Lecture Outline: Introductory Biological Concepts

I. What it Means to be an Organism (Living Thing)

A. Defining an organism is not easy; it's often easier to determine by observation.

B. Three Kinds of Things in the Universe

1. Living things
2. Non-living things (never been alive, e.g., a rock)
3. Dead things (were once alive)

C. **Six Major Characteristics of Living Things**

1. Organisms **respond to their environment** or surroundings.
    a. Even simple organisms like bacteria respond, though response might be death.
2. Organisms **reproduce**.
    a. Some non-living things (e.g., crystals) can reproduce, but they lack all six characteristics.
3. Organisms undergo **growth and development**.
    a. Growth: Increase in size.
        (1) Unicellular organisms: Cell grows larger before splitting.
        (2) Multicellular organisms: Grow by adding many cells (e.g., human starts as one zygote and becomes ~100 trillion cells).
    d. Development: Changes taking place during an individual's lifetime (e.g., zygote cells differentiating into liver cells, blood cells).
4. Organisms perform **energy processing** (Metabolism).
    a. **Life is metabolism** biologically.
    b. Metabolism: The sum of all chemical reactions occurring within an organism.

(1) Thousands of different reactions occur in a single cell.

d. **Cells are the functional unit of life** because metabolism occurs inside them.

e. Cells are like "little test tubes" isolated by a membrane.

5. Organisms exhibit **regulation**.

a. Control of chemical reactions (metabolism) by turning them on or off.

6. Organisms maintain a **high degree of order**.

a. This order is not free; it requires a lot of energy to maintain.

7. Organisms undergo **evolutionary adaptation**.

a. Adaptation: Changing for a better fit, increasing the fitness of an individual to its environment.

b. Fitness: How well an organism is suited to its living conditions.

c. Occurs over generations, increasing population fitness due to evolution.

d. Evolution: Simply means change.

e. **Natural selection**: The only mechanism of evolution that reliably increases adaptation.

(1) Darwin is famous for explaining this mechanism.

(2) Based on **genes** (physical things passed from parents to offspring that determine traits).

(3) Individuals with adaptive traits are more likely to survive and reproduce, passing on those genes.

(4) Maladaptive genes are less likely to be passed on.

(5) Results in a higher percentage of individuals with adaptive traits in the next generation.

D. **Bare Minimum Requirement for an Organism**: At least one cell.

1. **Viruses are not organisms** because they are not cells; they are just molecules and cannot do anything on their own.

II. Hierarchy of Biological Organization

A. A hierarchy is a nested arrangement where larger groups contain smaller

groups.

B. Levels (from smallest to largest) :

1. **Atoms**: Smallest level relevant to biology.
2. **Molecules**: Different kinds of atoms make up molecules.
3. **Organelles**: Different kinds of molecules make up organelles ("little organs within a cell," e.g., ribosomes, mitochondria).
4. **Cells**: Organelles make up cells.
   a. The level at which an organism begins.
   b. For unicellular organisms, cell and organism levels are the same.
5. **Tissues**: For multicellular organisms, different types of cells form tissues.
   a. Perform a specific function.
   b. Vertebrates have four main tissue types :
      (1) **Epithelial tissue** (forms linings, e.g., outer skin).
      (2) **Muscle tissue** (e.g., smooth muscle).
      (3) **Connective tissue** (e.g., skeletal tissue).
      (4) **Nervous tissue**.
6. **Organs**: Different types of tissues form organs for specialized functions (e.g., leaf, liver, kidney, skin).
7. **Organ Systems**: Different types of organs make up organ systems (e.g., reproductive system, digestive system).
8. **Organism**: An individual living thing.
9. **Population**: A group of individuals of the same species living in a specific area.
10. **Community**: A group of different populations (different species) living in the same place.
11. **Ecosystem**: The community plus all of the non-living things (e.g., water, rocks, air).
12. **Biosphere**: The hollow sphere around the Earth where life is found (from deep underground to high in the air).

