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КАФЕДРА ІНОЗЕМНИХ МОВ

АНГЛІЙСЬКА МОВА ДЛЯ СТУДЕНТІВ СПЕЦІАЛЬНОСТІ «БІОЛОГІЯ». Частина I

ENGLISH FOR STUDENTS OF "BIOLOGY" SPECIALITY. Part I

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Мета методичних рекомендацій − забезпечити практичне оволодіння студентами лексичними та мовленнєвими моделями, необхідними для вільного спілкування англійською мовою за фахом. Матеріали методичних рекомендацій сприятимуть оволодінню навичками та вмінням читання, мовлення (діалогічного і монологічного) та письма на фахову тематику. Методичні рекомендації призначені для широкого кола читачів: слухачів курсів іноземних мов, студентів та аспірантів, викладачів вищих навчальних закладів.

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ПЕРЕДМОВА

З прискоренням глобалізації і поширенням міжнародних ділових зв'язків України з іншими державами на політичному та економічному рівнях зростає потреба у висококваліфікованих фахівцях, які здатні вільно володіти основами професійного іншомовного спілкування. У таких умовах важливим є усвідомлення майбутніми фахівцями різних галузей необхідності їх майбутніх зв'язків із міжнародним середовищем, а одним з першочергових завдань освіти стає якісна підготовка фахівців, здатних до успішної професійної діяльності в межах світової спільноти. В цьому контексті істотно змінюються вимоги до володіння іноземною мовою фахівцями всіх рівнів, першорядного значення набувають практичні навички, що передбачають знання ділової іноземної мови в усному та писемному мовленні, вміння використовувати іноземну мову у своїй професійній діяльності.

Пропоновані методичні рекомендації мають на меті ознайомити з основами іншомовного професійного спілкування, розширити словниковий запас за рахунок спеціальної лексики, виробити комунікативні навички мовлення, навички письма.

Методичні рекомендації складаються з тематичних розділів, кожен з яких містить 1) тексти інформативного характеру, які допоможуть орієнтуватися в певних ситуаціях професійної сфери, 2) лексичний матеріал з найчастіше вживаними мовленнєвими конструкціями відповідної тематики, які допоможуть у побудові діалогів та монологічних повідомлень та 3) систему вправ для успішного засвоєння та вдосконалення комунікативних навичок професійно орієнтованого спілкування.

CONTENTS

Unit 1.Biology - The Life Science

Living things	Живі істоти
Matter structured in an orderly way	Матерія, структурована впорядкованим чином
GRIMNER	Акронім/абревіатура, яку використовують біологи для визначення життя
To grow	Рости
To respire	Дихати
To interact	Взаємодія ти
To move	Рухатися
To need nutrients	Потребувати поживних речовин
To excrete (to waste)	Виділяти
To reproduce	Відтворювати
Death	Смерть
Cell	Клітина
Application of knowledge	Застосування знань
Systematic investigation	Системне дослідження
Reproducible results	Відтворювані результати
Hypotheses	Гіпотеза
Reasoning	Вступ
Induction	Індукція
Deduction	Дедукція
Natural selection	Природній відбір
Imaginative preconception	Образне припущення

Quick Definitions

Observation - Quantitative and qualitative measurements of the world.

Inference - Deriving new knowledge based upon old knowledge.

Hypotheses - A suggested explanation.

Rejected Hypothesis - An explanation that has been ruled out through experimentation.

Accepted Hypothesis - An explanation that has not been ruled out through excessive experimentation and makes verifiable predictions that are true.

Experiment - A test that is used to rule out a hypothesis or validate something already known.

Scientific Method - The process of scientific investigation.

Theory - A widely accepted hypothesis that stands the test of time. Often tested, and usually never rejected.

Abstract – opening section of a scientific paper that summarizes the research and conclusions

Applied science – form of science that aims to solve real-world problems

Basic science – science that seeks to expand knowledge and understanding regardless of the short-term application of that knowledge

Biology – the study of living organisms and their interactions with one another and their environments

The word ***biology*** means, "the science of life", from the Greek **bios,** *life,* and **logos,** *word* or *knowledge.* Therefore, Biology is the science of Living Things. That is why Biology is sometimes known as Life Science.

The science has been divided into many subdisciplines, such as botany, bacteriology, anatomy, zoology, histology, mycology, embryology, parasitology, genetics, molecular biology, systematics, immunology, microbiology, physiology, cell biology, cytology, ecology, and virology. Other branches of science include or are comprised in part of biology studies, including paleontology, taxonomy, evolution, phycology, helminthology, protozoology, entomology, biochemistry, biophysics, biomathematics, bio engineering, bio climatology and anthropology.

1.1 Characteristics of life

Not all scientists agree on the definition of just what makes up life. Various characteristics describe most living things. However, with most of the characteristics listed below we can think of one or more examples that would seem to break the rule, with something nonliving being classified as living or something living classified as nonliving. Therefore we are careful not to be too dogmatic in our attempt to explain which things are living or nonliving.

• Living things are composed of **matter structured in an orderly way** where simple molecules are ordered together into much larger macromolecules.

An easy way to remember this is GRIMNERD C All organisms; - **G**row, **R**espire, **I**nteract, **M**ove, Need **N**utrients, **E**xcrete (Waste), **R**eproduce, **D**eath, **C**ells (Made of)

• Living things are **sensitive,** meaning they are able to **respond to stimuli.**
• Living things are able to **grow**, **develop**, and **reproduce**.
• Living things are able to **adapt** over time by the process of **natural selection.** • All known living things use the **hereditary molecule, DNA**.
• Internal functions are coordinated and **regulated** so that the internal environment of a living thing is relatively constant, referred to as **homeostasis.**

Living things are organized in the microscopic level from atoms up to cells. Atoms are arranged into molecules, then into macromolecules, which make up organelles, which work together to form cells. Beyond this, cells are organized in higher levels to form entire multicellular organisms. Cells together form tissues, which make up organs, which are part of organ systems, which work together to form an entire organism. Of course, beyond this, organisms form populations which make up parts of an ecosystem. All of the Earth's ecosystems together form the diverse environment that is the earth.

1.2 Nature of science

Science is a **methodology** for **learning about the world**. It involves the **application of knowledge**.

The scientific method deals with **systematic investigation**, **reproducible results**, the formation and testing of **hypotheses**, and **reasoning.**

Reasoning can be broken down into two categories, **induction** (specific data is used to develop a generalized observation or conclusion) and **deduction** (general information leads to specific conclusion). Most reasoning in science is done through induction.

Science as we now know it arose as a discipline in the 17th century.

1.3 Scientific Reasoning

One thing is common to all forms of science: an ultimate goal "to know." Curiosity and inquiry are the driving forces for the development of science. Scientists seek to understand the world and the way it operates. To do this, they use two methods of logical thinking: inductive reasoning and deductive reasoning.

Inductive reasoning is a form of logical thinking that uses related observations to arrive at a general conclusion. This type of reasoning is common in descriptive science. A life scientist such as a biologist makes observations and records them. These data can be qualitative or quantitative, and the raw data can be supplemented with drawings, pictures, photos, or videos. From many observations, the scientist can infer conclusions (inductions) based on evidence. Inductive reasoning involves formulating generalizations inferred from careful observation and the analysis of a large amount of data. Brain studies provide an example. In this type of research, many live brains are observed while people are doing a specific activity, such as viewing images of food. The part of the brain that "lights up" during this activity is then predicted to be the part controlling the response to the selected stimulus, in this case, images of food. The "lighting up" of the various areas of the brain is caused by excess absorption of radioactive sugar derivatives by active areas of the brain. The resultant increase in radioactivity is observed by a scanner. Then, researchers can stimulate that part of the brain to see if similar responses result.

Deductive reasoning or deduction is the type of logic used in hypothesis-based science. In deductive reason, the pattern of thinking moves in the opposite direction as compared to inductive reasoning. **Deductive reasoning** is a form of logical thinking that uses a general principle or law to forecast specific results. From those general principles, a scientist can extrapolate and predict the specific results that would be valid as long as the general principles are valid. Studies in climate change can illustrate this type of reasoning. For example, scientists may predict that if the climate becomes warmer in a particular region, then the distribution of plants and animals should change. These predictions have been made and tested, and many such changes have been found, such as the modification of arable areas for agriculture, with change based on temperature averages.

Both types of logical thinking are related to the two main pathways of scientific study: descriptive science and hypothesis-based science. **Descriptive (or discovery) science**, which is usually inductive, aims to observe, explore, and discover, while **hypothesis-based science**, which is usually deductive, begins with a specific question or problem and a potential answer or solution that can be tested. The boundary between these two forms of study is often blurred, and most scientific endeavors combine both approaches. The fuzzy boundary becomes apparent when thinking about how easily observation can lead to specific questions. For example, a gentleman in the 1940s observed that the burr seeds that stuck to his clothes and his dog's fur had a tiny hook structure. On closer inspection, he discovered that the burrs' gripping device was more reliable than a zipper. He eventually developed a company and produced the hook-and-loop fastener popularly known today as Velcro. Descriptive science and hypothesis-based science are in continuous dialogue.

1.4 Scientific method

Biologists study the living world by posing questions about it and seeking science-based responses. This approach is common to other sciences as well and is often referred to as the scientific method. The scientific method was used even in ancient times, but it was first documented by England's Sir Francis Bacon (1561–1626), who set up inductive methods for scientific inquiry. The scientific method is not exclusively used by biologists but can be applied to almost all fields of study as a logical, rational problem-solving method.

The scientific method is not a step by step, linear process. It is an intuitive process, a methodology for learning about the world through the application of knowledge. Scientists must be able to have an "imaginative preconception" of what the truth is. Scientists will often observe and then hypothesize the reason why a phenomenon occurred. They use all of their knowledge and a bit of imagination, all in an attempt to uncover something that might be true. A typical scientific investigation might go like so:

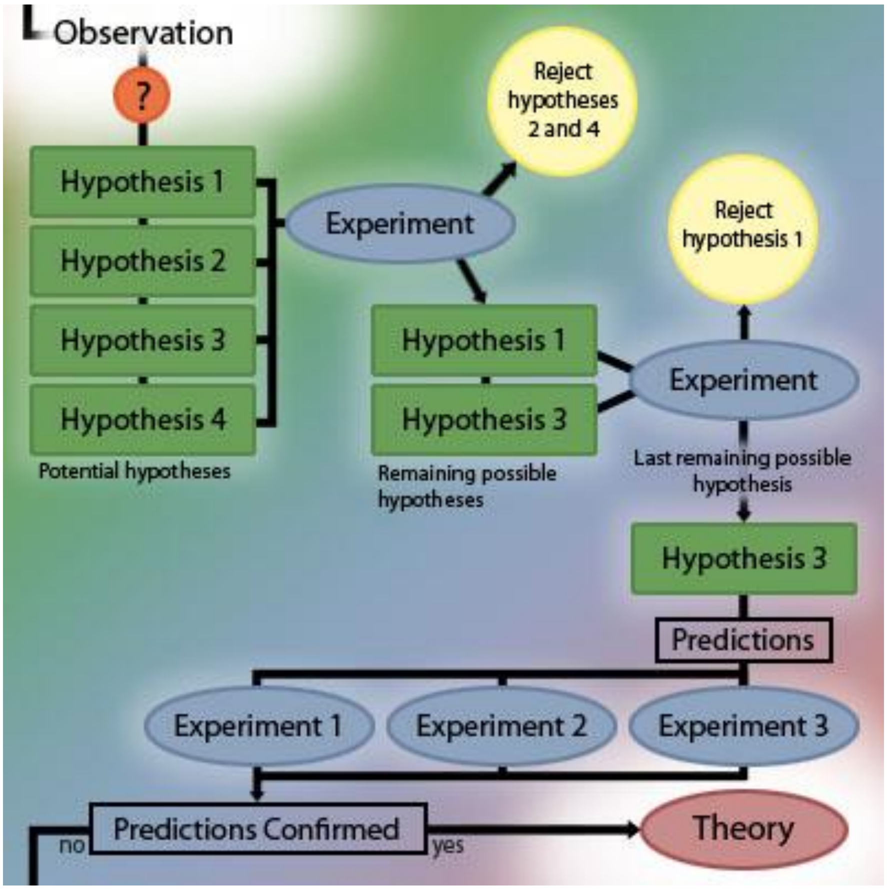
You *observe* that a room appears dark, and you ponder *why* the room is dark. In an attempt to find explanations to this curiosity, your mind unravels several different *hypotheses*. One hypothesis might state that the lights are turned off. Another hunch might be that the room's lightbulb has burnt out. Worst yet, you could be going blind. To discover the truth, you *experiment*. You feel your way around the room and find a light switch and turn it on. No light. You *repeat* the experiment, flicking the switch back and forth. Still nothing. That means your initial hypothesis, the room is dark because the lights are off, has been *rejected*. You devise more experiments to test your hypotheses, utilizing a flashlight to prove that you are indeed not blind. In order to *accept* your last remaining hypothesis as the truth, you could *predict* that changing the light bulb will fix the problem. If all your predictions succeed, the original hypothesis is valid and is accepted. In some cases, however, your predictions will not occur, in which you'll have to start over. Perhaps the power is off.

