞**

一、了解細胞的構造與功能。

Understand the structure and function of cells.

二、比較與整合原核細胞與真核細胞的胞器。

Compare and contrast prokaryotic cells and eukaryotic cells.

例題講解

例題一

說明：學生能夠釐清題目重點為比較原核生物與真核生物之間的異同，因此學生需要知道原核生物與真核生物的構造，並比較出兩者之間的差異與共同性，以判斷選項正確與否。

Students are able to compare and contrast between prokaryotic cell and eukaryotic cell. They need to understand structures of both cells, and analyze the correct answer by telling the difference and similarity in both cells.

(英文) There are similarities and differences in bacteria and human cells. Which of the following statements is correct between the comparison of bacteria and human cells?

- (A) There are mitochondria in both of their cell nuclei.
- (B) There are Golgi apparatus in both cells.
- (C) There are ribosomes in both of their cytoplasm.**
- (D) There is no plasma membrane in a bacterium, but there is a cell wall to separate the cell from exterior space.
- (E) There is no cell walls in human cells, the interior second-class organelles are surrounded by plasma membranes.

(中文) 細菌和人體細胞的構造，有共通性也有歧異性，下列有關兩者的比較何者正確？

- (A) 兩者的細胞核中都有粒線體。
- (B) 兩者的細胞內都有高基氏體。
- (C) 兩者的細胞質中都有核糖體。**
- (D) 細菌沒有細胞膜，但有細胞壁與外界區隔。
- (E) 人體細胞沒有細胞壁，內部的次構造皆用膜包圍。

(108 年學測第 9 題)

解析：

先將題目中比較的重點釐清，細菌屬於「原核生物」，而人體細胞屬於「真核生物」。原核生物，缺乏細胞核與膜質胞器；而真核細胞，具有細胞核與膜質胞器。理解題目的重點為比較「原核生物細胞」與「真核生物細胞」後，再一一釐清每一個選項。

To distinguish what to compare, we need to classify bacteria as “prokaryote”, while human cells are classified as “eukaryote”. Prokaryotes lack of cell nucleus and organelles with membrane. While eukaryotes are equipped with cell nuclei and organelles with membrane. After we find out that the key point of solving the question lies in the comparison between “prokaryote cells” and “eukaryote cells”, we can analyze each option in detail.

解題 Solution:

老師以提問的方式點題，引導同學們回答出細菌和人體細胞分別屬於何種細胞，答案為「細菌是原核細胞；人體細胞是真核細胞」，以釐清題目方向。

The teacher guide students to answer the question by asking them what do bacteria and human cells each belong to. We can infer that bacteria are classified as “prokaryote”, while human cells are classified as “eukaryote”, to grab the key point of the question.

Teacher: What do bacteria and human cells each belong to?

Student: Bacteria belong to prokaryote, and human cells belong to eukaryote.

Teacher: That’s right! Therefore, what do we need to compare indeed?

Student: We need to compare between prokaryote and eukaryote.

Teacher: Then what are some differences between “prokaryote” and “eukaryote”?

Student: Prokaryotes lack of cell nucleus and organelles with membrane. While eukaryotes have cell nucleus and organelles with membrane.

Teacher: Great! Let’s take a look at option (A), does mitochondria belong to organelle with membrane?

Student: Yes, it belongs to organelle with membrane. It is an organelle with double membranes.

Teacher: Good. So, which one is equipped with organelle with membrane, prokaryote or eukaryote?

Student: Eukaryote is.

Teacher: Therefore, we can infer that option (A) is wrong. By analogy, are the Golgi apparatus in option (B) and the ribosome in option (C) organelles with membrane? Do they exist both in prokaryote and eukaryote?

Student: Golgi apparatus is organelle with single membrane which only exists in eukaryote. Ribosome is not organelle with membrane so it exists in both prokaryote and eukaryote.

Teacher: Then take a look at option (D), do bacteria have plasma membrane or cell wall?

Student: There are both plasma membrane and cell wall in bacteria.

Teacher: Good! Then let's go to option (E), are there cell walls in human cells? Are the interior second-class organelles surrounded by cellular membranes?

Student: There are no cell walls in human cells, and the interior second-class organelles like ribosome have no plasma membrane.

Teacher: Can anyone tell me another organelle without membrane in human cells?

Student: It's centriole.

老師：同學們知道細菌和人體細胞分別是屬於哪一種細胞嗎？

學生：細菌是原核細胞；人體細胞是真核細胞。

老師：沒錯！因此這個題目真正是要比較的是哪兩種細胞？

學生：原核細胞跟真核細胞。

老師：那麼「原核細胞」與「真核細胞」之間的差異有哪些呢？

學生：原核細胞缺乏細胞核與膜狀胞器；真核細胞則具有細胞核與膜狀胞器。

老師：很好！那我們一起來看選項(A)，請問同學們「粒線體」是不是屬於膜狀胞器呢？

學生：屬於，它是具有雙層膜的胞器。

老師：很好，所以是原核細胞還是真核細胞才具有「粒線體」這個構造呢？

學生：真核細胞。

老師：因此選項(A)錯誤。那依此類推，請問選項(B)與選項(C)中的高基氏體與核糖體是不是膜狀胞器？原核細胞和真核細胞具有嗎？

學生：高基氏體是單層膜狀胞器，因此只有真核細胞才有；核糖體不是膜狀胞器，因此原核細胞和真核細胞都具有此構造。

老師：那麼選項(D)中細菌有無細胞膜呢？又有沒有細胞壁呢？

學生：細菌有細胞膜也有細胞壁。

老師：很好！那麼最後的選項(E)人體細胞有沒有細胞壁？內部的次構造皆是用膜包圍的嗎？

學生：人體細胞沒有細胞壁，而且內部的次構造例如核糖體為非膜結構。

老師：那還有沒有同學知道人體細胞中其他的非膜結構呢？

學生：還有中心粒！

例題二

說明：學生能夠了解細胞的基本構造與其功能。

Students are able to understand the structure and function of cells.

(英文) Which of the following statements about the structure and function of cells is correct?

- (1) Lysosome originates from Golgi apparatus, which is able to decompose old organelles.
- (2) Ribosome does not have a membrane structure and is the place where proteins are synthesized.
- (3) Chloroplasts are single-layer membranous organelles composed of a single-layered thylakoid and stroma.
- (4) Mitochondria are membrane-containing organelles where cells undergo anaerobic respiration to produce ATP.

- | | | |
|--------------|--------------|--------------|
| (A) (1), (2) | (B) (1), (3) | (C) (1), (4) |
| (D) (2), (3) | (E) (2), (4) | (F) (3), (4) |

(中文) 下列是關於細胞構造及功能的敘述。

- 甲、溶體源自高基氏體，可分解老舊胞器。
 - 乙、核糖體不具膜之構造，是合成蛋白質的場所。
 - 丙、葉綠體為單層膜狀胞器，由單層類囊體和基質組成。
 - 丁、粒線體為含膜胞器，是細胞行無氧呼吸以製造 ATP 之場所。
- 下列選項中，哪一選項是正確的？

- (A)甲、乙 (B)甲、丙 (C)甲、丁 (D)乙、丙 (E)乙、丁 (F)丙、丁。

(97 年學測第 60 題)

解題 Solution:

丙－葉綠體為雙層膜狀胞器，由外膜、內膜、葉綠餅和基質組成。

丁－粒線體是細胞行有呼吸以製造 ATP 之場所；無氧呼吸於細胞質中進行。

In option (3), chloroplast is a double-layered membranous organelle composed of outer membrane, inner membrane, chloroplast, and stroma.

In option (4), mitochondria are where cells undergo aerobic respiration to produce ATP; anaerobic respiration takes place in the cytoplasm.

Teacher: Please read the description of the question stem and decide which options are correct. First of all, let's look at option (1) that "Lysosome originates from Golgi apparatus, which is able to decompose old cells". Which organelle does the lysosome originate from?

Student: Golgi apparatus.

Teacher: That's right, and the lysosome contains various hydrolases. So what is its main function?

Student: To break down macromolecules in cells.

Teacher: That's right. Then what else does lysosome do?

Student: It can decompose old organelles.

Teacher: Therefore, the statement in option (1) is correct. Then let's look at option (2), "Ribosome does not have a membrane structure and is the place where proteins are synthesized". Does ribosome have a membrane structure?

Student: No, it doesn't.

Teacher: That's right, and what is the function of ribosome?

Student: To synthesize protein.

Teacher: Therefore, the statement in option (2) is also correct. Let's look at option (3), "Chloroplasts are single-layer membranous organelles composed of a single-layered thylakoid and stroma". How many layers does a chloroplast have?

Student: It has double layers.

Teacher: Chloroplasts are "double-layer" membranous organelles composed of a double membrane and what?

Student: Stroma and grana.

Teacher: That's correct. So how should we correct option (3)?

Student: Chloroplast is an organelle composed of "double membrane, grana, and stroma".

Teacher: At last, let's look at option (4), "Mitochondria are membrane-containing organelles where cells undergo anaerobic respiration to produce ATP". How many layers does a mitochondrion have?

Student: It has double layers.

Teacher: That's right. Then what is the main function of mitochondria?

Student: It is where cells perform aerobic respiration and produce ATP.

Teacher: Therefore, the correct ones are option (1) and (2). Hence, we choose option (A) as the correct answer.

- 老師：請看題幹的敘述並判斷哪些選項是正確的。首先看到甲的敘述「溶體源自高基氏體，可分解老舊胞器」，請問溶體源自於哪一個胞器呢？
- 學生：高基氏體。
- 老師：沒錯，而溶體內含有各種水解酶，因此它主要的功能是什麼？
- 學生：分解細胞內的大分子物質。
- 老師：沒錯，除此之外溶體還有什麼功能呢？
- 學生：分解衰老的胞器。
- 老師：因此甲的敘述為正確的，再來我們看到乙的敘述「核糖體不具膜之構造，是合成蛋白質的場所」，請問核糖體有沒有膜呢？
- 學生：沒有膜。
- 老師：沒錯，而核糖體的功能是什麼？
- 學生：合成蛋白質。
- 老師：因此乙的敘述也是正確的。看到丙選項「葉綠體為單層膜狀胞器，由單層類囊體和基質組成」，請問葉綠體是有幾層膜的胞器？
- 學生：雙層膜。
- 老師：葉綠體是由雙層膜和什麼組合而成的胞器？
- 學生：基質和葉綠餅。
- 老師：沒錯，因此丙的敘述應該修正為何，才是正確的？
- 學生：葉綠體為「雙層」膜狀胞器，由「雙層膜、葉綠餅和基質」所組成。
- 老師：最後我們看到丁選項「粒線體為含膜胞器，是細胞行無氧呼吸以製造 ATP 之場所」，請問粒線體有幾層膜？
- 學生：雙層膜。
- 老師：沒錯，那粒線體的主要功能是什麼？
- 學生：細胞進行有氧呼吸作用、製造 ATP 的場所。
- 老師：因此最後要選擇正確的敘述為甲、乙，因此選擇(A)。

1-2 細胞與能量 Cells and Energy

■ 前言 Introduction

細胞就有如小型的化學工廠一般，隨時都在進行著各式各樣的化學反應。反應過程中，除了物質的改變外，也常常伴隨著能量的轉移。細胞能夠藉由能量轉移的過程獲取能量，進而運用所獲得的能量進行各種生理作用。

生物體所需的能量直接或間接來自光能，有些生物能夠利用葉綠體進行光合作用，將二氧化碳和水轉變成醣類等養分，供生物本身生長所需，例如藻類及植物；有的生物則是能夠利用養分進行呼吸作用，將醣類分解並釋放能量，供生物生存、生長所需，例如動物。

自然界存在各種形式的能量，生物體即是藉由光合作用與呼吸作用將能量作轉換、儲存或釋放，例如光合作用將光能轉換成化學能儲存於醣類，呼吸作用再將醣類分解，釋放出的能量則用來合成 ATP。在本章節我們將了解細胞內通用的能量貨幣－腺苷三磷酸（ATP）的構造，以及它是如何提供細胞生理作用所需的能量，並且進一步了解光合作用與呼吸作用是如何進行的？又是在哪裡進行的？

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
pyruvic acid	丙酮酸	saccharomyces	酵母菌
anaerobic respiration	發酵呼吸	adenine	腺嘌呤
anabolism	同化代謝	adenosine triphosphate	腺苷三磷酸(ATP)
phosphate	磷酸根(Pi)	adenosine diphosphate	腺苷二磷酸(ADP)

Thylakoid	類囊體	lactate/ lactate fermentation	乳酸/乳酸發酵
carbon fixation reactions	固碳反應	catabolism	異化代謝
light reactions	光反應	granum {pl. grana}	葉綠餅
photosynthesis	光合作用	chloroplast	葉綠體
photosynthetic pigment	光合色素	chlorophyll	葉綠素
respiration	呼吸作用	aerobic respiration	有氧呼吸
		alcohol/alcohol fermentation	酒精/酒精發酵

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

① _____ transforms _____ into _____.

例句：Anabolism **transforms** big molecules **into** small molecules.

異化代謝是將大分子轉換成小分子。

② The _____ in cells can be divided into _____ and _____.

例句：The metabolism **in cells can be divided into** catabolism **and** anabolism.

細胞內的代謝可分為異化代謝與同化代謝。

③ There is _____, which is the place where _____ takes place.

