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

〔高中選修(III)〕

國立彰化師範大學雙語教學研究中心 發行

目次 Table of Contents

★ 主題一 動物體的組成與恆定性 ★
The Composition and Homeostasis of the Animal Body

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■ 前言 Introduction

本章節中，希望學生能先瞭解大部分的動物體是由許多細胞聚集而形成的，並建立組成構造的階層由小而大為細胞、組織、器官、器官系統、個體的架構，以及器官由許多不同組織組成，組織又分為四種類型之概念，老師在課程中除了讓學生學習組織的分類與其所具有的特性外，也可以藉由構造去介紹不同組織的功能和分佈，亦可設計表格讓學生比較不同組織間的差異，最後介紹動物體器官彼此協調運作，主要目的為維持體內的恆定狀態，可以透過舉例補充說明恆定的重要性，亦可搭配心智圖幫助學生整理觀念。

語言除了用於溝通，也可作為引導學生問答的媒介，老師可以事先規劃關鍵的句型，幫助學生學習，希望學生透過思考和比較分析來理解組織之構造、特性、功能與差異，並瞭解恆定的重要性，因此課堂中老師可透過連結學生生活實例，闡述組織特性差異與人體的恆定機制。

1-1 動物組織的構造與功能
The Structure and Function of Animal Tissues

■ 前言 Introduction

在此小節，學生初次學習組織的概念，藉由觀察不同組織永久玻片標本實驗活動，學生認識動物體有上皮、結締、肌肉與神經四種組織，構成每種組織的細胞有一定的大小、形狀及連接方式。

語言方面，在授課中，老師需要清楚介紹四種組織的構造與功能，並讓學生認識不同組織在人體內的分佈位置，間接搭配英語句型的使用，讓學生能在課本與範例中相互對應，必要時提供整理表格，讓學生更容易的比較和學習不同組織的特性與異同之處。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
smooth muscle	平滑肌	adipose tissue	脂肪組織
skeletal muscle	骨骼肌	axon	軸突
striated muscle	橫紋肌	epithelial tissue	上皮組織
basement membrane	基底膜	dentrite	樹突
connective tissue	結締組織	neuroglia	神經膠細胞
myocyte	肌細胞	nerve tissue	神經組織
myofiber	肌纖維	neuron	神經元
muscle tissue	肌肉組織	chondrocyte	軟骨細胞

單字	中譯	單字	中譯
extracellular matrix	細胞間質	voluntary muscle	隨意肌
cardiac muscle	心肌	myelin sheath	髓鞘

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

❶ _____ be composed of _____.

例句：Nervous tissue **is composed of** neurons and neuroglial cells.
神經組織是由神經元和神經膠細胞所組成。

❷ _____ protect _____ from _____.

例句：The epithelial tissues lining the stomach wall **protect** the stomach **from** the influence of gastric acid and other enzymes, and aid in the absorption of nutrients.
排列在胃壁上的上皮組織保護胃免受胃酸和其他酶的影響，並有助於吸收營養。

❸ _____ be divided into _____.

例句：Muscle tissue can **be divided into** cardiac muscle, skeletal muscle and smooth muscle.
肌肉組織可分為心肌、骨骼肌和平滑肌。

❹ _____ be characterized by _____.

例句：Connective tissue **is characterized by** a rich extracellular matrix and relatively fewer cells.
結締組織以細胞間質豐富與細胞相對較少為特徵。

❺ _____ be specialized to V/for N.

例句(1)：Nervous tissue **is** highly **specialized to receive** electrical or chemical stimuli and to transmit this information to various parts of the body.

神經組織高度專門於接收電刺激或化學刺激，並將該信息傳遞給身體的各個部位。

例句(2)：Muscle tissue **is specialized for** contraction.

肌肉組織專門於收縮。

❻ _____ be responsible for_____.

例句：Nervous tissue **is responsible for** coordinating and controlling many body activities.

神經組織負責協調和控制許多身體活動。

❼ _____ occur/be found in _____.

例句：Smooth muscle tissue **occurs/is found in** the walls of hollow organs such as the intestines, stomach, and urinary bladder, and around passages such as the respiratory tract and blood vessels.

平滑肌組織存在於腸、胃和膀胱等中空器官的壁上，以及呼吸道和血管等通道周圍。

❽ _____ make up/form/constitute _____.

例句(1)：Stratified squamous epithelium **makes up/forms** the outermost layer of skin on the body.

複層扁平上皮構成身體最外層的皮膚。

例句(2)：Cardiac muscle **makes up/constitutes** the thick middle layer of the heart.

心肌構成心臟的厚中間層。

❾ _____ be arranged in _____.

例句：Epithelial cells may be squamous, cuboidal, or columnar in shape and may **be arranged in** single or multiple layers.

上皮細胞的形狀可以是鱗狀、立方形或柱狀，以及以單層或多層排列。

⑩ In addition to _____, _____ can also _____.

例句：**In addition to** maintaining structure, connective tissue **can also** protect organs.

除了維持結構，結締組織還可以保護器官。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、學生能清楚知道並區分不同組織的特性。

Students can clearly understand and distinguish the characteristics of different tissues.

二、學生能瞭解四種組織分別具有的功能，並能從功能或特性判斷組織類型。

Students can understand the functions of the four types of tissues, and can identify the types of tissues based on their functions or characteristics.

三、學生能夠記得平滑肌、骨骼肌與心肌三者間的差異，並透過結構或形狀去辨別肌肉類型。

Students can remember the differences between smooth muscle, skeletal muscle and cardiac muscle, and distinguish muscle types by their structure or shape.

例題講解

例題一

說明：學生能理解上皮組織和結締組織分別有哪些特性與功能，並能夠分辨出兩者間的差異。

Students should understand the characteristics and functions of epithelial tissue and connective tissue, and be able to distinguish between the two.

Which of the following statements about animal epithelial tissue is/are correct?

(A) It consists of single or multiple layers of tightly packed cells.

(B) It has an abundant intercellular substance whose composition is closely related to the function of the tissue.

(C) It is the main component of sweat glands.

(D) Its function is to tightly connect the different tissues within an organ.

(E) The epithelial tissue of the small intestine has the functions of digestion and absorption.

下列有關動物上皮(皮膜)組織的敘述，哪些正確？

(A) 由單層或多層排列緊密的細胞組成。

(B) 具有豐富的細胞間質，其成分與組織的功能密切相關。

(C) 是構成汗腺的主要成員。

(D) 其功能是將組成器官中的不同組織緊密的連結在一起。

(E) 小腸的上皮組織具有消化、吸收的功能。

（105 指考 30）

Teacher: Which tissue has less intercellular matrix, epithelial tissue or connective tissue?

Student: The epithelial tissue! Epithelial tissue contains less intercellular matrix because the cells are more tightly packed, whereas connective tissue contains more intercellular matrix because the cells are loosely arranged.

Teacher: That's right! What are the functions of epithelial tissue?

Student: To protect, absorb, and secrete.

Teacher: Which other organs or tissues in the body have the function of absorption or secretion?

Student: The small intestine has the function of absorption and digestion, while the glands, such as the thyroid gland and adrenal gland, have the function of secretion, which are all endocrine glands.

Teacher: Very good. In addition, glands also have exocrine functions. Sweat glands are one of them.

Student: I see!

老師： 請問上皮組織和結締組織中，何者的細胞間質較少呢？

學生： 上皮組織！因為上皮組織中細胞排列的較緊密，因此含有較少細胞間質，而結締細胞因為細胞排列疏鬆，而含有豐富的細胞間質。

老師： 沒錯！那上皮組織有哪些功能呢？

學生： 保護、吸收、分泌。

老師： 那請問身體中還有哪些器官或組織具有吸收或分泌的功能？

學生： 小腸具有吸收和消化的功能，而腺體則具有分泌的功能，像是甲狀腺和腎上腺等都是屬於內分泌的腺體。

老師： 非常好，另外腺體也有外分泌的功能，汗腺就是其中一種。

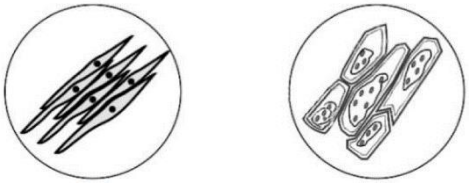
學生： 原來如此！

例題二

說明：學生能夠透過肌肉的形狀和構造辨別出肌肉組織的類型。

Students are able to identify the type of muscle tissue based on the shape and structure of the muscles.

Picture A　　Picture B

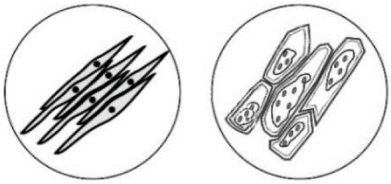


Student Chang used a microscope to observe two kinds of tissue cells during a biology tissue exploration activity and drew diagrams A and B.

Which of the following cells is most likely represented in diagram A?

(A) Nerve cells (B) Skeletal muscle cells **(C) Smooth muscle cells** (D) Columnar cells

甲圖　　乙圖



張生在做有關生物組織探討活動時，利用顯微鏡觀察兩種組織細胞，並繪出下列甲、乙兩圖。

甲圖最有可能是下列何種細胞？

(A) 神經細胞 (B) 骨骼肌細胞 **(C) 平滑肌細胞** (D) 柱狀細胞

（110 指考 44）

Teacher: How can we distinguish the three kinds of muscle tissue?

Student: They can be distinguished based on the shape of the cells, the number of nuclei, and the presence or absence of striations.

Teacher: Great. If the muscle cells in the picture are spindle-shaped, what type of muscle tissue do they belong to?

Student: They belong to smooth muscle because both skeletal muscle cells and cardiomyocytes have striations.

Teacher: That's right. Which kind of muscle tissue is not striated muscle?

Student: The smooth muscle, too. Both skeletal and cardiac muscle are striated muscles.

Teacher: Ok. So what are the differences between skeletal and cardiac muscle?

Student: Skeletal muscle has multiple nuclei and no branching, whereas cardiac muscle has only one nucleus and is branched.

Teacher: Very good. Seems like you have learned how to identify muscle tissue by its shape and structure.

老師： 如何區分三種肌肉組織呢？

學生： 可以依照細胞形狀、細胞核數量和是否有橫紋來區分。

老師： 很棒，假如圖片中的肌肉細胞形狀是紡錘狀，請問他屬於哪一種肌肉類型？

學生： 平滑肌！因為骨骼肌細胞和心肌細胞的形狀都橫紋。

老師： 沒錯，那哪一種肌肉組織不是橫紋肌呢？

學生： 一樣也是平滑肌。骨骼肌和心肌都是橫紋肌。

老師： 好的，那骨骼肌和心肌的差異有哪些？

學生： 骨骼肌具有多個細胞核且不具有分支，然而心肌只有一個細胞核且具有分支。

老師： 非常好，看來你們已經學會如何藉由外形與構造辨別肌肉組織了。

1-2 恆定的生理意義與重要性
Homeostasis Physiological Significance and Importance

■ 前言 Introduction

在此小節，老師可先藉由介紹恆定概念的發展科學史幫助學生建立體內恆定的初步架構，再搭配上一章不同組織分工合作的概念，加深學生對於動物體的不同系統協同運作，主要目的為維持體內的恆定狀態的重點概念。

學生瞭解動物體內恆定的重要性後，可用體溫與血糖恆定為例，融入學生的生活經驗，說明當恆定狀態改變時，體內會如何調節，引導學生思考器官系統間的相互作用，以及維持恆定狀態對人體的重要性，並透過體內恆定調控方式，解釋拮抗與回饋控制的概念。語言方面，老師可以將重點字彙融入句型中，運用設計的句型說明當恆定狀態改變時，體內會如何調節，以及器官系統間的相互作用，透過實際的舉例幫助學生熟悉恆定的概念與調控方式。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
negative feedback control	負回饋控制	positive feedback control	正回饋控制
body temperature	體溫	antagonism	拮抗作用
internal environment	內環境	synergism	協同作用
feedback control	回饋控制	blood sugar/glucose	血糖

單字	中譯	單字	中譯
homeostasis	恆定	enzyme	酵素
hormone	激素	external environment	外環境

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

❶ _____ be controlled by _____.

例句：Blood sugar homeostasis **is controlled by** insulin and glucagon.

= The regulation of blood glucose levels **is controlled by** insulin and glucagon.

血糖恆定由胰島素和升糖素控制。

❷ _____ coordinate with _____.

例句：The nervous system **coordinates with** the endocrine system to maintain homeostasis in human body.

神經系統與內分泌系統協調以維持人體內的恆定。

❸ _____ stimulate _____ to V.

例句：When body temperature rises, the human body **stimulates** the thermoregulatory center **to dilate** blood vessels and lower the body temperature.

當體溫上升時，人體會刺激體溫調節中樞使血管擴張，降低體溫。

❹ _____ lead to _____.

例句：Hyperthermia can **lead to** heat stroke or shock.

過高的體溫會導致中暑或休克。

❺ _____ that _____ be called _____.

例句：Two hormones **that** have opposite effects **are called** antagonistic.

兩個激素具有相反的作用，稱為拮抗作用。

❻ _____ be opposite to _____.

例句：The function of insulin **is opposite to** that of glucagon.

胰島素的功能與升糖素相反。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、學生能熟悉恆定的意義與重要性。

Students become familiar with the meaning and importance of homeostasis.

二、學生能瞭解人體水分、血壓和血糖的恆定，及恆定狀態改變時，體內的調控方式。

Students can understand the homeostasis of water, blood pressure and blood sugar in the human body, and how the body regulates itself when these homeostatic conditions change.

三、學生能理解人體內的恆定是由器官系統共同協調運作維持。

Students can understand that homeostasis in the human body is maintained through the coordinated function of various organ systems.

例題講解

例題一

說明：學生能夠理解恆定的意義，並能辨別有關體內恆定的調控方式。

Students can fully understand the meaning of homeostasis and identify the mechanisms of the regulation related to it within the body.

Which of the following statements about the regulation of homeostasis within the body is correct?

(A) When blood volume decreases, it stimulates the adrenal medulla to secrete hormones.

(B) When blood Ca^{2+} levels are too low, the thyroid gland is stimulated to secrete hormones.

(C) When the body's water level is too low, it stimulates the release of hormones from the posterior pituitary.

(D) When the blood glucose level drops, it stimulates pancreatic cells to secrete hormones.

下列有關體內恆定調控的敘述，何者正確？

(A) 當血量減少時，會刺激腎上腺髓質分泌激素。

(B) 當血液 Ca^{2+} 濃度過低時，會刺激甲狀腺分泌激素。

(C) 當體內水分過少時，會刺激腦垂腺後葉釋放激素。

(D) 當血糖下降時，會刺激胰腺細胞分泌激素。

（107 指考 16）

Teacher: What aspects of homeostasis are present in the human body?

Student: Thermostasis and blood glucose homeostasis.

Teacher: Very good. But there are many other homeostasis in the body, such as: water, blood pressure, and substance concentration.

Student: I see! What are the homeostasis regulation mechanisms related to blood?

Teacher: Homeostasis in the body is mainly regulated by hormones. When the blood volume decreases, the body will stimulate the kidneys to secrete renin, which will increase the blood volume. When the concentration of Ca^{2+} ions in the blood is too low, the human body will stimulate the parathyroid gland to secrete parathyroid hormone to increase the blood calcium concentration. When there is too little water in the body, the human body will stimulate the posterior pituitary to release antidiuretic hormone, reducing the amount of urine excreted.

Student: The regulation of homeostasis in the human body is quite complex! The homeostasis coordination is related to so many different systems.

Teacher: Because maintaining homeostasis is very important for living things! How does the body regulate blood glucose?

Student: When blood glucose drops, it stimulates the pancreas to secrete glucagon, and when blood sugar rises, it stimulates the pancreas to secrete insulin.

Teacher: Very good! you will learn more homeostasis regulation mechanisms in the future.

老師： 人體內的恆定有哪些？

學生： 體溫恆定、血糖恆定。

老師： 很好。不過體內還有許多其他的恆定，比如：水分、血壓與物質濃度。

學生： 原來如此！那與血液相關的恆定調控方式有哪些？

老師： 體內恆定主要受到激素的調控。當血量減少時，體內就會刺激腎臟分泌腎素，使血量增加。而當血液中的 Ca^{2+}離子濃度過低時，人體會刺激副甲狀腺分泌副甲狀腺素，提升血鈣濃度。當體內水分過少時，人體會刺激腦垂腺後葉釋放抗利尿激素，減少尿液的排出量。

學生： 人體恆定的調控方式好複雜喔！人體的恆定協調與許多不同的系統有關。

老師： 因為對於生物來說，維持恆定是很重要的！那人體如何調控血糖恆定呢？

學生： 血糖下降時，會刺激胰臟分泌升糖素，而當血糖上升時，則會刺激胰臟分泌胰島素。

老師： 非常好！以後你們會學習到更多恆定的調控方式。

例題二

說明：學生能夠瞭解拮抗作用的意義，並運用拮抗的概念判斷激素間的關係。

Students can understand the significance of antagonism and use the concept of antagonism to determine the relationships between hormones.

Which of the following group(s) of hormones is mutually antagonistic?

(A) Growth hormone and thyroxine.

(B) Insulin and adrenaline.

(C) Testosterone and estrogen.

(D) Glucocorticoid and mineralocorticoid.

下列哪一組激素具有互相拮抗的關係？

(A) 生長激素與甲狀腺素。

(B) 胰島素與腎上腺素。

(C) 睪固酮與動情素。

(D) 葡萄糖皮質素與礦物性皮質素。

（103 指考 12）

Teacher: What is the concept of hormone antagonism?

Student: Hormone antagonism means that two hormones have opposite effects.

Teacher: Which hormones are antagonistic?

Student: Insulin and glucagon.

Teacher: That's right! What is the feedback control between these two hormones?

Student: It's negative feedback regulation. When the blood glucose concentration is too low, the secretion of insulin can be inhibited through negative feedback regulation.

Teacher: Great! Because adrenaline also has the function of raising blood glucose, insulin and adrenaline also have a mutual antagonistic relationship.

Student: I see. So adrenaline can also speed up the heartbeat and raise blood pressure. It has many different functions.