Scientists first make observations that raise a particular question. In order to explain the observed phenomenon, they develop a number of possible explanations, or hypotheses. This is the inductive part of science, observing and constructing plausible arguments for why an event occurred. Experiments are then used to eliminate one of more of the possible hypotheses until one hypothesis remains. Using deduction, scientists use the principles of their hypothesis to make predictions, and then test to make sure that their predictions are confirmed. After many trials (repeatability) and all predictions have been confirmed, the hypothesis then may become a theory.

The scientific method is based primarily on the testing of hypotheses by experimentation. This involves a **control**, or subject that does not undergo the process in question. A scientist will also seek to limit variables to one or another very small number, single or minimum number of variables. The procedure is to form a hypothesis or prediction about what you believe or expect to see and then do everything you can to violate that, or falsify the hypotheses. Although this may seem unintuitive, the process serves to establish more firmly what is and what is not true.

A founding principle in science is a lack of absolute truth: the accepted explanation is the most likely and is the basis for further hypotheses as well as for falsification. All knowledge has its relative uncertainty.

Theories are hypotheses which have withstood repeated attempts at falsification. Common theories include evolution by natural selection and the idea that all organisms consist of cells. The scientific community asserts that much more evidence supports these two ideas than contradicts them.



A diagram that illustrates scientific investigation

Exercise 1. Give the definition to the following concepts:

1. Sub atom ____
2. Atom ____
3. Molecule ____
4. Macromolecule ____
5. Cell ____
6. Tissue ____
7. Organ ____
8. Organ system ____
9. Organisms ____
10. Population ____
11. Eco system ____

Exercise 2. Answer the questions.

1. What does the word biology mean?
2. What subdisciplines the science of biology has been divided into?
3. What are the characteristics of living things?
4. Explain the concept of “GRIMNERDC” all organisms.
5. How could you explain the concept of “scientific method”?
6. What is “Inference”?
7. What is the difference between deductive and inductive reasoning? What is a hypothesis?
8. What are variables? How are control experiments used in testing hypotheses?
9. What is the difference between hypothesis and theory?
10. How does a hypothesis become a theory? At what point does a theory become accepted as an absolute truth, no longer subject to any uncertainty?
11. Explain the difference between rejected and accepted hypothesis.
12. Do you know the main hypothesis about origin of life? What does it say?
13. What is the difference between basic and applied research?
14. Identify the characteristics of the natural sciences.
15. Summarize the steps of the scientific method.
16. Compare inductive reasoning with deductive reasoning.
17. Describe the goals of basic science and applied science.

Exercise 3. Decide if each of the following is an example of inductive or deductive reasoning.

1. All flying birds and insects have wings. Birds and insects flap their wings as they move through the air. Therefore, wings enable flight.
2. Insects generally survive mild winters better than harsh ones. Therefore, insect pests will become more problematic if global temperatures increase.
3. Chromosomes, the carriers of DNA, separate into daughter cells during cell division. Therefore, DNA is the genetic material.
4. Animals as diverse as humans, insects, and wolves all exhibit social behavior. Therefore, social behavior must have an evolutionary advantage.

Exercise 4. In the example below, the scientific method is used to solve an everyday problem. Order the scientific method steps (numbered items) with the process of solving the everyday problem (lettered items). Based on the results of the experiment, is the hypothesis correct? If it is incorrect, propose some alternative hypotheses.

1. Observation
2. Question
3. Hypothesis (answer)
4. Prediction
5. Experiment
6. Result

a. There is something wrong with the electrical outlet.
b. If something is wrong with the outlet, my coffeemaker also won’t work when plugged into it.
c. My toaster doesn’t toast my bread.
d. I plug my coffee maker into the outlet.
e. My coffeemaker works.
f. Why doesn’t my toaster work?

Exercise 5. Critical thinking questions.

1. Although the scientific method is used by most of the sciences, it can also be applied to everyday situations. Think about a problem that you may have at home, at school, or with your car, and apply the scientific method to solve it.
2. Give an example of how applied science has had a direct effect on your daily life.
3. Name two topics that are likely to be studied by biologists, and two areas of scientific study that would fall outside the realm of biology.
4. Thinking about the topic of cancer, write a basic science question and an applied science question that a researcher interested in this topic might ask
5. Select two items that biologists agree are necessary in order to consider an organism "alive." For each, give an example of a non-living object that otherwise fits the definition of "alive,"
6.Consider the levels of organization of the biological world, and place each of these items in order from smallest level of organization to most encompassing: skin cell, elephant, water molecule, planet Earth, tropical rainforest, hydrogen atom, wolf pack, liver.
7.You go for a long walk on a hot day. Give an example of a way in which homeostasis keeps your body healthy.
8.Using examples, explain how biology can be studied from a microscopic approach to a global approach.

Exercise 5. Explore more. Watch the movie. What facts were new and the most significant for you?

https://www.youtube.com/watch?v=HdENszxwmCA

Unit 2. Life: History and Origin

Properties of life	Властивості життя
Extraterrestrial origin (panspermia)	Позаземне походження (панспермія)
Spontaneous origin	Спонтанне походження
Bacterial fossils	Бактеріальні викопні
Testable hypothesis	Прийнята гіпотеза
Multicellularity	Багатоклітинність
Self replication	Самовідтворення
Photosynthesis	Фотосинтез
Aerobic respiration	Аеробне дихання
Hereditary material	Спадковий матеріал
Heredity	Спадковість
Natural selection	Природній відбір
Diversity of life	Різноманітність життя
Proponent	Пропонент, захисник, ініціатор пропозиції
Special creation	Особливе створення
Intelligent Design	Розумне творіння
Amino acid	Амінокислота
Significant issue	Важлива проблема

2.1 Properties of life

1. Organization: Being structurally composed of one or more cells, which are the basic units of life.
   • prokaryote: no nucleus;
   • eukaryote: membrane bound nucleus.

2. Sensitivity: respond to stimuli.
3. Energy Processing.
4. Growth and Development.
5. Reproduction: hereditary mechanisms to make more of self; DNA based.
6. Regulation, including homeostasis.
7. Evolution.

2.2 Origin of life: 3 hypotheses

1. Extraterrestrial origin (panspermia): meteor, comet borne from elsewhere in universe;
2. Evidence of amino acids and other organic material in space (but often both D & L forms);
3. Questionable bacterial fossils in Martian rock.

However, this would imply that some other origin of life was likely because it would have had to happen elsewhere before it could be transported here, and the only difference would be that life did not originate on Earth.

Spontaneous origin on earth: primitive self-replicating macromolecules acted upon by natural selection ((macro)Evolution is one example of this)

This is often attacked for the seeming impossibility for life to have been produced by a chemical reaction triggered by lightning and the ability of any produced DNA to actually be in a sequence that could produce a working model of life if replicated. It is also attacked for religious reasons, as it bypasses things like the idea of a supreme being directly creating humans. It also seems unlikely to some that such huge changes are possible in evolution without evidence of an "in-between stage" that is credible. Many of the stages of man are disputed due to their somewhat shaky grounds. For example, bones from other animals have been taken accidentally in some cases to be part of a humanoid, and complete skeletons have been sketched out from a limited number of bones.

Special creation: religious explanations (Intelligent Design is one popular example of this.) These explanations contend that life was created by God (or perhaps some other Intelligent Designer).
Proponents of Intelligent design suggest that the vast complexity of life could only have been intentionally designed while other creationists cite biblical support.

This is often attacked for many of the same reasons that religion is attacked, and is often regarded as superstitious and/or unscientific.

It is debated as to whether schools should teach one hypothesis or the other when talking about the origin of life. However, since they are all currently known major hypotheses (and sometimes hypotheses proven wrong are shown for educational purposes).

2.3 The early earth

It is believed that the Earth was formed about 4.5 billion years ago.

- Heavy bombardment by rubble ceased about 3.8 billion years ago.
- Reducing atmosphere: much free H

• also H_2O, NH_3, CH_4
• little, if any, free O_2
• with numerous H electrons, require little energy to form organic compounds with C

- Warm oceans, estimated at 49-88°C
- Lack of O_2 and consequent ozone (O_3) meant considerable UV energy

Chemical reactions on early earth. UV and other energy sources would promote chemical reactions and formation of organic molecules. Testable hypothesis: Miller-Urey experimentsimulated early atmospheric conditions, found amino acids, sugars, etc., building blocks of life, won Nobel prize for workexperiment showed prebiotic synthesis of biological molecules was possible Issues. Miller later conceded that the conditions in his experiments were not representative of what is currently thought to be those of early earth. He also conceded that science has no answer for how amino acids could self-organize into replicating molecules and cells. In the 50 years since Miller-Urey, significant issues and problems for biogenesis have been identified. This is a weak hypothesis at this time.

Conclusion: Life exists, we don't know why.

2.4 Major steps in evolution of life

- Prebioticsynthesis of macromolecules
- Self replication
- RNA? (primitive metabolism)
- DNA as hereditary material
- 1st cells
- Photosynthesis
- Aerobic respiration
- Multicellularity (more than once)

Exercise 1. Answer the questions.

1. What hypothesis of life origin do you believe in?
2. What do you think about life origin teaching at schools?
3. What major steps in evolution of life could you list?
4. How does sweating help the human body maintain homeostasis?
5. Explain cell theory and gene theory.
6. Describe the picture of the early earth.
7. Describe an example of homeostasis in the atmosphere.
8. Describe how you can apply the concepts of evolution, natural selection, adaptation, and homeostasis to the human ability to sweat.
9. Which of the four unifying principles of biology is primarily concerned with:
   a. how DNA is passed down to offspring?
   b. how internal balance is maintained?
10. _____________ arelocatedon _______________.
    a. chromosomes; genes
    b. genes;chromosomes
    c. genes; traits
    d. noneoftheabove
11. Define an adaptation and give one example.
12. Explain how gene theory and evolutionary theory relate to each other.
13. Does evolution by natural selection occur within one generation? Whyorwhynot?

14. Why did chameleons evolve the ability to change their colour to match their background?
15. Are there any disagreements about evolution?
16. What is the statement of intelligent design? Do you think it should be taught in Biology? Why?

Exercise 2. Myth or reality? What could you tell about the following thesis of the theory of evolution in biology?

1. Evolution is “just” a theory or educated guess. ___________ (myth)
2. Scientists accept evolutionary theory as the best explanation for the diversity of life on Earth because of the large body of scientific evidence supporting it. Like any scientific theory, evolution is a broad, evidence-supported explanation for multiple phenomena. ________ (Reality)
3. The theory of evolution explains how life on Earth began. ________ (myth)
4. The theory of evolution explains how life changed on Earth after it began. ______ (reality)
5. The theory of evolution means that humans evolved from apes like those in zoos.______ (myth)
6. Humans and modern apes both evolved from a common ape-like ancestor millions of years ago. _________ (Reality)

Exercise 3. Falls or true?

