General Biology: Descent With Modification

AI-Generated Study Guide

(Based on lectures delivered by Dr. Ty C.M. Hoffman)

I. Introduction to Evolution and Historical Overview
Evolution as a Core Concept Evolution, fundamentally, means change. It is an important biological concept that explains the variety of organisms alive now and those that have lived previously. Evolution leads to **speciation**, which is the creation of new species.
Unity and Variety of Life There is an enormous variety of organisms, from plants and caterpillars to bacteria and humans. Despite this huge variety, there is also a **unity of all living things**. All organisms share important characteristics (like using energy and having a high degree of order) because they all descended from the same original successful lineage of cells that started billions of years ago. All organisms are part of one family tree with a single common ancestor at its base.
Early Views on Species For most of human history, the majority opinion held that species were created during a single event and did not change (creationism). Evolutionary thinkers, who believed species evolve, were a drastic minority.
Cuvier and Paleontology The science of paleontology is the study of **fossils**, which are mineralized remains of dead organisms. Fossils are often found in **strata** (layers) of soil, particularly underwater. Since the lowest strata formed first, different layers represent different ages. Paleontologists, such as **Cuvier** (the father of paleontology), noticed that different strata contain different collections of fossils. This observation suggested that different sets of species existed at different times, which conflicts with the creationist notion that all species were present originally. Cuvier accepted that species could go **extinct** (fossils disappearing in newer strata) but struggled to reconcile the appearance of new fossils in newer strata and remained a creationist.
Lamarck's Hypothesis Darwin was not the first to propose evolution; rather, he was the first to explain *how* it happens. **Lamarck** was the first historical figure recognized for being a scientific evolutionary thinker because he offered a hypothesis (an explanation) for how evolution occurs.
• **Lamarck's Idea:** Organisms gain traits throughout their lifetime due to experience, and these acquired traits are passed on to their offspring.
• **Example:** Giraffes developed long necks because ancestors stretched their necks during their lifetimes to reach higher leaves, and this longer neck trait was then inherited by the next generation.

• **Correction:** This hypothesis is incorrect; traits acquired during a lifetime (such as muscle bulk from weight lifting or the trained shape of a bonsai tree) are not genetically passed on to offspring.

Science vs. Faith Science requires belief based on evidence, and scientists are obligated to change their beliefs if new evidence contradicts what they previously held. Faith, conversely, is belief without evidence, sometimes despite evidence to the contrary.

II. Darwin and the Development of Natural Selection

The Voyage of the Beagle Darwin served as the naturalist aboard the HMS **Beagle** during its years-long voyage in the 1830s. The main purpose of the voyage was early mapmaking, specifically to chart the shape of South America, requiring many stops along the coast. Darwin cataloged wildlife at each stop.

Influence of Geology Darwin read the work of geologists **Lyell and Hutton** during the voyage. They proposed the radical notion that the physical features of the Earth (like mountains and valleys) are not permanent but gradually come into existence through normal, slow physical processes (like erosion). This suggested the Earth must be far older than the few thousand years most people believed. Darwin concluded the Earth was millions of years old, though the actual age is about 4.5 billion years.

Shift in Thinking Darwin started his voyage as a creationist but gradually transitioned to an evolutionary thinker due to the experiences he gained (such as witnessing an earthquake) and the geographical and biological variety he observed, particularly the distinct wildlife found in certain places (like the **Galapagos Islands**) and not others. The Galapagos Islands were visited late in the voyage, but they were important because they featured organisms drastically different from those in England.

III. Natural Selection: The Mechanism of Evolution

Darwin's Fame and Book Darwin is famous for his explanation of *how* evolution occurs: **Natural Selection**. His book, *On the Origin of Species by Means of Natural Selection*, details this mechanism. Natural selection is the most important way evolution happens and is one of three ways evolution occurs.

Core Idea of Natural Selection Natural selection is the process by which a population, across successive generations, becomes better adapted to its surroundings. Individuals with beneficial traits are more likely to survive and reproduce, passing those traits on.

The Role of Genes and Proteins Traits are passed from parent to offspring via **DNA** (genes). **Proteins** are what directly give an organism its traits (such as metabolism or appearance). DNA holds the instructions (via RNA) for assembling the proteins. Since DNA, not proteins, is passed on through reproduction, traits must be heritable to evolve.

