HOLIDAY HOMEWORK 假期作业

AP Biology

Exercise sheets and past-paper practice, topic by topic.

每个单元：练习卷 + 历年真题。

For class or self-study • no answer keys included.

Contents 目录

1 Water and the molecules of life – Part 1

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
polar	极性			
hydrogen bonds	氢键			
Carbon	碳			
macromolecules	大分子			
polymers	聚合物			
monomers	单体			
dehydration synthesis	脱水缩合			
hydrolysis	水解			
Carbohydrates	碳水化合物			
cellulose	纤维素			
Lipids	脂质			
hydrophobic	疏水			

Recall

You already know some biology chemistry:

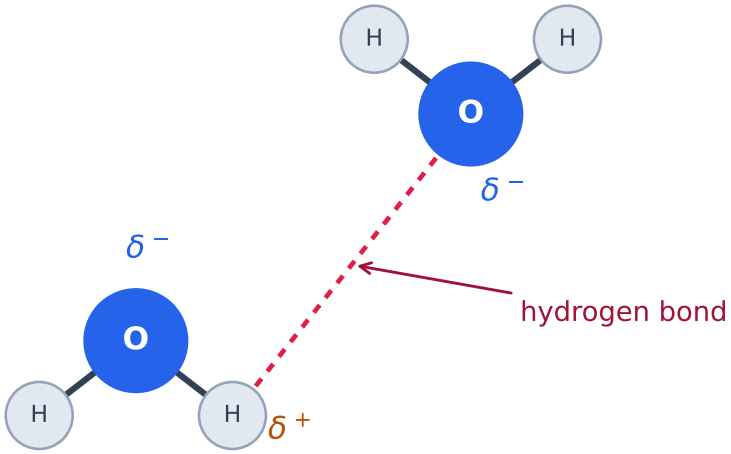
- Living things are built mostly from a few elements – carbon, hydrogen, oxygen, nitrogen.
- Water is everywhere in life, inside and around cells.
- You have met carbohydrates, fats, and proteins as the main food molecules.

This sheet lines up why these molecules matter. Each idea has a short worked example.

New ideas

1 Water is special

Water is **polar** 极性: its oxygen pulls electrons a little more than its hydrogens, so one end is slightly negative and the other slightly positive. This lets water molecules form **hydrogen bonds** 氢键 with each other.



H-bond: δ^+H ⋯ δ^-O · cohesion, adhesion, high c

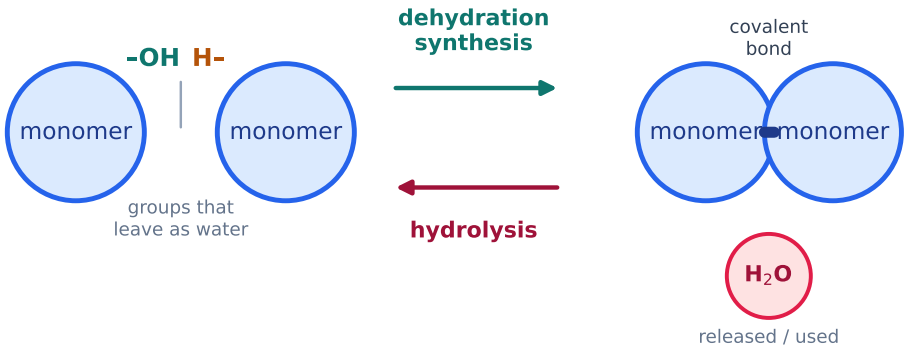
These bonds give water its life-supporting properties: it sticks together, dissolves many substances, and resists temperature change.

2 Carbon builds life

Carbon 碳 can form four bonds, so it builds long chains and rings – the skeletons of all biological molecules.

3 Building and breaking big molecules

Large molecules (**macromolecules** 大分子) are **polymers** 聚合物 built from repeating units called **monomers** 单体. Cells join monomers by **dehydration synthesis** 脱水缩合 (removing water) and break them by **hydrolysis** 水解 (adding water).



dehydration synthesis: monomers → polymer + H_2O

4 Carbohydrates and lipids

- **Carbohydrates** 碳水化合物 (sugars) store energy and give structure (like **cellulose** 纤维素 in plants).
- **Lipids** 脂质 (fats) are **hydrophobic** 疏水 (they do not mix with water); they store energy and build cell membranes.

Watch out: all of water's helpful properties – sticking together, dissolving things, resisting temperature change – come from the **hydrogen bonds** between its molecules.

Practice

Try these in order. The methods are all above.

2.1 Explain why a water molecule is described as polar. [2]

2.2 State why carbon is able to build such a wide variety of large molecules. [2]

2.3 Name the process that (a) joins monomers into a polymer, (b) breaks a polymer apart. [2]

2.4 Give one function of carbohydrates and one function of lipids in living things. [2]

2.5 State what "hydrophobic" means and give one example of a hydrophobic molecule.[2]

2. Geneticists investigated the mode of inheritance of a rare disorder that alters glucose metabolism and first shows symptoms in adulthood. The geneticists studied a family in which some individuals of generations II and III are known to have the disorder. Based on the pedigree (Figure 1), the geneticists concluded that the disorder arose in individual II−2 and was caused by a mutation in mitochondrial DNA.

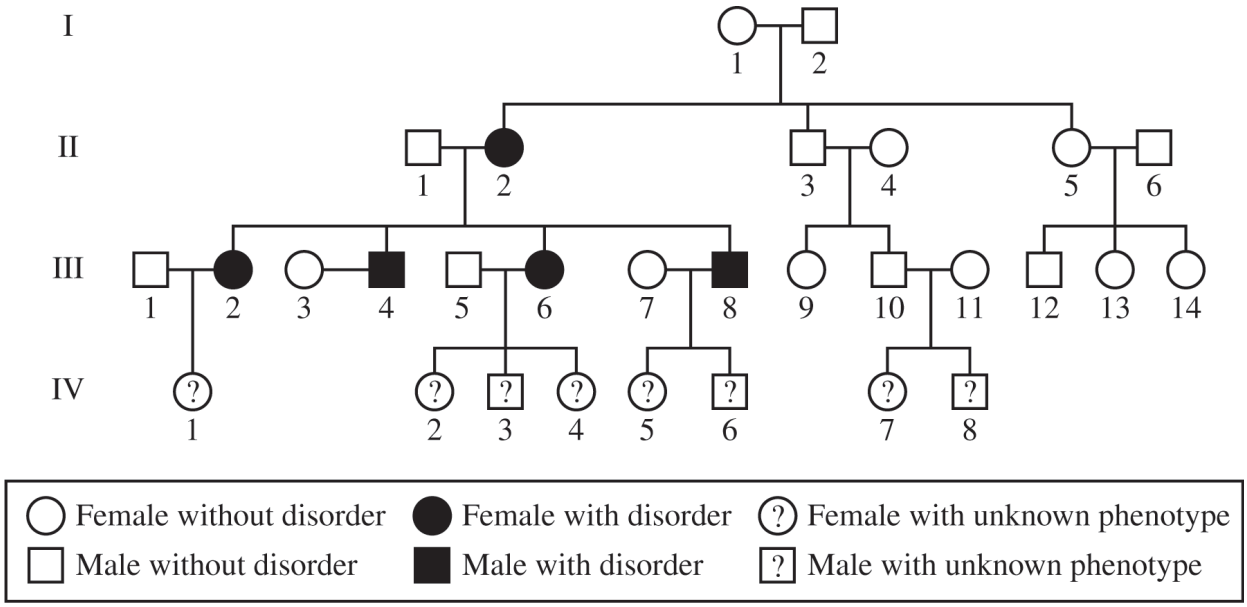


Figure 1. Pedigree of a family showing individuals with the glucose metabolism disorder. A question mark indicates that the phenotype is unknown.

TABLE 1. AVERAGE BLOOD GLUCOSE LEVELS OF INDIVIDUALS IN GENERATION IV

Individual	Average Blood Glucose Level (mg/dL ± $2SE_{\bar{x}}$)
IV−1	170 ± 15
IV−2	190 ± 10
IV−3	145 ± 5
IV−4	165 ± 15
IV−5	110 ± 15
IV−6	125 ± 5
IV−7	105 ± 15
IV−8	120 ± 10

TABLE 2. PHENOTYPIC CLASSIFICATIONS BASED ON BLOOD GLUCOSE LEVELS

Phenotype	Blood Glucose Level (mg/dL)
Normal	< 140 mg/dL
At risk	140 – 199 mg/dL
Affected	≥ 200 mg/dL

(a) The disorder alters glucose metabolism. **Describe** the atoms AND types of bonds in a glucose molecule.

(b) Using the template in the space provided for your response, **construct** an appropriately labeled graph based on the data in Table 1. **Determine** one individual who is both at risk of developing the disorder and has a significantly different blood glucose level from that of individual IV–1.

(c) Based on the pedigree, **identify** all individuals in generation IV who can pass on the mutation to their children.

(d) Based on the fact that individual II–2 is affected, a student claims that the disorder is inherited in an X-linked recessive pattern. Based on the student's claim, **predict** which individuals of generation III will be affected by the disorder. Based on the pedigree, **justify** why the data do NOT support the student's claim.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

1 Proteins and nucleic acids – Part 2

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

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Proteins	蛋白质			
amino acids	氨基酸			
peptide bonds	肽键			
denature	变性			
Nucleic acids	核酸			
nucleotides	核苷酸			

Recall

In Part A you met the idea that big biological molecules are polymers of small units. Two of them run all of life:

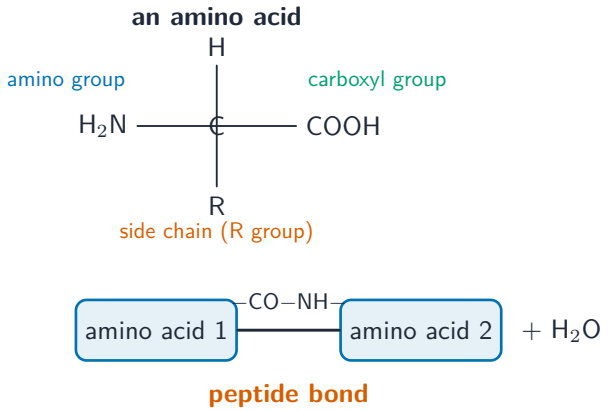
- **Proteins** do most of the work in cells (enzymes, muscle, structure).
- **DNA** carries the genetic instructions.

Each idea has a short worked example before the Practice.

New ideas

■ 1 Proteins

Proteins 蛋白质 are long chains of **amino acids** 氨基酸 joined by **peptide bonds** 肽键. There are 20 different amino acids, so a huge variety of proteins is possible.



condensation removes one water for each peptide bond

2 Shape decides function

A protein chain folds into a specific 3-D shape, and **its shape decides its job** – as an enzyme, a transporter, or a structural part.

primary (1°)	**secondary (2°)**	**tertiary (3°)**	**quaternary (4°)**
order of amino acids	α-helix & β-sheet (hydrogen bonds)	folded into a precise 3-D shape	two or more chains together

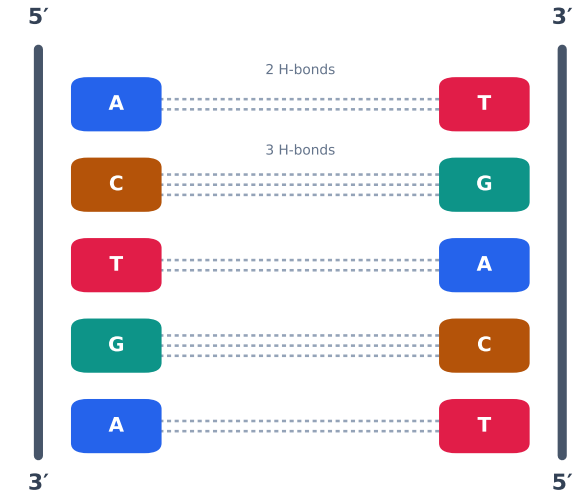
Heat or a change in pH can **denature** 变性 a protein – unfold it – which stops it working.

3 Nucleic acids

Nucleic acids 核酸 (DNA and RNA) store and carry genetic information. They are built from units called **nucleotides** 核苷酸, each a sugar, a phosphate, and a base.

4 DNA base pairing

DNA is two strands held together by pairing of the bases: A pairs with T, and C pairs with G.



A–T (2 H-bonds) · G–C (3 H-bonds) · antiparallel strands

complementary pairing: A with T, G with C · strands run antiparallel (5′ ↔ 3′)

Watch out: a protein's job depends completely on its **shape**. If heat or acid denatures (unfolds) it, the protein stops working – which is why high fever or the wrong pH is dangerous for enzymes.

Practice

Try these in order. The methods are all above.

2.1 State the small units that make up a protein, and the bond that joins them. [2]

2.2 Explain why a protein's shape is so important. [2]

2.3 State what "denature" means and give one thing that can cause it. [2]

2.4 Name the two nucleic acids and state what they do. [2]

2.5 In DNA, state which base pairs with (a) A, (b) C. [2]

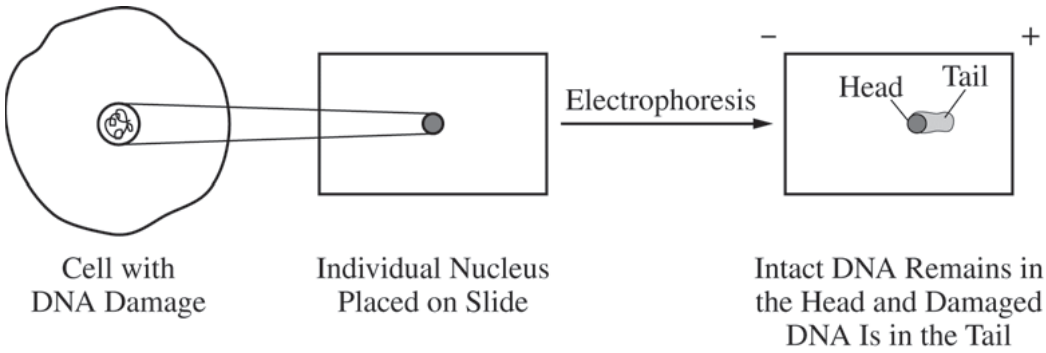


Figure 1. Comet assay to detect double-stranded breaks in DNA

6. A comet assay is a technique used to determine the amount of double-strand breaks in DNA (DNA damage) in cells. The nucleus of an individual cell is placed on a microscope slide coated with an agarose gel. An electric current is applied to the gel that causes DNA to move (electrophoresis), and the DNA is stained with a fluorescent dye. When viewed using a microscope, undamaged DNA from the nucleus appears as a round shape (the head), and the fragments of damaged DNA extend out from the head (the tail). The length of the tail corresponds to the amount of the damage in the DNA (see Figure 1).

   (a) To explain the movement of DNA fragments in the comet assay, **identify** one property of DNA and **provide reasoning** to support how the property contributes to the movement during the comet assay technique.

   (b) In a different experiment, cells are treated with a chemical mutagen that causes only nucleotide substitutions in DNA. **Predict** the likely results of a comet assay for this treatment.

3. Gibberellin is the primary plant hormone that promotes stem elongation. GA 3-beta-hydroxylase (GA3H) is the enzyme that catalyzes the reaction that converts a precursor of gibberellin to the active form of gibberellin. A mutation in the *GA3H* gene results in a short plant phenotype. When a pure-breeding tall plant is crossed with a pure-breeding short plant, all offspring in the F_1 generation are tall. When the F_1 plants are crossed with each other, 75 percent of the plants in the F_2 generation are tall and 25 percent of the plants are short.

Second Base in Codon

First Base in Codon	U	C	A	G	Third Base in Codon
U	UUU, UUC: Phe UUA, UUG: Leu	UCU, UCC, UCA, UCG: Ser	UAU, UAC: Tyr UAA Stop UAG Stop	UGU, UGC: Cys UGA Stop UGG Trp	U C A G
C	CUU, CUC, CUA, CUG: Leu	CCU, CCC, CCA, CCG: Pro	CAU, CAC: His CAA, CAG: Gln	CGU, CGC, CGA, CGG: Arg	U C A G
A	AUU, AUC, AUA: Ile AUG: Met or Start	ACU, ACC, ACA, ACG: Thr	AAU, AAC: Asn AAA, AAG: Lys	AGU, AGC: Ser AGA, AGG: Arg	U C A G
G	GUU, GUC, GUA, GUG: Val	GCU, GCC, GCA, GCG: Ala	GAU, GAC: Asp GAA, GAG: Glu	GGU, GGC, GGA, GGG: Gly	U C A G

Figure 1. The universal genetic code

(a) The wild-type allele encodes a GA3H enzyme with alanine (Ala), a nonpolar amino acid, at position 229. The mutant allele encodes a GA3H enzyme with threonine (Thr), a polar amino acid, at position 229. **Describe** the effect of the mutation on the enzyme and **provide reasoning** to support how this mutation results in a short plant phenotype in homozygous recessive plants.

(b) Using the codon chart provided, **predict** the change in the codon sequence that resulted in the substitution of alanine for threonine at amino acid position 229.

(c) **Describe** how individuals with one (heterozygous) or two (homozygous) copies of the wild-type *GA3H* allele can have the same phenotype.

2 Cells and their membranes – Part 1

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
organelles	细胞器			
nucleus	细胞核			
mitochondria	线粒体			
chloroplasts	叶绿体			
surface-area-to-volume ratio	表面积与体积比			
phospholipid bilayer	磷脂双分子层			
fluid mosaic model	流动镶嵌模型			
selectively permeable	选择透过性			

Recall

You already know that cells are the building blocks of life:

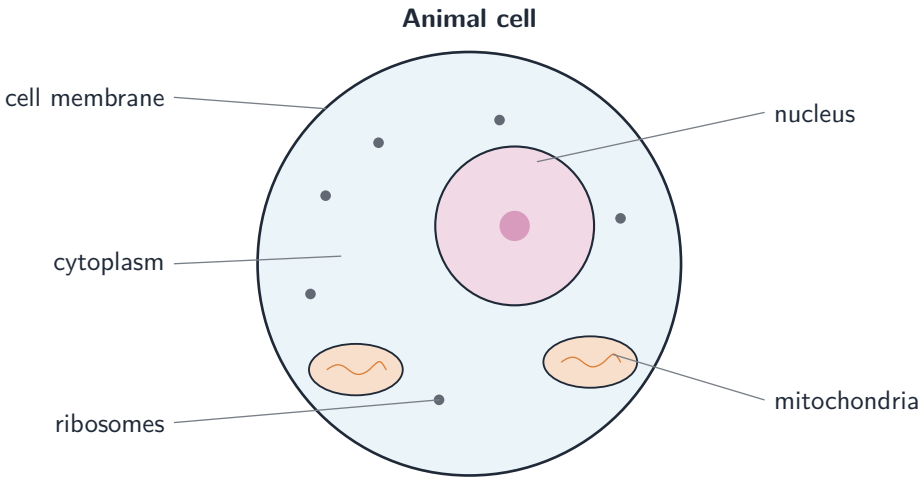
- You have seen animal and plant cells and named their parts.
- A **nucleus** holds the DNA; **mitochondria** release energy; plant cells have **chloroplasts**.
- A membrane surrounds every cell.

This sheet lines up cell structure for AP. Each idea has a short worked example.

New ideas

1 Organelles

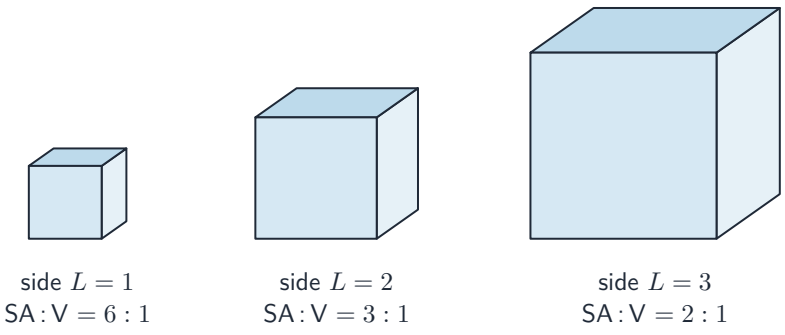
A cell divides its work among **organelles** 细胞器:



- the **nucleus** 细胞核 holds the DNA,
- **mitochondria** 线粒体 carry out respiration (release energy),
- **chloroplasts** 叶绿体 carry out photosynthesis (in plants).

