Chapter 21
Adaptation & Speciation

Biology 3201

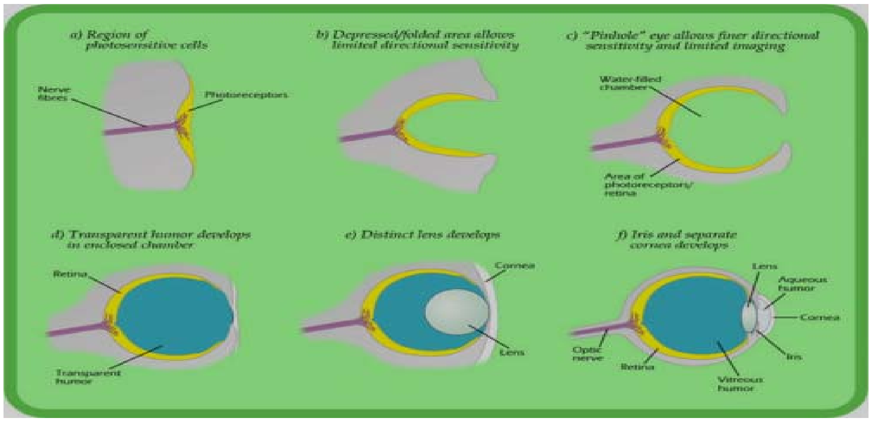
21.1
Adaptation

- Any trait that enhances an organisms fitness or increases it's chance of survival and probability of successful reproduction is called an **adaptation**.
- Adaptations arise from natural selection.
- Over a period of time, ***individual organisms*** become adapted to their immediate environment.
- Only those organisms that possess characteristics that enable them to survive are able to pass on these favorable adaptations to their offspring.

Evolution of Complex Adaptations

- Adaptations do not arise all at once. They evolve over time as a result of a series of small adaptive changes.
- An example of a complex adaptation is the evolution of the human eye from the eyes of lesser organisms. This complex form of the eye is a result of many years of developing in stages from a more simple eye.
- As the structural changes giving rise to more complex organs benefit organisms, these changes are then passed on to offspring

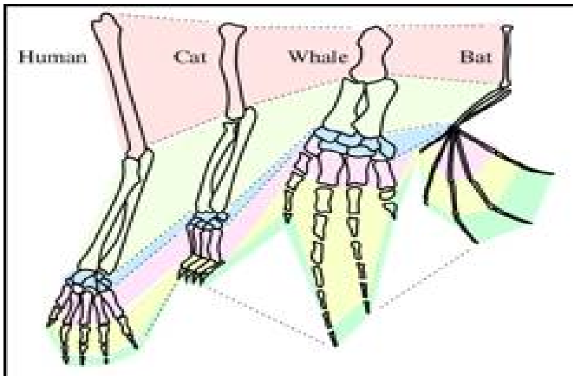
Evolution of the Human Eye



Changing Function of Adaptations

- Sometimes an adaptation which evolved for one function can have another use. This is called **exaptation**.
- **Example** Evolution of limbs and digits of terrestrial vertebrates.
  - Used by aquatic organisms to move around in their environment. These limbs were used to crawl, run, etc as the organisms moved onto land to live
  - Thus, what evolved as an adaptation for an aquatic existence eventually became useful for living on land.

Limb Evolution Illustrated



The limb bones of different mammals are clearly equivalent. We can "morph" one into another just by changing the sizes and proportions. Genetic mutations altering the gene-control proteins, the diffusible molecules, and the patterns of expression of the limb-development genes, are sufficient to make these changes in living things. One mutation occurs at a time, and the internal control mechanisms of embryo development integrate the body parts to form a working whole.

Types of Adaptations

- Three types of adaptations:

  1. Structural
  2. Physiological
  3. Behavioral

Structural Adaptations

- **Adaptations that affect the appearance, shape, or arrangement of particular physical features. Includes adaptations such as mimicry and cryptic coloration.**

- **<u>Mimicry</u>** allows one species to resemble another species or part of another species.
  - Ex: Syrphid Fly will often mimic a more harmful yellow-jacket wasp.

- **<u>Cryptic colouration (camouflage)</u>** allows prey to blend in with their environment. This is accomplished when an organism camouflages itself by shape or color.
  - Ex: A sea dragon resembling seaweed.