1. The theory of evolution addresses how life began, not how it has changed since it began. __________Falls
2. Modern apes were out direct ancestors. _______ Falls
3. Every living thing on earth is made of cells. _____ True
4. Four basic principles or theories unify all fields of biology: cell theory, gene theory, homeostasis, and evolutionary theory. ______ true
5. According to cell theory, all living things are made of cells and come from other living cells. ______ true
6. Gene theory states that the characteristics of living things are controlled by genes that pass from parents to offspring. _______True
7. All living things strive to maintain internal balance, or **homeostasis**.
8. The characteristics of populations of living things change over time through the process of micro-evolution as organisms acquire adaptations, or traits that better suit them to a given environment. _______ true
9. Genes are passed from parent to offspring. ________ true
10. Non-living things carry out homeostasis. _________ falls

Exercise 4. Choose the correct answer.

1. The first forms of life on Earth were _________.

a. plants
b. microorganisms
c. birds
d. dinosaurs

1. A suggested and testable explanation for an event is called a _________.

a. hypothesis
b. variable
c. theory
d. control

2. Which of the following sciences is not considered a natural science?

a. biology
b. astronomy
c. physics
d. computerscience

3. The type of logical thinking that uses related observations to arrive at a general conclusion is called ________.

a. deductivereasoning
b. thescientificmethod
c. hypothesis-basedscience
d. inductivereasoning

4. The process of ________ helps to ensure that a scientist's research is original, significant, logical, and thorough.

a. publication
b. publicspeaking
c. peerreview
d. thescientificmethod

5. A person notices that her houseplants that are regularly exposed to music seem to grow more quickly than those in rooms with no music. As a result, she determines that plants grow better when exposed to music. Thisexamplemostcloselyresembleswhichtypeofreasoning?

a. inductivereasoning
b. deductivereasoning
c. neither, because no hypothesis was made
d. bothinductiveanddeductivereasoning

6. The smallest unit of biological structure that meets the functional requirements of "living" is the ________.

a. organ
b. organelle
c. cell
d. macromolecule

7. Viruses are not considered living because they ________.

a. arenotmadeofcells
b. lackcellnuclei
c. do not contain DNA or RNA
d. cannotreproduce

8. The presence of a membrane-enclosed nucleus is a characteristic of ________.

a. prokaryoticcells
b. eukaryoticcells

c. livingorganisms
d. bacteria

9. A group of individuals of the same species living in the same area is called a(n) ________.

a. family
b. community
c. population
d. ecosystem

10. Which of the following sequences represents the hierarchy of biological organization from the most inclusive to the least complex level?

a. organelle, tissue, biosphere, ecosystem, population
b. organ, organism, tissue, organelle, molecule
c. organism, community, biosphere, molecule, tissue, organ
d. biosphere, ecosystem, community, population, organism

11. Where in a phylogenetic tree would you expect to find the organism that had evolved most recently?

a. atthebase
b. withinthebranches
c. atthenodes
d. atthebranchtips

Exercise 4. Explore more. Watch the following movies on TED-Ed. What facts werenew and the most significant for you?

TED-Ed. The wacky history of cell theory – Lauren Royal-Woods. YouTube. https://www.youtube.com/watch?v=4OpBylwH9DU&feature=youtu.be

TED-Ed. Myths and misconceptions about evolution – Alex Gendler. YouTube. https://www.youtube.com/watch?v=mZt1Gn0R22Q&t=10s

Unit 3. Levels of Organization of Living Things

Living things	Живі істоти
Cell	Клітина
Deoxyribonucleicc acid (DNA)	Дезоксирибонуклеїнова кислота (ДНК)
To perform specialized functions	Виконувати особливі функції
Prokaryotes	Прокаріоти
Eukaryotes	Еукаріоти
To examine	Досліджувати
Multicellular organisms	Багатоклітинний організм
Tissue	Тканина
Single-celled or colonial organisms	Одноклітинний або колоніальний організм
Membrane-bound organelles	Пов’язані мембраною органели
Functionally related organs	Органи, пов’язані однією функцією
Population	Популяція

Community	Спільнота
Ecosystem	Екосистема
Environment	Навколишнє середовище

Quick Definitions

Biosphere – collection of all the ecosystems on Earth

Cell – smallest fundamental unit of structure and function in living things

Community – set of populations inhabiting a particular area

Ecosystem – all the living things in a particular area together with the abiotic, nonliving parts of that environment

Eukaryote – organism with cells that have nuclei and membrane-bound organelles

Evolution – process of gradual change during which new species arise from older species and some species become extinct

Falsifiable – able to be disproven by experimental results

Homeostasis – ability of an organism to maintain constant internal conditions

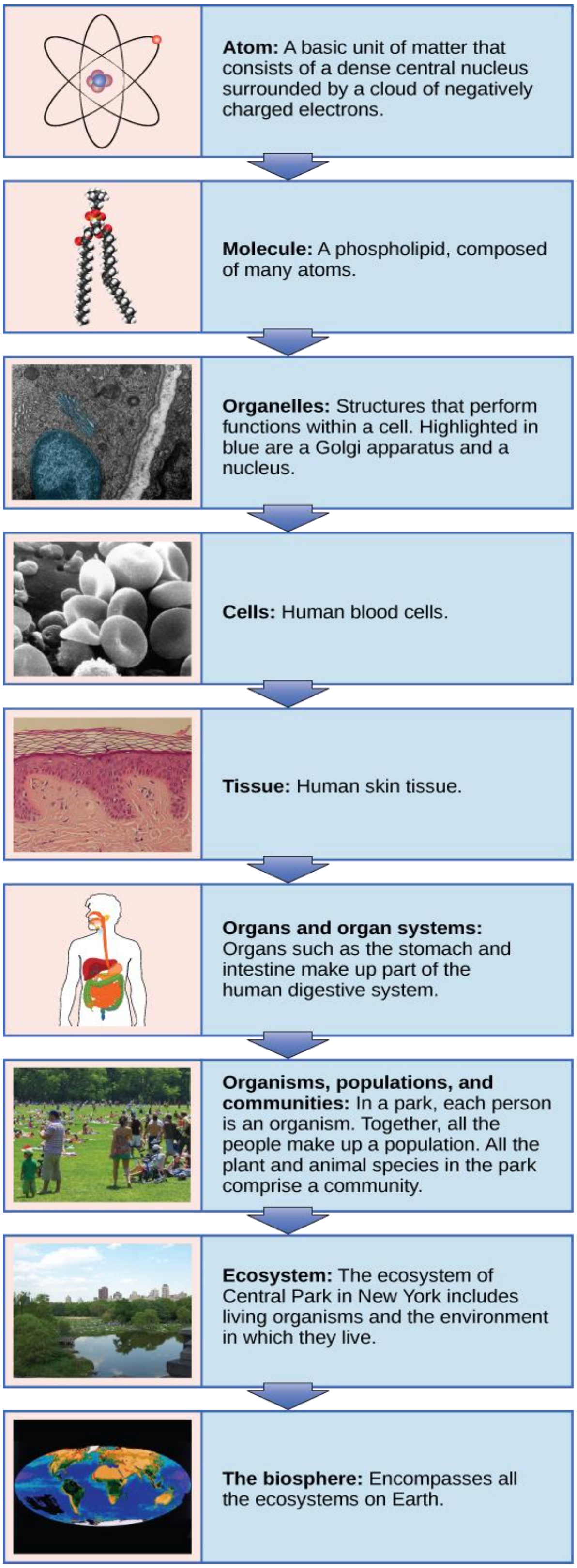
Living things are highly organized and structured, following a hierarchy of scale from small to large. The **atom** is the smallest and most fundamental unit of matter. It consists of a **nucleus** surrounded by **electrons**. Atoms combine to form **molecules**, which are chemical structures consisting of at least two atoms held together by a chemical bond. Many molecules that are biologically important are **macromolecules**, large molecules that are typically formed by polymerization (a polymer is a large molecule that is made by combining smaller units called monomers, which are simpler than macromolecules). An example of a macromolecule is deoxyribonucleic acid (**DNA**), which contains the instructions for the structure and functioning of all living organisms.

In plants, animals, and many other types of organisms, molecules come together in specific ways to create structures called **organelles.** Organelles are small structures that exist within cells and perform specialized functions. Examples of organelles include mitochondria and chloroplasts, which carry out indispensable functions: mitochondria produce energy to power the cell, while chloroplasts enable green plants to utilize the energy in sunlight to make sugars.

All living things are made of **cells**; the cell itself is the smallest fundamental unit of structure and function in living organisms. (This requirement is why viruses are not considered living: they are not made of cells. To make new viruses, they have to invade and hijack the reproductive mechanism of a living cell; only then can they obtain the materials they need to reproduce.) Some organisms consist of a single cell and others are multicellular. Cells are classified as prokaryotic or eukaryotic. **Prokaryotes** are single-celled or colonial organisms that do not have membrane-bound nuclei; in contrast, the cells of **eukaryotes** do have membrane-bound organelles and a membrane-bound nucleus.

From an atom to the entire Earth, biology examines all aspects of life.

In most multicellular organisms, cells combine to make **tissues**, which are groups of similar cells carrying out similar or related functions. **Organs** are collections of tissues grouped together performing a common function. Organs are present not only in animals but also in plants. An organ system is a higher level of organization that consists of functionally related organs. For example vertebrate animals have many organ systems, such as the circulatory system that transports blood throughout the body and to and from the lungs; it includes organs such as the heart and blood vessels.



Organisms are individual living entities. For example, each tree in a forest is an organism. Single-celled prokaryotes and single-celled eukaryotes are also considered organisms and are typically referred to as microorganisms.

All the individuals of a species living within a specific area are collectively called a **population**. For example, a forest may include many pine trees. All of these pine trees represent the population of pine trees in this forest. Different populations may live in the same specific area. For example, the forest with the pine trees includes populations of flowering plants and also insects and microbial populations.

A **community** is the set of different populations inhabiting a common area. For instance, all of the trees, flowers, insects, and other populations in a forest form the forest's community.

The forest itself is an **ecosystem**. An ecosystem consists of all the living things in a particular area together with the abiotic, or non-living, parts of that environment such as nitrogen in the soil or rainwater.

At the highest level of organization, the **biosphere** is the collection of all ecosystems, and it represents the zones of life on Earth. It includes land, water, and portions of the atmosphere.

Exercise 1. Give definitions to the following concepts:

Atom
____

Nucleon ____

Electron____

RNA____

DNA____

Tissue____

Organ____

Organism ____

Community____

Population____

Ecosystem ____

Exercise 2. Which of the following statements is false?

a. Tissues exist within organs which exist within organ systems.
b. Communities exist within populations which exist within ecosystems.
c. Organelles exist within cells which exist within tissues.
d. Communities exist within ecosystems which exist in the biosphere.

Unit 4. Structure and Function of Biological Macromolecules

Biological macromolecules	Біологічні макромолекули
Organic molecule	Органічні молекули
Carbohydrates	Вуглеводи

Lipids	Жири
Proteins	Білки
Nucleic acids	Нуклеїнова кислота
Carbon	Вуглець
Hydrogen	Водень
Oxygen	Кисень
Nitrogen	Азот
Phosphorus	Фосфор
Sulfur	Сірка
Additional minor elements	Додаткові другорядні елементи
Linear sequence of nucleotides with defined ends	Лінійна послідовність нуклеотидів з визначеними закінченнями
Amino acid chain	Амінокислотний ланцюг
Monosaccharide	Моносахариди
Disaccharides	Дисахариди
Polysaccharides	Полісахариди

The large molecules required for life built from smaller organic molecules are called biological macromolecules. There are four major biological macromolecules classes: carbohydrates, lipids, proteins, and nucleic acids. Together, these molecules form the majority of a cell's mass. Biological macromolecules are organic, as they contain carbon. In addition, they may contain hydrogen, oxygen, nitrogen, phosphorus, sulfur, and additional minor elements.

4.1 Structure and function of polymers:

The directionality of their components determines the structure and function of polymers.

1. Carbohydrates comprise linear chains of sugar monomers connected by covalent bonds. Carbohydrate polymers may be linear or branched.
2. The four elements of protein structure determine the function of a protein. The primary structure is determined by the sequential order of their constituent amino acids.
   - The secondary structure resulting from the folding of the amino acid chain into elements such as alpha-helices and beta-sheets
   - The tertiary structure is the overall three-dimensional shape of the protein and often minimizes free energy.
   - The quaternary structure is formed from interactions between multiple polypeptide units.
3. Nucleic acids have a linear sequence of nucleotides with defined ends. During the synthesis of DNA and RNA, nucleotides get added to the end of the growing strand, resulting in the formation of a covalent bond between nucleotides.

