

Supplementary Notes: (PJ Shlachtman, Miller book) Evolution and Biodiversity: Origins, Niches and Adaptation

Why should we care about the alligators?

The alligator:

- North America's largest reptile
- it has no natural predators (except man)

Ecological role of the alligator

- dig depressions that collect fresh water (serving as refuges for aquatic life and supplies fresh water and food for many animals).
- Alligator nesting mounds provide nesting and feeding sites for species of herons and egrets.

Keystone species: its important ecological roles in helping to maintain the structure function and sustainability of its natural ecosystem.

The subject of this chapter is understanding evolution, the evolutionary origins of biodiversity, and the ecological roles of species.

Major Types of Life on Earth:

The Earth's biodiversity: the many types of life on this planet.

All forms of life consist of one or more cells. Each cell consists of two types of components:

1. **genes** - containing DNA - determines the **form** the cell will take and its **functions**
2. **other parts** which protect the cell and carry out instructions encoded in the cell's DNA.

Based on cell structure cells are classified as either:

- **eukaryotic** - cells surrounded by a membrane and have a nucleus and other internal parts
- **prokaryotic** - surrounded by a membrane - no distinct nucleus or other internal parts enclosed by membranes. **Bacteria** are a good example of this.

Taxonomic Classification (classification of organisms based on common characteristics)

Kingdom

Monera - microorganisms; (bacteria and cyanobacteria) single-celled, prokaryotic; decomposers; a few bacteria cause disease in humans (*Streptococcus*; *Salmonella*); billions of beneficial bacteria in the human body (aid in digestion; crowd out disease-causing bacteria)

Protists (Protista) - microorganisms; single-celled, eukaryotic; (diatoms; dinoflagellates, amoebas, golden brown and yellow-green algae, and protozoans); some protists cause human disease (malaria, sleeping sickness, Chagas' disease).

Fungi - microorganisms; many-celled, eukaryotic; (mushrooms, molds, mildews, yeasts); many are decomposers; some fungi kill plants and cause huge losses of crops and valuable trees.

Plants (plantae) - many-celled, eukaryotic; (red, brown and green algae; mosses, ferns, conifers, and flowering plants).

Annuals: complete life cycles in one growing season.

Perennials: can live for more than two years (roses, grapes, elms, magnolias).

Animals (animalia) - many celled, eukaryotic

Invertebrates - no backbones (sponges, jellyfish, worms, arthropods (insects), shrimp, spiders), mollusks (snails, clams, octopuses) and echinoderms (sea urchins and sea stars).

Vertebrates - animals with backbones and a brain protected by skull bones. fishes (sharks and tuna), amphibians (frogs and salamanders), reptiles (crocodiles and snakes), birds (eagles and robins) and mammals (bats, elephants, whales and humans).

Nomenclature (how species are named):

Each kingdom is subdivided into subcategories based on anatomical, physiological and behavioral characteristics:

Domain

Kingdom

Phylum (pl. Phyla)

Subphylum

Class

Order

Family

Genus (pl. genera)

Species

Subspecies

Scientific nomenclature: consists of two words (italicized):

Word 1: genus, capitalized: **Word 2:** species

e.g., robin: *Turdus migratorius*

grizzly bear: *Ursus horribilis*

Species - a distinct type of organism

- If members of two populations that reproduce sexually have the potential to interbreed with one another and produce live fertile offspring, they belong to the same species. i.e., each sexually reproducing species is *reproductively isolated from every other species in nature.*
- Species that do not fit this definition (because of limitations) must be identified by their appearance, biochemical traits and DNA sequences.

ORIGINS OF LIFE

Life on earth evolved in two (2) phases:

1. **chemical evolution** of the organic molecules, biopolymers, and systems of chemical reactions needed to form the first protocells (lasted approx. 1 billion years).
2. **biological evolution** of single-celled organisms (first prokaryotes and then eukaryotes) and then multi-cellular organisms (approx. 3.7-3.8 billion years).

Chemical Evolution

- 4.6-4.7 billion years ago: cosmic dust cloud condensed to form Earth (heated from meteorite impact and radioactive decay (interior)). As the Earth cooled, a hardened crust formed (no atmosphere and no water).
- 4.4 billion years ago - atmosphere was formed (initially CO₂, N₂, H₂O, with trace amounts of CH₄, NH₃, H₂S and HCl). **No oxygen (O₂)** since it is very reactive chemically.
- Energy from lightning, heat from volcanoes and UV light and other solar radiation was available. Russian biochemist Alexander Oparin proposed that the inorganic chemicals in

the primitive atmosphere along with these energy sources lead to the formation of the first organic molecules. Such compounds have been formed in the laboratory.

