Chapter 3

Biodiversity and Evolution

DID YOU KNOW?

Consider that an estimated 71% of the earth is covered by water, with its greatest volume found within the far-reaching oceans. The oceans serve as the largest storehouse for carbon—we call any such storehouse a *sink*. In this case, the oceans act as **carbon sinks**.

When carbon dioxide reacts with ocean water, carbonic acid is formed. As large amounts of carbon molecules are released into the atmosphere as a by-product of burning fossil fuels, high concentrations of carbonic acid accumulate in the oceans. Carbonic acid lowers the pH of oceans causing **acidification**.

To counteract this, oceans use calcium as a buffer to neutralize pH. Calcium is taken from calcium carbonate, which is found in shells on the ocean floor. This threatens any aquatic life with hard shells (such as corals that create the coral reefs). In fact, acidification threatens the livelihood of any aquatic species with a narrow range of tolerance to dramatic changes in pH.

Biodiversity

It is estimated that 99% of the species that once roamed earth have now gone extinct. Currently, estimates of the extinction rate range from 1,000 to 10,000 times its normal rate as a result of climate change, pollution, deforestation, and other human-influenced activities.

Extinction results in a dramatic loss of biodiversity. Every week through deforestation alone, we lose an area of the rainforest almost twice the size of Rhode Island! In the last 40 years, we have lost 20% of the rainforests, which contain half of the world's biodiversity! Is our addiction to overconsumption worth such a dramatic loss of biodiversity?

In this chapter, we will explore what factors *influence* or correlate with high ecosystem biodiversity. We will also examine compelling incentives to *protect* biodiversity, as well as major existing *threats* to biodiversity.

Biodiversity refers to the various species living and interacting with each other in a given area. This encompasses all individual organisms, as well as their populations and species. It includes genetic diversity and the complex community and ecosystem structures.

Species diversity is the number of different species (see **species richness**) as well as the differences among and within those species. These include all different kinds of species: microorganisms, fungi, plants, and animals. **Genetic diversity** refers to the variety of genes within a species. Genetic diversity is beneficial for a species because it helps the species adapt to a changing environment. **Ecosystem diversity** encompasses different biological communities, ecological processes, and various habitats.

Species diversity can be high, as is the case with the tropical rainforests that contain 50% of the world's species. It is estimated that the rainforests contain over 5 million species of plants and animals! High biodiversity is a sign of ecosystem health and a good indicator that it will recover in a reasonable amount of time after a disturbance or periods of stress.

Areas of high biodiversity are called **hot spots**. The tropical rainforests, coral reefs, and the state of California are considered hot spots. Although not a tropical climate, California is a hot spot because it harbors biodiversity not found anywhere else in the world: Sequoias, Redwoods, Joshua Trees, coastal sage scrub, chaparral, etc.

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Biodiversity can also be low as is the case with the Gulf of Mexico. Here, water quality is so poor and concentrations of oxygen are so low that only simple organisms like **microbes** can grow. Areas with low biodiversity are called **dead zones**. (Please note that in the case of the Gulf of Mexico, poor water quality can be attributed to pollution caused by human activity.)

Biodiversity is further defined by **species richness** and **species abundance**. Species richness refers to the total number of different species present in a given area, while species abundance refers to the number of individuals of a given species that is present in that area.

An area may have high species richness but low species abundance. Take the tropical rainforests again as an example; it has *high* species richness (high species number) but *low* species abundance (a relatively low number of individuals *within* a species). Conversely, other areas such as the Arctic have *low* species richness but *high* species abundance. Relatively fewer types of plant and animal species are found in the arctic, but of those species represented (reindeer, caribou, polar bears, and the arctic fox), there is an abundance of individuals.