例句：There is chlorophyll scattered on thylakoid that can absorb solar power, **which is the place where** light reaction **takes place**.

類囊體的膜上分布著葉綠素，可吸收光能，是進行光反應的場所。

- ④ Many _____ factors affect the process of _____, such as _____, _____, and _____.

例句：Many environmental factors affect the process of photosynthesis, such as light, temperature, carbon dioxide, and water.

許多環境因素會影響光合作用的進行，例如：光、溫度、二氧化碳和水等。

- ⑤ _____ usually comes along with _____.

例句：Catabolism that releases energy usually comes along with anabolism that consumes energy.

釋能的異化代謝與耗能的同化代謝常常伴隨發生。

- ⑥ When _____ is being absorbed by cells, it can be divided into _____.

例句：When glucose is being absorbed by cells, it can be divided into carbon dioxide and water.

葡萄糖經細胞吸收後，可藉由異化代謝分解成二氧化碳和水。

- ⑦ When _____, would the cell accelerate the synthesis or the decomposition of _____?

例句：When there are more ATP and less ADP in a cell, would the cell accelerate the synthesis or the decomposition of glycogen?

當細胞內 ATP 多而 ADP 少時，細胞會加速進行肝糖的合成還是分解反應？

- ⑧ _____ is made up of the combination of _____ and _____.

例句：ATP is made up of the combination of adenosine diphosphate and phosphate.

ATP 是由腺苷二磷酸與磷酸根結合所形成。

■ 問題講解 Explanation of Problems

☞ 學習目標 ☞

一、了解細胞行光合作用與呼吸作用的過程與發生的場所。

Understand what metabolism is and its operating mechanism.

二、了解有氧呼吸與發酵作用的過程，並比較其異同。

Understand, compare and contrast the features of aerobic respiration and fermentation.

☞ 例題講解 ☞

例題一

說明：此題目連結 1-1 與 1-2 小節的學習內容，使學生能夠靈活地將所學應用在解題之中。學生需能夠比較與整合(一)葉綠體與粒線體的功能。(二)動植物細胞的異同。(三)光合作用和呼吸作用的過程與發生場所。

Students need to connect the concept from the previous subsection of the important organelles (chloroplast and mitochondrion) of eukaryotes and their functions, the definition of semiautonomous organelles. First, students need to be able to compare and integrate the function of mitochondrion and chloroplast. Second, they need to compare the different and similar structures in plant and animal cells. Third, they need to understand the process and places of respiration and photosynthesis.

(英文) Mitochondrion and chloroplast are both organelles that deal with energy in cells, but with different functions. Which of the following statements is true?

(A) Both are equipped with DNA in order to produce the protein they need.

(B) The decomposition of glucose happens in mitochondrion.

(C) Mitochondrion is able to produce ATP and chloroplast isn't.

(D) Chloroplast exists only in plants and mitochondrion exists only in animals.

(E) The production of ATP happens all on the inner membrane.

(中文) 粒線體與葉綠體都是細胞處理能量的胞器，但兩者的分工不同，下列何者正確？

(A)各自都具有 DNA，以製造本身所需蛋白。

(B)葡萄糖分解在粒線體內進行。

(C)粒線體可產生 ATP 而葉綠體則否。

(D)葉綠體為植物獨有，粒線體為動物獨有。

(E)ATP 的產生都發生在內膜上。

(107 年學測第 9 題)

解題 Solution:

學生需要連結前一小節－真核細胞重要的胞器(葉綠體與粒線體)及其功能、了解半自主胞器的定義、並能夠比較植物細胞與動物細胞，兩種細胞構造上的異同，還要了解細胞行呼吸作用與光合作用的過程與發生的場所。

Students need to connect the concept from the previous subsection of the important organelles (chloroplast and mitochondrion) of eukaryotes and their functions, the definition of semiautonomous organelles, and need to be able to compare the different and similar structures in plant and animal cells. Also, they need to understand the process and places of respiration and photosynthesis.

Teacher: Which two organelles are semiautonomous in eukaryotic cells in eukaryotic cells?

Student: Mitochondrion and chloroplast are.

Teacher: What is the definition of semiautonomous organelle?

Student: There are DNAs in the organelles, which can synthesize part of the protein they need.

Teacher: That's right. So, option (A) is explaining the definition of semiautonomous organelle.

Teacher: Then let's take a look at option (B). "Glycolysis is one of the processes in respiration." Where does it take place during the process of the decomposition of glucoses?

Student: In the cytoplasm!

Teacher: So, the "mitochondrion" in option (B) should be changed into "cytoplasm"

Teacher: Next let's look at option (C). Mitochondrion is able to produce ATP and chloroplast isn't. Do you remember what are the two stages of photosynthesis?

Student: They are light reactions and carbon fixation reactions.

Teacher: The purpose of the carbon fixation reaction is to fix carbon dioxide to synthesize sugars. The assimilation and metabolism process requires energy, so which will provide the energy required for the carbon fixation reaction?

Student: Light reactions.

Teacher: Then let's go back to option (C), does chloroplast produce ATP or not?

Student: Yes, it does.

Teacher: So, option (C) should be change into "both mitochondrion and chloroplast are able to produce ATP."

Teacher: Then let's look at option (D). "Chloroplast exists only in plants and mitochondrion exists only in animals." Does chloroplast exist only in plants? Why?

Student: Yes, because photosynthesis happens only in plants, not in animals.

Teacher: Then does mitochondrion exist only in animals? Why?

Student: No, because respiration happens both in plants and animals. Therefore, mitochondrion exists both in plants and animals.

Teacher: That's right. Next, option (E), "the production of ATP happens on the inner membrane." The concept includes the content in selected biology, we would explain it in the future. However, what is the first step in respiration?

Student: The glucoses in cytoplasm are decomposed into pyruvic acids.

Teacher: Would ATP also be produced during the process?

Student: Yes.

Teacher: Therefore option (E) should be changed into "the production of ATP happens on the inner membrane and in cytoplasm."

老師：同學們記得有哪兩個胞器屬於半自主胞器嗎？

學生：粒線體和葉綠體。

老師：請問半自主胞器是甚麼？

學生：胞器內含有 DNA，能合成自身所需的部分蛋白質。

老師：沒錯因此選項(A)就是在說明半自主胞器的定義。

老師：那麼我們看到選項(B)，分解葡萄糖是呼吸作用的一環，請問同學們糖解作用發生的場所在哪裡呢？

學生：細胞質！

老師：因此選項(B)中的「粒線體」應該改成「細胞質」。

老師：接下來我們看到選項(C)「粒線體可產生 ATP 而葉綠體則否」，同學們記得光合作用分為哪兩個階段嗎？

學生：光反應和固碳反應。

老師：固碳反應的目的是將二氧化碳固定以合成醣類，其同化代謝的過程中需要能量，那麼固碳反應所需的能量由誰來提供呢？

學生：光反應！

老師：那麼我們看回選項(C)，也就是說葉綠體是不是也會產生 ATP 呢？

學生：是。

老師：因此選項(C)應改為「粒線體和葉綠體皆可產生 ATP」。

老師：接著我們看到選項(D)「葉綠體為植物獨有，粒線體為動物獨有」，請問同學們葉綠體是植物獨有的嗎？為什麼？

學生：對，因為只有植物才會行光合作用，而動物不會。

老師：那麼粒線體是動物獨有的嗎？為什麼？

學生：錯，因為無論是植物或是動物都需要行呼吸作用，因此粒線體為植物和動物共有的。

老師：沒錯，接下來選項(E)「ATP 的產生都發生在內膜上」，因為這部分涉及選修生物的內容，因此我們以後會再解釋。但是請問同學們，在呼吸作用的過程中，第一個步驟是甚麼？

學生：細胞質中的葡萄糖分解為丙酮酸。

老師：過程中會不會產生 ATP 呢？

學生：會！

老師：因此這個選項(E)應改為「ATP 的產生發生在內膜上和細胞質內」。

例題二

說明：學生需要了解細胞中能量的轉換，以及了解細胞呼吸作用的過程與其發生的場所，並且能夠比較有氧呼吸與發酵作用的過程的異同。

Students should know the transformation of energy in cells and how and where the respiration process. Also, they should be able to compare the different and similar process between aerobic respiration and fermentation.

(英文) Cells get energy through respiration. Which of the following statements about respiration is correct?

(A) During aerobic respiration, O_2 goes into mitochondria and is involved in the process.

(B) During aerobic respiration, glucoses go into mitochondria and are decomposed into pyruvic acids.

(C) When the ratio of ADP to ATP is too low, the cell accelerates its respiration.

(D) When the skeletal muscle cells are under hypoxia, pyruvic acids go into mitochondria and then be decomposed into ATP.

(E) When yeast cells are under hypoxia, glucoses go into mitochondria and are decomposed into ATP.

(中文) 細胞利用呼吸作用以獲得能量，下列有關呼吸作用的敘述，何者正確？

- (A) 有氧呼吸的過程中， O_2 會進入粒線體參與作用。
- (B) 有氧呼吸的過程中，葡萄糖會進入粒線體，然後被分解為丙酮酸。
- (C) 當細胞內 ADP/ATP 的比值太低時，細胞會加速進行呼吸作用。
- (D) 當骨骼肌細胞缺氧時，丙酮酸會進入粒線體，然後被分解產生 ATP 。
- (E) 當酵母菌在缺氧環境下，葡萄糖會進入粒線體，然後被分解產生 ATP 。

(102 年學測第 10 題)

Teacher: Everyone, what is the formula of respiration?

Student: $\text{Glucose} + O_2 \rightarrow CO_2 + \text{water} + \text{energy}$.

Teacher: Therefore, glucoses are decomposed into pyruvic acids first, and then enter the mitochondria. What else enters the mitochondria into the process as well?

Student: Oxygen.

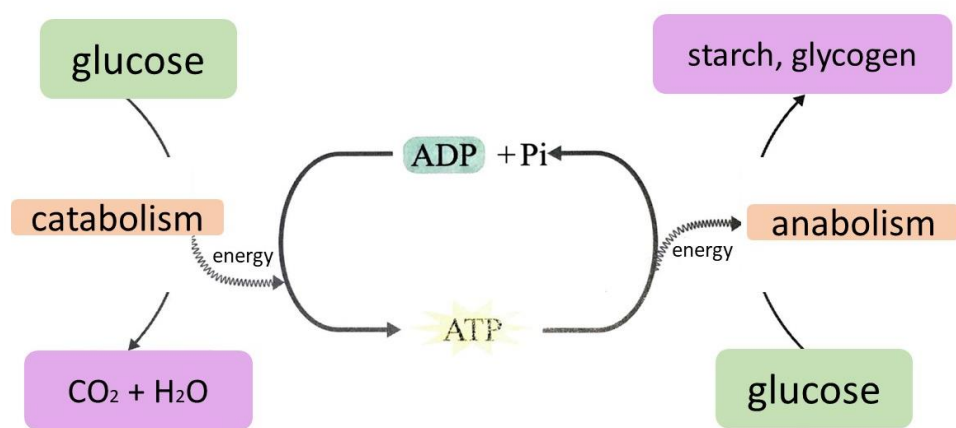
Teacher: Yes, so option (A) is correct.

Teacher: Next, let's look at option (B). "During aerobic respiration, glucoses go into mitochondria and are decomposed into pyruvic acids." Where do glucoses be decomposed into pyruvic acids?

Student: In cytoplasm.

Teacher: That's right. So, option (B) should be changed into "During aerobic respiration, glucoses are decomposed into pyruvic acids in cytoplasm."

Teacher: Option (C), "When the ratio of ADP to ATP is too low, the cell accelerates its respiration." Let's look at the picture below.



Teacher: The ratio of ADP to ATP affects how the cell metabolizes. When the ratio is high, it means that the cell lack of ATP while ADP is sufficient, hence the cell would accelerate dissimilatory metabolism, and generate the production of ATP . When the ratio is low, it means that the ATP is sufficient, hence the cell would consume

more ATP, and accelerate anabolic metabolism.

Teacher: In option (C), what does it mean when the ratio of ADP to ATP is too low?

Student: ATP is more sufficient in the cell than ADP is.

Teacher: Then, would the cell accelerate anabolic metabolism or dissimilatory metabolism?

Student: Anabolic metabolism.

Teacher: The respiration in option (C) is catabolic, which makes more ATP. Hence when the ratio of ADP to ATP is too low, respiration won't be accelerated.

Teacher: In option (D) "When the skeletal muscle cells are under hypoxia, pyruvic acids go into mitochondria and then be decomposed into ATP". Do pyruvic acids go into mitochondria when the skeletal muscle cells are under hypoxia?

Student: No, they don't.

Teacher: Then where do they go?

Student: They stay in the cytoplasm.

Teacher: Also, what do pyruvic acids turn into?

Student: They turn into lactate.

Teacher: What can we also call this respiration that could be done without oxygen?

Student: We can call it fermentation.

Teacher: In option (E), when yeast cells are in anaerobic conditions, glucose enters the mitochondria and is subsequently broken down to produce ATP. What function does the cell perform when yeast cells are anaerobic?

Student: Fermentation.

Teacher: And where does it happen?

Student: It happens in the cytoplasm.

Teacher: What is the process of fermentation?

Student: Glucose breaks down into pyruvic acids, then turn into alcohol and carbon dioxide.

Teacher: What else are produced glucose breaks down into pyruvic acids?

Student: A small amount of ATP.