III. Energy Flow and Material Cycling in Ecosystems

A. **Energy flows through** an ecosystem.

1. Enters as sunlight (source of all life on Earth).
2. Transformed (e.g., sunlight into chemical energy by photosynthesis) and transferred.
3. Eventually degraded to a lower form (heat) and exits the ecosystem.

B. **Materials (matter) more or less stay within** an ecosystem and are recycled.

1. Transformed and moved around (e.g., CO_2 and O_2 exchange).

IV. Form Follows Function in Biology

A. There is a tight fit between the form (structure) and function in biological organisms.

B. Organisms are not designed but arise gradually through **evolutionary adaptation**.

1. Evolution is a continuous refinement process, not a "start from scratch" design.
2. Random mutations occur, and those that work better are favored by natural selection.

C. Example: **Pneumatized (air-filled) bones in birds**.

1. Bird bones are more hollow than human bones.
2. A hollow tube is stronger for the same amount of material than a solid rod, allowing for a larger diameter.
3. This structure reduces weight while maintaining strength, essential for flight.

V. Dichotomy of Cell Types

A. **Prokaryotic Cells**

1. "Pro" means before; "karyo" means kernel/nucleus.
2. **Do not have a true nucleus** (not enclosed by its own membrane).
3. **Do not have any other membrane-bounded organelles**.
4. Only have a plasma membrane, making the entire interior a single compartment called **cytoplasm**.
5. **Much smaller** than eukaryotic cells (approx. 1/10th the size in each

dimension, 1/1000th the volume).

6. Were the original cells and remain the most successful in terms of numbers (e.g., bacteria).

B. **Eukaryotic Cells**

1. "Eu" means true; named for having a **true nucleus**.
2. Have a true nucleus (enclosed by its own membranes).
3. Possess **other membrane-bounded organelles** (e.g., mitochondrion, chloroplast, endoplasmic reticulum).
4. **Compartmentalized** within the cell (e.g., nucleus has nucleoplasm, distinct from cytoplasm).
5. **Note on Terminology**:
   a. "Membrane bounded" means enclosed by a membrane (e.g., nucleus).
   b. "Membrane bound" means connected to a membrane (e.g., membrane-bound proteins).

VI. Cell Theory

A. The major tenet is that **cells come only from pre-existing cells**.

1. The original cells were an exception, coming into existence without pre-existing cells.
2. Since then (for billions of years), all cells originate from existing cells.
3. Your body's trillions of cells are a continuation of this process back to the original successful cells.

B. Cell division usually involves a single cell splitting into two new cells.

1. This is how multicellular organisms grow from a zygote.
2. Unicellular organisms like bacteria reproduce asexually by splitting; the original cell ceases to exist.

C. Cell fusion can also occur (e.g., sperm and egg fusing to form a zygote).

VII. Macromolecules of Life

A. All organisms are made of four categories of vitally important organic (carbon-containing) macromolecules (large molecules).

B. These are polymers, built by hooking together smaller parts called

monomers.

C. Four Categories :

1. **Proteins**
    a. Polymer made of **amino acid** monomers.
    b. Also called **polypeptides** (due to peptide bonds between amino acids).
    c. **Directly give you your traits** (e.g., appearance, abilities).
2. **Polysaccharides**
    a. Large carbohydrates (e.g., starch, glycogen).
    b. Polymer made of **monosaccharide** (e.g., glucose) monomers.
3. **Lipids**
    a. Third category.
4. **Nucleic Acids**
    a. Polymer made of **nucleotide** monomers.
    b. Also called **polynucleotides**.
    c. Two major types:
        (1) **DNA** (Deoxyribonucleic Acid)
            1. Most famous molecule.
            2. Has the ability to make exact copies of itself, essential for cell division.
            3. Contains **codes called genes**.
            4. **Indirectly determines traits** by coding for RNA molecules.
            5. Forms a **double helix** structure (two polynucleotide strands).
            6. Information is stored in the sequence of A, T, C, G bases.
        (2) **RNA** (Ribonucleic Acid)
            1. Gets code from DNA and then codes how to build proteins.

