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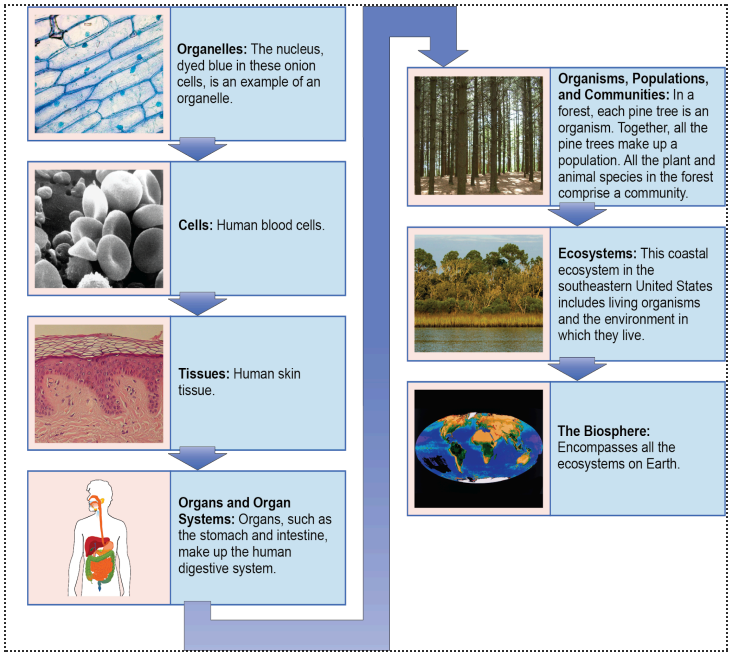
Chapter 1: The Study of Life

Themes and Concepts of Biology

- Introduction
  - Biology has always struggled with three questions:
    - What are the shared properties that make something "alive"?
    - How does one find the meaningful levels of organization and structure within a living thing?
    - How can living organisms be organized so that we can better understand them?
- 1.1a: Properties of Life
  - All living things share some key characteristics/functions that define life
    - Order - the organization and coordinated structures that make up an organism
      - Examples: organ systems, cellular structure, tissues
    - Sensitivity or Response to Environment - reaction to the world around you
      - Examples: bacteria moving away from chemicals, plants bending towards sunlight
    - Reproduction - producing offspring
      - Creating new cells for maintenance in the body (healing, growing, etc.)
      - Single-celled organisms replicate DNA before dividing equally into two cells
      - Multicellular organisms generally produce specialized reproductive germline cells that form new individuals; DNA is passed from parent to offspring
        - Mitotic division - process that creates gametes
    - Adaptation - a change or the process of change by which an organism or species becomes better suited to its environment; genetic changes that aid in survival
    - Growth and Development
      - Organisms grow and develop based off coding in genes
        - Genes provide instructions that direct growth and development; ensures offspring will grow up to exhibit similar characteristics to its parents
    - Regulation - the ability to coordinate internal functions, respond to stimuli, and cope with environmental stresses
      - Examples: nutrient transport and blood flow
    - Homeostasis - the ability of an organism to maintain constant internal conditions
      - Cells function only under proper conditions (temperature, pH, chemical concentration)
      - Examples: insulation that keeps a polar bear warm
    - Energy Processing - the ability of an organism to use a source of energy for metabolic activities
      - Examples: photosynthesis of sunlight, chemical energy from consuming other animals
    - Evolution - the change in the characteristics of a species over several generations and relies on the process of natural selection
- 1.1b: Levels of Organizing Living Things
  - "Living things are highly organized and structured, following a hierarchy that can be examined on a scale from small to large."
    - Atom - the smallest and most fundamental unit of matter, consisting of a nucleus surrounded by electrons
    - Molecule - particle formed by at least two atoms held together by chemical bonds
    - Macromolecule - large molecules, typically formed by polymerization
      - Polymerization - a polymer is a large molecule that is made by combining smaller units called monomers, which are simpler than macromolecules
    - Organelles - groups of macromolecules surrounded by membranes; small structures within cells
    - Cells - smallest fundamental unit of structure and function in living organisms
      - Composed of three parts
        - Cell membrane
        - Cytoplasm
        - DNA/genome
          - Mutation - errors in DNA
      - Classified as prokaryotic or eukaryotic
      - Why viruses aren't considered living

- Not made of cells; have to invade and hijack the reproductive mechanisms of a living cell to be able to reproduce

- Prokaryotes - single-celled or colonial organisms that do not have membrane bound nuclei; DNA is not enclosed in a nucleus
- Eukaryotes - single- or multicellular organisms with membrane bound nuclei and membrane bound nucleus that houses DNA
- Tissues - a group of cells, proteins, and fluid that work together to perform some function
- Organs - collections of tissues grouped together performing a common function
- Organ Systems - higher level of organization that consists of functionally related organs
- Organisms - living things
- Population - all the individuals of a species living within a specific area collectively
- Community - the sum of populations inhabiting a particular area; not just one species
- Ecosystem - consists of all the living things in a particular area together with the abiotic
  - Abiotic - non-living parts of that environment such as nitrogen in the soil or rainwater
- Biome - all related ecosystems; the same type
- Biosphere - a collection of all the ecosystems on Earth