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The Arctic Fox

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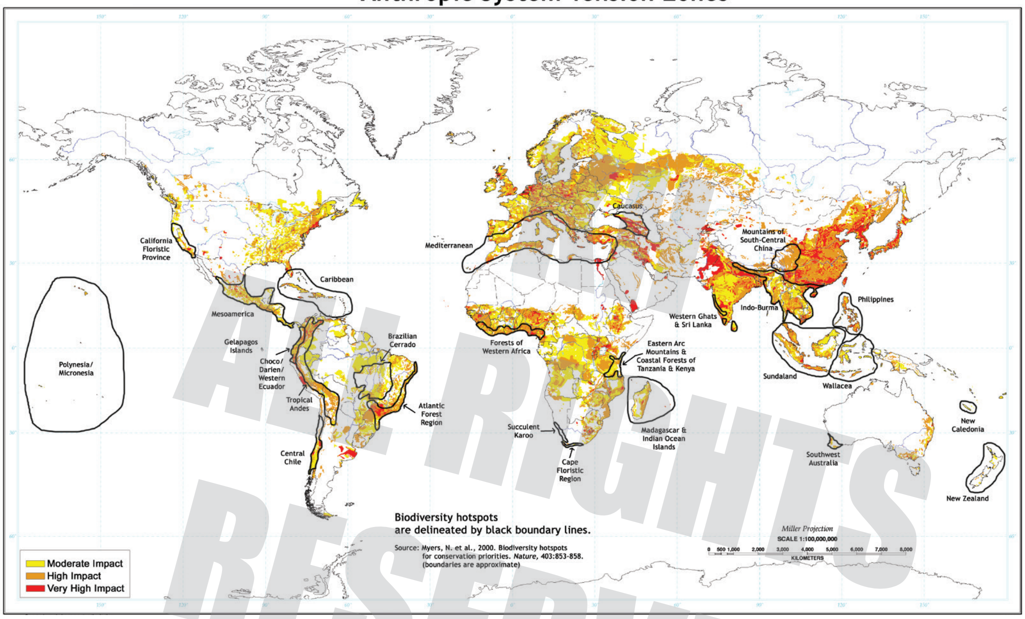
Caribou

When we think of biodiversity, we tend to think of beautiful and colorful **flora** and **fauna**, but we must not forget less attractive species living in the soil. Earthworms and mushrooms, although not particularly aesthetically pleasing, are just as important to maintaining an ecosystem's biodiversity and health as are the majestic rainforest trees. These species break down decaying matter and are essential for maintaining biodiversity as they enrich the soil, enabling other species to grow and thrive. In fact, some historians even link the scarcity of earthworms to the collapse of the Sumerian empire! Their irrigation system (they started using saltwater) killed off their earthworm population. A paucity of earthworms meant poor soil quality and therefore few crops. This, in turn, probably weakened their health and social structures, rendering them vulnerable to invasion!

Anthropic System Tension Zones



Global Hotspots Outlined in Black. Human impact to Global Hotspots

Source: Land Quality map, USDA-NRCS, Soil Survey Division, World Soil Resources, Washington D.C. Population density map, Tobler, W., V. Deichmann, J. Gottsegen, and K. Maloy. 1995. The global demography project. Technical Report TR-95-6. National Center for Geographic Information analysis. Univ. Santa Barbara, CA, 75pp. Biodiversity hotspots, Myers, N. et al., 2000. Biodiversity hotspots for conservation priorities. *Nature*, 403:853–858.

Factors that Influence Biodiversity

Many factors influence ecosystem biodiversity, but in the following paragraphs we will focus on the most salient variables such as amount of sunlight, age, and size. Let us examine these variables in more detail:

A. The **ambient light hypothesis** states that the *more sunlight* accessible to an ecosystem, the more functional it becomes. Functional in this context means having many varied and specific roles within an ecosystem (decomposition, photosynthesis, predation, pollination, etc.). This leads to high ecosystem richness. The more functional an ecosystem, the more biodiversity it harbors, and the more Carbon, Nitrogen, and biomass it creates. A highly functional ecosystem has many plants, herbivores, predators, prey, and decomposers—all forming an intricate and robust food web.