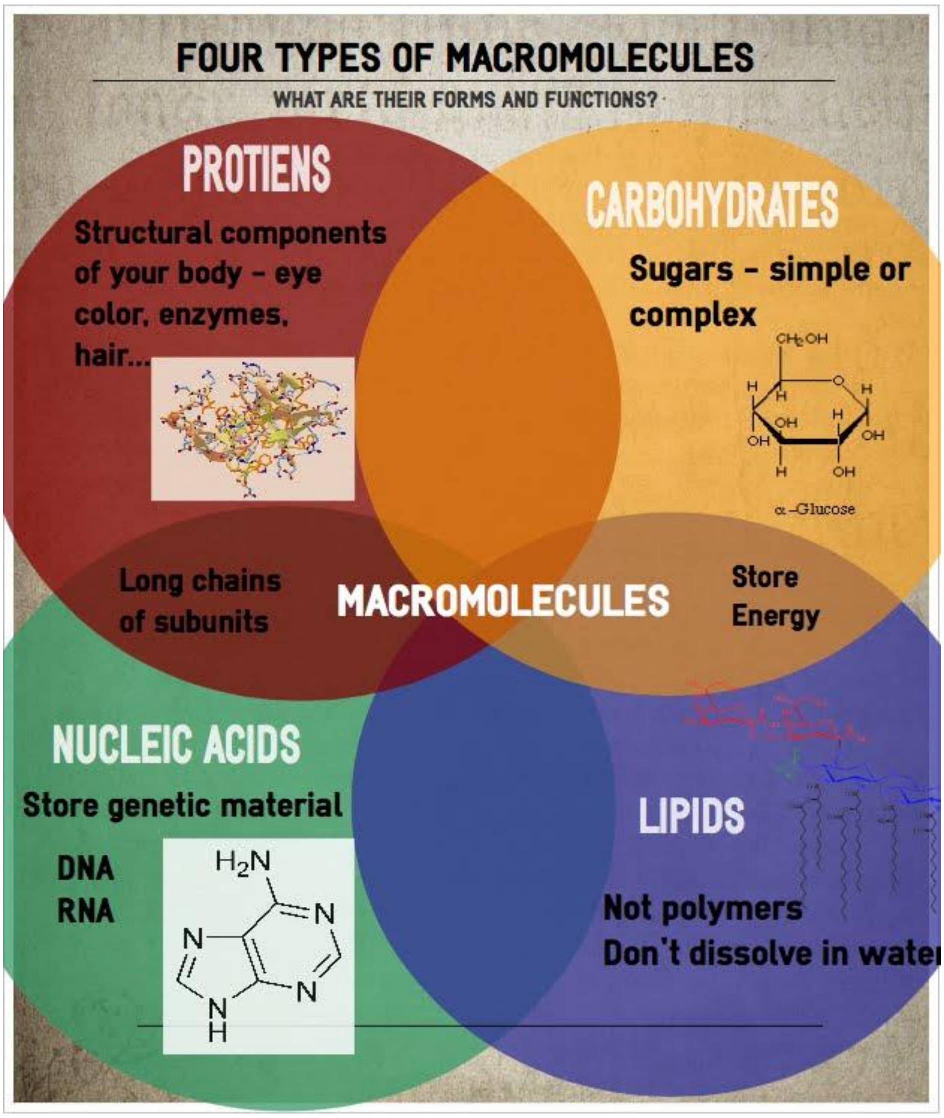
4.2 Understanding macromolecules

Biological macromolecules are very large molecules formed from polymerizing smaller molecules called monomers.

3.3 Structure and functions of biological macromolecules:

The three-dimensional structure of the biological Macromolecules influences their functioning. It is the three-dimensional shape of proteins and nucleic acids responsible for their biological activities.

Biological macromolecule	Monomers Building blocks	Functions	Examples
Carbohydrates	Monosaccharides (simple sugars)	Provide cells with short-term energy It is a source of dietary fiber	Glucose, sucrose, starch, cellulose, chitin
Lipids	Fatty acids and glycerol	Provide cells with long-term energy It is made up of biological membranes.	Fats, phospholipids, waxes, oils, grease, steroids
Proteins	Amino acids	Provide cell structure Send chemical signals Speed up chemical reactions	Keratin (found in hair and nails), hormones, enzymes, antibodies
Nucleic acids	Nucleotides	Store and pass on genetic information	DNA, RNA



I. Carbohydrates:

Carbohydrates are biological molecules made up of carbon, hydrogen, and oxygen, in a ratio of approximately one carbon atom to one water molecule. Carbohydrates get their name from this composition, and it is made up of carbon plus water. Some carbohydrates are in the form of Sugar. When people eat potatoes, they get energy or carbohydrates. Carbohydrates in potatoes are in the form of fiber, including cellulose polymers that provide structure to the potato's cell walls.

The main functions of carbohydrates are:

a) They are a vital energy source for the cell b) provide structural support to many organisms c) Serve as receptors for cell recognition.

Biologically important carbohydrates can be categorized into three categories:

1.Monosaccharide: Gets its name from 'Mono' meaning 'one' and 'sacchar,' meaning 'sugar.' Therefore, it can be called 'simple sugar.' The most common example is glucose.

2. Disaccharides: Gets its name from 'Di,' meaning 'two.' It is produced when two monosaccharides undergo a dehydration reaction. **3. Polysaccharides:** Poly means many. A long chain of monosaccharides connected by Glycosidic bonds is called polysaccharides.

II. Lipids:

Oils and fats, which may be saturated or unsaturated, are healthy and serve important functions for plants and animals. Lipidsdon'tmakepolymers.

Thecharacteristicoflipidsare:

- They have minimal or no affinity for water because it consists of mostly hydrocarbons.
- Lipids are highly diverse in function and form. Fats store a large amount of energy.

The three main types of lipids are:

- Triacylglycerols (alsocalledTriglycerides)
- Phospholipids
- Sterols

Lipids perform these primary biological functions within the body:

a) Serve as structural components of cell membranes b) Act as energy storehouses c) Regulate hormones d) Transmit nerve impulses e) Cholesterol formation f) Transport fat-soluble nutrients

III. Proteins:

The protein enzymes function as catalysts in cells and perform adaptable metabolism by selectively accelerating chemical reactions without consuming them. Humans have thousands of proteins, each unique or specific in function and structure. Proteins are known to have the structurally most complex molecules.

Proteinshavefourstructures:

- **Primary structure:** is formed by the linear sequence of amino acids in a peptide or protein.
- **Secondary structure:** The hydrogen-bonding pattern determines the secondary structure of proteins. The most common types of secondary structures are the α helix and the β pleated sheet.
- **Tertiary structure:** interactions between the R groups of the amino acids result in the three-dimensional arrangement of the polypeptide chain in space.
- **Quaternary Structure:** The number and the arrangement of several protein chains or subunits into a closely packed arrangement forms this structure.

Protein's main functions include:

a) Structural support b) Growth and Maintenance c) Transport and storage of nutrients d) Storage e) Cellular signaling f) Movement g) Provide defense against foreign materials.

IV. Nucleic acids:

There are two types of nucleic acid - DNA and RNA. DNA and RNA are the molecules that allow living organisms to pass on genetic material from generation to generation. DNA directs the RNA synthesis and controls the protein synthesis through RNA. The organisms inherit DNA from their parents.

Directionality, in molecular biology and biochemistry, is the end-to-end chemical orientation of a single strand of nucleic acid. In a single strand of DNA or RNA, the chemical convention of naming carbon atoms in the nucleotide pentose-sugar-ring means that: there will be a 5′-end, which regularly contains a phosphate group attached to the 5′ carbon of the ribose ring, and a 3′-end, which normally is unmodified from the ribose -OH substituent. DNA is always synthesized in the 5'-to-3' direction. In other words, nucleotides are added only to the 3' end of the growing strand.

Nucleic acids' main functions are:

- Storage and expression of genetic information
- Physiologicalsignalingmediators
- Secondarymessengers
- Sources of energy - in the form of ATP

4.4 Conclusion

- Most of the biological nutrients are macromolecules essential for carrying out various life activities.
- Proteins, carbohydrates, lipids, and nucleic acids, are the four major macromolecules.
- They perform important functions, including providing structural support, being a source of stored fuel, storing and retrieving genetic information, and speeding biochemical reactions.

Exercise 1. Answer the questions.

1. What is the structure and function of macromolecules? What are the properties of biological macromolecules?

The structure of a macromolecule is a single molecule that consists of many covalently linked subunit molecules, and a polymer is a single molecule composed of many similar monomers. The four major macromolecules are Proteins, carbohydrates, lipids, and nucleic acids.
Thefunctionofmacromoleculesare:

- Providestructuralsupport
- Serve as a source of stored fuel
- To store and retrieve genetic information
- Speedbiochemicalreactions

2. How does the structure of biological macromolecules determine their properties and functions?

Biological macromolecules' three-Dimensional Structure determines their functioning. Further, this three-dimensional shape of proteins and nucleic acids is responsible for their biological activities.

3. What are the functions of the four organic macromolecules?

The broad functions of the 4 organic macromolecules are:

- Proteins - MolecularMachines
- NucleicAcids - InformationRepositories
- Lipids - WaterproofMembranes
- Carbohydrates - StoredEnergy

4. What types of molecules are formed by dehydration reactions? What types of molecules are formed by hydrolysis?
5. How are amino acids linked to form proteins?
6. Explain what is meant by the primary, secondary, tertiary, and quaternary structure of a protein.

7. What are the two kinds of subunits that make up a fat molecule, and how are they arranged in the molecule?
8. Describe the differences be- tween a saturated and an unsaturated fat.
9. What does it mean to say that glucose, fructose, and galactose are isomers? Which two are structural isomers, and how do they differ from each other? Which two are stereoisomers, and how do they differ from each other?

Exercise2. Explore more. Watch the following movies on TED-Ed. What facts were for new and the most significant for you?

https://study.com/academy/lesson/macromolecules-definition-types-examples.html

https://www.inspiritvr.com/ap-bio/unit-1/structure-and-function-of-biological-macromolecules-study-guide

Unit 5. Cell as a Smallest Unit of Life

Cell theory	Клітинна теорія
Prokaryotic cell	Прокаріотична клітина
Eukaryotic cell	Еукаріотича клітина
Organelle	Органела
Darkened region	Затемнена область
Nucleoid	Нуклеоїд
Ecological perspective	Екологічна перспектива
Chloroplast	Хлоропласт
Particularly important type	Особливо важливий тип
Evolved structural adaptation	Розвинене структурне пристосування
Surface	Поверхня

5.1. Cell Theory

Close your eyes and picture a brick wall. What is the basic building block of that wall? It is a single brick, of course. Like a brick wall, your body is composed of basic building blocks and the building blocks of your body are cells. Your body has many kinds of cells, each specialized for a specific purpose. Just as a home is made from a variety of building materials, the human body is constructed from many cell types. For example, bone cells help to support and protect the body. Cells of the immune system fight invading bacteria. And red blood cells carry oxygen throughout the body. Each of these cell types plays a vital role during the growth, development, and day-to-day maintenance of the body. In spite of their enormous variety, however, all cells share certain fundamental characteristics.