Mimicry and Cryptic Colouration

Physiological Adaptations

- Adaptations which are associated with particular functions in organisms.
- Examples:
  1. Enzymes needed for blood clotting.
  2. Proteins used for spider silk. →
  3. Chemical defenses of plants.
  4. The ability of certain bacteria to withstand

Behavioural Adaptations

- Adaptations which are associated with how organisms respond to their environment.
- Examples:
  1. Migration patterns.
  2. Courtship patterns.
  3. Foraging behaviors.
  4. Plant responses to light and gravity.

- These types of adaptation do not exist in isolation, they depend on one another.

Is Evolution Perfection??

- Although many people think that adaptation and natural selection tend to make an organism perfect, **this is not the case**.
- Adaptation and natural selection simply change an organ or organism in a way that improves the organisms chance of survival in its environment.

Why Evolution Is Not Perfect

1. Natural selection only edits variations that already exist in a population. Evolution has to make do with what is created; the new designs, although better than the old ones, are less than perfect.
2. Adaptations are often compromises of what an organism is ideally aiming to achieve.
3. Not all evolution is adaptive. Sometimes chance events can change the composition of a populations gene pool. Those organisms which survive a chance events do so randomly, not because they were better than other organisms.

- **The individuals that do survive are able to reproduce and pass on their genes to their offspring. Over time the population will change, hopefully for the better**.

21.2
How Species Form

- A species is a population that can interbreed and produce viable, fertile offspring.
- There are two pathways which lead to the formation of a new species
  1. **Transformation**
  2. **Divergence**
- **Transformation** is a process by which one species is transformed into another species as the result of accumulated changes over long periods of time.
- **Divergence** is the process in which one or more species arise from a parent species, but the parent species continues to exist.
- The formation of species, a process called **speciation**, is a continuous process.

Biological Barriers to Speciation

- In order for species to remain distinct they must remain reproductively isolated.
- Species which are reproductively isolated from each other are unable to interbreed, thus restricting the mixing of genetic information between species.
- Species are often isolated by particular types of barriers. Two main types of barriers include:
  1. Geographical barriers
  2. Biological barriers

Geographical Barriers

- Keep populations physically isolated from each other. Thus, the organisms from the populations are unable to interbreed with each other.
- Examples include:
- Rivers, mountains, oceans

Biological Barriers

- Keep species reproductively isolated from each other.
- Reproductive barriers fall into two broad categories:
  1. Pre-zygotic barriers
  2. Post-zygotic barriers

Pre-zygotic Barriers

- Pre-fertilization barriers, either impede mating between species or prevent fertilization of the egg if individuals from different species attempt to mate.
- Types of pre-zygotic barriers include:
  - Behavioural isolation – ex. Different mating calls
  - Habitat isolation – ex. Occupying different parts of a region
  - Temporal isolation – ex. Different mating seasons
  - Mechanical isolation – ex. Anatomical differences
  - Gametic isolation – ex. Egg and sperm not compatible

Post-zygotic barriers

- Post-fertilization barriers, prevent hybrid zygotes from developing into normal, fertile individuals.

- Types of post-zygotic barriers include:
  - Hybrid inviability – hybrid dies
  - Hybrid sterility – hybrid is unable to reproduce
  - Hybrid breakdown

Alternative Concepts of Species

- Historically, organisms have been classified into separate species based on measurable physical features, this is called the **morphological species concept**.

- Regardless of how species are defined, it is important to remember that speciation requires populations of organisms to remain genetically isolated from other species.

21.3
Patterns of Evolution

- Speciation is the process by which a single species becomes two or more species.

- There are two modes of speciation:
  1. Sympatric Speciation
  2. Allopatric Speciation

Sympatric Speciation I

- Occurs when populations become reproductively isolated from each other.

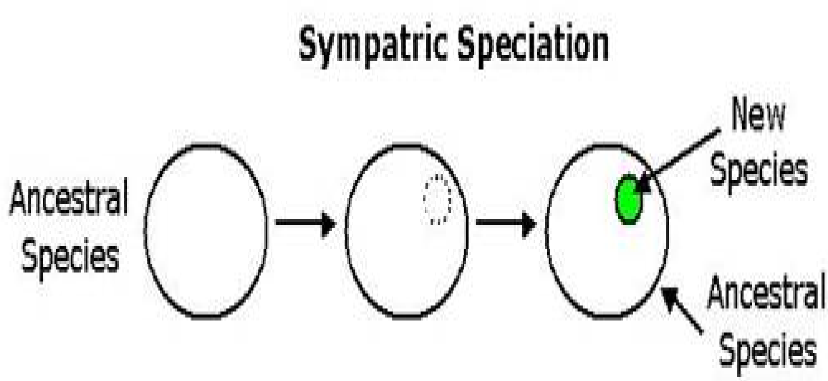
- This type of speciation is more common in plants than in animals.