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Consistent with the ambient light hypothesis, high biodiversity is observed near the equator. Because the earth spins on its axis, the equator receives the most sunlight throughout the year. An abundance of sunlight means more photosynthesis, which means more plants and trees. More plants and trees mean more herbivores, more species that feed on herbivores, and more species that help decompose dead plant and animal matter.

The coral reefs, also found along the equator and also considered hot spots, are sometimes referred to as the "tropical rainforests of the ocean." Coral reefs get an abundance of sunlight and, therefore, are also a highly functional ecosystem.

B. Tropical rainforests, relative to other ecosystems on the earth, are extremely *old*. This factor may also help explain its high biodiversity. One hundred thousand years ago, during an era we call the **Ice Age**, North America was covered by glaciers, sheets of ice as thick as the height of the Empire State Building. The glaciers eventually receded, leaving lakes, streams, hills, valleys, and new ecosystems in their wake. The glaciers never reached as far south as the equator, leaving the rainforests undisturbed and intact. As a result, the rainforests have a longer historical legacy for the many species that live and flourish today. The millions of different species found throughout this biome have had time to evolve and adapt, undisturbed by glaciers.

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The older an ecosystem is the more death and decaying matter that is present. Ironically, more death in this case means more life, since decomposers such as bacteria, earthworms, and fungi break down dead and rotting organic matter, enriching the soil and making it ripe for new vegetation to grow to be consumed by a growing animal population thriving on the abundance.

C. Hot spots such as the tropical rainforests are often massive in size. *Large land mass* as well as *large amounts of biomass* provide more habitats for species to live and adapt. They also provide more places to hide from predators or competitors. The result is a lower extinction rate. The tropical rainforest trees grow extremely tall (some up to 80 meters high!), providing niches in which other species can live. In the canopies one finds **epiphytes** (plants that live on the tops of trees), along with the many different rainforest tree frogs and insects. Among the understory live many different snakes, birds, lizards, and even large cats such as jaguars!


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Jaguar

D. There are some places on earth where evolution seems to speed up and create an explosion of biodiversity. In such areas, species venture into new niches and become uniquely and specifically adapted to each niche. An example of this is the finches that Charles Darwin examined while he was exploring the Galapagos Islands (see the paragraph on evolution below). He observed various finches uniquely adapted to eating seeds, fruit, insects, and plants. These finches, he presumed, were so similar that a recent common ancestor was apparent. However, they were so uniquely adapted to their environment that he could also not discount that they were distinct. Such a phenomenon is called **adaptive radiation**. Adaptive radiation often occurs on volcanic islands and mountain tops, where there are ecological islands of biodiversity and species inhabit and adapt to the available unique niche. (Such ecological islands have very little gene flow with other populations and so are often threatened by habitat destruction or disturbance.) Criteria for adaptive radiation include plenty of food and resources, little competition, and little predation. In other words, there is not a lot of **natural selection** working the species being discussed (see below paragraph on natural selection).


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A Black Darwin Finch Atop a Prickly Pear

E. Ecosystems with **intermediate amounts of disturbance** tend to have high biodiversity. (A disturbance in this sense is an environmental factor that compromises the integrity of the ecosystem: storm, fire, flood, etc.) An ecosystem with *too much* disturbance makes it difficult, if not impossible, for species to thrive and adapt, as they are


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A Galapagos Finch. Note the Difference in Beak Morphology consistently out of their range of tolerance. Too little disturbance, on the other hand, often lends itself to having one single-dominant species that happens to be a superior competitor, to the detriment of other species and biodiversity.

Why Protect Biodiversity?

There is no simple answer to this question. The many factors involved in this discussion topic are, of course, a matter of opinion and subject to debate. Nonetheless, possible compelling responses are both philosophical and practical in nature.

Let us begin with practical considerations: One cannot deny the *economic value* of biodiversity. According to a 1997 study by Robert Costanza, if we were to take on the daunting task of assigning a monetary value to the goods and services that biodiversity supplies humans, it would run somewhere in the ballpark of $44 trillion![i] This value may seem like a staggering amount, but consider that biodiversity provides us with food, crops, safaris, and other materials and services to be sold and exported. Most economies—even energy economies—are built on natural resources from biodiversity.