老師： 激素的拮抗作用是什麼概念？
學生： 激素的拮抗作用是指兩個激素具有相反的作用。
老師： 哪些激素的關係為拮抗作用？
學生： 胰島素和升糖素。
老師： 沒錯！那這兩種激素間的回饋控制是什麼？
學生： 負回饋調控。當血糖濃度過低，可以透過負回饋調控抑制胰島素的分泌。
老師： 很好！因為腎上腺素也具有升高血糖的功能，所以胰島素和腎上腺素也具有互相拮抗的關係。
學生： 原來如此，腎上腺素還可以加快心跳、升高血壓，具有好多不同的功能喔。

★ 主題二 循環與消化 ★
Circulation and Digestion

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■ 前言 Introduction

生物體要維持恆定就需要從環境中取得食物（能量來源）來獲取養分並排除廢物，而食物是大分子物質，細胞無法直接吸收利用，必須進行消化作用將其分解為小分子才可以吸收，養分在體內的運輸需藉助循環系統的協助，循環系統兩大功能：運送養分和排除廢物。

語言部分，第一小節教師可以先從較簡易的定義句型引導學生說出專有名詞的定義，講解到心臟構造時，可以給學生構造圖，讓他們運用句型描述出各構造的相對位置，介紹各構造的功能時也可以代入句型，讓學生用英文說出各構造在人體中負責的功用。在教授第二小節時，教師可以著重在描述消化作用的特性（屬於物理或化學消化），在提到消化系統中的分解、運輸時也可帶入句型，讓學生試著用英文描述。

2-1 人體的循環系統
The Circulatory System of Human Body

■ 前言 Introduction

人體循環系統包括心血管系統和淋巴系統，其負責運輸養分、代謝廢物等各物質，在不同器官系統間為橋樑般的角色，所以與恆定作用相關，在國中學過的知識基礎上，本章節主要敘述心臟如何推動血液循環、心臟的構造與功能間的關係。

語言部分，教師可以先透過句型引導學生分類、定義專有名詞，在提到心臟各構造的位置和功能時，教師可以帶入句型，讓學生用英文描述心臟個構造的相對位置和負責的功能。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
circulatory system	循環系統	tissue fluid	組織液
cardiovascular system	心血管系統	lymph	淋巴
lymphatic system	淋巴系統	Lymph (lymphatic) vessel	淋巴管
blood vessel	血管	lymphoid organ	淋巴器官
blood	血液	lymph circulation	淋巴循環
heart	心臟	aorta	主動脈
left atrium	左心房	left ventricle	左心室
right atrium	右心房	right ventricle	右心室

單字	中譯	單字	中譯
pulmonary artery	肺動脈	pulmonary vein	肺靜脈
superior vena cava	上大靜脈	inferior vena cava	下大靜脈
valve	瓣膜	atrioventricular valve (AV valve)	房室瓣
semilunar valve	半月瓣	tricuspid valve	三尖瓣
mitral valve	二尖瓣	coronary artery	冠狀動脈
coronary sinus	冠狀竇	myocardium; cardiac muscle	心肌
cardiac cycle	心搏週期	diastole	舒張期
capillary	微血管	systole	收縮期
erythrocyte	紅血球	leukocyte	白血球
sinoatrial node (SA node)	節律點（竇房結）	blood plasma	血漿
platelet	血小板	cardiac output (CO)	心輸出量

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

❶ _____ refers to _____

例句：Blood pressure **refers to** the force exerted on the walls of blood vessels when blood flows within them.

血壓是血液在血管中流動時，施予血管壁的壓力。

❷ _____ be divided into _____

例句：The circulatory system **is divided into** the cardiovascular system and the lymphatic system.
循環系統分為心血管系統和淋巴系統。

❸ _____ be in charge of _____

例句：Circulatory system **is in charge of** transporting nutrients and metabolic waste in the human body.
循環系統在人體內負責運輸養分、代謝廢物。

❹ _____ be located at _____

例句：The sinoatrial node **is located at** the base of the superior vena cava.
節律點位於上大靜脈基部。

■ 問題講解 Explanation of Problems

學習目標

在學習完本章節後，學生應習得以下概念：
After completing this section, students should acquire the following concepts:

一、循環系統分為心血管系統和淋巴系統，在人體內負責運輸養分、代謝廢物，且連結各器官系統。
The circulatory system is divided into the cardiovascular system and the lymphatic system. It is in charge of transporting nutrients and metabolic waste, and connecting various organ systems in the human body.

二、組織間液（組織液）是由微血管溢出、富含蛋白質的液體，而且會滲入遍佈全身的微淋管，而進入微淋管的液體才是淋巴。
Tissue fluid is a protein-rich fluid that overflows from the capillaries and leaks into the lymphatic vessels all over the body. The fluid that enters the lymphatic vessels is lymph.

三、藉由解剖豬心來觀察認識心臟各瓣膜的位置，心臟有左、右心室及左、右心房。左、右心房有房室瓣，房室瓣分為三尖瓣和二尖瓣，三尖瓣位於右心房，二尖瓣位於左心房，半月瓣在主動脈和肺動脈。房室瓣和半月瓣能防止血液逆流。

By dissecting a pig's heart, one can observe and understand the positions of the heart's valves. The heart has the left and right ventricles and the left and right atria. The atrioventricular (AV) valves are present in the atria, with the tricuspid valve located in the right atrium and the bicuspid (mitral) valve located in the left atrium. Semilunar valve is located at the aorta and pulmonary artery. Atrioventricular valve and semilunar valve can prevent blood from flowing reversal.

四、右心房的節律點是心搏週期的起源，節律點位於上大靜脈的基部，是特化的心肌，可規律的產生電位變化，刺激心肌收縮，所以心臟的搏動具規律性，稱心搏週期。收縮期：房室瓣關閉，半月瓣打開，將血液泵入主動脈運送至全身；舒張期：房室瓣打開，半月瓣關閉。

The sinoatrial node of the right atrium is the origin of the cardiac cycle. This sinoatrial node is located at the base of the superior vena cava. It is a specialized cardiac muscle that can generate regular electrical potential changes and stimulate the contraction of the myocardium. Thus, the heartbeat occurs rhythmically, forming the cardiac cycle. Systole: the atrioventricular valve closes while the semilunar valve opens, allowing blood to be pumped into the aorta for distribution throughout the body. Diastole: the atrioventricular valve opens while the semilunar valve closes.

五、血壓是血液在血管中流動時，施予血管壁的壓力。正常人血壓收縮壓約 120 mmHg，舒張壓約 80 mmHg。血壓恆定與心輸出量和周邊血管阻力的因素相關，心輸出量是指每分鐘由心臟輸入主動脈的血量，周邊血管阻力是指血液經流血管時所產生的阻力。

Blood pressure refers to the force exerted on the walls of blood vessels when blood flows within them. The systolic pressure of a normal individual is about 120 mmHg, and the diastolic blood pressure is about 80 mmHg. Blood pressure regulation is related to factors like cardiac output and peripheral vascular resistance. Cardiac output refers to the amount of blood pumped by the heart into the aorta per minute, while peripheral vascular resistance refers to the resistance produced by blood as it flows through blood vessels.

例題講解

例題一

說明：學生可以了解節律點在心臟的位置。

Students will know the position of the sinoatrial node in the heart.

To record the electrical impulses of the sinus node in the heart of a lab rat, where should the student place the recording electrode?

(A) cardiac septum

(B) aorta

(C) near the base of the superior vena cava in the right atrium

(D) Near the entrance of the pulmonary artery in the left atrium

某生為了記錄實驗大鼠心臟的節律點電衝動訊號，他應將記錄電極放置於下列哪一個位置？

(A) 心中隔

(B) 主動脈

(C) 右心房近上大靜脈基部

(D) 左心房近肺動脈入口處

（109 年指考補考生物試卷第 14 題）

Teacher: Where is the sinoatrial node located in the heart?

Student: It is located near the base of the superior vena cava in the right atrium.

Teacher: Exactly! What functions does it have?

Student: It can generate regular electrical potential changes and stimulate the contraction of the myocardium.

老師： 節律點位在心臟的哪裡？

學生： 在右心房、靠近上大靜脈基部。

老師： 正確，那麼它有什麼功能？

學生： 它可以規律地產生電位變化，刺激心肌收縮。

例題二

說明：學生可以了解體、肺循環，和心臟結構及其功能。

Help students understand systemic circulation, pulmonary circulation, the cardiac structure and functions.

Which of the following statements is correct?

(A) The tricuspid valve can prevent oxygenated blood from flowing back to the right atrium.

(B) When water is poured into the superior and inferior vena cava, it will flow from the left atrium to the left ventricle.

(C) When water is poured into the pulmonary artery, it will flow from the right atrium to the right ventricle.

(D) The muscular wall thickness of the left ventricle is greater than that of the right ventricle because blood is going to be pumped into the aorta for distribution throughout the body.

下列敘述何者正確？

(A) 三尖瓣膜可防充氧血逆流回右心房。

(B) 將水灌入上下大靜脈，水從左心房流入左心室。

(C) 將水灌入肺動脈，水會從右心房流入右心室。

(D) 因為要將血液打入主動脈送至全身，左心室肌肉壁厚度大於右心室。

（111 學年度分科測驗試題生物考科第 31 題）

Teacher: During the process of pulmonary circulation, oxygenated blood flows back to which part of the heart from the pulmonary vein?

Student: Left atrium.

Teacher: After oxygenated blood flows from the left atrium to the left ventricle, which blood vessel does it pump into?

Student: Aorta. Why is the muscular wall of the left ventricle thicker than that of the right ventricle?

Teacher: Good question. It's because the blood pumped into the aorta by the left ventricle needs to be distributed throughout the body.

老師： 在肺循環過程中，充氧血由肺靜脈流回心臟哪個部位？

學生： 左心房。

老師： 充氧血由左心房流入左心室後，泵入何處血管？

學生： 主動脈。請問為什麼左心室肌肉壁厚於右心室？

老師： 很好的問題。這是因為由左心室泵入主動脈的血液需能送至全身。

2-2 人體的消化系統
The Digestive System of Human Body

■ 前言 Introduction

生物體由多種有機物組成，也稱有機體，生物體要維持基本生存就必須藉由攝食獲取合成有機物的原料，經消化系統消化和吸收其中養分後再經由循環系統運送至身體各處利用。本章節主要敘述消化（物理性和化學性消化）、消化系統的組成、各種食物消化的歷程（澱粉、蛋白質和中性脂）和營養素如何在人體被吸收。

語言部分，在教授物理／化學消化時，教師可以舉多個消化作用並帶入句型，讓學生判斷並用英文說出消化作用是屬於物理或化學消化，如果學生的程度更好，也可以引導學生用英文說出判斷的原因，此外，在提到分解、運輸物質時也可以帶入句型，讓學生試著用英文描述。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
digestion	消化作用	mouth	口腔、口
digestive system	消化系統	pharynx	咽
digestive tract	消化道	esophagus	食道
digestive gland	消化腺	stomach	胃
gland	腺體	small intestine	小腸
gastric gland	胃腺	large intestine	大腸

intestine gland	腸腺	anus	肛門
salivary gland	唾液腺	liver	肝臟
pancreatic juice	胰液	pancreas	胰腺（胰臟）
saliva	唾液	neutral fat	中性脂
gastric juice	胃液	glucose	葡萄糖
intestine juice	腸液	maltose; malt sugar	麥芽糖
bile	膽汁	protein	蛋白質
monoglyceride	單酸甘油脂	amino acid	胺基酸
fatty acid	脂肪酸	starch (asylum)	澱粉
nutrient	營養素	polypeptide	多肽
hydrosoluble	水溶性	liposoluble	脂溶性
hepatic portal vein	肝門靜脈	hepatic vein	肝靜脈
right lymphatic duct	右淋巴總管	vena subclavia	鎖骨下靜脈
lacteal	乳糜管	intestinal villus	腸絨毛
amylase	澱粉酶	pepsin	胃蛋白酶
sphincter	括約肌	cardia	賁門
pylorus	幽門	segmental contraction	分節運動
microvillus	微絨毛	gastrin	胃泌素
enterogastrone	腸抑胃泌素	secretin	胰泌素
cholecystokinin (CCK)	膽囊收縮素	organism	有機體
digestive enzymes	消化酶	duodenum	十二指腸

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

❶ _____ belongs to mechanical/chemical digestion.

例句：The act of salivary amylase breaking starch and glycogen down into maltose **belongs to chemical digestion.**

= Salivary amylase breaks down starch and glycogen into maltose, which is a form of **chemical digestion.**

唾液澱粉酶將澱粉、肝糖分解為麥芽糖，屬於化學消化。

❷ break _____down into_____

例句：The digestive enzymes in the digestive fluid can **break** the food **down into** small molecules that can be absorbed by cells.

消化液的消化酵素作用可以讓食物分解為可讓細胞吸收的小分子。

❸ transport/move_____ from _____ to _____

例句：Primary active transport will **directly move** substances **from** an area of low concentration **to** an area of high concentration.

初級主動運輸會直接將物質由低濃度處運至高濃度處。

❹ _____ be controlled/regulated by _____

例句：Bile secretion **is regulated by** hormones and the nervous system.

膽汁的分泌受激素及神經系統的調控。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、消化是指食物中的大分子分解為小分子後被人體吸收的過程。人體的消化系統包含消化道和消化腺。消化道是指食物在人體內移動的通道，消化腺則是分泌消化液的腺體。物理性消化是藉由咀嚼、攪拌、乳化等使食物變小塊來增加食物與消化液接觸的面積；化學性消化是由消化腺分泌的消化液含有酵素能將小塊的食物分解成細胞可吸收的小分子。

Digestion refers to the process of breaking down large molecules in food into smaller molecules that can be absorbed by the human body. The digestive system of the human body includes the digestive tract and digestive glands. The digestive tract is the passage through which food moves within the body, while the digestive glands are the glands that secrete digestive fluid. Mechanical digestion involves breaking food into smaller pieces through chewing, mixing, and emulsifying to increase the surface area of food in contact with digestive fluids. Chemical digestion is the process by which digestive glands secrete digestive fluids containing enzymes that break down small food particles into absorbable small molecules by cells.

二、不同的酵素需要特定的酸鹼值環境下作用，每種酵素所需的環境不同，所以消化過程是分段進行的，而消化道由括約肌區隔，括約肌分布在管腔壁，在管腔收縮時使其關閉，例如賁門區隔胃和食道、幽門位於胃的下端區隔十二指腸。

Different enzymes require specific pH environments to function. Since each enzyme needs a different environment, the process of digestion is carried out in stages. The digestive tract is separated by sphincter muscles, which are located in the walls of the lumen. The sphincter muscles will close when the lumen contracts. For instance, the cardia separates the stomach and the esophagus, and the pylorus, located at the lower end of the stomach, separates it from the duodenum.

三、消化道的運動方式：

A. 消化道的蠕動：消化道肌肉收縮，使食團得以向前推進，運動方向單一。

B. 小腸的分節運動：小腸肌肉為小段收縮放鬆交替進行，將食糜擠壓分段使食糜與消化液充分混合。

Types of digestive tract movements:

A. Peristalsis of the digestive tract: The muscles of the digestive tract contract, allowing the bolus to move forward in a single direction.

B. Segmental movement of the small intestine: The muscles of the small intestine undergo short contractions and relaxations in succession, squeezing and segmenting the chyme to mix it with digestive fluid thoroughly.

四、消化過程順序為：口腔、胃、十二指腸（小腸前段）、小腸、大腸、肛門。

口腔：牙齒切碎及磨碎食物，舌將食物與唾液攪拌形成食團，是物理消化；唾液有唾液澱粉酶將澱粉、肝糖分解為麥芽糖，是化學消化。口腔和食道不吸收養分。

胃：胃壁肌肉收縮反覆攪拌食團，將食團磨成食糜並且與胃液混合，是物理消化；胃裡的胃液有胃蛋白酶，將蛋白質分解為多肽，是化學消化。胃只能吸收少量的水、無機鹽類、酒精及某些藥物。

十二指腸（小腸前端）：受食糜刺激可刺激膽囊排出膽汁、刺激胰液與小腸液分泌脂質由膽汁進行乳化，乳化是將油脂和水打散成小顆粒而相互融合，是消化作用主要場所，為物理性消化。

小腸：藉由分節運動攪拌混合食糜與消化液，為物理消化；腸內菌及消化酶協助分解食物，為化學消化。小腸絨毛吸收養分與水分，是養分與水分吸收的主要場所。養分再由血管運送至各個細胞。

大腸：接續進行水分吸收，胃消化的食物殘渣與消化道分泌物、脫落的腸道細胞、細菌及少量的水形成糞便。

肛門：糞便排除體外的開口。

The sequence of digestive process: mouth, stomach, duodenum (the first part of small intestine), small intestine, large intestine, anus.

Mouth: The teeth cut and grind the food. The tongue mixes the food with saliva to form bolus, which is a form of mechanical digestion. The salivary amylase in saliva will break down starch and glycogen into maltose, representing (which is a form of) chemical digestion. The oral cavity and esophagus do not absorb nutrients.

Stomach: The muscles of the stomach wall repeatedly contract and mix the bolus, grinding it into chyme and mixing it with gastric juices. It is a form of mechanical digestion. There is pepsin in the stomach's gastric juices, which can break down proteins into peptides. This kind of process is chemical digestion. Stomach can only absorb limited amounts of water, inorganic salts, alcohol, and certain medications

Duodenum (the front part of small intestine): Stimulated by chimy, it will trigger the gallbladder to release bile and stimulate the secretion of pancreatic and intestinal fluids. Lipids are emulsified by bile a process that breaks down fats and water into small particles, allowing them to mix. It is the primary place of digestion and is a form of mechanical digestion.

Small intestine: Segmentation movements mix and blend chimy with digestive juices, which is a form of mechanical digestion. Intestinal bacteria and digestive enzymes help break down food, which is chemical digestion. The villi in the small intestine absorb nutrients and water, serving as the primary site for nutrient and water absorption. The nutrients are then transported by blood vessels to individual cells.

