



## Chapter 4 Evolution and Biodiversity



### “It’s A Small World After All”

#### Outline

##### Origins of Life

- A. Chemical evolution of organic molecules, biopolymers, and systems of chemical reactions were needed to form the first cell. It took about 1 billion years
- B. Biological evolution followed, from single-celled prokaryotic bacteria to single-celled eukaryotic organisms to multicellular organisms. It has been continuing for 3.7 billion years.
- C. Knowledge of past life comes from fossils, ice-core drilling, chemical analysis and DNA analysis. These records are incomplete

##### Evolution, Natural Selection and Adaptation

Evolution is the change in a population’s genetic makeup over time.

- A. Populations evolve by becoming genetically different.
- B. All species descend from earlier, ancestral species—theory of evolution.
- C. Microevolution describes the small genetic changes that occur in a population over time.
  1. Over time, a population’s gene pool changes when mutations (beneficial changes) in DNA molecules are passed on to offspring. There may be several different forms (alleles) of a single gene.
  2. Sexual reproduction leads to random recombination of alleles from individual to individual.
  3. The population develops genetic variability brought about by mutations.
    - a. Mutations are random changes in the structure/number of DNA molecules in a cell.
    - b. Mutations occur in two ways.
      - 1) Gene DNA is exposed to external agents like X rays, chemicals (mutagens) or radioactivity.
      - 2) Random mistakes that occur in coded genetic instructions.
    - c. Only mutations in reproductive cells are passed to offspring.
    - d. Many mutations are neutral, some are deadly; a few are beneficial.
  - D. Natural selection’s role in microevolution occurs when members of a population have genetic traits that improve their ability to survive and produce offspring with those specific traits.
    1. For natural selection to evolve in a population, three conditions are necessary:
      - a. The population must have genetic variability.
      - b. The trait must be heritable, capable of being passed from one generation to another.
      - c. The trait must enable individuals with the trait to produce more offspring than individuals without the trait; this is differential reproduction.
    2. Adaptation or adaptive traits are heritable traits that help organisms to survive and reproduce better under prevailing environmental conditions.
    3. Environmental changes require adaptations also. Organisms must:
      - a. Adapt to the new conditions.
      - b. Migrate to an area with more favorable environment.
      - c. Become extinct.
    4. Microevolution follows this process: genes mutate, individuals are selected, and populations evolve.
  - E. Interactions between species can result in microevolution in each of their populations, a process called coevolution. Sometimes the predators have the advantage; sometimes the prey is better adapted.
  - F. Individuals of two species can crossbreed to produce a hybrid and some species can exchange genes without sexual reproduction through horizontal gene transfer.
  - G. Natural selection can only act on existing genes and is limited by reproductive capacity.
  - H. Natural selection does not strive to create the perfect organism; the purpose is to leave the most descendants.

##### Geologic Processes, Climate Change, Catastrophes, and Evolution

- A. Processes such as the shifting of tectonic plates, volcanic eruptions, and earthquakes influence earth’s climate and in turn affect evolution by removing and/or isolating habitats and species.

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- B. Long-term climate changes relocate ecosystems, thus determining where certain species can live.
- C. Asteroids and meteorites have caused environmental stress and mass extinctions.

#### Ecological Niches and Adaptations.

- A. An ecological niche is a species’ way of life in an ecosystem, everything that affects its survival and reproduction.
  - 1. The niche includes the members’ adaptations; its range of tolerance for physical and chemical conditions, its interactions with other components of the ecosystem, and its role in energy flow and matter recycling.
  - 2. The fundamental niche is the full potential range of conditions and resources a species could potentially use. Its realized niche is the part of the potential niche that allows a species to survive and avoid competition with other species for the same resources.
- B. Some species have broad ecological roles and are termed generalist species.
  - 1. Their living range is broad, includes many different places.
  - 2. They can eat a variety of foods, and tolerate a wide range of environments.
  - 3. If environment is changeable, the generalist will survive better than the specialist.
- C. Some species have narrow ecological roles and are termed specialist species.
  - 1. Specialist species can live only in very specific environments.
  - 2. This makes them more prone to extinction when environmental conditions change.
  - 3. If the environment is constant, specialists have fewer competitors.
  - 4. Intense competition may lead to evolutionary divergence of a single species into variety of similar species with specialized niches.
- D. A population’s gene pool and its rate of reproduction limit the population’s ability to adapt to new environmental conditions.
  - 1. The only genetic traits that can adapt are those already in the gene pool.
  - 2. A population’s reproductive capacity limits those genes that can adapt.
    - a. Genetically diverse species that reproduce quickly, can often adapt quickly.
    - b. Populations that reproduce slowly take a long time to adapt through natural selection.
    - c. For a new favorable trait to predominate most of an existing population would have to die prematurely.

