Chapter 4
Energy and Metabolism

Life Runs on Energy

- **Energy**
  - The capacity to do work
- Work occurs as a result of energy transfers
  - Example: A plant cell powers glucose synthesis by absorbing light energy from the sun
- Some energy is lost during every transfer or conversion

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Laws of Thermodynamics

• First law of thermodynamics

- Energy cannot be created or destroyed
- Energy can be converted from one form to another and transferred between objects or systems

• Second law of thermodynamics

- Energy tends to disperse spontaneously
- Some energy disperses at each energy transfer, usually in the form of heat

One-Way Flow of Energy

- Living things maintain their organization by harvesting energy from someplace else
- Energy flows in one direction through the biosphere (starting mainly from the sun) then into and out of ecosystems
- Energy in chemical bonds is a type of potential energy

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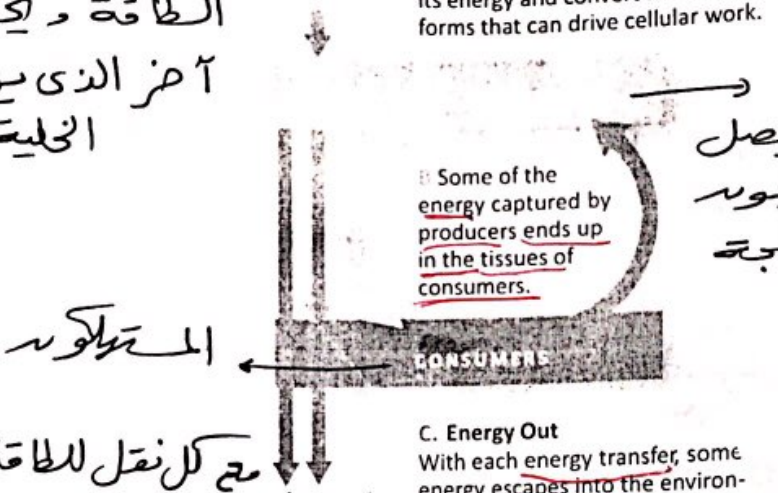
Energy Flow in the World

الطاقة التي يضوء الشمس تصل البيئة على الأرض . المنتجون في هذه البيئة الحصول على بعض الطاقة و يحولونها لشكل آخر الذي يؤدي لعمل الخلية .



(المنتجون) بعض الطاقة التي يحصل عليها بواسطة المنتجون تؤول إلى أنسجة المستهلكون .

المستهلكون

مع كل نقل للطاقة بعض الطاقة تفقد في البيئة على شكل حرارة . الأشياء الحية لا تستخدم الحرارة في الأداء الخلوي لذا الطاقة تتدفق خلال العالم في اتجاه واحد .

Energy in the Molecules of Life

الحياة جزيئات في الطاقة

تفاعلات الأيض في الطاقة تترجم و تخزن الخلايا

- Cells store and retrieve energy in metabolic reactions التفاعلات
- Some reactions require a net input of energy – others end with a net release of energy

بعض تتطلب إجمالي مدخلات من بتحرر الى الطاقة بعض الطاقة التفاعلات

1) • Reaction عملية تغير كيميائي
  – Process of chemical change

المتفاعلات 2) • Reactant الذي جزيء التفاعل يدخل
  – Molecule that enters a reaction

3) المنتج • Product الجزيء يبقى التفاعل لنهاية
  – A molecule remaining at the end of a reaction