- Two common ways in which sympatric speciation can occur are polyploidy and

Sympatric Speciation II

- Errors in cell division can result in cells which have extra sets of chromosomes, a condition called **polyploidy**. This is more common in plants than in animals, in fact, polyploidy is quite rare in animals. Any mating which occurs between a polyploid organism and a normal organism will result in sterile offspring. Since the new organisms are sterile and cannot successfully reproduce, they are considered to be a new species.

- Sometimes two species can **interbreed** to produce a sterile offspring. Eventually, the sterile hybrid organism can be transformed into a fertile species. This as well occurs most

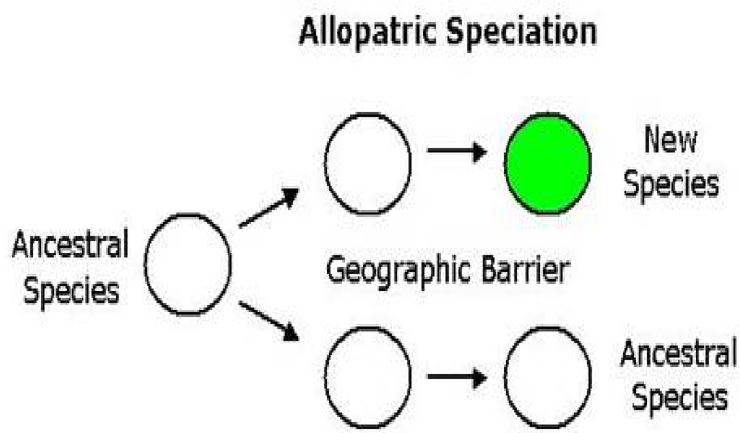


Allopatric Speciation I

- Occurs when a population of organisms is split into two or more isolated groups by a geographical barrier.
- Over time, the gene pools of the two populations become so different that the two groups are unable to interbreed even if they are brought back together.
- The geographical isolation of a population does not have to be maintained forever for a species to be transformed, however, it must be maintained long enough for the populations to become reproductively incompatible before they are rejoined.

Allopatric Speciation II

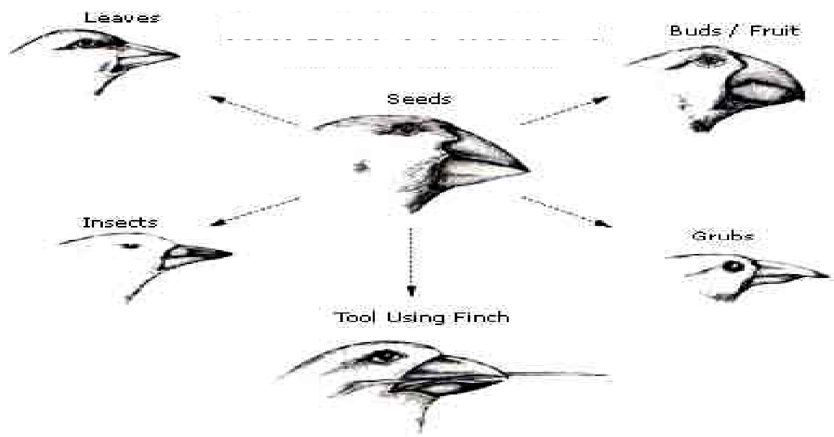
- The degree to which geographic isolation affects a population of organisms depends on the organisms ability to disperse in its environment.
- Generally, small populations that become isolated from the parent population are more likely to change enough to become a new species, especially those organisms which exist at the periphery of a parent population.
- Factors such as genetic drift, mutations, and natural selection will increase the chance of an isolated population forming into a new species.
- The finches of the Galapagos islands are an example of speciation.



Adaptive Radiation I

- The diversification of a common ancestral species into a variety of species is called **adaptive radiation**.
- Darwin's finches are a good example of adaptive radiation.
- The first inhabited a single island. Eventually, the finches began to inhabit other neighboring islands. These islands had slightly different environments from each other and the selective pressures of the different environments resulted in different feeding habits and morphological differences for the finches.

