Summary Questions

1. If a codon is changed by mutation, what specifically happens to protein synthesis?

2. Define allele.

3. List the three events during sexual reproduction that guarantee evolution.

4. What creates new alleles?

5. List and describe three factors (other than natural selection) that can increase the speed of evolution.

6. What process leads to genetically isolated populations and eventually to different species?

7. What separated the evolution of early humans from the evolution of chimps and apes?

8. What substance in the sediment of rocks indicates when an asteroid may have struck the earth?

9. List the causes for three of the major extinctions.

EVOLUTION

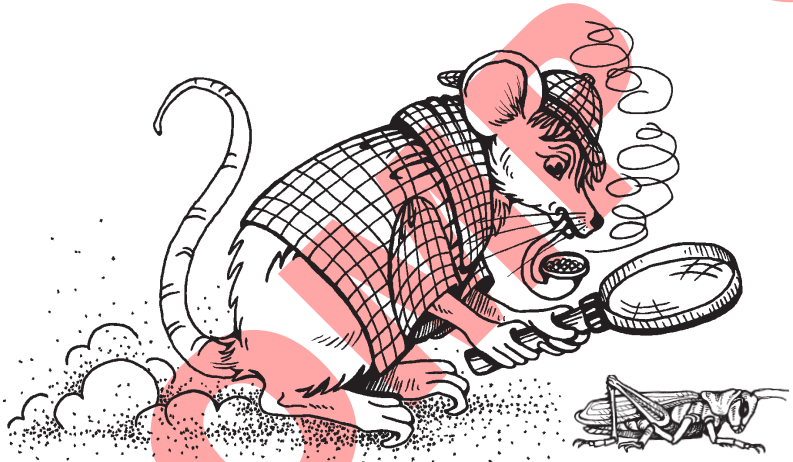
Sceptical scrutiny is the means, in both science and religion, by which deep thoughts can be winnowed from deep nonsense.
—Carl Sagan, American scientist (1934-1997)

INTRODUCTION

A topic like evolution seems to push everybody's button. Mention it and you're likely to start an argument.

Most people think that the central issue of this controversy is about the descent of humans from other animals. It is not! The argument is not about human ancestry, it is about *change*. In its simplest definition, ***evolution is change***. Disagreements arise because humans both crave and fear change. The social argument about evolution becomes a projection of the dilemma we've created inside our own minds. Religions and philosophies meditate on change, whereas science investigates it. Both ways of thinking are natural, expected by-products of human awareness and curiosity. Both ways of thinking can provide value to people.

Your textbook and lecture class will do a thorough job of presenting the traditional scientific evidence and implications of evolution. The purpose of the following Activities is to start you on the path of understanding evolution, and to offer you some different ways of thinking about it.



ACTIVITIES

ACTIVITY #1

"GENETIC CHANGE"

Biologists define ***evolution*** as genetic change in a species over time. Based on what you have learned about DNA, protein synthesis, sexual reproduction, and genetics, you should be able to answer one of the most profound questions about life on this planet:

Is it possible for life to stay the same, or is all life destined to change?

DNA AND TRAITS

In the chapter on "Genes and Protein Synthesis" you learned that small pieces of DNA, called genes, produce ***traits*** in organisms. These genes contain messages that make amino acids assemble into an exact sequence to produce protein. Proteins are used in cellular structure and as enzymes in an organism's biochemistry.

If it has been more than two weeks since you covered DNA and protein synthesis in lecture, then review Activity #2 and #3 in "Genes and Protein Synthesis" now.

? QUESTION

1. A gene is a long chain of nucleotides. Each group of three nucleotides in a row along the gene is called a _____ , and is responsible for the insertion of an _____ into a protein.

2. Define evolution in the simplest terms from a biological perspective.

3. Does anything stay exactly the same over time? Explain.

MUTATIONS

A ***mutation*** is a change in the sequence of nucleotides in the gene (DNA). These changes are caused by a variety of natural events.

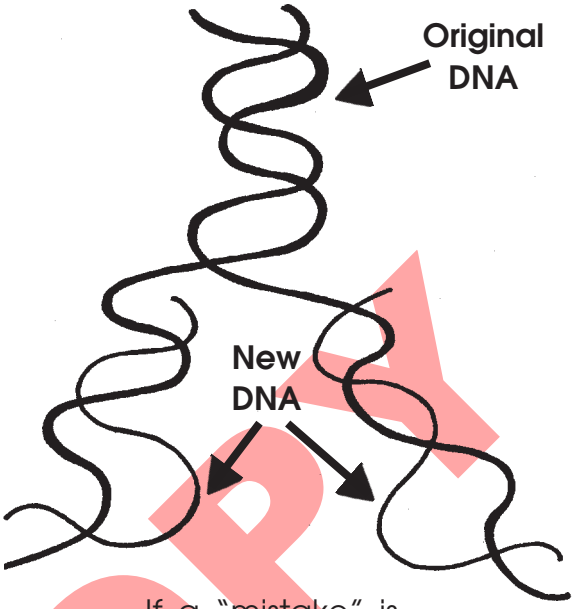
You might think that your DNA is exactly replicated every time a cell divides or an egg or sperm is produced, but this is not always true. Small amounts of certain chemicals, produced by your own metabolism and in the foods you eat, can chemically alter the sequence of nucleotides. That new sequence will be the model for the *next* replication, and so on.

Nucleotides can also be changed when they are struck by cosmic radiation from outer space or UV rays in sunlight. If these abnormal nucleotides become incorporated into the DNA of an egg or sperm, then a mutation will be passed on to the next generation.

Another mutation event occurs when a nucleotide is accidentally skipped during DNA replication, or when an extra nucleotide is inserted in the DNA. (Accidents do happen!)

Whatever the cause, these mutations will continue to be copied by all future generations of cells.

Mutations can have either minor or major effects in the biochemistry of the organism. Most amino acids have more than one mRNA codon controlling their insertion into a protein. For example, glutamic acid is coded by both GAA and GAG in the mRNA. Therefore, a mutation of GAG to GAA or from GAA to GAG would have no effect on the protein being made. However, a mutation of GAG to GAU would result in *aspartic acid* being inserted instead of *glutamic acid*.



If a "mistake" is incorporated into this new DNA, then that error will be recopied the next time the DNA replicates.

In Activity #3, "Genes and Protein Synthesis," you learned that a single nucleotide change results in sickle-cell anemia. Single nucleotide mutations don't always create radical changes in the protein's basic chemical and physical properties. Sometimes the new protein is equal to the original protein in its performance for the organism. However, if a nucleotide is *deleted* during DNA replication, or if an extra nucleotide is *inserted* into the DNA, then the effects can be major. The following questions will clarify this point.

? QUESTION

1. Define *mutation.*

2. If a three-letter code is changed in the DNA, what happens to protein synthesis? (Be specific.)

3. Does a single nucleotide replacement always create a different protein?

4. Does a single amino acid change in a protein always radically change the properties of the protein?

5. Consider the consequences if an extra nucleotide is inserted into a gene. (The consequence is the same if a nucleotide is deleted.)

What happens to all of the three-letter codes in the gene following that one nucleotide change? (Draw brackets around each codon in both the original and mutated gene to illustrate the consequences.)

6. How many amino acids in the protein will be changed by the type of mutation described in the previous question?

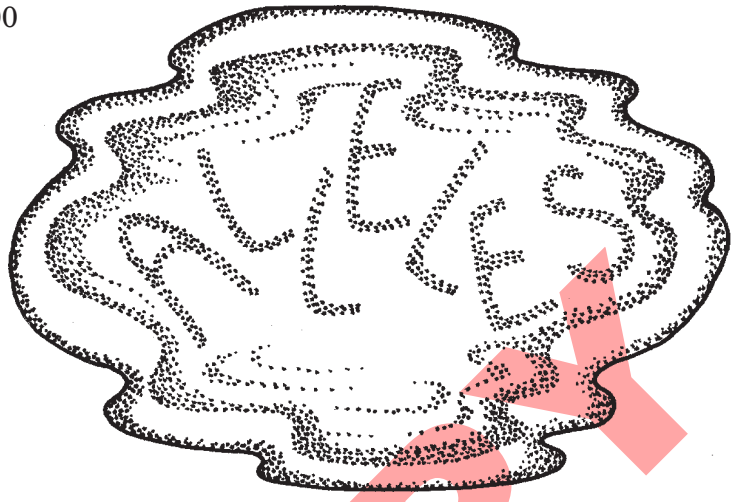
7. Researchers estimate that you have 30,000 genes. If the chance of any of your genes being mutated before it ends up in a gamete (egg or sperm) is 1 in 30,000, how many new mutations would be in each gamete you make?

8. Is there any way that the DNA can stay exactly the same from generation to generation?

ALLELES IN A POPULATION

You learned in the "Genetics" chapter that humans are diploid, which means that you have two copies of each gene. When using the word *gene,* we are usually referring to a function—for example, "the *gene* for eye color." The word ***allele*** refers to the particular form of a gene. There is a blue-eye allele and a brown-eye allele. We also know that there are variations of each allele. (Remember our examples of minor mutation events?) In fact, there are many minor variations of the blue-eye allele and the brown-eye allele.