Biodiversity provides us with wood for our homes and paper to write on. It provides us with recreation, clean water, clean air, clothing, shoes, jobs, perfume, emollients, aesthetics, and medicine. In fact, some species contain chemicals that are anti-inflammatory, antiviral, and antimicrobial. And some have chemicals that act as painkillers!

Biodiversity also provides *ecological value*. It provides us with protection from storms and floods. It moderates climate, provides wildlife habitats, acts as a carbon storehouse, creates food-webs, recycles waste, and maintains an overall balance to the biosphere.

It provides us with a means for eco-tourism in which we travel to exotic destinations and educate ourselves on endemic flora, fauna, and ecological systems. This sometimes stretches our comfort level but also broadens our horizons with its immeasurable educational value. It enables us to feel connected to the earth and landscape and its native people. It also provides us with an ecological sanctuary—somewhere to escape the stresses and burdens of everyday life. The earth's remote pockets of nature are places to clear our heads, breathe fresh air, commune with nature, and gain perspective on our problems and obstacles.

Biodiversity provides us with *scientific value*. It offers areas in which scientists can go, undisturbed by urban noise and distraction, and conduct field research. This inevitably provides us with a wealth of knowledge and inspiration relevant to all aspects of society.

On a more philosophical level, all life on earth possesses its own *intrinsic value*—an innate integrity and unique place in the biotic world. But it appears as though our approach (stemming from our materials economy based on extraction) has morphed into treating biodiversity as though it is fungible—easily replaced or substituted over time. Not only is this approach unrealistic and unsustainable, but it devalues biodiversity and denies its intrinsic value.

Furthermore, there are *cultural* reasons to protect biodiversity. There is a positive link between biodiversity and cultural and societal diversity, as well as the diversity of languages. If we lose our biodiversity, we lose the others linked to it, and cultural knowledge associated with it. So making efforts to preserve biodiversity and live more sustainably ultimately protects many other cultures, their native languages, and knowledge surrounding biodiversity.

And finally, our plants, animals, fungi, microbes—*all* of life's biodiversity—comprise a legacy that should get passed down to future generations so that they too can experience its natural beauty and immeasurable value. We must act as responsible stewards of the environment in order to achieve this.

Threats to Biodiversity

Biodiversity is the result of billions of years of evolution. Now through human activity, the process is increasing and we are faced with many threats to which would lead to a loss of biodiversity. Some are more obvious and on a grander scale than others. For simplicity, we will summarize the major threats to biodiversity and collectively give them the acronym HIPPCO (using the first letter of each heading to create this mnemonic):

Habitat Loss

Habitat loss is the number one cause for extinction. Our growing human population needs homes, schools, paved roads, and other resources. This means construction, logging, mining, constructing dams, and paving over land inhabited by other species. This ultimately leads to fragmenting their land. Species that do not die out (as a result of habitat and food loss) are driven to other habitats where they encounter new parasites, new competition, and new predators. Such prolonged stress would attenuate the already struggling number of species. The conversion of land for agriculture and development creates an overall loss of biodiversity.

Another cause for habitat loss is unsustainable agriculture. An example of this practice includes cutting down the rainforests to grow African Palm that feeds the growing demand for palm oil. It also includes cutting down rainforests to provide rangeland for cows to supply the world's substantial meat consumption.

Climate change and other major environmental shifts (in pH, salinity, oxygen concentration, water temperature, etc.) can also directly or indirectly lead to habitat loss. Because communities are so interconnected, even a minor shift in environmental conditions can have dire consequences.

Invasive Species

Invasive (sometimes called exotic) species are species from other parts of the world introduced to a new habitat. These transplanted species now lack their natural predators, competitors, and other population controls. Some exotic species prey on or outcompete native species which severely compromises biodiversity. So it should not come as a surprise that the introduction of invasive species is a major cause for the extinction of native species.