2 Why cells stay small

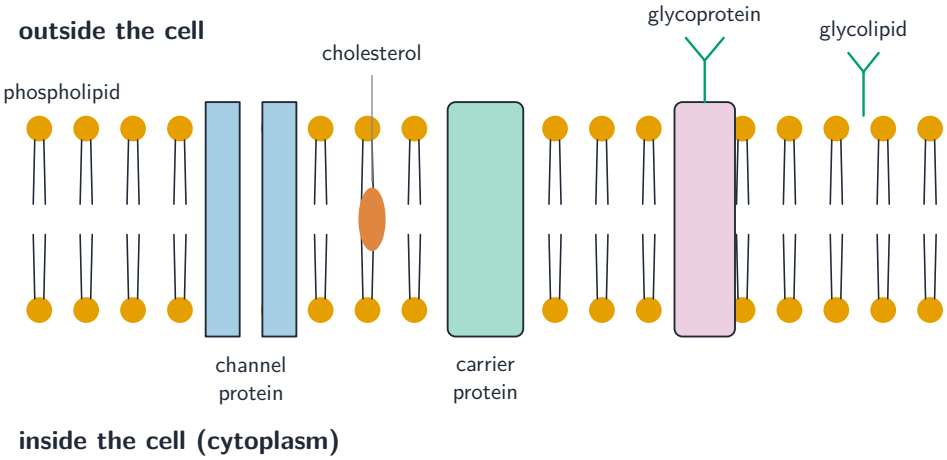
As a cell grows, its volume rises faster than its surface area, so its **surface-area-to-volume ratio** 表面积与体积比 falls. A small cell has enough surface to exchange materials fast enough for its inside.



a bigger cube (or cell) has a **smaller** surface area : volume ratio

3 The cell membrane

The membrane is a **phospholipid bilayer** 磷脂双分子层 – a double sheet with water-loving heads outside and water-hating tails inside – studded with proteins. This **fluid mosaic model** 流动镶嵌模型 pictures it as a fluid sheet in which the parts drift.



4 A selective barrier

The membrane is **selectively permeable** 选择透过性: small non-polar molecules pass easily, but large or charged particles need help. This lets the cell control what goes in and out.

Watch out: a bigger cell is worse at exchange, not better – its volume grows faster than its surface, so the surface-area-to-volume ratio drops and it cannot supply its interior fast enough.

Practice

Try these in order. The methods are all above.

2.1 State the job of (a) the nucleus, (b) the mitochondria. [2]

2.2 Explain why cells stay small, using the surface-area-to-volume ratio. [2]

2.3 Name the type of molecule that makes up most of the cell membrane. [1]

2.4 State what "selectively permeable" means. [2]

2.5 Name one organelle found in a plant cell but not an animal cell, and state its job.[2]

8. Estrogens are small hydrophobic lipid hormones that promote cell division and the development of reproductive structures in mammals. Estrogens passively diffuse across the plasma membrane and bind to their receptor proteins in the cytoplasm of target cells.

   (a) **Describe** ONE characteristic of the plasma membrane that allows estrogens to passively cross the membrane.

   (b) In a laboratory experiment, a researcher generates antibodies that bind to purified estrogen receptors extracted from cells. The researcher uses the antibodies in an attempt to treat estrogen-dependent cancers but finds that the treatment is ineffective. **Explain** the ineffectiveness of the antibodies for treating estrogen-dependent cancers.

STOP

END OF EXAM

8. Estrogens are small hydrophobic lipid hormones that promote cell division and the development of reproductive structures in mammals. Estrogens passively diffuse across the plasma membrane and bind to their receptor proteins in the cytoplasm of target cells.

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STOP

END OF EXAM

3. To investigate whether red blood cells of animals lose the ability to take in glucose from their environment as they age, scientists collected red blood cells from guinea pigs that ranged in age from one day old to seven months old. Scientists incubated an equal number of red blood cells in separate culture dishes that contained a 300 nM solution of radioactively labeled glucose. The amount of radioactively labeled glucose present inside the red blood cells of each group was measured over time.

   (a) **Describe** a difference between passive transport and active transport.

   (b) **Justify** why the scientists used an equal number of red blood cells in each culture dish as a control.

   (c) Glucose transporters are required for the facilitated diffusion of glucose into red blood cells. The scientists claim that the expression of the gene encoding these transporters decreases as guinea pigs age. If the scientists' claim is supported by experimental data, **predict** the effect of increased age on the amount of radioactively labeled glucose present inside the cells of each group.

   (d) **Justify** your prediction in part (c).

Write your responses to this question only on the designated pages in the separate Free Response booklet.

If there are multiple parts to this question, write the part letter with your response.

2 Moving substances across the membrane – Part 2

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
Diffusion	扩散			
Osmosis	渗透			
tonicity	张力			
Active transport	主动运输			
endocytosis	内吞			
exocytosis	外排			

Recall

In Part A you met the selectively permeable cell membrane. Now see how things cross it:

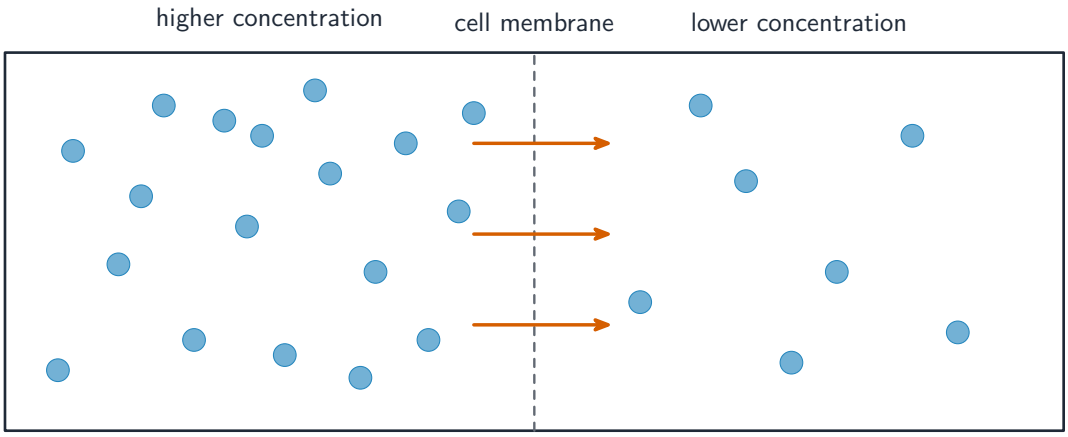
- You have watched a drop of dye spread through water (diffusion).
- You know water moves in and out of cells (osmosis).
- Some things need energy to move; others move on their own.

Each idea has a short worked example before the Practice.

New ideas

1 Diffusion

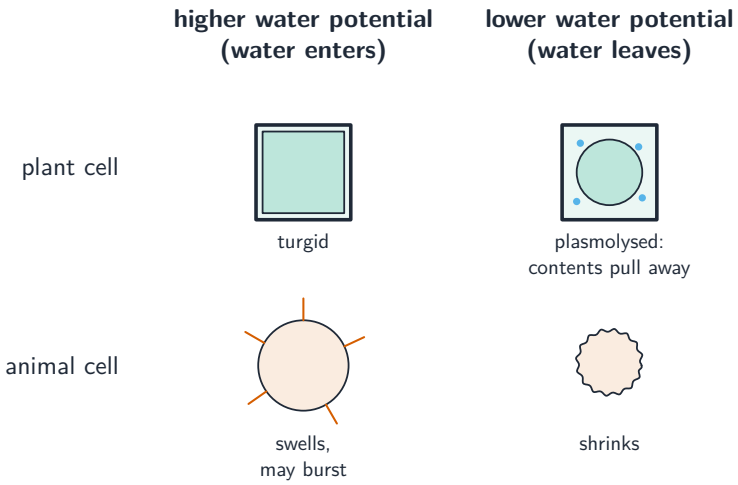
Diffusion 扩散 is the spreading of particles from where they are **crowded** (high concentration) to where they are **spread out** (low concentration). It needs **no energy**.



net movement of particles down the concentration gradient

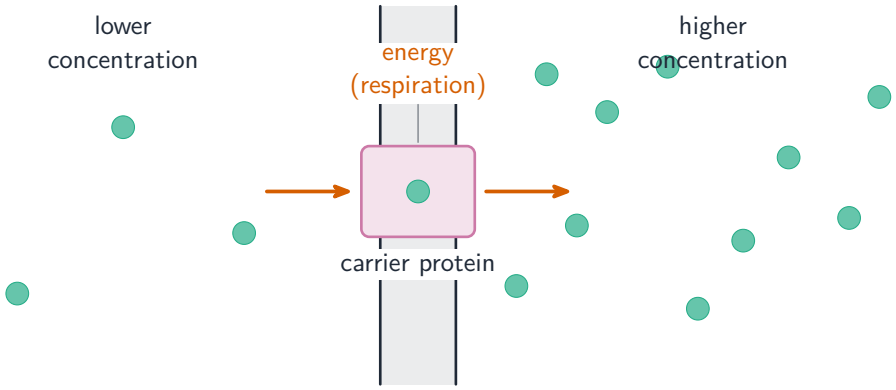
2 Osmosis and tonicity

Osmosis 渗透 is the diffusion of **water** across a membrane. Comparing the solution's strength (**tonicity** 张力): in a weaker (hypotonic) solution a cell gains water; in a stronger (hypertonic) one it loses water.



3 Active transport

Active transport 主动运输 moves particles the "wrong" way – from low to high concentration – so it needs **energy** (ATP) and a carrier protein.



particles moved against the gradient, using energy

4 Moving big things

Very large items cross in bulk: **endocytosis** 内吞 brings material **in** (the membrane wraps around it), and **exocytosis** 外排 sends material **out**.

Watch out: diffusion and osmosis need **no** energy (particles move down their gradient on their own); active transport needs energy because it pushes particles **against** the gradient.

Practice

Try these in order. The methods are all above.

2.1 State the direction (high to low, or low to high) that particles move during diffusion. [1]

2.2 Explain what osmosis is. [2]

2.3 A cell is placed in a very strong (hypertonic) sugar solution. State what happens to it and why. [2]

2.4 State the two things active transport needs that diffusion does not. [2]

2.5 Name the process that a cell uses to take in a large particle from outside. [1]

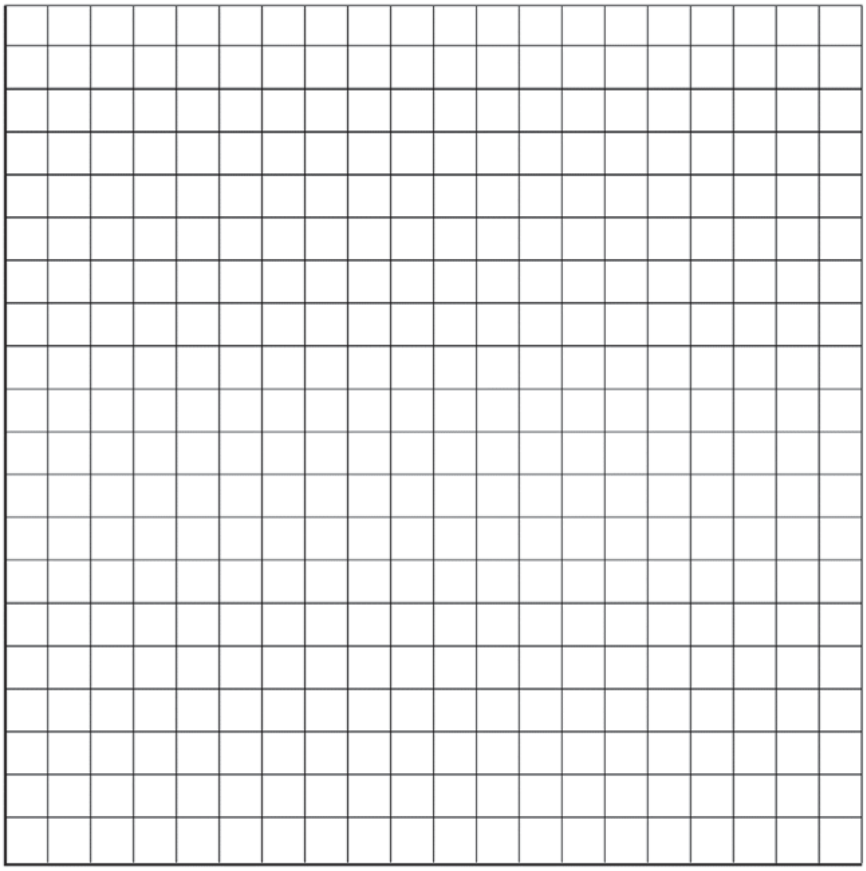
1. Leucine aminopeptidases (LAPs) are found in all living organisms and have been associated with the response of the marine mussel, *Mytilus edulis*, to changes in salinity. LAPs are enzymes that remove N-terminal amino acids from proteins and release the free amino acids into the cytosol. To investigate the evolution of LAPs in wild populations of *M. edulis*, researchers sampled adult mussels from several different locations along a part of the northeast coast of the United States, as shown in Figure 1. The researchers then determined the percent of individuals possessing a particular *lap* allele, lap^{94}, in mussels from each sample site (table 1).

   (a) On the axes provided, **construct** an appropriately labeled bar graph to illustrate the observed frequencies of the lap^{94} allele in the study populations.

   (b) Based on the data, **describe** the most likely effect of salinity on the frequency of the lap^{94} allele in the marine mussel populations in Long Island Sound. **Predict** the likely lap^{94} allele frequency at a sampling site between site 1 and site 2 in Long Island Sound.

   (c) **Describe** the most likely effect of LAP^{94} activity on the osmolarity of the cytosol. **Describe** the function of LAP^{94} in maintaining water balance in the mussels living in the Atlantic Ocean.

   (d) Marine mussel larvae are evenly dispersed throughout the study area by water movement. As larvae mature, they attach to the rocks in the water. **Explain** the differences in lap^{94} allele frequency among adult mussel populations at the sample sites despite the dispersal of larvae throughout the entire study area. **Predict** the likely effect on distribution of mussels in Long Island Sound if the lap^{94} allele was found in all of the mussels in the population. **Justify** your prediction.



3. To investigate whether red blood cells of animals lose the ability to take in glucose from their environment as they age, scientists collected red blood cells from guinea pigs that ranged in age from one day old to seven months old. Scientists incubated an equal number of red blood cells in separate culture dishes that contained a 300 nM solution of radioactively labeled glucose. The amount of radioactively labeled glucose present inside the red blood cells of each group was measured over time.

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   (d) **Justify** your prediction in part (c).

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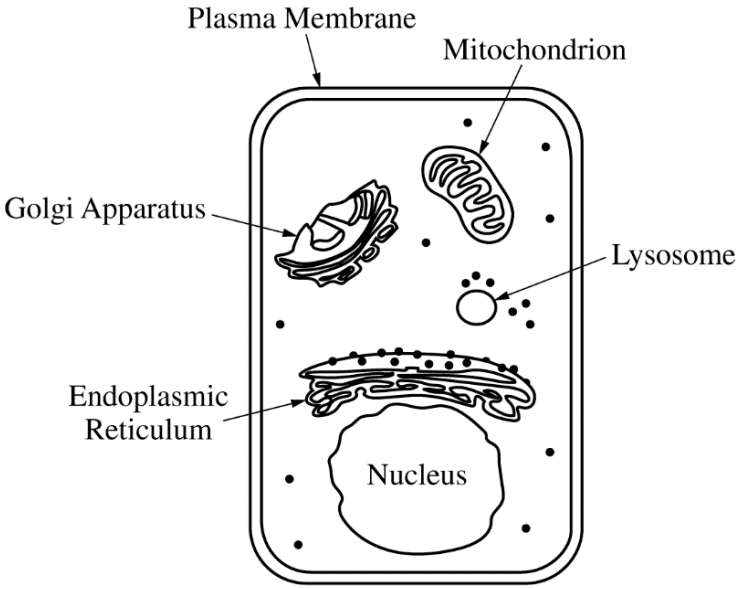
6. Cystic fibrosis is a genetic condition that is associated with defects in the CFTR protein. The CFTR protein is a gated ion channel that requires ATP binding in order to allow chloride ions (Cl^-) to diffuse across the membrane.

   (a) In the provided model of a cell, **draw** arrows to describe the pathway for production of a normal CFTR protein from gene expression to final cellular location.

   (b) **Identify** the most likely cellular location of the ribosomes that synthesize CFTR protein.

   (c) **Identify** the most likely cellular location of a mutant CFTR protein that has an amino acid substitution in the ATP-binding site.



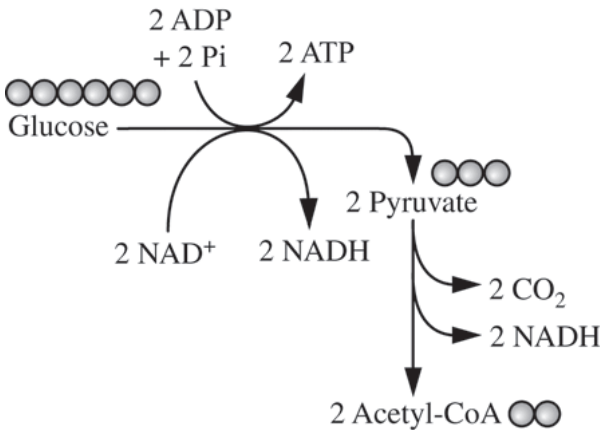


Figure 1. Glycolysis and pyruvate oxidation

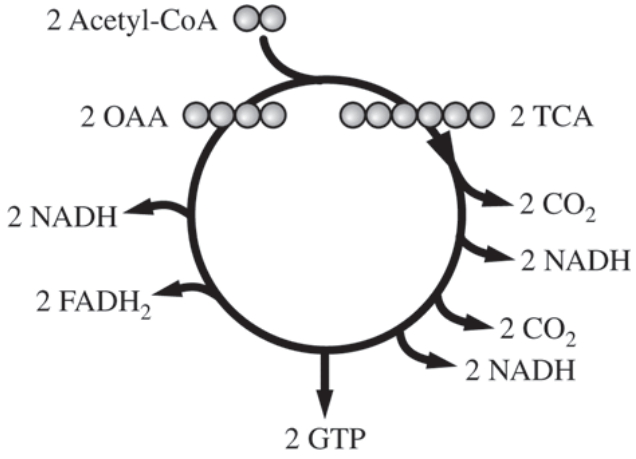


Figure 2. Krebs cycle

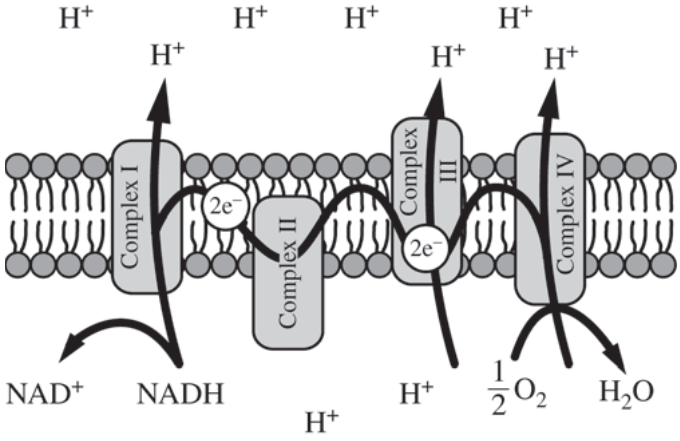


Figure 3. Electron transport chain

2. Cellular respiration includes the metabolic pathways of glycolysis, the Krebs cycle, and the electron transport chain, as represented in the figures. In cellular respiration, carbohydrates and other metabolites are oxidized, and the resulting energy-transfer reactions support the synthesis of ATP.

   (a) Using the information above, **describe** ONE contribution of <u>each</u> of the following in ATP synthesis.

   - Catabolism of glucose in glycolysis and pyruvate oxidation
   - Oxidation of intermediates in the Krebs cycle
   - Formation of a proton gradient by the electron transport chain

   (b) Use each of the following observations to **justify** the claim that glycolysis first occurred in a common ancestor of all living organisms.

   - Nearly all existing organisms perform glycolysis.
   - Glycolysis occurs under anaerobic conditions.
   - Glycolysis occurs only in the cytosol.