老師：請問同學們，有氧呼吸的過程的簡式為何？

學生：葡萄糖＋氧氣變成二氧化碳＋水＋能量。

老師：因此葡萄糖分解為丙酮酸，再進入粒線體與甚麼分子作用？最後分解為二氧化碳與水，並產生更多 ATP。

學生：氧氣。

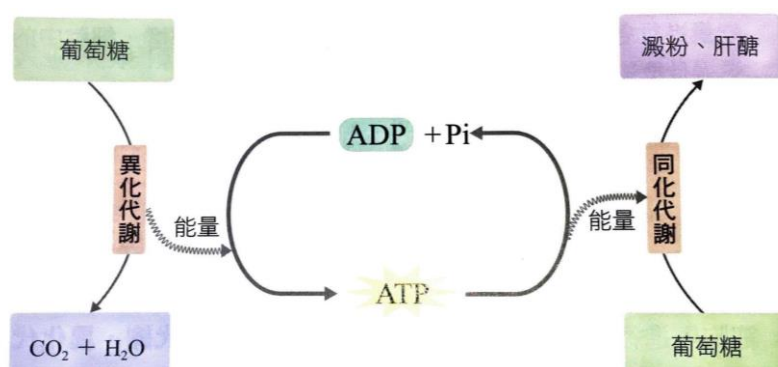
老師：沒錯，所以選項(A)的敘述為正確的。

老師：接下來，我們看到選項(B)中的敘述「有氧呼吸的過程中，葡萄糖會進入粒線體，然後被分解為丙酮酸」，請問葡萄糖分解為丙酮酸發生在細胞的何處？

學生：細胞質內。

老師：沒錯，所以選項(B)的敘述應改為「有氧呼吸的過程中，葡萄糖會在細胞質中被分解為丙酮酸」

老師：選項(C)「當細胞內 ADP/ATP 的比值太低時，細胞會加速進行呼吸作用」，讓我們看到下面這張示意圖。



老師： ADP/ATP 的比值會影響細胞新陳代謝方向。首先當比值高時：代表細胞缺乏 ATP，而 ADP 相對充足，此時會加速異化代謝，促進細胞生成 ATP。當比值低時：代表細胞 ATP 充足，此時會促進細胞消耗 ATP，加速同化代謝。

老師：因此我們看到選項(C)中的敘述為「當細胞內 ADP/ATP 的比值太低時」，代表什麼？

學生：細胞中的 ATP 比 ADP 充足。

老師：那麼當 ATP 較多時，細胞應該會加速進行同化代謝還是異化代謝？

學生：同化代謝。

老師：選項(C)中的呼吸作用是異化代謝，會產生更多 ATP，因此當細胞內 ADP/ATP 的比值太低時，「不會」加速進行呼吸作用。

老師：選項(D)中「當骨骼肌細胞缺氧時，丙酮酸會進入粒線體，然後被分解產生 ATP」，請問當骨骼肌細胞缺氧時，丙酮酸還會進入粒線體嗎？

學生：不會。

老師：那它會跑到細胞的哪裡呢？

學生：留在細胞質內。

老師：並且丙酮酸會轉變為甚麼產物？

學生：乳酸。

老師：這一連串不需要氧氣參與的呼吸作用又稱為什麼作用？



學生：發酵作用。

老師：選項(E)中「當酵母菌在缺氧環境下，葡萄糖會進入粒線體，然後被分解產生 ATP」，請問當酵母菌缺氧時，細胞會行什麼作用呢？

學生：發酵作用。

老師：那發酵作用的地點在哪裡？

學生：細胞質內。

老師：發酵作用的過程是什麼？

學生：葡萄糖會先分解丙酮酸，再轉變為酒精和二氧化碳。

老師：在葡萄糖分解為丙酮酸的這個過程中，還會產生什麼呢？

學生：少量的 ATP。

1-3 細胞週期與細胞分裂

Cell Cycle and Cell Division

■ 前言 Introduction

根據細胞學說的內容我們知道：細胞都是源自細胞分裂所形成的，也就是說生命必須依賴「細胞分裂」才得以延續。首先我們要瞭解何謂「細胞週期」，細胞週期是指細胞由母細胞分裂形成後，經生長再到分裂為兩個新細胞的整個過程，包括生長期間的「間期」與「細胞分裂期」，真核細胞的細胞分裂包括「細胞核分裂」和「細胞質分裂」兩個階段，而細胞核分裂可分為「有絲分裂」和「減數分裂」兩種類型。有絲分裂通常發生於生長旺盛或需要修補的組織，使體細胞增殖；而減數分裂則通常發生於生物進行生殖，產生生殖細胞（配子）時。

細胞分裂進行時，染色體的變化是一大重點，先了解染色體的構造與變化，能有助於探討細胞分裂的過程。在這一章節中，我們不但要了解有絲分裂與減數分裂過程中，細胞核內遺傳物質 DNA 的變化、與細胞分裂有關的構造，還要了解到減數分裂的重要性與必須存在性、有絲分裂與減數分裂的異與同，以及形成人體生殖細胞的重要過程，才能了解細胞的分裂與分化對於多細胞生物體的重要性。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
embryo	胚胎	cell division	細胞分裂
gamete	配子	cell division phase	細胞分裂期
cleavage furrow	分裂溝	cellular differentiation	細胞分化
spindle fiber	紡錘絲	cell cycle	細胞週期

haploid	單倍體染色體	kinetochore	著絲點
somatic cell	體細胞	centromere	中節
homologous chromosome	同源染色體	centriole	中心粒
synapsis	聯會	primary oocyte	初級卵母細胞
egg cell	卵細胞	primary spermatocyte	初級精母細胞
ovary	卵巢	oosperm	受精卵
oogonium	卵原細胞	gonotokont	生殖母細胞
testis	睪丸	germ cell	生殖細胞
stem cell	幹細胞	chromosome	染色體
polar body	極體	daughter cell	子細胞
sister chromatids	姊妹染色分體	secondary oocyte	次級卵母細胞
interphase	間期	secondary spermatocyte	次級精母細胞
meiosis	減數分裂	tetrad	四分體
spermatid/sperm	精細胞/精子	diploid	二倍體染色體
spermatogonia {sing. spermatogonium}	精原細胞	dyad	二分體
cell plate	細胞板	mitosis	有絲分裂

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

① _____ consist of _____ and _____.

例句：Chromosomes **consist of** DNA **and** protein.

染色體由 DNA 和蛋白所組成。

② Half of the _____ come from _____; the other half come from _____.

例句：Half of the chromosomes **come from** the mother; **the other half come from** the father.

一半的染色體來自母方，另一半來自父方。

③ _____, with the assistance of _____.

例句：The sister chromatids separate to both ends, **with the assistance of** spindle fiber.

在紡錘絲的幫助下，姊妹染色體分離至兩端。

④ Each _____ has half as many _____ as _____.

例句：Each gamete **has half as many** chromosomes **as** the original cell.

每個配子的染色體數目只有母細胞的一半。

⑤ _____ can _____ to make sure that _____ maintain consistency.

例句：Gonocytes **can** undergo meiosis that produce sperms or egg cells **to make sure that** the chromosome number **maintain consistency**.

生殖母細胞可再進行減數分裂產生精子或卵細胞，確保染色體數目維持一致。

■ 問題講解 Explanation of Problems

☞ 學習目標 ☞

一、了解真核細胞的細胞週期，包括間期與細胞分裂期。

Understand the cell cycle in eukaryotic cells including interphase and cell division phase.

二、了解有絲分裂的過程，及細胞核內遺傳物質 DNA 的變化。

Understand the process of mitosis, and the change of DNA in the cell nucleus.

三、了解減數分裂在產生生殖細胞（配子）時進行，減數分裂的過程及染色體的動態變化。

Understand that meiosis happens when the cell is producing gamete, the process of meiosis, and the dynamic changes of chromosomes.

☞ 例題講解 ☞

例題一

說明：學生能夠了解植物減數分裂形成孢子的過程。

Students can understand the process of plant's meiosis.

（英文）Which of the following phenomena can be observed during plant's meiosis-II?

- (A) The duplication of centrosome.
- (B) The synapsis of chromosome.
- (C) Dyads array in the middle of the cell.
- (D) The splitting of centromeres.
- (E) The formation of cell plate.

（中文）下列哪些現象可在植物細胞行減數分裂II時觀察到？（應選 3 項）

- (A) 中心體複製。
- (B) 染色體聯會。
- (C) 二分體排列於細胞中央。
- (D) 中節分裂。
- (E) 細胞板形成。

（104 年學測第 36 題）

解題 Solution:

(A)植物細胞一般不具有中心粒。

(B)染色體聯會是發生於減數分裂 I 時。

(C)二分體排列於細胞中央，是減數分裂 II 準備進行第二次分裂的階段。

(D)中節分裂發生於(C)之後，當姊妹染色分體互相分離往兩端移動時，連結二分體的中節會先分裂。

(E)細胞板形成發生於(D)之後，當姊妹染色分體已分離至兩端後，將進行細胞質分裂，植物細胞中央會形成細胞板，形成新的細胞膜及細胞壁。

因此，可觀察到(C)(D)(E)的現象。

(A) Normally there is no centriole in plant cells.

(B) The synapsis of chromosome happens during meiosis-I.

(C) Dyads array in the middle of the cell in the second splitting of meiosis-II.

(D) The splitting of centromeres happens after (C), when sister chromatids separate from each other toward both ends, the centromere connecting the dyads would split.

(E) The formation of cell plate happens after (D), when sister chromatids separate to both ends, the splitting of cytoplasm begins. Cell plate is formed in the middle of the plant cell, with new cell membrane and cell wall.

Therefore, we can observe the phenomena of (C), (D), and (E).

Teacher: Can we observe the duplication of centrosome during plant's meiosis-II?

Student: No, normally there is no centriole in plant cells.

Teacher: Then when does the synapsis of chromosome happen? (option (B))

Student: In meiosis-I.

Teacher: That's right. And when do dyads array in the middle of the cell? (option (C))

Student: In meiosis-II, when the cell is ready for the second splitting.

Teacher: Can we observe the splitting of centromeres during meiosis-II? (option (D))

Student: Yes, we can.

Teacher: When does it happen?

Student: When sister chromatids separate from each other toward both ends, the centromere connecting the dyads would split.

Teacher: What would happen in the plant cell after sister chromatids separate from each other toward both ends? (option (E))

Student: The splitting of cytoplasm.

Teacher: When the plant cell is undergoing the splitting of cytoplasm, what is it that is newly formed in the middle of the plant cell?

Student: The cell plate.

Teacher: Therefore, we can observe the phenomena of (C), (D), and (E) during meiosis-II in plant cells.

老師：請問同學們植物在進行減數分裂 II 時，可以觀察到中心體的複製嗎？(選項 A)

學生：不行，因為植物細胞一般不具有中心粒。

老師：那麼染色體聯會發生在哪一個階段呢？(選項 B)

學生：減數分裂第一階段。

老師：沒錯，二分體排列於細胞中央又是發生在哪一個階段呢？(選項 C)

學生：減數分裂第二階段，細胞準備進行第二次分裂。

老師：那麼在減數分裂 II 時能夠觀察到中節分裂嗎？(選項 D)

學生：可以。

老師：發生在什麼時候？

學生：當姊妹染色分體互相分離，往細胞的兩端移動時，連結二分體的中節會分裂。

老師：在姊妹染色分體分離至細胞的兩端後，接下來植物細胞會進行什麼分裂？(選項 E)

學生：細胞質分裂。

老師：那麼在植物細胞進行細胞質分裂時，植物細胞會在細胞中央形成新的細胞膜和細胞壁，又稱為什麼？

學生：細胞板。

老師：因此，我們可以在植物細胞行減數分裂 II 時觀察到(C)(D)(E)的現象。

例題二

說明：學生能夠了解真核細胞的細胞週期、有絲分裂的過程，以及了解細胞核內染色體套數和遺傳物質 DNA 的動態變化。

Students can understand the process of cell cycle and mitosis in eukaryotic cells, and the dynamic changes of chromosomes in nucleus and genetic materials.

(英文) We can understand the stage or the number of chromosomes in the tissue cells by analyzing the amount of DNA. Researchers dye the diploid with fluorescent material. Because the amount of DNA is proportional to the fluorescence intensity, they can count the cell numbers in different fluorescence intensities.

According to the information mentioned above, which of the following statements about mitosis is correct?

(A) During cell division, a haploid cell has the weakest fluorescence intensity.

(B) When cell division is completed, the fluorescence intensity in a diploid cell is weaker than the intensity during interphase.

(C) When the duplication of DNA is completed, a triploid cell has the strongest fluorescence intensity.

(D) DNA is being duplicated under cell division phase.

(E) The stage goes on to interphase after the duplication of DNA, and the fluorescence intensity is the strongest.