VIII. Homeostasis

A. **Definition**: Maintenance of a relatively constant internal environment.
    1. **Necessary for life**; organisms die if not maintained.

B. Involves **variables** (biological conditions that can vary, e.g., temperature).

C. **Set point**: The desired or ideal value for a variable.

D. **Error**: The difference between the set point and the actual value.

E. Maintained by **feedback mechanisms**.

1. **Negative Feedback**

a. **The only homeostatic feedback mechanism**.

b. **Reduces the error**, bringing the variable closer to the set point.

c. Works regardless of whether the variable is too high or too low.

d. Example: If a final product (D) of a biochemical pathway builds up too much, D interferes with the first enzyme, shutting down its own production.

2. **Positive Feedback**

a. **Never leads to homeostasis**.

b. **Always makes the error worse**, driving the variable farther from the set point.

c. Vastly outnumbered by negative feedback mechanisms.

d. **Must be temporary**; negative feedback mechanisms eventually reestablish homeostasis.

e. Classic example: **Parturition (childbirth)**.

(1) Fetus's head stretches the cervix, sending signals to the brain.

(2) Brain releases oxytocin.

(3) Oxytocin causes stronger uterine contractions, stretching the cervix even more.

(4) This "vicious circle" intensifies until birth.

IX. Taxonomy (Classification of Organisms)

A. **Definition**: A hierarchical classification system for organisms based on similarities.

1. A "taxon" is a group.

B. Levels (from largest/most inclusive to smallest):

1. **Domains**: The largest and most inclusive groups, containing all organisms.
    a. **Bacteria** (includes prokaryotic organisms).
    b. **Archaea** (includes prokaryotic organisms, chemically distinct from Bacteria despite similar appearance).
    c. **Eukarya** (includes all eukaryotic organisms; e.g., humans belong here).
2. **Kingdoms** (many more than five now).
3. **Phyla**.
4. **Classes**.
5. **Orders**.
6. **Families**.
7. **Genus**.
8. **Species**.

C. **Shared ancestry** is the fundamental basis of taxonomy.

X. Evolution and Phylogeny

A. **Phylogeny (Phylogenetic Tree)**: A representation of evolutionary relationships.
    1. A hierarchical/nested arrangement.
    2. Lineages split where new species are created, often by natural selection.
    3. Groups are based on their common ancestors; more recent splits indicate closer relationships.
    4. The "tree of life" goes back to a single common ancestor (original successful cells).

XI. The Scientific Process (Scientific Method)

A. **Science is fundamentally based on evidence**.
    1. Distinct from faith, which is belief without evidence (and sometimes despite it).
    2. Scientific "facts" are not absolute truths but things that continuously withstand tests to prove them wrong.

3. Facts can change with new evidence (e.g., Newtonian mechanics superseded by quantum mechanics at microscopic levels).

B. Steps of the Scientific Method :

1. **Observation**: Noticing phenomena (e.g., a flashlight doesn't work).
2. **Question**: Inspired by observations (e.g., "Why doesn't it work?").
3. **Hypothesis**: An explanation, stated as if it is true, often using "because" (e.g., "The flashlight doesn't work **because** the battery is dead.").
4. **Prediction**: A logical consequence of the hypothesis, stated as something that **will** happen **if** the hypothesis is true (e.g., "**If** I put in a fresh battery, the light **will** work again.").
5. **Experiment**: A formal way to test whether predictions come true.
    a. **If prediction does NOT come true**: The hypothesis is **refuted** (assuming no experimental error).
    b. **If prediction DOES come true**: The hypothesis **could be correct**, but it is not definitively proven true (other factors might be involved).
        (1) Experiments are repeated to bolster hypotheses; repeated success leads to acceptance as a "fact".