(c) A researcher estimates that, in a certain organism, the complete metabolism of glucose produces 30 molecules of ATP for each molecule of glucose. The energy released from the total oxidation of glucose under standard conditions is 686 kcal/mol. The energy released from the hydrolysis of ATP to ADP and inorganic phosphate under standard conditions is 7.3 kcal/mol. **Calculate** the amount of energy available from the hydrolysis of 30 moles of ATP. **Calculate** the efficiency of total ATP production from 1 mole of glucose in the organism. **Describe** what happens to the excess energy that is released from the metabolism of glucose.

(d) The enzymes of the Krebs cycle function in the cytosol of bacteria, but among eukaryotes the enzymes function mostly in the mitochondria. **Pose** a scientific question that connects the subcellular location of the enzymes in the Krebs cycle to the evolution of eukaryotes.

3 Enzymes – Part 1

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
enzyme	酶			
catalyst	催化剂			
lowering the activation energy	活化能			
active site	活性位点			
substrate	底物			
denatures	变性			
inhibitor	抑制剂			

Recall

You already know that living things use enzymes:

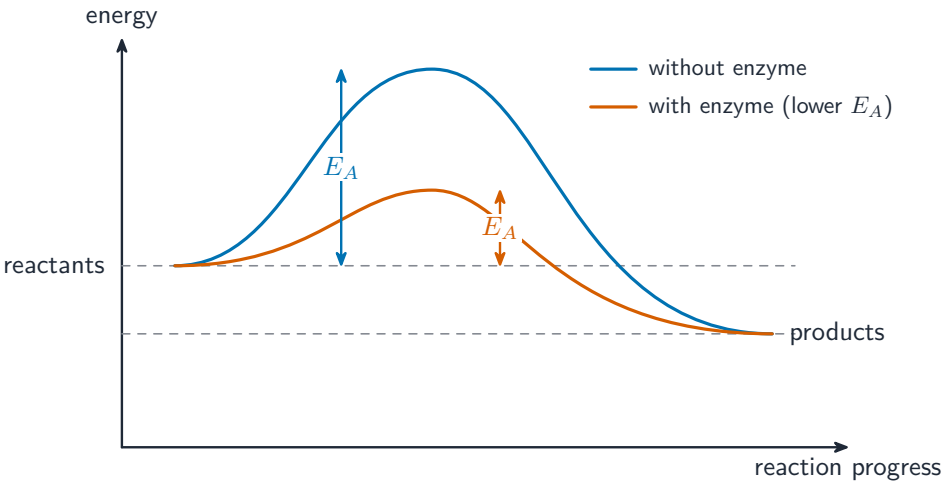
- Enzymes speed up the reactions in your body, like digesting food.
- They work best at a certain temperature (about body temperature) and pH.
- Too much heat "kills" an enzyme.

This sheet makes enzyme action exact. Each idea has a short worked example.

New ideas

1 Enzymes lower the barrier

An **enzyme** 酶 is a protein **catalyst** 催化剂: it speeds up a reaction by **lowering the activation energy** 活化能, and is not used up.

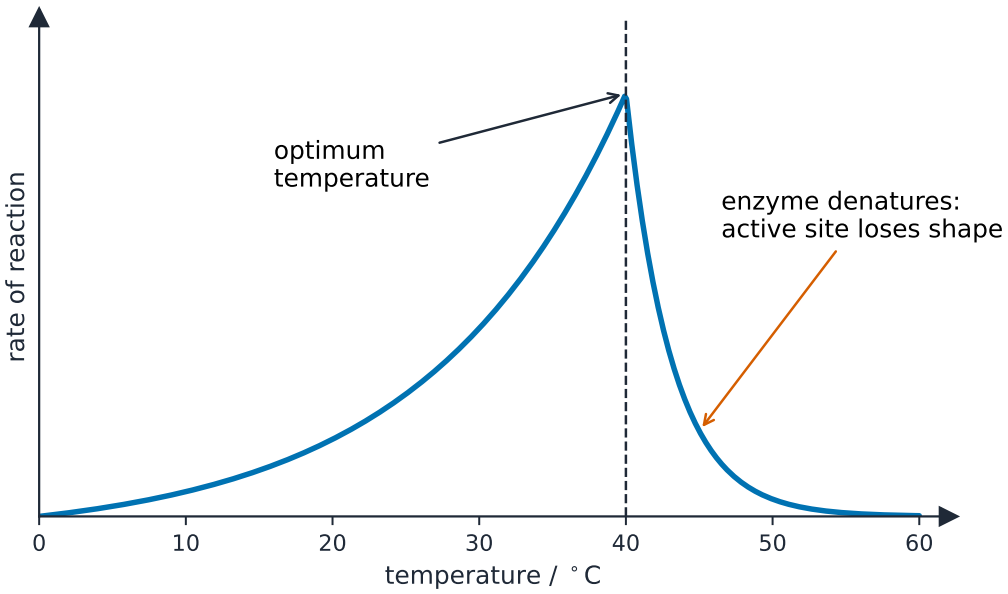


2 The active site

Each enzyme has an **active site** 活性位点 shaped to fit one particular **substrate** 底物 – like a lock and key. This makes each enzyme highly **specific** to its reaction.

3 Temperature and pH

Each enzyme has an **optimum** temperature and pH where it works fastest. Beyond that, the protein **denatures** 变性 (loses its shape) and stops working.



■ 4 Inhibitors

An **inhibitor** 抑制剂 slows an enzyme down – by blocking the active site, or by changing the enzyme's shape.

Watch out: raising the temperature speeds an enzyme up only **up to its optimum**. Past that, the heat denatures the enzyme and the rate **drops** – unlike an ordinary reaction, which just keeps speeding up.

Practice

Try these in order. The methods are all above.

2.1 State how an enzyme speeds up a reaction. [2]

2.2 Explain why each enzyme only works on one particular substrate. [2]

2.3 State what happens to an enzyme when it is heated well above its optimum temperature. [2]

2.4 Sketch in words how the rate of an enzyme reaction changes as temperature rises from cold to very hot. [2]

2.5 State what an enzyme inhibitor does. [1]

3. Fireflies emit light when the enzyme luciferase catalyzes a reaction in which its substrate, D-luciferin, reacts to form oxyluciferin and other products (Figure 1). In order to determine the optimal temperature for this enzyme, scientists added ATP to a solution containing D-luciferin, luciferase, and other substances needed for the reaction. They then measured the amount of light emitted during the first three seconds of the reaction when it was carried out at different temperatures.

$$\text{D-Luciferin} + O_2 + \text{ATP} \xrightarrow{\text{Luciferase}} \text{Oxyluciferin} + CO_2 + \text{AMP} + PP_i + \text{Light}$$

Figure 1. Light is emitted as a result of the reaction catalyzed by luciferase.

(a) **Describe** a characteristic of the luciferase enzyme that allows it to catalyze the reaction.

(b) **Identify** the dependent variable in the experiment.

(c) **State** the null hypothesis for the experiment.

(d) A student claims that, as temperature increases, there will be an increase in the amount of light given off by the reaction in the first three seconds. **Support** the student's claim.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

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Write your responses to this question only on the designated pages in the separate Free Response booklet.

3 ATP, photosynthesis, and respiration – Part 2

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	**中文**	**Write it 3 times** (English)		
Photosynthesis	光合作用			
Cellular respiration	细胞呼吸			

Recall

You already know the two great energy processes of life:

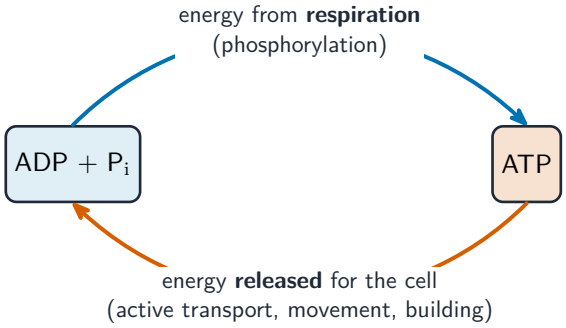
- Plants make food from sunlight – **photosynthesis**.
- All living things release energy from food – **respiration**.
- Your cells need a constant supply of energy to work.

This sheet lines up how cells store and release energy. Each idea has a short worked example.

New ideas

■ 1 ATP – the energy currency

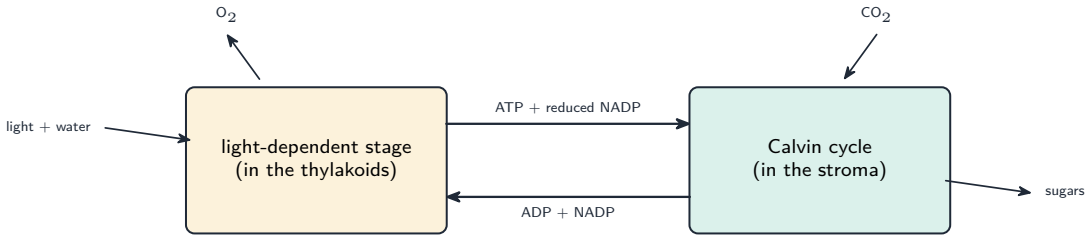
ATP is the molecule cells use to carry energy. Breaking off one of its phosphate groups (ATP → ADP) **releases** energy to power the cell's work; adding it back **stores** energy.



2 Photosynthesis

Photosynthesis 光合作用 captures light energy to build glucose from carbon dioxide and water, releasing oxygen:

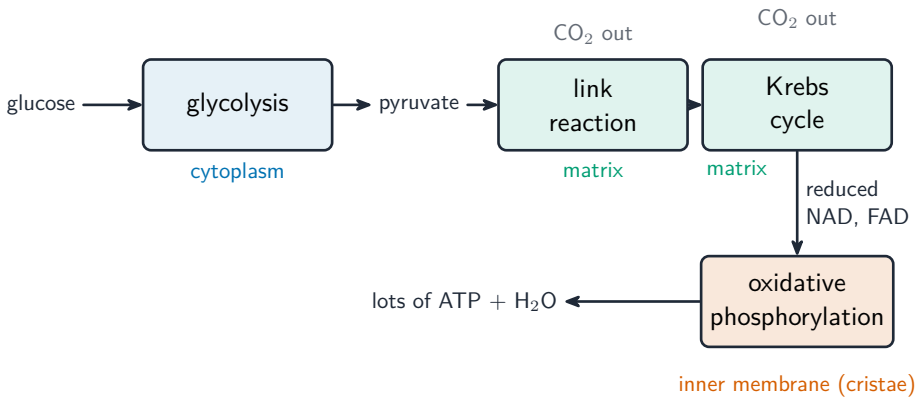
$$\mathrm{CO_2} + \text{water} \xrightarrow{\text{light}} \text{glucose} + \mathrm{O_2}.$$



3 Cellular respiration

Cellular respiration 细胞呼吸 releases the energy stored in glucose to make ATP, usually using oxygen:

$$\text{glucose} + \mathrm{O_2} \to \mathrm{CO_2} + \text{water} + \text{ATP}.$$



■ 4 Two sides of one coin

Photosynthesis and respiration are **complementary**: the products of one are the reactants of the other. Plants do both; animals only respire.

Watch out: photosynthesis *stores* energy (building glucose) while respiration *releases* it (breaking glucose down). They are opposite processes, not the same thing run twice.

Practice

Try these in order. The methods are all above.

2.1 State what happens to energy when ATP is broken down into ADP. [1]

2.2 Write, in words, the overall equation for photosynthesis. [2]

2.3 Write, in words, the overall equation for aerobic respiration. [2]

2.4 State one way photosynthesis and respiration are opposite processes. [2]

2.5 State which of the two processes an animal cell can carry out. [1]

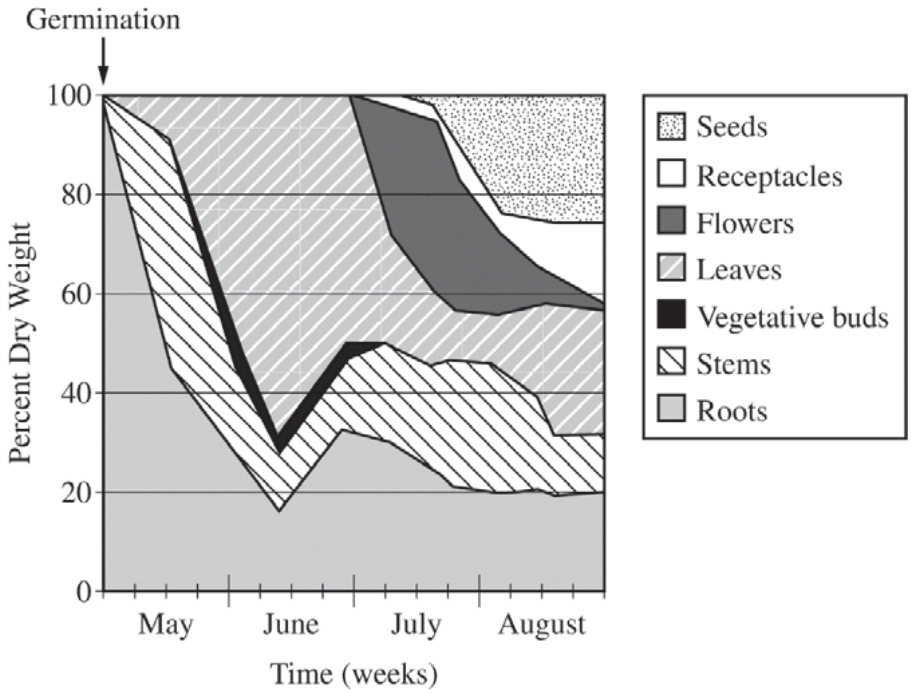


Figure 1. Percent dry weight of different plant structures during the growing season for an annual plant

3. The graph above illustrates the percent dry weight of different parts of a particular annual plant (plants that live less than one year) from early May to late August. The percent dry weight can be used to estimate the amount of energy a plant uses to produce its leaves, vegetative buds, stems, roots, and reproductive parts (seeds, receptacles, and flowers).

   (a) **Identify** the direct source of the energy used for plant growth during the first week of May, and **identify** the part of the plant that grew the most during the same period.

   (b) Based on the data on the graph, **estimate** the percent of the total energy that the plant has allocated to the growth of leaves on the first day of July.

   (c) Compared with perennials (plants that live more than two years), annual plants often allocate a much greater percentage of their total energy to growth of their reproductive parts in any given year. **Propose** ONE evolutionary advantage of the energy allocation strategy in annual plants compared with that in perennial plants.

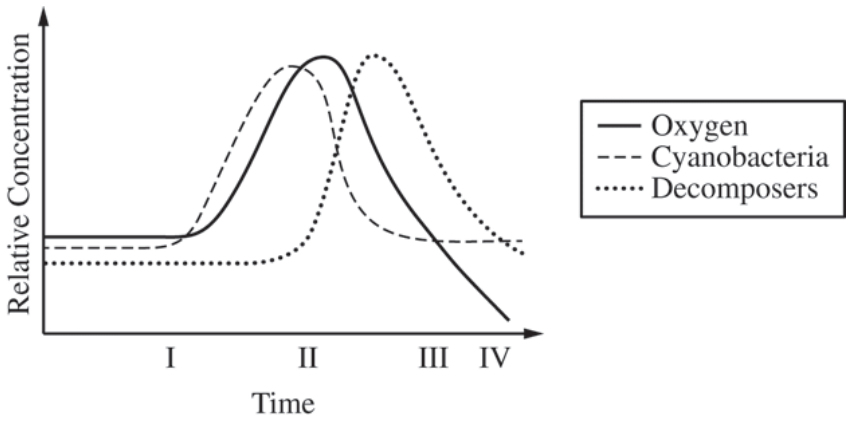


Figure 1. Characteristics of a pond community over time

5. *Microcystis aeruginosis* is a freshwater photosynthetic cyanobacterium. When temperatures increase and nutrients are readily available in its pond habitat, *M. aeruginosis* undergoes rapid cell division and forms an extremely large, visible mass of cells called an algal bloom. *M. aeruginosis* has a short life span and is decomposed by aerobic bacteria and fungi. **Identify** the metabolic pathway and the organism that is primarily responsible for the change in oxygen level in the pond between times I and II AND between times III and IV.

3. Researchers hypothesize that the plant compound resveratrol improves mitochondrial function. To test this hypothesis, researchers dissolve resveratrol in dimethyl sulfoxide (DMSO). The solution readily passes through cell membranes. They add the resveratrol solution to mammalian muscle cells growing in a nutrient-rich solution (culture medium) that contains glucose. They measure ATP production at several time points after the addition of the resveratrol solution and find an increase in ATP production by the muscle cells.

   (a) **Describe** the primary advantage for a mammalian muscle cell in using aerobic respiration over fermentation.

   (b) **Identify** an appropriate negative control for this experiment that would allow the researchers to conclude that ATP is produced in response to the resveratrol treatment.

   (c) **Predict** the effect on short-term ATP production when resveratrol-treated mammalian muscle cells are grown in a culture medium that lacks glucose or other sugars.

   (d) The researchers find that resveratrol stimulates the production of components of the electron transport chain. The researchers claim that treatment with resveratrol will also increase oxygen consumption by the cells if glucose is not limiting. **Justify** the claim.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

AP Biology: **2017**

7. Many species of bacteria grow in the mouths of animals and can form biofilms on teeth (plaque). Within plaque, the outer layers contain high levels of oxygen and the layers closest to the tooth contain low levels of oxygen. The surface of the tooth is covered in a hard layer of enamel, which can be dissolved under acidic conditions. When the enamel breaks down, the bacteria in plaque can extract nutrients from the tooth and cause cavities.

   Certain types of bacteria (e.g., *Streptococcus mutans*) thrive in the innermost anaerobic layers of the plaque and are associated with cavities. Other types of bacteria (*Streptococcus sanguinis*) compete with *S. mutans* but are unable to thrive in acidic environments.

   (a) **Identify** the biochemical pathway *S. mutans* uses for metabolizing sugar and **describe** how the pathway contributes to the low pH in the inner layers of plaque.

   (b) Normal tooth brushing effectively removes much of the plaque from the flat surfaces of teeth but cannot reach the surfaces between teeth. Many commercial toothpastes contain alkaline components, which raise the pH of the mouth. **Predict** how the population sizes of *S. mutans* AND *S. sanguinis* in the bacterial community in the plaque between the teeth are likely to change when these toothpastes are used.

4 Cell communication and feedback – Part 1

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	**中文**	**Write it 3 times** (English)		
signals	信号			
ligand	配体			
receptor	受体			
hormones	激素			
Signal transduction	信号转导			
Negative feedback	负反馈			
homeostasis	稳态			
Positive feedback	正反馈			

Recall

You already know that the body's cells work together:

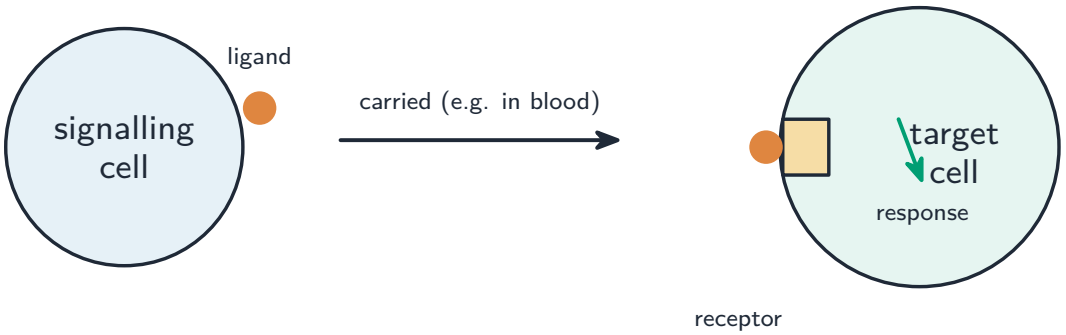
- Hormones carry chemical messages through the blood.
- Your body keeps a steady temperature and blood sugar.
- Nerves and chemicals let cells "talk" to one another.

This sheet lines up how cells communicate. Each idea has a short worked example.

New ideas

1 Cell signals

Cells send chemical **signals** 信号 to each other. A signalling cell releases a **ligand** 配体 (a signal molecule), which binds to a matching **receptor** 受体 on the target cell.