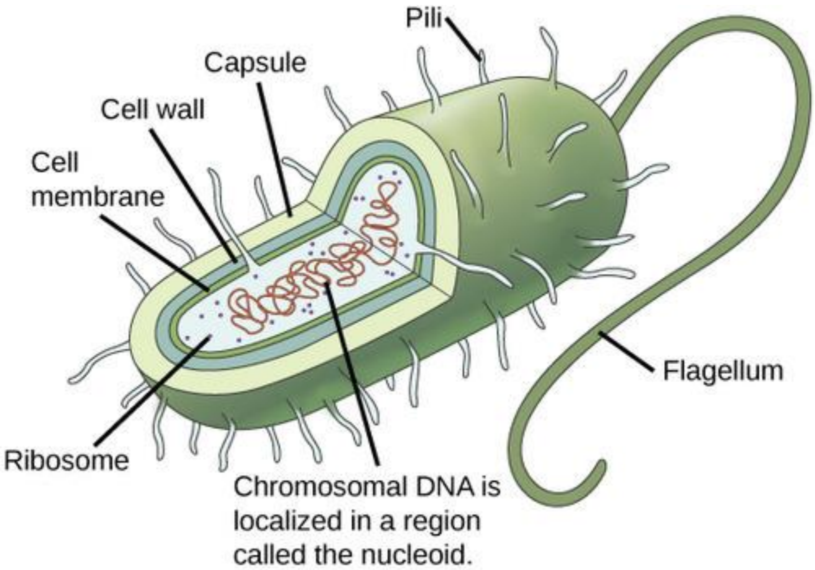
The microscopes we use today are far more complex than those used in the 1600s by Antony van Leeuwenhoek, a Dutch shopkeeper who had great skill in crafting lenses. Despite the limitations of his now-ancient lenses, van Leeuwenhoek observed the movements of single-celled organism and sperm, which he collectively termed “animalcules.” In a 1665 publication called *Micrographia*, experimental scientist Robert Hooke coined the term “cell” (from the Latin *cella*, meaning “small room”) for the box-like structures he observed when viewing cork tissue through a lens. In the 1670s, van Leeuwenhoek discovered bacteria and protozoa. Later advances in lenses and microscope construction enabled other scientists to see different components inside cells.

By the late 1830s, botanist Matthias Schleiden and zoologist Theodor Schwann were studying tissues and proposed the unified **cell theory**, which states that all living things are composed of one or more cells, that the cell is the basic unit of life, and that all new cells arise from existing cells. These principles still stand today. There are many types of cells, and all are grouped into one of two broad categories: prokaryotic and eukaryotic. Animal, plant, fungal, and protist cells are classified as eukaryotic, whereas bacteria and archaea cells are classified as prokaryotic.

All cells share four common components: 1) a plasma membrane, an outer covering that separates the cell's interior from its surrounding environment; 2) cytoplasm, consisting of a jelly-like region within the cell in which other cellular components are found; 3) DNA, the genetic material of the cell; and 4) ribosomes, particles that synthesize proteins. However, prokaryotes differ from eukaryotic cells in several ways.

5.2. Components of Prokaryotic Cells

A **prokaryotic cell** is a simple, single-celled (unicellular) organism that lacks a nucleus, or any other membrane-bound organelle. We will shortly come to see that this is significantly different in eukaryotes. Prokaryotic DNA is found in the central part of the cell: a darkened region called the nucleoid.



Generalized structure of a prokaryotic cell.

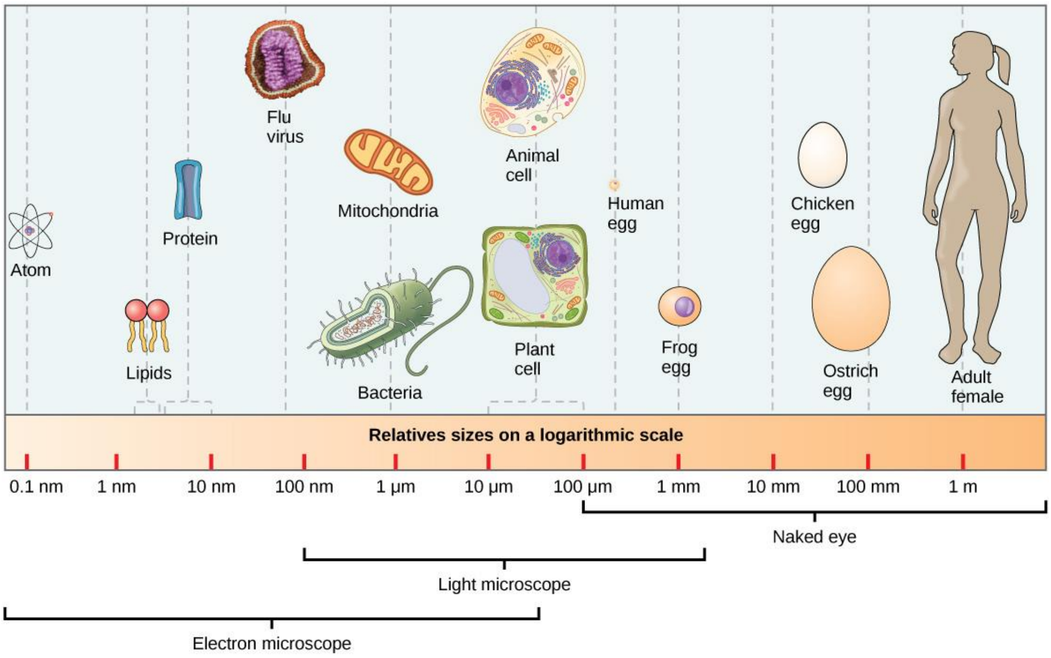
Unlike Archaea and eukaryotes, bacteria have a cell wall made of peptidoglycan (molecules comprised of sugars and amino acids) and many have a polysaccharide capsule. The cell wall acts as an extra layer of protection, helps the cell maintain its shape, and prevents dehydration. The capsule enables the cell to attach to surfaces in its environment. Some prokaryotes have flagella, pili, or fimbriae. Flagella are used for locomotion. Pili are used to exchange genetic material during a type of reproduction called conjugation. Fimbriae are protein appendages used by bacteria to attach to other cells.

5.3 Eukaryotic Cells

A **eukaryotic cell** is a cell that has a membrane-bound nucleus and other membrane-bound compartments called **organelles.** There are many different types of organelles, each with a highly specialized function. The word eukaryotic means "true kernel" or "true nucleus," alluding to the presence of the membrane-bound nucleus in these cells. The word "organelle" means "little organ," and, as already mentioned, organelles have specialized cellular functions, just as the organs of your body have specialized functions.

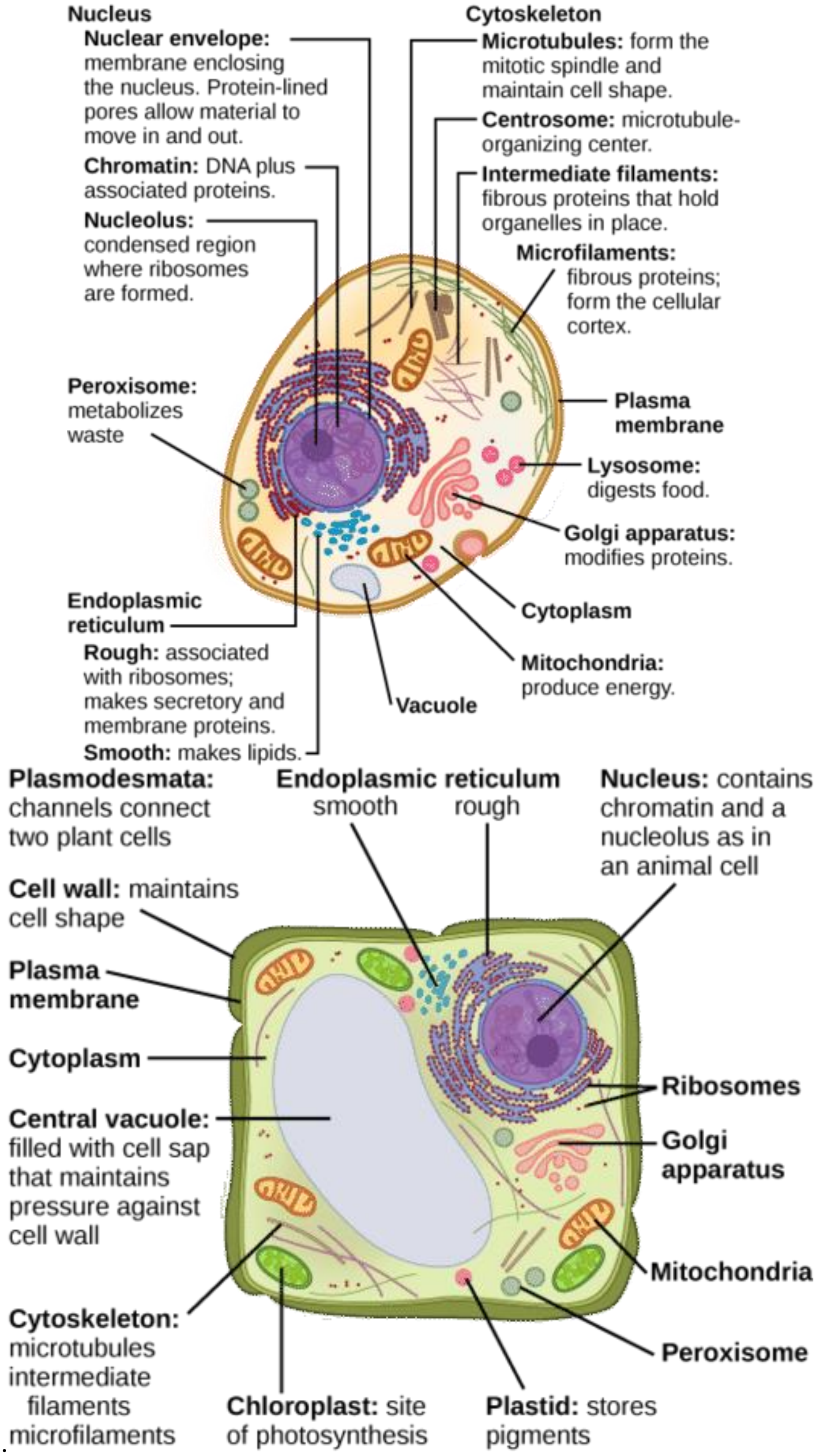
5.4 Cell Size

At 0.1–5.0 µm in diameter, most prokaryotic cells are significantly smaller than eukaryotic cells, which have diameters ranging from 10–100 µm. The small size of prokaryotes allows ions and organic molecules that enter them to quickly spread to other parts of the cell. Similarly, any wastes produced within a prokaryotic cell can quickly move out. However, larger eukaryotic cells have evolved different structural adaptations to enhance cellular transport. Indeed, the large size of these cells would not be possible without these adaptations. In general, cell size is limited because volume increases much more quickly than does cell surface area. As a cell becomes larger, it becomes more and more difficult for the cell to acquire sufficient materials to support the processes inside the cell, because the relative size of the surface area through which materials must be transported declines.



This figure shows the relative sizes of different kinds of cells and cellular components. An adult human is shown for comparison.

Animal Cells versus Plant Cells

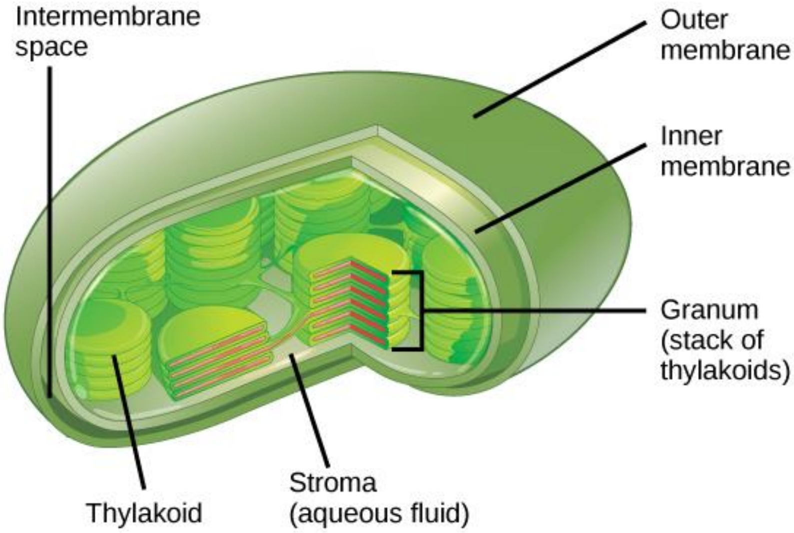


. 3

Despite their fundamental similarities, there are some striking differences between animal and plant cells. Animal cells have centrioles, centrosomes, and lysosomes, whereas plant cells do not. Plant cells have a rigid cell wall that is external to the plasma membrane, chloroplasts, plasmodesmata, and plastids used for storage, and a large central vacuole, whereas animal cells do not.