Take for example the African honeybee (*Apis mellifera*) which was introduced to Latin America in order to assist pollination. After being transplanted, it soon became evident that this aggressive species of bee often swarms, and its sting is sometimes lethal to humans. Due to its aggressive nature, African honeybees have outcompeted and killed off much of the honeybee population native to South America. Black rats introduced to the Galapagos Islands in the 1800s prey on giant tortoise hatchlings. They have, in part, been responsible for the giant tortoises having been close to extinction in the 1970s. (With rigorous conservation efforts, the giant tortoises are now stable and breeding in the wild.)

African Honeybees

Another example of an invasive species is the lamprey, an eel-like sucker fish accidently introduced to the American Great Lakes. Lampreys prey on native lake trout and have been such successful predators that presently, very few trout can be found in the Great Lakes.

Lamprey

Invasive species can also contaminate the gene pool of native species, ultimately negatively impacting native populations. It is estimated that the economic loss as a result of invasive species is roughly 1.4 trillion in U.S. currency.[ii]

Population

All other threats to biodiversity can be traced back to overpopulation. Having over 7 billion people on earth means our resources are exhausted—from land to minerals to freshwater, the earth simply does not have enough bounty to effectively distribute its goods to such a large and growing population.

Humans are not the only ones feeling the pinch from diminishing resources; other species rely on them as well and suffer as a result. Because of the increase in international trade of plants, animals, and food, pathogens are traveling much more rapidly than ever. This means that wildlife, once shielded from pathogens across the globe, are now exposed to new threats at a growing rate. Often they do not have developed immunity to fight off the newly introduced pathogens. Diseases carried by domestic animals and livestock can harm wildlife populations. African wild dogs for example, have been exposed to rabies and distemper. See Chapter 4 for more information on population growth.

Pollution

There are many types of pollution: air, water, thermal, noise, and land, to name a few.

Chemicals and toxic waste from our labs, factories, and urban areas leach into our soil and our water supply, and accumulate in the atmosphere.

Wealthy nations have the resources and technology to purify water and air, but what about those living in developing nations that do not have access to clean water or air? Almost 1 billion people worldwide are without clean water and that number is expected to increase.

We must also consider plants and wildlife that also share our land, air, and water and are also negatively impacted by pollution. Species that communicate acoustically, like whales and dolphins, are vulnerable to noise pollution; while other aquatic animals are vulnerable to changes in water temperatures. Pollution is linked to **eutrophication** of bodies of water, causing algal blooms and often leading to loss of fisheries.

Since the Second World War, wild animals have been increasingly exposed to artificial toxins and chemicals. They have no evolutionary history with these toxins, which means there has been little selective pressure on detection. This in turn means that wildlife have little or no evolutionary adaptation to detect and avoid them. Birds readily eat artificial pesticides and have become poisoned. Marine mammals eat fish contaminated with dioxins and DDT. There are many more examples of species vulnerable to pollution, so please see Chapter 9 for more information on pollution.

Some of our common apparatus, material and gear that are characteristic and common to human lifestyle can become injurious to wildlife. Barbed-wire fence, derelict fishing nets, and electric cables can all be harmful or even deadly to wild animals. Speaking from an evolutionary standpoint, the wildlife have had little time to adapt to their presence and learn avoidance of harm or injury.

Climate Change

As we discussed in Chapter 1, global temperatures have increased 1°C in the last 100 years. This has devastating effects on biodiversity. Flowers are blooming before their pollinators can successfully access them. Species are forced to migrate to the poles to find more amenable temperature ranges. Species' ranges are both constricting and contracting. We are seeing greater extinction rates and changes in species composition and interaction. Pathogens are attacking new species that lack the immunity to fight back against them. We are experiencing droughts and other temperature extremes—photosynthesis rates decrease with extreme temperatures, possibly causing ecosystem collapse. We are experiencing a spike in vector-borne (spread by mosquitoes or ticks) diseases that harm not only us but wildlife as well. The melting glaciers and ice caps leave polar bears, which perch atop arctic glaciers while fishing, weakened from exhaustion and lack of food.