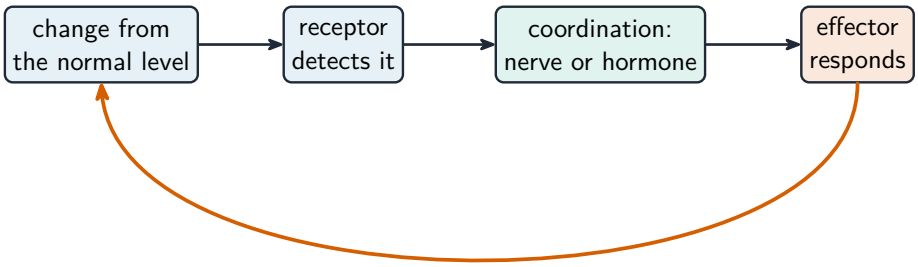
Long-distance signals are **hormones** 激素, carried in the blood.

2 Signal transduction

Signal transduction 信号转导 turns an outside signal into a response, in three steps: **reception** (ligand binds receptor), **transduction** (a relay inside the cell), and **response** (the cell changes what it does).

3 Negative feedback

Negative feedback 负反馈 reverses a change to return to a set point – like a thermostat. It keeps conditions steady, which is **homeostasis** 稳态.



the response pushes the level back to normal (negative feedback)

4 Positive feedback

Positive feedback 正反馈 does the opposite: it **amplifies** a change to push a process to completion, like the contractions of childbirth or blood clotting.

Watch out: "negative" feedback does not mean bad – it means the response **opposes** the change, bringing the system back to normal. It is what keeps you stable.

Practice

Try these in order. The methods are all above.

2.1 State what a ligand and a receptor are. [2]

2.2 Name the three stages of signal transduction. [2]

2.3 Explain how negative feedback keeps body temperature steady. [2]

2.4 State the main difference between negative and positive feedback. [2]

2.5 Give one example of a process controlled by positive feedback. [1]

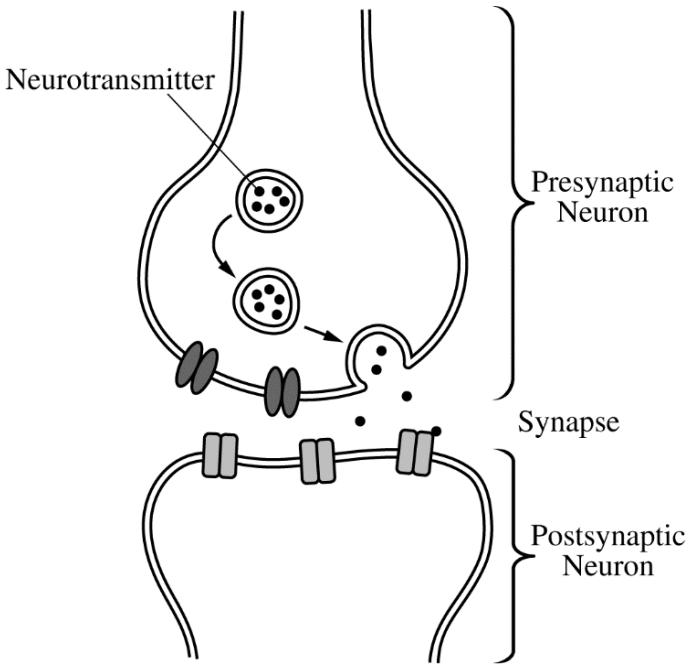


Figure 1. Release of neurotransmitters into the synapse in response to an action potential

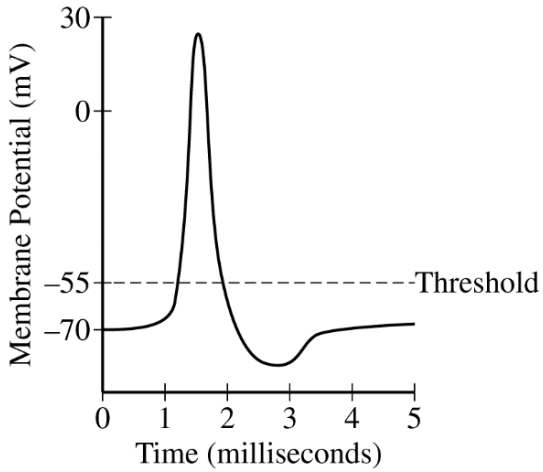


Figure 2. Model of a typical action potential in a neuron

4. Acetylcholine is a neurotransmitter that can activate an action potential in a postsynaptic neuron (Figures 1 and 2). A researcher is investigating the effect of a particular neurotoxin that causes the amount of acetylcholine released from presynaptic neurons to increase.

   (a) **Describe** the immediate effect of the neurotoxin on the number of action potentials in a postsynaptic neuron. **Predict** whether the maximum membrane potential of the postsynaptic neuron will increase, decrease, or stay the same.

   (b) The researcher proposes two models, A and B, for using acetylcholinesterase (AChE), an enzyme that degrades acetylcholine, to prevent the effect of the neurotoxin. In model A, AChE is added to the synapse. In model B, AChE is added to the cytoplasm of the postsynaptic cell. **Predict** the effectiveness of EACH proposed model. **Provide reasoning** to support your predictions.

8. Estrogens are small hydrophobic lipid hormones that promote cell division and the development of reproductive structures in mammals. Estrogens passively diffuse across the plasma membrane and bind to their receptor proteins in the cytoplasm of target cells.

   (a) **Describe** ONE characteristic of the plasma membrane that allows estrogens to passively cross the membrane.

   (b) In a laboratory experiment, a researcher generates antibodies that bind to purified estrogen receptors extracted from cells. The researcher uses the antibodies in an attempt to treat estrogen-dependent cancers but finds that the treatment is ineffective. **Explain** the ineffectiveness of the antibodies for treating estrogen-dependent cancers.

STOP

END OF EXAM

8. Acetylcholine receptor (AChR) proteins are found at the synapse between neurons and skeletal muscle cells. Acetylcholine released from neurons binds to a specific site on the receptor proteins, which causes an ion channel in the receptors to open and allow sodium ions (Na^+) to enter muscle cells. The resulting depolarization of muscle cells initiates muscle contractions. Another molecule, nicotine, can also bind to certain types of AChR proteins and activate the receptors.

   A researcher is investigating two different types of AChR proteins: type 1 and type 2. To determine which stimuli activate the receptors, the researcher exposes muscle cells expressing the different types of receptor proteins to stimuli and observes the results indicated in Table 1.

   TABLE 1. RESPONSE OF AChR PROTEINS TO DIFFERENT STIMULI

AChR Protein Type	Acetylcholine	Nicotine
Type 1	+	+
Type 2	+	–

   + indicates activation
   – indicates no activation

   (a) **Describe** the difference in the structure AND function between AChR type 1 and AChR type 2.

   (b) Acetylcholinesterase is an enzyme that breaks down acetylcholine in the synapse. **Describe** the effect of inhibiting acetylcholinesterase on the muscle cells with AChR type 2.

STOP

END OF EXAM

4 The cell cycle and its control – Part 2

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
cell cycle	细胞周期			
interphase	间期			
mitosis	有丝分裂			
checkpoints	检查点			
cancer	癌症			

Recall

You already know that cells divide:

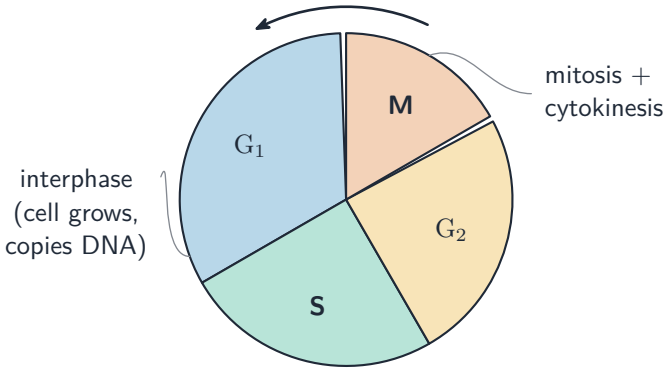
- Your body makes new cells to grow and to repair injuries.
- **Mitosis** produces two identical cells from one.
- You have heard that cancer is cells dividing out of control.

This sheet lines up how a cell's life and division are controlled. Each idea has a short worked example.

New ideas

■ 1 The cell cycle

The **cell cycle** 细胞周期 is the life of a cell from one division to the next. It has two main parts:



- **interphase** 间期 – the cell grows and copies its DNA,
- **mitosis** 有丝分裂 – the cell divides into two identical daughter cells.

2 DNA is copied once

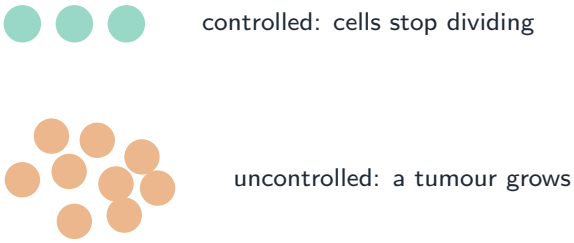
The DNA is copied only during the S phase of interphase, so each daughter cell gets a complete, identical copy.

3 Checkpoints

The cycle is controlled at **checkpoints** 检查点 that check conditions before the cell continues (Is the DNA undamaged? Are the chromosomes ready?). If something is wrong, the cycle pauses.

4 When control fails

If the checkpoints fail – often through a mutation – cells divide uncontrollably, forming a tumour. This is the basis of **cancer** 癌症.



Watch out: mitosis makes two **identical** daughter cells, each with a full copy of the DNA – not half each. The DNA is copied first (in interphase) so nothing is lost.

Practice

Try these in order. The methods are all above.

2.1 Name the two main parts of the cell cycle and state what happens in each. [2]

2.2 State when in the cell cycle the DNA is copied, and why this matters. [2]

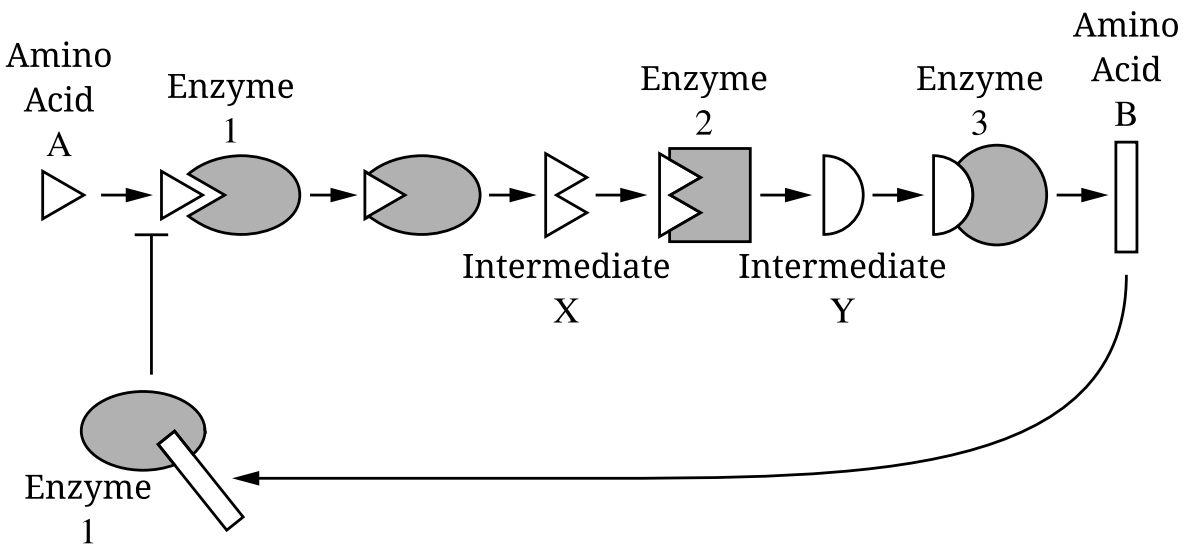
2.3 State what checkpoints do in the cell cycle. [2]

2.4 Explain how a failure of cell-cycle control can lead to cancer. [2]

2.5 State how many daughter cells mitosis produces, and whether they are identical. [1]

5. Figure 1 shows the reactions of the metabolic pathway used to synthesize amino acid B from amino acid A in cells.

Figure 1. Synthesis of amino acid B from amino acid A



A. Describe a characteristic of an enzyme's active site that allows it to catalyze a specific chemical reaction.

B. Based on Figure 1, **explain** how the binding of amino acid A to enzyme 1 is regulated by amino acid B.

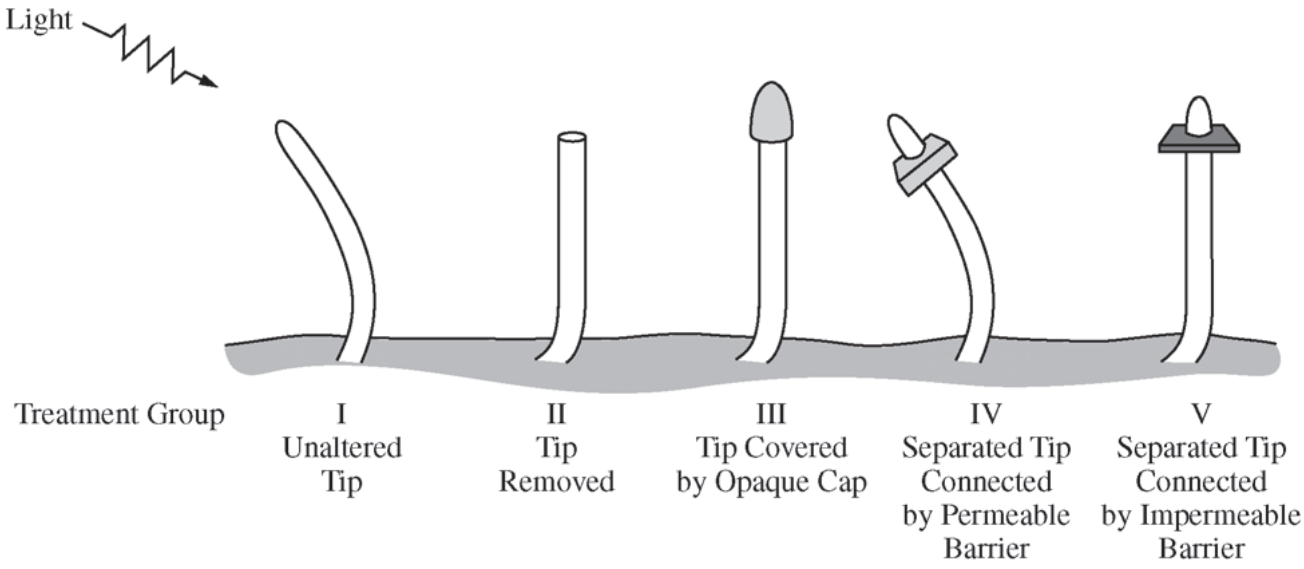
C. Using the information in Figure 1, **identify** the product of the reaction catalyzed by enzyme 2: intermediate X, intermediate Y, or amino acid B.

D. Based on Figure 1, **explain** how a change in pH could affect enzyme 3 in such a way that amino acid B cannot be produced.

4. Both mitosis and meiosis are forms of cell division that produce daughter cells containing genetic information from the parent cell.

   (a) **Describe** TWO events that are common to both mitosis and meiosis that ensure the resulting daughter cells inherit the appropriate number of chromosomes.

   (b) The genetic composition of daughter cells produced by mitosis differs from that of the daughter cells produced by meiosis. **Describe** TWO features of the cell division processes that lead to these differences.



1. Polycystic kidney disease (PKD) is an inherited disease that causes water loss from the body and affects cell division in the kidneys. Because water movement across cell membranes is related to ion movement, scientists investigated the role of the Na^+/K^+ATPase (also known as the sodium/potassium pump) in this disease. Ouabain, a steroid hormone, binds to the Na^+/K^+ATPase in plasma membranes. Individuals with PKD have a genetic mutation that results in an increased binding of ouabain to the Na^+/K^+ATPase. The scientists treated normal human kidney (NHK) cells and PKD cells with increasing concentrations of ouabain and measured the number of cells (Figure 1) and the activity of the Na^+ / K^+ATPase (Figure 2) after a period of time. The scientists hypothesized that a signal transduction pathway that includes the protein kinases MEK and ERK (Figure 3) may play a role in PKD symptoms.

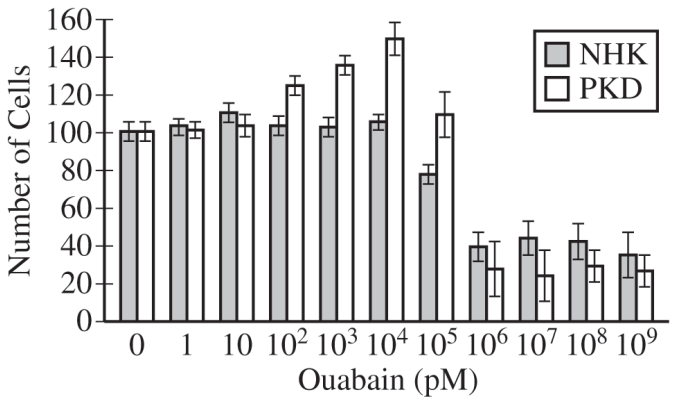


Figure 1. Cell number compared with the number of cells at 0 pM ouabain. Normal human kidney (NHK) cells and polycystic kidney disease (PKD) cells were treated with increasing concentrations of ouabain. Error bars represent $\pm 2SE_{\bar{x}}$.

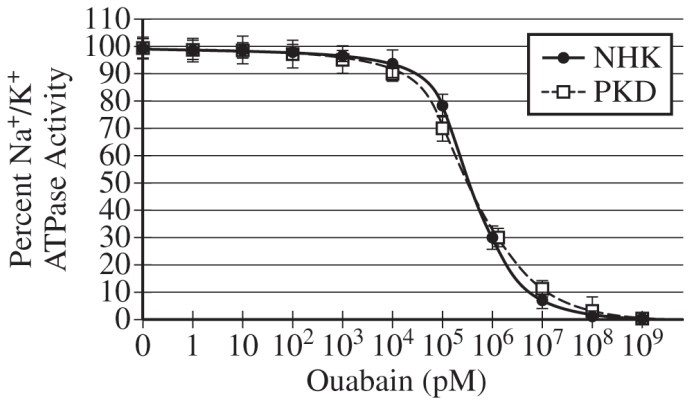


Figure 2. Percent Na^+/K^+ATPase activity of NHK and PKD cells treated with increasing concentrations of ouabain. Error bars represent $\pm 2SE_{\bar{x}}$.

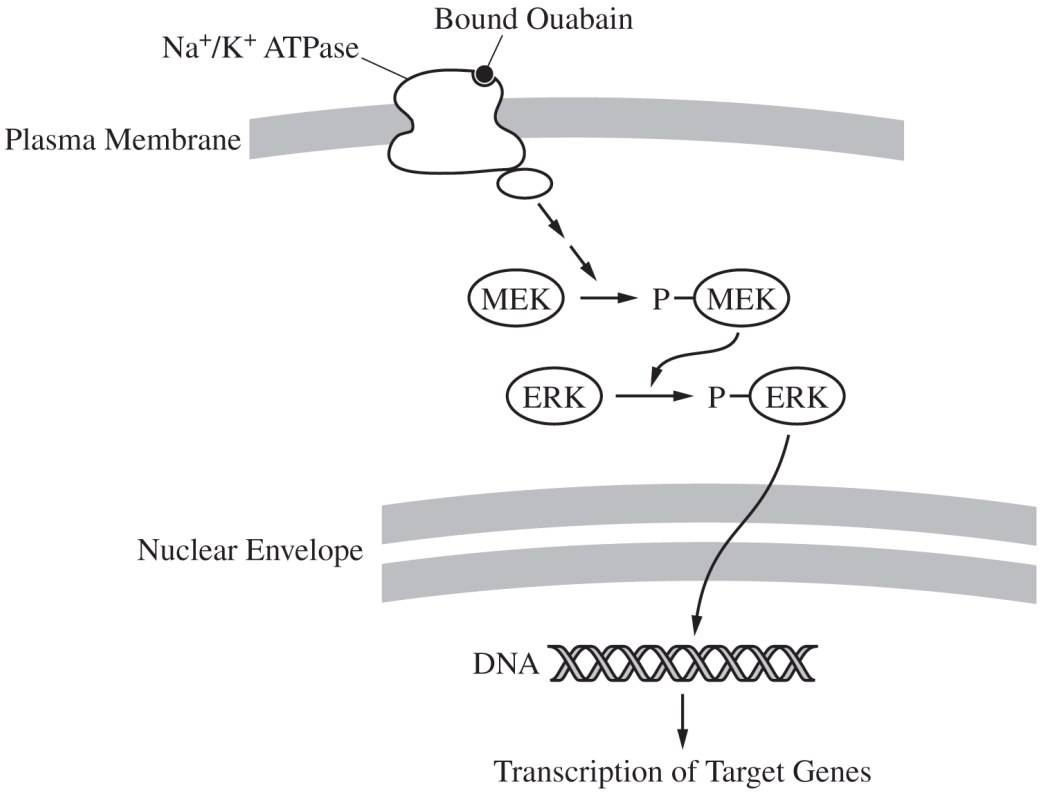


Figure 3. Signal transduction pathway hypothesized to play a role in the increased number of PKD cells

(a) **Describe** the characteristics of the plasma membrane that prevent simple diffusion of Na^+ and K^+ across the membrane. **Explain** why ATP is required for the activity of the Na^+ / K^+ATPase.