#### Speciation, Extinction, and Biodiversity

- A. Natural selection can lead to development of an entirely new species.

In speciation, two species arise from one when some members of a population cannot breed with other members to produce fertile offspring. Speciation occurs in two phases:

  - 1. Geographic isolation, physical separation for long time periods.
  - 2. Reproductive isolation. The gene pools are so changed that members become so different in genetic makeup that they cannot produce fertile offspring.
- B. When population members cannot adapt to changing environmental conditions, the species becomes extinct.
  - 1. A species manages to survive one to ten million years before extinction occurs.
  - 2. Life has had to cope with many major natural disasters that may reduce or eliminate species.
  - 3. Introduction of new species into an area has also led to reduction in number or elimination of species.
- C. When local environmental conditions change, some species will disappear at a low rate; this is called background extinction.
- D. Mass extinction is a significant rise in extinction rates above the background extinction level. Usually, from 25-70% of species are lost. Recent evidence suggests that there have been two mass extinctions on earth. There appear to have been three mass extinctions on earth.
- E. Adaptive radiations are recovery periods after mass extinction when numerous new species evolve to fill niches in changed environments. It takes one to ten million years to rebuild biological diversity after a mass extinction/depletion.
- F. The earth’s biodiversity is decreasing because of human activities.
  - 1. Biodiversity equals speciation minus extinction.
  - 2. Humans are causing the premature extinction of species, estimated to be 100 to 1,000 species per million species.

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3. It has been predicted that by the end of the 21<sup>st</sup> century we may see the extinction of half of the present species now on earth.
4. Humans and their activities are also destroying/degrading ecosystems that might be centers for future speciation.

#### Genetic Engineering and the Future of Evolution

- A. Man has used artificial selection to change the genetic characteristics of populations.
  1. We use selective breeding to obtain specific desired traits.
  2. Traditional crossbreeding is a slow process; it takes many generations of selection for the desired trait.
  3. Genetic engineering/gene splicing are techniques that isolate, modify, multiply and recombine genes from different organisms. Genes from different species that would never interbreed in nature are being transferred to each other.
  4. Genetically modified organisms (GMOs)/transgenic organisms are the results of this gene splicing.
    - a. Gene splicing takes half as much time to develop a new crop/animal, as does traditional crossbreeding.
    - b. Cloning produces a genetically identical version of an individual.
    - c. Biopharming is a new field where genetically engineered animals act as biofactories to produce drugs, vaccines, antibodies, hormones, etc.
- B. Genetic engineering is an unpredictable process and raises privacy, ethical, legal and environmental issues. It is a trial and error process.
  1. The average success rate of genetic engineering experiments is about 1%.
  2. There are many questions about gene therapy: who will be helped with genetic knowledge—only those who can pay for it? If one has a defect, will s/he be able to get health insurance, or a job? Should we clone spare parts for people’s bodies?
  3. A backlash developed in the 1990’s against increased use of genetically modified food plants and animals.
  4. Proponents of more careful control of genetic engineering point out that most new technologies have had unintended, harmful consequences, so that caution should be practiced regarding genetic engineering.
- C. Humans have become such a powerful species so quickly due to two evolutionary adaptations: complex brain and strong opposable thumbs.
  1. Humans have quickly developed powerful technologies to meet our needs and wants.
  2. Humans need to change our ways in order not to be called *Homo ignoramus* instead of *Homo sapiens*, the doubly wise.