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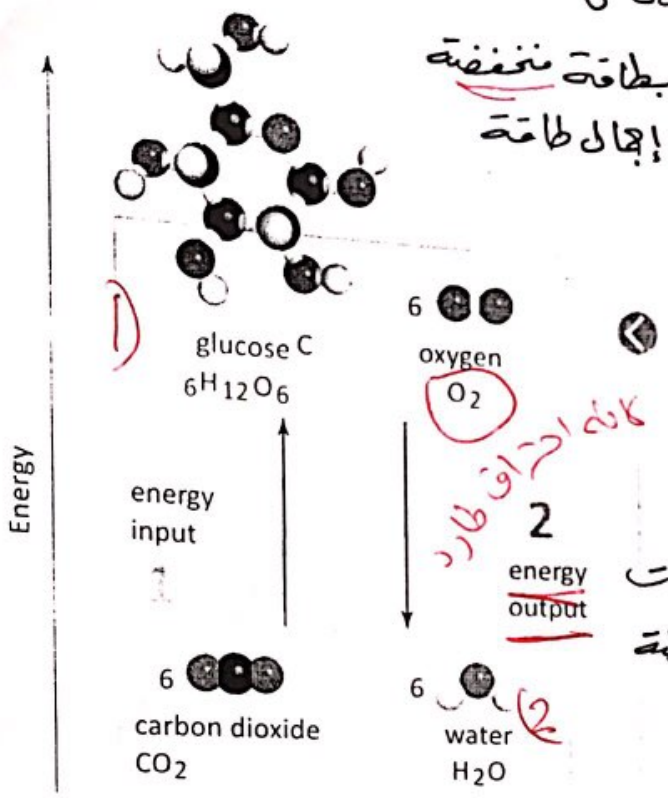
Energy Inputs and Outputs in Chemical Reactions

مدخلات ومخرجات الطاقة في التفاعلات الكيميائية



* بعض التفاعلات تحول الجزيئات بطاقة منخفضة لجزيئات طاقة عالية لذا تتطلب إمداد طاقة مدخلة لكي ينفذ.

1 Some reactions convert molecules with lower energy to molecules with higher energy, so they require a net energy input in order to proceed.

2 Other reactions convert molecules with higher energy to molecules with lower energy, so they end with an energy release.

بعض التفاعلات الأخرى تحول جزيئات بطاقة عالية لجزيئات بطاقة منخفضة لذا يتطلب طاقة إجمالية لكي يحرر طاقة

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4.4 How Enzymes Work كيف تعمل الإنزيمات

- **Enzyme** الإنزيم
  - Protein or RNA that speeds a reaction without being changed by it بروتين يسرع التفاعل دون تغير فيه
  - Makes a reaction run much faster than it would on its own يجعل التفاعل يحدث أسرع مما يفعله بنفسه
  - Reduces activation energy يقلل طاقة التنشيط
- **Substrate** المتفاعل
  - Reactant molecule specifically acted upon by an enzyme جزيء متفاعل بواسطة إنزيم يعمل خاصة
  - An enzyme's particular substrates bind at its active site يرتبط المتفاعلات الخاصة بالإنزيم بالموقع النشط

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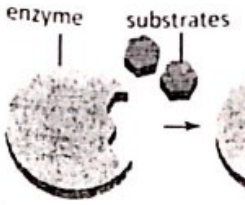
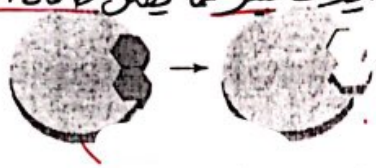
How an Active Site Works

A. An active site binds substrates that are complementary in shape, size, polarity, and charge.



B. Binding at an active site squeezes substrates together, influences their charge, or causes some change that lowers activation energy, and the reaction proceeds.