(b) **Identify** a dependent variable in the experiment represented in Figure 1. **Justify** the use of normal human kidney (NHK) cells as a control in the experiments. **Justify** the use of a range of ouabain concentrations in the experiment represented in Figure 1.

(c) Based on the data shown in Figure 2, **describe** the relationship between the concentration of ouabain and the Na^+ / K^+ ATPase activity both in normal human kidney (NHK) cells AND in PKD cells. The scientists determined that Na^+ / K^+ATPase activity in PKD cells treated with 1 pM ouabain is 150 units of ATP hydrolyzed/sec. **Calculate** the expected Na^+ / K^+ATPase activity (units/sec) in PKD cells treated with 10^6 pM ouabain.

(d) In a third experiment, the scientists added an inhibitor of phosphorylated MEK (pMEK) to the PKD cells exposed to 10^4 pM ouabain. Based on Figure 3, **predict** the change in the relative ratio of ERK to pERK in ouabain-treated PKD cells with the inhibitor compared with ouabain-treated PKD cells without the inhibitor. Provide reasoning to **justify** your prediction. Using the data in Figure 1 AND the signal transduction pathway represented in Figure 3, **explain** how the concentration of cyclin proteins may increase in PKD cells treated with 10^4 pM ouabain.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

5 Meiosis and genetic variation – Part 1

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	**中文**	**Write it 3 times** (English)		
Meiosis	减数分裂			
gametes	配子			
crossing over	交叉互换			
independent assortment	自由组合			

Recall

You already know that offspring resemble their parents but are not identical:

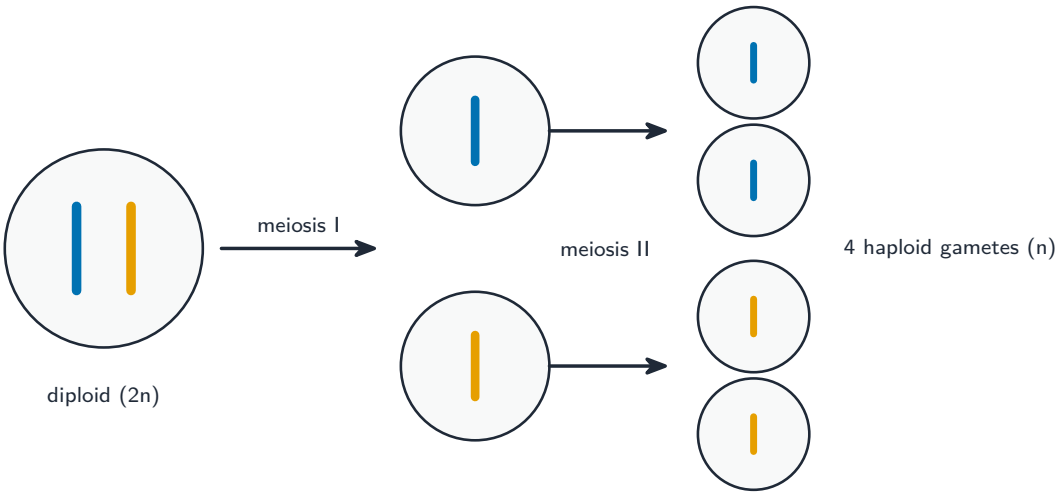
- Body cells divide by mitosis to make identical copies.
- Sex cells (eggs and sperm) are made a different way.
- Brothers and sisters differ, even with the same parents.

This sheet explains where that variety comes from. Each idea has a short worked example.

New ideas

■ 1 Meiosis

Meiosis 减数分裂 makes sex cells, called **gametes** 配子 (eggs and sperm), with **half** the number of chromosomes. One cell divides **twice** to give four cells.

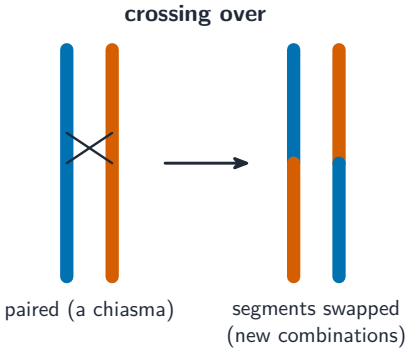


2 Fertilisation restores the number

When an egg and sperm join at fertilisation, the full chromosome number is restored – half from each parent.

3 Shuffling the genes

Meiosis mixes the genes so each gamete is different:



- **crossing over** 交叉互换 – homologous chromosomes swap pieces,
- **independent assortment** 自由组合 – each chromosome pair lines up randomly.

4 Random fertilisation

On top of that, any sperm can meet any egg – **random fertilisation** adds even more variety.

Watch out: meiosis makes **four** cells that are **not identical**, each with **half** the chromosomes. This is different from mitosis, which makes **two identical** cells with the **full** number.

Practice

Try these in order. The methods are all above.

2.1 State what meiosis produces and how many chromosomes those cells have compared with a body cell. [2]

2.2 Explain why the chromosome number is restored at fertilisation. [2]

2.3 Name two ways meiosis mixes the genes to create variety. [2]

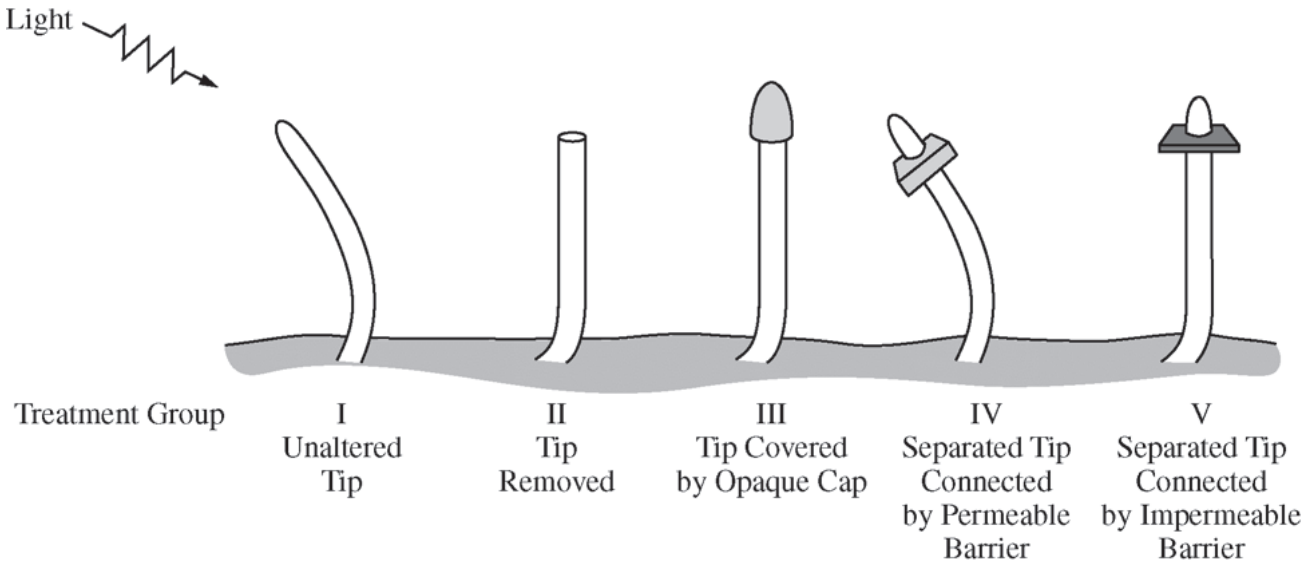
2.4 State two differences between meiosis and mitosis. [2]

2.5 Explain why brothers and sisters are not genetically identical (unless they are identical twins). [2]

4. Both mitosis and meiosis are forms of cell division that produce daughter cells containing genetic information from the parent cell.

   (a) **Describe** TWO events that are common to both mitosis and meiosis that ensure the resulting daughter cells inherit the appropriate number of chromosomes.

   (b) The genetic composition of daughter cells produced by mitosis differs from that of the daughter cells produced by meiosis. **Describe** TWO features of the cell division processes that lead to these differences.



8. A research team has genetically engineered a strain of fruit flies to eliminate errors during DNA replication. The team claims that this will eliminate genetic variation in the engineered flies. A second research team claims that eliminating errors during DNA replication will not entirely eliminate genetic variation in the engineered flies.

   (a) **Provide** ONE piece of evidence that would indicate new genetic variation has occurred in the engineered flies.

   (b) **Describe** ONE mechanism that could lead to genetic variation in the engineered strain of flies.

   (c) **Describe** how genetic variation in a population contributes to the process of evolution in the population.

STOP

END OF EXAM

5 Genetics and Punnett squares – Part 2

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
alleles	等位基因			
genotype	基因型			
phenotype	表型			
dominant	显性			
recessive	隐性			
homozygous	纯合			
heterozygous	杂合			
Punnett square	庞纳特方格			

Recall

You already know some genetics:

- Genes come in different versions, and some are dominant, some recessive.
- You have used a Punnett square to predict offspring.
- Traits like eye colour are passed from parents to children.

This sheet lines up how inheritance works. Each idea has a short worked example.

New ideas

■ 1 Alleles, genotype, and phenotype

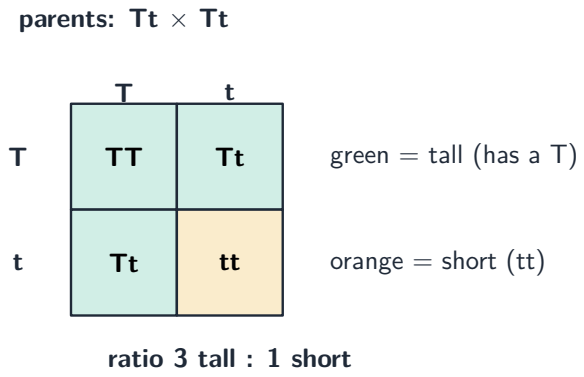
A gene's different versions are **alleles** 等位基因. An organism's **genotype** 基因型 (its alleles) produces its **phenotype** 表型 (its visible traits).

■ 2 Dominant and recessive

A **dominant** 显性 allele shows even if only one copy is present; a **recessive** 隐性 allele shows only with two copies. Two identical alleles is **homozygous** 纯合; two different is **heterozygous** 杂合.

■ 3 Punnett squares

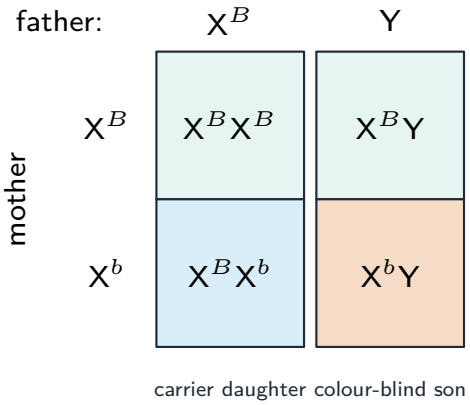
A **Punnett square** 庞纳特方格 predicts offspring ratios. Crossing two heterozygotes ($Aa \times Aa$) gives a 3 : 1 ratio of dominant to recessive.



Worked example. $Aa \times Aa$ gives offspring AA, Aa, Aa, aa – so 3 show the dominant trait and 1 shows the recessive, a 3 : 1 ratio.

■ 4 Not always so simple

Some traits break the simple rule – **incomplete dominance** (a blend, red × white → pink), **codominance** (both show, like blood group AB), and **sex-linked** genes on the X chromosome.



Watch out: the **genotype** is the alleles an organism has; the **phenotype** is what you actually see. Two organisms can look the same (phenotype) but have different genotypes (AA and Aa both show the dominant trait).

Practice

Try these in order. The methods are all above.

2.1 State the difference between an organism's genotype and its phenotype. [2]

2.2 State what "homozygous" and "heterozygous" mean. [2]

2.3 A cross is $Aa \times Aa$. State the ratio of dominant to recessive offspring. [2]

2.4 A homozygous dominant (AA) is crossed with a homozygous recessive (aa). State the genotype of all the offspring. [2]

2.5 Two purple flowers produce some white offspring. Explain how this is possible. [2]

7. In the tongue sole fish (*Cynoglossus semilaevis*), sex is determined by a combination of genetics and environmental temperature. Genetically male fish have two Z chromosomes (ZZ), and genetically female fish have one Z chromosome and one W chromosome (ZW). When fish are raised at 22°C, ZZ fish develop into phenotypic males and ZW fish develop into phenotypic females. However, when fish are raised at 28°C, the Z chromosome is modified (denoted as Z*). Z*W individuals develop as phenotypic males that are fertile and can pass on the Z* chromosome to their offspring even when the offspring are raised at 22°C. A cross between a ZW female and a Z*Z male is shown in the Punnett square below.

	Z	W
Z*	Z* Z	Z* W
Z	Z Z	Z W

(a) **Predict** the percent of phenotypic males among the F_1 offspring of the cross shown in the Punnett square if the offspring are raised at 22°C.

(b) At least one Z or Z* chromosome is necessary for survival of the fish. A researcher crossed two fish and observed a 2:1 ratio of males to females among the offspring. Based on the information, **identify** the genotype of the male parent in the cross. **Describe** ONE fitness cost to the female of mating with this particular male.

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6 DNA and making proteins – Part 1

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
double helix	双螺旋			
complementary base pairing	互补配对			
semiconservative replication	半保留复制			
Transcription	转录			
Translation	翻译			
ribosome	核糖体			
codons	密码子			

Recall

You already know the basics of DNA:

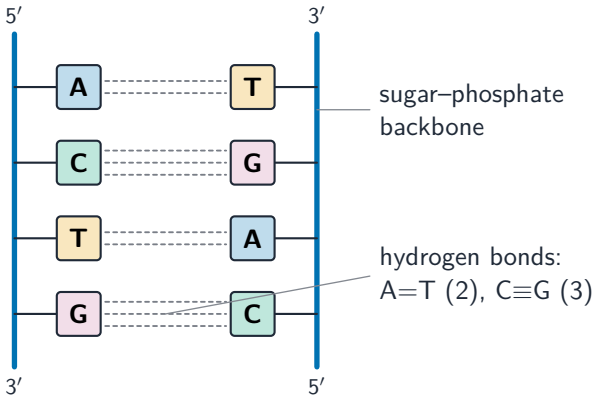
- DNA carries the genetic instructions, in a shape called the **double helix**.
- Its bases pair in a fixed way: A with T, and C with G.
- DNA codes for proteins.

This sheet lines up how a cell reads DNA to build proteins. Each idea has a short worked example.

New ideas

1 DNA structure

DNA is a **double helix** 双螺旋 of two strands. The bases pair by rule – A with T, C with G – called **complementary base pairing** 互补配对. So one strand tells you the other.



the two strands run in opposite directions (antiparallel)

2 DNA replication

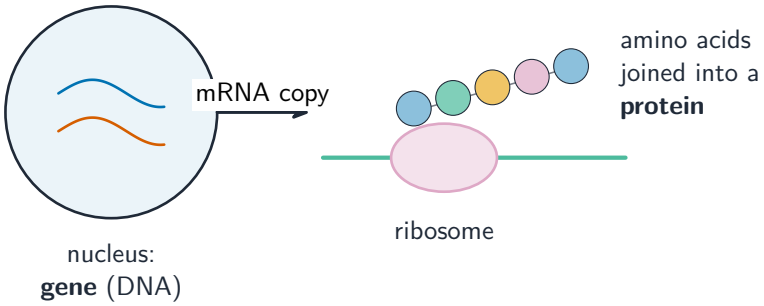
Before a cell divides, DNA is copied by **semiconservative replication** 半保留复制: the helix unwinds and each old strand acts as a template for a new one, so each new helix has one old and one new strand.

3 Transcription

Transcription 转录 copies a gene from DNA into a messenger molecule, mRNA. Note that RNA uses the base U (uracil) in place of T, and is single-stranded.

4 Translation

Translation 翻译 builds a protein from the mRNA at the **ribosome** 核糖体. The mRNA is read in three-base groups called **codons** 密码子, each choosing one amino acid. The overall flow is the "central dogma": DNA → RNA → protein.



Watch out: RNA is **single-stranded** and uses **U** (uracil) instead of the T found in DNA. Don't carry the DNA rules straight over to RNA.

Practice

Try these in order. The methods are all above.

2.1 In DNA, state which base pairs with (a) A, (b) G. [2]

2.2 A DNA strand reads A–T–C–G. Write the sequence of the complementary strand. [2]

2.3 State what happens during transcription. [2]

2.4 State what a codon is and what it codes for. [2]

2.5 State two ways RNA differs from DNA. [2]

2. During meiosis, double-strand breaks occur in chromatids. The breaks are either repaired by the exchange of genetic material between homologous nonsister chromatids, which is the process known as crossing over (Figure 1A), or they are simply repaired without any crossing over (Figure 1B). Plant breeders developing new varieties of corn are interested in determining whether, in corn, a correlation exists between the number of meiotic double-strand chromatid breaks and the number of crossovers.

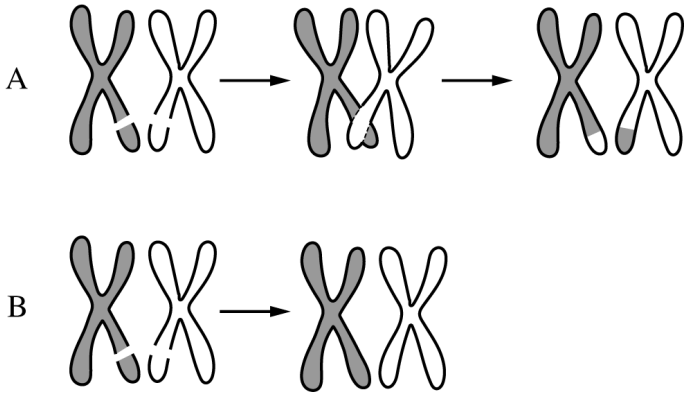


Figure 1. Double-strand breaks in chromatids are repaired with crossing over (A) or without crossing over (B).

Using specialized staining and microscopy techniques, scientists counted the number of double-strand chromatid breaks and the number of crossovers in the same number of meiotic gamete-forming cells of six inbred strains of corn (Table 1).

TABLE 1. NUMBER OF CHROMATID DOUBLE-STRAND BREAKS AND AVERAGE NUMBER OF CROSSOVERS IN INBRED STRAINS OF CORN

Strain of Corn	Number of Double-Strand Breaks	Average Number of Crossovers ($\pm$ 2SE$_{\bar{x}}$)
I	710	19.5 $\pm$ 0.5
II	650	18.0 $\pm$ 0.7
III	600	17.5 $\pm$ 1.0
IV	510	16.0 $\pm$ 1.0
V	425	14.0 $\pm$ 0.5
VI	325	11.0 $\pm$ 1.5

(a) The double-strand breaks occur along the DNA backbone. **Describe** the process by which the breaks occur.

(b) Using the template in the space provided for your response, **construct** an appropriately labeled graph that represents the data in Table 1 and allows examination of a possible correlation between double-strand breaks and crossovers. Based on the data, **determine** whether corn strains I, II, and III differ in their average number of crossovers.

(c) Based on the data, **describe** the relationship between the average number of double-strand breaks and the average number of crossovers in the strains of corn analyzed in the experiment.