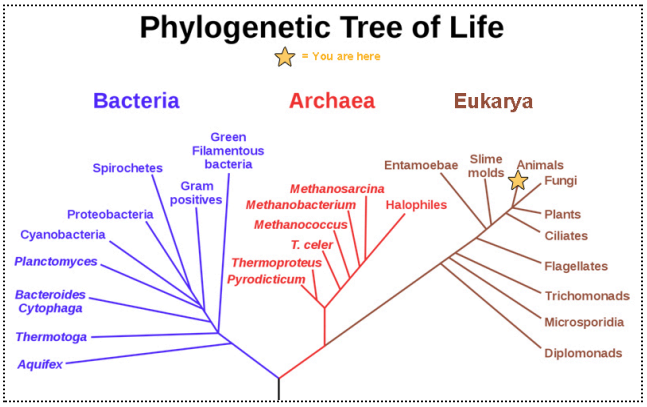


❖ 1.1c: The Diversity of Life

➢ Evolution - source of the diversity of life on Earth; process of gradual genetic change in a population over time

➢ Phylogenetic tree - diagram showing the evolutionary relationships among various biological species based on similarities and differences in genetic or physical traits or both; in essence, a hypothesis concerning evolutionary connections

- Consists of nodes and branches
  - Node - represent ancestors and are points of evolution when an ancestor may have diverged into a new species
  - Branch - line that connects nodes; proportional to the time elapsed since the split



Themes and Concepts of Biology

❖ Introduction

➢ What is biology? Simply put, it's the study of organisms and their interactions with one another and their environments

❖ 1.2a: The Process of Science

➢ Vocabulary

- Science - (from the Latin *scientia* , meaning "knowledge") can be defined as knowledge that covers general truths or the operation of general laws, especially when acquired and tested by the scientific method
- Scientific Method - method of research with defined steps that include observation, formulation of a hypothesis, testing, and confirming or falsifying the hypothesis
  - Cannot be used to define science due to sciences like archeology or geology where the scientific method is less applicable
- Hypothesis - a suggested explanation for an observation, which can be tested
- Theory - tested and confirmed explanation for observations or phenomena

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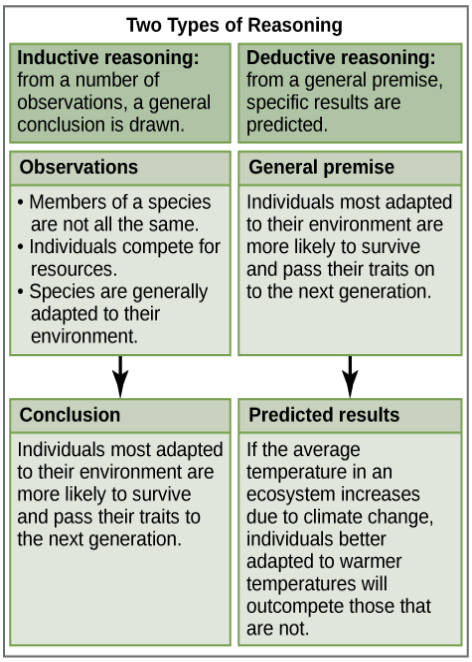
- Scientific Reasoning
  - One goal is common of all sciences: the goal of knowledge
    - Scientists seek to understand the natural world around them and how it operates, which is done through inductive and deductive reasoning
      - Inductive Reasoning - a form of logical thinking that uses related observations to arrive at a general conclusion
        - Common of descriptive sciences; a scientist makes observations and records them
        - Can consist of qualitative or quantitative data
        - Involves formulating generalizations inferred from careful observation and analysis of lots of data
      - Deductive Reasoning - a form of logical thinking that uses a general principle or law to forecast specific results
        - From general principales, scientists can extrapolate and predict specific results



- Both types of reasoning are related to two main pathways of scientific study: descriptive-based and hypothesis-based science
  - Descriptive/Discovery Science - form of science that aims to observe, explore, and investigate
  - Hypothesis-Based Science - form of science that begins with a specific question and potential testable answers
- Both can blend together when thinking of how an observation can lead to questions
- Descriptive and hypothesis-based science are a continuous dialogue