(中文) 分析細胞的 DNA 含量可瞭解組織中細胞的染色體套數或細胞所處之時期。研究者對某一具雙套染色體之生物，將其 DNA 以螢光物質染色，利用 DNA 含量與螢光強度成正比的原理，統計組織中不同螢光強度的細胞個數。

依據上文，下列對於細胞有絲分裂的敘述，何者正確？

(A)細胞分裂過程中，細胞因具單套染色體，螢光強度最弱。

(B)細胞分裂完成時，細胞具雙套染色體，螢光強度較間期時弱。

(C)細胞完成 DNA 複製時，細胞具三套染色體，螢光強度最強。

(D)細胞 DNA 複製時，是處於細胞分裂期。

(E)細胞完成 DNA 複製後進入間期，此時螢光強度最強。

(111 年學測第 19 題)

解題 Solution:

老師先引導同學完成以下表格以後，幫助同學統整「細胞分裂過程中」、「細胞分裂完成時」以及「細胞完成 DNA 複製時」，三個階段的染色體套數、DNA 含量以及相對的螢光強度。

細胞週期	染色體套數	DNA 的量	螢光強度
間期 (DNA 複製)	雙套	4a	強
細胞分裂過程	雙套	4a	強
細胞分裂完成 (形成 2 個子細胞)	雙套	2a	弱

Teacher guides students to finish the following chart, to help them systemize the number of chromosomes, the amount of DNA, and the fluorescence intensity in three stages.

cell cycle	ploidy	amount of DNA	fluorescence intensity
Interphase (Duplication of DNA)	diploid	4a	strong
cell division	diploid	4a	strong
completion of cell division (two daughter cells)	diploid	2a	weak

Teacher: We've known that a cell is diploid before it undergoes mitosis, and we assume that the DNA amount be 2a.

Teacher: Then what is the ploidy level during interphase?

Student: Diploid.

Teacher: How much amount of DNA is there?

Student: 4a.

Teacher: What is the ploidy level during cell division? And how much of DNA is there?

Student: Diploid and 4a.

Teacher: When cell division is completed and two daughter cells are formed, what is the ploidy level during cell division? And how much of DNA is there?

Student: Diploid and 2a.

- Teacher: So the amount of DNA would be $4a$ in interphase, $4a$ during cell division, and $2a$ when cell division is completed. Then what are the fluorescence intensities in these three stages?
- Student: The fluorescence intensity is the strongest in interphase and during cell division, and it is the weakest when cell division is completed.
- Teacher: Let's get back to the options. Option (A) "during cell division, a haploid cell has the weakest fluorescence intensity", what is the ploidy level in this stage? Is the fluorescence intensity the weakest?
- Student: The cell is diploid in this stage, but the amount of DNA is $4a$. Therefore, the fluorescence intensity is the strongest.
- Teacher: Is option (B) "when cell division is completed, the fluorescence intensity in a diploid cell is weaker than the intensity during interphase" correct?
- Student: The cell is diploid in this stage; the amount of DNA is $2a$. The fluorescence intensity when cell division is completed is weaker than the fluorescence intensity during interphase. Therefore, option (B) is correct.
- Teacher: Is option (C) "when the duplication of DNA is completed, a triploid cell has the strongest fluorescence intensity" correct?
- Student: The amount of DNA is $4a$ in this stage, so the fluorescence intensity is the strongest. But the cell is still diploid in this stage.
- Teacher: Is option (D) "DNA is being duplicated under cell division phase" correct?
- Student: No, DNA is being duplicated under interphase.
- Teacher: Is option (E) "the stage goes on to interphase after the duplication of DNA, and the fluorescence intensity is the strongest" correct?
- Student: The cell completes the duplication of DNA during interphase.

老師：我們已知尚未進行有絲分裂的細胞，它的染色體是為雙套，並假設其 DNA 的含量為 $2a$ 。

老師：那麼在細胞週期的間期 DNA 複製的階段，染色體有幾套？

學生：雙套。

老師：DNA 含量為幾 a ？

學生： $4a$ 。

老師：細胞分裂的過程中，染色體套數為何？DNA 的量又為幾 a ？

學生：雙套； $4a$ 。

老師：細胞分裂完成，也就是形成 2 個子細胞的時候，染色體套數和 DNA 的量分別又為幾？

學生：雙套； $2a$ 。

老師：因此 DNA 複製階段的間期、細胞分裂過程、細胞分裂完成三個階段，DNA 的量分別為 $4a$ 、 $4a$ 、 $2a$ ，那麼對應到的螢光強度強弱又為何？

學生：DNA 複製階段的間期和細胞分裂過程的強度為最強，細胞分裂完成的強度為最弱。

老師：接著我們回到選項。選項(A)「細胞分裂過程中，細胞因具單套染色體，螢光強度最弱。」，此階段的細胞應具有幾套染色體？螢光染色強度為最弱的嗎？

學生：此時染色體仍為雙套，但 DNA 量為 $4a$ ，故螢光強度最強。

老師：選項(B)「細胞分裂完成時，細胞具雙套染色體，螢光強度較間期時弱。」是對的嗎？

學生：此時細胞染色體為雙套，DNA 的量為 $2a$ ，而間期時 DNA 的量為 $4a$ ，所以細胞分裂完成時螢光強度較間期時弱，因此這個選項是對的。

老師：選項(C)「細胞完成 DNA 複製時，細胞具三套染色體，螢光強度最強。」是對的嗎？

學生：此時 DNA 量為 $4a$ ，因此螢光強度最強沒錯，但是此時細胞的染色體套數仍為雙套。

老師：選項(D)「細胞 DNA 複製時，是處於細胞分裂期。」對嗎？

學生：錯誤，細胞 DNA 複製時，仍是處於間期。

老師：選項(E)「細胞完成 DNA 複製後進入間期，此時螢光強度最強。」對嗎？

學生：細胞是在間期完成 DNA 的複製。

★主題二 生殖與遺傳★

Reproduction and Genetics

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■ 前言 Introduction

小孩剛出生時，大人們都會開心地討論他的五官看起來像誰誰誰，例如眼睛看起來像爸爸、鼻子長得像媽媽、而臉型像奶奶等等，這種來自同一個家庭的成員彼此會長得很相像的遺傳現象，是所有人都有的日常生活經驗。其實人類早就發現生物親代的一些特徵可以遺傳給子代，但是個體與個體之間又會有些微差異，像是兄弟姊妹間的外觀特徵，彼此有共同之處，但是也有不同的地方，這些相似與相異處，可以透過數學的計算來推算變化的規律，「遺傳學之父」－孟德爾即透過科學的方法設計出實驗，並以數學統計實驗的結果，由此推導出重要的遺傳法則，成為開啟遺傳學研究的先驅。隨著後續生物學家的研究與發現，人類對於遺傳學與分子生物學有了日新月異的了解，生物學家也著手操控或是改造生物的基因，使生物可以產生新的性狀。

2-1 性狀的遺傳

Inheritance of Traits

■ 前言 Introduction

小孩子長得像是父母或是像祖父母，是因為遺傳物質由親代傳給了子代，使子代獲得親代的特徵，這種現象即是「遺傳」。經過許多科學家的努力，我們對於遺傳法則已經有相當程度的理解，其中，奧地利的修道士孟德爾更是開啟遺傳法則研究的先驅。

孟德爾選出了多種特定的「性狀」作為觀察的項目，包括花色、花長出的位置、種子的顏色與形狀、豆莢的顏色與形狀以及植株的高度等，這些性狀都有對比明顯的兩種「表徵」，像是種子的顏色有「綠色」以及「黃色」兩種表徵。他先將選定的豌豆「自花授粉」，若連續數代所產生的子代表徵都相同，就可以確認為性狀穩定的「純品系」，然後再設計並進行各種雜交實驗。每次的雜交實驗都會重複進行多次相同的交配，以此獲得大量的子代，並以數學模式推導出重要的遺傳法則。

近代科學家以孟德爾的遺傳法則為基礎，持續進行其他遺傳研究，發現了許多有別於孟德爾所觀察到的遺傳現象。隨著性染色體的發現，生物學家開始了解有些生物的性別主要由性染色體決定，而性染色體是如何被發現的？若控制性狀的等位基因位於性染色體上，遺傳模式有何不同？本節也將介紹這種與性別有關的遺傳模式，稱為「性聯遺傳」。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
Punnett square	棋盤方格法	trait	表徵
sex-linkage	性聯遺傳	phenotype	表現型
character	性狀	incomplete dominance	不完全顯性遺傳 (中間遺傳)
sex chromosome	性染色體	Mendel's law of inheritance; Mendelism	孟德爾遺傳法則
dominant trait	顯性表徵	multiple alleles	複等位基因遺傳
law of dominance	顯性律	law of segregation	分離律(孟德爾第一遺傳法則)
true-breeding line	純品系	law of independent assortment	獨立分配律(孟德爾第二遺傳法則)
normal distribution	常態分布	polygenic inheritance	多基因遺傳
quantitative genetics	數量遺傳	monohybrid cross	單性狀雜交
test cross	試交	allele	等位基因
artificial cross-pollination	人工異花授粉	homozygote	同型合子
self-pollination	自花授粉(自交)	codominant expression	共顯性遺傳
cross	雜交	reciprocal cross	互交
recessive trait	隱性表徵	gene	基因
heterozygote	異型合子	genotype	基因型

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

① To understand _____, _____ designed _____ to observe _____.

例句：To understand the mode of inheritance of one certain trait, Mendel **designed** a cross-breeding experiment **to observe** one single trait.

為了了解單一性狀的遺傳模式，孟德爾設計針對某一性狀進行觀察的雜交實驗。

② If _____ is _____, then _____ would be _____.

例句：If one of the phenotypic traits **is** dominant and another **is** recessive, **then** the representation of phenotypic traits **would be** dominant.

若決定遺傳表徵的遺傳因子分別為隱性與顯性，則表現顯性表徵。

③ Would _____ affect each other?

例句：Would the two genetic factors that control different hereditary traits **affect each other**?

控制不同遺傳性狀的兩對遺傳因子是否會互相影響呢？

④ The various creatures on earth, including _____, all _____.

例句：The various creatures on earth, including plants, animals, and microorganisms, **all** show hereditary phenomena.

地球上各式各樣的生物，包括植物、動物、微生物等，這些生物都具有遺傳現象。

⑤ Except for _____, _____ is also an example of _____.

例句：Except for human height, human skin color **is also an example of** polygenic inheritance.

除了人類的身高外，人類的膚色亦為多基因遺傳的例子。

■ 問題講解 Explanation of Problems

學習目標

一、了解性聯遺傳的遺傳模式。

Understand the inheritance patterns of sex-linked inheritance

二、了解孟德爾遺傳法則與其他延伸出的遺傳模式。

Understand Mendelian laws of inheritance and other extended patterns of inheritance.

例題講解

例題一

說明：學生能根據圖表與題目提供的線索等資料，對於各選項的敘述作出解釋與推論。

Students can explain, compare, or make inferences through context, data, or charts.

(英文) Picture 11 shows the pedigree charts of two families. The circle represents females, the square represents males. The one with color means that it has the characteristic of a certain trait. Which of the following statements is true about the genetic type? (Choose three answers.)

- (A) I is the dominant sex linkage of the X chromosome.
- (B) I is maybe the recessive sex linkage of the X chromosome.
- (C) II is the recessive sex linkage of the X chromosome.
- (D) II is the dominant sex linkage of the X chromosome.
- (E) Both I and II are both the dominant sex linkage of the X chromosome.

(中文) 圖 11 所示為兩家族之譜系圖，圓形代表女性，方形代表男性，深色代表表現出某性狀的特徵，則下列有關其遺傳型式的敘述，哪些正確？（應選 3 項）

- (A) I 是 X 染色體顯性性聯遺傳。
- (B) I 可能是 X 染色體隱性性聯遺傳。
- (C) II 是 X 染色體隱性性聯遺傳。
- (D) II 是 X 染色體顯性性聯遺傳。
- (E) 兩者都是 X 染色體顯性性聯遺傳。

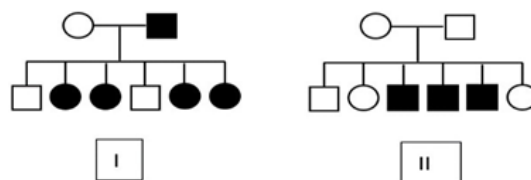


圖 11

(109 年試辦考試選擇題 26)

解題 Solution:

學生必須了解 X 染色體顯性及隱性遺傳的規則，並能夠解析族譜。

Students must understand the rule of dominance-recessive inheritance of X chromosome, and be able to analyze pedigree charts.

Teacher: First, let's take a look at option (A) "I is the dominant sex-linkage of the X chromosome." If we use R to represent a certain trait that exists, and r represents that the trait does not exist, then how is the genetic type of parental generation in I being shown?

Student: $X^rX^r \times X^RY$.

Teacher: Then can the parental generation of $X^rX^r \times X^RY$ give birth to a daughter with the trait and a son without the trait? If possible, what would their genetic type be?

Student: It is possible that the daughter has the trait in X^RX^r , and the son does not have the trait in $X^r \times Y$.

Teacher: Therefore option (A) is correct.

Teacher: Then in option (B), it is assumed that "I is the recessive sex-linkage of the X chromosome." In this way, what is the genetic type of parental generation in I?

Student: $X^rX^r \times X^RY$ or $X^RX^r \times X^RY$.

Teacher: Then can the parents give birth to a daughter with the trait and a son without the trait?

Student: They can give birth to a daughter with the genetic type X^RX^r or X^rX^r , and a son with the genetic type X^RY or X^rY . Then they can give birth to a daughter with the trait and a son without the trait.

Teacher: Therefore statement (B) is correct as well.

Teacher: Then look at option (C) "II is the recessive sex-linkage of the X chromosome." Then what is the genetic type of parental generation in I be?

Student: $X^RX^r \times X^RY$.

Teacher: Then what kinds of genetic types can the parents give birth to? Do they have certain traits?