Biologists haven't identified all of the 30,000 individual human genes or the millions of possible alleles of these genes, but eventually they will discover what each of them does. In order to continue our discussion of evolution, the term *gene pool* must be defined. All of the alleles in a species (or a population) alive at a particular time is called the ***gene pool***.



Gene Pool

? QUESTION

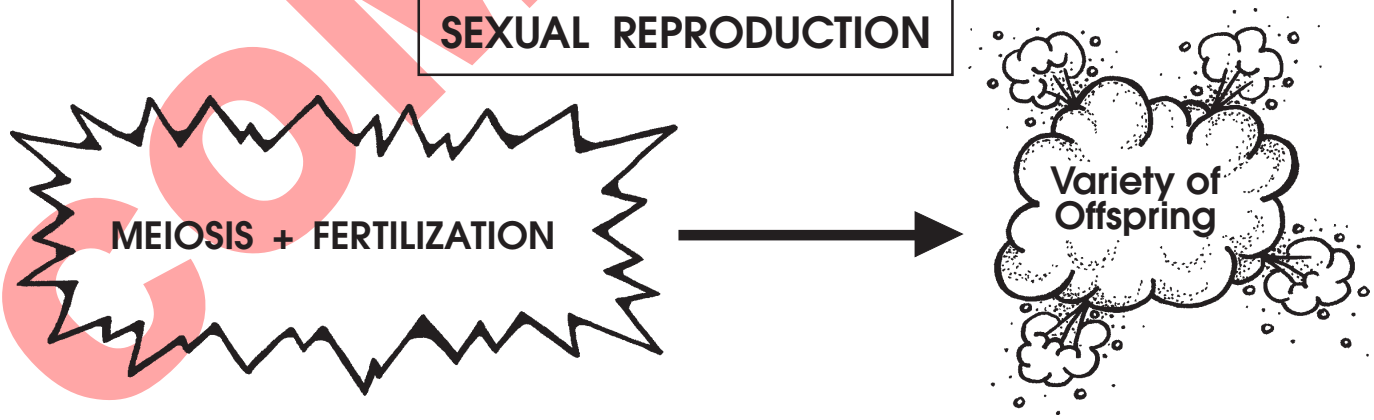
1. What is the difference between a *gene* and an *allele*?

2. Assume that a particular human gene is 100 nucleotides long. How many different variations of this gene are possible? (circle your choice)

- **a.** less than 100
- **b.** two or three hundred
- **c.** many thousands

3. Define *gene pool*.

SEXUAL REPRODUCTION



Certain events during sexual reproduction increase the genetic combinations of alleles in a species. ***Crossing-over*** recombines chromosomes into new mixes of alleles. ***Independent assortment*** creates variety in combinations of maternal and paternal chromosomes that are then segregated into separate gametes. ***Random fertilization*** further increases the mixing of alleles from one generation to the next. Review Activities #6 and #7 in "Sameness and Variety" if you have difficulty remembering the general events that take place during sexual reproduction.

? QUESTION

1. What process makes it impossible for all genes to remain unchanged from generation to generation in a species?

2. What process makes it impossible for any one chromosome to be passed on to the next generation with exactly the same set of alleles?

3. You received 23 chromosomes from your mother and 23 chromosomes from your father. What process during meiosis makes it nearly impossible for you to pass on all of those chromosomes to your children?

4. If you don't reproduce, do your genes get passed on to the next generation?

5. Is it possible for one generation of humans to pass on all of its alleles in exactly the same form and frequency (percent) to the next generation?

MICRO-EVOLUTION

Evolution in its smallest scale is called ***micro-evolution***. It is a change in the *frequency* of alleles in the gene pool over time. You should have concluded from the previous questions that it is impossible for the gene pool *not* to change over time. Therefore, genetic change (the most specific definition of evolution) does happen—there is no question about it. Two aspects of evolution that should be considered are: "How fast can it happen?" and "How much change can it create?"

? QUESTION

1. Define *micro-evolution.*

2. From a scientific point of view, what is the one question about evolution that is no longer considered appropriate in an argument?

3. From a scientific point of view, what are two questions about evolution that are appropriate to ask?

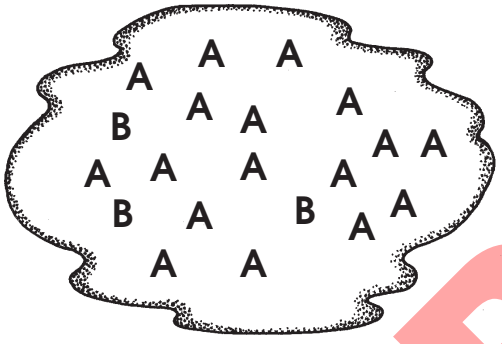
ACTIVITY #2

"HOW FAST CAN EVOLUTION HAPPEN?"

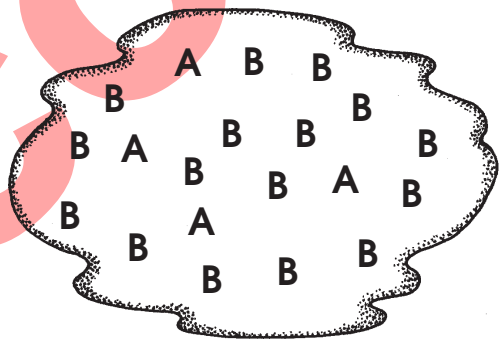
You learned in Activity #1 that genetic change over time is inevitable. In this Activity you will examine several easy-to-understand events that increase the rate of genetic change in a population. (Your textbook and lecture will spend time discussing more complicated factors related to the rate of micro-evolution.)

MIGRATION

Migration is a simple example of how micro-evolution can happen rapidly in a population. We can represent this situation with two alleles (A and B) of a gene that exists in a species. Assume that the population in one region has a higher frequency of the "A" allele, and in another region there is a higher frequency of the "B" allele.

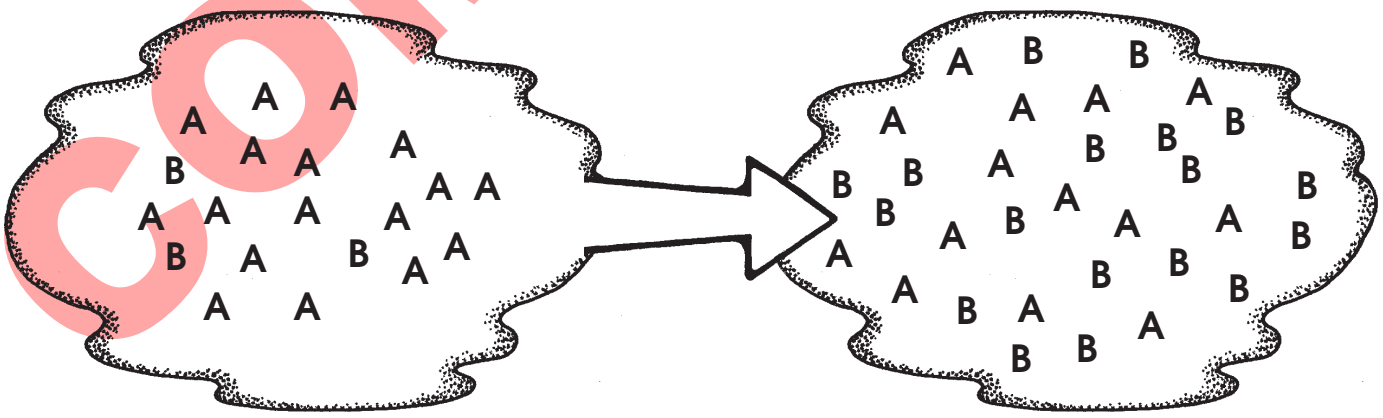


Population of Region 1
(85% have "A" allele).



Population of Region 2
(20% have "A" allele).

Now assume that there is a large migration of organisms from Region 1 into Region 2.



The frequency of alleles changes in Region 2. This change in the gene pool of Region 2 is micro-evolution, and it is a simple example of how genetic change happens on our planet.