- Other hypotheses include organic molecules coming from meteors/comets, or forming near hydrothermal vents (black smokers).
- Organic molecules then accumulated and underwent countless reactions in warm shallow waters. Different combinations of molecules may have formed membrane-bound protocells.

Biological Evolution

- Protocells evolved into single-celled prokaryotes having the properties we describe as life.
- These single celled bacteria multiplied and underwent mutations resulting in new prokaryotic cells. Since there was no ozone layer, life could not have existed on land (intense UV from Sun).
- **2.3-2.5 billion years ago**, evolution of photosynthetic prokaryotes: cyanobacteria removed CO₂ from water and combined it with water to form carbohydrates - releasing oxygen into the atmosphere. O₂ began increasing in the atmosphere about 2.0-2.1 billion years ago.
- The Oxygen Revolution lasted about 500 million years. More complex organisms formed.
- **1.2 billion years ago**: the first eukaryotic cells formed. Since they reproduce sexually, they produced offspring with different genetic characteristics. These changes eventually produced an amazing variety of protists, fungi, and plants and animals.
- As oxygen accumulated in the atmosphere, it reacted with solar radiation to form ozone (lower stratosphere)
- **400-500 million years ago**: first plants on land. Then mammals, then man.

How do we know what organisms lived in the past?

- Fossils - however, only about 1% of species have been found.
- Chemical and radioactive dating of fossils.

EVOLUTION AND ADAPTATION

Evolution: the change in a population's genetic makeup through successive generations.

Individuals do not evolve, only populations.

Microevolution - describes the *small genetic changes* that occur in a population

Macroevolution - describes the *long-term, large-scale evolutionary changes* among groups of species: new species are formed from ancestral species; other species are lost through extinction.

How Microevolution Works

Driven by genetic variability

- **Gene pool** - the sum total of all genes possessed by the individuals of the population
- microevolution - a change in a population's gene pool over time.
- **alleles** - two or more forms of a particular gene

Microevolution works through a combination of four processes:

1. Mutation - only changes in reproductive cells are passed on to offspring
 - random and unpredictable
 - the only source of totally new genetic material

- very rare events
- Natural Selection - three conditions necessary for evolution by natural selection to occur
 1. natural variability
 2. heritable trait
 3. differential reproduction

Adaptive trait
Selective pressure
 3. Three types of natural selection (3):
 1. directional natural selection
 2. stabilizing natural selection
 3. diversifying natural selection
 3. Gene Flow
 4. Genetic Drift

Coevolution - interaction between species can result in microevolution in each of their populations

Ecological Niche - the species' way of life or functional role in an ecosystem; involves everything that affects its survival and reproduction and includes:

- the range of tolerance
- the types of resources it uses
- how it interacts with other living and nonliving components of the ecosystem
- the role it plays in the flow of energy and cycling matter

Habitat - the physical location where a species lives.

Speciation, Extinction and Biodiversity

Macroevolution

- concerned with how evolution takes place above the level of species and over a much longer period of time.
- Macroevolutionary patterns include:
 1. genetic persistence
 2. genetic divergence
 3. genetic losses (background extinction or mass extinction)

Speciation - formation of a new species

1. Geographic isolation
2. Reproductive isolation

How do species become extinct?

When environmental conditions change, a species may cease to exist if it cannot adapt.

Several major factors affecting speciation:

1. large-scale movements of the continents
2. gradual climate changes
3. rapid climate changes (catastrophic events)

Background extinction - disappearance of a species at a low gradual rate.

Mass extinction

- abrupt rise in extinction rate above the background level
- catastrophic and worldwide where large numbers of species are eliminated.

Adaptive radiation - period of recovery following mass extinctions

There are two theories about how rapidly macroevolution occurs:

1. gradualist model of evolution
2. punctuated equilibrium hypothesis

The actual rate of evolution is probably a wide spectrum of time frames from one extreme to the other.

Speciation - Extinction = Biodiversity

People are a major force in the premature extinction of species

We have had five major extinctions with the last being 65 million years ago (at the end of the mesozoic era). The sixth mass extinction is caused by **humans**.

Can the Earth be Healed?

Prevention is the best approach

Description	Time to Recover / Renew
Ecosystems damaged by air and water pollution	decades
Desertification	century
Tropical Rain Forest loss	1,000 years
loss of plant / animal species	millions of years