Student: They may have daughters with X^RX^R or X^RX^r , and sons with X^rY or X^RY . The daughters would not have the traits, and the sons may neither have the traits.

Teacher: So is option (C) correct?

Student: Yes.

Teacher: Then let's look at option (D), "II is the dominant sex-linkage of the X chromosome." What are the genetic types of the parents?

Student: Because their son has the trait, his genetic type must be $X^R Y$. Their allele X^R must come from the mother. However, the mother does not have the trait, the mother's genetic type must $X^r X^r$ be. The statement is wrong.

Teacher: And the last option (E), "Both I and II are both the dominant sex-linkage of the X chromosome." Is it correct?

Student: No, family I may be the dominant or recessive sex linkage of the X chromosome. And family II can only be the recessive sex linkage of the X chromosome.

老師：首先我們看到選項(A)的敘述「I 是 X 染色體顯性性聯遺傳」，如果以 R 代表表示出某性狀，r 代表沒有，請問族譜 I 的親代的基因型要怎麼表示？

學生： $X^r X^r \times X^R Y$ 。

老師：那麼 $X^r X^r \times X^R Y$ 的親代有可能生出「有某性狀」的女兒和「沒有某性狀」的兒子嗎？如果可能的話，他們的基因型又是甚麼？

學生：可能，女兒的基因型為 $X^r X^R$ 皆有某性狀，兒子的基因型為 $X^r Y$ 皆沒有某性狀。

老師：所以選項(A)的敘述為合理的。

老師：那麼選項(B)的假設為「I 是 X 染色體隱性性聯遺傳」，這樣的話，族譜 I 的親代的基因型是甚麼？

學生： $X^R X^R \times X^r Y$ ，或是 $X^R X^r \times X^r Y$ 。

老師：那麼這對父母有可能生出「有某性狀」的女兒和「沒有某性狀」的兒子嗎？如果可能的話，他們的基因型又是甚麼？

學生：他們可能生出基因型為 $X^R X^r$ 或 $X^r X^r$ 的女兒， $X^R Y$ 或 $X^r Y$ 的兒子，因此有可能會生出「有某性狀」的女兒和「沒有某性狀」的兒子。

老師：因此這個選項的敘述合理。

老師：接著我們看到選項(C)「II 是 X 染色體隱性性聯遺傳」，那麼族譜 II 的親代基因型為何？

學生： $X^R X^r \times X^R Y$ 。

老師：那麼這對父母生出的後代基因型可能有哪些？有沒有某個性狀？

學生：基因型 $X^R X^R$ 、 $X^r X^R$ 的女兒，和基因型 $X^r Y$ 、 $X^R Y$ 的兒子。女兒皆沒有某性狀，而兒子可能有也可能沒有某性狀。

老師：所以選項(C)的敘述合理嗎？

學生：合理。

老師：再來我們看到選項(D)「II 是 X 染色體顯性性聯遺傳」，請問這對父母的基因型為何？

學生：因為他們的兒子「具有某性狀」，所以他的基因型為 $X^R Y$ ，等位基因 X^R 一定是來自母親，但是母親並不具有某性狀，所以母親的基因型必為 $X^r X^r$ ，所以這個選項的敘述並不合理。

老師：最後選項(E)「兩者都是 X 染色體顯性性聯遺傳」，對嗎？

學生：錯，族譜 I 可能為 X 染色體顯性或隱性性聯遺傳，而族譜 II 只能為 X 染色體隱性性聯遺傳。

例題二

說明：學生能夠從圖表中讀出資訊，對應至所學的各种遺傳模式並形成解釋。

Students need to know and understand the definition of important scientific terms.

(英文) Pictures A and B are the figures of the relative frequency of the filial generation (F), after the heterozygotes (H) of a certain trait are crossed. According to Mendelism, what are the types of inheritance in Picture A and B belong to?

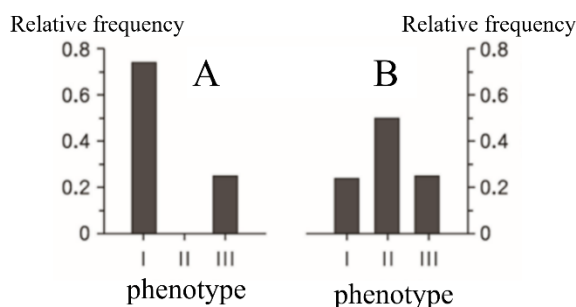
(A) A belongs to the monomeric inheritance; B belongs to the polygenic inheritance.

(B) A belongs to the monomeric inheritance; B belongs to the intermediate inheritance.

(C) A belongs to the intermediate inheritance; B belongs to the polygenic inheritance.

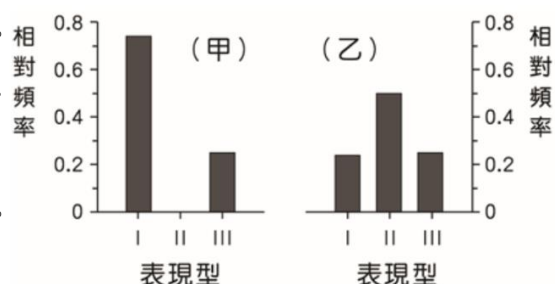
(D) A belongs to the polygenic inheritance; B belongs to the intermediate inheritance.

(E) A belongs to the two-factor inheritance; B belongs to the three-factor inheritance.



(中文) 圖 21 之甲、乙兩圖為某性狀之異型合子 (H) 經雜交 (即 $H \times H$) 試驗後，其子代 (F) 表現型之相對頻率分布圖。若依照孟德爾之遺傳法則推理，則甲、乙圖之遺傳類型依序屬於下列何者？

- (A) 甲為單基因遺傳、乙為多基因遺傳。
 (B) 甲為單基因遺傳、乙為中間型遺傳。
 (C) 甲為中間型遺傳、乙為多基因遺傳。
 (D) 甲為多基因遺傳、乙為中間型遺傳。
 (E) 甲為二基因遺傳、乙為三基因遺傳。



(108 年選擇題 57)

解題 Solution:

學生應能理解圖中相對頻率指的是表現型出現的機率。

Students should understand that relative frequency refers to the probability of the appearance of phenotype.

Teacher: Let's look at the question stem. Mark down the key point. What is the key point?

Student: Pictures A and B are the figures of the relative frequency of the filial generation (F), after the heterozygotes (H) of a certain trait being crossed.

Teacher: Then let's analyze the information in the figure. What are written on the horizontal and vertical axes?

Student: Phenotype and relative frequency.

Teacher: How many kinds of phenotypes are there in Picture A? And how many are there in Picture B?

Student: Two kinds in Picture A and three kinds in Picture B.

Teacher: We can interpret the relative frequency as "the possible appearance of a certain trait". Then let's focus on Picture A. What is the ratio between phenotype I and phenotype II's relative frequency?

Student: 3 to 1.

Teacher: Let's think about it. What would the inheritance type in which the ratio of the filial generation of the heterozygotes being crossed is 3 to 1 be, monomeric, two-factor, polygenic, or intermediate inheritance?

Student: Monomeric inheritance.

Teacher: Why?

Student: According to the Mendelism, there are two phenotypes in a monomeric inheritance progeny of the heterozygotes being crossed, dominant and recessive, and the relative

frequency would be 3 to 1. If it is two-factor or polygenic inheritance, there would be more than two phenotypes; if it is intermediate inheritance, there would be three phenotypes.

Teacher: In Picture B, what is the ratio of filial generation in I, II, and III?

Student: 1:2:1.

Teacher: What inheritance type would be a response to the result?

Student: Intermediate inheritance.

Teacher: Why?

Student: Because only the filial generation of intermediate inheritance has three phenotypes, the ratio of filial generation would most likely be 1:2:1.

老師：首先我們看到題幹敘述，請同學們把題目的重點畫下來，請問重點在哪裡？

學生：「甲、乙兩圖為某性狀之異型合子（H）經雜交，其子代（F）表現型之相對頻率分布圖」。

老師：接著我們來解讀圖中的資訊，同學們可以看到橫軸和縱坐標分別是什麼？

學生：表現型和相對頻率。

老師：甲圖中有幾種表現型？乙圖中的表現型又有幾種？

學生：兩種和三種。

老師：相對頻率我們可以解讀為「某種表現型出現的機率」，那麼請同學們聚焦在甲圖中，請問表現型 I 與 III 的相對頻率大概是幾比幾？

學生：3：1。

老師：同學們可以思考一下，異型合子經過雜交後的子代比例為 3：1 的遺傳類型，可能為單基因遺傳、二基因遺傳、多基因遺傳還是中間型遺傳的哪一種？

學生：單基因遺傳。

老師：為什麼？

學生：依照孟德爾遺傳法則，單基因遺傳的異型合子經過雜交後產生的子代，其表現型有兩種－顯性與隱性，且兩種表現型的相對頻率為 3:1。若為二基因或多基因遺傳的話，表現型不只兩種；中間型遺傳的話，表現型會有三種。

老師：乙圖中，子代表現型的比例 I：II：III 約為多少？

學生：1：2：1。

老師：那麼這種結果可能對應哪一種遺傳類型？

學生：中間型遺傳。

老師：為什麼？

學生：因為只有中間型遺傳的子代的表現型為 3 種，而且子代表現型的比例最接近 1：2：1。

2-2 遺傳物質 Genetic Material

■ 前言 Introduction

孟德爾遺傳法則的發現，讓科學家逐漸理解到性狀是由基因所控制的，但是基因到底是存在於細胞的哪一個部位或構造中呢？隨著 19 世紀末顯微鏡的改進，以及染色技術運用到細胞的研究中，生物學家陸續觀察到真核細胞的有絲分裂及減數分裂現象，並發現了染色體。後來的科學家藉由觀察減數分裂中染色體的分離過程，推論出「遺傳的染色體學說」，認為「基因位於染色體上」，而染色體是具體可觀察的實體構造，從此基因不再只是個推論出來的抽象名詞。

1953 年，華生和克里克提出了 DNA 雙股螺旋結構後，科學家了解基因就是一段 DNA 序列，那麼基因是如何讓生物體表現遺傳現象？在細胞分裂時，又如何維持 DNA 序列不變呢？克里克在 1958 年提出的分子遺傳學中心法則回答了這些問題，即 DNA 可以透過複製，將遺傳訊息傳遞至新的 DNA 上，也可以透過轉錄，將訊息傳遞至 RNA 上，再由 RNA 轉譯出蛋白質，蛋白質的表現又影響了生物性狀。至此，科學家開始可以分子的層次來研究遺傳學。雖然基因決定了性狀，但是許多基因在表現時仍會受到環境因子的影響。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
DNA polymerase	DNA 聚合酶	nitrogenous base	含氮鹼基
RNA polymerase	RNA 聚合酶	gene mutation	基因突變
cytosine	胞嘧啶	base-pair	鹼基對

semiconservative replication	半保留複製	polynucleotide	聚核苷酸鏈
purine	嘌呤	deoxyribose	去氧核糖
pyrimidine	嘧啶	deoxyribonucleic acid	去氧核糖核苷酸
central dogma of molecular biology	分子生物學的中 心法則	adenine	腺嘌呤
guanine	鳥糞嘌呤	thymine	胸腺嘧啶
uracil	尿嘧啶	transcription	轉錄
phosphate group	磷酸基	translation	轉譯
ribosome	核糖體	double helix/double helix model structure	雙股螺旋狀/雙股螺 旋構造模型
ribonucleotide	核糖核苷酸	heritable variation	遺傳變異
nucleic acid	核酸	chromosome theory of inheritance	遺傳的染色體學說

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

① _____ have done research to prove that _____ is _____.

例句：Biologists **have done research to prove that** the material that brings genetic information to chromosomes **is** DNA.

生物學家經過研究證明染色體中帶有遺傳訊息的物質是 DNA。

② _____ is a kind of _____ that is a short form of _____.

例句：DNA **is a kind of** nucleic acid **that is a short form of** deoxyribonucleic acid.

DNA 是去氧核糖核酸的簡稱，為核酸的一種。

③ _____ is a must during _____.

例句：The duplication of DNA **is a must during** the multiplication of cells.

細胞增殖的過程中，必須要進行 DNA 的複製。

④ The reason for _____ is not _____ but _____.

例句：The reason for the variation in hydrangeas color **is not** heritable variation **but** is affected by the environment.

繡球花花色變異的原因並非來自遺傳變異，而是受到環境因子的影響。

⑤ The involvement of _____ is needed in the completion of _____.

例句：The involvement of enzymes **is needed in the completion of** translation.

轉譯的過程需要酵素參與才能完成。

⑥ The _____ happens in _____, while _____ happens in _____.

例句：The transcription in eukaryotes **happens in** the nucleus, **while** the translation **happens in** the cytoplasm.

真核細胞的轉錄在細胞核中進行，而轉譯則發生在細胞質中。

■ 問題講解 Explanation of Problems

☞ 學習目標 ☞

一、了解孟德爾遺傳法則與分子生物學的中心法則。

Understand Mendel's laws of inheritance and the central dogma of molecular biology.

二、了解基因與性狀表現之間的關係。

Understand the relationship between genes and trait performance.

☞ 例題講解 ☞

例題一

說明：以科學史的發展脈絡來串連孟德爾古典遺傳學到現代的分子遺傳學，學生必須了解孟德爾如何推導兩個遺傳法則與分子生物學的中心法則，才能融會貫通，選出正確答案。

(英文) From Mendel's inheritance experiment to genetics nowadays, which are correct among the statements about concepts of genetics and material basis? (Choose two answers.)