Large intestine: Continuing the process of water absorption. The remaining food residues from stomach digestion, along with secretions from the digestive tract, shed intestinal cells, bacteria, and a small amount of water, form feces.

Anus: The opening through which feces is discharged from the body.

五、大部分消化液的分泌可受神經系統及激素調控，其中唾液的分泌僅受神經系統調控；胃液的分泌受神經系統和激素調控；胰液的分泌受胰泌素、膽囊收縮素（CCK）及神經系統的調控；膽汁的分泌受激素及神經系統的調控。

The secretion of most digestive fluids is controlled by the nervous system and hormones. Saliva secretion is regulated only by the nervous system. Gastric fluid secretion is regulated by both the nervous system and hormones. Pancreatic fluid secretion is controlled by secretin, cholecystokinin (CCK), and the nervous system. Bile secretion is regulated by hormones and the nervous system.

六、小腸有環狀褶皺、腸壁的絨毛及絨毛上皮細胞的微絨毛，三者均可增加小腸內壁用於吸收的表面積。絨毛腔內有微血管網，中央具有一條乳糜管。

The small intestine has circular folds, the villi on the intestinal wall, and microvilli on the surface of villus epithelial cells. All three of these can increase the surface area for the absorption in the inner wall of the small intestine. Within the villi, there is a network of microvessels, and there is a lacteal in the center.

七、物質通過細胞膜的運輸方式：

1. **被動運輸**：不耗能、濃度高至濃度低
   a. 簡單擴散：不需要運輸蛋白。
   b. 促進性擴散：透過運輸蛋白。
   c. 滲透作用：運輸蛋白、通過選擇性通透膜(半透膜) 。
2. **主動運輸**：耗能、運輸蛋白、濃度低至濃度高（初級主動運輸）濃度高至濃度低（次級主動運輸）、在活細胞中進行。
   a. 初級主動運輸：指細胞經由 ATP 提供能量，對抗濃度差，直接將物質由低濃度處運至高濃度處。
   b. 次級主動運輸：能量主要藉由細胞膜兩側的離子濃度差所產生的電化學能提供，如細胞外 Na^+濃度高而細胞內 Na^+濃度低，並不是直接使用 ATP 為能量來源。

Transport mechanisms across the cell membrane:

1. **Passive Transport:** does not require energy, moves from high concentration to low concentration.
   a. Simple Diffusion: does not involve transport of proteins.
   b. Facilitated Diffusion: involves transport of proteins.
   c. Osmosis: involves transport of proteins and passes through selectively permeable membrane (semipermeable membrane).
2. **Active Transport:** requires energy, transports proteins, moves from low to high concentration (primary active transport), or from high to low concentration (secondary active transport), occurs in living cells.
   a. Primary Active Transport: The cell uses energy provided by ATP to move substances directly from a low concentration area to a high concentration area against the concentration gradient.
   b. Secondary Active Transport: The energy derives primarily from the electrochemical gradient created by the ion concentration differences across the cell membrane, such as having high extracellular Na+ and low intracellular Na+; it does not directly use ATP as an energy source.

八、養分吸收的方式為主動運輸、簡單擴散及促進性擴散

1. 進入絨毛上皮細胞：

   (a) 主動運輸：葡萄糖、胺基酸。

   (b) 簡單擴散：水溶性維生素 B、C。

   葡萄糖、胺基酸和水溶性維生素 B、C 進入絨毛上皮細胞後，透過促進性擴散進入絨毛內微血管網。

2. 脂肪酸、單酸甘油脂、膽固醇透過擴散作用進入絨毛上皮細胞，形成乳糜微粒後經胞吐作用進入乳糜管，結合成脂質，才進入淋巴管。

The methods of nutrients absorption include active transport, simple diffusion and facilitated diffusion.

1. Enter the villus epithelial cells:

   (a) Active Transport: glucose, amino acid.

   (b) Simple Diffusion: water-soluble vitamins B and C.

   After glucose, amino acid and water-soluble vitamins B and C enter the villus epithelial cells, the nutrients enter the intervillous microvascular network by facilitated diffusion.

2. Fatty acids, monoglycerides, and cholesterol enter the villus epithelial cells by diffusion, forming chylomicron. After that, these chylomicrons are then exocytosed into lacteals, where they combine to form lipids before entering the lymphatic vessels.

例題講解

例題一

說明：學生能了解胰臟、肝臟、大腸及小腸的功能。

Students will understand the functions of pancreas, liver, large intestine and small intestine.

The organs A, B and C are three organs in the human body related to glucose metabolism. Organ A can produce glucagon. Organ B can absorb glucose. Organ C can convert glucose into polysaccharide for storage. What are the organs corresponding to A, B, and C in order?

(A) pancreas, small intestine, liver

(B) pancreas, large intestine, liver

(C) liver, small intestine, pancreas

(D) pituitary gland, small intestine, liver

人體的甲、乙、丙三種器官與葡萄糖代謝有關，甲能產生升糖素，乙能吸收葡萄糖，丙能將葡萄糖轉化成多醣儲存。試問甲乙丙依序為何？

(A) 胰臟、小腸、肝臟

(B) 胰臟、大腸、肝臟

(C) 肝臟、小腸、胰臟

(D) 腦下垂體、小腸、肝臟

（109 年指考補考生物試卷第 12 題）

Teacher: Which organ will convert glucose into polysaccharides for storage?

Student: Pancreas.

Teacher: Not exactly. It is liver. Pancreas secretes glucagon.

Student: How about the large intestine? Will it absorb glucose?

Teacher: Glucose is mainly absorbed by the small intestine, while the large intestine absorbs the remaining water.

老師： 哪個器官將葡萄糖轉化成多醣儲存呢？

學生： 胰臟。

老師： 不對，是肝臟；胰臟分泌升糖素。

學生： 那大腸會吸收葡萄糖嗎？

老師： 葡萄糖主要在小腸被吸收，大腸則吸收剩餘水分。

例題二

說明：學生能了解營養在人體小腸如何被吸收和運輸。

Students will understand how nutrients are absorbed and transported in the small intestine of the human body.

The small intestine of the human body is the main site for nutrient absorption. Which of the following method(s) of absorption and transport of various nutrients is/are correct?

(A) Lipids and proteins form chylomicrons and exit the villus epithelial cells through exocytosis.

(B) Glucose exits the villus epithelial cells through facilitated diffusion and enters the microvessels in the end.

(C) Amino acids enter the villus epithelial cells from the lumen of the small intestinal through active transport.

(D) Fatty acids enter the villus epithelial cells through facilitated diffusion.

(E) Na+ enters the villus epithelial cells through diffusion.

人體小腸是主要吸收養分的部位。下列各種養分的吸收與運輸方式，哪些正確？

(A) 脂質與蛋白質等組成乳糜微粒，經胞吐作用離開絨毛上皮細胞。

(B) 葡萄糖經由促進性擴散離開絨毛上皮細胞，最後進入微血管。

(C) 胺基酸經由主動運輸由小腸腔進入絨毛上皮細胞中。

(D) 脂肪酸經由促進性擴散進入絨毛上皮細胞中。

(E) Na^+經由擴散作用進入絨毛上皮細胞中。

（109 年指考生物試卷第 24 題）

Teacher: By which type of passive transport do fatty acids enter the villus epithelial cells?

Student: Facilitated diffusion.

Teacher: Incorrect. The answer is simple diffusion. Because the outer layer of the cell membrane is composed of lipids, liposoluble fatty acids can easily pass through the cell wall of the villus epithelial cells. How about Na^+? How does it enter the villus epithelial cells?

Student: Via Active transport.

Teacher: Excellent! Then why do chylomicrons leave the villus epithelial cells through exocytosis?

Student: I don't really know.

Teacher: It's because chylomicrons are formed by the aggregation of fatty acids, monoglycerides, and cholesterol, and are further coated with proteins, so they are relatively large. Thus, they leave the villus epithelial cells through exocytosis.

老師： 脂肪酸透過哪種被動運輸方式進入絨毛上皮細胞中？

學生： 促進性擴散。

老師： 不對，是簡單擴散，因為細胞膜外層是脂質，所以脂溶性的脂肪酸可以很容易的通過絨毛上皮細胞的細胞壁；那麼Na^+透過哪種運輸方式進入絨毛上皮細胞中？

學生： 主動運輸。

老師： 很好！那麼乳糜微粒是因為什麼原因而使用胞吐作用離開絨毛上皮細胞呢？

學生： 不知道。

老師： 因為乳糜微粒由脂肪酸、單酸甘油脂、膽固醇組合成團，外面再被蛋白質包覆而成，體積比較大，所以經胞吐作用離開絨毛上皮細胞。

★ 主題三 呼吸與排泄 ★
Respiration and Excretion

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■ 前言 Introduction

本章以呼吸與排泄為兩大主題，內容包含氣體交換、呼吸運動、排泄、體液恆定等，帶領學生認識人體呼吸系統的構造與功能，呼吸運動的原理、目的、過程與調節機制，瞭解呼吸與體液酸鹼恆定的概念，並引導學生思考氣體與體液在動物體內環境的恆定調節，學生先前已有呼吸與恆定的基本觀念，然而對於呼吸運動的原理和調節方式以及腎臟構造和尿液形成過程等皆未接觸過，因此建議教師在教學時可以搭配圖表和影片，以多模態的方式進行教學，幫助學生理解與建立正確觀念。

3-1 呼吸運動
Breathing movements

■ 前言 Introduction

學生先前已學過細胞呼吸的目的是產生能量，需要氧氣並排出二氧化碳，人體呼吸系統的氣體交換亦是如此，在本小節會深入介紹呼吸運動的原理與調節機制，並說明氣體交換與體液恆定間的關聯，學習重點包含動物的呼吸構造、人體呼吸系統與呼吸運動的原理及其調節方式，建議教師教學時，可以搭配教具模型讓學生實際操作，或播放示範影片，以利學生理解呼氣和吸氣時壓力與體積變化的關係。英文的部分可以先讓學生認識關鍵字，再配合設計句型，協助學生理解本節的知識內容，亦可尋找相關教學影片資源，加深學生的印象，提升學習效率。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
lung	肺	respiratory movement	呼吸運動
volume	體積	inspiration / inhale	吸氣
internal respiration	內呼吸	chest cavity	胸腔
rib	肋骨	peripheral chemoreceptor	周邊化學受器
intercostal muscle	肋間肌	central chemoreceptor	中樞化學受器
thoracic diaphragm	橫膈肌	pressure	壓力
expiration / exhale	呼氣	oxygen	氧氣

單字	中譯	單字	中譯
respiratory system	呼吸系統	external respiration	外呼吸
respiration center	呼吸中樞	carbon dioxide	二氧化碳

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

❶ **_____ while _____.**

例句：The main job of the human respiratory system is to transport oxygen into the body **while** removing carbon dioxide from the body.

人體呼吸系統的主要工作是將氧氣輸送到體內，同時排除體內的二氧化碳。

❷ **When _____, _____ presents _____.**

例句：**When** a human inhales, the chest cavity **presents** negative pressure and inhales air.

人體吸氣時的胸腔是呈現負壓而吸入空氣。

❸ **Regardless of _____, _____ must eventually go through _____.**

例句：**Regardless of** body size, the gas exchange of animals **must eventually go through** diffusion.

不論體型大小，動物最終氣體交換的方式必經過擴散作用。

❹ **_____ occurs when _____ is too _____.**

例句：Low blood pH **occurs when** the body's carbon dioxide concentration **is too** high.

血液 pH 值低會在體內二氧化碳濃度過高時發生。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、瞭解呼吸運動的機制與呼吸調節方式。

Understand the mechanism of breathing movement and breathing regulation.

二、瞭解體內氧氣與二氧化碳的運輸過程。

Understand the transport process of oxygen and carbon dioxide in the body.

❧ 例題講解 ☙

例題一

說明：學生能夠清楚呼吸運動的相關機制。

Students can clearly understand the mechanisms related to breathing movements.

Which of the following statements about breathing is correct?

(A) Breathing mainly relies on the lung muscles to complete.

(B) During inhalation, the chest cavity presents positive pressure and introduces air.

(C) Breathing can assist venous blood return to the chest cavity.

(D) Only the aorta has chemoreceptors that sense oxygen partial pressure.

下列有關呼吸運動的敘述，何者正確？

(A) 主要是依賴肺臟肌肉來完成。

(B) 吸氣時的胸腔是呈現正壓而引入空氣。

(C) 可協助靜脈血液回流到胸腔。

(D) 只有主動脈具有感受氧分壓的化學受器。

（107 指考 12）

Teacher: Why can't the human lungs change their volume independently?

Student: Because the lungs don't have muscles. The human body changes the volume of the chest cavity, which in turn affects the pressure in the chest cavity, causing changes in the volume of the lungs.

Teacher: Great answer. How does the volume and pressure of the chest cavity change when you inhale?

Student: When I inhale, the diaphragm and intercostal muscles contract, causing the chest cavity to expand and pressure to decrease.

Teacher: Therefore, when you inhale, the chest cavity presents a negative pressure and introduces air. In addition, both the aorta and carotid arteries have peripheral chemoreceptors that detect partial pressure of oxygen and regulate respiratory movement.

Student: Why is option C correct?

Teacher: The contraction of the muscles during the breathing movement helps in the return of venous blood to the chest cavity.

Student: I see!

老師： 為何人體的肺臟無法自主改變體積？

學生： 因為肺臟沒有肌肉。人體透過胸腔體積的改變，進而影響胸腔內的壓力，引起肺臟體積變化。

老師： 回答得很好。那吸氣時，胸腔的體積和壓力會如何變化？

學生： 吸氣時，橫膈肌和肋間肌會收縮，造成胸腔的體積變大，壓力變小。

老師： 因此吸氣時，胸腔呈現負壓而引入空氣。另外，主動脈和頸動脈都具有周邊化學受器，他們能偵測氧分壓，調節呼吸運動。

學生： 那 C 選項為何正確？

老師： 呼吸運動時肌肉的收縮，因此能幫助靜脈血回流到胸腔。

學生： 原來如此，我懂了！

例題二

說明：學生能瞭解哺乳類氣體交換與運送的方式。

Students can understand the methods of gas exchange and transport in mammals.

Which of the following statements about gas exchange in mammals is/are correct?

(A) Regardless of body size, the gas exchange of animals must eventually go through diffusion.

(B) Gas can pass directly through the cell membrane without first dissolving in water.

(C) Vertebrates' heme binds only with oxygen for optimal transport efficiency.

(D) Most carbon dioxide can be directly dissolved in plasma for delivery.

(E) A low blood pH occurs when the body's carbon dioxide concentration is excessively high.

對於哺乳類氣體交換的敘述，下列哪些正確？

(A) 不論體型大小，動物最終氣體交換的方式必經過擴散作用。

(B) 氣體可直接通過細胞膜，不需要先溶於水。

(C) 脊椎動物的血紅素只會與氧結合，以達最佳運輸效率。

(D) 多數的二氧化碳可直接溶於血漿進行輸送。

(E) 血液低 pH 值會在體內二氧化碳濃度過高時發生。

（107 指考 35）

Teacher: What is the main mode of gas exchange in animals?

Student: Diffusion.

Teacher: That's right. Gases dissolve in water and pass through cell membranes by diffusion.

Student: Then, in addition to combining with oxygen, what kind of gas will heme combine with?

Teacher: Heme also binds to carbon dioxide and carbon monoxide. After being catalyzed by enzymes in red blood cells, 70% of carbon dioxide will react with water to form carbonic acid and dissociate into bicarbonate and hydrogen ions. Therefore, when the concentration of carbon dioxide is excessively high, the blood pH will drop.

Student: I see!

老師： 動物體內氣體交換的主要方式是什麼？

學生： 擴散作用。

老師： 沒錯。氣體溶於水後藉由擴散作用通過細胞膜。

學生： 那請問血紅素除了與氧氣結合外，還會與哪種氣體結合？

老師： 血紅素還會與二氧化碳和一氧化碳結合喔。70%的二氧化碳在紅血球內經酵素的催化後，會與水作用形成碳酸並解離成碳酸氫根和氫離子，因此當二氧化碳的濃度過高時，會造成血液 pH 值下降。

學生： 瞭解了！

3-2 排泄
Excretion

■ 前言 Introduction

本小節的重點包含有含氮廢物的種類與差異、人體的排泄系統構造、尿液的組成和形成，以及體液恆定。本小節的內容較複雜，各概念間的關聯明確，建議教師可以先介紹體液分類和腎臟構造與功能的基礎概念，在說明腎臟如何調節體液酸鹼值恆定的整合概念，於含氮廢物分類與排泄構造的教學可採圖表呈現，幫助學生加深印象，而尿液形成機制和體液恆定，則可透過階層圖或心智圖協助學生整理複雜內容，釐清概念。

英文的部分多數構造的單字對學生來說較陌生，建議可以製作填圖或以關鍵字的方式學習，讓學生逐漸熟悉，而尿液形成的三大作用多由動詞延伸，因此學生認得動詞，可以有更佳的學習效果。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
Bowman's capsule	鮑氏囊	extracellular fluid	細胞外液
urinary bladder	膀胱	efferent arteriole	出球小動脈
excretion	排泄作用	renal corpuscle	腎小體
secretion	分泌作用	renal tubule	腎小管
metabolic waste	代謝廢物	kidney	腎臟
urethra	尿道	nephron	腎元

單字	中譯	單字	中譯
filtration	過濾作用	ureter	輸尿管
nitrogenous waste	含氮廢物	afferent arteriole	入球小動脈
Henle's loop	亨耳環管	reabsorption	再吸收
proximal convoluted tubule	近曲小管	renal glomerulus	腎絲球
intracellular fluid	細胞內液	distal convoluted tubule	遠曲小管

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

❶ Up to _____.

例句：Under normal conditions, **up to** 180 grams of glucose per day is filtered by the glomerulus and virtually all of it is subsequently reabsorbed in the proximal convoluted tubule.
在正常情況下，絲球體每天過濾高達 180 克的葡萄糖，並且幾乎所有葡萄糖隨後都在近曲小管中被再吸收。

❷ _____, while _____.