❖ 1.2b: The Scientific Method: A Process of Inquiry

- Used throughout history
- First documented by Sir Francis Bacon (1561-1626) of England
- Begins with observations that brings about questions
- Proposing a Hypothesis
  - Hypothesis - a statement that is an answer to a research question; must be able to be measured
  - To solve a problem, several hypotheses may be proposed
  - Must be testable and falsifiable
- Testing a Hypothesis
  - Science doesn't "prove" anything because scientific understandings are always subject to modification with further information
  - Searching for how to disprove a hypothesis
  - Tested by conducting experiments
    - Must do multiple tests
      - Must have appropriate sample sizes
        - More variation in a species means bigger sample size
    - Variable - any part of the experiment that can vary or change during the experiment
      - Dependent Variable - some changing aspect of the experiment that you want to find out
      - Independent Variable - what you changed to get results
      - Controlled Variable - any part of the experimental setup that you kept the same; the more controlled variables, the more accurate your findings will be
    - Every experiment should have a control group
      - Control Group - contains every feature of the experimental group except it is not given the manipulation that is hypothesized about; provides a baseline of "regular" data
        - Negative Control - one or more samples/individuals who are known in advance to demonstrate a negative result
          - Example: a drug study in which one group does not receive the drug; many studies like this will give their patients a placebo

- Placebo - a harmless pill, medicine, or procedure prescribed more for the psychological benefit to the patient than for any physiological effect

➢ Positive Control - a sample/individual or group of samples/individuals who you know will actually demonstrate a difference from the negative control
- Example: if you were comparing the effectiveness of Drug A and a new drug, B, the group that you gave A would be the positive control

◆ Experiments exist to eliminate hypotheses, but the elimination of one does not mean any other is valid

◆ Specific results are predicted from a general premise in deductive reasoning, though it can happen the other way around in which observations create hypotheses in inductive reasoning

➢ Scientific method is very rigid, so remember there can be flexibility if the research demands

➢ Scientific reasoning is more complex than the method alone

❖ 1.2c: Two Types of Science: Basic and Applied
- Basic Science - "pure" science seeks to expand knowledge regardless of the short-term application of that knowledge; knowledge for knowledge's sake
- Applied Science - "technology," aims to use science to solve real-world problems, making it possible

➢ Applied science relies on the basic knowledge from basic science to solve anything to begin with

➢ Some discoveries happen without science at all
- Serendipity - a fortunate accident or a lucky surprise

❖ 1.2d: Reporting Scientific Work

➢ Sharing work is essential to allow discoveries to be expanded and built upon

➢ Can be shared through presentations, but many prefer peer-reviewed manuscripts because it can reach more people
- Peer-reviewing colleagues are qualified (often experts in the same field) who judge whether a report is ready for publication

➢ Scientific Paper
- Must be brief, precise, and accurate
- Consists of an introduction, abstract, materials and methods, results, discussion, conclusion, acknowledgement, and a section reference
  - Introduction - starts with brief, but broad, background information about what is known in the field; gives rationale of the work; briefly mentions the end of the paper, where the hypothesis or research question driving the research will be presented; should include proper citations
  - Abstract - concise summary at the beginning of the paper
  - Materials and Methods - includes a complete and accurate description of the substances used, and the method and techniques used by the researchers to gather data; should be thorough enough to allow another researcher to repeat the experiment and obtain similar results, but it does not have to be verbose
  - Results - narrates the findings without any further interpretation
  - Discussion - interpret the results, describe how variables may be related, and attempt to explain the observations; indispensable to conduct an extensive literature search to put the results in the context of previously published scientific research; should include proper citations
  - Conclusion - summarizes the importance of the experimental findings

Types of Life

❖ Taxonomy - naming and classifying of organisms

❖ Carl Linnaus - first modern taxonomist; came up with the binomial system

❖ Domains - broadest classification of life

➢ Eubacteria or Bacteria - single celled, no nucleus (prokaryotic)

➢ Archaea - single celled, no nucleus (prokaryotic); genetically closer to eukaryotes than eubacteria

➢ Eukarya - some single-single celled, but most are multicellular
- Can be divided into kingdoms
  - Animalia
  - Plantae

- Protista
  - Comprised of three main groups
  - Example: algaes, water and slime molds, amoebas
- Fungi

❖ Taxonomy Levels
- ➢ Domain (Dumb)
- ➢ Kingdom (Kings)
- ➢ Phylum (Play)
- ➢ Class (Cards)
- ➢ Order (On)
- ➢ Family (Fat)
- ➢ Genus (Green)
- ➢ Species (Stools)

  - Genus and species make up the scientific name of an organism
    - Written as: *Homo sapiens*
      - Italics
      - Genus is capitalized; species is not

Word Use

❖ Theory - extremely well-supported hypothesis
- ➢ Tested many, many times
- ➢ Never been refuted
- ➢ Takes thousands of scientists and many years to change a hypothesis into a theory

❖ Prove - testing of every possible variable and condition; impossible to do
- ➢ Theories can be refuted; they just haven't, yet

❖ Laws - a phenomenon that has no refuting evidence, but a complete scientific explanation is lackin g
- ➢ Super, super strong time-tested theory