(A) One pair of genetic factors in pea genetics equals two genotypes in modern genetics.

(B) The hypothesis of genetic factor is an abstract concept with symbols when describing pea genetics by genetic factor.

(C) The central dogma of molecular biology describes the relationship between traits and genetic factors in Mendel's experiment.

(D) It is highly possible that the genes on the same chromosome would follow Mendel's law of independent assortment.

(E) Mendel's First Law and Second Law can be applied to creatures with DNA and also to viruses.

(中文) 從孟德爾的遺傳實驗中，延續到目前的遺傳學，有關基因的概念及其物質基礎的敘述，下列哪些正確？（應選 2 項）

(A) 描述豌豆遺傳所說的一對遺傳因子等同現代遺傳學的兩個基因型之概念。

(B) 用遺傳因子描述豌豆的遺傳現象時，遺傳因子假說是一種具符號的抽象概念。

(C) 分子生物學的中心法則說明了孟德爾實驗中性狀和遺傳因子之間的關連性。

(D) 位於同一條染色體上的基因，還是有很高的機會遵循孟德爾的獨立分配律。

(E) 孟德爾的第一及第二遺傳法則適用於含 DNA 之生物，也適用於病毒。

(111 年學測第 22 題)

- Teacher: After reading the question stem, let's look at option (A) "One pair of genetic factors in pea genetics equals two genotypes in modern genetics." What do we call the one pair of genetic factors from Mendel nowadays?
- Student: Gene.
- Teacher: So what does the one pair of genetic factors mean in modern genetics?
- Student: One genotype.
- Teacher: Therefore, the answer should be changed to "one genotype".
- Teacher: Then let's look at option (B) "The hypothesis of genotype is an abstract concept with a symbol when describing pea genetics by the genetic factor". Why do we say that the hypothesis of the genetic factor is an abstract concept?
- Student: Back then the scientists didn't have the concept of chromosomes, DNA, and genetics. They only have the theory deduced from Mendel's experiment that "traits are affected by genetic factors". Furthermore, he assumed that dominant genetic factors control dominant traits, and are shown in capital letters; recessive genetic factors control recessive traits and are shown in lower cases.
- Teacher: That's right, so the option is correct! Then let's look at option (C) "The central dogma of molecular biology describes the relationship between traits and genetic factors in Mendel's experiment." Is the statement correct?
- Student: Yes, it is.
- Teacher: Can anyone explain what the central dogma of molecular biology is?
- Student: The dogma refers to DNA being transcribed into RNA, and RNA is translated into protein. The proteins being translated have different functions, then develop into different traits.
- Teacher: That's right! Then how can the dogma explain the relationship between the traits and genetic factors in Mendel's experiment?
- Student: Because the genetic factors from Mendel are equal to genetics nowadays. Gene expression can produce proteins by transcribing and translating, and then affect certain traits of organisms. This is what the central dogma is talking about.
- Teacher: Good! Then let's look at option (D) "It is highly possible that the genes on the same chromosome would follow Mendel's law of independent assortment." Is the statement correct?
- Student: Wrong.
- Teacher: That's right. In the nucleus, what kind of chromosomes would separate from each other and be divided into each gamete when germ cells are producing gametes?

Student: Homologous chromosome and sister chromatids.

Teacher: Therefore the genes on the same chromosome, most of them would go into the same gamete. They do not follow the law of independent assortment from Mendel. What kind of genes would follow the law of independent assortment from Mendel?

Student: The genes that are located on different pairs of chromosomes.

Teacher: Lastly, let's look at option (E) "Mendel's First Law and Second Law can be applied to creatures with DNA and also to viruses." Do viruses or bacteria undergo meiosis?

Student: No, they don't.

Teacher: Mendelism describes what is relevant to meiosis, hence Mendel's First Law and Second Law cannot be applied to bacteria and viruses that are unable to undergo meiosis.

老師：同學們我們看完題目來直接看到(A)選項「描述豌豆遺傳所說的一對遺傳因子等同現代遺傳學的兩個基因型之概念」，請問同學們，孟德爾提出的一對遺傳因子是我們現今所稱的什麼？

學生：基因。

老師：因此題目所指一對遺傳因子應該相當於現代遺傳學的什麼？

學生：一種基因型。

老師：所以說這個選項要把「兩個基因型」改成「一種基因型」。

老師：再來我們看到(B)選項「用遺傳因子描述豌豆的遺傳現象時，遺傳因子假說是一種具符號的抽象概念」，為什麼會說遺傳因子假說是一種具符號的抽象概念？

學生：因為當時的科學家還沒有染色體、DNA 跟基因的概念，只有孟德爾從實驗中推論出來的「性狀是由遺傳因子所決定」理論，並且他假設：顯性遺傳因子控制顯性表徵，用大寫英文字母表示；隱性遺傳因子控制隱性表徵，用小寫英文字母表示。

老師：沒錯，所以這個選項是對的！再來看到選項(C)「分子生物學的中心法則說明了孟德爾實驗中性狀和遺傳因子之間的關連性」，這個敘述對嗎？

學生：對。

老師：同學們可以先解釋分子生物學的中心法則是什麼嗎？

學生：這個法則指的是 DNA 會轉錄為 RNA、RNA 會轉譯為蛋白質，而轉譯出來的蛋白質具有不同的功能，進而展現不同的性狀。

老師：沒錯！那為什麼這個法則可以解釋孟德爾實驗中性狀與遺傳因子之間的關係？

學生：因為孟德爾的遺傳因子就相當於現今所稱的基因，基因表現可藉由轉錄與轉譯

產生蛋白質，進而影響生物體表現特定的表徵，這就是中心法則所說的。

老師：很好！那我們要看到選項(D)「位於同一條染色體上的基因，還是有很高的機會遵循孟德爾的獨立分配律」，這個敘述對嗎？

學生：錯誤。

老師：沒錯，是因為在生殖細胞產生配子時，細胞核內的什麼染色體會彼此分離，並且分配到各個配子中？

學生：同源染色體跟姊妹染色體。

老師：因此位於同一條染色體上的基因，大多都會一起進入相同配子中，並不遵循孟德爾的獨立分配律，只有位於哪裡基因才會遵循孟德爾的獨立分配律？

學生：位於不同對的染色體上的基因。

老師：最後我們看到選項(E)「孟德爾的第一及第二遺傳法則適用於含 DNA 之生物，也適用於病毒」，請問同學們病毒或者是細菌會行減數分裂嗎？

學生：不會。

老師：而孟德爾遺傳法則描述的現象等同減數分裂，所以無法進行減數分裂的細菌、病毒，根本不會出現孟德爾遺傳法則。

例題二

說明：學生能夠了解基因與性狀表現的過程與發生的場所。

Students are able to understand the process and place of occurrence related to gene performance.

- (英文) The options below are about the expression of hereditary substances from eukaryotic cells. Which is correct? (Choose two answers.)
- (A) Transcriptions are conducted on ribosomes.
 - (B) Translations are conducted in the cytoplasm.**
 - (C) The process of copying genetic messages from DNA to RNA is called translation.
 - (D) Using DNA polymerase to copy genetic messages from DNA to RNA.
 - (E) When genes manifest, the two strands of DNA first separate, and the nucleotide sequence of one of the strands would be a template to synthesize one strand of RNA.**

(中文) 下列有關真核細胞遺傳物質表現的敘述，哪些正確？(應選 2 項)

(A)轉錄作用在核糖體上進行。

(B)轉譯作用在細胞質內進行。

(C)將 DNA 上的遺傳訊息抄錄至 RNA 上的過程稱為轉譯作用。

(D)利用 DNA 聚合酶，將 DNA 上遺傳訊息抄錄至 RNA 上。

(E)當基因表現時，DNA 的兩股會先分開，僅以其中一股的核苷酸序列為模版，合成一股 RNA。

(103 年學測第 30 題)

Teacher: Which statements about the expression of hereditary substances from eukaryotic cells are correct? First, option (A) "Transcriptions are conducted on ribosomes."

Student: Incorrect. Transcriptions are the process of copying genetic messages of DNA to RNA. Moreover, DNA is stored in the nucleus of a cell. Thus, transcriptions are conducted in the nucleus of a cell.

Teacher: Then, let's talk about option (B). After DNA is transcribed into RNA, where is RNA being translated into protein?

Student: In cytoplasm.

Teacher: So, this option is correct. option (C) "The processes of copying genetic messages on DNA to RNA are called translations." As we just mentioned, what are the processes of copying genetic messages from DNA to RNA called?

Student: Transcriptions.

Teacher: That's right. Let's correct this statement. Then, let's take a look at option (D) "Using DNA polymerase to copy genetic messages from DNA to RNA." Is this correct? If not, what is wrong?

Student: Eukaryotes use a RNA polymerase to transcribe DNA into RNA.

Teacher: Then, what process does DNA polymerase participate in?

Student: The replication of DNA.

Teacher: Great. Last, option (E) "When genes manifest, the two strands of DNA first separate, and use the nucleotides sequence of one of the strands as templates to synthesize one strand of RNA." Is this correct?

Student: Yes.

老師：請問同學們下列有關真核細胞遺傳物質表現的敘述，哪些正確？首先(A)「轉錄作用在核糖體上進行」。

學生：錯誤，轉錄作用為 DNA 的遺傳訊息抄錄至 RNA 的過程，而 DNA 位於細胞核內，因此轉錄作用在細胞核內進行才對。

老師：那麼接著是(B)選項，當 DNA 轉錄為 RNA 後，RNA 轉譯為蛋白質的過程又在哪裡進行？

學生：在細胞質內進行。

老師：所以這個選項正確，選項(C)「將 DNA 上的遺傳訊息抄錄至 RNA 上的過程稱為轉譯作用」，這個我們剛剛提過了，將 DNA 上的遺傳訊息抄錄至 RNA 上的過程稱為？

學生：轉錄作用。

老師：沒錯，同學們要把選項改成正確的，再來我們看到選項(D)「利用 DNA 聚合酶，將 DNA 上遺傳訊息抄錄至 RNA 上」，請問這個敘述正確嗎？如果不對的話，錯在哪？

學生：真核生物是利用 RNA 聚合酶，將 DNA 轉錄為 RNA 的。

老師：那麼 DNA 聚合酶參與的過程是什麼？

學生：DNA 的複製。

老師：很好，最後看到選項(D)「當基因表現時，DNA 的兩股會先分開，僅以其中一股的核苷酸序列為模版，合成一股 RNA」，這個過程正確嗎？

學生：正確。

2-3 遺傳工程及其應用

Genetic Engineering and Its Applications

■ 前言 Introduction

隨著人類對遺傳學與分子生物學日新月異的了解，生物學家開始操控或改造生物的基因，使生物可以產生新的性狀，這些相關的技術稱為遺傳工程（又稱為基因工程），透過遺傳工程改變遺傳物質的生物，稱為基因改造生物（簡稱基改生物），基改生物的範疇從早期主要以醫療用途，發展至現今已廣泛應用到農漁產品的改良、生產藥物與替代能源，隨著生命科技的快速開發與應用，為人類帶來新的省思，其引發的爭議值得我們深思。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
DNA ligase	DNA 連接酶	plasmid	質體
target gene	目標基因	recombinant DNA	重組 DNA
genetically modified organism	基因改造生物（基改生物，GMO）	carrier	載體
transgenic	基因轉殖	genetic engineering	遺傳工程（基因工程）
restriction enzyme	限制酶		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

① _____ functions like _____, which can _____.

例句：The carrier **functions like** a transport vehicle, **which can** carry DNA fragments into the cells.

載體的功能就像運輸工具，能載運 DNA 片段進入細胞。

② _____ have been widely used in _____.

例句：Genetically modified organisms **have been widely used in** agriculture, medical care, energy, etc.

基因改造生物已廣泛的運用到農業、醫療、能源等範圍。

③ From _____ to _____, genetically modified organisms require _____.

例句：**From** field trials **to** planting, **genetically modified organisms require** strict control and safety assessment.

基因改造生物從田間試驗到種植過程，都需嚴謹的管控，進行安全評估。

④ On _____ issues, do humans have the right to _____?

例句：**On** social and ethical **issues, do humans have the right to** transform life?

在社會倫理議題上，人類是否有權改造生命？

⑤ Genetically modified crops may _____, leading to _____.

例句：**Genetically modified crops may** pose a threat to non-target organisms, **leading to** the growth of GM-resistant insects.

基因改造作物可能會對非目標生物造成威脅，導致抗基改作物昆蟲的滋長。

■ 問題講解 Explanation of Problems

☞ 學習目標 ☞

一、了解遺傳工程的技術，包括重組 DNA 的製作、基因轉殖。

Understand the technique of genetic engineering, including the production of recombinant DNA and transgenic.

二、了解基因改造生物的應用範疇。

Understand the application of genetically modified organisms.

☞ 例題講解 ☞

例題一

說明：學生能夠了解遺傳工程的應用，與其他生物技術。

Students can understand the application of genetic engineering and other biological techniques.

(英文) Scientists have obtained a new variety of silkworms with black markings after years of crossbreeding. Which of the following options is similar to the technical principle of black silkworm breeding?