C. The product leaves the active site after the reaction is finished. The enzyme is unchanged, so it can work again.

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Factors That Influence Enzyme Activity

- Each enzyme works best within a characteristic range of temperature, pH, and salt concentration
- When conditions break hydrogen bonds, an enzyme changes its characteristic shape (denatures), and stops working
- Regulatory molecules affect an enzyme by binding directly to its active site; or elsewhere on the enzyme

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Cofactors العوامل المساعدة

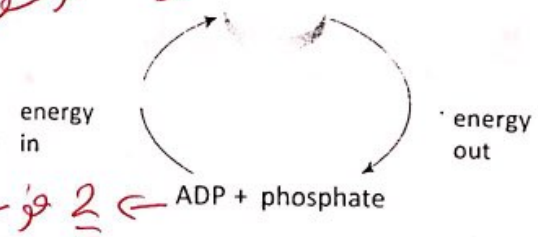
- Metal ions or coenzymes that associate with an enzyme and are necessary for its function
  - **Example:** many dietary vitamins and minerals

- **Coenzyme**
  - An organic cofactor
  - Unlike enzymes, it may be modified by a reaction
  - **Example:** coenzyme NAD^+ + electrons + H → NADH

ATP and Phosphorylation

- ATP functions as a coenzyme in many reactions

ATP as an Energy Carrier



- When a phosphate group is transferred to or from a nucleotide, energy is transferred along with it

B. ADP forms in a reaction that removes a phosphate group from ATP. Energy released in this reaction drives other reactions that are the stuff of cellular work. ATP forms again in reactions that phosphorylate ADP.

$ATP \xrightarrow{-P} ADP$ ($\xleftarrow{+P}$ فسفرة)

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Metabolic Pathways مسار الأيض

- **Metabolic pathway**
  - Series of enzyme-mediated reactions by which cells build, remodel, or break down an organic molecule

Electron Transfers

- **Electron transfer chain**
  - An array of membrane-bound enzymes and other molecules that accept and give up electrons in sequence

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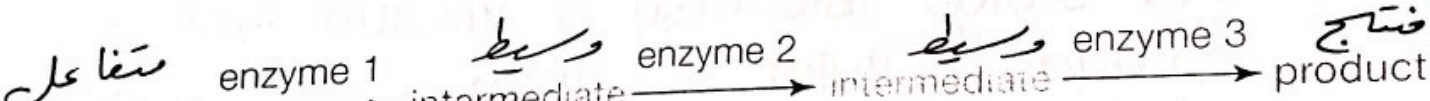
Linear and Cyclic Metabolic Pathways



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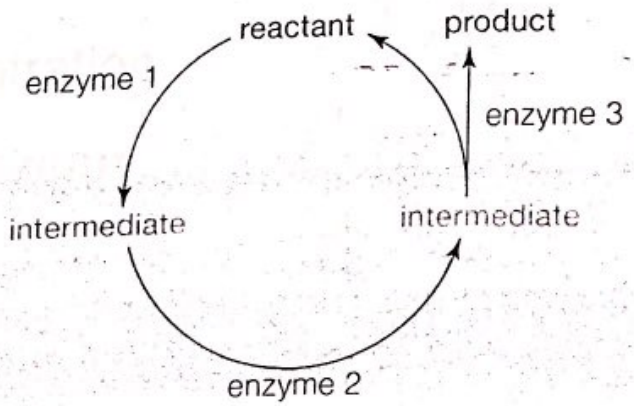

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4.5 Diffusion and Membranes

- **Diffusion**
  - Spontaneous spreading of molecules or ions through a liquid or gas

ANY EXAMPLE?

THINK ABOUT IT

Diffusion Rate

- How quickly a particular solute diffuses through a particular solution depends on five factors:

1) - Concentration
2) - Temperature
3) - Size
4) - Charge
5) - Pressure

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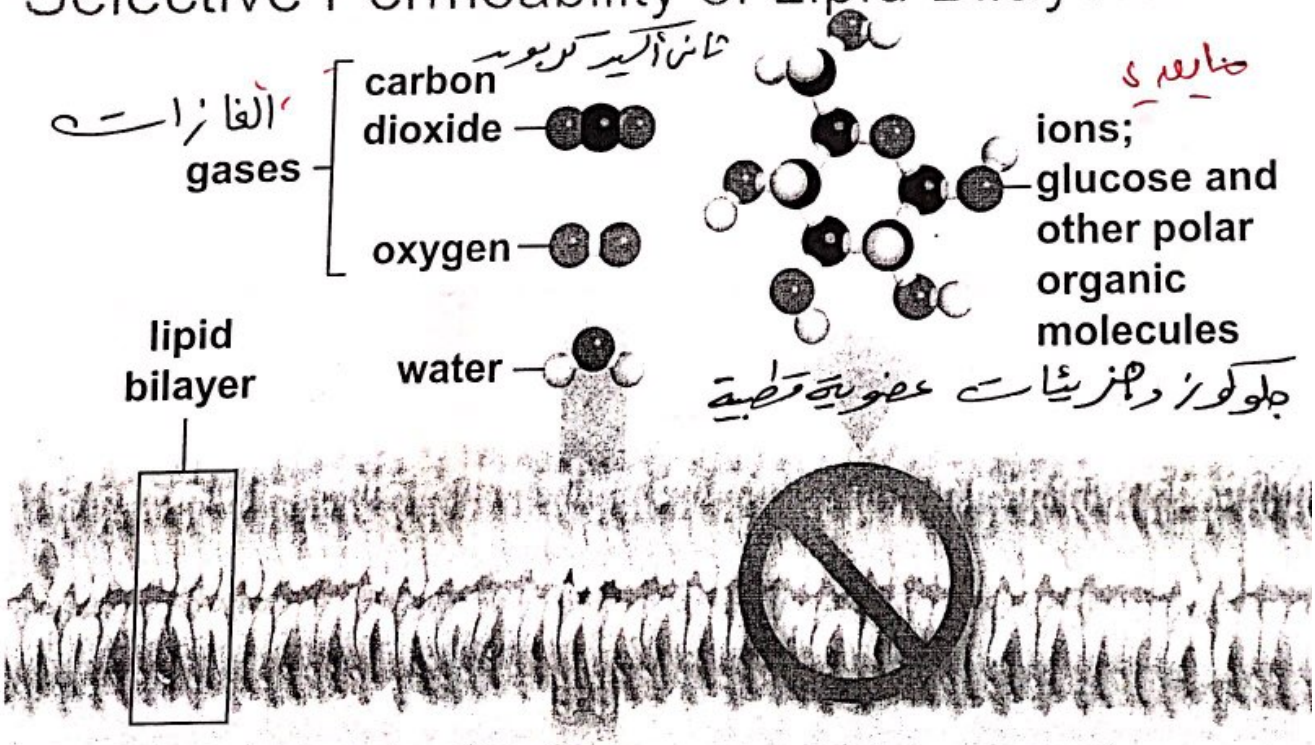
Semipermeable Membranes

- When fluids on either side of a selectively permeable membrane differ in solute concentration
- Water diffuses across the membrane in a direction that depends on tonicity:
  1. **Hypotonic:** low solute concentration relative to another fluid
  2. **Hypertonic:** high solute concentration relative to another fluid
  3. **Isotonic:** same solute concentration relative to another fluid

Selective Permeability of Lipid Bilayers



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Osmosis

الاسموزية

- Osmosis
  - Diffusion of water across a selectively permeable membrane between two fluids that are not isotonic

الانتشار / النفاذ — الماء — عبر — نسبياً — مائعين — الغشاء — لا يكونا متعادلين بالضغط