(d) Crossing over (Figure 1A) creates physical connections that are required for proper separation of homologous chromosomes during meiosis. A diploid cell with four pairs of homologous chromosomes undergoes meiosis to produce four haploid cells. Crossing over occurs between only three of the pairs. **Predict** the number of chromosomes most likely present in each of the four haploid cells. Provide reasoning to **justify** your prediction. **Explain** how plant breeders can use the information in Table 1 to help develop new varieties of corn.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

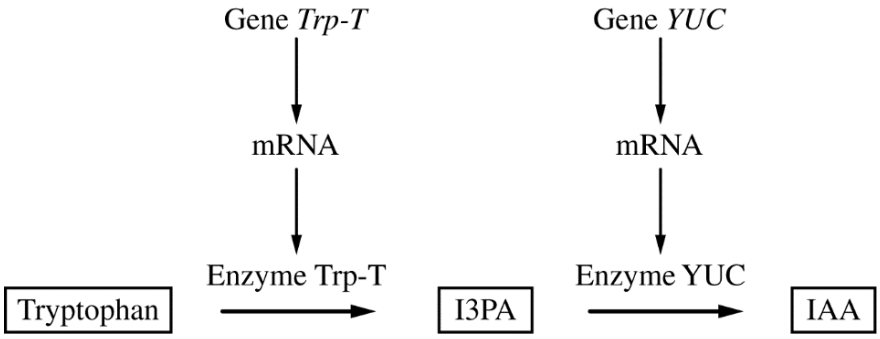


Figure 1. Model of two-step enzymatic plant pathway for synthesis of IAA from tryptophan

1. Auxins are plant hormones that coordinate several aspects of root growth and development. Indole-3-acetic acid (IAA) is an auxin that is usually synthesized from the amino acid tryptophan (Figure 1). Gene *Trp-T* encodes an enzyme that converts tryptophan to indole-3-pyruvic acid (I3PA), which is then converted to IAA by an enzyme encoded by the gene *YUC*.

   (a) **Circle** ONE arrow that represents transcription on the template pathway. **Identify** the molecule that would be absent if enzyme YUC is nonfunctional.

   (b) **Predict** how the deletion of one base pair in the fourth codon of the coding region of gene *Trp-T* would most likely affect the production of IAA. **Justify** your prediction.

   (c) **Explain** one feedback mechanism by which a cell could prevent production of too much IAA without limiting I3PA production.

   (d) Rhizobacteria are a group of bacteria that live in nodules on plant roots. Rhizobacteria can produce IAA and convert atmospheric nitrogen into forms that can be used by plants. Plants release carbon-containing molecules into the nodules. Based on this information, **identify** the most likely ecological relationship between plants and rhizobacteria. **Describe** ONE advantage to the bacteria of producing IAA.

   (e) A researcher removed a plant nodule and identified several "cheater" rhizobacteria that do not produce IAA or fix nitrogen. **Describe** the evolutionary advantage of being a bacterial cheater in a population composed predominantly of noncheater bacteria. Plants can adjust the amount of carbon-containing molecules released into nodules in response to the amount of nitrogen fixed in the nodule. **Predict** the change in the bacterial population that would cause the plant to reduce the amount of carbon-containing molecules provided to the nodule.

3. Gibberellin is the primary plant hormone that promotes stem elongation. GA 3-beta-hydroxylase (GA3H) is the enzyme that catalyzes the reaction that converts a precursor of gibberellin to the active form of gibberellin. A mutation in the *GA3H* gene results in a short plant phenotype. When a pure-breeding tall plant is crossed with a pure-breeding short plant, all offspring in the F_1 generation are tall. When the F_1 plants are crossed with each other, 75 percent of the plants in the F_2 generation are tall and 25 percent of the plants are short.

Second Base in Codon

First Base in Codon	U	C	A	G	Third Base in Codon
U	UUU, UUC: Phe UUA, UUG: Leu	UCU, UCC, UCA, UCG: Ser	UAU, UAC: Tyr UAA: Stop UAG: Stop	UGU, UGC: Cys UGA: Stop UGG: Trp	U C A G
C	CUU, CUC, CUA, CUG: Leu	CCU, CCC, CCA, CCG: Pro	CAU, CAC: His CAA, CAG: Gln	CGU, CGC, CGA, CGG: Arg	U C A G
A	AUU, AUC, AUA: Ile AUG: Met or Start	ACU, ACC, ACA, ACG: Thr	AAU, AAC: Asn AAA, AAG: Lys	AGU, AGC: Ser AGA, AGG: Arg	U C A G
G	GUU, GUC, GUA, GUG: Val	GCU, GCC, GCA, GCG: Ala	GAU, GAC: Asp GAA, GAG: Glu	GGU, GGC, GGA, GGG: Gly	U C A G

Figure 1. The universal genetic code

(a) The wild-type allele encodes a GA3H enzyme with alanine (Ala), a nonpolar amino acid, at position 229. The mutant allele encodes a GA3H enzyme with threonine (Thr), a polar amino acid, at position 229. **Describe** the effect of the mutation on the enzyme and **provide reasoning** to support how this mutation results in a short plant phenotype in homozygous recessive plants.

(b) Using the codon chart provided, **predict** the change in the codon sequence that resulted in the substitution of alanine for threonine at amino acid position 229.

(c) **Describe** how individuals with one (heterozygous) or two (homozygous) copies of the wild-type *GA3H* allele can have the same phenotype.

6 Gene regulation, mutations, and biotechnology – Part 2

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
operon	操纵子			
differential gene expression	差异表达			
mutation	突变			
PCR	聚合酶链反应			
gel electrophoresis	凝胶电泳			

Recall

In Part A you saw how a cell reads DNA to make proteins. Now two important extras:

- Every cell has the same DNA, yet a muscle cell and a nerve cell are very different.
- DNA can change – a mutation – and scientists can now read and copy DNA.

Each idea has a short worked example before the Practice.

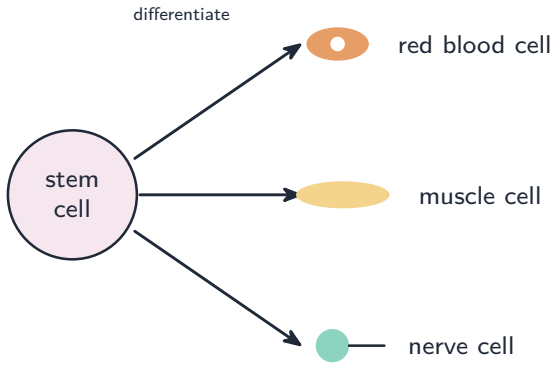
New ideas

■ 1 Controlling genes

Cells control **which** genes are switched on and when – so they use only the genes they need. In bacteria, an **operon** 操纵子 switches a group of genes on or off together.

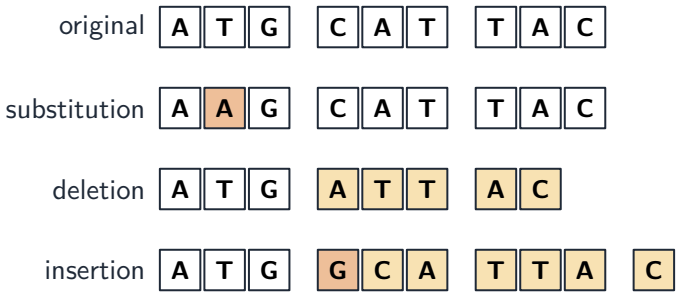
2 Why cells differ

Every cell in your body has the **same** DNA, but different cells switch on **different** genes – **differential gene expression** 差异表达. This is how one fertilised egg builds muscle, nerve, and skin cells.



3 Mutations

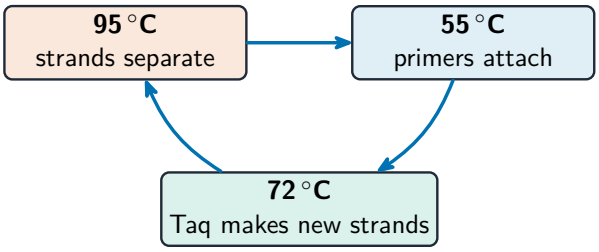
A **mutation** 突变 is a change in the DNA sequence. It may be harmful, neutral, or beneficial – and beneficial ones give the variation that natural selection acts on.



red = changed base; shaded = shifted by a frameshift (deletion or insertion)

4 Biotechnology

Scientists can work with DNA directly: **PCR** 聚合酶链反应 copies DNA many times, and **gel electrophoresis** 凝胶电泳 separates DNA pieces by size.



each cycle **doubles** the DNA → millions of copies

Watch out: all your cells share the **same** DNA – a skin cell and a brain cell differ only because they switch on **different genes**, not because they have different DNA.

Practice

Try these in order. The methods are all above.

2.1 Explain why a muscle cell and a nerve cell are different, even though they have the same DNA. [2]

2.2 State what a mutation is. [1]

2.3 State whether a mutation is always harmful, and explain. [2]

2.4 State what PCR is used for. [1]

2.5 State what gel electrophoresis separates DNA pieces by. [1]

7. Smell perception in mammals involves the interactions of airborne odorant molecules from the environment with receptor proteins on the olfactory neurons in the nasal cavity. The binding of odorant molecules to the receptor proteins triggers action potentials in the olfactory neurons and results in transmission of information to the brain. Mammalian genomes typically have approximately 1,000 functional odorant-receptor genes, each encoding a unique odorant receptor.

   (a) **Describe** how the signal is transmitted across the synapse from an activated olfactory sensory neuron to the interneuron that transmits the information to the brain.

   (b) **Explain** how the expression of a limited number of odorant receptor genes can lead to the perception of thousands of odors. Use the evidence about the number of odorant receptor genes to **support** your answer.

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   (b) **Explain** how the expression of a limited number of odorant receptor genes can lead to the perception of thousands of odors. Use the evidence about the number of odorant receptor genes to **support** your answer.

8. A research team has genetically engineered a strain of fruit flies to eliminate errors during DNA replication. The team claims that this will eliminate genetic variation in the engineered flies. A second research team claims that eliminating errors during DNA replication will not entirely eliminate genetic variation in the engineered flies.

   (a) **Provide** ONE piece of evidence that would indicate new genetic variation has occurred in the engineered flies.

   (b) **Describe** ONE mechanism that could lead to genetic variation in the engineered strain of flies.

   (c) **Describe** how genetic variation in a population contributes to the process of evolution in the population.

STOP

END OF EXAM

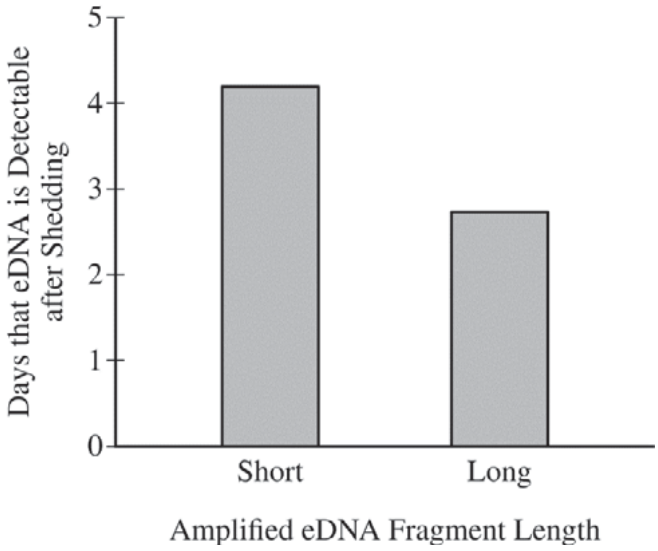


Figure 1. Detectability of eDNA fragments of varying lengths

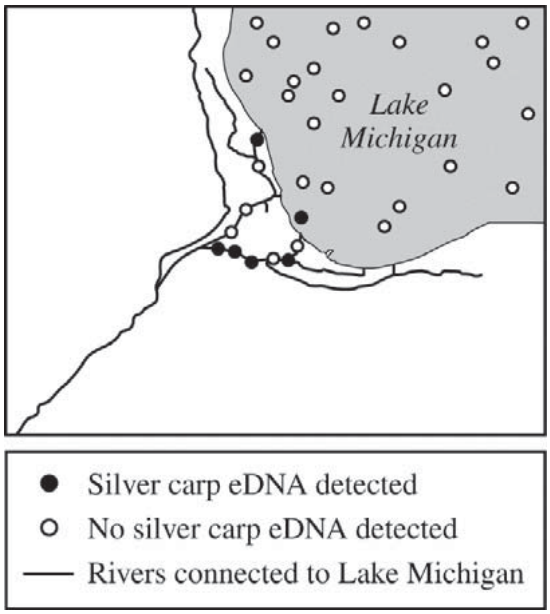


Figure 2. Map of the waterways that connect a nearby river system to Lake Michigan

6. Living and dead organisms continuously shed DNA fragments, known as eDNA, into the environment. To detect eDNA fragments in the environment, the polymerase chain reaction (PCR) can be used to amplify specific eDNA fragments. eDNA fragments of different lengths persist in the environment for varying amounts of time before becoming undetectable (Figure 1).

   To investigate whether silver carp, an invasive fish, have moved from a nearby river system into Lake Michigan, researchers tested water samples for the presence of eDNA specific to silver carp (Figure 2).

   (a) **Justify** the use of eDNA sampling as an appropriate technique for detecting the presence of silver carp in an environment where many different species of fish are found. **Propose** ONE advantage of identifying long eDNA fragments as opposed to short fragments for detecting silver carp.

   (b) The researchers tested a large number of water samples from Lake Michigan and found eDNA specific to silver carp in a single sample in the lake, as indicated in Figure 2. The researchers concluded that the single positive sample was a false positive and that no silver carp had entered Lake Michigan. **Provide reasoning** other than human error to support the researchers' claim.

7 Natural selection and evolution – Part 1

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	**中文**	**Write it 3 times** (English)		
Evolution	进化			
natural selection	自然选择			
variation	变异			
Fitness	适合度			
adaptation	适应			
artificial selection	人工选择			

Recall

You have likely met Darwin's big idea already:

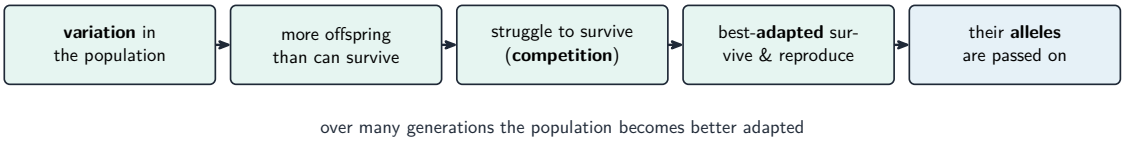
- Living things vary – no two are exactly alike.
- Those best suited to their environment tend to survive and have more offspring.
- Farmers breed animals and plants for the features they want.

This sheet lines up how evolution works. Each idea has a short worked example.

New ideas

1 Natural selection

Evolution 进化 is a change in a population's inherited traits over generations. Its main cause is **natural selection** 自然选择:



- individuals show **variation** 变异,
- some variations survive and reproduce better,
- those helpful traits become more common over time.

2 Fitness and adaptation

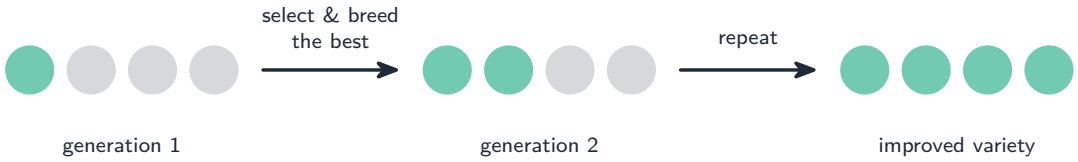
Fitness 适合度 means reproductive success – how many offspring an individual leaves, not how strong it is. A well-suited trait is an **adaptation** 适应.

3 Selection changes populations

Over many generations, natural selection makes helpful traits common and harmful ones rare, reshaping the whole population.

4 Artificial selection

In **artificial selection** 人工选择, humans (not nature) choose which individuals breed – for bigger crops, faster horses, or friendlier dogs.



Watch out: "fitness" in biology means **reproductive success**, not being strong or healthy. An animal that survives but leaves no offspring has zero fitness.

Practice

Try these in order. The methods are all above.

2.1 State the three key parts of natural selection. [3]

2.2 State what "fitness" means in biology. [1]

2.3 State the difference between natural selection and artificial selection. [2]

2.4 Explain why a helpful trait becomes more common in a population over time. [2]

2.5 Give one example of a trait produced by artificial selection. [1]

BIOLOGY
Section II
8 Questions
Planning Time—10 minutes
Writing Time—80 minutes

Directions: Questions 1 and 2 are long free-response questions that require about 22 minutes each to answer and are worth 10 points each. Questions 3–8 are short free-response questions that require about 6 minutes each to answer. Questions 3–5 are worth 4 points each and questions 6–8 are worth 3 points each.

Read each question carefully and completely. Write your response in the space provided for each question. Only material written in the space provided will be scored. Answers must be written out in paragraph form. Outlines, bulleted lists, or diagrams alone are not acceptable.

1. Trichomes are hairlike outgrowths of the epidermis of plants that are thought to provide protection against being eaten by herbivores (herbivory). In a certain plant species, stem trichome density is genetically determined.

   To investigate variation in stem trichome density within the plant species, a student counted the number of trichomes on the stems of six plants in each of three different populations. The student used the data to calculate the mean trichome density (numbers of hairs per square centimeter) for each population. The results are provided in the table below.

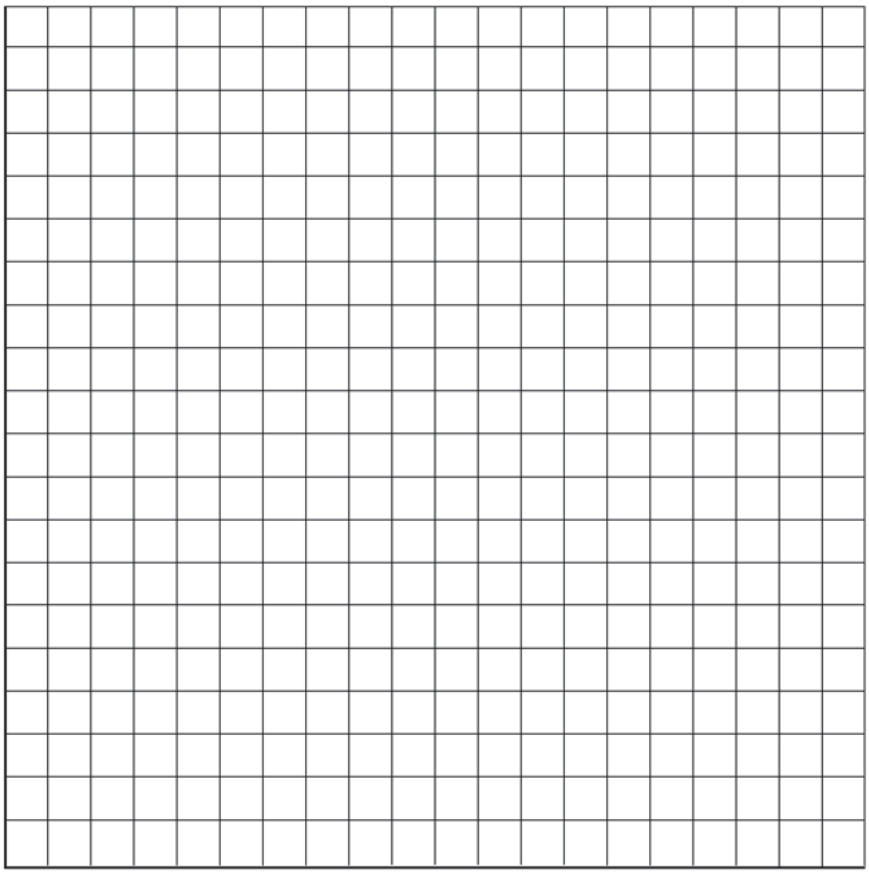
   TRICHOME DENSITY IN THREE PLANT POPULATIONS (number of trichomes/cm^2)

Population	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Mean	Standard Error of the Mean (SEM)
I	8	11	9	10	8	6	9	1
II	12	6	15	9	13	8	11	1
III	13	17	9	14	12	16	14	1

   (a) On the axes provided, **create** an appropriately labeled graph to illustrate the sample means of the three populations to within 95% confidence (i.e., sample mean ± 2 SEM).

   (b) Based on the sample means and standard errors of the means, **identify** the two populations that are most likely to have statistically significant differences in the mean stem trichome densities. **Justify** your response.

   (c) **Describe** the independent and dependent variables and a control treatment for an experiment to test the hypothesis that higher trichome density in plants is selected for in the presence of herbivores. **Identify** an appropriate duration of the experiment to ensure that natural selection is measured, and **predict** the experimental results that would support the hypothesis.