5.5 Chloroplasts

From an ecological perspective, **chloroplasts** are a particularly important type of organelle because they perform photosynthesis. Photosynthesis forms the foundation of food chains in most ecosystems. Chloroplasts are only found in eukaryotic cells such as plants and algae. During photosynthesis, carbon dioxide, water, and light energy are used to make glucose and molecular oxygen. One major difference between algae/plants and animals is that plants/algae are able to make their own food, like glucose, whereas animals must obtain food by consuming other organisms.



This simplified diagram of a chloroplast shows its structure.

Chloroplasts have outer and inner membranes, but within the space enclosed by a chloroplast's inner membrane is a set of interconnected and stacked, fluid-filled membrane sacs called thylakoids. Each stack of thylakoids is called a granum (plural = grana). The fluid enclosed by the inner membrane and surrounding the grana is called the stroma. Each structure within the chloroplast has an important function, which is enabled by its particular shape. A common theme in biology is that form and function are interrelated. For example, the membrane-rich stacks of the thylakoids provide ample surface area to embed the proteins and pigments that are vital to photosynthesis.

Exercise 1. Give the definition to the following concepts:

Cell ____

Prokaryotic cell ____________________________________

Eukaryotic cell ____________________________________

Vacuole ______________________________________

Organelle ______________________________________

Single-celled organisms ________________________________

Mitosis _______________________________________

Cell division_____________________________________

Cell cycle ____

Exercise 2. Answer the questions.

a. Why are the most cells so small?
b. Why it is beneficial for cells to be small?
c. Why are cells considered to be the basic units of living things?
d. Why are cells limited in the size to which they can grow?
e. Why do animal cells have small vacuoles?
f. Why are prokaryotic cells generally smaller than eukaryotic ones?
g. Why do cells contain a smaller amount of ATP?
h. Why are cells important for living things?
i. Why do cells have organelles?
j. What is organelle?
k. Why do cells divide?
l. Why do cells go through cell differentiation?
m. Why is the cell cycle shorter in epithelial cells?
n. Why is cell division important for both unicellular and multicellular organisms?
o. Why does cell signaling exist in single-celled organisms?
p. Why is cell differentiation important in multicellular organism?
q. Why are colonial organisms not classified as multicellular despite having many cells?
r. Why are there so few multicellular anaerobes?
s. Why does cell undergo mitosis?
t. Why is amoeba a unicellular organism?
u. Why is the cell cycle important?
v. Why do complex organism need specialized cells?
w. Why can't small hydrophilic molecules cross the cell membrane?
x. Why is red blood cell considered as a cell?
y. Why did Robert Hooke use the term "cell"?
z. Why are animal cells more irregularly shaped than plant cells?

Exercise 3. Choose the correct answer.

1.When viewing a specimen through a light microscope, scientists use ________ to distinguish the individual components of cells.

a. beamofelectrons
b. radioactiveisotopes
c. specialstains
d. hightemperatures

2.The ________ is the basic unit of life.

a. organism
b. cell
c. tissue
d. organ

3.Prokaryotes depend on ________ to obtain some materials and to get rid of wastes.

a. ribosomes

b. flagella
c. celldivision
d. diffusion

4.Bacteria that lack fimbriae are less likely to ________.

a. adheretocellsurfaces
b. swimthroughbodilyfluids
c. synthesizeproteins
d. retaintheabilitytodivide

5.Which of the following is surrounded by two phospholipid bilayers?

a. theribosomes
b. thevesicles
c. thecytoplasm
d. thenucleoplasm

6.Peroxisomes got their name because hydrogen peroxide is:

a. usedintheirdetoxificationreactions
b. producedduringtheiroxidationreactions
c. incorporatedintotheirmembranes
d. a cofactor for the organelles' enzymes

7.In plant cells, the function of the lysosomes is carried out by __________.

a. vacuoles
b. peroxisomes
c. ribosomes
d. nuclei

8.Which of the following is found both in eukaryotic and prokaryotic cells?

a. nucleus
b. mitochondrion
c. vacuole
d. ribosomes

9.Which of the following is not a component of the endomembrane system?

a. mitochondrion
b. Golgiapparatus
c. endoplasmicreticulum
d. lysosome

10.The process by which a cell engulfs a foreign particle is known as:

a. endosymbiosis
b. phagocytosis
c. hydrolysis
d. membranesynthesis

11.Which of the following is most likely to have the greatest concentration of smooth endoplasmic reticulum?

a. a cellthatsecretesenzymes
b. a cellthatdestroyspathogens
c. a cell that makes steroid hormones
d. a cell that engages in photosynthesis

12.Which of the following sequences correctly lists in order the steps involved in the incorporation of a proteinaceous molecule within a cell?

a. synthesis of the protein on the ribosome; modification in the Golgi apparatus; packaging in the endoplasmic reticulum; tagging in the vesicle
b. synthesis of the protein on the lysosome; tagging in the Golgi; packaging in the vesicle; distribution in the endoplasmic reticulum
c. synthesis of the protein on the ribosome; modification in the endoplasmic reticulum; tagging in the Golgi; distribution via the vesicle
d. synthesis of the protein on the lysosome; packaging in the vesicle; distribution via the Golgi; tagging in the endoplasmic reticulum

13.Which of the following have the ability to disassemble and reform quickly?

a. microfilamentsandintermediatefilaments
b. microfilamentsandmicrotubules
c. intermediatefilamentsandmicrotubules
d. onlyintermediatefilaments

14.Which of the following do not play a role in intracellular movement?

a. microfilamentsandintermediatefilaments
b. microfilamentsandmicrotubules
c. intermediatefilamentsandmicrotubules
d. onlyintermediatefilaments

15.Which of the following are found only in plant cells?

a. gapjunctions
b. desmosomes
c. plasmodesmata
d. tightjunctions

16.The key components of desmosomes are cadherins and __________.

a. actin
b. microfilaments
c. intermediatefilaments
d. microtubules

Exercise 3. Critical thinking questions.

a. In your everyday life, you have probably noticed that certain instruments are ideal for certain situations. For example, you would use a spoon rather than a fork to eat soup because a spoon is shaped for scooping, while soup would slip between the tines of a fork. The use of ideal instruments also applies in science. In what situation(s) would the use of a light microscope be ideal, and why?

b. In what situation(s) would the use of a scanning electron microscope be ideal, and why?
c. In what situation(s) would a transmission electron microscope be ideal, and why?
d. What are the advantages and disadvantages of each of these types of microscopes?
e. Antibiotics are medicines that are used to fight bacterial infections. These medicines kill prokaryotic cells without harming human cells. What part or parts of the bacterial cell do you think antibiotics target? Why?
f. Explain why not all microbes are harmful.
g. You already know that ribosomes are abundant in red blood cells. In what other cells of the body would you find them in great abundance? Why?
h. What are the structural and functional similarities and differences between mitochondria and chloroplasts?
i. In the context of cell biology, what do we mean by form follows function? What are at least two examples of this concept?
j. In your opinion, is the nuclear membrane part of the endomembrane system? Why or why not? Defend your answer.
k. What are the similarities and differences between the structures of centrioles and flagella?
l. How do cilia and flagella differ?
m. How does the structure of a plasmodesma differ from that of a gap junction?
n. Explain how the extracellular matrix functions.

Exercise 3. Explore more. Watch the video.

https://homework.study.com/explanation/why-is-the-cell-the-smallest-unit-of-life.html#:~:text=Answer%20and%20Explanation%3A&text=The%20cell%20is%20the%20smallest,block%20of%20every%20living%20organism.

Unit 6. Metabolism

Bioenergetics	Біоенергетика
Metabolism	Метаболізм
Muscle	М’яз
Cellular processes	Клітинні процеси
Nutrient	Поживна речовина
Protein	Білок
Hormone	Гормон
Neurotransmitter	Нейромедіатор
Chemicalreaction	Хімічна реакція
Surrounding material	Навколишній матеріал
To release energy	Вивільняти енергію
Carbohydrate	Вуглевод
To consume	Споживати
Bond	Зв'язок
Cellular appendage	Клітинний придаток
Catabolic pathway	Катаболічний шлях

6.1 Metabolism

Virtually every task performed by living organisms requires energy. Energy is needed to perform heavy labor and exercise, but humans also use a great deal of energy while thinking, and even during sleep. In fact, the living cells of every organism constantly use energy. Nutrients and other molecules are imported, metabolized (broken down) and possibly synthesized into new molecules, modified if needed, transported around the cell, and may be distributed to the entire organism. For example, the large proteins that make up muscles are actively built from smaller molecules. Complex carbohydrates are broken down into simple sugars that the cell uses for energy. Just as energy is required to both build and demolish a building, energy is required for both the synthesis and breakdown of molecules. Additionally, signaling molecules such as hormones and neurotransmitters are transported between cells. Pathogenic bacteria and viruses are ingested and broken down by cells. Cells must also export waste and toxins to stay healthy, and many cells must swim or move surrounding materials via the beating motion of cellular appendages like cilia and flagella.

The cellular processes listed above require a steady supply of energy. From where, and in what form, does this energy come? How do living cells obtain energy, and how do they use it? This chapter will discuss different forms of energy and the physical laws that govern energy transfer. This chapter will also describe how cells use energy and replenish it, and how chemical reactions in the cell are performed with great efficiency.

Scientists use the term **bioenergetics** to discuss the concept of energy flowthrough living systems, such as cells. Cellular processes such as the building and breaking down of complex molecules occur through stepwise chemical reactions. Some of these chemical reactions are spontaneous and release energy, whereas others require energy to proceed. Just as living things must continually consume food to replenish what has been used, cells must continually produce more energy to replenish that used by the many energy-requiring chemical reactions that constantly take place. All of the chemical reactions that take place inside cells, including those that use energy and those that release energy, are the cell's **metabolism**.

6.2 Metabolism of Carbohydrates

The metabolism of sugar (a simple carbohydrate) is a classic example of the many cellular processes that use and produce energy. Living things consume sugar as a major energy source, because sugar molecules have a great deal of energy stored within their bonds. The breakdown of glucose, a simple sugar, is described by the equation:

C6H12O6+6O2→6CO2+6H2O+energyC6H12O6+6O2→6CO2+6H2O+energy

Carbohydrates that are consumed have their origins in photosynthesizing organisms like plants. During photosynthesis, plants use the energy of sunlight to convert carbon dioxide gas (CO_2) into sugar molecules, like glucose ($C_6H_{12}O_6$). Because this process involves synthesizing a larger, energy-storing molecule, it requires an input of energy to proceed. The synthesis of glucose is described by this equation (notice that it is the reverse of the previous equation):

6CO2+6H2O+energy→C6H12O6+6O26CO2+6H2O+energy→C6H12O6+6O2

During the chemical reactions of photosynthesis, energy is provided in the form of a very high-energy molecule called ATP, or adenosine triphosphate, which is the primary energy currency of all cells. Just as the dollar is used as currency to buy goods, cells use molecules of ATP as energy currency to perform immediate work. The sugar (glucose) is stored as starch or glycogen. Energy-storing polymers like these are broken down into glucose to supply molecules of ATP.