例句：Reabsorption is the return of substances to the capillaries, **while** secretion is the secretion of substances into the renal tubules.
再吸收是物質回到微血管，然而分泌作用是物質分泌到腎小管內。

❸ Both _____ and _____.

例句：Both sodium and potassium ions undergo filtration and reabsorption in the human kidney.
在人體腎臟中鈉離子和鉀離子都歷經過濾和再吸收過程。

❹ When _____, it means that _____.

例句：**When** glucose appears in the glomerular filtrate, **it means that** it has been filtered by Bowman's capsule.
當腎絲球濾液中出現葡萄糖，表示其有被鮑氏囊過濾。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、瞭解腎臟構造的分佈與功能，及尿液形成有關的三大作用的意義。
Understand the distribution and functions of the kidney structures, and the significance of the three major functions related to the formation of urine.

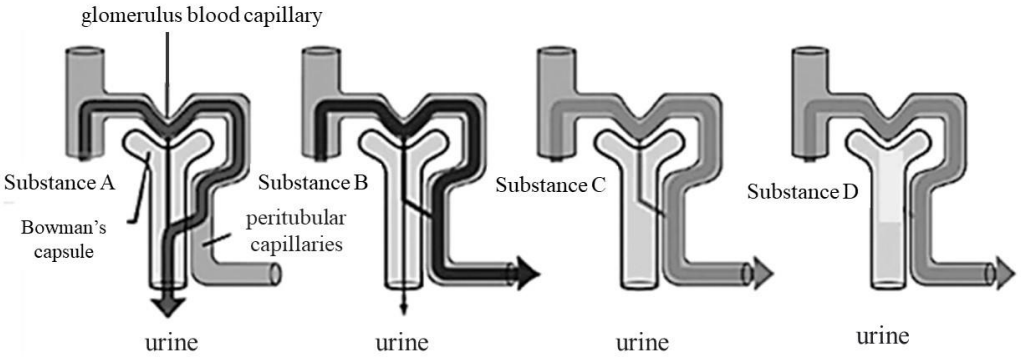
二、認識體內體液恆定的調節機制與激素的功能。
Understand the regulation mechanisms of body fluid homeostasis and the functions of hormones.

❧ 例題講解 ☙

例題一

說明：學生能瞭解過濾作用、再吸收、分泌作用的意義，並能透過例圖判斷出物質移動方向。
Students can understand the significance of filtration, reabsorption, and secretion, and can determine the direction of substance movement through diagrams.

The kidney is the excretory organ of the human body. Blood from the renal artery enters the capillaries of the renal glomerulus from the afferent arteriole, and small molecules in the blood can enter the Bowman's capsule of the renal tubule through filtration to form a filtrate. The useful substances in the filtrate will be reabsorbed back into the body and enter the capillaries surrounding the renal tubules. Excessive or harmful substances in the blood will be secreted into the filtrate by the renal tubules, and finally excreted as urine (as shown in the figure).



According to the figure, which of the following statements about substances A-D is/are correct?

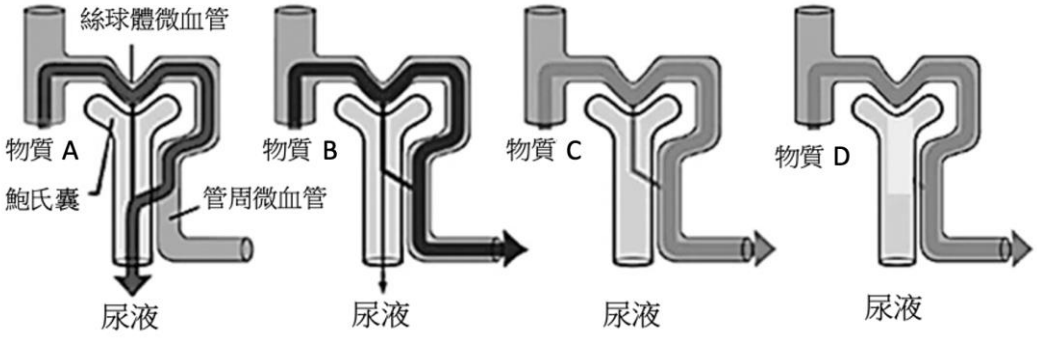
(A) A small amount of substance A is filtered and the rest is secreted into urine.

(B) Substance B is completely reabsorbed after being filtered.

(C) Substance C is filtered and partly reabsorbed.

(D) Substance D is filtered but not secreted.

腎臟是人體的排泄器官，腎動脈的血液由入球小動脈進入絲球體的微血管，血液中的小分子可在此經由過濾作用進入腎小管的鮑氏囊中形成過濾液。過濾液中有用物質會被再吸收回體內，進入圍繞在腎小管周圍的微血管，血液中過多或有害的物質則會被(腎小管分泌至濾液中，最後形成尿液排泄出體外（如附圖）。



根據附圖所示，下列有關物質 A～D 的敘述，何者正確？

(A) 物質 A 少量經過濾，其他被分泌至尿液。

(B) 物質 B 被過濾後完全被再吸收。

(C) 物質 C 被過濾，部分被再吸收。

(D) 物質 D 被過濾，但不被分泌。

（111 分科 34）

Teacher: What is filtering?
Student: The process by which blood enters Bowman's capsule to form a filtrate.
Teacher: Very good, the substance has passed through the Bowman's capsule, which means that it has been filtered. Which substances in the diagram have been filtered?
Student: A, B, and C.
Teacher: That's right. What is the difference between the directions of reabsorption and secretion?
Student: Reabsorption is the return of substances to the capillaries, while secretion is the secretion of substances into the renal tubules, so the two act in opposite directions.
Teacher: Great. Substances B and C both undergo filtration and reabsorption. What is the difference between the two?
Student: Substance C is completely reabsorbed and therefore does not appear in the urine.

老師： 過濾作用是什麼？
學生： 血液進入鮑氏囊形成濾液的過程。
老師： 很好，物質有經過鮑氏囊表示有被過濾，那圖示中的哪些物質有被過濾？
學生： 甲、乙、丙。
老師： 沒錯，那再吸收和分泌作用兩者方向上的差別是什麼？
學生： 再吸收是物質回到微血管，而分泌作用是物質分泌到腎小管內，兩者作用方向相反。
老師： 很棒。物質乙和丙都有發生過濾作用和再吸收，請問兩者差別在哪？
學生： 物質丙被完全再吸收，所以沒有出現在尿液中。

例題二

說明：學生能瞭解體液恆定的機制，並記得不同激素的功能。

Students can understand the mechanisms of fluid homeostasis and remember the functions of different hormones.

After exercise, the human body loses water and electrolytes due to excessive sweating. Based on what you have learned, answer the following question.

Under the above physiological conditions, what changes will occur in the blood?

(A) Increased osmolarity in blood.

(B) Increased blood angiotensin concentration.

(C) Increased blood antidiuretic hormone.

(D) Elevated concentration of atrial natriuretic peptide in the blood.

(E) Decrease of the blood volume due to lack of water, resulting in a sharp drop in blood pressure.

人體在運動後，因大量流汗造成水分與電解質流失。依習得的知識，回答下列問題。

在上述生理狀況下，血液會有哪些變化？

(A) 血液的滲透濃度升高。

(B) 血液的血管收縮素濃度升高。

(C) 血液的抗利尿激素濃度升高。

(D) 血液的心房排鈉肽濃度升高。

(E) 血液的體（容）積因缺水而下降，導致血壓劇烈下降。

（109 指考 25）

Teacher: When the body loses water, blood osmotic pressure increases and blood pressure decreases. What will the body secrete to increase blood pressure?

Student: When blood pressure drops, the body activates the renin-angiotensin-aldosterone system (RAAS). Angiotensin causes blood vessels to constrict, leading to an increase in blood pressure.

Teacher: How does aldosterone regulate water balance?

Student: Aldosterone promotes the reabsorption of water and sodium ions, resulting in increased blood volume. What is the effect of atrial natriuretic peptide on blood pressure?

Teacher: Atrial natriuretic peptide (ANP) inhibits renal reabsorption of water and sodium ions. Now you know the relationship between atrial natriuretic peptide and the renin-angiotensin-aldosterone system.

Student: Both of them are antagonistic!

Teacher: That's right!

老師： 人體水份流失時，血液滲透壓上升，血壓下降，此時身體會分泌什麼以增加血壓？

學生： 當血壓下降時，身體會啟動腎素-血管張力素-醛固酮系統 (RAAS)。血管收縮素能夠引發血管收縮，使血壓回升。

老師： 那醛固酮如何調節水分？

學生： 醛固酮會促進水和鈉離子的再吸收，造成血液體積增加。那心房排鈉肽對血壓的影響是什麼？

老師： 心房排鈉肽會抑制腎臟對水和鈉離子的再吸收。現在你知道心房排鈉肽和腎素-血管張力素-醛固酮系統的關係了。

學生： 他們兩者為拮抗作用！

老師： 沒錯。

★ 主題四 感應 ★
Response

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■ 前言 Introduction

本章的主題名稱為感應，內容包含了神經與內分泌系統，目的為引導學生了解這兩大系統的構造與功能，並探討兩者的交互作用是如何調節動物體內環境、如何影響動物的行為。本章共有四小節，分別為 4-1 動物體內的受器、4-2 動物的神經系統、4-3 肌肉與骨骼和 4-4 內分泌。

學生在國中的生物課已學過神經和內分泌系統的基本觀念，因此學生已大致理解何謂受器與動器、神經元、反射、神經傳導路徑、內分泌器官與一些常見的內分泌腺。但尚未學習受器的種類、神經傳導物質、肌肉與骨骼在運動時的功能或神經電位和回饋機制等較抽象的概念，因此建議教師在教學時可使用生活化的舉例幫助理解複雜的生理機制，以利學生學習。

4-1 動物體內的受器
Receptors in Animals

■ 前言 Introduction

動物體內的視覺、聽覺、嗅覺、味覺和觸覺等感官皆依賴受器的幫助，學生在國中時學習過受器具有專一性，一種受器僅能接受固定種類的刺激。在本小節中，將深入介紹各種的受器，及其如何與相對應的刺激進行反應，進而讓動物體產生知覺。由於各感官擁有各自的受器，因此專有名詞較多，在記憶上存有一定的難度，建議教師可設計簡單的教學活動，例如角色扮演法，幫助學生更清楚理解各受器接收的反應類型和方式。英文重點方面，本單元的專有名詞常以字根結合受器之英文"receptor"來表示，教師在教學時可提示學生，增加學習效率。需要特別注意的單字為痛覺受器"nociceptor"之發音。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
receptor	受器	thermoreceptor	溫度受器
photoreceptor	光受器	nociceptor	痛覺受器
retina	視網膜	mechanoreceptor	機械受器
cone cell	視錐細胞	chemoreceptor	化學受器
rod cell	視桿細胞	pacinian corpuscle	巴氏小體
cochlea	耳蝸	hair cell	毛細胞
taste bud	味蕾	olfactory cell	嗅細胞
gustatory cell	味細胞		

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

❶ _____ detect _____ stimuli.

例句：Photoreceptors can **detec**t light **stimuli.**
光受器可偵測光刺激。

❷ _____ consist of _____.

例句：Taste buds **consist of** different taste cells.
味蕾由不同的味細胞組成。

❸ _____ be located in _____.

例句：Olfactory cells **are located in** the olfactory mucosa of the nasal cavity.
嗅細胞位於鼻腔嗅黏膜。

❹ _____ belong to _____.

例句：Auditory receptors **belong to** mechanoreceptors.
聽覺屬於機械受器。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、了解不同受器接受的刺激種類。

Understand the types of stimuli received by different receptors.

二、了解各受器的位置。

Understand the location of each receptor.

三、了解不同受器的分類。

Understand the classification of different receptors.

❧ 例題講解 ☙

例題一

說明：測試學生是否能夠分辨光暗視覺對應的細胞類型。

Test whether students can distinguish between the types of cells corresponding to light and dark vision.

The leopard cat is a nocturnal animal. Compared to the human retina, which type of receptor cells may have a higher proportion in their retina?

(A) Mechanoreceptors (B) Cone cells **(C) Rod cells** (D) hemoreceptors

石虎屬於夜行性動物，相較於人的視網膜，牠們的視網膜上何種受器細胞可能會有較高的比例？

(A) 機械受器 (B) 視錐細胞 **(C) 視桿細胞** (D) 化學受器

（111 分科 13）

Teacher: Do you know the difference between cone cells and rod cells?

Student: Cone cells need a brighter environment to detect light of different wavelengths, while rod cells are highly sensitive to light and mainly detect the brightness and darkness of the environment.

Teacher: The answer is correct. Do nocturnal animals need a clear color or do they need to absorb light as much as possible?
Student: Absorb as much light as possible.
Teacher: That's right, so the answer should be rod cells.

老師： 同學們知道視錐細胞和視桿細胞的差異嗎？
學生： 視錐細胞需要較亮的環境偵測不同波長的光線、視桿細胞對光的敏感度高，主要偵測環境的明暗。
老師： 答對了，那你們再想想夜行性動物需要的是明確的色彩還是盡可能吸收光線呢？
學生： 盡可能吸收光線。
老師： 沒錯，因此答案應該要選視桿細胞。

例題二

說明：測試學生是否了解各類型感覺受器的特性。
Test whether students understand the characteristics of different types of sensory receptors.

Which of the following statements about sensory receptors is/are correct?

(A) Olfactory receptors are specialized neurons that transmit olfactory messages directly to the brain.

(B) After the photoreceptor receives light stimulation, it can release chemical substances to continue to transmit the message.

(C) Taste receptors are taste cells, which are specialized neurons.

(D) After the thermal receptor receives a stimulus, it will transmit the message to the connected sensory neuron.

(E) Balance receptors are hair cells, which are affected by the oppression of otoliths.

下列有關感覺受器的敘述，哪些正確？

(A) 嗅覺受器是特化的神經元，可直接將嗅覺訊息傳到大腦。

(B) 光受器接受光刺激後，可釋出化學物質將訊息繼續傳遞。

(C) 味覺受器是味細胞，屬於特化後的神經元。

(D) 熱覺受器接收到刺激後，會將訊息傳給相連的感覺神經元。

(E) 平衡覺受器是毛細胞，受耳石之壓迫而牽動。

（108 指考 29）

Teacher: Which common sensory receptors are specialized neurons?

Student: Good question, specialized neurons include photoreceptors, thermoreceptors, and olfactory receptors.

Teacher: So what's wrong with options C and D?

Student: The statements in options C and D are just the opposite. Taste cells are specialized epithelial cells that need to transmit information to the central nervous system through sensory neurons; on the other hand, heat sensory cells themselves are specialized sensory neurons, so they do not need to transmit information through other sensory neurons.

Teacher: I see!

老師： 請問老師在常見的感覺受器中，有哪些屬於特化的神經元？

學生： 問得很好，特化的神經元有光受器、溫度受器和嗅覺受器。

老師： 那 C 和 D 選項是哪裡錯誤呢？

學生： C 和 D 選項的敘述剛好相反。味細胞是特化後的上皮細胞，需要再經由感覺神經元將訊息傳至中樞；熱覺細胞本身就是一種特化的感覺神經元，因此不需要再經由其他的感覺神經元協助傳遞訊息。

老師： 原來如此！我學會了。

4-2 動物的神經系統
Animal Nervous System

■ 前言 Introduction

學生在國中階段已學過神經系統中的基礎概念，例如中樞神經和周圍神經的基本介紹，本小節重點包含細胞膜電位和神經衝動的關聯性以及神經元之間如何傳遞訊息。所需記憶的內容不少，且膜電位為抽象的概念，建議教師可針對不同種類的離子通道如何影響膜電位做較詳細的介紹，並配合歷屆大考的試題幫助學生了解。英文的部分，本小節的單字大多由電位“potential”、極化“polarization”和突觸“synapse”延伸，若上課前能帶領學生先認識這三個名詞，能幫助學生更有效率地學習本小節的內容。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
membrane potential	膜電位	saltatory conduction	跳躍傳導
resting membrane potential	靜止膜電位	synapse	突觸
polarization	極化	synaptic gap	突觸間隙
depolarization	去極化	synaptic	突觸囊泡
hyperpolarization	過極化	neurotransmitter	神經傳遞物
repolarization	再極化	node of Ranvier	朗氏結
threshold potential	閾值電位		

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

❶ _____ be called_____.

例句：The potential difference between the inside and outside of the cell **is called** the membrane potential

細胞內外的電位差稱為膜電位。

❷ When_____, _____.

例句：**When** the membrane potential rises to -50 mV, the sodium ion channels will be opened extensively.

當膜電位上升至-50 mV，鈉離子通道將大量開啟。

❸ _____ only if _____.

例句：An Action potential is generated **only if** the depolarization reaches the threshold potential.

僅當去極化達到閾電位時才會產生動作電位。

❹ The function of _____ is/are _____.

例句：**The function of** myelin sheath **is** protection and insulation

髓鞘的功能為保護與絕緣。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、了解膜電位的形成與變化。

Understand the formation and change of membrane potential

二、了解動作電位的產生與傳遞方式。

Understand the generation and transmission of action potentials

三、了解神經訊息在神經元間的傳遞機制。

Understand the transmission mechanism of neural information between neurons

❧ 例題講解 ☙

例題一

說明：測試學生是否能夠判斷動作電位中鈉鉀離子的分布情形。

Test whether students can determine the distribution of sodium and potassium ions during an action potential.

Which of the following statements about the general generation of action potentials in nerve cells is/are correct?

(A) An action potential is initiated when the membrane potential exceeds the threshold.

(B) Depolarization is caused by the opening of potassium channels.

(C) As long as the sodium ions are unevenly distributed inside and outside the cell, a resting membrane potential will be caused.

(D) Hyperpolarization is caused by the activation of the sodium-potassium ion pump.

(E) Potassium ions flow out of nerve cells during repolarization.

有關一般神經細胞產生動作電位的敘述，下列哪些正確？

(A) 膜電位高於閾值時會啟動動作電位。

(B) 去極化是因鉀離子通道的開啟。

(C) 只要鈉離子在細胞內外分布不均就會造成靜止膜電位。

(D) 過極化是因為鈉鉀離子幫浦啟動所造成。

(E) 再極化時鉀離子會流出神經細胞。

（102 指考 32）

Teacher: Students, what kind of ion is the main cause of depolarization?