- (A) Insect-resistant corn produced by transgenic technology.
- (B) Replicated animal, Dolly the Sheep.
- (C) Propagating phalaenopsis in tissue culture.
- (D) Mendelian pea trials.**
- (E) Salmon implanted with growth hormone gene.

(中文) 科學家經多年雜交選育獲得了具黑色斑紋的家蠶新品種。下列選項何者與黑色家蠶的培育技術原理相似？

- (A) 以轉殖技術產生的抗蟲玉米。
- (B) 複製動物桃莉羊。
- (C) 以組織培養繁殖蝴蝶蘭。
- (D) 孟德爾豌豆試交實驗。**
- (E) 殖入生長激素基因的鮭魚。

(110 年學測第 47 題)

Teacher: After browsing through the question stem and options, what is the breeding technology principle of black silkworm?

Student: Human breeding and selection.

Teacher: Which of the following options also uses artificial breeding and selection of species?

Student: Option (D) “Mendelian pea trials”.

Teacher: Then let’s look at other options. What is the technique used in option (A) “insect-resistant corn produced by transgenic technology” and option (E) “salmon implanted with growth hormone gene”?

Student: Transgenic or genetic engineering.

Teacher: That’s right. The two statements refer to transferring target genes into the specific organism through genetic engineering.

Teacher: Then how about the technique used in option (B) “Replicate animal, Dolly the Sheep”?

Student: Replicating sheep involves removing the nuclei of mammary gland cells and transplanting them into egg cells from which the nucleus has been removed.

Teacher: And what’s the technique used in option (C)?

Student: Tissue culture is a technique that reproduces through agamogony.

老師：大致上看完題幹與選項以後，請問同學們題幹中「黑色家蠶的培育技術原理」是什麼？

學生：是透過人為進行物種繁殖與挑選。

老師：哪一個選項中也是利用人為進行物種繁殖與挑選？

學生：選項(D)「孟德爾豌豆試交實驗」。

老師：那麼我們接著看其他選項，請問同學們選項(A)「以轉殖技術產生的抗蟲玉米」和選項(E)「殖入生長激素基因的鮭魚」運用到的生物技術是什麼？

學生：遺傳工程的基因轉殖。

老師：沒錯，這兩個選項的敘述都是透過遺傳工程將目標基因轉殖到特定的生物體內。

老師：那麼選項(B)「複製動物桃莉羊」運用到的生物技術是什麼呢？

學生：複製羊是將乳腺細胞的核取出，並移植進入去除細胞核的卵細胞內。

老師：最後選項(C)運用到的生物技術又是什麼？

學生：組織培養是透過無性生殖進行繁殖。

例題二

說明：學生能夠了解重組 DNA 的製作過程及應用。

Students are able to understand the process and application of recombinant DNA.

- (英文) Transgenic is an important biotechnology. Which of the following statements about transgenic is correct?
- (A) It is unlikely to successfully synthesize food with transgenic.
 - (B) Transgenic bacteria refers to the delivery of recombinant DNA into the nucleus of the host bacteria.
 - (C) At present, transgenic research has been able to successfully transfer foreign genes into eukaryotic cells.**
 - (D) At present, insulin-related exogenous genes can be transferred to diabetic patients to help them produce insulin.
 - (E) Recombinant DNA technology needs to cut the carrier DNA with a specific restriction enzyme, and then use other specific restriction enzymes to cut the gene that is ready for transfer. Lastly, the gene would be recombined with DNA ligase.
- (中文) 基因轉殖是一項重要的生物技術，下列有關基因轉殖技術的敘述，何者正確？
- (A) 目前尚無法成功利用基因轉殖生物做成食品。
 - (B) 基因轉殖細菌是將重組的 DNA 送入宿主細菌的細胞核。
 - (C) 目前基因轉殖研究已能成功的將外源基因轉殖入真核細胞中。**
 - (D) 目前已可將胰島素相關外源基因轉殖入糖尿病患者體內，幫助其產生胰島素。
 - (E) 重組 DNA 技術需先以特定限制酶切開載體 DNA，另以其他種特定限制酶切取欲轉殖的基因，再以 DNA 接合酶（連接酶）重組。

(102 年學測第 12 題)

Teacher: Can we now make food transgenic?

Student: Yes, there is now genetically modified food.

Teacher: For example?

Student: Such as soymilk made from genetically modified soybeans or genetically modified canned corn.

Teacher: Therefore option (A) is wrong. We can now make food with transgenic.

- Teacher: In option(B), “transgenic bacteria are the delivery of recombinant DNA into the nucleus of the host bacteria”? What is wrong with this option?
- Student: The recombinant DNA is delivered into the cytoplasm of bacteria. Bacteria are prokaryotes and do not have a nucleus.
- Teacher: That’s right. Therefore, this option is wrong. Please correct it.
- Teacher: In option (C), “at present, transgenic research has been able to successfully transfer foreign genes into eukaryotic cells”? Can anyone give a practical example?
- Student: For example, the transfection of human coagulation factor genes into goats mentioned in the textbook is an example of the transfection of foreign genes into eukaryotic cells.
- Teacher: That’s right. Another example of biologists transfecting growth hormone genes into Atlantic salmon to make salmon grow rapidly is also an example of transgenic foreign genes into eukaryotic cells.
- Teacher: In option (D), can our current medical technology transfer insulin-related exogenous genes into diabetic patients to help them produce insulin?
- Student: No. At present, genetic engineering can only be used in the treatment of diabetes by transfecting human insulin-related exogenous genes into bacteria. And by multiplying bacteria in large numbers, they can produce large amounts of insulin for medical use.
- Teacher: So option (D) needs to be corrected. This kind of technique cannot be operated at present.
- Teacher: Lastly, let’s look at option (E) “Recombinant DNA technology needs to cut the carrier DNA with a specific restriction enzyme, and then use other specific restriction enzymes to cut the gene that is ready for transfer. Lastly, the gene would be recombined with DNA ligase”. Is this statement wrong?
- Student: It uses the same restriction enzyme to cut the vector DNA and cut the gene to be transfected.

老師：請問同學們，我們現在可以利用基因轉殖生物製做成食品嗎？

學生：可以，現在已經有基因改造食品。

老師：舉例來說？

學生：像是基改黃豆製成的豆漿，基因改造的玉米罐頭。

老師：所以選項(A)錯誤，目前已經可以成功利用基因轉殖生物做成食品。

老師：選項(B)「基因轉殖細菌是將重組的 DNA 送入宿主細菌的細胞核」，請問這個選項錯在哪？

學生：是將重組 DNA 送回宿主細菌的細胞質內，細菌是原核生物，不具有細胞核。

老師：沒錯，所以這個選項也是錯誤的，請同學們修正。

老師：選項(C)「目前基因轉殖研究已能成功的將外源基因轉殖入真核細胞中」，同學們可以舉出實際的例子嗎？

學生：像是課本中提到的將人類凝血因子的基因轉殖到山羊體內，就是將外源基因轉殖進入真核細胞的例子。

老師：沒錯，還有像是生物學家將生長激素基因轉殖到大西洋鮭魚身上，使鮭魚生長快速，也是將外源基因轉殖進真核細胞中的例子。

老師：選項(D)我們目前的醫療技術已經可以將胰島素相關外源基因轉殖入糖尿病患者體內，幫助其產生胰島素嗎？

學生：不行，目前遺傳工程在糖尿病的治療方面，只能透過將人類胰島素相關的外源基因轉殖到細菌身上，並透過大量繁殖細菌，使其產生大量胰島素供醫療使用。

老師：所以選項(D)也需要修正，這樣的技術是還無法達成的。

老師：最後我們看到選項(E)「重組 DNA 技術需先以特定限制酶切開載體 DNA，另以其他種特定限制酶切取欲轉殖的基因，再以 DNA 接合酶（連接酶）重組」，請問同學們這段敘述有錯嗎？

學生：是利用同一種的限制酶切開載體 DNA 和切取欲轉殖的基因。



★主題三 演化與多樣的生物★ Evolution and Biodiversity

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■ 前言 Introduction

本章介紹演化觀念的發展。先介紹不同時期科學家的理論，以及各個理論發展的過程。接著介紹支持演化論的證據，來解釋為何演化論被廣泛接受。最後介紹生物的分類系統的演變。

3-1 生物的演化

The Evolution of Life

■ 前言 Introduction

介紹不同時期對於演化觀念的改變，讓學生了解今天演化論如何漸漸被構築起來。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
specimen	標本	variety	形態差異
embryo	胚胎	evidence	證據
develop	發展	creationism	神創論
taxonomy	分類學	offspring	子代
natural selection	天擇說	evolution	演化
fossil	化石	species	物種
common ancestor	共同祖先	use and disuse theory	用進廢退說
artificial selection	人擇	genotype	基因型

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

① _____ change with time.

例句：Species **change with time**.

物種隨著時間變化。

② _____ classify species by _____.

例句：Biologists **classify species by** their characteristics.

生物學家根據特徵對物種進行分類。

③ _____ evolve from _____.

例句：Birds **evolved from** a group of meat-eating dinosaurs called theropods.

鳥類是從一群被稱為獸腳亞目的食肉恐龍進化而來的。

④ _____ pass on _____.

例句：The giraffes with the longest necks **passed on** their genes to their offspring through natural selection.

脖子最長的長頸鹿通過天擇傳遞基因給後代。

⑤ _____ put forward the theory of _____.

例句：Darwin **put forward the theory of** natural selection

達爾文提出了天擇說理論。

⑥ _____ created by _____.

例句：Greek philosophers believed that creatures were **created by** God.

希臘學者相信生物是由神所創造的。

■ 問題講解 Explanation of Problems**🌀 學習目標 🌀**

一、了解達爾文演化論內容、與其他與相關的理論，並且不要互相混淆。

Understand Darwin's theory of evolution and other related theories, don't obfuscate the theories.

二、了解演化的發展史。

Learn about the history of evolution.

例題講解

例題一

說明：學生了解達爾文演化論的內容，並且不要與其他學說混淆。

Students understand the content of Darwin's theory of evolution and don't be confused with other theories.

(英文) Which of the following statements are true about Darwin's theory of evolution? (2 options should be selected)

- (A) Parents' more competitive traits appear more frequently in offspring populations.
- (B) When Darwin proposed the theory of natural selection, he did not refer to Mendel's laws of inheritance.
- (C) Organs that are used more often will be more developed, and this advantage will be passed on to the next generation.
- (D) When the environmental resources are limited, the advantage can be improved and the number of individuals can be increased through mutation.
- (E) Endemic species all evolved from different ancestors in different geographical environments.

(中文) 有關達爾文的演化論，下列哪些敘述正確？（應選 2 項）

- (A) 親代競爭力較強的性狀在後代族群中出現的頻率會提高。
- (B) 達爾文提出天擇說時，未參考孟德爾的遺傳定律。
- (C) 愈常使用的器官會愈發達，且此優勢會遺傳到下一代。
- (D) 當環境資源有限時，可經由突變提高優勢並增加個體數。
- (E) 特有種皆是由不同地理環境的不同始祖演化而來。

(110 年學測第 44 題)

解題 Solution：

根據演化論內容解題，並且對於理論的發展過程、科學家們的理論不要混淆。

Solve the problem according to the content of evolution, and don't confuse the theory development process and the scientists' theories.

Teacher: Both option A and B are correct, so let's check why option C is wrong. This is not Darwin's theory. Do you remember it is whose theory?

Student: This is Lamarck's use and disuse theory!

Teacher: That's right! Then let's look at option D, can creatures control their own mutations?

Student: No!

Teacher: Yes, mutation happens randomly and has nothing to do with environmental resources limitation. As for option E, according to Darwin's theory, all living things have a common ancestor.

Student: Understand!

老師：A、B 都是正確的，那讓我們來看看 C 選項錯在哪裡。這並不是達爾文的理論，還記得是誰的理論嗎？

學生：這是拉馬克的用進廢退說！

老師：沒錯！那我們看 D 選項，生物能控制自身發生突變的時機嗎？

學生：不行！

老師：對，突變是隨機發生的，與環境資源沒有關係。至於 E 選項，根據達爾文的理論，生物皆有共同的祖先。

學生：瞭解！

例題二

說明：了解演化論與天擇說。

Learn about evolution and natural selection.

(英文) Which of the following statements about evolution is correct?

(A) Mutations are often harmful to organisms, so they are not conducive to biological evolution.

(B) Individuals with dominant traits have greater chance of survival.

(C) The large-scale use of antibiotics in humans has led to an increase in drug-resistant bacteria, which is the result of anthropogenic effects.

(D) Lamarck's use and disuse theory is the basis of Darwin's theory of evolution.

(中文) 有關演化的敘述，下列何者正確？

(A) 突變常對生物體有害，故不利於生物演化。

(B) 有優勢表徵的個體，有較多的生存機會。

(C) 人類大量使用抗生素，使得抗藥性的細菌增加，為人擇作用的結果。

(D) 拉馬克用進廢退理論，是達爾文演化論的基礎。

(修改自 106 年指考 14)

Teacher: Let's look at option A first. The first sentence says that "mutations are often harmful to organisms" is correct, but mutations are also the driving force of evolution.

Teacher: And option B is correct.

Teacher: As for option C, artificial selection means that humans select parents according to their own preferences, and select strains that are beneficial to humans. Will people like bacteria that are highly resistant to antibiotics?

Student: No!

Teacher: Should this be natural selection or artificial selection?

Student: Natural selection!

Teacher: Finally, move on to option D, Darwin did not refer to Lamarck's theory.