Solar energy is required to synthesize a molecule of glucose during the reactions of photosynthesis. In photosynthesis, light energy from the sun is initially transformed into chemical energy that is temporally stored in the energy carrier molecules ATP and NADPH (nicotinamide adenine dinucleotide phosphate). The stored energy in ATP and NADPH is then used later in photosynthesis to build one molecule of glucose from six molecules of CO_2. This process is analogous to eating breakfast in the morning to acquire energy for your body that can be used later in the day. Under ideal conditions, energy from 18 molecules of ATP is required to synthesize one molecule of glucose during the reactions of photosynthesis. Glucose molecules can also be combined with and converted into other types of sugars. When sugars are consumed, molecules of glucose eventually make their way into each living cell of the organism. Inside the cell, each sugar molecule is broken down through a complex series of chemical reactions. The goal of these reactions is to harvest the energy stored inside the sugar molecules. The harvested energy is used to make high-energy ATP molecules, which can be used to perform work, powering many chemical reactions in the cell. The amount of energy needed to make one molecule of glucose from six molecules of carbon dioxide is 18 molecules of ATP and 12 molecules of NADPH (each one of which is energetically equivalent to three molecules of ATP), or a total of 54 molecule equivalents required for the synthesis of one molecule of glucose. This process is a fundamental and efficient way for cells to generate the molecular energy that they require**.** Plants, like this oak tree and acorn, use energy from sunlight to make sugar and other organic molecules. Both plants and animals (like this squirrel) use cellular respiration to derive energy from the organic molecules originally produced by plants. (credit “acorn”: modification of work by Noel Reynolds; credit “squirrel”: modification of work by Dawn Huczek)

6.3 Metabolic Pathways

The processes of making and breaking down sugar molecules illustrate two types of metabolic pathways. A metabolic pathway is a series of interconnected biochemical reactions that convert a substrate molecule or molecules, step-by-step, through a series of metabolic intermediates, eventually yielding a final product or products. In the case of sugar metabolism, the first metabolic pathway synthesized sugar from smaller molecules, and the other pathway broke sugar down into smaller molecules. These two opposite processes—the first requiring energy and the second producing energy—are referred to as anabolic (building) and catabolic (breaking down) pathways, respectively. Consequently, metabolism is composed of building (anabolism) and degradation (catabolism).

Evolution of Metabolic Pathways. There is more to the complexity of metabolism than understanding the metabolic pathways alone. Metabolic complexity varies from organism to organism. Photosynthesis is the primary pathway in which photosynthetic organisms like plants (the majority of global synthesis is done by planktonic algae) harvest the sun’s energy and convert it into carbohydrates. The by-product of photosynthesis is oxygen, required by some cells to carry out cellular respiration. During cellular respiration, oxygen aids in the catabolic breakdown of carbon compounds, like carbohydrates. Among the products of this catabolism are CO_2 and ATP. In addition, some eukaryotes perform catabolic processes without oxygen (fermentation); that is, they perform or use anaerobic metabolism.

Organisms probably evolved anaerobic metabolism to survive (living organisms came into existence about 3.8 billion years ago, when the atmosphere lacked oxygen). Despite the differences between organisms and the complexity of metabolism, researchers have found that all branches of life share some of the same metabolic pathways, suggesting that all organisms evolved from the same ancient common ancestor. Evidence indicates that over time, the pathways diverged, adding specialized enzymes to allow organisms to better adapt to their environment, thus increasing their chance to survive. However, the underlying principle remains that all organisms must harvest energy from their environment and convert it to ATP to carry out cellular functions.

6.4 Anabolic and Catabolic Pathways

Anabolic pathways require an input of energy to synthesize complex molecules from simpler ones. Synthesizing sugar from CO_2 is one example. Other examples are the synthesis of large proteins from amino acid building blocks, and the synthesis of new DNA strands from nucleic acid building blocks. These biosynthetic processes are critical to the life of the cell, take place constantly, and demand energy provided by ATP and other high-energy molecules like NADH (nicotinamide adenine dinucleotide) and NADPH.

ATP is an important molecule for cells to have in sufficient supply at all times. The breakdown of sugars illustrates how a single molecule of glucose can store enough energy to make a great deal of ATP, 36 to 38 molecules. This is a **catabolic** pathway. Catabolic pathways involve the degradation (or breakdown) of complex molecules into simpler ones. Molecular energy stored in the bonds of complex molecules is released in catabolic pathways and harvested in such a way that it can be used to produce ATP. Other energy-storing molecules, such as fats, are also broken down through similar catabolic reactions to release energy and make ATP.

It is important to know that the chemical reactions of metabolic pathways don't take place spontaneously. Each reaction step is facilitated, or catalyzed, by a protein called an enzyme. Enzymes are important for catalyzing all types of biological reactions—those that require energy as well as those that release energy.

Exercise 1. Answer the questions.

1.Look at each of the processes shown, and decide if it is endergonic or exergonic. In each case, does enthalpy increase or decrease, and does entropy increase or decrease?

2.If no activation energy were required to break down sucrose (table sugar), would you be able to store it in a sugar bowl?

Exercise 2. Choose the correct answer.

1.Energy is stored long-term in the bonds of _____ and used short-term to perform work from a(n) _____ molecule.

a. ATP : glucose
b. ananabolicmolecule : catabolicmolecule
c. glucose : ATP
d. a catabolicmolecule : anabolicmolecule

2.DNA replication involves unwinding two strands of parent DNA, copying each strand to synthesizecomplementary strands, and releasing the parent and daughter DNA. Which of the following accurately describes this process?

a. Thisisananabolicprocess
b. Thisis a catabolicprocess

c. This is both anabolic and catabolic
d. This is a metabolic process but is neither anabolic nor catabolic

3.Which of the following is not an example of an energy transformation?

a. Turningon a lightswitch
b. Solarpanelsatwork
c. Formationofstaticelectricity
d. Noneoftheabove

4.The energy released by the hydrolysis of ATP is

a. primarily stored between the alpha and beta phosphates
b. equalto −57 kcal/mol
c. harnessed as heat energy by the cell to perform work
d. providingenergytocoupledreactions

5.Which of the following molecules is likely to have the most potential energy?

a. sucrose
b. ATP
c. glucose
d. ADP

6.Which of the following does an allosteric inhibitor do?

a. Binds to an enzyme away from the active site and changes the conformation of the active site, increasing its affinity for substrate binding
b. Binds to the active site and blocks it from binding substrate
c. Binds to an enzyme away from the active site and changes the conformation of the active site, decreasing its affinity for the substrate
d. Binds directly to the active site and mimics the substrate

7.Which of the following analogies best describe the induced-fit model of enzyme-substrate binding?

a. A hugbetweentwopeople
b. A key fitting into a lock
c. A square peg fitting through the square hole and a round peg fitting through the round hole of a children's toy
d. The fitting together of two jigsaw puzzle pieces.

Exercise 3. Critical thinking questions.

a. Does physical exercise involve anabolic and/or catabolic processes? Give evidence for your answer.
b. Name two different cellular functions that require energy that parallel human energy-requiring functions.
c. Explain in your own words the difference between a spontaneous reaction and one that occurs instantaneously, and what causes this difference.

d. Describe the position of the transition state on a vertical energy scale, from low to high, relative to the position of the reactants and products, for both endergonic and exergonic reactions.
e. Imagine an elaborate ant farm with tunnels and passageways through the sand where ants live in a large community. Now imagine that an earthquake shook the ground and demolished the ant farm. In which of these two scenarios, before or after the earthquake, was the ant farm system in a state of higher or lower entropy?
f. Energy transfers take place constantly in everyday activities. Think of two scenarios: cooking on a stove and driving. Explain how the second law of thermodynamics applies to these two scenarios.
g. Do you think that the E_A for ATP hydrolysis is relatively low or high? Explain your reasoning.
h. With regard to enzymes, why are vitamins necessary for good health? Give examples.
i. Explain in your own words how enzyme feedback inhibition benefits a cell.

Unit 7. Cell Communication

Paracrine Signaling	Паракринна сигналізація
Endocrine Signaling	Ендокринна сигналізація
Autocrine Signaling	Аутокринна сигналізація
Neurotransmitter	Нейромедіатор
Extension	Розширення
Fast-movingelectrical impulse	Швидкий електричний імпульс
An immediate response	Негайна відповідь
Recipientt nerve	Реципієнтний нерв
Pituitary gland	Гіпофіз
Bloodstream	Кровотік
Ligand	Ліганд (атом, функціональна група або молекула)
Enzyme	Фермент
Target cell	Клітина-мішень
proper function	Належна функція
Proper developmental outcome	Правильний результат розвитку

7.1 Cell Communication

Imagine what life would be like if you and the people around you could not communicate. You would not be able to express your wishes to others, nor could you ask questions to find out more about your environment. Social organization is dependent on communication between the individuals that comprise that society; without communication, society would fall apart.

As with people, it is vital for individual cells to be able to interact with their environment. This is true whether a cell is growing by itself in a pond or is one of many cells that form a larger organism. In order to properly respond to external stimuli, cells have developed complex mechanisms of communication that can receive a message, transfer the information across the plasma membrane, and then produce changes within the cell in response to the message.

In multicellular organisms, cells send and receive chemical messages constantly to coordinate the actions of distant organs, tissues, and cells. The ability to send messages quickly and efficiently enables cells to coordinate and fine-tune their functions.

While the necessity for cellular communication in larger organisms seems obvious, even single-celled organisms communicate with each other. Yeast cells signal each other to aid mating. Some forms of bacteria coordinate their actions in order to form large complexes called biofilms or to organize the production of toxins to remove competing organisms. The ability of cells to communicate through chemical signals originated in single cells and was essential for the evolution of multicellular organisms. The efficient and error-free function of communication systems is vital for all life as we know it.

7.2 Forms of Signaling

There are four categories of chemical signaling found in multicellular organisms: paracrine signaling, endocrine signaling, autocrine signaling, and direct signaling across gap junctions. The main difference between the different categories of signaling is the distance that the signal travels through the organism to reach the target cell. Not all cells are affected by the same signals.

7.3 Paracrine Signaling

Signals that act locally between cells that are close together are called paracrine signals. Paracrine signals move by diffusion through the extracellular matrix. These types of signals usually elicit quick responses that last only a short amount of time. In order to keep the response localized, paracrine ligand molecules are normally quickly degraded by enzymes or removed by neighboring cells. Removing the signals will reestablish the concentration gradient for the signal, allowing them to quickly diffuse through the intracellular space if released again.

One example of paracrine signaling is the transfer of signals across synapses between nerve cells. A nerve cell consists of a cell body, several short, branched extensions called dendrites that receive stimuli, and a long extension called an axon, which transmits signals to other nerve cells or muscle cells. The junction between nerve cells where signal transmission occurs is called a synapse. A synaptic signal is a chemical signal that travels between nerve cells. Signals within the nerve cells are propagated by fast-moving electrical impulses. When these impulses reach the end of the axon, the signal continues on to a dendrite of the next cell by the release of chemical ligands called neurotransmitters by the presynaptic cell (the cell emitting the signal). The neurotransmitters are transported across the very small distances between nerve cells, which are called chemical synapses. The small distance between nerve cells allows the signal to travel quickly; this enables an immediate response, such as, Take your hand off the stove!

When the neurotransmitter binds the receptor on the surface of the postsynaptic cell, the electrochemical potential of the target cell changes, and the next electrical impulse is launched. The neurotransmitters that are released into the chemical synapse are degraded quickly or get reabsorbed by the presynaptic cell so that the recipient nerve cell can recover quickly and be prepared to respond rapidly to the next synaptic signal.

7.4 Endocrine Signaling

Signals from distant cells are called endocrine signals, and they originate from endocrine cells. (In the body, many endocrine cells are located in endocrine glands, such as the thyroid gland, the hypothalamus, and the pituitary gland.) These types of signals usually produce a slower response but have a longer-lasting effect. The ligands released in endocrine signaling are called hormones, signaling molecules that are produced in one part of the body but affect other body regions some distance away.

Hormones travel the large distances between endocrine cells and their target cells via the bloodstream, which is a relatively slow way to move throughout the body. Because of their form of transport, hormones get diluted and are present in low concentrations when they act on their target cells. This is different from paracrine signaling, in which local concentrations of ligands can be very high.

7.5 Autocrine Signaling

Autocrine signals are produced by signaling cells that can also bind to the ligand that is released. This means the signaling cell and the target cell can be the same or a similar cell (the prefix *auto-* means self, a reminder that the signaling cell sends a signal to itself). This type of signaling often occurs during the early development of an organism to ensure that cells develop into the correct tissues and take on the proper function. Autocrine signaling also regulates pain sensation and inflammatory responses. Further, if a cell is infected with a virus, the cell can signal itself to undergo programmed cell death, killing the virus in the process. In some cases, neighboring cells of the same type are also influenced by the released ligand. In embryological development, this process of stimulating a group of neighboring cells may help to direct the differentiation of identical cells into the same cell type, thus ensuring the proper developmental outcome.