Student: Sodium ions. But how do sodium ions cause depolarization?

Teacher: Good question, a massive influx of sodium ions from outside the cell membrane into the inside the cell membrane will cause depolarization.

Student: Then, Teacher, is there any relationship between hyperpolarization and the activation of the sodium-potassium ion pump?

Teacher: Good question, hyperpolarization is mainly due to the slow closure of potassium ion channels, resulting in continuous outflow of potassium ions, and has nothing to do with the sodium-potassium ion pump.

Student: So how should we correct the statement that unequal distribution of sodium ions will cause resting membrane potential?

Teacher: The resting membrane potential is about -70mV. This value is the joint influence of many ions and the electrochemical balance achieved through the channel protein on the membrane. Therefore, it is a very complex result and cannot be formed by unequal distribution of sodium ions alone.

老師： 同學們請問去極化主要是因為何種離子呢？

學生： 鈉離子。請問鈉離子如何造成去極化呢？

老師： 問得很好，細胞膜外的鈉離子大量流入細胞膜內時將導致去極化。

學生： 那請問老師，過極化和鈉鉀離子幫浦啟動有甚麼關聯嗎？

老師： 問得很好，過極化主要是因為鉀離子通道關閉較慢，導致鉀離子持續流出，和鈉鉀離子幫浦較沒有關係。

學生： 那麼鈉離子分布不均就會造成靜止膜電位這句話應該怎麼修正呢？

老師： 靜止膜電位約為-70mV，這個數值是很多離子之間的共同影響，並透過膜上的通道蛋白達成的電化學平衡，因此是很複雜的結果，不是僅靠鈉離子分布不均就能形成靜止膜電位唷！

例題二

說明：測試學生是否能夠根據圖片判斷動作電位中膜電位的變化。

Test whether students can determine changes in membrane potential during an action potential based on a diagram.

Figure 3 shows the changes of the cell membrane potential when a nerve cell is stimulated to generate an action potential.

Which of the following statements about point A in the diagram is correct?

(A) The cell membrane is more permeable to potassium ions than to sodium ions.

(B) Most sodium channels are open.

(C) The concentration of sodium ions inside the cell is higher than that outside the cell.

(D) The sodium Potassium Pump (Na/K Pump) has stopped functioning.

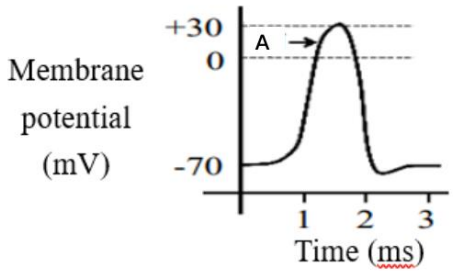


Figure 3

圖 3 表示神經細胞受到刺激而產生動作電位時，其細胞膜的電位變化。

關於圖中甲點的敘述，下列何者正確？

(A) 細胞膜對鉀離子的通透性大於鈉離子。

(B) 多數的鈉離子通道處於開啟狀態。

(C) 胞內的鈉離子濃度高於胞外的鈉離子濃度。

(D) 鈉鉀幫浦（Na／K Pump）停止作用。

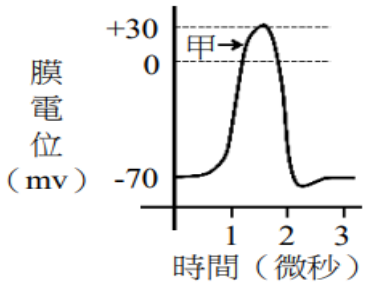


圖 3

（106.指考 16）

Student: May I ask what determines the permeability of cells to ions?

Teacher: Good question. It is usually determined by the number of channel proteins open in the cell membrane.

Student: So during depolarization, the permeability of sodium ions will be greater than that of potassium ions?

Teacher: Yes, so there's a massive influx of sodium ions into the cells at this point, but be aware that the sodium potassium pump remains the same.

Student: I see!

學生： 請問老師甚麼決定了細胞對離子的通透性呢？

老師： 問得很好，通常是細胞膜上的通道蛋白開啟數量決定。

學生： 所以去極化時，鈉離子的通透性會大於鉀離子囉？

老師： 沒錯，因此這時鈉離子會大量流入細胞中，但要注意，鈉鉀幫浦的功能一直維持不變。

學生： 原來如此！我學會了。

4-3 肌肉與骨骼
Muscles and Skeleton

■ 前言 Introduction

學生在國中階段已學過神經元的相關構造與種類，例如腦神經或脊神經，是由感覺神經元與運動神經元的纖維組成的。本小節重點包含了神經系統對運動的協調、肌肉與骨骼的運作、體神經與自律神經控制對象的差異，以及交感神經與副交感神經的協調作用。由於本章節考試重點為交感神經與副交感神經，建議老師可利用對比方式，呈現交感與副交感神經系統的構造與功能特徵。英文的部分，提到了許多不同神經系統相關之單字，如交感神經系統“sympathetic nerve system”及副交感神經系統“parasympathetic nerve system”，雖然單字較長，老師可以透過字根（如“para-”）拆解並解釋字根意思，能幫助學生更有效率地理解並記憶這些單字。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
skeleton	骨骼	joint	關節
cardiac muscle	心肌	ligament	韌帶
smooth muscle	平滑肌	inorganic salt	無機鹽
autonomic nervous system	自律神經系統	tendon	肌腱
somatic nervous system	體神經系統	antagonism	拮抗作用
sympathetic nerve system	交感神經系統	motor end-plate	運動終版

單字	中譯	單字	中譯
parasympathetic nerve system	副交感神經系統	muscle fiber	肌纖維
connective tissue	結締組織	bone	硬骨
cartilage	軟骨	acetylcholine	乙醯膽鹼

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

❶ _____ refers to _____.

例句：Voluntary movement **refers to** the coordinated operation between muscles and bones controlled by the brain's conscious awareness through the somatic nervous system.
隨意運動是大腦意識經由體神經系統控制肌肉與骨骼之間的相互協調運作。

❷ _____ be part of _____.

例句：Both ligaments and tendons **are parts of** connective tissues, composed of bundles of collagen fibers.
韌帶與肌腱均屬於結締組織，兩者皆由膠原纖維束組成。

❸ It is _____ that _____.

例句：**It is** the control of the nervous system **that** the human body can perform various actions through muscles and bones.
有了神經系統的調控，人體可以藉由肌肉牽動骨骼而表現各種動作。

❹ _____ be known as_____.

例句：The motor terminal **is** also **known as** a type of synapse, whose structure is similar to that of synapses between neurons.
運動終版也是一種突觸，其構造和神經元間的突觸類似。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、了解肌肉與骨骼之間關係與運作。

Understand the relationship and function of muscles and bones.

二、了解交感及副交感神經系統如何共同維持體內環境的恆定。

Understand how the sympathetic and parasympathetic nervous systems work together to maintain the internal environment's homeostasis.

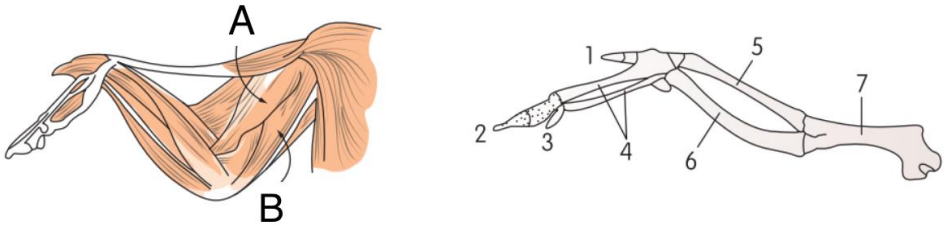
❧ 例題講解 ☙

例題一

說明：測試學生是否能夠了解肌肉與骨骼的連接以及運作的關係。

Test whether students can understand the connection and functional relationship between muscles and bones.

The following diagrams show the muscles and skeleton of a chicken wing, respectively. Answer the following question based on this diagram.



Which of the following statements about muscles A and B in the diagram is correct?

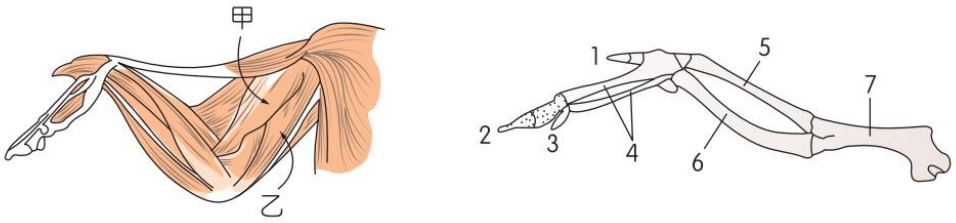
(A) Muscles A and B are the main muscles used for flapping wings. Chickens have poor flying ability, so these two muscles are not as developed as those in other birds.

(B) When muscles A and B contract at the same time, the wings of a chicken are folded to the shortest.

(C) The tendons at both ends of muscle A are connected to bones 5 and 7 respectively. When muscle A contracts, it can bend the wings.

(D) The tendons at both ends of B are connected to the proximal and distal ends of bone 7. When muscle B contracts, the wings extend.

下圖分別為雞翅的肌肉及骨骼的示意圖。根據此圖回答下列問題。



下列有關圖中甲、乙肌肉的敘述，何者正確？

(A) 甲、乙為振翅使用的主要肌肉，雞飛行力不佳，故此兩塊肌肉不如其他鳥類發達。

(B) 甲、乙兩肌肉同時收縮時，雞的翅膀收疊至最短。

(C) 甲兩端的肌腱分別與骨骼 5 及骨骼 7 連接，甲收縮時可使翅彎曲。

(D) 乙兩端的肌腱與骨骼 7 的近端及遠端連接，乙收縮時翅伸直。

（111 分科 32）

Teacher: Can you tell which parts of the chicken wings muscles A and B are respectively?

Student: Muscle A is the biceps brachii and muscle B is the triceps brachii.

Teacher: That's right, muscles A and B are antagonistic muscles.

Student: Does "antagonist muscles" mean that the two muscles will not contract or relax at the same time when they are working?

Teacher: Yes, for example, muscle A is connected to bones five and seven. When it contracts, it can bend the chicken wing, while muscle B relaxes at this time.

老師： 同學們能分辨出甲、乙分別是雞翅的什麼部位嗎？

學生： 甲是肱二頭肌，乙是肱三頭肌。

老師： 沒錯，甲、乙肌肉為拮抗肌。

學生： 拮抗肌意思是兩個肌肉運作的時候不會同時收縮或是舒張嗎？

老師： 對，譬如甲與骨骼五、七連結，它收縮的時候就可以使雞翅彎曲，而這時乙則是舒張的情形。

例題二

說明：測試學生是否能夠了解自律神經系統的組成及運作。

Test whether students can understand the composition and function of the autonomic nervous system.

When a person sweats excessively, causing blood osmotic pressure to increase, blood volume to decrease, and blood pressure to drop, the body's regulatory mechanism will be activated to try to maintain the internal environment's homeostasis. Which of the following related statements is/are correct? (Multiple choice)

(A) Sympathetic nervous activity increases, causing heartbeat to increase, blood vessels to constrict, and blood pressure to rise.

(B) The concentration of renin in the blood decreases, reducing the reabsorption of sodium by the renal tubules and reducing the osmotic pressure of the blood.

(C) The concentration of vasopressin in the blood increases, which greatly increases the reabsorption of water by the proximal convoluted tubule to increase blood volume.

(D) The thirst center of the hypothalamus is stimulated, resulting in water drinking behavior, increased blood volume, and blood pressure rise.

(E) The concentration of atrial natriuretic peptide in the blood increases, which inhibits the reabsorption of sodium by the renal tubules and reduces the blood osmotic pressure.

當一個人大量出汗，導致血液滲透壓上升、血量減少、血壓下降時，身體的調節機制會啟動，盡量維持體內環境的恆定。下列相關敘述，哪些正確？（多選）

(A) 交感神經活性增加，使得心跳加快，血管收縮，血壓回升。

(B) 血液中腎素的濃度下降，減少腎小管對鈉的再吸收，降低血液滲透壓。

(C) 血液中抗利尿素的濃度上升，使近曲小管對水的再吸收大量增加，以增加血量

(D) 下視丘的口渴中樞受到刺激，產生飲水行為，增加血量，血壓回升。

(E) 血液中的心房排鈉肽濃度上升，抑制腎小管對鈉的再吸收，降低血液滲透壓。

（111 分科 6）

Teacher: Which nervous system is responsible for our profuse sweating and rapid heartbeat?
Student: Sympathetic nervous system.
Teacher: Yes, the sympathetic nervous system causes our blood vessels to constrict to cope with emergency situations, while the parasympathetic nervous system helps the body to return to a resting state. Have you noticed that if we sweat a lot, how will our body react?
Student: We will start to feel very thirsty.
Teacher: That's right. After blood vessels constrict, the hypothalamus will start to trigger the brain's thirsty sensation, encouraging us to drink more water.

老師： 我們大量出汗、心跳加快的情形，是哪個神經系統作用而成的？
學生： 交感神經系統。
老師： 是的，交感神經系統是讓我們血管收縮以應付警急狀況，而副交感神經則是讓個體回復休息的狀態。那同學有發現我們如果大量出汗，人體還會有什麼反應呢？
學生： 我們會開始覺得口很渴。
老師： 沒錯，人體血管收縮後，會導致下視丘開始引起大腦渴覺來讓我們增加飲水。

4-4 內分泌 Endocrine

■ 前言 Introduction

學生在國中階段已學過基本的人體內分泌系統，以及主要的內分泌線與激素，包含腦垂腺、甲狀腺、副甲狀腺等等。本小節會再根據國中所學的內分泌系統再新增更多延伸概念，包含激素的作用機制、內分泌系統如何維持體內環境的恆定（回饋控制、拮抗作用、協同作用）。此外，本章節由於激素名稱多元且複雜，老師可以利用表格的方式呈現激素名稱及其功能，抑或是視覺化呈現激素分布在人體的各個部位。在英文方面，許多激素的字根有重複出現，如 “thyroid-”甲狀腺的； “adrenal-”腎上的； “corticoid”皮質素，如能利用字根之概念，能讓學生較容易聯想此激素的中文。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
endocrine	內分泌	progesterone	黃體素
endocrine gland	內分泌腺	adrenocorticotropic hormone, ACTH	促腎上腺皮質素
hypothalamus	下視丘	thyroid stimulating hormone, TSH	甲狀腺促素
hormone	激素	follicle-stimulating hormone, FSH	濾泡刺激素
glycogen	肝糖	luteinizing hormone, LH	黃體成長激素
vasopressin	抗利尿素	corticotropin-releasing hormone, CRH	促腎上腺皮質素釋素

單字	中譯	單字	中譯
oxytocin	催產素	erythropoietin	紅血球生成素
posterior pituitary	腦垂腺後葉	atrial natriuretic peptide, ANP	心房排鈉肽
anterior pituitary	腦垂腺前葉	mineralocorticoid	礦物皮質素
calcitonin	降鈣素	glucocorticoid	糖皮質素
noradrenaline	去甲基腎上腺素	first messenger	第一傳訊者
hormone-receptor complex	激素－受體複合體	second messenger	第二傳訊者
negative feedback	負回饋	thyrotropin releasing hormone, TRH	甲狀腺促素釋素
thyroxine	甲狀腺素	gonadotropin-releasing hormone, GnRH	促性素釋素
prolactin	催乳素		

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

❶ _____ stimulates/promotes ____.

例句：Thyroid stimulating hormone **promotes/stimulates** the thyroid gland to secrete thyroxine hormones.

甲狀腺促素促進甲狀腺分泌甲狀腺素。

❷ _____ turn/become/grow _____.

例句：When thyroxine hormones levels **turn** too high, it will trigger negative feedback.
當甲狀腺素含量過高，則會引發負回饋。

❸ _____ so that _____.

例句：Insulin increases **so that** blood glucose concentrations turn to normal values.
胰島素增加，使血糖濃度恢復正常值。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、了解激素的作用原理。

Understand how hormones work.

二、了解內分泌系統如何透過激素的作用來維持體內環境的恆定。

Understand how the endocrine system maintains the internal environment's homeostasis through the action of hormones.

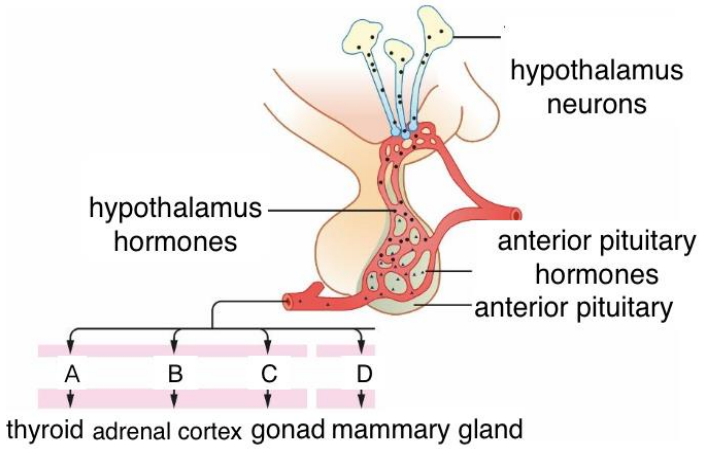
例題講解

例題一

說明：測試學生是否能夠了解下視丘及其激素之間的關聯。

Test whether students can understand the relationship between the hypothalamus and its hormones.

The picture below is a schematic diagram of the role of hypothalamus-pituitary gland-hormones-target organs. A, B, C, and D respectively represent anterior pituitary gland hormones.
Which of the following related statements is correct?