Overexploitation

Our economy and many others are built on **extraction**—taking vital goods and resources from the earth. This leads to the excess use of vital goods and resources taken from the earth faster than they are able to replenish naturally. Over-fishing, over-hunting and over-collecting of species can quickly result in a loss of biodiversity.

The assembly of an ecosystem and all its inhabitants are vital for the evolutionary process. Because of the complexity of ecosystems, most wildlife and plants suffer from losing such resources. They also suffer from being exposed to the pollution caused by the extraction. It drives them from their homes, forces more competition for resources, and depletes food supply.

Biodiversity and habitat loss can cause some species to be considered formally endangered. **Endangered species** are species with such low abundance that they are at high risk of becoming extinct.

MVP (minimal viable population) is the minimum number of individuals that must be present in a species population for it to be considered at low extinction risk. For most land animals, this number is at least 500. Approximately 20,000 members of a population must be present for biological evolution to occur.

A **threatened species** has a good chance of becoming endangered in the near future. A **sensitive species** is a species that is vulnerable to habitat loss; therefore, conserving habitats should be a top priority in order to preserve the species. We will explore more on endangered and threatened species in Chapter 14.

Protecting Biodiversity

Drafted in 1992 and enforced in December of 1993, the United Nations created an international treaty called The Convention on Biological Diversity, often referred to by its acronym CBD. Its mission is:

1. The conservation of biological diversity,
2. The sustainable use of the components of biological diversity, and
3. The fair and equitable sharing of the benefits arising out of the uses of genetic resources.[iii]

In other words, the CBD is committed to ensuring that biodiversity and natural resources are used sustainably to avoid long-term biodiversity loss or depletion. It also secures fair access to and benefit from biodiversity and natural resources for *everybody*.

This treaty is seminal because it protects citizens of countries with rich natural resources (often living in poverty) from getting short changed by big companies (from developed nations) that cut down forests and remove natural resources for monetary gain. It offers financial assistance and resources to the least-developed countries (LDCs) and advises on implementation. The CBD would theoretically help alleviate worldwide poverty and help stabilize the economies of countries with rich natural resources.

Indeed, its efforts have been met with marked success: more countries are ratifying this treaty; already there is compelling evidence that deforestation rates in tropical areas have declined as a result of efforts to decelerate it; countries in the Caribbean are increasing their marine and coastal conservation; the Maldives pledged to make the country a Biosphere reserve; and finally, measures to control alien invasive species have resulted in many species being moved to a lower extinction risk category.

Evolution

What we observe as earth's impressive biodiversity is, in fact, the result of millions of years of evolution. **Evolution** is defined as *the change in gene frequency of a given population over time*. It is important to note that populations evolve, not the individuals within a population.

In 1831 Charles Darwin, an English naturalist, embarked on the British ship *H.M.S. Beagle* to study the biodiversity of the Galapagos Islands of the South Pacific. He noticed that the tortoises were much larger than they were on the mainland. He also thoroughly examined the Galapagos finches for their unusual morphological diversity.

Darwin observed that each distinct species of finch has its own unique adaptations, making it undeniably separate and different from other birds on the island. At the same time, however, morphologically they appeared very similar, and so one could not deny a common ancestor. He could not answer the question why, if species are created for the environment (as previously believed), were there 13 species of birds for one single environment? This observation was the catalyst for further examination of the question: perhaps species *can* change, but how?

In 1859 Darwin published his book *The Origin of Species* in which he describes the evolution of species through natural selection. According to Darwin, the theory of natural selection is based on several observations:

1. There is observed variation in every species population,
2. Within the population, some members of the species will have beneficial variations that will ensure better likelihood of survival,
3. The members of a population with the beneficial variations will leave the most offspring, and
4. The beneficial traits are heritable and passed on to future generations.

In colloquial terms, we call this process survival of the fittest.