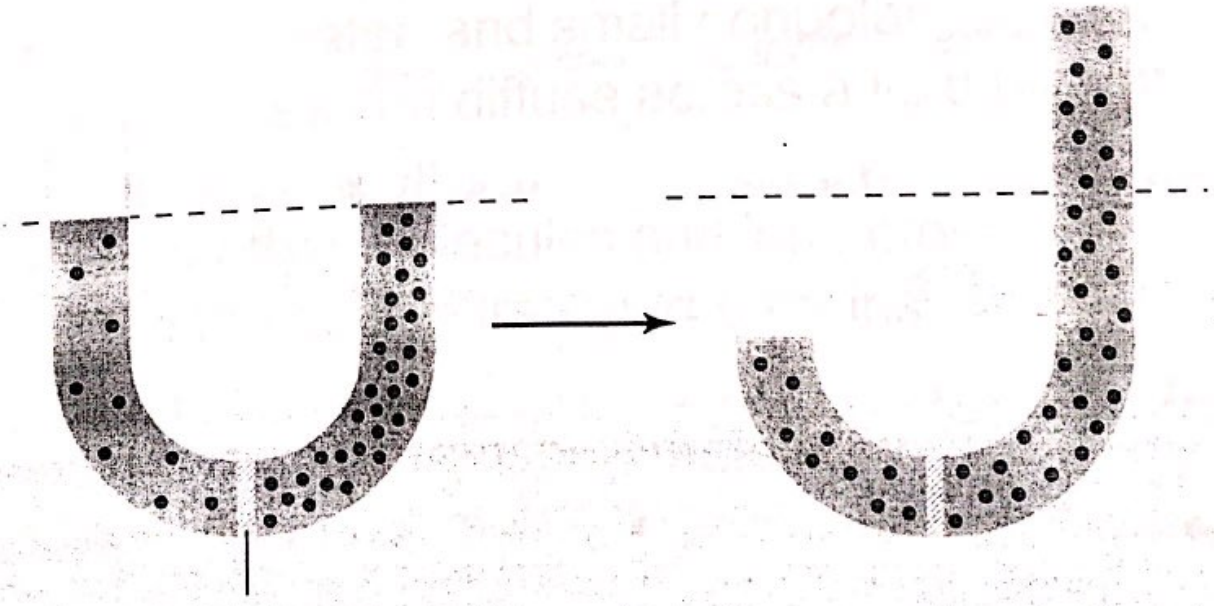
- If extracellular fluid is not isotonic, cell volume changes

لو أن السائل خارج الخلية — ليس متعادل — حجم الخلية — يتغير

  - Cells in hypertonic fluid shrink
  - Cells in hypotonic fluid swell

يتقلص / ينكمش — يتضخم

Osmosis (cont'd.)



selectively permeable membrane

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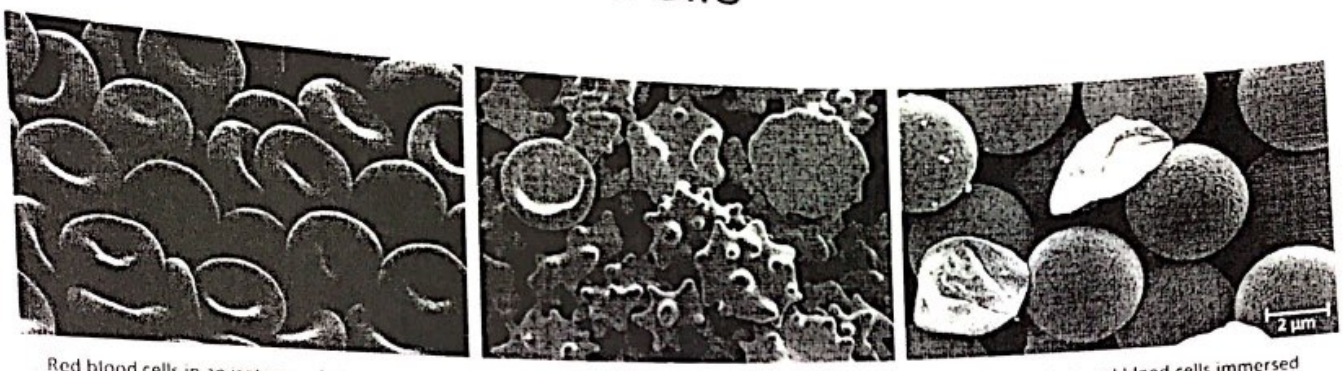
Effects of Tonicity in Human Red Blood Cells