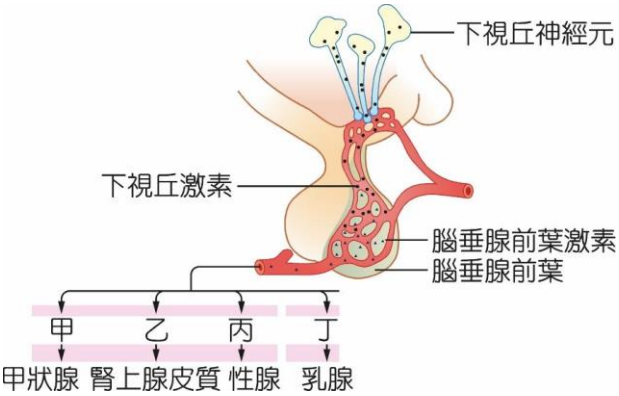
(A) The secretion of hormone A is not regulated by hypothalamic hormones.

(B) Hormone B has an antagonistic effect on epinephrine and helps the body cope with stress.

(C) Hormone C includes at least two hormones, the secretion of which is controlled only by the negative feedback from gonadal hormones.

(D) The secretion of Hormone D can have a positive feedback response due to lactation stimulation.

下圖為下視丘─腦垂腺─激素─目標器官之作用示意圖，甲、乙、丙、丁分別代表腦垂腺前葉激素。下列相關敘述何者正確？



(A) 甲分泌量不受下視丘激素所調控。

(B) 乙與腎上腺素具拮抗作用，協助人體應付壓力。

(C) 丙至少包含兩種激素，其分泌量僅受性腺激素的負回饋控制。

(D) 丁的分泌可因授乳刺激而有正回饋反應。

（108 指考 8）

Teacher: Do you know what positive feedback is?

Student: That is, after certain specific hormones are produced, they are fed back to the glands to secrete the hormones again.

Teacher: Yes. Good job!

Student: Can Teacher give some examples?

Teacher: For example, during lactation, the secretion of prolactin-inhibiting factor from the hypothalamus is greatly reduced, leading to increased secretion of the prolactin by the pituitary gland, which in turn promotes the development of mammary glands and produces milk.

老師： 大家知道什麼是正回饋嗎？

學生： 就是某些特定的激素產生後，會回饋至腺體使得激素再分泌。

老師： 沒錯，同學們很厲害。

學生： 那老師可以舉一些例子嗎？

老師： 舉例來說，在哺乳期的時候，下視丘分泌的催乳素抑制因子大幅減少，使得腦垂腺大量分泌泌乳激素，進而促進乳腺發育並製造乳汁。

例題二

說明：測試學生是否能夠了解血液裡的激素恆定 。

Test whether students can understand the regulation of hormone levels in the blood.

After exercise, the human body loses water and electrolytes due to heavy sweating. Based on what you have learned, answer the following question.

What change(s) will occur in the blood under the above physiological condition?

(A) The osmotic concentration of blood increases.

(B) The concentration of vasoconstrictors in the blood increases.

(C) The concentration of antidiuretic hormone (ADH) in the blood increases.

(D) The concentration of atrial natriuretic peptide (ANP) in the blood increases.

(E) Blood volume (volume) decreases due to lack of water, resulting in a sharp drop in blood pressure.

人體在運動後，因大量流汗造成水分與電解質流失。依習得的知識，回答下列問題。在上述生理狀況下，血液會有哪些變化？

(A) 血液的滲透濃度升高。

(B) 血液的血管收縮素濃度升高。

(C) 血液的抗利尿激素濃度升高。

(D) 血液的心房排鈉肽濃度升高。

(E) 血液的體（容）積因缺水而下降，導致血壓劇烈下降。

（109 指考 25）

Teacher: We know that the human body loses a significant amount of water through sweating. In addition to the increase in blood osmotic pressure, why does it also lead to increased levels of vasoconstrictors and antidiuretic hormone (ADH)?

Student: We are not sure.

Teacher: Because the loss of water will lead to a decrease in blood pressure and the RAAS is activated to activate angiotensin. Let's extend the question further: after arteriole constriction, will it increase or lower blood pressure? How will it lead to an increase in the concentration of antidiuretic hormone?

Student: It will increase blood pressure and then stimulate the hypothalamus to secrete antidiuretic hormone (ADH), leading to increased water reabsorption.

Teacher: That's right!

老師： 同學知道人體大量流汗失去水分，我們人體除了血液滲透壓上升外，為什麼也會導致血管收縮素及抗利尿素的濃度升高呢？

學生： 不大清楚。

老師： 因為水分喪失之後，會導致血壓降低，啟動了 RAAS 來活化血管收縮素。再延伸考考大家，小動脈收縮後會提升還降低血壓，以及後續會如何導致抗利尿激素濃度升高？

學生： 會提升血壓，然後再刺激下視丘分泌抗利尿激素 增加水分再吸收。

老師： 沒錯！同學答對嘍！

★ 主題五 防禦 ★
Defense

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■ 前言 Introduction

本章的主題名稱為防禦，內容包含了各式各樣的防禦與免疫系統，目的為引導學生了解人體如何抵禦病原體，並探討先天性與後天性免疫在人體中啟動的機制，以及如何辨認、記憶並移除病原體。本章共有四小節，分別為 5-1 免疫系統、5-2 先天性免疫、5-3 後天性免疫和 5-4 免疫失調與排斥。

國中生物很少提到免疫反應或防禦作用，但是在國中與選修第三冊的「循環」中，有提到過淋巴系統，不過描述僅見於「淋巴循環」，主要強調循環，對於人體的防禦只有提到淋巴結的功能，但由於前幾年全球疫情肆虐，學生多數也聽過病毒、疫苗和免疫等名詞，所以本單元可能是學生最熟悉的陌生人，因此建議教師在教學時可使用生活化的舉例幫助理解複雜的生理機制，以利學生學習。

5-1 免疫系統
Immune System

■ 前言 Introduction

本小節主要講解白血球的種類，可分為顆粒性白血球（嗜酸性球、嗜中性球、嗜鹼性球）及單核性白血球（單核球、巨噬細胞、樹突細胞、淋巴球等），以及淋巴器官的組成。而這些也組成了我們人體的免疫系統，並可以透過先天性免疫與後天性免疫組成三道防線來進行防禦作用，為我們的人體抵抗疾病入侵。在英文方面，提到許多白血球相關的單字，如嗜酸性球 eosinophil、嗜中性球 neutrophil、嗜鹼性球 basophil，都有相同字根 -phil；淋巴相關的單字，如淋巴 lymph、淋巴結 lymph node 等，有相同的字首 lymph。老師可以多利用字根幫助同學學習。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
immune system	免疫系統	cardiovascular System	心血管系統
lymph	淋巴	white blood cells	白血球
eosinophil	嗜酸性球	neutrophil	嗜中性球
basophil	嗜鹼性球	monocyte	單核球
lymph node	淋巴結	epithelial barrier	皮膜屏障
lymphocyte	淋巴球	dendritic cell	樹突細胞
macrophage	巨噬細胞	lymphatic vessels	淋巴管

單字	中譯	單字	中譯
T cell	T 細胞	B cell	B 細胞
thymus	胸腺	bone marrow	骨髓
primary lymphoid organ	初級淋巴器官	hematopoietic stem cell	造血幹細胞
secondary lymphoid organ	次級淋巴器官	spleen	脾臟
acquired immunity	後天性免疫	tonsil	扁桃腺
innate immunity	先天性免疫		

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

❶ _____serve(s) as_____.

例句：Bone marrow and the thymus, which are classified as primary lymphoid organs, **serve as** the locations for the origin or maturation of white blood cells.

初級淋巴器官包括骨髓和胸腺，是白血球起源或發育成熟的地方。

❷ _____ can respond to _____.

例句：Acquired immunity **can respond to** specific defense targets, so it is also called specific defense.

後天性免疫可針對特定的防禦對象做出反應，故又稱為專一性防禦。

❸ Based on/According to_____, _____.

例句：**According to** changes in the number of white blood cells in the blood, it is possible to infer what type of external threat the body is facing.

依據血液中白血球數量的變動，可推知人體正面臨何種外來威脅。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、學生了解人體免疫系統的組成和功能。

Students understand the composition and function of the human immune system.

二、學生了解白血球的種類及其功能與用途。

Students understand the types of white blood cells and their functions and uses.

❧ 例題講解 ☙

例題一

說明：測試學生是否理解免疫細胞的基本形成概念及其功能。

Assess students' understanding of the basic concepts of immune cell formation and their functions.

Which of the following statements about immune cells is/are correct?

(A) T cells are generated from hematopoietic stem cells in the thymus.

(B) B cells are generated from hematopoietic stem cells in the bone marrow.

(C) The most abundant granules are neutrophils.

(D) Antigen-presenting cells are mainly composed of helper T cells.

(E) Natural killer cells can identify cancer cells.

下列有關免疫細胞的敘述，哪些正確？

(A) T 細胞生成自胸腺內的造血幹細胞。

(B) B 細胞生成自骨髓中的造血幹細胞 。

(C) 顆粒球中含量最高的是嗜中性白血球 。

(D) 抗原呈現細胞主要由輔助 T 細胞擔任 。

(E) 自然殺手細胞可以辨識癌細胞。

（108 年指考 22）

Teacher: Where are T cells and B cells generated?

Student: Primitive T cells are formed from hematopoietic stem cells in the bone marrow. Primitive T cells enter the thymus to form T cells. B cells are generated from hematopoietic stem cells in the bone marrow.

Teacher: So do you know why option A is wrong?

Student: Because hematopoietic stem cells are in the bone marrow, not the thymus.

Teacher: Yes, you can draw inferences from one example. So do you know what functions natural killer cells have?

Student: They identify tumor cells and release toxic substances to destroy the target cells.

老師： 想請問大家，T 細胞跟 B 細胞分別是在哪裡生成的？

學生： T 細胞是從骨髓中的造血幹細胞中形成原始 T 細胞，原始 T 細胞進入胸腺後才形成 T 細胞；B 細胞則是從骨髓中的造血幹細胞生成。

老師： 那你們知道為什麼 A 選項是錯的了嗎？

學生： 因為造血幹細胞是在骨髓內，而不是胸腺。

老師： 沒錯，同學們能舉一反三。那大家知道自然殺手細胞有什麼功能嗎？

學生： 它可以辨識腫瘤細胞，並釋放有毒物質以破壞目標細胞。

例題二

說明：測試學生是否理解嗜中性白血球的相關特性。

Assess students' understanding of the characteristics of neutrophils.

Which of the following statements about neutrophils is correct?

(A) They account for the smallest percentage of total white blood cells.

(B) They have a large round nucleus.

(C) They do not contain granular structure in the cytoplasm.

(D) They are related to inflammatory response.

有關嗜中性白血球的敘述，下列何者正確？

(A) 在總白血球中占的百分比最少。

(B) 具有圓形的大細胞核。

(C) 細胞質中不帶有顆粒構造。

(D) 和發炎反應有關。

（107 指考 39）

Student: Teacher, why are neutrophils related to inflammation?

Teacher: Neutrophils are an important cell in the immune system and play a key role in inflammatory responses. These white blood cells are able to travel to areas of infection or injury and participate in fighting infection by engulfing bacteria and other pathogens.

Teacher: Are neutrophils the largest or smallest group of granular leukocytes?

Student: The largest.

Teacher: Yes, they account for about 60-70% of all granular leukocytes. The nuclei of mature neutrophils are mostly leaf-like.

學生： 老師，為什麼嗜中性白血球和發炎反應有關呢？

老師： 嗜中性白血球是免疫系統中的一種重要細胞，它在發炎反應中扮演著關鍵的角色。這些白血球能夠移動到感染或損傷的區域，並通過吞噬細菌和其他病原體來參與抵抗感染。

老師： 那嗜中性白血球是顆粒性白血球中數量最多還最少的？

學生： 最多的。

老師： 沒錯，大概佔 60-70%，而且成熟的嗜中性白血球細胞核多呈分葉狀。

5-2 先天性免疫
Innate immunity

■ 前言 Introduction

本小節主要講述先天性免疫如何透過第一道防線的皮膜屏障及第二道防線的吞噬作用、發炎反應、干擾素及自然殺手細胞等作用，來抵禦與清除人體面對的病毒威脅。最後則是探討人體遭逢病原體感染時，會導致下視丘設定點偏移，使體溫恆定失衡，造成發燒現象。在英文方面，本小節的單字較分散，相似性不高，但建議老師在教學時除了利用字根外（如干擾素的字根 interfere 有打擾、干擾意思），也可以結合教學句型或搭配圖像幫助學生加深印象。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
phagocytosis	吞噬作用	inflammatory response	發炎反應
gastric juice	胃液	mast cell	肥大細胞
histamine	組織胺	prostaglandin, PG	前列腺素
interferon	干擾素	natural killer cell, NK	自然殺手細胞
phagocytes	吞噬細胞	mucosal cells	黏膜細胞

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

❶ _____ due to/because of _____.

例句：The epidermis of human skin may also be wounded **due to** injuries, causing pathogens to pass through the wounds and invade the body.
人體表皮皮膚也可能因為受傷產生傷口，導致病原體藉由傷口入侵體內。

❷ _____ is composed of _____.

例句：The epidermis of human skin **is composed of** multiple layers of squamous epithelial cells.
人體皮膚的表皮由多層扁平上皮細胞組成。

❸ Although_____, _____.

例句：**Although** some mucosal surfaces do not have a keratinized structure, they can secrete mucus for protection.
有些黏膜表面雖不具有角質化的構造，但可分泌黏液保護。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：
After completing this section, students should acquire the following concepts:
一、學生了解先天性免疫的基本概念，包括其功能及重要性。
Students understand the basic concepts of innate immunity, including its function and importance.
二、學生了解干擾素的運作。
Students understand the operation of interferons.

例題講解

例題一

說明：測試學生是否理解發炎反應等先天性免疫。

Assess students' understanding of innate immunity, such as the inflammatory response.

Which of the following statements about immune responses is/are correct?

(A) Cells involved in specific and non-specific immune responses only exist in the blood.

(B) Interferon can help cells resist viral infection.

(C) During an inflammatory response, the permeability of microvessels will be reduced to avoid plasma leakage.

(D) Allergic reactions are caused by acquired immune system disorders.

(E) The main function of cytotoxic T cells is to kill pathogens.

下列有關於免疫反應的敘述，哪些正確？

(A) 參與專一性及非專一免疫反應的細胞只存在於血液中。

(B) 干擾素可協助細胞抵抗病毒感染。

(C) 在發炎反應時，微血管的通透性會降低以避免血漿滲出。

(D) 過敏反應是後天性免疫系統失調所造成。

(E) 胞毒 T 細胞的主要作用是殺死病原體。

（105 年指考 24）

Student: What is the role of inflammatory response?

Teacher: Generally, the inflammatory response releases histamine and other substances to increase the blood flow and permeability of microvessels. The volume of plasma will also increase to resist the spread of pathogens.

Teacher: In addition to the inflammatory response, what other functions does the human body have that can help us fight viruses?

Student: Interferons and natural killer cells?

Teacher: Right! Interferon is an antiviral protein released by virus-infected cells that can induce other uninfected cells to synthesize antiviral substances in advance. As for natural killer cells, they can release toxic substances to destroy target cells.

Teacher: Finally, I would like to add that many people are often confused about cytotoxic T cells. They can induce apoptosis in infected cells and, consequently, are used to kill cancer cells. Therefore, they are common in cancer treatment.

學生： 發炎反應有什麼作用？
老師： 通常來說，發炎反應會釋放組織胺等物質來增加微血管的血流量與通透性，血漿量也會增加，以抵抗病原體的散播。
老師： 人體除了發炎反應外，還有哪種作用能幫助我們抵抗病毒？
學生： 干擾素跟自然殺手細胞嗎？
老師： 對！干擾素是由被病毒感染的細胞所釋放的一種抗病毒蛋白質，能誘發其他未受感染的細胞預先合成抗病毒物質。那至於自然殺手細胞，它可釋放毒性物質破壞目標細胞。最後老師想補充，很多人搞混的胞毒 T 細胞，它可以使感染細胞凋亡，也因此可以殺死癌細胞，是用來治療癌症的常見手法。

例題二

說明：測試學生是否理解干擾素的功能及作用。

Assess students' understanding of the functions and roles of interferons.

Which of the following statements about interferon is correct?

(A) Its serves as a specific immune response.

(B) The cells that release interferon themselves can be protected.

(C) It mainly responds to infection by bacterial pathogens.

(D) It can induce neighboring cells to synthesize immune-related proteins.

下列有關干擾素的敘述，何者正確？

(A) 其作用屬於專一性免疫反應。

(B) 釋放干擾素的細胞本身可因此獲得保護。

(C) 其主要是因應細菌病原體的感染。

(D) 可誘發鄰近細胞合成免疫相關的蛋白質。

（106 年指考 18）

Student: Do interferons have specificity?

Teacher: This is a good question. Interferon is a nonspecific defense. In addition, interferon produced by animals of the same species is not specific to viruses!

Teacher: What is the role of interferon?

Student: Interferon is an antiviral protein released by infected cells, which then allows other cells that are not infected to synthesize antiviral substances.

Teacher: That's right! So the cells that release interferon themselves are not protected.

Student: Got it!

學生： 干擾素有沒有專一性呢？

老師： 這是個好問題，干擾素屬於非專一性防禦，此外，同種動物產生的干擾素對病毒沒有專一性喔！

老師： 干擾素有什麼作用？

學生： 干擾素是由被感染的細胞，釋放出一種抗病毒蛋白質，然後讓其他未被敢染的細胞先合成抗病毒的物質。

老師： 沒錯！所以釋放干擾素的細胞本身是沒有被保護的。

學生： 了解了！

5-3 後天性免疫
Acquired immunity

■ 前言 Introduction

由於後天性免疫需要病原體入侵後才能對其產生記憶，因此又稱為「適應性免疫」。後天性免疫的特性為：專一性與記憶性，主要可分為體液免疫和細胞免疫。在本小節中，將深入介紹兩種免疫的詳細作用機制，著重於抗原-抗體之間的概念，並提及疫苗的原理。在英文方面，此處的單字量很大，建議教師可以帶領學生探討單字的衍生意涵，以提升學習效率。例：acquired immunity 是後天性免疫，但字面上的意思更接近於適應性免疫，因此是否能由「適應性」的概念出發，對後天免疫的整體意涵更加了解。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
acquired immunity	後天性免疫	cytokine	細胞介素
anitgen	抗原	perforin	穿孔蛋白
antibody	抗體	granzyme	顆粒酶
major histocompatibility complex (MHC)	主要組織相容性複體 (MHC)	cell-mediated immunity	細胞媒介免疫
antigen-MHC complex	抗原－MHC 複合體	humoral immunity	體液免疫
cytotoxic T cell	胞毒 T 細胞	vaccine	疫苗

單字	中譯	單字	中譯
helper T cell	輔助 T 細胞	preventive inoculation	預防接種
antigen-presenting cell	抗原呈現細胞	primary immune response	初級免疫反應
active immunity	主動免疫	secondary immune response	次級免疫反應
passive immunity	被動免疫		

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

❶ _____ is/are classified into _____.