Darwin's Finches & Adaptive Radiation



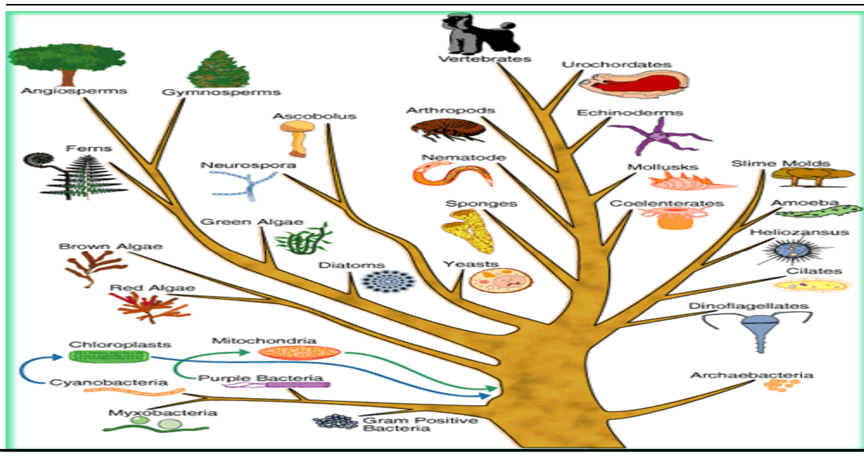
Adaptive Radiation II

- Islands are a great environment for studying speciation because they give organisms the opportunity to change in response to new environmental conditions.
- Each island has different physical characteristics which help the process of adaptive radiation to occur.
- Adaptive radiation can also occur after mass extinction events in the Earth's history.

Divergent & Convergent Evolution

- **Divergent evolution**
  - Pattern of evolution in which species that were once similar diverge or become increasingly different from each other
  - Divergent evolution occurs when populations change as they adapt to different environmental conditions.
- **Convergent evolution**
  - Two unrelated species develop similar traits after developing independently in similar environmental conditions.

Phylogenetic Tree shows Divergence



Co-evolution

- Co-evolution occurs when organisms are linked with other organisms and gradually evolve together.Predators and prey, pollinators and plants, and parasites and hosts all influence each others evolution.
- Many plants rely on insects and birds to spread their pollen, this causes the plants to change themselves in ways that will entice these organisms to come to the plants.
- Examples:
  - The constant threat of predators can cause prey species to evolve faster legs, stronger shells, better camouflage, more effective poisons, etc.
  - The struggle between parasites and hosts is another example of co-evolution. Parasites such as bacteria, protozoa, fungi, algae, plants and animals consume their host in order to survive. Thus, the hosts must develop ways to defend themselves against the predator.

Co-evolution Examples

Pace of Evolution

- Two models attempt to explain the rate of evolutionary change
  - **Gradualism**
    - change occurs within a particular lineage at a slow and steady pace. According to this model, big changes occur from the accumulation of many small changes.
  - **Punctuated equilibrium**
    - evolutionary change consists of long periods of stasis (equilibrium) or no change interrupted by periods of rapid divergence or change.

21.4
Origins of Life on Earth

- Scientists have identified and classified around 1,400,000 species of life on Earth.
- It is estimated that there may be as many as 30,000,000 species of organisms on this planet.
- Because of this large variety of life, scientists are very interested in how life began on our planet in the first place.
- Science has proposed several theories and hypotheses concerning the origins of life on Earth. These are based on available evidence.