? QUESTION

1. List some modern examples of micro-evolution created by human migration.

2. Describe a situation in which organisms in one region would suddenly be able to migrate into a new region.

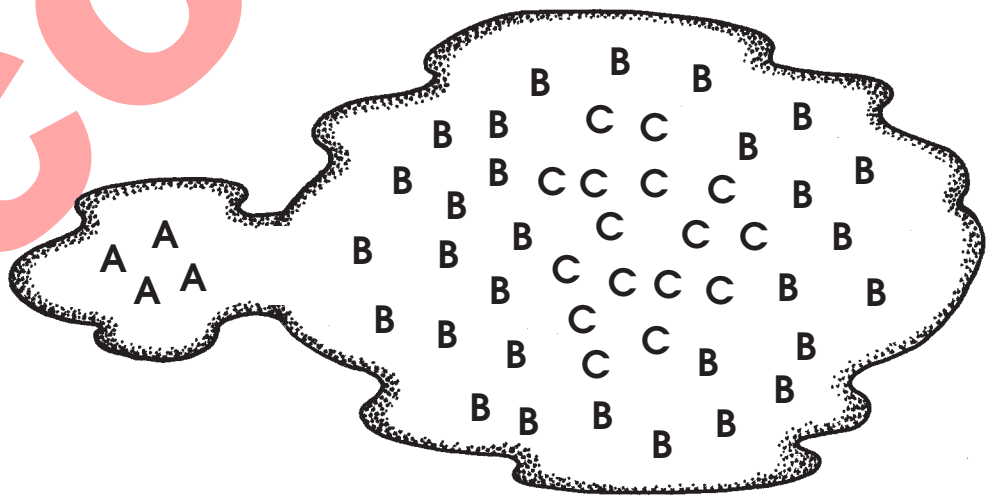
LUCK

In this example, assume there are three alleles for a particular gene in a species.

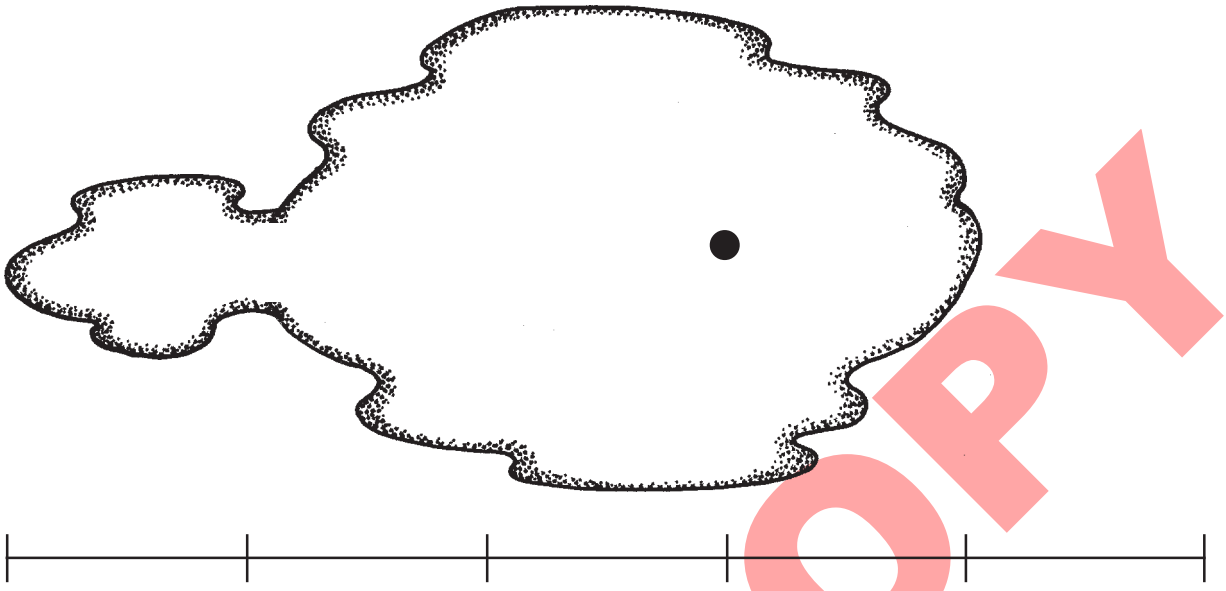
Allele "A" is a real "clunker," and organisms with it survive and reproduce, but don't compete well against allele "B." Only a few of them live along the edge of the distribution of this species.

Allele "B" produces a trait that works well for the species, and has been the most common allele for thousands of years.

Allele "C" is a newly evolved mutation, and has been doing fantastically well for the last 100 years. This allele has produced the "best" animal of this species to ever have been on the planet.



Scenario: An asteroid is heading for the earth and scientists have calculated it will hit at the black spot. All life in the area will be vaporized for 500 miles in every direction from the impact point.



Species Habitat—250 Mile Segments

? QUESTION

1. Draw the asteroid zone of destruction on the species habitat map.

2. Which allele will be passed on to future generations?

3. Did the "best" allele survive?

4. Did the most common allele survive?

5. Which allele had the "good luck"?

6. Does this event represent micro-evolution?

7. Does the idea of "survival of the fittest" explain this example of micro-evolution?

8. How would disasters like fire and flood speed micro-evolution?

SMALL GROUP PHENOMENON

Change can be fast and the direction of change is by chance when small groups are involved. Small groups do not necessarily represent the same percent of alleles found in the total species. *Think about it!* If 30 people got in a boat tomorrow and sailed away to a distant island and started a new population, there is no way that all of the existing human alleles would be in that boat. Furthermore, compared to the total species, it is very likely that there will be a significant difference in the frequencies of alleles that get in the boat (perhaps several red-haired families). The future generations of people on that faraway island won't be like the original group. Micro-evolution occurred because of the ***small group phenomenon***.

Whenever small groups survive a catastrophe, or a small group migrates to a new region and starts another population, there will be genetic change. Evidence suggests that this type of micro-evolution may be much more common than biologists of a century ago thought.

? QUESTION

1. How does the small group phenomenon lead to fast changes in the gene pool?

2. How could natural disasters like fires and floods influence evolution?

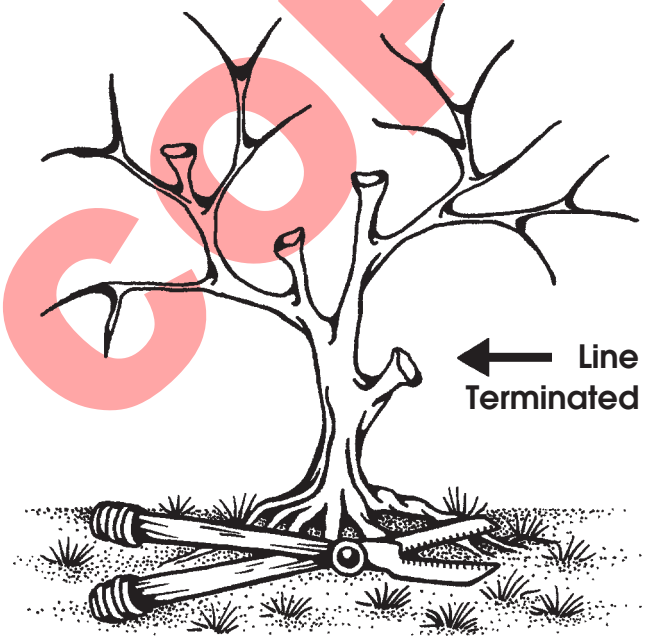
3. What would you expect organisms to look like that live on islands compared to those of the same species living on the mainland?

NATURAL SELECTION

Natural selection occurs when some particular aspect of the environment causes organisms with certain alleles to survive better and reproduce more than organisms with other alleles. It is the situation in which "survival of the fittest" applies. Review the last section of Activity #3 in "Genes and Protein Synthesis." This section covers the natural selection of grasshoppers in different soil habitats.

There are two very important aspects about natural selection that you should remember. First, it does not create new alleles. Mutation does that! Natural selection only changes the frequencies of alleles already existing in the gene pool. Second, there is no "one direction" for natural selection. In the grasshopper scenario, brown alleles do better in areas of brown soil. In areas of red soil, red alleles do better.

Genetic change in the gene pool of a species can be visualized as a young growing bush. Mutation creates many new branches of variety. Some of those branches are pruned back by natural selection, migration, small group phenomenon, or just bad luck. The remaining branches of variety continue to reproduce, and more variety is added to them by new mutations. This process repeats over and over through the eons of time.