例句：T cells can **be classified into** helper T cells and cytotoxic T cells.
細胞可分為輔助 T 細胞和胞毒 T 細胞。

❷ _____ can activate _____.

例句：Cytokines can activate T cells and B cells.
細胞介素能活化 T 細胞與 B 細胞。

❸ After _____, _____ will _____.

例句：**After** engulfing a pathogen, phagocytes **will** present antigens to helper T cell.
在吞噬病原體後，吞噬細胞將病原體上的抗原呈現給輔助 T 細胞。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、學生了解後天性免疫的特性。

Students understand the characteristics of acquired immunity.

二、學生了解體液免疫與細胞媒介免疫。

Students understand humoral immunity and cell-mediated immunity.

三、學生了解疫苗的功能。

Students understand the functions of vaccines.

❧ 例題講解 ☙

例題一

說明：測試學生是否理解免疫系統的基本概念。

Assess students' understanding of the basic concepts of the immune system.

Which of the following statements about the human immune system and its functions is/are correct?

(A) B cells differentiate into plasma cells to produce and release antibodies.

(B) B cells and T cells mature in the bone marrow and then travel to the lymph nodes.

(C) Histamine is involved in the process of inflammation and allergic reactions.

(D) Without helper T cells, no immune response can occur.

(E) Neutrophils are the immune cells mainly involved in inflammation and allergic reactions.

下列有關人體免疫系統及功能的敘述，哪些正確？

(A) B 細胞分化為漿細胞後製造並釋放抗體。

(B) B 細胞和 T 細胞在骨髓中成熟後會進入淋巴結。

(C) 組織胺參與發炎和過敏反應發生的過程。

(D) 沒有輔助性 T 細胞存在，就不會發生免疫反應。

(E) 嗜中性血球是參與發炎和過敏反應的主要免疫細胞。

（103 年指考 24）

Student: Teacher, don't T cells mature in the bone marrow?

Teacher: T cells enter the lymph nodes after the maturation in the thymus, but even without T cells the body still has other immune responses, such as innate immunity.

Teacher: Do you know which cells are involved in the inflammatory response?

Student: Neutrophils are the main immune cells involved in inflammatory responses.

Teacher: Very good! What about allergic reactions?

Student: The immune cells mainly involved in allergic reactions are B cells and mast cells. In addition, mast cells secrete histamine. Histamine can dilate microvessels and increase the permeability of microvessel walls to white blood cells. In this way, histamine is involved in inflammation and allergic reactions.

學生： 請問老師 T 細胞不是在骨髓成熟嗎？

老師： T 細胞在胸腺成熟後進入淋巴結，但即使沒有 T 細胞，人體還是有其他的免疫反應，如先天性免疫。

老師： 那你們知道發炎反應是哪種細胞參與呢？

學生： 嗜中性血球是參與發炎反應的主要免疫細胞。

老師： 很好！那過敏反應呢？

學生： 參與過敏反應的主要免疫細胞則是 B 細胞和肥大細胞，另外肥大細胞也會分泌組織胺，組織胺能使微血管擴張和增加微血管壁對白血球的通透性，以參與發炎和過敏反應。

例題二

說明：測試學生是否了解各類型免疫細胞的特性。

Assess students' understanding of the characteristics of different types of immune cells.

Injecting modified, specific immune cells into patients is one method of treating cancer. These immune cells will recognize cancer cells and kill them through specific actions. What are these immune cells? How do they kill cancer cells?

(A) Macrophages; phagocytosis

(B) B cells; neutralizing effect of antibodies

(C) Helper T cells; rupture cells

(D) Cytotoxic T cells; apoptosis

利用修改後的專一性免疫細胞注射入患者體內是治療癌症的方法之一。此免疫細胞會辨識癌細胞，經特定的作用殺死癌細胞。此免疫細胞為何？

以何種方式殺死癌細胞？

(A) 巨噬細胞；吞噬

(B) B 細胞；抗體的中和作用

(C) 輔助型 T 細胞；使細胞破裂

(D) 胞毒型 T 細胞；凋亡作用

（109 年指考（補）17）

Student: Teacher, what are the main differences between B cells and T cells?

Teacher: Good question, T cells are mainly involved in cell-mediated immunity; B cells are involved in humoral immunity.

Student: How do they carry out immunity?

Teacher: T cells recognize cancer cells and induce apoptosis; B cells produce antibodies but do not directly kill cells.

Student: I see!

學生： 請問老師 B 細胞和 T 細胞主要的差別？

老師： 問得很好，T 細胞主要參與細胞免疫；B 細胞參與體液免疫。

學生： 那他們分別用甚麼方式進行免疫作用？

老師： T 細胞會辨識癌細胞，誘發其凋亡；B 細胞製造抗體，但不會直接殺死細胞

學生： 原來如此！我學會了。

5-4 免疫失調與排斥
Immune disorder and rejection

■ 前言 Introduction

學完先天性和後天性免疫後，了解到免疫系統具有辨識外來物的能力，但有時辨識能力會失準或是免疫反應過當，就會造成免疫的失調或排斥，進而引發疾病，嚴重時甚至可能危害生命安全。此章節的主題包含：過敏、先天性免疫疾病、愛滋病與排斥，雖然是較為應用的部分，但學生仍需要前三節的觀念來了解這些主題，因此教師講解時宜多使用提問的方式，讓學生思考某細胞或是某機制失去功能時，身體可能會有哪些變化。

在英文方面，此節和前三節比單字量較少，雖然有幾個複合性的單字較長，但大多是由常見的單字組合而成，教師可從此觀點做單字介紹，學生較容易理解，另外教師可以多安排使用句型的活動，協助學生產出學習成果。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
disorder	失調	rejection	排斥
allergy	過敏	allergic reaction	過敏反應
allergen	過敏原	transplant	移植
disorder	失調	severe combined immunodeficiency disease (SCID)	嚴重合併性免疫缺失病 (SCID)

單字	中譯	單字	中譯
autoimmune disease	自體免疫疾病	human immunodeficiency virus, HIV	人類免疫缺失症病毒 (HIV)
acquired immunodeficiency syndrome (AIDS)	後天免疫缺乏症候群 (AIDS)		

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

❶ _____ allergy cause(s) _____.

例句：Seafood **allergies cause** skin redness, swelling, and rashes.
海鮮過敏症造成皮膚紅腫出疹。

❷ The symptoms of _____ include _____.

例句：**The symptoms of** systemic lupus erythematosus **include** widespread inflammation and tissue damage.
全身性紅斑狼瘡的症狀包含廣泛性發炎、造成組織損害。

❸ The greater _____, the stronger_____.

例句：**The greater** the difference is in MHC molecules, **the stronger** the rejection is.
MHC 分子差異愈大，排斥作用愈強。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、學生了解引發過敏反應的過程。

Students understand the processes that trigger allergic reactions.

二、學生了解自體免疫疾病及免疫缺失症等免疫失調疾病。

Students understand immune disorders such as autoimmune diseases and immunodeficiency disorders.

三、學生了解排斥作用的產生的原因。

Students understand the causes of rejection.

❧ 例題講解 ☙

例題一

說明：測試學生是否理解免疫系統的延伸概念。

Assess students' understanding of extended concepts related to the immune system.

What is/are the main causes of myasthenia gravis?

(A) Genetic diseases lead to neurodegeneration.

(B) Autoimmunity causes motor neurodegeneration.

(C) Autoimmunity leads to a reduction in the number of neurotransmitter receptors.

(D) Poor immunity causes infection and degeneration of muscle cells.

(E) Neutrophils are the primary immune cells involved in inflammatory and allergic reactions.

重症肌無力的主要原因是什麼？

(A) 遺傳疾病導致神經退化。

(B) 自體免疫引起運動神經退化。

(C) 自體免疫導致神經傳遞物質的受體數目減少。

(D) 免疫力不佳引起肌肉細胞感染並退化。

(E) 嗜中性血球是參與發炎和過敏反應的主要免疫細胞。

（97 年指考 7）

Student: Teacher, what type of disease is myasthenia gravis?

Teacher: It is an autoimmune disease.

Student: How does the immune system cause muscle weakness?

Teacher: That's a good question. Since the patient has produced antibodies that act on the acetylcholine receptors on the motor endplate, this prevents the signals for movement from being transmitted, leading to muscle weakness.

Student: I see! No wonder the answer is C.

學生： 請問老師重症肌無力是什麼類型的疾病？

老師： 屬於一種自體免疫疾病。

學生： 那免疫系統是怎麼造成肌肉無力的呢？

老師： 問得很好，因為患者產生了抗體作用在運動終板的乙醯膽鹼受體上，導致運動的訊息無法傳遞，進而導致肌無力。

學生： 原來如此！難怪答案要選 C。

例題二

說明：測試學生是否了解過敏、先天性免疫、後天性免疫等免疫系統的重要觀念。
Assess students' understanding of key concepts of the immune system, such as allergies, innate immunity, and adaptive immunity.

The human defense system not only provides the ability to resist infectious diseases, but is also related to disease prevention or the occurrence of some diseases. Which of the following statements about defense systems is/are correct?

(A) People who are allergic to peanuts can detect allergic symptoms when they eat peanuts for the first time.

(B) To generate protective immunity, influenza vaccination primarily induces a lymphocyte-dominated adaptive (acquired) immune response.

(C) Patients bitten by venomous snakes should receive antivenom, which contains antibodies that neutralize the venom.

(D) Myasthenia gravis is an autoimmune disease in which patients produce T cells which fight against their own muscle cells.

(E) If the cells of two people have different major histocompatibility complexes (MHC), they can still transfuse blood to each other if their blood types match.

人類防禦系統不僅提供抵抗感染性疾病的能力，也與疾病預防或一些病症發生有關。下列有關防禦系統的敘述，哪些正確？（多選）

(A) 對花生過敏的人，在第一次吃花生時就可以察覺自身的過敏症狀。

(B) 為產生保護力，接種流感疫苗主要引發淋巴球為主的後天（獲得）免疫反應。

(C) 毒蛇咬傷的患者應接受抗蛇毒血清，此血清具有能中和蛇毒的抗體。

(D) 重症肌無力為自體免疫疾病，是因患者產生 T 細胞對抗自身肌肉細胞。

(E) 當兩人細胞的主要組織相容性複體（MHC）不同，若血型相符仍可以相互輸血。

（109 年指考 28）

Student: Teacher, will patients have allergic reactions when exposed to allergens for the first time?

Teacher: That's a good question. When first exposed, usually the immune system has not yet recognized the allergen, so it is unable to secrete histamine and other substances quickly and in large quantities. Therefore, allergic reactions are less likely to occur during the first exposure.

Student: So why can two people with the same blood type still receive blood transfusions if they have different MHCs?

Teacher: Although red blood cells lack a nucleus and do not express MHC, they do have A or B antigens on their surface. So, you still need to pay attention to blood type.

Student: I see!

學生： 請問老師，患者在第一次接觸過敏原時會有過敏反應嗎？

老師： 問得很好，第一次接觸時，通常免疫系統尚未辨識過敏原，因此無法快速、大量分泌組織胺等物質，因此較不會有過敏反應。

學生： 那為甚麼具不同 MHC 的兩人，血型相同還是可以輸血呢？

老師： 因為紅血球缺乏細胞核，不會表現 MHC，但表面具有 A 或 B 抗原，因此仍需注意血型相符。

學生： 原來如此！我學會了。

★ 主題六 生殖 ★
Reproduction

國立彰化師範大學生物學系 張惟蓁
國立彰化師範大學英語學系 顏妤真

■ 前言 Introduction

在國中階段學生已學過「人類的生殖系統」，本章節希望學生能夠進一步了解人體生殖系統與整個生殖的歷程。人類的生殖週期相當複雜，尤其涉及下視丘、腦垂腺、卵巢、子宮之間複雜的關係，教師可以以排卵為中心區分出各個時期，排卵前的的重點在於準備受孕的卵，排卵後的重點則在為懷孕作準備。生殖的意義在於動物需透過生殖系統以繁衍後代，學生系統性地理解生殖的歷程，進而也能理解生命的可貴、尊重生命。

語言作為輔助學科教學使用，希望透過定義、順序，及相似句構、不同內容的英文句型，學生能夠更容易抓到本章重點。

6-1 生殖腺與配子形成
Gonads and Gametogenesis

■ 前言 Introduction

在此小節，學生在國中階段學過「人類的生殖系統」，教師藉由探討活動讓同學觀察雌、雄鼠或兔的生殖腺與生殖細胞，並推測配子的形成過程，接著以人體為例，讓同學認識精子的構造、精子與卵形成時的激素調節等。在授課中，教師可以搭配相似句型結構、不同內容的英文句型，說明男女生殖構造的差異、精子不同部位的功能、以及激素的分泌，透過代換重要詞語的方式幫助學生抓到重點。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
seminiferous tubule	細精管	oogonium (pl. oogonia)	卵原細胞
hormone	激素	primary oocyte	初級卵母細胞
spermatogonium	精原細胞	secondary oocyte	次級卵母細胞
primary spermatocyte	初級精母細胞	ovum (pl. ova)	卵
secondary spermatocyte	次級精母細胞	follicle	濾泡
spermatid	精細胞	polar body	極體
sperm	精子	follicle-stimulating hormone (FSH)	濾泡刺激素
acrosome	頂體	luteinizing hormone (LH)	黃體成熟素
testosterone	睪固酮	corpus luteum	黃體

單字	中譯	單字	中譯
Estrogen	動情素	follicular phase	濾泡期
menstrual cycle	月經週期	ovulatory phase	排卵期
ovarian cycle	卵巢週期	luteal phase	黃體期
uterine cycle	子宮週期	secretory phase	分泌期
menstrual flow stage	行經期	endometrium	子宮內膜
proliferative stage	增生期	fertilization	受精

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

❶ _____ is regulated by _____.

例句：The ovarian cycle **is regulated by** hormones secreted by the hypothalamus, anterior pituitary gland, and gonads.
卵巢週期受到下視丘、腦垂腺前葉與生殖腺分泌的激素調控。

❷ During _____, _____.

例句：**During** ovulation phase, the mature follicle releases a secondary oocyte into the oviduct.
在排卵期間，成熟的濾泡會將次級卵母細胞釋放到輸卵管。

❸ _____ consists of _____.

例句：The uterine cycle **consists of** the menstrual phase, proliferative phase, and secretory phase.
子宮週期包括行經期、增生期和分泌期。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、學生了解人類配子的形成過程。

Students understand the process of human gamete formation.

二、學生了解明精子與卵形成時的激素調節。

Students understand the hormone regulation of sperm and ovum formation.

❧ 例題講解 ☙

例題一

說明：學生能夠了解人體配子的形成與排卵。

Students are able to learn about human gamete formation and ovulation.

Reproductive medicine technology cultivates external fertilized embryos and then implants them into the mother's body. This has assisted many people in having children. Using this technique, what kind of cells do mothers need to provide for in vitro fertilization and embryo culture?

(A) Oogonium (B) Primary oocyte

(C) Secondary oocyte (D) Mature ovum

生殖醫學技術利用體外受精胚胎培養再植入母體，協助非常多人生兒育女。應用此技術，需要母親提供何種細胞以進行體外受精與胚胎培養？

(A) 卵原細胞

(B) 初級卵母細胞

(C) 次級卵母細胞

(D) 成熟的卵細胞

（110 年生物指考 18）

Teacher: What type of cells do oogonia become as an embryo develops?

Student: Primary oocytes.

Teacher: That's right! After entering puberty, each month usually only one primary oocyte completes the first meiotic division. So, what kind of cell does it become?

Student: Secondary oocyte.

Teacher: The follicle ruptures and the secondary oocyte is released into the oviduct. What do we call this process?

Student: Ovulation.

Teacher: Very good! When does the secondary oocyte complete the second meiotic division and form an ovum?

Student: After being fertilized.

Teacher: What kind of cells should be removed from the mother's body for in vitro fertilization and embryo culture when using reproductive medicine technology?

Student: Secondary oocyte.

Teacher: Correct! The secondary oocyte will form an ovum after fertilization, and the oosperm will continue to divide and develop after the fusion of the egg nucleus and the sperm nucleus.

老師： 請問同學在胚胎發育時，卵原細胞就已經成為什麼樣的細胞了？

學生： 初級卵母細胞。

老師： 沒錯！進入青春期後，每個月通常只有一個初級卵母細胞能完成減數分裂第一階段，成為什麼樣的細胞？

學生： 次級卵母細胞。

老師： 濾泡破裂，次級卵母細胞被釋出進入輸卵管，此過程稱為什麼？

學生： 排卵。

老師： 很好！等到什麼時候，次級卵母細胞才會完成減數分裂第二階段，形成卵？

學生： 受精以後。

老師： 因此生殖醫學技術在進行體外受精時，應該要取出母親體內的何種細胞以進行體外受精與胚胎培養？

學生： 次級卵母細胞。

老師： 正確！次級卵母細胞，受精後才會形成卵，待卵核與精核融合後才成為受精卵繼續分裂發育。

例題二

說明：學生能了解生殖相關激素及其作用。

Students can learn about reproductive hormones and their roles.

Which of the following statements about reproductive hormones is/are correct?

(A) Testosterone is secreted by the cells lining the seminiferous tubules.

(B) Follicle-stimulating hormone (FSH) is secreted by the anterior pituitary.

(C) Luteinizing hormone (LH) peaks after ovulation.

(D) Estrogen levels tend to increase before ovulation.

