Earth is home to a tremendous diversity of species

- **Ecosystem diversity** - the variety of ecosystems within a given region.

- **Species diversity** - the variety of species in a given ecosystem.

- **Genetic diversity** - the variety of genes within a given species.
(a) Ecosystem diversity

(b) Species diversity

(c) Genetic diversity

Figure 5.2

*Environmental Science*

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• **Species richness** - the number of species in a given area.

• **Species evenness** - the measure of whether a particular ecosystem is numerically dominated by one species or are all represented by similar numbers of individuals.
Evolution is the mechanism underlying biodiversity

- **Evolution** - a change in the genetic composition of a population over time.
- **Microevolution** - evolution below the species level.
- **Macroevolution** - Evolution which gives rise to new species or new genera, family, class or phyla.
Variety of multicellular organisms form, first in the seas and later on land

Chemical Evolution
(1 billion years)

Formation of the earth’s early crust and atmosphere
Small organic molecules form in the seas
Large organic molecules (biopolymers) form in the seas
First protocells form in the seas

Biological Evolution
(3.7 billion years)

Single-cell prokaryotes form in the seas
Single-cell eukaryotes form in the seas

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Monday, May 16, 16
Modern humans (Homo sapiens sapiens) appear about 2 seconds before midnight

Recorded human history begins about 1/4 second before midnight

Origin of life (3.6-3.8 billion years ago)
Creating Genetic Diversity

- **Genes** - physical locations on chromosomes within each cell of an organism.

- **Genotype** - the complete set of genes in an individual.

- **Phenotype** - the actual set of traits expressed in an individual.

- **Mutation** - a random change in the genetic code.
Evolution by artificial and natural selection

- **Evolution by artificial selection** - when humans determine which individuals breed.
- **Evolution by natural selection** - the environment determines which individuals are most likely to survive and reproduce.
The wolf is the ancestor of the various breeds of dogs. It is illustrated at the same level as the dogs in this tree because it is a species that is still alive today.
Darwin’s theory of evolution by natural selection

- Individuals produce an excess of offspring.
- Not all offspring can survive.
- Individuals differ in their traits.
- Differences in traits can be passed on from parents to offspring.
- Differences in traits are associated with differences in the ability to survive and reproduce.
Figure 5.10

In this crustacean, known as an amphipod, parents produce offspring that vary in body size.

The larger offspring are more easily seen and eaten by fish. Thus, proportionally more small offspring survive to reproduce (that is, they have higher fitness).

If this natural selection continues over many generations, the crustacean population will evolve to contain only small individuals.
Common Myths about Evolution through Natural Selection

- Evolution through natural selection is about the most descendants.
  - Organisms do not develop certain traits because they need them.
  - There is no such thing as genetic perfection.
Evolution by Random Processes

• **Mutation** - occur randomly and can add to the genetic variation of a population.

• **Genetic drift** - change in the genetic composition of a population over time as a result of random mating.

• **Bottleneck effect** - a reduction in the genetic diversity of a population caused by a reduction in its size.

• **Founder effect** - a change in a population descended from a small number of colonizing individuals.
Mutation creates variation

Unfavorable mutations selected against

Reproduction and mutation

Favorable mutations more likely to survive

...and reproduce

bottleneck: catastrophic reduction in population

original population → chance survivors → new population

Newly founded populations don’t always represent the genetic diversity in their sources.
Coevolution: A Biological Arms Race

- Interacting species can engage in a back and forth genetic contest in which each gains a temporary genetic advantage over the other.
  - This often happens between predators and prey species.
Speciation: A new species can arise when a member of a population becomes isolated for a long period of time.

- Genetic makeup changes, preventing them from producing fertile offspring with the original population if reunited.
Speciation and extinction determine biodiversity

- **Allopatric speciation** - when new species are created by geographic or reproductive isolation.
Maui Parrotbill

Fruit and seed eaters

Greater Koa-finch

Kona Grosbeak

Akiapolaau

Maui Parrotbill

Insect and nectar eaters

Kuai Akialaoa

Amakihi

Crested Honeycreeper

Apapane

Unknown finch ancestor
Different environmental conditions lead to different selective pressures and evolution into two different species.

Adapted to cold through heavier fur, short ears, short legs, short nose. White fur matches snow for camouflage.

Adapted to heat through lightweight fur and long ears, legs, and nose, which give off more heat.
• **Sympatric speciation** - the evolution of one species into two species in the absence of geographic isolation, usually through the process of polyploidy, an increase in the number of sets of chromosomes.
The pace of evolution

A. The rate of environmental change
B. The amount of genetic variation in species
C. The size of the population involved.
D. How fast the species reproduces (generation time)
(a) Directional selection  
(b) Diversifying selection  
(c) Stabilizing selection
Humans?

- <iframe width="560" height="315" src="https://www.youtube.com/embed/4B2xOvKFFz4" frameborder="0" allowfullscreen></iframe>
Evolution shapes ecological niches and determines species distributions

- **Range of tolerance** - all species have an optimal environment in which it performs well. The limit to the abiotic conditions they can tolerate is known as the range of tolerance.