? QUESTION

1. Define *natural selection*.

2. Does natural selection create new alleles in the gene pool?

3. How is natural selection different from the small group phenomenon?

4. Is there one direction to natural selection? Explain.

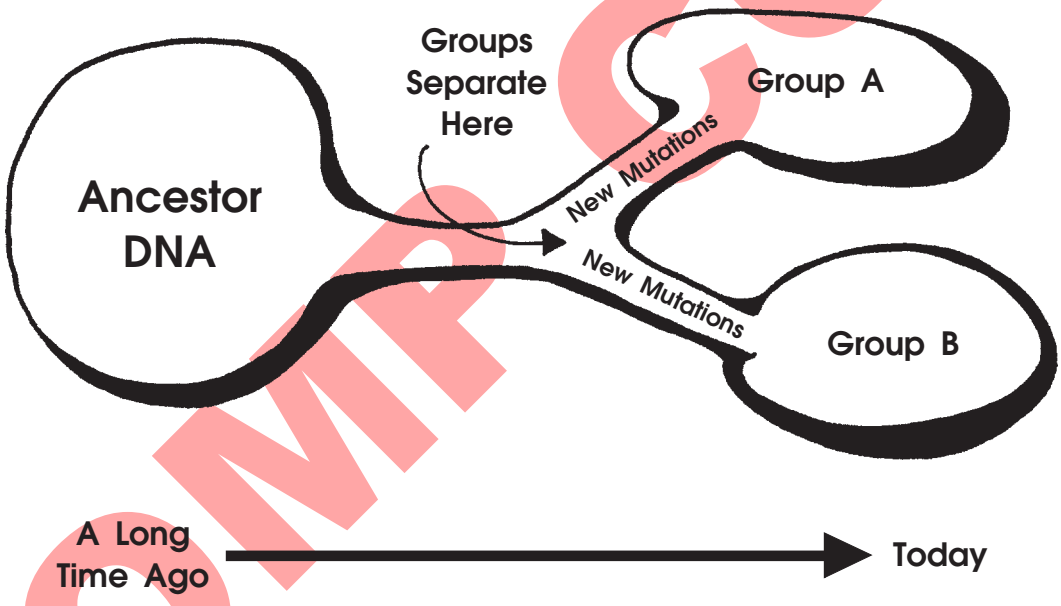
ACTIVITY #3

"EVOLUTION OF ONE SPECIES INTO TWO SPECIES"

Genetic change is created by random mutations and factors that increase or decrease the frequencies of alleles in future generations. The key to understanding the evolution of one species into many species is the event of ***separation***. If two groups become separated, each will change over time, but they will not change in exactly the same way.

GENETIC CONSEQUENCES OF SEPARATION

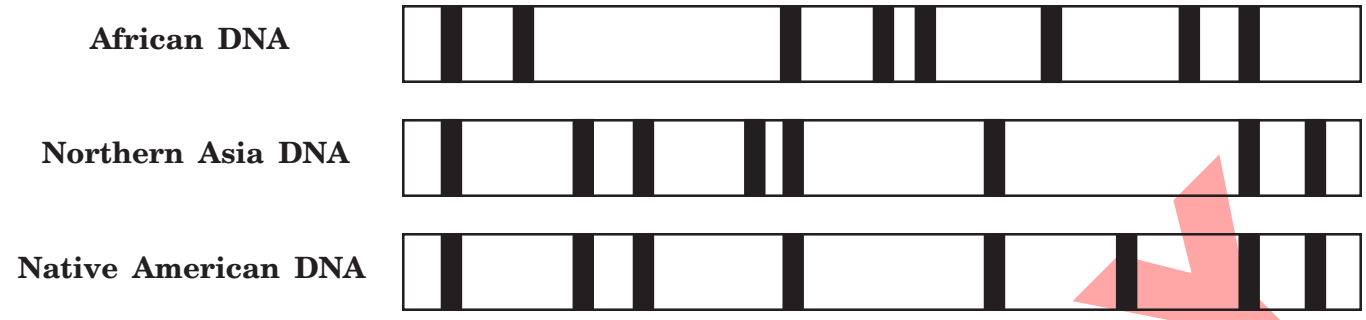
When the organisms of a species live together, they mate, exchanging and blending their genes over many generations. What happens if one group splits into two separate groups and they migrate far away from each other, never having a chance to interbreed again? As you would expect, the two groups no longer mix their genes or their mutations, and over time they will begin to look somewhat different from each other.



By comparing DNA patterns, chemists can detect the new mutations that have been added to the DNA. If an ancestral group splits into two groups, then both groups will begin to accumulate different mutations from each other. Each group is genetically separated from the other group when they no longer interbreed.

The easiest way to show that two groups have separated in the past is to count the number of new mutations found in the DNA of one group and not found in the DNA of the other group. The greater the number of new mutations, the longer the time span that the two groups have been separated. If however, the DNA of the two groups is quite similar, then the groups have not been separated for very long.

Diagramed below is a comparison of the DNA of three geographically separate human racial groups. Each bar represents a mutation.



? QUESTION

1. Which two groups are the most similar?

2. Which of the three groups is the most different from the other two groups?

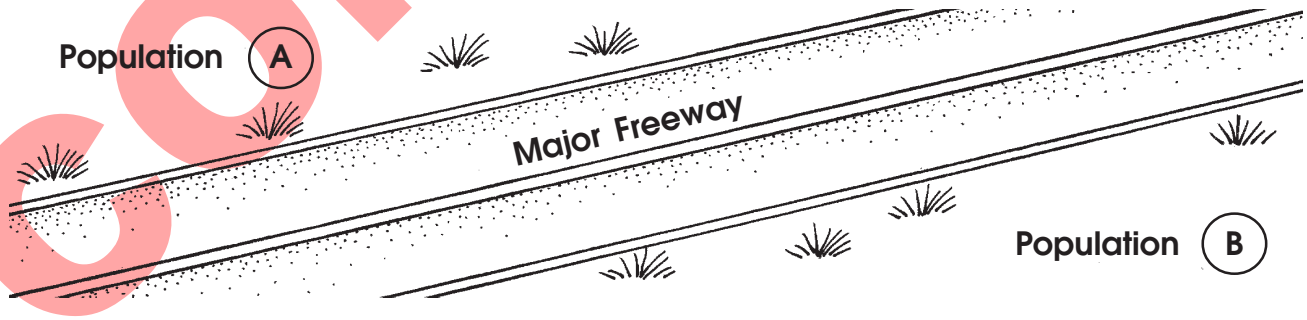
3. Which group has been separated from the others for the longest time?

4. Which of the two groups haven't been separated from each other for very long?

EVENTS THAT CAUSE SEPARATION

Your textbook and lecture will present several different situations that lead to genetic separation of two populations. One of the situations is created by changes in the geography. ***Geographical separation*** leads to genetically isolated populations and eventually to different species.

MOUNTAINS, RIVERS, AND HIGHWAYS

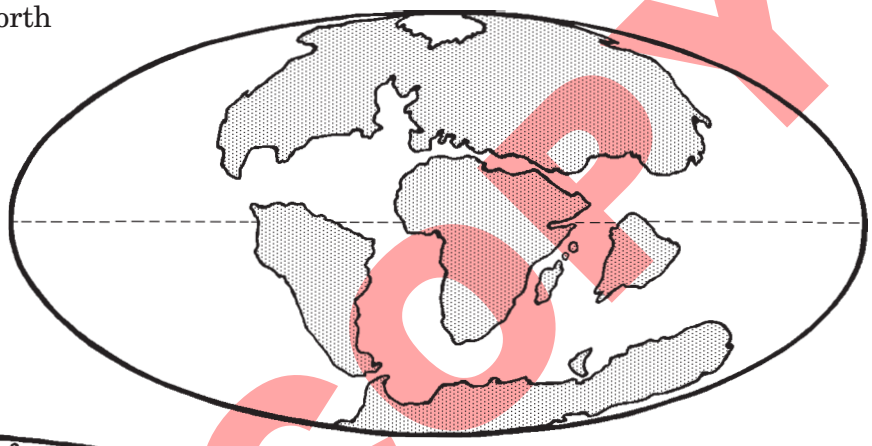


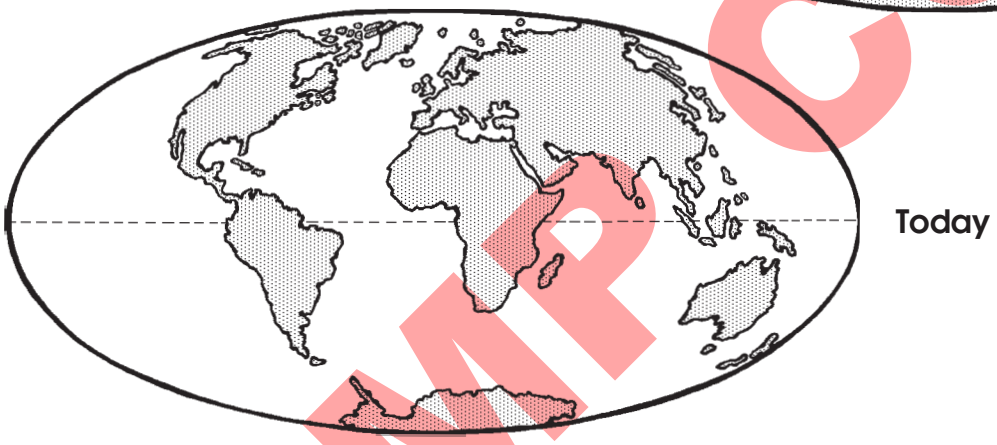
Graduate students at the local college studied the mouse populations around campus and in the neighboring communities on the opposite side of a major freeway. White-faced mice, purchased for physiological and behavioral studies, routinely escaped from the lab and became part of the campus population of wild mice. For years, the students sampled the neighboring communities across the freeway, but no white-face varieties were collected. The freeway acted as a geographical barrier between the two mouse populations.

The college mouse story is a fun example of small scale isolation, but many studies have been done on populations separated by rivers and mountain ranges. These investigations demonstrate that geographical separation leads to new species. For example, the squirrels on the north and south sides of the Grand Canyon are separate species now. Separation leads to ***speciation***.