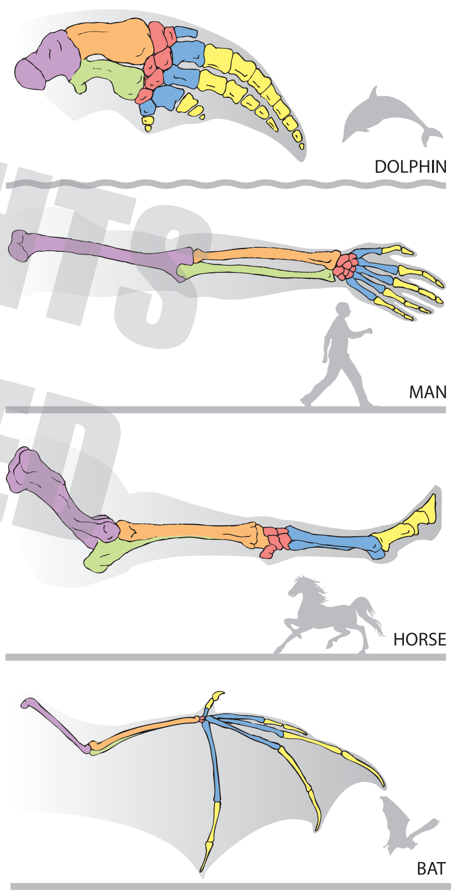
The Origin of Species also established that all species descended from a common ancestor through a process called speciation.

Speciation is the process through which a new species arises as a result of adaptation to an ever-changing environment.

Allopatric speciation is speciation occurring in the presence of a physical barrier, such as a mountain range or a river, etc. In such a case, gene flow is blocked, and evolutionary agents work on the now-isolated population, resulting in new species.

Sympatric speciation is speciation occurring *without* the presence of a physical barrier. Often the reason for lack of gene flow between populations is behavioral. In the case of plants, speciation may be the result of self- or cross-pollination, as is the case with plants. Plants have a higher threshold for abnormal chromosome number than humans, and so hybridization is a common occurrence in the Kingdom Plantae. This is an example of sympatric speciation.

Adaptations are structures or behaviors that increase the livelihood or **fitness** of an individual. Over time, structures and genetic frequencies shift so profoundly that a new species forms.



Comparable Arm-bone Orientation of Different Animals, Suggesting a Shared Evolutionary Past.

Various anatomical structures and much other observable evidence support Charles Darwin's theory of evolution through descent from a common ancestor:

A. Although sizes and shapes may vary, the arm bones of dogs, cats, whales, and humans all have similar orientations. This suggests they all share a common ancestor with this anatomical trait and evolved separately into new species. Anatomical structures that provide evidence of a shared evolutionary past are called **homologous structures**.

B. Further evidence to support evolution comes in the form of **analogous structures**, similar structures that are the result of **convergent evolution**. Convergent evolution results when unrelated species occupy similar environments and so natural selection favors similar adaptations. This causes the unrelated species to look or behave similarly. These behaviors or appearances are considered analogous. Analogous structures, therefore, are anatomical structures that do not share an evolutionary past but are the result of similar environmental selective pressures. Consider the eyes of a squid and the eyes of humans. They evolved separately as a result of similar selective pressures, although there is no evidence of a recently shared evolutionary past. The fact that both bats and dolphins communicate and navigate through echolocation is also an example of convergent evolution.

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C. Goosebumps in humans is left over from a time when we had fur! When the flight or fight response was initiated long ago, the *erector pili* muscles in the skin would contract. This would theoretically make our hair stand on end and so make us look larger to potential predators or other threats. Such a structure is considered **vestigial**; it is no longer employed by the organism but left over from a time when it was. This suggests that humans adapted to their environment, changing genetically and morphologically.

D. The fact that all living organisms, from the bacterium to the cow, share the same molecules of DNA and sequences of amino acids for building proteins is **biochemical evidence** that supports the idea that we evolved from a common ancestor.