4. Existing isolated brook trout populations in Newfoundland, Canada, were once part of a larger population that was fragmented at the end of the most recent glaciation period about 10,000 to 12,000 years ago. Researchers investigated 14 naturally separated stream populations of brook trout. They found that the populations are all genetically distinct and show differences in morphology.

   (a) **Describe** the prezygotic barrier that results in these genetically distinct populations.

   (b) Brook trout with longer fins are able to swim faster than brook trout with shorter fins. In one of the Newfoundland streams, the main prey of the brook trout evolved to move faster. For brook trout living in this stream, **explain** the difference in fitness between longer-finned individuals and shorter-finned individuals.

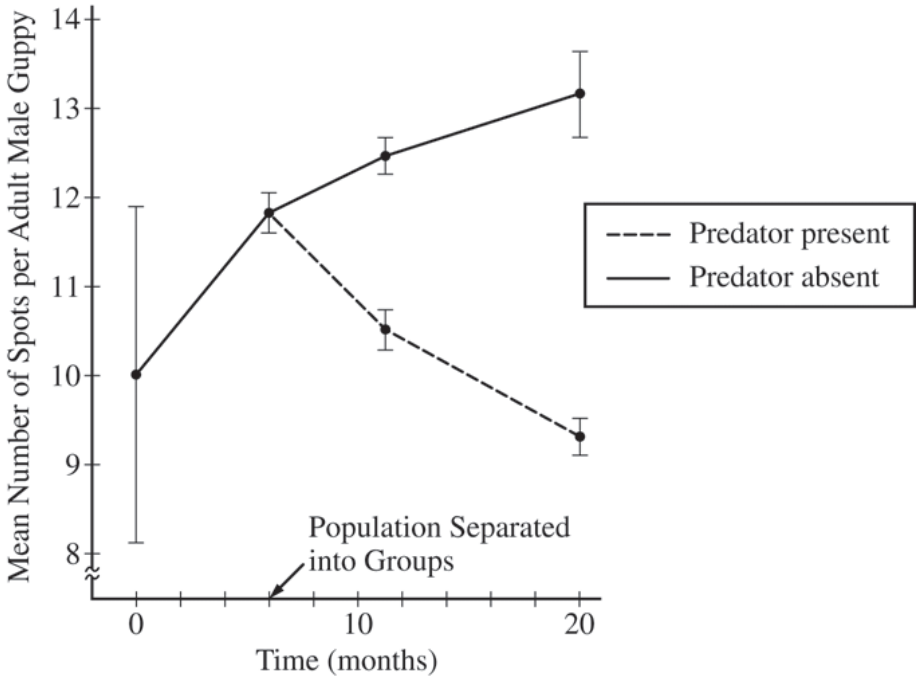
   (c) If two morphologically and behaviorally distinct populations of brook trout remain isolated for many generations, **predict** the likely impact on both populations.

   (d) Researchers claim that there are more genetic differences between any two current brook trout populations than there are between any single current population and the ancestral brook trout population from which all the trout are descended. Provide reasoning to **justify** their claim.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

4. Adult male guppies (*Poecilia reticulata*) exhibit genetically determined spots, while juvenile and adult female guppies lack spots. In a study of selection, male and female guppies from genetically diverse populations were collected from different mountain streams and placed together in an isolated environment containing no predators.

   The study population was maintained for several generations in the isolated area before being separated into two groups. One group was moved to an artificial pond containing a fish predator, while a second group was moved to an artificial pond containing no predators. The two groups went through several generations in their new environments. At different times during the experiment, the mean number of spots per adult male guppy was determined as shown in the figure below. Vertical bars in the figure represent two standard errors of the mean (SEM).



(a) **Describe** the change in genetic variation in the population between 0 and 6 months and **provide** reasoning for your description based on the means and SEM.

(b) **Propose** ONE type of mating behavior that could have resulted in the observed change in the number of spots per adult male guppy between 6 and 20 months in the absence of the predator.

(c) **Propose** an evolutionary mechanism that explains the change in average number of spots between 6 and 20 months in the presence of the predator.

4. Existing isolated brook trout populations in Newfoundland, Canada, were once part of a larger population that was fragmented at the end of the most recent glaciation period about 10,000 to 12,000 years ago. Researchers investigated 14 naturally separated stream populations of brook trout. They found that the populations are all genetically distinct and show differences in morphology.

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Write your responses to this question only on the designated pages in the separate Free Response booklet.

4. Twenty million years ago the Caribbean Sea and Pacific Ocean were connected, and water flowed freely between the two bodies of water. Many of the same marine species were found in both areas. Over millions of years, the land referred to as the Isthmus of Panama formed, eventually closing off the connection between the Caribbean Sea and Pacific Ocean and creating two separate bodies of water. The ecology of these two marine habitats was dramatically altered by this land formation. The warmer Caribbean water could no longer flow west, so the Pacific water cooled and became more nutrient-rich, while the Caribbean water became warmer.

A. Describe the genetic evidence that evolution is occurring in a population.

B. Explain how the isolation of marine species by the formation of a land barrier can lead to divergent evolution of those species.

The formation of the Isthmus of Panama connected two continents, North America and South America. Many North American land animal species migrated to South America after the formation of the isthmus and occupied similar niches as South American species.

C. Predict the effect the formation of the isthmus had on resource availability for South American species.

D. Justify your prediction in part C.

7 Populations, speciation, and evidence – Part 2

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
allele frequency	等位基因频率			
gene flow	基因流			
genetic drift	遗传漂变			
Speciation	物种形成			
reproductively isolated	生殖隔离			

Recall

In Part A you met natural selection. Now see it acting on whole populations:

- Bacteria can become resistant to antibiotics.
- Over long times, populations can split into new species.
- Fossils and DNA give evidence for evolution.

Each idea has a short worked example before the Practice.

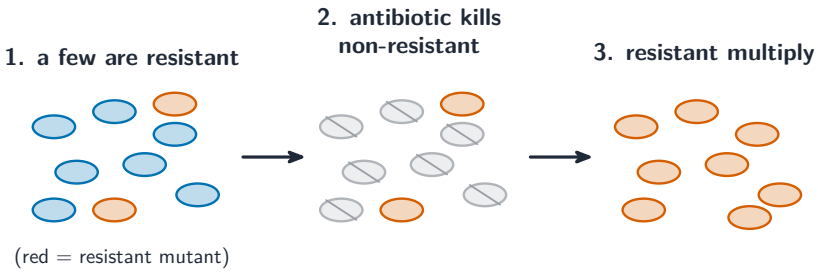
New ideas

■ 1 Evolution changes allele frequencies

A population's gene pool holds many **alleles**. Evolution is a change in how common each allele is – its **allele frequency** 等位基因频率. Besides natural selection, this changes through mutation, **gene flow** 基因流 (migration), and **genetic drift** 遗传漂变 (random change, strongest in small populations).

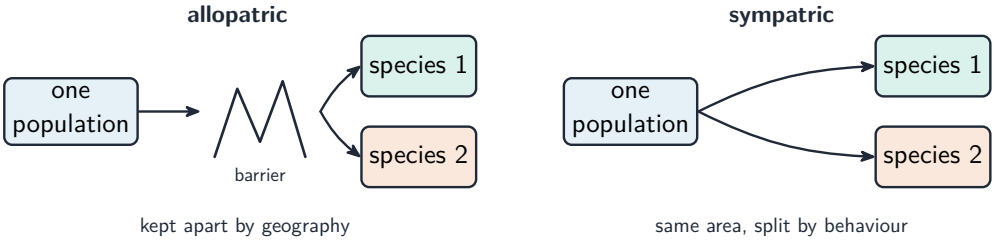
2 Antibiotic resistance

Antibiotic resistance is natural selection in fast-forward: a few bacteria happen to survive the drug, then reproduce, so the whole population becomes resistant.



3 Speciation

Speciation 物种形成 is the origin of a new species. It usually happens when populations become **reproductively isolated** 生殖隔离 (often by a geographic barrier) and slowly diverge until they can no longer interbreed.



4 Evidence for evolution

Many independent lines support evolution: the fossil record, shared anatomy between related species, and matching DNA sequences.

Watch out: individuals do **not** evolve – **populations** do. A single bacterium doesn't "become resistant"; rather, resistant ones survive and multiply, shifting the whole population.

Practice

Try these in order. The methods are all above.

2.1 State what evolution is, in terms of alleles in a population. [2]

2.2 Explain how a population of bacteria becomes resistant to an antibiotic. [3]

2.3 State what usually must happen for two populations to become separate species. [2]

2.4 Give two kinds of evidence that support evolution. [2]

2.5 Explain why it is wrong to say a single individual “evolves”. [2]

2. Mammalian milk contains antibodies that are produced by the mother's immune system and passed to offspring during feeding. Mammalian milk also contains a sugar (lactose) and may contain proteins (protein A, protein B, and casein), as indicated in the table.

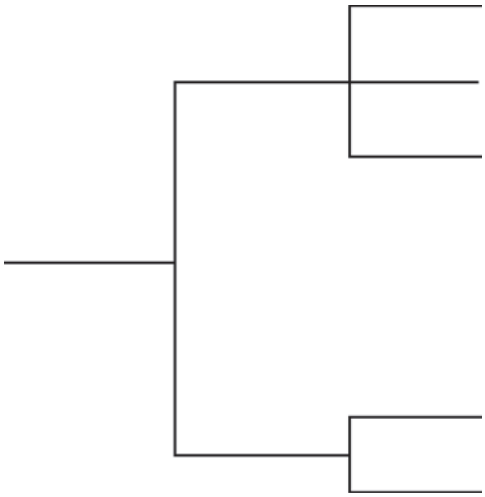
MILK COMPONENTS IN DIFFERENT MAMMALS

Character	Cat	Cow	Horse	Human	Pig
Lactose	+	+	+	+	+
Protein A	+	+	+	+	+
Protein B	–	+	+	–	+
Casein	–	+	+	–	+
+ indicates the presence of the character, and – indicates the absence of the character					

(a) Using the data in the table, **construct** a cladogram on the template provided to indicate the most likely evolutionary relationships among the different mammals. **Indicate** on the cladogram where each of the characters most likely arose in the evolutionary process, and **justify** the placement of the characters on the cladogram.

(b) **Describe** FOUR steps in the activation of the mother's specific immune response following exposure to a bacterial pathogen. **Predict** how the mother's immune response would differ upon a second exposure to the same bacterial pathogen a year later.

(c) **Predict** the most likely consequence for a nursing infant who is exposed to an intestinal bacterial pathogen (e.g., *Salmonella*) to which the mother was exposed three months earlier. **Justify** your prediction.



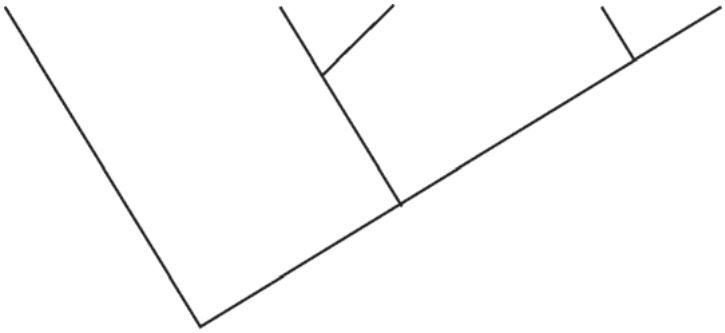
3. The amino acid sequence of cytochrome *c* was determined for five different species of vertebrates. The table below shows the number of differences in the sequences between each pair of species.

THE NUMBER OF AMINO ACID DIFFERENCES
IN CYTOCHROME *c* AMONG FIVE SPECIES

	E. ferus	*D. polylepis*	*G. gallus*	*A. forsteri*	*E. africanus*
E. ferus	0	21	11	13	1
D. polylepis		0	18	17	20
G. gallus			0	3	10
A. forsteri				0	12
E. africanus					0

(a) Using the data in the table, **create** a phylogenetic tree on the template provided to reflect the evolutionary relationships of the organisms. **Provide reasoning** for the placement on the tree of the species that is least related to the others.

(b) **Identify** whether morphological data or amino acid sequence data are more likely to accurately represent the true evolutionary relationships among the species, and **provide reasoning** for your answer.



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AP Biology: **2022**

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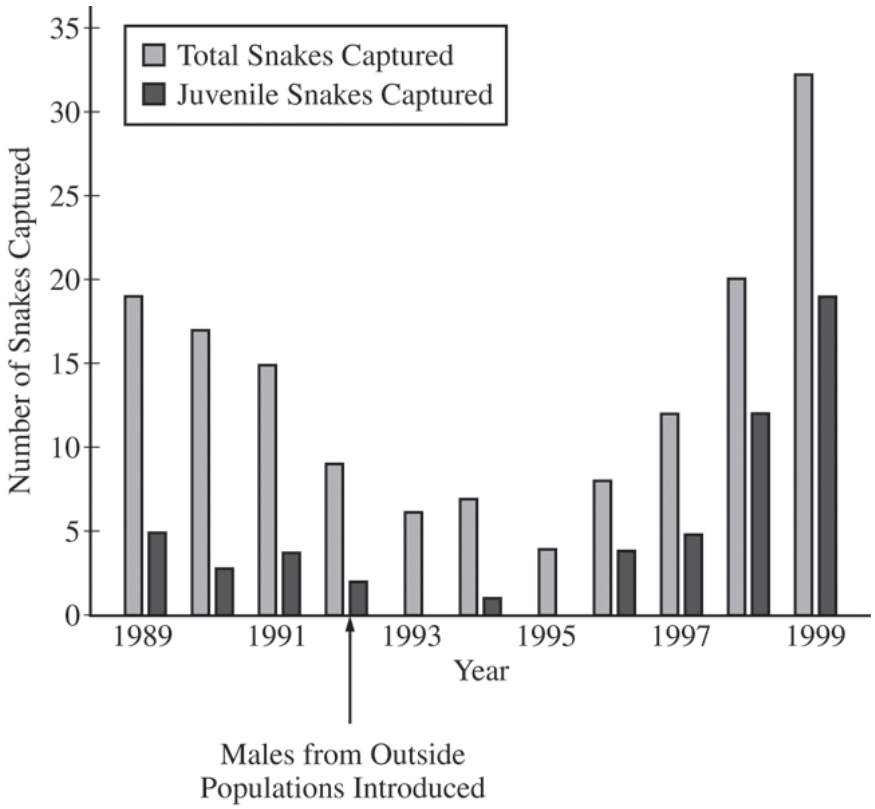
Write your responses to this question only on the designated pages in the separate Free Response booklet.

6. In an attempt to rescue a small isolated population of snakes from decline, a few male snakes from several larger populations of the same species were introduced into the population in 1992. The snakes reproduce sexually, and there are abundant resources in the environment.

   The figure below shows the results of a study of the snake population both before and after the introduction of the outside males. In the study, the numbers of captured snakes indicate the overall population size.



(a) **Describe** ONE characteristic of the original population that may have led to the population's decline in size between 1989 and 1993.

(b) **Propose** ONE reason that the introduction of the outside males rescued the snake population from decline.

(c) **Describe** how the data support the statement that there are abundant resources in the environment.

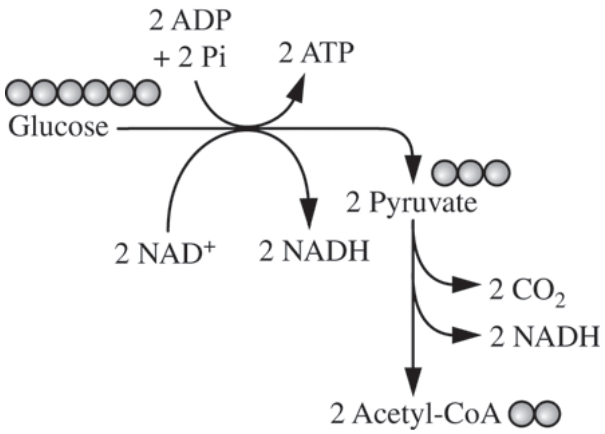


Figure 1. Glycolysis and pyruvate oxidation

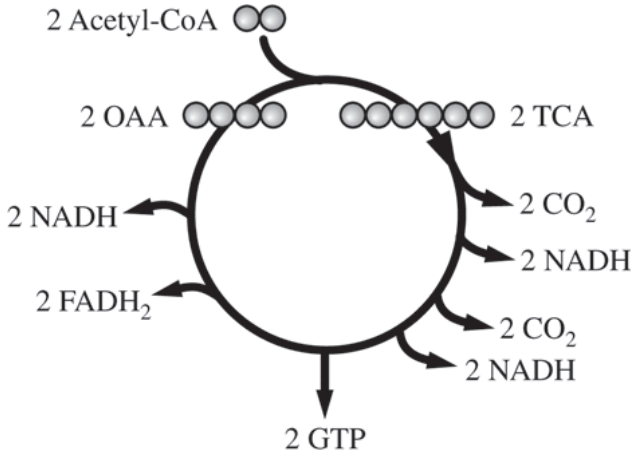


Figure 2. Krebs cycle

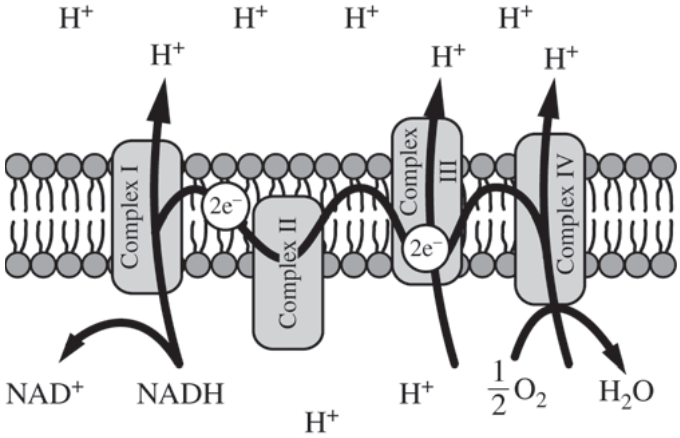


Figure 3. Electron transport chain

2. Cellular respiration includes the metabolic pathways of glycolysis, the Krebs cycle, and the electron transport chain, as represented in the figures. In cellular respiration, carbohydrates and other metabolites are oxidized, and the resulting energy-transfer reactions support the synthesis of ATP.

   (a) Using the information above, **describe** ONE contribution of <u>each</u> of the following in ATP synthesis.

   - Catabolism of glucose in glycolysis and pyruvate oxidation
   - Oxidation of intermediates in the Krebs cycle
   - Formation of a proton gradient by the electron transport chain

   (b) Use each of the following observations to **justify** the claim that glycolysis first occurred in a common ancestor of all living organisms.

   - Nearly all existing organisms perform glycolysis.
   - Glycolysis occurs under anaerobic conditions.
   - Glycolysis occurs only in the cytosol.

(c) A researcher estimates that, in a certain organism, the complete metabolism of glucose produces 30 molecules of ATP for each molecule of glucose. The energy released from the total oxidation of glucose under standard conditions is 686 kcal/mol. The energy released from the hydrolysis of ATP to ADP and inorganic phosphate under standard conditions is 7.3 kcal/mol. **Calculate** the amount of energy available from the hydrolysis of 30 moles of ATP. **Calculate** the efficiency of total ATP production from 1 mole of glucose in the organism. **Describe** what happens to the excess energy that is released from the metabolism of glucose.

(d) The enzymes of the Krebs cycle function in the cytosol of bacteria, but among eukaryotes the enzymes function mostly in the mitochondria. **Pose** a scientific question that connects the subcellular location of the enzymes in the Krebs cycle to the evolution of eukaryotes.