#### Summary

1. Life emerged on the earth through two phases of development: a chemical evolution of the organic molecules, biopolymers, and systems of chemical reactions to form the first cells and the biological evolution from single-celled prokaryotic bacteria to single-celled eukaryotic creatures to, then, to multicellular organisms.
2. Evolution is the change in a population’s genetic makeup over time. Evolution forces adaptations to changes in environmental conditions in a population. The diversity of life on earth reflects the wide variety of adaptations necessary and suggests that environmental conditions have varied widely over the life of the earth.
3. An ecological niche is a species’ way of life or its functional role in a community. Everything that affects its survival and reproduction (temperature tolerance, water needs, space needs, interactions with other organisms, etc.) is a part of that niche. The ecological niche helps a population survive by the adaptive traits that its organisms have acquired.
4. Extinction of species and formation of new species constantly changes the biodiversity of the earth

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5. In the future, evolution will continue to influence our environment. Man’s use of artificial selection and genetic engineering to evolve species may have unintended consequences because evolution is a long, slow process and is unpredictable.

### Objectives

1. Briefly describe the evolution of life from chemical evolution to the development of eukaryotic cells.
2. Describe the tools available to researchers for learning the evolutionary history of life.
3. Briefly describe the theory of evolution, being sure to include the roles played by variation within the gene pool and natural selection, extinction, speciation, and adaptive radiation.
4. Define natural selection and the three conditions that are necessary for evolution of a population by natural selection. Summarize and address two common misconceptions about evolution.
5. Define *coevolution*.
6. Distinguish between a *specialist* and a *generalist*. Evaluate the conditions that favor these two approaches.
7. Define *ecological niche*. Distinguish between *condition* and *resource*; *fundamental niche* and *realized niche*. List the factors that determine the realized niche.
8. Define speciation and compare *allopatric speciation* with *sympatric speciation*. Indicate which of these mechanisms is more common.
9. Define extinction and distinguish between background extinction and mass extinction. Discuss the role of humans on the rate of extinction at present.
10. Discuss the pros and cons of artificial selection and genetic engineering. Consider the possible environmental impacts on resource use, pollution and environmental degradation.
11. Indicate what it is that has allowed humans to have such a profound influence on their environment.

Key Terms (**Terms are listed in the same font style as they appear in the text.**)

<p><b>adaptation</b> (p. 86)  <b>adaptive trait</b> (p. 86)  <b>artificial selection</b> (p. 94)  <b>background extinction</b> (p. 93)  <b>biological evolution</b> (p. 83)  <i>biological evolution</i> (p. 83)  <i>biopharming</i> (p. 96)  <i>chemical evolution</i> (p. 83)  <i>clone</i> (p. 96)  <b>coevolution</b> (p. 86)  <i>designer babies</i> (p. 96)  <b>differential reproduction</b> (p. 86)  <b>ecological niche</b> (p. 89)  <b>geographic isolation</b> (p. 92)  <i>heritable</i> (p. 86)  <i>horizontal gene transfer</i> (p. 86)  <i>hybrid</i> (p. 86)  <i>hybridization</i> (p. 86)</p>	<p><b>endemic species</b> (p. 92)  <i>evolutionary divergence</i> (p. 91)  <b>extinction</b> (p. 92)  <i>fitness</i> (p. 87)  <i>fossil record</i> (p. 85)  <b>fossils</b> (p. 85)  <b>fundamental niche</b> (p. 89)  <b>gene splicing</b> (p. 95)  <b>generalist species</b> (p. 89)  <i>generalists</i> (p. 89)  <b>genetic engineering</b> (p. 95)  <i>genetic variability</i> (p. 85)  <b>genetically modified organisms (GMOs)</b> (p. 95)  <b>realized niche</b> (p. 89)  <b>recombinant DNA</b> (p. 95)  <b>reproductive isolation</b> (p. 92)  <i>scientific theory</i> (p. 83)  <i>selective breeding</i> (p. 94)</p>
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<b>mass depletion</b> (p. 93) <b>mass extinction</b> (p. 93) <i>mutagens</i> (p. 85) <b>mutations</b> (p. 85) <b>natural selection</b> (p. 83) <b>natural selection</b> (p. 85) <b>niche</b> (p. 89)	<b>specialist species</b> (p. 89) <i>specialists</i> (p. 89) <b>speciation</b> (p. 91) <i>synthetic biology</i> (p. 96) <i>tectonic plates</i> (p. 86) <b>transgenic organisms</b> (p. 95)
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