E. Sediment such as dead plant and other organic matter settles in layers and eventually forms sedimentary rock. Each layer of sedimentary rock is called a stratum and collectively called strata. Each stratum represents a distinct period of time in earth's geological history. Some fossils are found in one strata of rock but not in another, suggesting that species have thrived during a specific finite period, and then either died out or evolved. This **fossil record**, therefore, gives evidence that species have evolved, adapted, or gone extinct, supporting Darwin's theory of adaptation and descent from a common ancestor.

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Fossil Trilobite Imprint in the Sediment

Sometimes, having the "highest fitness" is the ability to cooperate with other species or share a resource or home, and avoid direct competition. The oak tree for example (Genus *Quercus*—an angiosperm) is one of the most reproductively successful trees in North America. Each tree is considered the land equivalent of a tropical reef (because of its high biodiversity) and the entire tree is protected in some states. The typical oak is home to over 40 species of insects, 30 species of birds, and at least 200 species of moths. Insects lay their eggs inside the leaves, which in turn provide food and protection. Because these trees have so many visitors and inhabitants, this cooperative nature of Oaks has proven to be quite an effective reproductive strategy. Oak trees are prolific—they can yield up to 100,000 acorns a year and provide an abundance of nutrients to many species, which disperse their seeds. We will examine some more of these examples in Chapter 5.

Review Questions

1. How does the presence of analogous, vestigial, and homologous structures support Darwin's ideas of descent through modification?

2. Compare and contrast "species richness" with "species abundance."

3. What factors make a species vulnerable to extinction?

4. Describe what major factors influence biodiversity.

5. Where might you find a 'hot spot?' How about a "dead zone?"

6. What is the difference between sympatric and allopatric speciation? Please provide examples.

7. Define evolution. What are the four observations upon which natural selection is based?

Discussion Questions for Class

A. How have the root causes of environmental problems compromised earth's biodiversity? How may they compromise biodiversity in the next 50 years?

B. We can point out many examples of aggressive and invasive species that have threatened and limited biodiversity: the honeybee population is threatened by Apis mellifera, and lampreys threaten rainbow trout. How might this impact the food chain? Can you think of others?

C. Beyond the $44 trillion economic value of biodiversity are the incalculable economic, medicinal, recreational, and intrinsic values of biodiversity. Do we have a moral obligation to maintain it?

D. Does intrinsic value matter more than economic value? Where should our priorities be as a society regarding these values? Does ecological value matter more than economic value? Why or why not?

E. Is Darwin's Theory of Evolution through natural selection in conflict with the Greeks' idea of provident ecology? Why or why not?

F. Can you think of other examples of homologous structures? Analogous structures? Vestigial structures?

G. How does the presence of analogous, vestigial, and homologous structures support Darwin's ideas of descent through modification?

H. What factors make a species vulnerable to extinction?

I. Describe what major factors influence biodiversity.

J. How can "cooperation" between species increase fitness? Please provide an example.

Your Personal Sustainability Journal

Take a walk around your home, office, or school and take a mental inventory of all wildlife. If there are native bird species, research on the internet to learn about their natural habitat. Now provide an appropriate, small, wildlife home or habitat.

Write down 10 things you noticed (that you used today that came from nature's biodiversity. Now think about how much land and resources were used to provide this service for you. What is involved? Can you limit the use of any of these products?

Cut down on meat consumption, especially red meat. This is the quickest way to reduce your ecological footprint. Try going vegetarian for a week!

Many of the rainforests in Southeast Asia are being cut down for palm oil plantations to meet growing demand in the West. This takes habitats away from Orangutans whose population is threatened, among other species. Educate yourself on food and products that use palm oil. Limit your consumption or buy from companies who have revised their policies regarding palm oil. Some are harvesting palm oil in a way that preserves the rainforests and peatlands.[iv]

Add your own suggestions here.

Endnotes

i. http://www.esd.ornl.gov/benefits_conference/nature_paper.pdf
ii. www.unep.org
iii. (www.cbd.int)
iv. http://www.ucsusa.org/assets/documents/global_warming/deforestation-free-palm-oil-scorecard.pdf