A. Red blood cells in an isotonic solution (such as the fluid portion of blood) have a normal, indented disk shape.

B. Water diffuses out of red blood cells immersed in a hypertonic solution, so they shrivel up.

C. Water diffuses into red blood cells immersed in a hypotonic solution, so they swell up. Some of these have burst.

ISOTONIC

HYPERTONIC

HYPOTONIC

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4.6 Membrane Transport Mechanisms

- Gases, water, and small nonpolar molecules can diffuse across a lipid bilayer
- Most other molecules and ions cross only with the help of transport proteins
- Each type of transport protein moves a specific ion or molecule across a membrane

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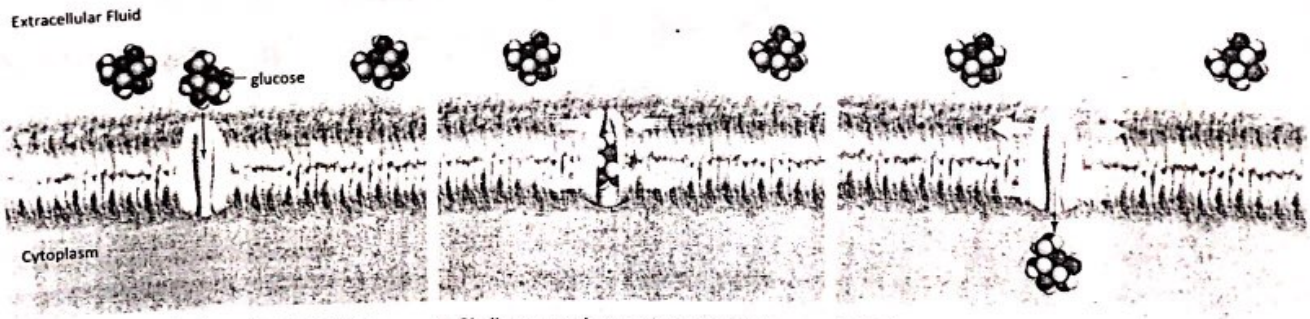
Passive and Active Transport النقل النشط والسلبي

- **Passive transport** النقل السلبي
  - Concentration gradient drives a solute across a cell membrane through a transport protein
  - Requires no energy input
  - Example: glucose transporters

- **Active transport** النقل النشط
  - A transport protein uses energy (ATP) to pump a solute across a cell membrane against its concentration gradient
  - Example: calcium pump

Passive Transport of Glucose



A. A glucose molecule (here, in extracellular fluid) binds to a glucose transporter (gray) in the plasma membrane.

B. Binding causes the transport protein to change shape.

C. The transport protein releases the glucose on the other side of the membrane (in cytoplasm) and resumes its original shape.

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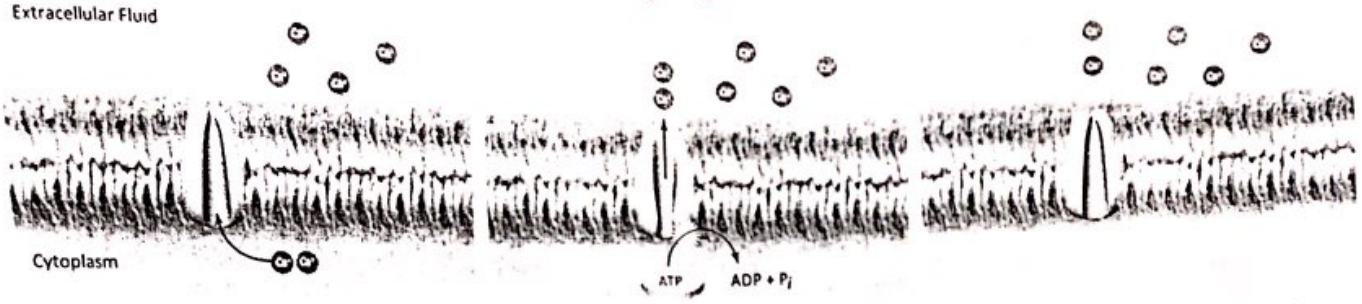
Active Transport of Calcium Ions



A Two calcium ions (blue) bind to the transport protein (a calcium pump, gray).