DRIFTING CONTINENTS—PLATE TECTONICS

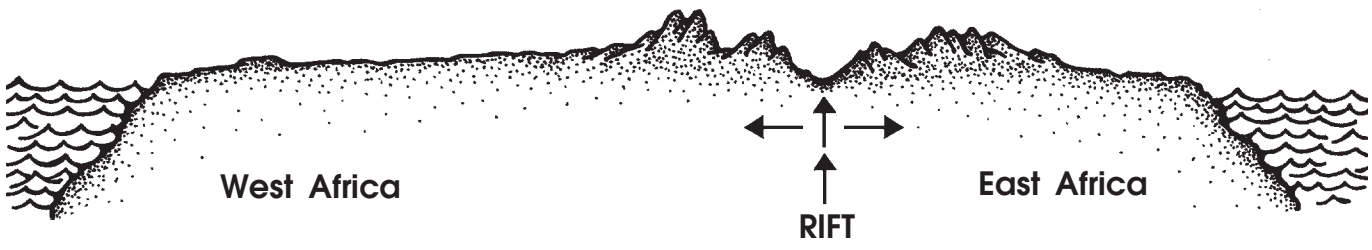
Sometimes geological processes create major opportunities for new speciation. North America and Europe were once connected, but following their separation, the species on each continent changed in different directions. Today, many species on both sides of the Atlantic are related, but each has evolved new traits that make them separate species.





THE AFRICAN EAST-SIDE/WEST-SIDE STORY

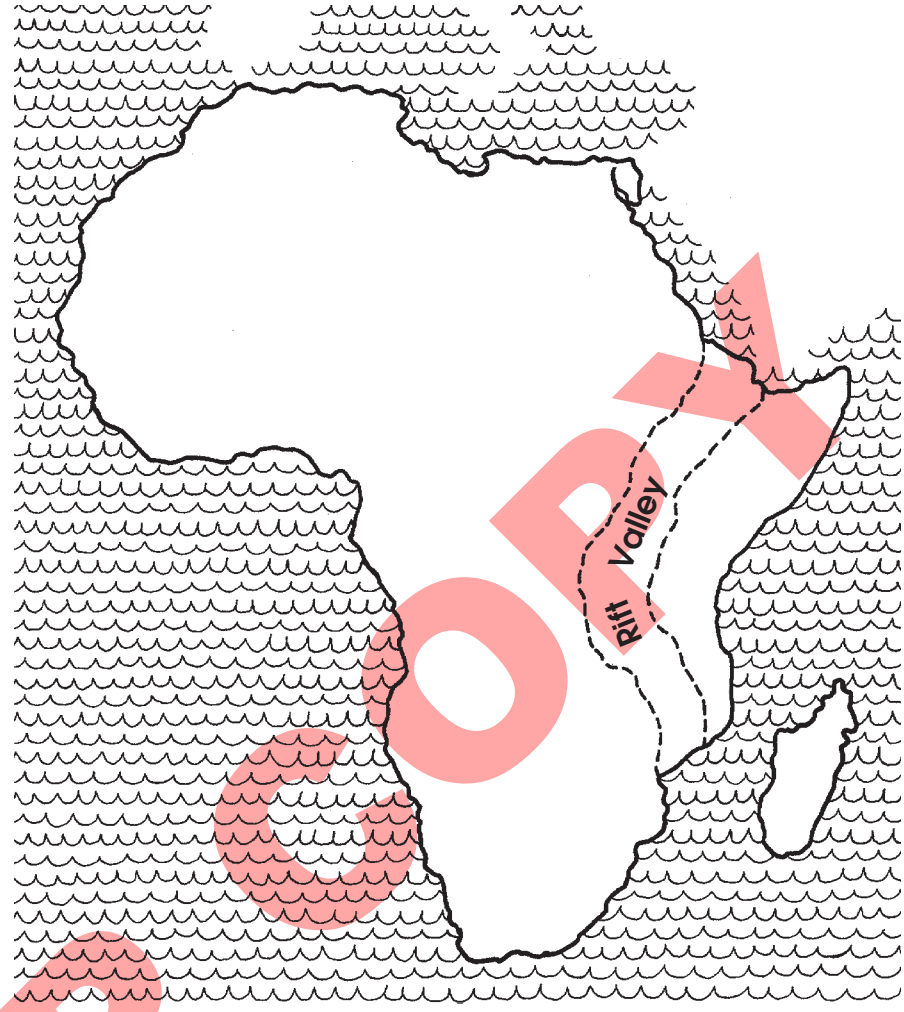
A fascinating geological separation event occurred in Africa starting about 8 million years ago. As a result of plate tectonics, a large rift valley and a high mountain range formed, separating East Africa from West Africa. By about 4–5 million years ago, East African fossils of elephants, antelope, rhinoceros, and other animals showed clear adaptations to a drier environment. East Africa was becoming drier, while West Africa remained wet as it is today.



The earliest hominids—the *Australopithecines*—appear only in the fossil record of East Africa. None of these fossils have been found in West Africa. It is as if the two worlds were separated by the rift valley.

Genus *Pan* evolved in West Africa, and led to today's chimpanzee.

Genus *Homo* evolved in East Africa. (Apparently we are the kids from the east side of the tracks.)



? QUESTION

1. List five geographical changes that could lead to genetic isolation of populations.

   a.

   b.

   c.

   d.

   e.

2. How long would it take for micro-evolution to begin changing geographically separated groups of a species?

3. How much change is required before there would be two distinct species?

4. Explain how the geographical separation of primates in Africa could have led to two separate lines—chimp and human.

ACTIVITY #4

"THE ROLE OF MASS EXTINCTIONS"

UTA'S STORY

Ngoma poked at the curious rock that had been split open by the heat of the fire. Quickly Uta's hands jabbed at a piece until it was positioned near the edge of the cooking pit. Then, she scooped it up and tossed it into the clay water crock where it sizzled and cooled. After a few minutes she removed the rock and held it up to the fire's light. She had seen this rock before in a distant place near the edge of a quiet bay with her fisherman father. Tonight, the story was hers.

Uta pointed at the large mushroom shape contained in the rock. The edge of her nail traced each of the inner layers of the mushroom shape. With the flames reflected in her eyes she began her tale.

"This rock is long dead! There are rocks like these today that are alive at a place where my father and I go to fish." She paused. "Each layer is a different age, like the rings of a tree. The parts towards the center are the oldest, and each new layer grew over the top of the inner layers."

Masango and Ngoma looked at each other enthusiastically. This would be a great night! Uta was telling another one of her astounding stories.

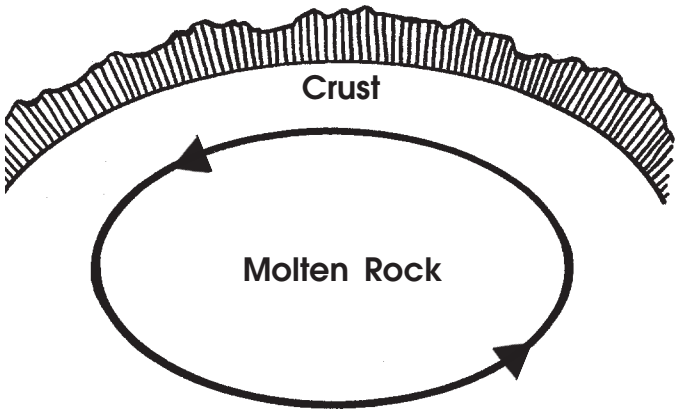
THE SCIENTIFIC ACCOUNT

Uta's story, as far as we have told it, agrees with modern scientific research. These same layered rocks have been found by scientists, and are part of the fabric of a new story emerging from the fields of geology, archeology, and biology. The scientific account tells of creation itself, fantastic life-forms, mass extinction, opportunities gained, and opportunities lost. A textbook would be required to summarize the many known details of the history of life, but we can consider the general facts.

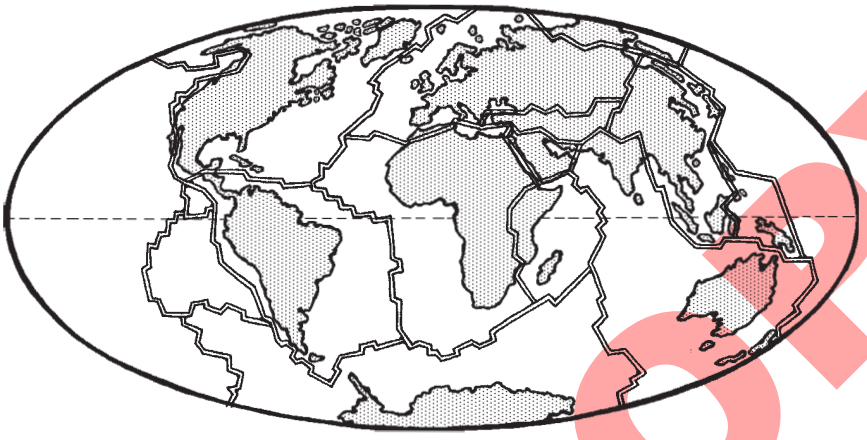
Science has discovered that life has been shaped by many processes. Four of these processes include: 1) plate tectonics, 2) impacts by objects from outer space, 3) new species evolving and destroying previously existing species, and 4) the destruction of habitats by modern humans.

