Variation and Evolution

Chapter 24: VARIATION • ADAPTATION FOR SURVIVAL • EVOLUTION

Learning Objectives: Upon completion of this chapter, students should be able to:

- Define variation and describe its types within a population.
- Explain the applications of variation (e.g., crime detection, blood transfusion, paternity detection).
- Discuss adaptations for survival in various organisms (competition, types of adaptations: structural, physiological, behavioral).
- Describe adaptive coloration.
- Explain behavioral adaptations in individual animals and social animals (e.g., wolves and foxes, honeybees and termites).
- Discuss vertebrate societies.
- Outline the theory of evolution (Lamarck's theory, Darwin's theory).
- Present modern views of evolution (neo-Darwinism).
- Provide evidence for evolution, including examples of microevolution.
- Discuss classification and evolution.

24.1 Variation in Population

- **Definition of Variation:** Differences in characteristics or traits among individuals within the same species. These differences can be morphological, physiological, or behavioral.
- **Types of Variation:**
    1. **Morphological Variations:** Differences in physical appearance or structure.
        - *Examples:* Height, skin color, hair color, eye color, fingerprint patterns.
    2. **Physiological Variations:** Differences in the functioning of body systems or metabolic processes.
        - *Examples:* Blood groups, ability to digest certain foods, disease resistance, metabolic rate.
    3. **Behavioral Variations:** Differences in the way individuals act or respond to stimuli.
        - *Examples:* Temperament, learning ability, courtship rituals.
- **Sources of Variation:**
    - **Genetic Variation:** Caused by differences in genes. Arises from:
        - **Mutations:** Random changes in DNA sequence.
        - **Meiosis:** Independent assortment of chromosomes and crossing over during gamete formation.
        - **Sexual Reproduction:** Random fusion of gametes from two parents.

    - **Environmental Variation:** Caused by differences in environmental factors (e.g., nutrition, climate, upbringing).
- **Applications of Variation:**
    - **Crime Detection:** DNA fingerprinting, blood typing, and fingerprint analysis utilize individual variations for identification.
    - **Blood Transfusion:** Understanding blood groups (e.g., ABO system) is critical to ensure compatibility and prevent adverse reactions.
    - **Detection of Paternity:** DNA profiling is used to determine biological parentage based on unique genetic variations.

24.2 Adaptation for Survival

- **Adaptation:** A feature (structural, physiological, or behavioral) that allows an organism to survive and reproduce more successfully in its environment.
- **Competition:** Organisms often compete for limited resources (food, water, mates, space). Adaptations can give individuals a competitive advantage.
- **Types of Adaptations:**
    1. **Structural Adaptations:** Physical features of an organism's body.
        - *Examples:* Webbed feet for swimming, thick fur for cold climates, sharp claws for hunting, thorns on plants for defense.
    2. **Physiological Adaptations:** Internal body processes or functions.
        - *Examples:* Hibernation, estivation, venom production, camouflage in chameleons (rapid skin color change), concentrated urine in desert animals.
    3. **Behavioral Adaptations:** Actions or ways an organism behaves.
        - *Examples:* Migration, courtship rituals, burrowing, schooling in fish, hunting strategies.
- **Adaptive Coloration:**
    - **Definition:** Color patterns in organisms that help them survive or reproduce.
    - **Types:**
        - **Camouflage (Cryptic Coloration):** Blending with the environment to avoid detection by predators or prey.
            - *Examples:* A chameleon changing color, a stick insect resembling a twig, polar bears' white fur.
        - **Mimicry:** One species evolves to resemble another species for protection or to gain advantage.
            - **Batesian Mimicry:** A harmless species mimics a harmful or unpalatable one (e.g., hoverfly mimicking a wasp).
            - **Müllerian Mimicry:** Two or more unpalatable species resemble each other, reinforcing the warning signal to predators (e.g., different species of stinging wasps having similar black and yellow stripes).
        - **Warning Coloration (Aposematism):** Bright, conspicuous colors that warn predators of toxicity or danger (e.g., poison dart frogs, ladybugs).
- **Behavioral Adaptations of Individual Animals:**
    - **Solitary Hunters:** Adaptations for independent foraging and survival (e.g., foxes).
    - **Territoriality:** Defending an area for resources or mating.
    - **Courtship:** Rituals to attract mates.

- **Behavioral Adaptations of Social Animals:**
    - **Insect Societies (Honeybees and Termites):** Highly organized societies with division of labor, complex communication, and cooperative care of young.
        - *Honeybees:* Queen (reproduction), workers (foraging, hive maintenance, nursing), drones (mating). Waggle dance for communication.
        - *Termites:* King, queen, soldiers, workers. Build elaborate mounds, farm fungi.
    - **Vertebrate Societies (Wolves and Foxes):** Many vertebrates live in groups for protection, hunting, or raising young.
        - *Wolves:* Live in packs with a strict hierarchy, cooperative hunting, raising pups.
        - *Foxes:* Often solitary hunters but may form small family groups.
    - **Benefits of Social Behavior:** Increased safety from predators, enhanced foraging efficiency, cooperative breeding, disease resistance.

24.3 Evolution

- **Evolution:** The process by which species change over time through changes in the genetic makeup of populations from generation to generation. It explains the diversity of life on Earth.
- **Theories of Evolution:**
    1. **Lamarck's Theory (Theory of Inheritance of Acquired Characteristics):**
        - **Main Idea:** Proposed that organisms acquire characteristics during their lifetime through use or disuse, and these acquired traits are then passed on to their offspring.
        - *Example:* Giraffes stretched their necks to reach high leaves, and their offspring inherited longer necks.
        - **Critique:** This theory is largely disproven as acquired traits (e.g., a bodybuilder's muscles) are generally not heritable.
    2. **Darwin's Theory (Theory of Evolution by Natural Selection):**
        - **Main Idea:** Proposed that species evolve through a process called natural selection.
        - **Key Principles:**
            - **Overproduction:** Organisms produce more offspring than can survive.
            - **Variation:** Individuals within a population exhibit variations in their traits.
            - **Competition (Struggle for Existence):** Individuals compete for limited resources.
            - **Survival of the Fittest (Differential Survival and Reproduction):** Individuals with traits best suited to their environment are more likely to survive and reproduce.
            - **Inheritance:** These advantageous traits are passed on to their offspring, leading to a gradual change in the population over generations.
        - *Example:* Giraffes with naturally longer necks could reach more food, survived better, and passed on their long-neck genes. Over generations, the average neck length increased.

- **Modern View of Evolution (Neo-Darwinism / Modern Synthesis):**
    - **Integration:** Combines Darwin's theory of natural selection with Mendelian genetics and molecular biology.
    - **Key Additions:**
        - **Genes as Units of Heredity:** Genetic basis for variation.
        - **Mutations and Recombination:** Primary sources of new genetic variation.
        - **Population Genetics:** Study of genetic variation within populations.
        - **Mechanisms of Evolution:** Natural selection, genetic drift, gene flow, mutation, non-random mating.
    - **Emphasis:** Evolution is a change in allele frequencies in a population over generations.
- **Evidence for Evolution:**
    1. **Fossil Record:** Provides a historical sequence of life, showing transitional forms and changes in organisms over geological time.
    2. **Comparative Anatomy:** Similarities in skeletal structures (homologous structures, e.g., pentadactyl limb in vertebrates) suggest common ancestry. Vestigial structures (reduced or non-functional organs) also provide evidence.
    3. **Comparative Embryology:** Similarities in embryonic development among different species suggest common ancestry.
    4. **Molecular Biology (Biochemical Evidence):** Similarities in DNA sequences, proteins (e.g., cytochrome c), and genetic code across diverse organisms strongly support shared ancestry.
    5. **Biogeography:** The geographical distribution of species, showing that related species are often found in nearby but isolated regions.
    6. **Direct Observation of Evolution (Microevolution):** Observable small-scale evolutionary changes within a species.
        - *Examples:*
            - **Antibiotic Resistance in Bacteria:** Bacteria evolve resistance to antibiotics due to natural selection.
            - **Pesticide Resistance in Insects:** Insect populations develop resistance to pesticides.
            - **Industrial Melanism in Peppered Moths:** Shift in moth coloration in response to industrial pollution.
            - **Heavy Metal Tolerance in Plants:** Plants evolving tolerance to contaminated soils.
- **Classification and Evolution:**
    - **Taxonomy/Classification:** The science of naming, defining, and classifying groups of biological organisms on the basis of shared characteristics.
    - **Evolutionary Relationship:** Modern classification systems (e.g., phylogenetic trees) are based on evolutionary relationships, where organisms sharing more recent common ancestors are grouped together. This reflects the branching pattern of evolution.