- **Fundamental niche** - the ideal conditions for a species.
Niches

- **Realized niche** - the range of abiotic and biotic conditions under which a species lives. This determines the species distribution, or areas of the world where it lives.

- **Niche generalist** - species that live under a wide range of conditions.

- **Niche specialist** - species that live only in specific habitats.
Generalist species with a broad niche

Specialist species with a narrow niche

Niche separation

Niche breadth

Region of niche overlap

Number of individuals

Resource use
Extinction occurs when the population cannot adapt to changing environmental conditions.

The golden toad of Costa Rica’s Monteverde cloud forest has become extinct because of changes in climate.
The Fossil Record

- **Fossils** - remains of organisms that have been preserved in rock. Much of what we know about evolution comes from the fossil record.
The Five Global Mass Extinctions

- **Mass extinction** - when large numbers of species went extinct over a relatively short period of time.
<table>
<thead>
<tr>
<th>Era</th>
<th>Period</th>
<th>Millions of years ago</th>
<th>Bar width represents relative number of living species</th>
<th>Species and families experiencing mass extinction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cenozoic</td>
<td>Quaternary</td>
<td>Today</td>
<td>Extinction</td>
<td>Current extinction crisis caused by human activities. Many species are expected to become extinct within the next 50–100 years.</td>
</tr>
<tr>
<td></td>
<td>Tertiary</td>
<td>65</td>
<td>Extinction</td>
<td>Cretaceous: up to 80% of ruling reptiles (dinosaurs); many marine species including many foraminiferans and mollusks.</td>
</tr>
<tr>
<td></td>
<td>Cretaceous</td>
<td>180</td>
<td>Extinction</td>
<td>Triassic: 35% of animal families, including many reptiles and marine mollusks.</td>
</tr>
<tr>
<td></td>
<td>Jurassic</td>
<td>250</td>
<td>Extinction</td>
<td>Permian: 90% of animal families, including over 95% of marine species; many trees, amphibians, most bryozoans and brachiopods, all trilobites.</td>
</tr>
<tr>
<td></td>
<td>Triassic</td>
<td>345</td>
<td>Extinction</td>
<td>Devonian: 30% of animal families, including agnathan and placoderm fishes and many trilobites.</td>
</tr>
<tr>
<td>Paleozoic</td>
<td>Carboniferous</td>
<td>350</td>
<td>Extinction</td>
<td>Orдовикан: 50% of animal families, including many trilobites.</td>
</tr>
<tr>
<td></td>
<td>Devonian</td>
<td>500</td>
<td>Extinction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Silurian</td>
<td></td>
<td>Extinction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ordovician</td>
<td></td>
<td>Extinction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cambrian</td>
<td></td>
<td>Extinction</td>
<td></td>
</tr>
</tbody>
</table>
The Sixth Mass Extinction

- Scientists feel that we are in our sixth mass extinction, occurring in the last two decades.

- Estimates of extinction rates vary widely, from 2% to 25% by 2020.

- In contrast to previous mass extinctions, scientists agree that this one is caused by humans.
Some species have characteristics that make them vulnerable to ecological and biological extinction.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low reproductive rate (K-strategist)</td>
<td>Blue whale, giant panda, rhinoceros</td>
</tr>
<tr>
<td>Specialized niche</td>
<td>Blue whale, giant panda, Everglades kite</td>
</tr>
<tr>
<td>Narrow distribution</td>
<td>Many island species, elephant seal, desert pupfish</td>
</tr>
<tr>
<td>Feeds at high trophic level</td>
<td>Bengal tiger, bald eagle, grizzly bear</td>
</tr>
<tr>
<td>Fixed migratory patterns</td>
<td>Blue whale, whooping crane, sea turtles</td>
</tr>
<tr>
<td>Rare</td>
<td>Many island species, African violet, some orchids</td>
</tr>
<tr>
<td>Commercially valuable</td>
<td>Snow leopard, tiger, elephant, rhinoceros, rare plants and birds</td>
</tr>
<tr>
<td>Large territories</td>
<td>California condor, grizzly bear, Florida panther</td>
</tr>
</tbody>
</table>
GENETIC ENGINEERING AND THE FUTURE OF EVOLUTION

- We have used *artificial selection* to change the genetic characteristics of populations with similar genes through *selective breeding*.

- We have used *genetic engineering* to transfer genes from one species to another.
Genetic Engineering: Genetically Modified Organisms (GMO)

GMOs use **recombinant DNA**
- genes or portions of genes from different organisms.
THE FUTURE OF EVOLUTION

- Biologists are learning to rebuild organisms from their cell components and to clone organisms.
  - Cloning has lead to high miscarriage rates, rapid aging, organ defects.

- Genetic engineering can help improve human condition, but results are not always predictable.
  - Do not know where the new gene will be located in the DNA molecule’s structure and how that will affect the organism.

Monday, May 16, 16
Case Study: 
How Did We Become Such a Powerful Species so Quickly?

- We lack:
  - strength, speed, agility.
  - weapons (claws, fangs), protection (shell).
  - poor hearing and vision.

- We have thrived as a species because of our:
  - opposable thumbs, ability to walk upright, complex brains (problem solving).