7.6 Direct Signaling Across Gap Junctions

Gap junctions in animals and plasmodesmata in plants are connections between the plasma membranes of neighboring cells. These water-filled channels allow small signaling molecules, called intracellular mediators, to diffuse between the two cells. Small molecules, such as calcium ions (Ca^{2+}), are able to move between cells, but large molecules like proteins and DNA cannot fit through the channels. The specificity of the channels ensures that the cells remain independent but can quickly and easily transmit signals. The transfer of signaling molecules communicates the current state of the cell that is directly next to the target cell; this allows a group of cells to coordinate their response to a signal that only one of them may have received. In plants, plasmodesmata are ubiquitous, making the entire plant into a giant, communication network.

Evolution Connection

How Viruses Recognize a Host. Unlike living cells, many viruses do not have a plasma membrane or any of the structures necessary to sustain life. Some viruses are simply composed of an inert protein shell containing DNA or RNA. To reproduce, viruses must invade a living cell, which serves as a host, and then take over the hosts cellular apparatus. But how does a virus recognize its host?

Viruses often bind to cell-surface receptors on the host cell. For example, the virus that causes human influenza (flu) binds specifically to receptors on membranes of cells of the respiratory system. Chemical differences in the cell-surface receptors among hosts mean that a virus that infects a specific species (for example, humans) cannot infect another species (for example, chickens).

However, viruses have very small amounts of DNA or RNA compared to humans, and, as a result, viral reproduction can occur rapidly. Viral reproduction invariably produces errors that can lead to changes in newly produced viruses; these changes mean that the viral proteins that interact with cell-surface receptors may evolve in such a way that they can bind to receptors in a new host. Such changes happen randomly and quite often in the reproductive cycle of a virus, but the changes only matter if a virus with new binding properties comes into contact with a suitable host. In the case of influenza, this situation can occur in settings where animals and people are in close contact, such as poultry and swine farms.[1] Once a virus jumps to a new host, it can spread quickly. Scientists watch newly appearing viruses (called emerging viruses) closely in the hope that such monitoring can reduce the likelihood of global viral epidemics.

Exercise 1. Visual connectionquestions.

HER2 is a receptor tyrosine kinase. In 30 percent of human breast cancers, HER2 is permanently activated, resulting in unregulated cell division. Lapatinib, a drug used to treat breast cancer, inhibits HER2 receptor tyrosine kinase autophosphorylation (the process by which the receptor adds phosphates onto itself), thus reducing tumor growth by 50 percent. Besides autophosphorylation, which of the following steps would be inhibited by Lapatinib?

a. Signaling molecule binding, dimerization, and the downstream cellular response.
b. Dimerization, and the downstream cellular response.
c. Thedownstreamcellularresponse.
d. Phosphatase activity, dimerization, and the downsteam cellular response.

Exercise 2. Answer the questions.

1. In certain cancers, the GTPase activity of the RAS G-protein is inhibited. This means that the RAS protein can no longer hydrolyze GTP into GDP. What effect would this have on downstream cellular events?

2. Which of the following statements about quorum sensing is false?

a. Autoinducer must bind to receptor to turn on transcription of genes responsible for the production of more autoinducer.
b. The receptor stays in the bacterial cell, but the autoinducer diffuses out.
c. Autoinducer can only act on a different cell: it cannot act on the cell in which it is made.
d. Autoinducer turns on genes that enable the bacteria to form a biofilm.

3.What advantage might biofilm production confer on the *S. aureus* inside the catheter?

Exercise 3. Choose the correct answer.

1.What property prevents the ligands of cell-surface receptors from entering the cell?

a. The molecules bind to the extracellular domain.
b. The molecules are hydrophilic and cannot penetrate the hydrophobic interior of the plasma membrane.
c. The molecules are attached to transport proteins that deliver them through the bloodstream to target cells.
d. The ligands are able to penetrate the membrane and directly influence gene expression upon receptor binding.

2.The secretion of hormones by the pituitary gland is an example of _______________.

a. autocrinesignaling
b. paracrinesignaling
c. endocrinesignaling

d. directsignalingacrossgapjunctions

3.Why are ion channels necessary to transport ions into or out of a cell?

a. Ions are too large to diffuse through the membrane.
b. Ions are charged particles and cannot diffuse through the hydrophobic interior of the membrane.
c. Ions do not need ion channels to move through the membrane.
d. Ions bind to carrier proteins in the bloodstream, which must be removed before transport into the cell.

4.Endocrine signals are transmitted more slowly than paracrine signals because ___________.

a. the ligands are transported through the bloodstream and travel greater distances
b. the target and signaling cells are close together
c. theligandsaredegradedrapidly
d. the ligands don't bind to carrier proteins during transport

5.Where do DAG and IP_3 originate?

a. They are formed by phosphorylation of cAMP.
b. They are ligands expressed by signaling cells.
c. They are hormones that diffuse through the plasma membrane to stimulate protein production.
d. They are the cleavage products of the inositol phospholipid, PIP_2.

6.What property enables the residues of the amino acids serine, threonine, and tyrosine to be phosphorylated?

a. Theyarepolar.
b. Theyarenon-polar.
c. They contain a hydroxyl group.
d. They occur more frequently in the amino acid sequence of signaling proteins.

7.What is the function of a phosphatase?

a. A phosphatase removes phosphorylated amino acids from proteins.
b. A phosphatase removes the phosphate group from phosphorylated amino acid residues in a protein.
c. A phosphatase phosphorylates serine, threonine, and tyrosine residues.
d. A phosphatase degrades second messengers in the cell.

8.How does NF-κB induce gene expression?

a. A small, hydrophobic ligand binds to NF-κB, activating it.
b. Phosphorylation of the inhibitor Iκ-B dissociates the complex between it and NF-κB, and allows NF-κB to enter the nucleus and stimulate transcription.
c. NF-κB is phosphorylated and is then free to enter the nucleus and bind DNA.
d. NF-κB is a kinase that phosphorylates a transcription factor that binds DNA and promotes protein production.

9.Apoptosis can occur in a cell when the cell is ________________.

a. damaged
b. nolongerneeded
c. infectedby a virus
d. alloftheabove

10.What is the effect of an inhibitor binding an enzyme?

a. Theenzymeisdegraded.
b. Theenzymeisactivated.
c. Theenzymeisinactivated.
d. The complex is transported out of the cell.

11.Which type of molecule acts as a signaling molecule in yeasts?

a. steroid
b. autoinducer
c. matingfactor
d. secondmessenger

12.Quorum sensing is triggered to begin when ___________.

a. treatmentwithantibioticsoccurs
b. bacteriareleasegrowthhormones
c. bacterial protein expression is switched on
d. a sufficient number of bacteria are present

Unit 8. Cell Division

Cell division	Поділ клітин
Human gamete	Гамети людини
Diploid	Диплоїдний
Haploid	Гаплоїдний
Homologous chromosome	Гомологічна хромосома
Gene	Ген
Compaction	Ущільнення
Histone protein	Гістоновий білок
Nucleosome	Нуклеосома
Karyokinesis	Каріокінез
Regular intervals	Регулярні проміки часу
Mitotic phase	Міотична фаза

8.1 Genomic DNA

The continuity of life from one cell to another has its foundation in the reproduction of cells by way of the cell cycle. The **cell cycle** is an orderly sequence of events that describes the stages of a cell’s life from the division of a single parent cell to the production of two new daughter cells. The mechanisms involved in the cell cycle are highly regulated.

Before discussing the steps a cell must undertake to replicate, a deeper understanding of the structure and function of a cell's genetic information is necessary. A cell's DNA, packaged as a double-stranded DNA molecule, is called its **genome**. In prokaryotes, the genome is composed of a single, double-stranded DNA molecule in the form of a loop or circle. The region in the cell containing this genetic material is called a nucleoid. Some prokaryotes also have smaller loops of DNA called plasmids that are not essential for normal growth. Bacteria can exchange these plasmids with other bacteria, sometimes receiving beneficial new genes that the recipient can add to their chromosomal DNA. Antibiotic resistance is one trait that often spreads through a bacterial colony through plasmid exchange.

In eukaryotes, the genome consists of several double-stranded linear DNA molecules. Each species of eukaryotes has a characteristic number of chromosomes in the nuclei of its cells. Human body cells have 46 chromosomes, while human **gametes** (sperm or eggs) have 23 chromosomes each. A typical body cell, or somatic cell, contains two matched sets of chromosomes, a configuration known as **diploid**. The letter *n* is used to represent a single set of chromosomes; therefore, a diploid organism is designated 2*n*. Human cells that contain one set of chromosomes are called gametes, or sex cells; these are eggs and sperm, and are designated *1n*, or **haploid**.

Matched pairs of chromosomes in a diploid organism are called **homologous** ("same knowledge") **chromosomes**. Homologous chromosomes are the same length and have specific nucleotide segments called **genes** in exactly the same location, or **locus**. Genes, the functional units of chromosomes, determine specific characteristics by coding for specific proteins. Traits are the variations of those characteristics. For example, hair color is a characteristic with traits that are blonde, brown, or black.

Each copy of a homologous pair of chromosomes originates from a different parent; therefore, the genes themselves are not identical. The variation of individuals within a species is due to the specific combination of the genes inherited from both parents. Even a slightly altered sequence of nucleotides within a gene can result in an alternative trait. For example, there are three possible gene sequences on the human chromosome that code for blood type: sequence A, sequence B, and sequence O. Because all diploid human cells have two copies of the chromosome that determines blood type, the blood type (the trait) is determined by which two versions of the marker gene are inherited. It is possible to have two copies of the same gene sequence on both homologous chromosomes, with one on each (for example, AA, BB, or OO), or two different sequences, such as AB.

Minor variations of traits, such as blood type, eye color, and handedness, contribute to the natural variation found within a species. However, if the entire DNA sequence from any pair of human homologous chromosomes is compared, the difference is less than one percent. The sex chromosomes, X and Y, are the single exception to the rule of homologous chromosome uniformity: Other than a small amount of homology that is necessary to accurately produce gametes, the genes found on the X and Y chromosomes are different.

8.2 Eukaryotic Chromosomal Structure and Compaction

If the DNA from all 46 chromosomes in a human cell nucleus was laid out end to end, it would measure approximately two meters; however, its diameter would be only 2 nm. Considering that the size of a typical human cell is about 10 μm (100,000 cells lined up to equal one meter), DNA must be tightly packaged to fit in the cell's nucleus. At the same time, it must also be readily accessible for the genes to be expressed. During some stages of the cell cycle, the long strands of DNA are condensed into compact chromosomes. There are a number of ways that chromosomes are compacted.

In the first level of compaction, short stretches of the DNA double helix wrap around a core of eight **histone proteins** at regular intervals along the entire length of the chromosome. The DNA-histone complex is called chromatin. The beadlike, histone DNA complex is called a **nucleosome**, and DNA connecting the nucleosomes is called linker DNA. A DNA molecule in this form is about seven times shorter than the double helix without the histones, and the beads are about 10 nm in diameter, in contrast with the 2-nm diameter of a DNA double helix. The next level of compaction occurs as the nucleosomes and the linker DNA between them are coiled into a 30-nm chromatin fiber. This coiling further shortens the chromosome so that it is now about 50 times shorter than the extended form. In the third level of packing, a variety of fibrous proteins is used to pack the chromatin. These fibrous proteins also ensure that each chromosome in a non-dividing cell occupies a particular area of the nucleus that does not overlap with that of any other chromosome.

DNA replicates in the S phase of interphase. After replication, the chromosomes are composed of two linked sister **chromatids**. When fully compact, the pairs of identically packed chromosomes are bound to each other by cohesin proteins. The connection between the sister chromatids is closest in a region called the **centromere**. The conjoined sister chromatids, with a diameter of about 1 μm, are visible under a light microscope. The centromeric region is highly condensed and thus will appear as a constricted area.

Exercise 1. Visual contact questions.

- Describe the structure of prokaryotic and eukaryotic genomes
- Distinguish between chromosomes, genes, and traits
- Describe the mechanisms of chromosome compaction

Exercise 2. Explore more. Watch the video "How DNA is packaged". What facts were the most significant for you?

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