Student: Teacher, who influenced him?

Teacher: Lyell's *principles of geology*, Malthus's Principle of Population, etc. They have influenced Darwin's theory.

老師：首先看 A 選項，第一句說「突變常對生物體有害」是對的，但突變同時也是演化的原動力。

老師：而 B 選項是正確的。

老師：至於 C 選項，人擇的意思是人類根據自己的喜好挑選親代，而篩選出對人類有利的品系。請問人們會喜歡抗藥性很強的細菌嗎？

學生：不會

老師：那麼這應該屬於天擇還是人擇呢？

學生：天擇！

老師：最後看到 D 選項，達爾文並沒有參考拉馬克的理論唷。

學生：那請問老師，他有參考誰的呀？

老師：萊爾的《地質學原理》、馬爾薩斯的《人口論》等等，都有影響到達爾文的學說。

3-2 演化證據與生物分類

Evidence for Evolution and Taxonomy

■ 前言 Introduction

介紹各種演化證據，例如化石、胚胎學、解剖學等等。這些演化證據可以重建親緣關係，進而畫出演化樹。接著介紹生物分類方式的演變，讓學生們了解分類系統如何從簡單的二分法演變為今日的三域五界系統。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
embryology	胚胎學	Three-domain system	三域系統
anatomy	解剖學	Domain Bacteria	細菌域
taxonomy	分類	Domain Archaea	古菌域
molecular biology	分子生物學	Domain Eukarya	真核生物域
animal kingdom	動物界	plant kingdom	植物界
analogous structure	同功構造	Fungi kingdom	真菌界
homologous structure	同源構造	biogeology	生物地理學
endotherms	內溫動物	evidence of evolution	演化的證據
vestigial structure	痕跡構造	ectotherm	外溫動物
phylogeny	親緣關係	feather	羽毛

phylogenetic reconstruction	親緣關係重建	prokaryotes	原核生物界
phylogenetic tree	親緣關係樹	Protista	原生生物界

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

① _____ be lacking in _____

例句：Viruses **are lacking in** enzymes needed for metabolism, so they cannot synthesize proteins by themselves.

病毒缺乏新陳代謝所需的酶，無法自行合成蛋白質。

② _____ use _____ as a basis for classification.

例句：Linnaeus **used** the morphological characteristics of organisms **as a basis for** classification.

林奈利用生物的形態特徵來作為分類的依據。

③ _____ classify _____ into _____.

例句：Biologists **classified** the three-domain system **into** bacterial, archaeal, and eukaryotic domains.

生物學家將三域生物歸類為細菌域、古菌域及真核生物域。

④ _____ rebuild the relationship between _____.

例句：Scientists **rebuild the relationship between** birds, reptiles and mammals.

科學家重建鳥類、爬蟲類與哺乳類的親緣關係。

■ 問題講解 Explanation of Problems

☞ 學習目標 ☞

一、了解分類學的基本原理。

Understand the basic principles of taxonomy.

二、能判讀親緣關係樹。

Able to read phylogenetic trees.

☞ 例題講解 ☞

例題一

說明：了解分類方式為何演變至此。

Learn how taxonomy has evolved.

(英文) In the systematic classification of Linnaeus and its successors, any species can be uniquely classified into one of the six levels of genus, family, order, class, phylum and kingdom. However, after the 1990s, "domain" was added to "kingdom" and was generally accepted by the biological community. Which of the following is the key to enabling this action?

(A) Discovered DNA-virus.

(B) Discovered RNA-virus.

(C) Discovered viruses with lipid bilayer outer membranes.

(D) Discovered archaea are more similar to eukaryotes than to eubacteria.

(E) Strata where eubacteria are found are older than archaea.

(中文) 林奈及其後繼者的系統分類中，任何一個物種均可唯一地被歸類於屬、科、目、綱、門及界等六個層級之一。然而 1990 年代之後，「域」被外加於「界」之上，並普遍為生物學界所接受。下列何者是促成此一行動之關鍵？

(A)發現 DNA 病毒。

(B)發現 RNA 病毒。

(C)發現具有雙層脂質外膜的病毒。

(D)發現現生古（細）菌較相似於真核生物，而非（真）細菌。

(E)發現（真）細菌存在的地層比古（細）菌更為古老。

(109 年學測第 53 題)

Teacher: Is virus a living thing?

Student: No.

Teacher: That's right, viruses exist between living things and non-living things, so they are not classified with living things! So option A, B and C are here to disturb you!

Option D is correct. At that time, this discovery surprised the scientific community!

Teacher: Let's take a look at option E. Do you still remember what fossils are?

Student: Organisms buried in the ground for years before being discovered (or other similar answers).

Teacher: What kind of parts do you think is easier to keep for a long time? Is it soft meat, or hard bones?

Student: Hard bones.

Teacher: That's right, so do bacteria have bones or other hard parts?

Student: No.

Teacher: Yes, so single-celled organisms such as bacteria or archaea are difficult to leave fossils, and of course there is no way to judge the age by the location of the fossils in the stratum.

老師：同學們，請問病毒是生物嗎？

學生：不是。

老師：沒錯，病毒是介於生物與非生物之間的存在，所以並不會和生物一起分類唷！

ABC 選項是來擾亂你們的！

而 D 選項是正確的，當時這個發現讓科學界非常訝異呢！

老師：再來看看 E 選項，同學們還記得化石是甚麼嗎？

學生：生物體被埋在地底多年後再被發現（或其他相似的答案）。

老師：那同學們覺得怎樣的部位比較容易保存這麼久呢？是柔軟的肉，還是堅硬的骨頭？

學生：堅硬的骨頭。

老師：答對了，那麼細菌有骨頭或其他堅硬的部分嗎？

學生：沒有。

老師：是的，所以細菌或古菌這些單細胞生物不容易留下化石，當然也無法用化石在地層中的位置來判斷年代。

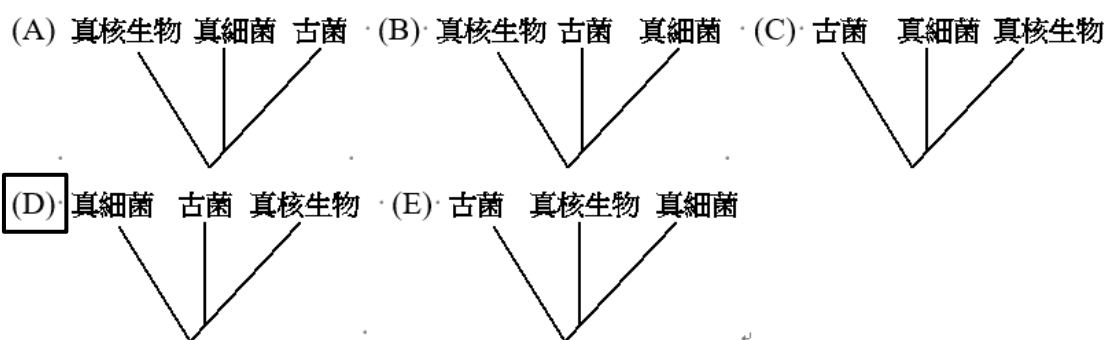
例題二

說明：了解古細菌、真細菌、真核生物三者的親緣關係，並能判讀親緣關係樹。

Understand the relationship between archaea, eubacteria, and eukaryotes, and be able to read the phylogenetic tree.

(英文) Different living species have evolved through divergence, so the divergence sequence between species or groups can be represented by the relationship between trees and branches, which is called the phylogenetic tree. Which of the following phylogenetic tree constitute the correct natural groupings of organisms and the relationships between groups?

(中文) 現生的不同物種都是經過分歧演化而來，因此物種或類群間的分歧順序可以用樹及樹枝的關係來表示，稱之為生命樹。下列構成生物體之自然分群及群間關係的生命樹，何者正確？



(108 年學測第 60 題)

解題 Solution：

在親緣關係樹中，越接近分岔末端的物種代表兩者間親緣關係越近。

In a phylogenetic tree, species that are closer to the bifurcation are more closely related to each other.

Teacher: In the kinship tree, the closer the species to the bifurcation represent the farther or closer the phylogeny between two organisms.

Student: Closer.

Teacher: So which has the closer relationship to eukaryotes? Eubacteria or Archaea?

Student: Archaea.

Teacher: That's right, so in the phylogeny tree, archaea and eukaryotes should branch near the ends, which means that the relationship between archaea and eukaryotes is closer than that of eukaryotes.

Teacher: Therefore, which figure is correct?

Student: D.

老師：同學們，在親緣關係樹中，越接近分岔末端代表兩生物之間的親緣關係越遠還是越近呢？

學生：越近。

老師：那麼真核生物和哪個親緣關係比較近呢？是真細菌還是古細菌？

學生：古細菌。

老師：沒錯，所以在親緣關係樹中，古菌與真核生物應該在比較接近末端的地方分岔，代表相較於真細菌，古菌與真核生物兩者間的親緣關係較接近。

老師：因此，哪一個圖是正確的呢？

學生：D。

例題三

說明：了解親緣關係如何判斷，以及親緣關係樹如何產生。

Understand how to judge phylogeny and how phylogenetic trees are generated.

(英文) Which of the following statements about the phylogenetic tree is correct?

- (A) Homologous structures will develop into organs with different functions, so they cannot be used as a basis for exploring the phylogenetic.
- (B) Dolphins are more closely related to sharks than killer whales.
- (C) The archaeal domain is closer to the eukaryotic domain than the bacterial domain (eubacteria domain).**
- (D) Viruses should be at the base of the tree of life.

(中文) 下列有關生命樹的敘述，何者正確？

- (A) 同源構造會發育成不同功能的器官，因此不能做為探討生命樹的依據。
- (B) 相較於虎鯨，海豚與鯊魚有較近的親緣關係。
- (C) 古菌域較接近真核生物域，而非細菌域（真細菌域）。**
- (D) 病毒應位於生命樹的基部。

(110 年指考第 4 題)

Teacher: Do you remember what homologous structures are?

Student: Bones are similar in basic structure but develop into different forms and functions.

Teacher: Yes, for example, the forelimbs of bats are specialized for wings, and the forelimbs of humans are specialized for grasping fingers. Having homologous organs means that these species likely evolved from a common ancestor.

Student: In this way, you can know which species have closer relationships.

Teacher: Looking at option B, killer whales and dolphins are mammals, while sharks are fish. Who are dolphins closer to?

Student: Killer whales.

Teacher: The statement of option C is correct. Look at option D. Is a virus a living thing?

Student: No!

Teacher: Yes! So the virus will not be drawn in the phylogenetic tree!

老師：大家還記得同源構造是什麼嗎？

學生：骨骼的基本構造相似但發展成不同形態與功能。

老師：是的，例如蝙蝠的前肢特化為翅膀，而人類的前肢則特化為能抓握的五指。具有同源器官代表這些物種很可能是由共同祖先演化而來的。

學生：這樣就能得知那些物種的親緣關係比較近。

老師：看看 B 選項，虎鯨與海豚都是哺乳類，而鯊魚是魚類。海豚究竟與誰比較接近呢？

學生：虎鯨。

老師：B 選項的敘述是正確的。看看 D 選項吧。請問病毒是生物嗎？

學生：不是！

老師：是的！所以病毒不會被畫在親緣關係樹中喔！

國內外參考資源 More to Explore

HHMI Biointeractive	
<p>教學資源網站，可以根據學生教育階段(高中或大學)及主題選擇教學資源(含影片)。</p> <p>https://www.biointeractive.org/</p>	
Rediscovering Biology: Molecular to Global Perspectives	
<p>是一個進階的課程。提供給高中老師最新的生物知識，網站有影片，課程指引，師生互動網頁。</p> <p>https://www.learner.org/classroom-resources/</p>	
Khan Academy	
<p>可汗學院，有分年級的生物教學影片及問題的討論。</p> <p>https://www.khanacademy.org/</p>	
Interactive Simulations, University of Colorado Boulder	
<p>互動式電腦模擬，除了生物，還有其他自然科。</p> <p>https://phet.colorado.edu/</p>	



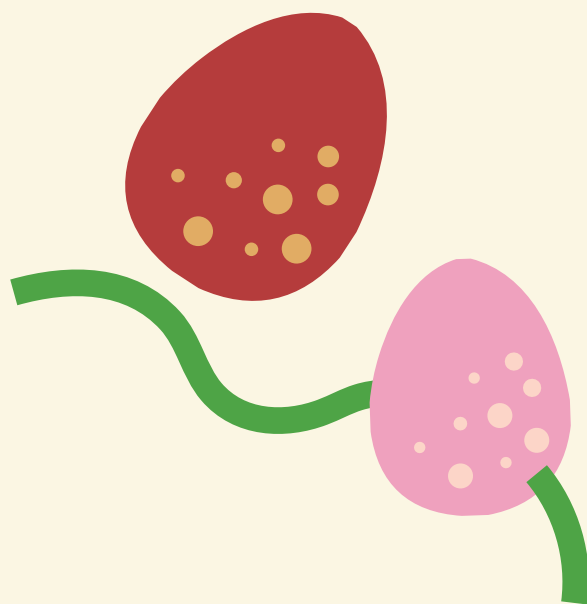
雙語教學資源手冊：生物科 英語授課用語

[十年級]

A Reference Handbook for Senior High School Bilingual Teachers in the Domain of Natural Sciences (Biology): Instructional Language in English

[10th grade]

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