(E) Luteinizing hormone (LH) stimulates contraction of the uterine smooth muscle.

下列有關生殖激素的敘述，哪些正確？

(A) 睪固酮是由細精管管壁細胞所分泌。

(B) 促濾泡成熟素（FSH）是由腦垂腺前葉所分泌。

(C) 黃體成長激素（LH）在排卵後達到最高濃度。

(D) 在排卵前動情素的濃度會有提升的趨勢。

(E) 黃體素可促進子宮平滑肌收縮。

（110 年生物指考 27）

Teacher: (A) Which cells in the seminiferous tubules secrete testosterone?

Student: Interstitial cells.

Teacher: What is the role of the cells on the wall of the seminiferous tubules?

Student: The spermatogonia on the wall undergo meiosis and then form spermatozoa.

Teacher: That's right! (B) What secretes follicle-stimulating hormone (FSH) and luteinizing hormone (LH)? Where does it function?

Student: It is secreted by the anterior pituitary and effects the gonads.

Teacher: Correct! (C) When does luteinizing hormone (LH) reach its highest concentration?

Student: Before ovulation, not after ovulation.

Teacher: That's right! And it is the day before ovulation that the concentration reaches its peak. Then (D) what is the trend of the concentration of estrogen before ovulation?

Student: In the last three days before ovulation, the release of estrogen increases greatly.

Teacher: Very good! (E) What are the functions of luteinizing hormones?

Student: Thickening and maintaining the endometrium and inhibiting contraction of the uterine smooth muscle.

老師： (A)睪固酮是由細精管的什麼細胞所分泌？

學生： 間質細胞。

老師： 而細精管的管壁細胞作用為何？

學生： 管壁上的精原細胞會行減數分裂，進而形成精子。

老師： 沒錯！(B)促濾泡成熟素（FSH）和黃體成長激素（LH）都是由誰來分泌？作用在哪裡？

學生： 由腦垂腺前葉所分泌，並作用在生殖腺上。

老師： 正確！(C)黃體成長激素（LH）在什麼時候達到最高濃度？

學生： 排卵前，而非排卵後。

老師： 沒錯！而且是在排卵前一天濃度達到最高峰。接著(D)在排卵前動情素的濃度有怎麼樣的趨勢？

學生： 在排卵前最後三天動情素釋放量大增，有提升的趨勢。

老師： 很好！(E)黃體素有哪些功能？

學生： 使子宮內膜增厚並維持子宮內膜厚度，以及抑制子宮平滑肌收縮。

6-2 受精過程
The Process of Fertilization

■ 前言 Introduction

在此小節，學生在國中階段已了解「受精作用」的定義以及「受精的過程通常發生於輸卵管前端」，教師以人體為例，來讓同學進一步了解受精的過程、卵外圍的構造、為何胚胎發育與懷孕要在母體內發展、為何需要如此多精子協同受精等。在授課中，教師可以搭配英文句型，說明相關定義及受精過程，幫助學生認識定義及辨別不同細胞在受精過程中扮演的角色。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
acrosin	頂體素	corona radiata	放射冠
zona pellucida	透明帶	oviduct	輸卵管
embryo	胚胎	nucleus	細胞核
haploid chromosome	單套染色體	identical twins	同卵雙胞胎
fraternal twins	異卵雙胞胎	oosperm	受精卵

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

❶ _____ is called _____.

例句：The process during which the sperm and ovum unite **is called** fertilization.
精子與卵結合的過程稱為受精作用。

❷ _____ enables _____ to _____

例句：The release of digestive enzymes from the acrosome **enables** the sperm **to** penetrate the zona pellucida of the ovum.
精子的頂體釋放消化酶，使精子能夠穿透卵子的透明帶。

■ 問題講解 Explanation of Problems

ଓ 學習目標 ଌ

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、學生了解受精過程如何進行。

Students understand how the process of fertilization works.

例題講解

例題一

說明：學生能了解受精過程。

Students can understand the process of fertilization.

Which of the following statements about fertilization is incorrect?

(A) Before the sperm can enter the ovum, it must pass through the outer layer of the ovum, the corona radiata and the zona pellucida.

(B) Twins result from fertilization after two sperm enter the nucleus of the ovum at the same time.

(C) Fertilization most often occurs in the ampulla of the oviduct.

(D) Fertilization is the union of a haploid chromosome sperm with a haploid chromosome ovum.

有關受精的敘述，下列何者錯誤？

(A) 精子在進入卵子之前，必須穿過卵子外層的放射冠及透明帶。

(B) 雙胞胎是指同時有二隻精子進入卵子的細胞核完成受精。

(C) 受精最常發生於輸卵管壺腹部。

(D) 受精是單套染色體的精子與單套染色體卵子的結合。

（110 年第一次專技高考護理師產兒科護理學 10）

Teacher: (A) What structures in the ovum must the sperm pass through before entering it?

Student: The outer corona radiata cells and the zona pellucida of the oocyte.

Teacher: That's right! (B) How are identical and fraternal twins formed?

Student: Identical twins are from the oosperm formed by the union of an ovum and a sperm. The embryo is naturally divided into two during development and forms into two embryos. On the other hand, fraternal twins are two independent oosperms formed by the union of an ovum and a sperm.

Teacher: That's right. Typically, only one sperm enters an ovum during fertilization. If more than two sperm enter an ovum, this occurrence is referred to as polyspermy. Next, let's look at (C). Where does fertilization most often occur?

Student: The front of the oviduct.

Teacher: That's right! In option (C) the ampulla of the oviduct is situated at the front, covering approximately 2/3 of the total length of the oviduct. It has a thick and elongated diameter with a curved route.

Teacher: Finally, let's look at (D). How many sets of chromosomes from sperm and ovum combine during fertilization?

Student: A single set of chromosomes from sperm and a single set of chromosomes from ovum.

老師： (A) 精子在進入卵子之前，必須穿過卵的哪些構造？

學生： 外層的放射冠細胞以及卵母細胞的透明帶。

老師： 沒錯！(B) 同卵雙胞胎和異卵雙胞胎分別是如何形成的？

學生： 同卵雙胞胎為一個卵子與一個精子結合而產生一個受精卵，胚胎在發育期間自然地一分為二，形成兩個胚胎；而異卵雙胞胎則是分別由一個卵子與一個精子結合，所形成兩顆獨立的受精卵。

老師： 沒錯，一般動物的受精是一個卵內只進入一個精子，若有兩個以上的精子進入一個卵內，則此現象稱為多精受精。接下來請問同學(C) 受精最常發生於哪個位置？

學生： 輸卵管的前端。

老師： 沒錯！(C)輸卵管的壺腹部位於前端，約佔輸卵管全長的 2/3，管徑粗而較長，行程彎曲。

老師： 最後(D) 受精是幾套染色體的精子與幾套染色體卵子的結合？

學生： 單套染色體的精子與單套染色體的卵。

例題二

說明：學生能夠了解受精過程。

Students can understand the process of fertilization.

Which of the following statements about fertilization is correct?

(A) It usually occurs in the cavity of the uterus.

(B) It occurs after the ovum produces the 2nd polar body.

(C) It usually occurs 3 to 5 days after ovulation.

(D) It can promote the activation of oocytes.

下列關於受精作用（fertilization）之敘述，何者正確？

(A) 通常發生於子宮腔。

(B) 在卵子產生第二極體（2nd polar body）後發生。

(C) 通常在排卵後 3-5 天發生。

(D) 可促使卵細胞（oocyte）活化。

（100 年第一次專技高考_醫師（一）29）

Teacher: Where does fertilization usually occur?

Student: It usually occurs in the oviduct.

Teacher: That's right! Does fertilization occur after the primary oocyte finishes the first meiotic division or after the second meiotic division?

Student: It occurs after the primary oocyte finishes the first meiotic division.

Teacher: Correct!

That is, fertilization occurs after the primary oocyte produces the first polar body.

Actually, option (C), "Fertilization usually occurs 3 to 5 days after ovulation." is incorrect. Because ova can survive for about 24 hours after being released, fertilization should occur within one day of ovulation.

Look at option (D), "Fertilization can promote the activation of oocytes." I hope that you can have a general understanding of this concept.

老師： 請問同學們，受精作用通常發生的位置在哪？

學生： 通常發生於輸卵管。

老師： 沒錯！那受精作用是發生在初級卵母細胞完成第一階段的減數分裂後，還是在次級卵母細胞完成減數分裂第二階段後？

學生： 是在初級卵母細胞完成第一階段的減數分裂後。

老師： 正確！也就是受精作用是在初級卵母細胞產生第一極體後所發生的。
那麼跟同學們補充選項(C) 受精作用通常在排卵 3-5 天發生是錯誤的，因為卵子被排出後可以存活約 24 小時，所以受精作用應該在排卵後 1 天內發生。
最後補充選項(D)受精作用會促使卵細胞活化，同學稍微了解知道就可以。

6-3 胚胎發育與懷孕
Embryonic Development and Pregnancy

■ 前言 Introduction

在此小節教師將以人體為例，來讓學生認識胚胎發育的過程，依序由排卵前卵的成熟、排卵後子宮準備著床的狀態、受精卵在輸卵管中移動、囊胚細胞發育而成的三個胚層、懷孕與胎兒期，最後成熟娩出的完整懷孕過程，並藉由探討活動，探討代理孕母的倫理與法律問題。在授課中，教師可以搭配英文句型，說明人體胚胎發育過程的順序，以及三個胚層各自分化為何種細胞，透過順序和代換重要詞語的方式幫助學生抓到重點。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
cleavage	卵裂	embryonic stage	胚胎期
morula	桑椹胚	fetal stage	胎兒期
blastula	囊胚	human chorionic gonadotropin (HCG)	人類絨毛膜促性腺素
gastrula	原腸胚	mitosis	有絲分裂
ectoderm	外胚層	umbilical cord	臍帶
mesoderm	中胚層	umbilical artery	臍動脈
endoderm	內胚層	umbilical vein	臍靜脈

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

❶ _____ occurs after _____

例句：Implantation **occurs after** the blastula attaches to the thickened endometrium.
胚胎著床發生於囊胚附著於增厚的子宮內膜之後。

❷ _____ develop(s) from _____(ectoderm/mesoderm/endoderm).

例句(1)：Skin and sensory organs **develop from** the ectoderm.
皮膚與感覺器官由外胚層發育而來。

例句(2)：Bones and muscles **develop from** the mesoderm.
骨骼與肌肉由中胚層發育而來。

例句(3)：Gastrointestinal epithelium **develops from** the endoderm.
消化道上皮組織由內胚層發育而來。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本章節後，學生應習得以下概念：

After completing this section, students should acquire the following concepts:

一、學生了解人體胚胎的發育過程。

Students understand the process of the development of human embryos.

例題講解

例題一

說明：學生了解人類受精、懷孕及胚胎發生過程。

Students can understand the process of human fertilization, pregnancy and embryogenesis.

Which of the following statements about human fertilization, pregnancy and embryogenesis is/are true?

(A) During fertilization sperm will unite with the secondary oocyte.

(B) The ovum and sperm unite in the uterus to form an oosperm.

(C) The arteries of the fetus are connected with the veins of the mother in the placenta.

(D) The blastocyst is formed by mitosis of the oosperm.

(E) The umbilical cord, which is between the fetus and the placenta, contains both arteries and veins.

下列有關人類受精、懷孕及胚胎發生過程，哪些正確？

(A) 精子會與次級卵母細胞結合以進行受精作用。

(B) 卵與精子在子宮中結合，形成受精卵。

(C) 胎兒的動脈與母體的靜脈在胎盤連通。

(D) 胚胞是由受精卵經有絲分裂所形成。

(E) 臍帶介於胎兒及胎盤之間，內有動脈與靜脈。

（104 年生物指考 22）

Teacher: (A) What type of cells come from mature follicles?

Student: Secondary oocytes.

Teacher: For fertilization, what type of cells will sperm bind to?

Student: Secondary oocytes.

Teacher: That's right! (B) Where in the mother's body does the union of ovum and sperm usually occur?

Student: The front of the oviduct.

Teacher: Very good! (C) Are the arteries of the fetus connected with the veins of the mother in the placenta?

Student: No, the blood vessels of the fetus and the blood vessels of the mother each form a capillary bed in the placenta.

Teacher: Correct! The fetal and maternal circulatory systems in the placenta are separate. (D) What is the process where an embryo forms from an oosperm?

Student: Mitosis.

Teacher: That's right! (E) Where is the umbilical cord located?

Student: Between the fetus and the placenta.

Teacher: Very good! There are two umbilical arteries and one umbilical vein in the umbilical cord, so (E) is correct.

老師： (A) 自成熟濾泡排出的是什麼細胞？

學生： 次級卵母細胞。

老師： 精子會與何種細胞結合，以進行受精作用？

學生： 次級卵母細胞。

老師： 沒錯！(B) 卵與精子的結合通常在母親體內的何處發生？

學生： 輸卵管的前端。

老師： 很好！(C) 胎兒的動脈與母體的靜脈在胎盤有相連通嗎？

學生： 沒有，胎兒的血管與母體的血管會各自在胎盤處形成微血管網。

老師： 正確！胎盤中胎兒與母體的循環系統是各自獨立的。(D) 胚胎是由受精卵經過甚麼樣的過程形成的？

學生： 有絲分裂。

老師： 沒錯！(E) 臍帶介於什麼和什麼之間？

學生： 胎兒和胎盤。

老師： 很好！臍帶內有兩條臍動脈與一條臍靜脈，因此(E) 正確。

例題二

說明：學生應用推理的能力，了解胚胎發育與懷孕的過程中激素的調節。

Students can apply reasoning skills to understand the regulation of hormones during embryonic development and pregnancy.

Certain hormones secreted by the placental tissue can enter the maternal circulatory system to maintain the secretion of maternal estrogen and luteinizing hormone and continue to thicken the endometrium. When the hormone concentration in maternal plasma is high, it also appears in urine. Pregnancy tests are used to determine whether a woman is pregnant by testing whether these hormones appears in her urine. Which of the following characteristics are the reasons why hormones can be used as the basis for pregnancy tests? (multiple choice)

(A) They are secreted by placental tissues.
(B) They maintain the secretion of estrogen.
(C) They maintain the secretion of luteinizing hormone.
(D) They maintain the thickness of the endometrium.
(E) They appear in urine.

胎盤的組織所分泌的某激素可進入母體循環系統，以維持母體動情素及黃體激素的分泌與子宮內膜繼續增厚。母體血漿中此激素濃度高時，也會出現在尿液中。驗孕筆即檢驗女性尿液中是否出現該激素，判斷是否懷孕。下列哪些特徵是該激素可作為驗孕的依據？（多選）

(A) 為胎盤的組織所分泌。
(B) 能維持動情素的分泌。
(C) 能維持黃體激素分泌。
(D) 能維持子宮內膜繼續增厚。
(E) 會出現在尿液中。

（110 年生物學測 23）

Teacher: What is the main point of this question?
Student: Finding out which characteristics are the reason why the hormones can be used as the basis for pregnancy tests.
Teacher: That's right! First, let's look at option (A). Can being secreted by placental tissue be the basis for pregnancy tests?

Student: Yes, because after an embryo implants in the endometrium, the structure of the placenta will be formed, and then secrete this hormone. Therefore, it can be the basis for a pregnancy test.

Teacher: Very good! Can (B) and (C), maintaining the secretion of maternal estrogen and luteinizing hormone, be the basis for pregnancy testing?

Student: No, because whether pregnant or not, the mother will secrete estrogen and luteinizing hormone.

Teacher: Correct! Next, let's look at (D). Can maintaining the thickness of the endometrium be the basis for pregnancy tests?

Student: No, because even if there is no pregnancy, the endometrium will thicken due to the effects of both estrogen and luteinizing hormone after every menstrual cycle.

Teacher: That's right! Finally, let's look at (E). Can hormones appearing in urine be the basis for pregnancy tests?

Student: Yes, because pregnancy tests test the components of urine, hormones must appear in the urine.

老師： 請問同學們此題幹敘述，主要是要問什麼？

學生： 找出該激素可作為驗孕的特徵。

老師： 沒錯！首先(A) 為胎盤的組織所分泌是否可作為驗孕的依據？

學生： 可以，因為胚胎在子宮內膜確實著床以後，才會形成胎盤的構造，進而分泌此激素，因此可作為是否懷孕的依據。

老師： 很好！(B)和(C)維持母體動情素及黃體激素的分泌是否可作為驗孕的依據？

學生： 不行，因為無論懷孕與否，母體都會分泌動情素與黃體素。

老師： 正確！再來(D) 能維持子宮內膜繼續增厚是否可作為驗孕的依據？

學生： 不行，因為每次月經週期，在行經期後，即使沒有受孕，受到動情素和黃體素兩種激素作用，子宮內膜都會增厚。

老師： 沒錯！最後(E) 會出現在尿液中是否可作為驗孕的依據？

學生： 可以，因為驗孕筆檢驗的是尿中的成分，故該激素一定要出現在尿液。

國內外參考資源 More to Explore

HHMI Biointeractive 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)。 https://www.biointeractive.org/	
Rediscovering Biology: Molecular to Global Perspectives 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。 https://www.learner.org/classroom-resources/	
Khan Academy 可汗學院，有分年級的生物教學影片及問題的討論。 https://www.khanacademy.org/	
Interactive Simulations, University of Colorado Boulder 互動式電腦模擬，除了生物，還有其他自然科。 https://phet.colorado.edu/	

自然領域雙語教學資源手冊：生物科英語授課用語
[選修生物(III)]
A Reference Handbook for Senior High School Bilingual Teachers in the Domain of Natural Sciences (Biology): Instructional Language in English
[Elective Biology (III)]

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- 指導單位：教育部師資培育及藝術教育司
- 撰稿：陳芷翎、陳郁暄、陳柳潔、陳瑞安、張濬濤、陳姵晏、張惟蓁、顏妤真
- 學科諮詢：駱奕帆
- 語言諮詢：龔慧懿
- 綜合規劃：曾松德
- 排版：吳依靜
- 封面封底：JUPE Design

發行單位　國立彰化師範大學雙語教學研究中心
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