Darwin's Observations and Inferences Natural selection rests on two major observations made by Darwin:

1. **Variation:** Individuals in a population (a group of the same species living together) vary in their heritable characteristics. They are not all identical, and this variation results in different levels of **fitness** (how well adapted an individual is to its living conditions).
2. **Overproduction:** Species produce far more offspring than the environment can support or that can possibly survive.

These observations led to two key inferences:
1. **Survival of the Fittest:** Individuals that are well-suited (adapted/high fitness) tend to leave more offspring than those that are less fit because they survive longer and reproduce more successfully.
2. **Accumulation of Favorable Traits:** Over time, the heritable traits that lead to higher fitness accumulate and become more represented in the population, causing the population as a whole to become better adapted.

Examples of Natural Selection

• **Camouflage:** Organisms that are well camouflaged survive because those with colors that stood out were eaten, preventing their genes from being passed on.
• **Galapagos Finches:** On different Galapagos islands, Darwin observed finches with highly related but different species, primarily distinguished by their **bill shape**. The beak shapes evolved to match the available food source (e.g., narrow/pointed bills for insect eaters, broad/tough bills for seed crackers).
• **Soapberry Bugs:** When golden rain trees (with thinner rinds) were introduced to Florida, the average proboscis (nose) length of soapberry bugs decreased because shorter noses are sturdier, offering an advantage over fragile long noses, provided they were still long enough to pierce the thin rind.
• **Antibiotic Resistance:** When antibiotics (first mass-produced around the 1940s) are used, they change the bacterial environment. Bacteria with random genetic variations that allow them to resist the antibiotic survive, while susceptible ones die. The resistant bacteria reproduce, leading to a new generation that is immune to the drug.

Artificial Selection Artificial selection operates exactly like natural selection, except that humans are the ones doing the selecting. Humans favor certain traits (regardless of their survival advantage in nature) and allow individuals with those traits to survive and reproduce. This process has led to the domestication of many species, such as the development of kale, Brussels sprouts, cabbage, broccoli, and kohlrabi from a common wild mustard ancestor.

Alfred Russel Wallace Wallace independently developed the same mechanism of natural selection as Darwin. Although Wallace was ready to publish sooner, he respected Darwin and ceded the credit, which is why Darwin is more famously associated with the idea today.

IV. Evolutionary Relationships and Evidence

Phylogenetic Trees Darwin's secret diaries contained the first known drawing of a **phylogenetic tree**, which is a treelike representation showing how species are related and how they come into existence.
• The base of the tree represents the ancestor.
• **Branch points** (nodes) show where one lineage diverges into two new species.
• Dead ends indicate species that went **extinct**.
• Two lineages that spring from a recent common node are closely related. All life traces back to one common ancestor.

Homology Homologous structures are found in different species and are similar in composition or structure because they arose from a **common ancestor**.

• **Example 1:** The forelimbs of mammals (human, cat, whale, bat) are used for vastly different functions (throwing, running, swimming, flying) but contain the same number and types of bones, inherited from a common ancestor.
• **Example 2:** A post-anal tail is visible in chick and human embryos, demonstrating homology in early development stemming from a common vertebrate ancestor.
Analogy and Convergent Evolution Analogous structures are structures in two different species that are similar in appearance or function but are *not* due to common ancestry.
• **Example:** The gliding flaps of a sugar glider (a marsupial) and a flying squirrel (a mammal) are almost identical but evolved independently in both lineages. This independent evolution of similar traits is called **convergent evolution**. It occurs because the trait offers the same selective advantage in similar environments, causing natural selection to favor it in both lineages independently.
The Importance of Fossils Fossils continue to be essential evidence for evolution, filling in the gaps (missing links) in our knowledge and helping to map out phylogenetic trees. For example, the discovery that both marine-dwelling mammals (citations/whales) and even-toed ungulates (pigs) share an ankle bone structure with two bumps suggests they are ancestrally more related to each other than to other mammals. Fossils provide crucial links showing how drastically different land-dwelling and marine species evolved.