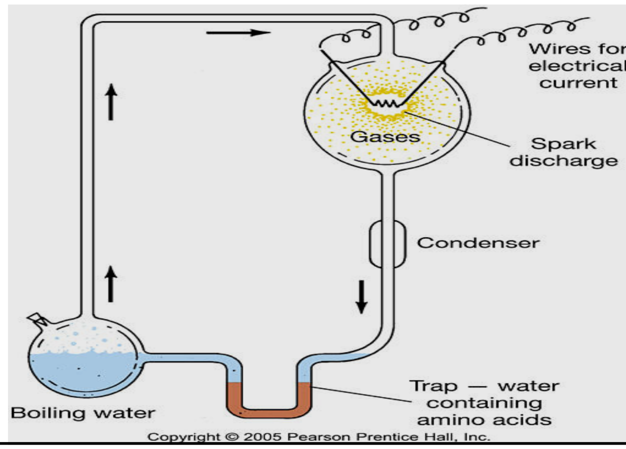
Chemical Evolution

- The most common scientific theory on the origin of life.
- Aleksander Oparin and John Haldane hypothesized that organic compounds, the building blocks of life could form spontaneously from the simple inorganic compounds present on Earth.
- **Oparin-Haldane theory**.
  - Early Earth had a reducing atmosphere which contained little or no oxygen, hydrogen, ammonia, methane gas, and water vapor.
  - These gases condensed to form pools on the Earth's surface which were called the **primordial soup**. Energy sources such as lightning and ultraviolet radiation caused the inorganic compounds in this "soup" to combine and form organic compounds. These organic compounds combined with each other and evolved over time to create an early form of life. From this early form of life, a common ancestor, all life evolved.

Stanley Miller's Experiment

- Stanley Miller performed an experiment to test the Oparin-Haldane theory. Miller created a system, (Fig. 21.21, P. 727) that contained an atmosphere similar to that of the early Earth.
- It contained methane, ammonia, hydrogen, and water vapor. It also contained a source of energy in the form of electrical sparks to simulate lightning. After a week, Miller collected samples from the system which contained several organic compounds such as amino acids. Since organic compounds such as amino acids are the building blocks of living things, this showed that life could indeed have began in this manner.
- Further experiments such as Miller's have shown that organic molecules such as amino acids, nucleotides, and sugars (carbohydrates) can develop under these types of conditions.

The Set-up



Molecules to Life?? How??

- Three ways that this could have occurred:
  1. Amino acids might have polymerized spontaneously to form a special kind of self- replicating protein.
  2. RNA might have self-replicated on its own.
  3. Both proteins and RNA might have developed at the same time inside some form of clay structure.

- The above ways resulted in some form of **protocell**. This protocell continued to evolve by the process of natural selection, becoming the first living cell from which all life developed

The Other Explanations

- **The Panspermia Theory**
  - Life originated elsewhere in the universe and migrated to our planet. This migration could have been performed by intelligent beings (aliens) or may have occurred by chance (meteorites)

- **The GAIA Theory**
  - proposed by Dr. James Lovelock, views the Earth as a living superorganism which is called Gaia. The Earth (Gaia) is maintained and regulated by the life which exists on its surface. It is the Earth's systems that keep themselves in balance by regulating the atmosphere and temperature of the planet. Life on the planet originated

More Explanations

- **The Intelligent Design Theory**
  - This theory suggests that life and the mechanisms which support it are too complex to have evolved by chance. Therefore, life must have been directed by some form of supernatural intelligence (eg. GOD).

Early Forms of Life

- Scientists believe that the first cell was a simple prokaryotic bacteria with no nucleus or organelles.
- The **heterotroph hypothesis** suggests that these first organisms were heterotrophs which could not make their own food. Therefore, they must have fed on the organic compounds in the primordial soup.
- Eventually most of the organic compounds became used up and therefore the bacteria which existed reverted to eating each other. However, as food became scarce, some of the bacteria began to manufacture their own food through the process of photosynthesis.

The First Bacteria

- The photosynthetic bacteria oxygen was produced as a waste material and began to accumulate in the atmosphere. The atmosphere eventually became an **oxidizing atmosphere**. As oxygen accumulated in the atmosphere, the first aerobic (oxygen-breathing) bacteria developed.
- The aerobic and anaerobic bacteria evolved by natural selection and eventually the first eukaryotic cells were formed, these cells contained a nucleus. Over billions of years of evolution, these cells became more advanced by forming internal organelles such as mitochondria, chloroplast. which performed specific jobs inside the organism.

Symbiogenesis

- Developed by the biologist Lynn Margulis
- Explains the development of eukaryotic cells.
- Development of a eukaryotic cell and its organelles could be a result of a process called **symbiogenesis**, the creation of new species through symbiosis.
- This theory is called **Serial Endosymbiosis Theory** (SET).

Serial Endosymbiosis

- Millions of years ago an anaerobic bacteria swallowed an aerobic bacteria. These bacteria then entered into a form of mutualistic relationship.
- The host anaerobic bacteria gained the benefit of being able to breathe oxygen while the guest aerobic bacteria obtained protection from a harsh environment.
- Over time, the guest bacteria developed into a mitochondria. Other swallowed bacteria developed into chloroplasts. As more organelles developed inside the bacteria, eventually a eukaryotic cell was formed

Endosymbiotic Hypothesis for the Origin of Mitochondria and Chloroplasts