B A phosphate group from ATP causes the protein to change shape so that the calcium ions are ejected to the opposite side of the membrane.

C After it loses the calcium ions, the transport protein resumes its original shape.

أيونيز كالسيوم ترتبط بالبروتين الناقل

مجموعة فوسفات من ATP تسبب أن يغير البروتين شكله لذا أيونات الكالسيوم تطرد للجانب الآخر من الغشاء

بعد فقد هما الأيون الكالسيوم البروتين الناقل يرجع لشكله الأصلي

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Membrane Trafficking

Endocytosis

الإدخال الخلوي (الالتقام)

- Process by which a cell takes in a small amount of extracellular fluid by a ballooning inward of its cellular membrane

عملية تأخذ الخلية حيث جزء صغير من السائل خارج الخلية بالداخل بواسطة انتفاخ بغشاء الخلوي

Exocytosis

الإخراج الخلوي (الإطلاق)

- Process by which a cell expels a vesicle's contents to extracellular fluid by merging the vesicle with the plasma membrane

عملية تفصل الخلية الحويصلة بواسطة خارج الخلية مكونات الحويصلة بالغشاء البلازمي

Phagocytosis ("cell eating")

الابتلاع الخلوي (البلعمة)

- Endocytic pathway by which cells such as macrophages and other white blood cells engulf particles such as microbes or cellular debris

بواسطة الخلية مثل الابتلاع البالعات الدم البيضاء بلع الجسيمات مثل الميكروبات الحطام الخلوي

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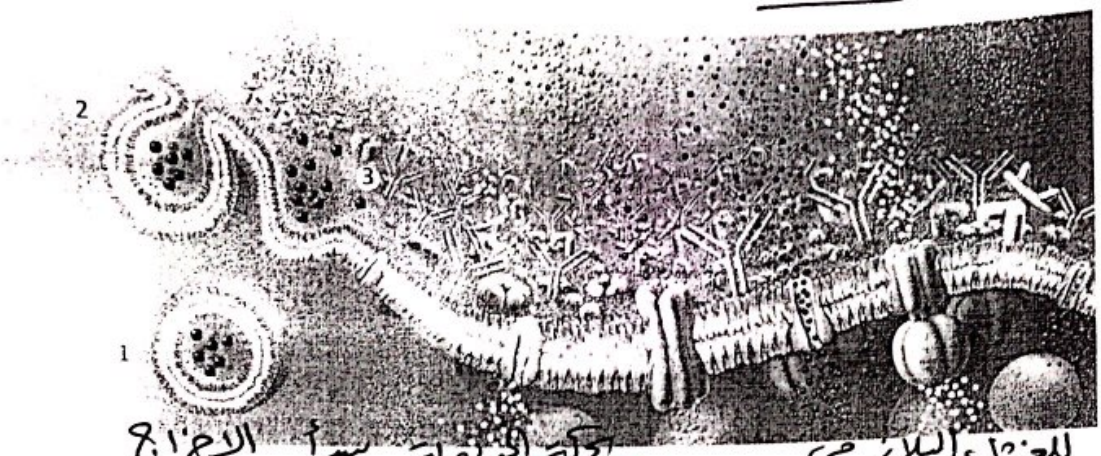
Membrane Crossings

عبور الخلية



1 Exocytosis begins as a vesicle moves to the plasma membrane.

2 The vesicle's membrane fuses with the plasma membrane.

3 As the membranes fuse, the vesicle's contents are released to the extracellular fluid.

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