PLATE TECTONICS

The interior of the earth is extremely hot. This heat is generated by various chemical and physical processes that are not completely understood today. Heat maintains a cycle of molten rock moving slowly beneath the earth's crust. (If you have ever watched fudge slowly boiling, then you have the general idea.)



Currents of molten rock affect the crust in two important ways. First, molten rock rises to the surface through cracks in the earth's crust. This continually adds new material to the surface of the planet. Second, the cracks break the crust into pieces, called ***plates***, that are moved around by the currents of molten rock beneath them. The movements of the earth's plates is called ***plate tectonics***. It has been a very important factor in the history of life. Plate tectonics makes, destroys, and moves continents around the surface of the planet.

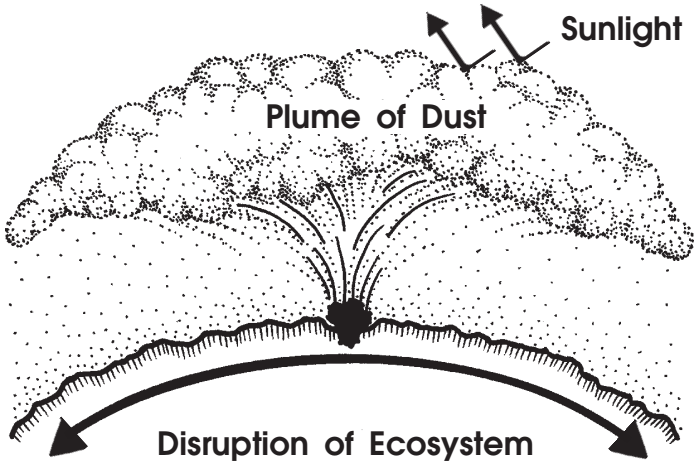


The location of a continent determines its climate. If a continent moves, then the environment will change for the organisms living there. When continents are scattered as smaller chunks of land, or are clumped in a large land mass (such as Pangaea of 240 million years ago), the weather conditions are profoundly different for life on land. If a continent drifts over a pole, then glaciation will occur and the sea level will drop, which transforms the environment for life at the edge of the seas. More details about the effects of plate tectonics are discussed later in this Activity.

IMPACTS FROM OUTER SPACE

The evidence for asteroid impacts as a force for mass extinction comes from the discovery of the element ***iridium*** in layers of sediment found in rocks. Iridium is a heavy metal that occurs naturally deep in our planet's interior, where it sank from the surface when the earth was forming. In other words, we would not expect to find any of this element near the surface of the planet. However, iridium is one of the metals found in asteroids moving around in outer space. When an asteroid impacts the earth, its mass and iridium is vaporized and scattered as dust in a thin layer around the impact zone.

Impacts from asteroids or comets explode huge amounts of earth into the atmosphere, and the resulting atmospheric plume blocks much of the sunlight. In addition, there is evidence that large impacts can trigger ongoing volcanic activity for a period of time. The resulting darkness drastically shuts down the world ecosystem, and can create a mass extinction. This type of extinction closes the door of opportunity for some species, but opens it for others.



? QUESTION

1. What force moves the crust plates across the surface of the earth?

2. How does plate tectonics influence the history of life?

3. What specific evidence suggests that an asteroid impact has occurred in the past?

4. How is an asteroid impact catastrophic to life?

IN THE BEGINNING

The dream world of humans has created thousands of stories about the origin of life. These are fascinating tales, but little of what they say is testable from a scientific perspective. Although science cannot provide all of the details of how life began, a general understanding has emerged that is supported by a growing record of scientific evidence.

The first life on earth evolved in an environment without oxygen. There was no oxygen in the air because it had combined with other elements like hydrogen, nitrogen, and carbon to form molecules. This meant that early lifeforms had to gain their energy from a type of metabolism that did not require oxygen. The oldest fossils are found in rocks nearly 4 billion years old. These fossils were originally living mats of bacteria, and look somewhat similar to the stromatolites discussed later. The fossilized bacteria also look similar to the anaerobic bacteria we find in today's world. Two contemporary types of anaerobic bacteria are called iron bacteria and sulfur bacteria. These are examples of organisms that can derive energy by metabolizing minerals. They do not require oxygen. Simple ***anaerobic bacteria*** are proof that life really can exist in an environment similar to that of the early earth.

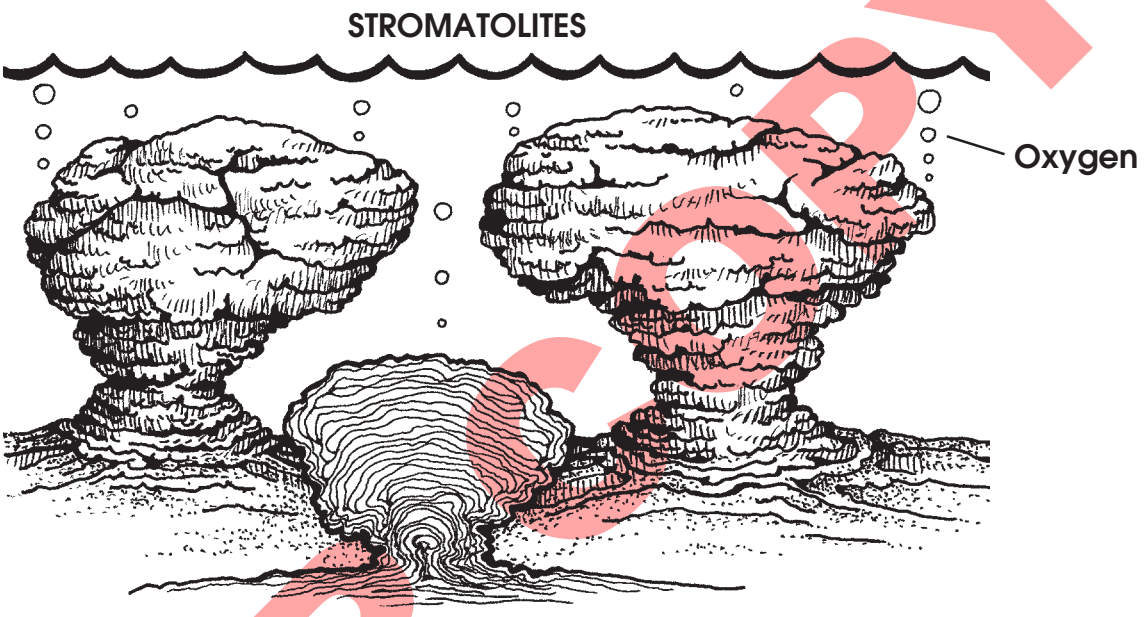
Some questions arise. If anaerobic bacteria were the first lifeforms, then why aren't they the only type of organism on the planet now? And, where did the oxygen in our atmosphere come from?

The answer to these questions is one of the first big lessons of life: ***Somebody else can put you out of business***! In biology, we call this extinction.

Let's finish Uta's story of the mushroom rocks.

UTA'S ROCKS

Anaerobic bacteria had this planet to themselves for a billion or more years. Then, about 3 billion years ago new kinds of organisms evolved in the shallow seas. These colonial micro-organisms produced rocklike deposits. They included two new types of bacteria called ***cyanobacteria*** and ***aerobic bacteria***. The cyanobacteria produced oxygen gas during their biochemistry, and aerobic bacteria used oxygen during theirs. These bacteria grew in layers. Each new generation covered the previous one, eventually forming a large mushroom-shaped deposit that we call a ***stromatolite***.



Once the stromatolites appeared, the anaerobic bacteria began to disappear from the fossil record. These "newcomer" stromatolites changed the world. The cyanobacteria transformed the atmosphere by using a kind of energy-trapping process called ***photosynthesis***. Photosynthesis produces oxygen, a substance that is *poisonous* to anaerobic life. This new gas killed all the early anaerobic life-forms except those living in areas of the planet where oxygen gas could not reach. The anaerobes were restricted to these limited habitats. Today we can still find these very old types of anaerobic bacteria (called archaebacteria) in the black mud of swamps, in salt marshes, and in volcanic hot springs. These smelly, hot places might seem disgusting to us, but they are a paradise for anaerobes. To the anaerobes, the whole planet was once a wonderful smelly place—until stromatolites evolved.

As stromatolites oxygenated the world, they changed it. They covered the floor of shallow seas until about one billion years ago. Then another new group, the ***invertebrates***, evolved. These multicellular animals became very diverse and included some that ate stromatolites. What the stromatolites did to the anaerobes was done to them by the invertebrates, and today there are only a few places where stromatolites can exist. We find them in isolated salty bays where they are protected from the appetites of invertebrate predators. This is the scientific story of Uta's rocks—alive for billions of years, and still living reminders of a previous chapter in life's long history.

? QUESTION

1. What were the first organisms and where do they live today?

2. There was an almost complete extinction of anaerobes about 3 billion years ago. What gas in the atmosphere was responsible for their extinction?

What biological process produced that gas?

Which organisms evolved that process?

3. How do stromatolites form, and what two groups of bacteria are part of their formation?

4. There was an almost complete extinction of stromatolites between 500 and 700 million years ago. Which group of organisms was responsible for eating stromatolites and out-competing them?

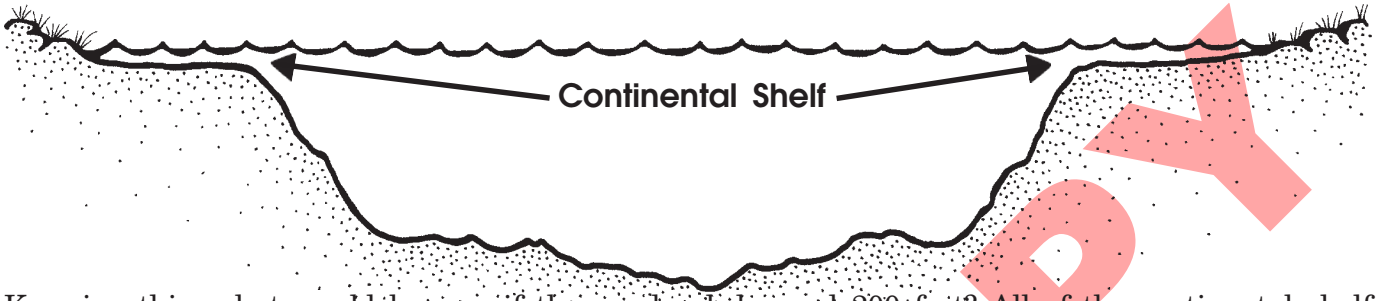
Where can living stromatolites be found today?

GLACIATION AND SEA LEVEL

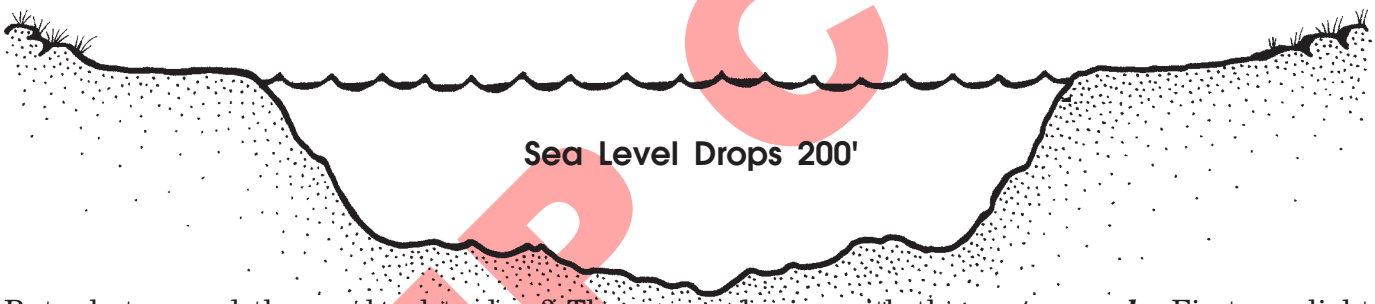
When thinking of life in the ancient seas, we usually visualize sharks and fish. But those early seas were filled with organisms far beyond our imaginations. Again, the history of life is best told by examining the fossil record. Invertebrate animals first evolved as very simple creatures somewhat like today's sponges and jellyfish. By about one-half billion years ago they blossomed into many varieties and bizarre forms. They shared the seas with a strange chordate group, the ***jawless fish***. One hundred million years later, a few ***cartilage fish*** and ***bony fish*** evolved. They were now the newcomers. Millions of species lived in the rich continental shelf zone. Today there are only a few jawless fish, and many of the early invertebrates are gone. What happened to them?

A big evolutionary event occurred ***370 million years ago*** that created a mass extinction of many invertebrate species and most of the jawless fish. Following this event we find new creatures in the fossil record—early types of amphibians. What could cause trouble for invertebrate sea life and jawless fish, yet open up opportunities for amphibians? Here we get some help from geologists. The oceans of the world are shaped like deep bowls with thin shallow rims. These rims are actually 200 feet below water and are called the ***continental shelves***. Ocean life is concentrated in the

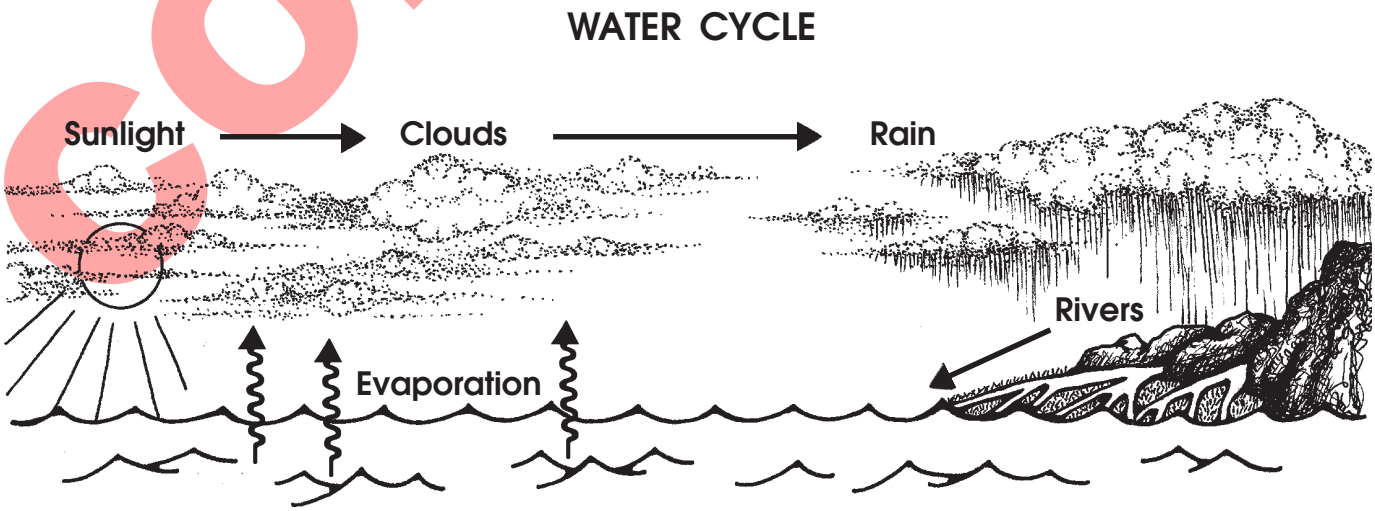
continental shelf waters. The shelf zone is the richest nutrient area in the oceans because ocean currents and runoff water from land constantly stir the bottom sediments. These two processes increase the availability of inorganic minerals that are necessary for photosynthesis. High nutrient levels are resources for plants—the basis of the food chain.



Knowing this, what would happen if the sea level dropped 200 feet? All of the continental shelf zone would be exposed, and the species that depended on food from those waters would vanish. This did happen. As the continental shelf habitat was eliminated, many marine species died out, and a new environment was left behind for the remaining groups.



But what caused the sea level to drop? The answer begins with the ***water cycle***. First, sunlight evaporates water from the oceans forming large clouds. Next, those clouds rain somewhere on the planet. This rain creates rivers that eventually return to the sea, and the cycle repeats.

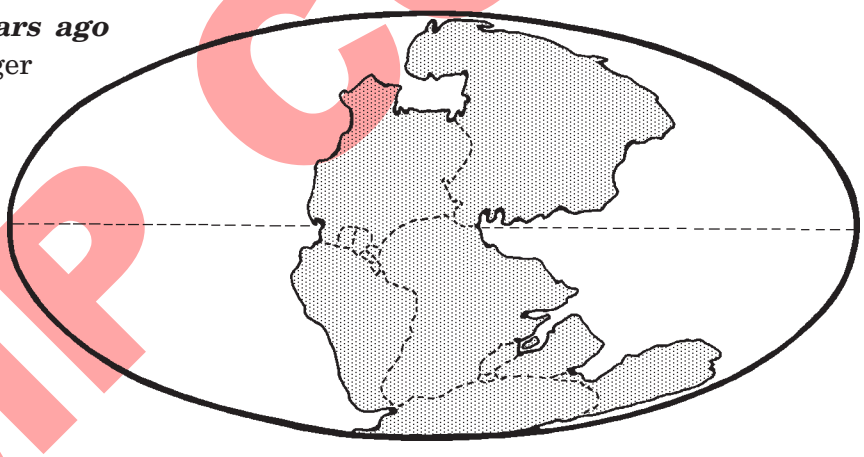


Now, consider how the position of continents might affect sea level. Modern geology has learned that geological forces constantly form and move continents. In this planet's history, continents were sometimes small and scattered, and at other times continents were crunched together into bigger pieces. About 370 million years ago a large continental mass drifted into position over the South Pole. Before then, the winter snow fell into the ocean and quickly melted. With a continent over the South Pole, the snow fell onto land and did not melt. The snow piled up forming huge ***glaciers***. This interrupted the water cycle. (If water doesn't return to the ocean, then the sea level will drop by an amount equal to the mass of the glacier.) This is the probable explanation for the lowering of the sea level that caused the extinction.

However, what was bad for invertebrates and jawless fish was a great opportunity for whomever was left behind. The surviving groups included some of the ***cartilage*** and ***bony fish***, from which many new species evolved. One group that adapted to the slowly changing conditions was an air-breathing fish with simple limbs. We call them ***early amphibians***. Amphibians were to have the stranded pockets of isolated lakes and shallow seas to themselves until the next big calamity on the planet.

PANGAEA—THE BIGGEST DESERT THAT EVER WAS

The amphibians of ***240 million years ago*** were challenged by a continent bigger and drier than anything in our modern experience. Geologists call this mega-continent ***Pangaea***. Pangaea formed as land masses drifted and merged together from the forces of plate tectonics. Compared to the comforts of the swamps, this land was hot!



When continents are small and surrounded by water, the rain clouds can reach most of the land and the environment is moderate. The smaller, scattered continents before 240 million years ago were suitable for early land vertebrates like amphibians. But, Pangaea was a huge land mass. Most of it was far from the ocean and the rain clouds. This supercontinent was the largest dry land environment that we know of in the last half-billion years of the Earth's geologic history.

The change from small swampy continents into one huge mass of dry land produced the first big land extinction during which ninety-five percent of the land animals were eliminated. All of the larger amphibians died. But, a newer group survived—one that had dry skin and a different method of reproduction. These animals could mate and raise their young on dry land. The new traits evolved from the old traits of the amphibians, and produced what we call a ***reptile***. The innovation was so profound for land habitats, and the opportunities for reptiles on dry land were so great, that every new species flourished.

With this new game, it seemed as if nothing could go wrong—well almost nothing—unless you are unfortunate enough to be hit by a ten–mile-diameter rock traveling at 150,000 miles an hour.

? QUESTION

1. About 370 million years ago an extinction of jawless fish and many invertebrate species occurred. Explain how this extinction happened. (Include in your discussion continental movements, glaciation, the water cycle, and sea level.)

2. Which group evolved and flourished in the new environment provided by the receding seas?

3. Does the sea level have to drop thousands of feet before sea life is affected? Explain.

4. Another extinction event (95% of known species) occurred about 240 million years ago. This is considered to be the first big land extinction. Explain how this event was created by continental movements, weather patterns, and reduced shorelines.

5. What name is given to the supercontinent of 240 million years ago?

6. Which animal group was almost exterminated by the reduction of swampy environments?

7. Which new animal group greatly benefited from the large amount of available dry land on the planet and the drastic reduction of competitors?

BAD TIMES FOR REPTILES

We know that many asteroids have struck our planet during its history, including one at about ***210 million years ago***. The crater made by this impact is located in eastern Quebec, Canada. It measures nearly 50 miles across. The crater has been dated near the time that an extinction event occurred for many of the early reptiles.

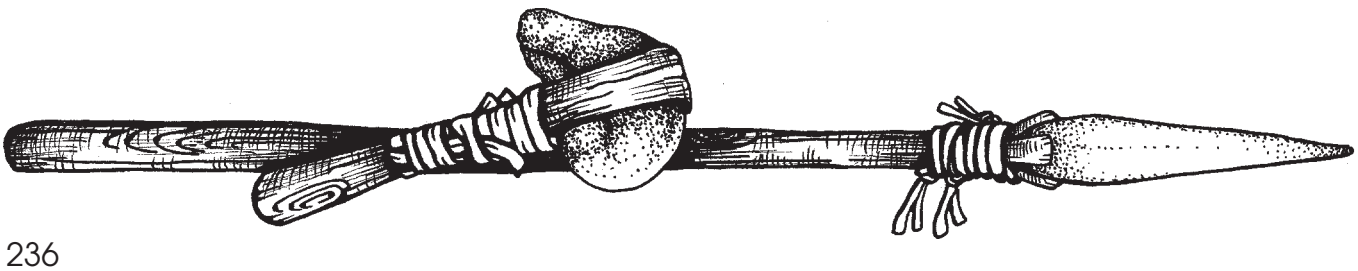
So, approximately 30 million years after the opportunity first developed for reptiles, about 60% of them became extinct. The reptiles that remained alive after this extinction would have the next big opportunity. Several groups, including crocodile, turtle, and snake-lizard types, remain until today. But, the first group to flourish were the predecessors of the ***dinosaurs***, and dinosaurs did very well indeed. There was every type and every size of dinosaur that you could imagine during their 150-million-year dynasty. But, their days of being the dominant land vertebrate were numbered.

Scientists now have evidence that about ***65 million years ago***, a huge object from outer space hit the earth. Preliminary evaluation of the evidence suggests that the dinosaur extinction was partly caused by the impact. Whether the object was a comet or an asteroid, there is a one-hundred–mile-diameter crater at the tip of the Yucatan Peninsula dated near the time of this extinction. An impact that large would create total destruction within at least 1,000 miles from ground zero. In addition, several thousand cubic miles of vaporized rock would be carried into the atmosphere, blocking sunlight and photosynthesis for months or longer. During this dark time the world's ecosystem was radically interrupted, destroying many species. Dinosaurs and about 75% of all marine species were eliminated near the time of this asteroid impact. Many of these species were instantly extincted, while others died out during the years that followed.

As with previous extinctions, whatever species survived had a special opportunity for new evolutionary experiments. Almost anything will work when there are few competitors. The next two successful land groups that flourished were ***mammals*** and ***birds***. From 65 million years ago until today, these two groups and the ***flowering plants*** have taken advantage of the land environments.

HUMAN HUNTERS

The previous examples are large-scale events that have radically affected the evolution of life. Fossil evidence also suggests that thousands of ***small-scale extinctions*** have happened on this planet. One such small-scale extinction of large mammals about 20,000 years ago followed the migration of humans from the Eastern Hemisphere into the Western Hemisphere. Hunting artifacts are dated at the same time that a dozen or so large mammal species disappeared. This type of extinction occurs whenever a new species moves into a region where there is easy prey. This is also an example of how much impact one successful species can have on another species, and serves as a warning to us concerning our destructive actions of today.



HABITAT DESTRUCTION

The most recent extinctions have been caused by humans eliminating the natural habitats of other species. When habitats are destroyed, the species that depend on those habitats are destroyed. This process is occurring at an alarming rate wherever there are dense populations of humans in or near geographically smaller or isolated habitats. One example is islands. But there are many small and strange habitats and associated species around the world that are vulnerable to human development..

Today there is an even faster rate of extinction occurring in the tropical rain forests of the world. These are the richest ecosystems that exist on land. Experts think that many species become extinct daily in these special forests. Rain forests are being cleared and burned for their wood, to grow crops, and to graze cattle. These ventures usually destroy the fragile top soil within a few years, and all benefit is lost for indigenous people as well as for the world ecosystem.

? QUESTION

1. Explain how the presence of the element iridium in sediment is related to asteroid impacts.

2. About 210 million years ago, an asteroid or meteorite hit the earth (perhaps creating the crater in Quebec), and about 60% of the existing species became extinct. Many early reptiles were eliminated, which allowed one of them the opportunity to become very successful. What group was that?

3. Explain how asteroid impacts can cause extinctions.

4. Another asteroid hit the planet (perhaps creating the crater in Yucatan) about 66 million years ago. Which reptile group was eliminated?

Which two vertebrate groups benefited from the reduction of reptilian competitors?

a.

b.

5. What caused the extinction of most of the large mammal species in the Western Hemisphere?

6. What specific change accounts for today's rapid rate of species extinction?

SUMMARY

Science has discovered some of the truths about the history of life. This short story covers only a partial description of all we know and suspect. The example events we have discussed include:

- an organism changing the environment for every other species on the planet,
- a new group of organisms that eats and eliminates other species,
- glaciation and the lowering of sea levels,
- what happens when swamps dry up,
- impacts by asteroids and comets,
- the effects of early human hunters, and
- the destruction of ecosystems and habitats by humans today.

What once began as exciting stories around the fire pit has expanded into a more complete understanding of Earth's history. Now, the challenge for humanity is to find a balance—to limit reproduction rates and develop lifestyles that are not as damaging to ourselves and other species. If we don't, the planet will continue to experience major changes in evolution because of us. And the new direction that evolution takes could cause serious problems for humans—even our own decline, possibly our extinction.