8 Energy flow and populations – Part 1

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
ecosystem	生态系统			
producers	生产者			
consumers	消费者			
food chain	食物链			
trophic level	营养级			
population	种群			
carrying capacity	环境容纳量			

Recall

You already know how living things depend on one another:

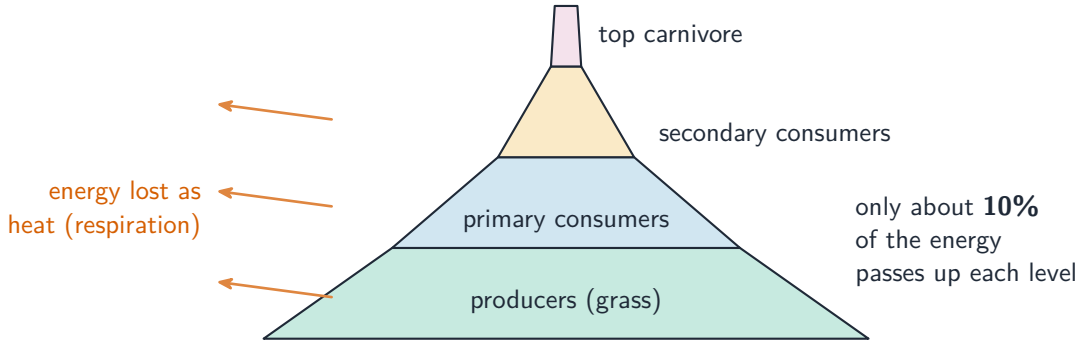
- Food chains show who eats whom, starting with plants.
- Energy from the Sun flows through an ecosystem.
- A population can grow, then level off when resources run low.

This sheet lines up energy flow and population growth. Each idea has a short worked example.

New ideas

1 Energy flow

Energy enters an **ecosystem** 生态系统 as sunlight, captured by **producers** 生产者 (plants), then passes to **consumers** 消费者 along a **food chain** 食物链. Each step is a **trophic level** 营养级.



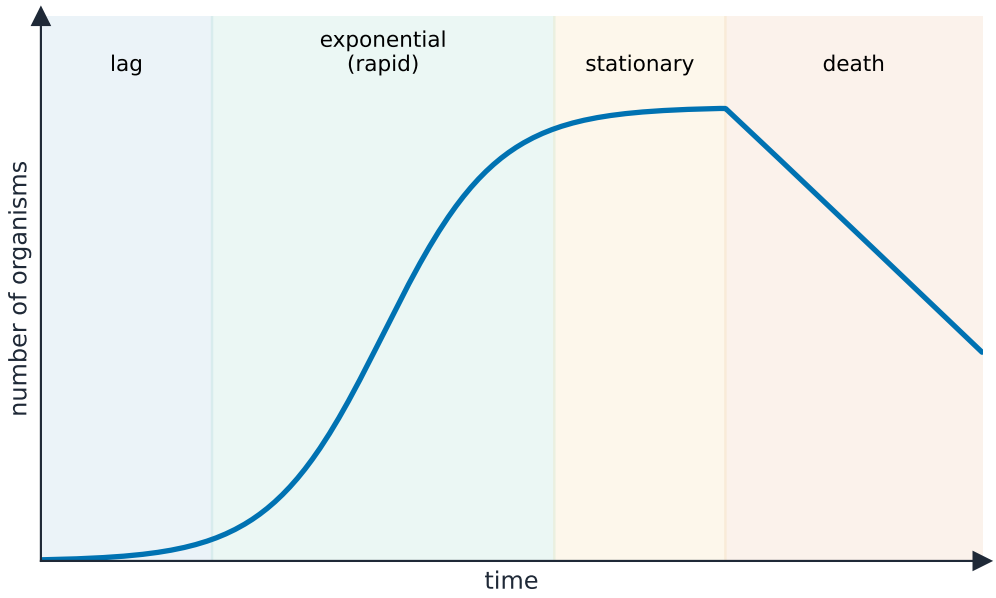
2 The 10% rule

Only about **10%** of the energy passes from one trophic level to the next – the rest is lost as heat. This is why food chains are short and top predators are few.

Worked example. If plants capture 10,000 units of energy, the next level gets about 1,000, then 100, then just 10 – losing 90% at each step.

3 Population growth

A **population** 种群 grows quickly when resources are plenty, then slows and levels off at the **carrying capacity** 环境容纳量 – the most the environment can support.



■ 4 What limits a population

Food, water, space, disease, and predators are **limiting factors** that stop a population growing without end.

Watch out: so much energy is lost between levels (about 90% each step) that a food chain rarely has more than four or five links – there is simply not enough energy left to support another predator.

Practice

Try these in order. The methods are all above.

2.1 State where the energy in an ecosystem originally comes from, and which organisms capture it. [2]

2.2 About what percentage of energy passes to the next trophic level? [1]

2.3 A plant level holds 8,000 units of energy. Estimate the energy at the next two levels. [2]

2.4 State what "carrying capacity" means. [2]

2.5 Give two factors that can limit the growth of a population. [2]

3. Sand lances of the genus *Ammodytes* are small fish that function as keystone organisms in several coastal ecosystems. These sand lances are prey fish that support organisms at higher trophic levels. Scientists performed experiments to examine how sand lance populations are likely to be affected by the rising temperatures and CO_2 levels associated with climate change.

   Sand lance embryos typically develop and mature into adult fish at low temperatures (approximately 5°C) and stable, low CO_2 levels (approximately 400 μatm). Over the course of two years, the scientists measured the survival rate of sand lance embryos allowed to develop and mature in a laboratory at three different temperatures, 5°C, 7°C, and 10°C, with the level of CO_2 maintained at 400 μatm, 1,000 μatm, and 2,100 μatm for each temperature.

   (a) **Describe** the effect of increased biodiversity on the resilience of an ecosystem in a changing environment.

   (b) **Justify** the scientists' selecting 5°C as the lowest temperature and 400 μatm as the lowest CO_2 level in their study of sand lance embryo survival.

   (c) **State** a null hypothesis for the experiment.

   (d) The scientists claim that a reduction in the population size of the *Ammodytes* sand lances will affect the stability of the entire coastal ecosystem. Provide reasoning to **support** the scientists' claim.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

AP Biology: **2015**

7. Smell perception in mammals involves the interactions of airborne odorant molecules from the environment with receptor proteins on the olfactory neurons in the nasal cavity. The binding of odorant molecules to the receptor proteins triggers action potentials in the olfactory neurons and results in transmission of information to the brain. Mammalian genomes typically have approximately 1,000 functional odorant-receptor genes, each encoding a unique odorant receptor.

   (a) **Describe** how the signal is transmitted across the synapse from an activated olfactory sensory neuron to the interneuron that transmits the information to the brain.

   (b) **Explain** how the expression of a limited number of odorant receptor genes can lead to the perception of thousands of odors. Use the evidence about the number of odorant receptor genes to **support** your answer.

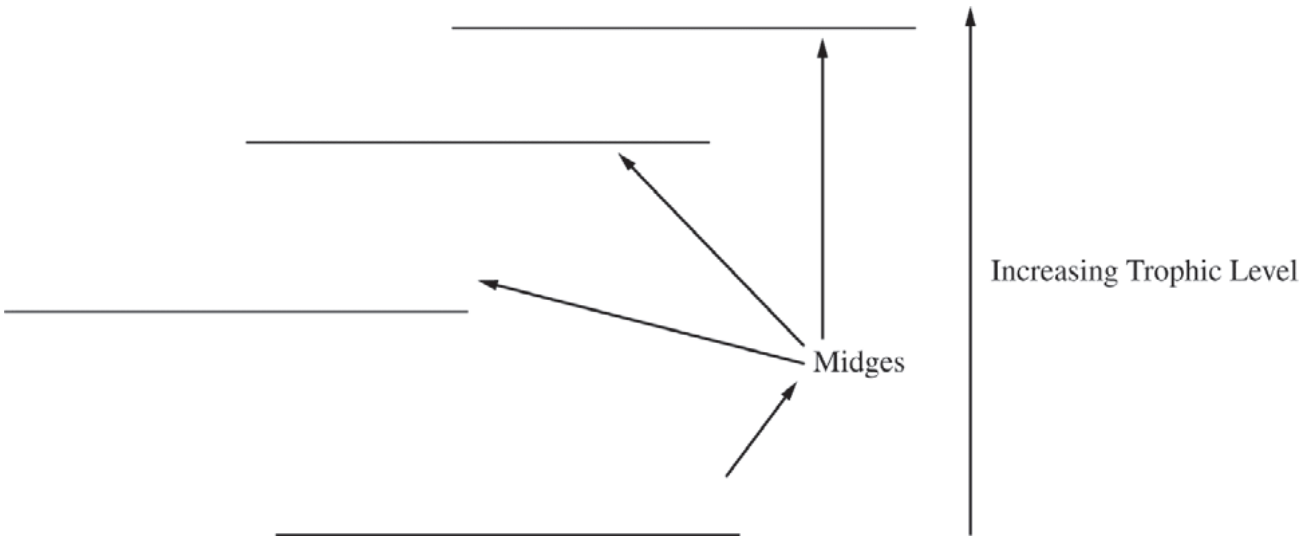
DIETARY COMPOSITION OF ORGANISMS IN AN AQUATIC ECOSYSTEM

Organism	Food Source (% of diet)				
	Algae	Stoneflies	Midges	Hellgrammites	Caddisflies
Algae					
Stoneflies			90		10
Midges	100				
Hellgrammites		20	10		70
Caddisflies	70		30		

4. The table above shows how much each organism in an aquatic ecosystem relies on various food sources. The rows represent the organisms in the ecosystem, and the columns represent the food source. The percentages indicate the proportional dietary composition of each organism. High percentages indicate strong dependence of an organism on a food source.

   (a) Based on the food sources indicated in the data table, **construct** a food web in the template below. Write the organism names on the appropriate lines AND draw the arrows necessary to indicate the energy flow between organisms in the ecosystem.

   (b) In an effort to control the number of midges, an area within the ecosystem was sprayed with the fungus *Metarhizium anisopliae*, which significantly decreased the midge population. Based on the data in the table, **predict** whether the spraying of the fungus will have the greatest short-term impact on the population of the stoneflies, the caddisflies, or the hellgrammites. **Justify** your prediction.



3. Buffelgrass, an invasive grass species in southwestern desert ecosystems, is threatening the saguaro cactus, a keystone species in these ecosystems. Buffelgrass is drought-tolerant and can survive wildfires. However, the dry buffelgrass also acts as fuel for wildfires, causing the fires to be more severe. Older saguaro cacti can survive wildfires; however, many of the young cacti cannot.

Scientists conducted an experiment to determine whether they could control the abundance of the buffelgrass population. The scientists identified several native grass species that, when grown with buffelgrass, might reduce the abundance of buffelgrass. They grew buffelgrass in the presence of several different native grass species in greenhouses, in either nondrought (watered every 3 days) or drought (watered every 9 days) conditions. After twelve weeks, they measured the height and dry weight of the buffelgrass in each treatment group.

A. **Describe** the effect that removing a keystone species will have on an ecosystem.

B. **Identify** a control group the scientists should include in their experiment.

C. **State** the null hypothesis of the experiment in which buffelgrass is grown in the presence of native grass species.

D. Scientists have found that the population growth rates of native grasses are much slower than the population growth rate of buffelgrass following a wildfire. The scientists claim that wildfires will therefore increase the abundance of buffelgrass plants in the ecosystem. Based on the information given, **justify** the scientists' claim.

8 Communities and ecosystems – Part 2

Name: _____ Class: _____ Date: _____

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
community	群落			
competition	竞争			
predation	捕食			
symbiosis	共生			
Biodiversity	生物多样性			
keystone species	关键种			

Recall

In Part A you followed energy through an ecosystem. Now look at how species live together:

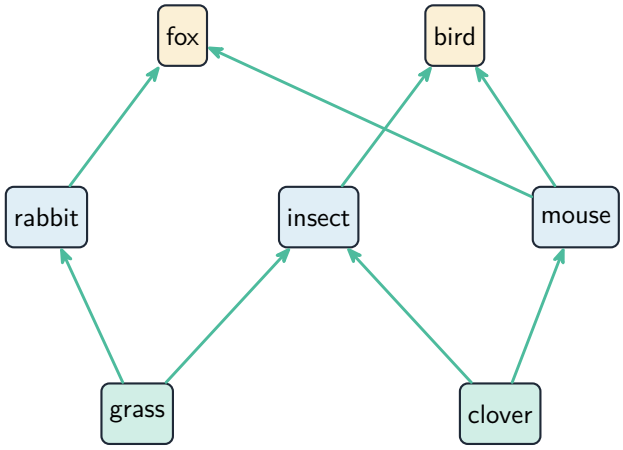
- Animals compete for food and space, hunt each other, and sometimes help each other.
- A variety of living things makes an ecosystem healthier.
- Human activity can damage ecosystems.

Each idea has a short worked example before the Practice.

New ideas

1 Community interactions

A **community** 群落 is all the species living together in an area. They interact by:



- **competition** 竞争 – for shared food, water, or space,
- **predation** 捕食 – one animal hunting another,
- **symbiosis** 共生 – living closely together (both may benefit, or one may harm the other).

2 Biodiversity

Biodiversity 生物多样性 is the variety of living things – genes, species, and habitats. Higher biodiversity usually makes an ecosystem more able to recover from disturbance.

3 Keystone species

A **keystone species** 关键种 has an outsized effect on its community – removing it can cause the whole system to collapse.

4 Human impact

Human actions – habitat loss, pollution, over-hunting, and climate change – reduce biodiversity and disturb ecosystems, and because species are linked, a change to one can ripple through many.

Watch out: because species are connected in a food web, harming one species (especially a keystone species) can affect many others – not just that one.

Practice

Try these in order. The methods are all above.

2.1 Name three ways species in a community interact. [3]

2.2 State what biodiversity means. [2]

2.3 Explain why higher biodiversity usually makes an ecosystem more resilient. [2]

2.4 State what a keystone species is. [2]

2.5 Give two ways human activity can reduce biodiversity. [2]

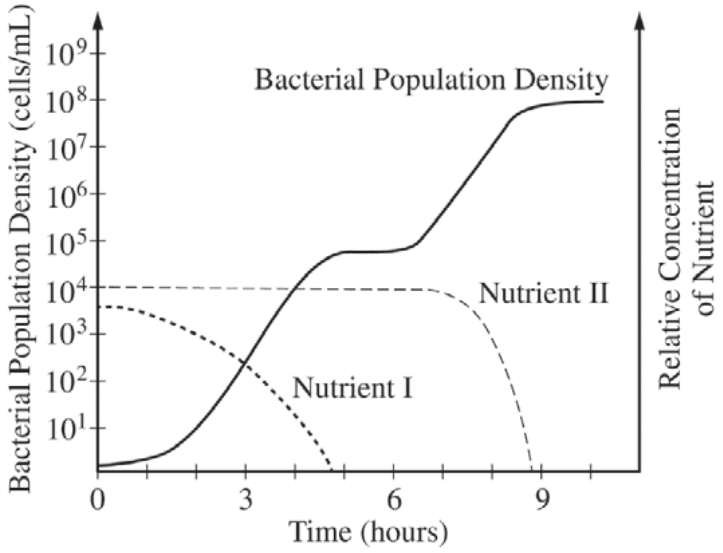


Figure 1. Bacterial population growth in the presence of two nutrients (nutrient I and nutrient II)

2. Bacteria can be cultured in media with a carefully controlled nutrient composition. The graph above shows the growth of a bacterial population in a medium with limiting amounts of two nutrients, I and II.

   (a) **Estimate** the maximum population density in $\frac{\text{cells}}{\text{mL}}$ for the culture. Using the data, **describe** what prevents further growth of the bacterial population in the culture.

   (b) Using the data, **calculate** the growth rate in $\frac{\text{cells}}{\text{mL}\times\text{hour}}$ of the bacterial population between hours 2 and 4.

   (c) **Identify** the preferred nutrient source of the bacteria in the culture over the course of the experiment. Use the graph to **justify** your response. **Propose** ONE advantage of the nutrient preference for an individual bacterium.

   (d) **Describe** how nutrient I most likely regulates the genes for metabolism of nutrient I and the genes for metabolism of nutrient II. **Provide** TWO reasons that the population does not grow between hours 5 and 6.

4. Twenty million years ago the Caribbean Sea and Pacific Ocean were connected, and water flowed freely between the two bodies of water. Many of the same marine species were found in both areas. Over millions of years, the land referred to as the Isthmus of Panama formed, eventually closing off the connection between the Caribbean Sea and Pacific Ocean and creating two separate bodies of water. The ecology of these two marine habitats was dramatically altered by this land formation. The warmer Caribbean water could no longer flow west, so the Pacific water cooled and became more nutrient-rich, while the Caribbean water became warmer.

A. Describe the genetic evidence that evolution is occurring in a population.

B. Explain how the isolation of marine species by the formation of a land barrier can lead to divergent evolution of those species.

The formation of the Isthmus of Panama connected two continents, North America and South America. Many North American land animal species migrated to South America after the formation of the isthmus and occupied similar niches as South American species.

C. Predict the effect the formation of the isthmus had on resource availability for South American species.

D. Justify your prediction in part C.

AP Biology: **2017**

7. Many species of bacteria grow in the mouths of animals and can form biofilms on teeth (plaque). Within plaque, the outer layers contain high levels of oxygen and the layers closest to the tooth contain low levels of oxygen. The surface of the tooth is covered in a hard layer of enamel, which can be dissolved under acidic conditions. When the enamel breaks down, the bacteria in plaque can extract nutrients from the tooth and cause cavities.

   Certain types of bacteria (e.g., *Streptococcus mutans*) thrive in the innermost anaerobic layers of the plaque and are associated with cavities. Other types of bacteria (*Streptococcus sanguinis*) compete with *S. mutans* but are unable to thrive in acidic environments.

   (a) **Identify** the biochemical pathway *S. mutans* uses for metabolizing sugar and **describe** how the pathway contributes to the low pH in the inner layers of plaque.

   (b) Normal tooth brushing effectively removes much of the plaque from the flat surfaces of teeth but cannot reach the surfaces between teeth. Many commercial toothpastes contain alkaline components, which raise the pH of the mouth. **Predict** how the population sizes of *S. mutans* AND *S. sanguinis* in the bacterial community in the plaque between the teeth are likely to change when these toothpastes are used.

4. The common wild oat is native to regions of Europe and Asia but is an invasive species in central California grasslands. In California, the common wild oat has almost completely replaced some species of native bunchgrass. Researchers found that aphids, a type of small insect that often carries plant viruses, have a much higher reproductive rate in grasslands that include the common wild oat than in grasslands composed of only native bunchgrass species. Additionally, the viruses carried by the aphids appear to affect only the native bunchgrasses and not the common wild oat. Native bunchgrasses infected by the virus have much higher death rates than do native bunchgrasses that are not infected.

   (a) **Describe** the change in the resilience of an ecosystem when there is a decrease in the number of species.

   (b) **Explain** how the addition of the common wild oat affects the number of native bunchgrass plants that can be supported by the California grasslands ecosystem.

   (c) Researchers suggest adding ladybugs, predators of aphids, to the California grasslands. **Predict** the effect of adding ladybugs on the abundance of the native bunchgrass population.

   (d) **Justify** your prediction in part (c).

Write your responses to this question only on the designated pages in the separate Free Response booklet.

If there are multiple parts to this question, write the part letter with your response.

3. Buffelgrass, an invasive grass species in southwestern desert ecosystems, is threatening the saguaro cactus, a keystone species in these ecosystems. Buffelgrass is drought-tolerant and can survive wildfires. However, the dry buffelgrass also acts as fuel for wildfires, causing the fires to be more severe. Older saguaro cacti can survive wildfires; however, many of the young cacti cannot.

Scientists conducted an experiment to determine whether they could control the abundance of the buffelgrass population. The scientists identified several native grass species that, when grown with buffelgrass, might reduce the abundance of buffelgrass. They grew buffelgrass in the presence of several different native grass species in greenhouses, in either nondrought (watered every 3 days) or drought (watered every 9 days) conditions. After twelve weeks, they measured the height and dry weight of the buffelgrass in each treatment group.

A. Describe the effect that removing a keystone species will have on an ecosystem.

B. Identify a control group the scientists should include in their experiment.

C. State the null hypothesis of the experiment in which buffelgrass is grown in the presence of native grass species.

D. Scientists have found that the population growth rates of native grasses are much slower than the population growth rate of buffelgrass following a wildfire. The scientists claim that wildfires will therefore increase the abundance of buffelgrass plants in the ecosystem. Based on the information given, **justify** the scientists' claim.

AP Biology: **2014**

3. As part of a new suburban development, a sports complex consisting of athletic fields and buildings is constructed in a formerly wooded area.

   (a) **Predict** ONE ecological consequence on the local plant community that is likely to result during the site preparation and construction of the sports complex. **Justify** your prediction.

   (b) To maintain the playing fields, large quantities of water and chemicals are applied regularly to the grass-covered areas. **Predict** ONE effect on the local animal community that might result from regular use and maintenance of the playing fields. **Justify** your prediction.