

MORNING EARTH



Yearning To Be Round

All Lives Transform

7. Transformation in Geologic Time Scale: Evolution

Note: For a graphics-rich treatment of this material, go [Here](#).

Introduction

The forms of species change over enormously long periods of time in the process called **Evolution**.

Co-evolution is the process in which species slowly transform together in natural communities toward a mutual "fit". Our new knowledge of ecology is teaching us to become aware that

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nature is usually cooperative, in spite of our cultural affection for competition.

Variation Within Species

One main key to evolution is variation. Variation is difference.

Within populations of each species, there are thousands of small differences. The young of all species have small differences among them.

In humans, we cherish those differences because they make us individuals.

Generally, each living organism is an individual, not quite like any other member of its kind. The exception, of course, are clones, in most cases among some kinds of insects and lizards, as well as trees such as aspen. Cloning is an ancient strategy of Earthlife, not unusual among plants and fungi, as well as animals. Many lizards seem to have the ability to reproduce parthenogenetically (only mom, no pop), but they don't seem to express the ability unless there are no males to be found (as in a zoo, for example, as recently occurred with a Komodo dragon).

The many little differences within a species are what make it possible for the offspring of that species to change in response to changing conditions in its environment.

- For every species, differences give a survival advantage.
- For our human species, diversity is strength.

Variation is “hard-wired” into all living things.

The key to survival is difference.

Without the continual flowering of difference (or variation) a species will not last. It will die out (go extinct).

Biological variation, or difference, is what keeps a species going.

Symbiogenesis

Symbiogenesis is the creation of new species by the merger of existing species. This is the

process which created the eucaryote kind of cell, which led to Protists, Fungi, Animals, and plants. This has been a hugely important process of nature, of course, but we don't know yet how common this process is. Distinguished microbiologist Lyn Margulis argues that microbial versatility in adapting to change, which includes lateral gene transmission through conjugation, is a main reason symbiogenesis is more an important driver of evolution than variation and random mutation.

Margulis claims that most of the DNA found in the cytoplasm of animal, plant, fungal and protist cells originated as genes of bacteria that became organelles, rather than from genetic drift or mutation.

Along these lines Margulis has argued that bacteria have the ability to exchange genes very easily and quickly, even between different species, by conjugation or through plasmids. For these reasons, the genetic material of bacteria is much more versatile than that of the eukaryote. Margulis claims that versatility is the process which enabled life to evolve so quickly, as bacteria were able to adapt to initial conditions of environment and to new changes by other bacteria.

Many more traditional scientists of evolution do not yet agree with Margulis that symbiogenesis drives evolution. It took thirty years of argument and demonstration for the scientific establishment to generally accept Margulis's theory of endosymbiosis. She may be right about ongoing symbiogenesis as well.

Life Is Increasingly Diverse: The Tree Of Life

Life becomes more and more transformed and more and more diverse as time and evolution goes on.

Picture the entire biosphere as an enormous **Tree of Life**.

Surrounding and nourishing the roots are Earth's generous conditions for life: liquid water, reasonable temperatures, a good mix of elements, dissolved from Earth's rocks, which readily form organic compounds.

The roots and lower trunk of the Tree are the oldest, the procaryote single-celled organisms that began things, recently discovered microbes called **archaea**, and **bacteria**.

Just up from the lower trunk are a large variety of protists, eucaryote single celled organisms which led to the first multicellular organisms.

Here the tree begins to branch, and then those branches branch. Once it began branching, it became a wildly growing tree that branches and branches endlessly, each leaf of each twig of each branch a new form of life.

The tree began to branch about 600 million years ago and has never stopped. