UNIT 4: EVOLUTION

4.1 Evolution

4.1.1 Definition

Evolution is the gradual change in the genetic composition of a population over successive generations. This change can be driven by mechanisms such as meiosis, hybridization, natural selection, or mutation. As a result, populations may diverge from one another, potentially leading to the emergence of new species.

Theories of the Origin of Life

Understanding how life began involves complex and sometimes controversial theories. Here are some prominent theories:

1. **Special Creationism**
   - This theory posits that life on Earth was created by supernatural or divine forces. It often aligns with religious beliefs and suggests that a supreme being created life in its current form. The theory is not scientifically verifiable and differs from scientific explanations of life's origins.
2. **Spontaneous Generation (Abiogenesis)**
   - Historically, this theory proposed that life could spontaneously arise from non-living matter. Aristotle suggested that life, such as mice or maggots, could emerge from inanimate objects. Experiments by Francesco Redi in the 17th century disproved this idea for larger organisms by showing that maggots came from fly eggs, not spontaneous generation. Later, Louis Pasteur further disproved the theory by demonstrating that microorganisms only appeared in sterilized broth when exposed to air carrying these microorganisms.
3. **Eternity of Life**
   - This theory suggests that life has always existed and has no beginning or end. Proponents argue that life is an inherent property of the universe, existing perpetually.
4. **Cosmozoan Theory (Panspermia)**
   - This hypothesis proposes that life on Earth originated from extraterrestrial sources, such as meteorites carrying resistant spores. The idea was suggested by Richter and Helmholz, who speculated that life or its precursors came to Earth from space.
5. **Biochemical Origin**
   - Aleksandr Oparin and John Haldane proposed that life originated through biochemical reactions. They theorized that organic

molecules formed from simple substances under the influence of energy sources like ultraviolet light. Miller's experiments later supported this idea by demonstrating that simple organic compounds could be synthesized from basic elements.

4.1.2 Theories of Evolution

1. **Lamarckism**
   - Jean-Baptiste Lamarck proposed the theory of inheritance of acquired characteristics. He suggested that:
     - **New Needs**: Environmental changes lead to new needs, prompting organisms to adapt.
     - **Use and Disuse**: Organs used more become more developed, while unused ones diminish.
     - **Inheritance**: Acquired traits are passed to offspring, leading to gradual changes in populations.
     - **Speciation**: Accumulation of new traits over generations leads to the formation of new species.
2. **Darwinism (Natural Selection)**
   - Charles Darwin's theory of natural selection is based on:
     - **Geometric Increase**: Species produce more offspring than can survive.
     - **Struggle for Existence**: Competition for resources leads to a struggle for survival.
     - **Variation**: Individuals within a species exhibit variations.
     - **Natural Selection**: Individuals with advantageous traits are more likely to survive and reproduce.
     - **Origin of Species**: Over time, these advantageous traits become common, leading to the emergence of new species.
3. **Neo-Darwinism**
   - Incorporates genetics into Darwin's theory, emphasizing:
     - **Genetic Variability**: Variations in genes contribute to evolutionary changes.
     - **Natural Selection**: Selection acts on these genetic variations.
     - **Reproductive Isolation**: Separation of populations leads to the development of new species.

4.1.3 Evidence for Evolution

1. **Comparative Anatomy**
   - Examines anatomical similarities among organisms to determine evolutionary relationships. Structures that are similar in form but different in function are called homologous structures. For example,

the forelimbs of humans, whales, cats, and bats share a similar bone structure, indicating a common ancestor.

4.1.3.2 Comparative Embryology and Paleontology: Evidence of Evolution

Comparative Embryology

Definition: Comparative embryology is the study of embryos from different species to understand their developmental processes and similarities. It provides insights into evolutionary relationships by revealing common developmental stages among diverse organisms.

Key Concepts:

1. **Embryonic Development:**
   - During early embryonic development, vertebrates such as fish, birds, reptiles, and mammals exhibit similar structures, including gill slits and tails.
   - **Gill Slits:** In the embryonic stages of vertebrates, structures that resemble gill slits appear. Although these do not develop into functional gills in all species, their presence in various embryos suggests a common ancestry. In humans, these structures eventually become part of the ear and throat.
   - **Tail:** Vertebrate embryos have a tail during early development. In humans, this tail is reduced to the coccyx or tailbone.
2. **Significance:**
   - The similarities in early embryonic stages among different species support the theory of a common evolutionary origin. As development progresses, these similarities diverge into species-specific structures.

Paleontology

Definition: Paleontology is the scientific study of fossils—preserved remains or traces of ancient organisms. Fossils provide critical evidence of past life forms and their evolutionary development.

Types of Fossils:

1. **Body Fossils:**
   - These are the physical remains of organisms, such as bones, teeth, and shells.
   - Example: Fossilized dinosaur bones that provide insight into the anatomy and size of ancient creatures.
2. **Trace Fossils:**
   - These include evidence of an organism's activities, such as footprints, burrows, or coprolites (fossilized feces).

- Example: Dinosaur footprints that reveal information about behavior and movement patterns.

Dating Fossils:

1. **Stratigraphy:**
   - Fossils are often found in sedimentary rock layers. The principle of superposition states that in undisturbed layers, the oldest fossils are found in the lowest layers, and the youngest in the topmost layers.
   - Stratigraphy helps to establish a relative timeline for fossil deposits and evolutionary changes.
2. **Radiometric Dating:**
   - This technique uses the decay of radioactive isotopes to determine the absolute age of fossils.
   - **Carbon-14 Dating:** Effective for dating fossils up to about 50,000 years old by measuring the decay of carbon-14 into nitrogen-14.
   - **Potassium-Argon Dating:** Useful for dating older fossils (millions of years old) by measuring the decay of potassium-40 into argon-40.

4.1.5 Human Evolution: Understanding Our Origins

Introduction: Who Are We and Where Have We Come From?

The phrase "we evolved from monkeys" is a common misconception. In reality, humans did not evolve directly from monkeys or apes. Instead, humans and modern apes share a common ancestor. Over millions of years, this lineage has branched into various groups, including old world monkeys, new world monkeys, great apes, and the different species of early humans.

Key Features of Humans

1. **Large Brain:**
   - One of the key features distinguishing humans from other primates is our very large brain relative to body size. This large brain supports complex thinking, problem-solving, and advanced communication.
2. **Bipedalism:**
   - Humans are uniquely adapted to walk on two legs. This bipedalism is another major feature that sets us apart from other primates, such as apes, which primarily move on all fours.

The Evolutionary Tree

- **Branching Points:**
  - The evolutionary tree of primates (Figure 4.27) shows how different groups, including humans and great apes, evolved from common ancestors. For

example, humans and chimpanzees share a common ancestor that lived about 6 million years ago (Figure 4.28).

- **Evolution of Early Humans:**
    - The genus *Homo* includes all human species, with *Homo sapiens* being the only surviving species today. Early human species, such as *Australopithecus* and *Ardipithecus*, are crucial to understanding human evolution.

Important Fossils

1. **Lucy (Australopithecus afarensis):**
    - Discovered in 1974 in Ethiopia, Lucy is about 3.2 million years old. Her nearly complete skeleton shows that she was bipedal and provides evidence that bipedalism evolved before larger brain sizes. Lucy's brain was similar in size to that of a chimpanzee (Figure 4.31).
2. **Ardi (Ardipithecus ramidus):**
    - Found in Ethiopia in 1992 and dated to about 4.4 million years ago, Ardi is one of the oldest known hominids. She was also bipedal and adapted for both walking and climbing (Figure 4.32). Ardi's discovery supports the idea that the common ancestor of humans and chimpanzees did not resemble modern chimpanzees.

Brain Size and Evolution

- **Increasing Brain Size:**
    - Over time, the human brain has increased in size. Early hominids had smaller brains, while modern humans have significantly larger brains relative to body size (Figure 4.33). This increase in brain size supports advanced cognitive functions and tool use.

Human Migration and Evolution

- **Migration Out of Africa:**
    - *Homo sapiens* originated in Africa and migrated to other parts of the world (Figure 4.34). As humans encountered different environments, they adapted to varying conditions.
- **Adaptations:**
    - In colder climates, human populations evolved features to conserve heat, such as shorter, stockier bodies, more body fat, and increased hairiness.

Current Evolution

- **Ongoing Evolution:**
    - Humans continue to evolve, although modern evolution is less visible than in the past. Genetic variations and adaptations to different environments show how populations have evolved over time.

4.1.6 Mutation

Definition: A mutation is a change in the DNA sequence of an organism's genome. These changes can be minor, affecting only one or a few base pairs, or major, affecting entire chromosomes.

Types of Mutations:

1. **Point Mutations:**
   - **Substitution:** A single base in the DNA sequence is replaced by another. For example, in sickle-cell anemia, a substitution mutation changes the codon GAG to GTG, which alters the hemoglobin protein.
   - **Addition (Insertion):** An extra base is inserted into the DNA sequence. This shifts the reading frame, causing significant changes in the resulting protein.
   - **Deletion:** A base is removed from the DNA sequence. Like additions, deletions can lead to a frameshift, disrupting the normal function of the protein.

   Example: Consider a DNA sequence:

   - Original: "ATT" (codes for isoleucine)
   - Mutated: "ATG" (codes for methionine)

   This change can lead to different protein functions or diseases, depending on the gene affected.

2. **Chromosomal Mutations:** These involve changes in the structure or number of chromosomes and can include:
   - **Inversion:** A segment of the chromosome is reversed. If the inversion does not include the centromere, it is called paracentric; if it includes the centromere, it is pericentric.
   - **Deletion:** A portion of the chromosome is lost. This can result in the loss of crucial genetic material.
   - **Duplication:** A segment of the chromosome is duplicated, leading to extra genetic material.
   - **Translocation:** A segment of one chromosome breaks off and attaches to a different chromosome. This can lead to conditions like Down syndrome.

Example: Down syndrome often results from a translocation involving chromosome 21.

Causes of Mutations:

- **Spontaneous Mutations:** These occur naturally without external influence, often due to errors during DNA replication.
- **Induced Mutations:** Caused by external factors known as mutagens, such as:
    - Radiation (e.g., UV rays, X-rays)
    - Chemical substances (e.g., certain drugs or industrial chemicals)

Effects of Mutations:

- **Neutral:** Many mutations have no observable effect on the organism.
- **Beneficial:** Occasionally, mutations can provide advantages, such as antibiotic resistance.
- **Harmful:** Some mutations can lead to genetic disorders or diseases, such as cystic fibrosis or sickle-cell anemia.

4.1.7 Genetic Drift

Definition: Genetic drift is a change in the frequency of alleles in a population due to random sampling effects. Unlike natural selection, which is based on the survival and reproduction of the fittest, genetic drift occurs purely by chance.

How Genetic Drift Works:

- In a small population, allele frequencies can fluctuate significantly from one generation to the next due to random events.
- For example, if a small population of rabbits with different coat colors experiences a population bottleneck (a sharp reduction in numbers), the allele frequencies in the surviving population may differ greatly from the original population.

Types of Genetic Drift:

1. **Bottleneck Effect:**
    - Occurs when a population undergoes a drastic reduction in size due to an external event (e.g., a natural disaster). The surviving population has a different allele frequency compared to the original population, which may lead to a loss of genetic diversity.

Example: After a flood that reduces a population of rabbits from 100 to 10, the allele frequencies in the survivors may be very different from the original population.

2. **Founder Effect:**
    - Occurs when a small group of individuals breaks away from a larger population to establish a new colony. The new colony's allele frequencies may differ significantly from those of the original population.

    Example: If a small group of birds colonizes a new island, their genetic makeup might differ from the original population, leading to a new set of allele frequencies in the island population.

Impact of Genetic Drift:

- **In Small Populations:** Allele frequencies can change rapidly and dramatically due to drift, potentially leading to the fixation or loss of alleles.
- **In Large Populations:** Drift has less impact because the larger gene pool buffers against random changes in allele frequencies.

Hardy-Weinberg Equilibrium:

- **Definition:** A state in which allele frequencies in a population remain constant over generations, assuming no evolutionary influences like selection, mutation, or migration.
- **Conditions for Equilibrium:**
    - No natural selection
    - No mutations
    - Large population size
    - No migration
    - Random mating

Equations:

1. Allele frequencies: $p+q=1p + q = 1p+q=1$
2. Genotype frequencies: $p^2+2pq+q^2=1$

    Example: For a gene with two alleles, if the frequency of allele A is 0.6 (p) and allele a is 0.4 (q), the expected genotype frequencies can be calculated using the Hardy-Weinberg equations.

4.1.8 Gene Flow (Immigration and Emigration)

Definition: Gene flow, also known as migration, is the movement of individuals and the genetic material they carry from one population to another. This process includes various events such as pollen dispersal by wind or the movement of people between cities or countries. Gene flow is a key factor in introducing genetic variation into populations.

Types of Gene Flow:

1. **Immigration:**
   - **Definition:** Immigration occurs when individuals move into a new population from elsewhere. This introduces new alleles (gene versions) that were not previously present in the receiving population.
   - **Effect:** The introduction of these new alleles can increase the genetic diversity of the population and potentially alter allele frequencies.

   Example: If a population of plants that has only green-colored flowers is pollinated by individuals from a population with red-colored flowers, the alleles for red coloration are introduced into the green population.

2. **Emigration:**
   - **Definition:** Emigration is the process where individuals leave a population, taking their alleles with them. This movement reduces the number of individuals and genetic diversity in the original population.
   - **Effect:** The departure of these individuals can change the allele frequencies and reduce genetic variation in the original population.

   Example: If individuals with a specific allele for disease resistance leave a population, the remaining population may have a reduced level of resistance to that disease.

Importance of Gene Flow:

- **Genetic Variation:** By introducing or removing alleles, gene flow contributes to the genetic diversity of populations. This diversity is essential for adaptation and survival in changing environments.
- **Population Dynamics:** Gene flow helps maintain balanced allele frequencies across populations, preventing genetic isolation.

Gene Transfer:

- **Definition:** Gene transfer involves the movement of genetic material between different species. This process, particularly common in bacteria, can occur through horizontal gene transfer.

Horizontal Gene Transfer:

- **Definition:** This type of gene transfer involves the exchange of genetic material between organisms in a non-reproductive manner. It is prevalent in bacteria and can lead to the spread of traits such as antibiotic resistance.

4.1.9 Causes of Species Extinction

Overview: Species extinction is the permanent loss of a species from a particular habitat or the entire planet. Both anthropogenic (human-caused) factors and natural events contribute to species extinction.

Anthropogenic Causes:

1. **Habitat Destruction:** The destruction or alteration of natural habitats due to urbanization, deforestation, and agriculture reduces the living space available for species.
2. **Pollution:** Pollution of air, water, and soil can create hostile environments that species cannot survive in.
3. **Overexploitation:** Excessive hunting, fishing, and harvesting of species can lead to population declines and extinction.
4. **Climate Change:** Changes in climate can alter habitats and food sources, making it difficult for species to survive.

Natural Causes:

1. **Natural Disasters:** Events such as volcanic eruptions, earthquakes, and floods can destroy habitats and lead to the extinction of species.
2. **Climate Fluctuations:** Natural climate changes can create conditions that some species cannot adapt to quickly enough, leading to their extinction.
3. **Predation and Competition:** Changes in the ecosystem, such as the introduction of new predators or competitors, can negatively impact native species.

4.3 Renowned Evolutionists in Ethiopia

Overview: Ethiopia has produced notable evolutionists whose work has significantly contributed to our understanding of human evolution and the history of life on Earth.

Renowned Evolutionists:

1. **Dr. Yves Coppens:**
   - **Contribution:** A French paleoanthropologist, Dr. Coppens has conducted extensive research in Ethiopia, particularly in the discovery of "Lucy" (Australopithecus afarensis). His work has been crucial in understanding early human evolution and the development of bipedalism.
2. **Dr. Tim White:**
   - **Contribution:** An American paleoanthropologist, Dr. White's research has focused on early human fossils in Ethiopia, including the discovery of the "Ardi" (Ardipithecus ramidus). His findings have provided insights into the evolutionary lineage of humans and their ancestors.
3. **Dr. Berhane Asfaw:**
   - **Contribution:** An Ethiopian paleoanthropologist, Dr. Asfaw has played a key role in the discovery of early human fossils in Ethiopia. His research has helped to reconstruct the timeline of human evolution and understand the origins of modern humans.

Summary: The contributions of these renowned evolutionists have been instrumental in piecing together the puzzle of human evolution. Their discoveries in Ethiopia have provided valuable evidence of early human ancestors and have advanced our knowledge of how humans evolved over millions of years.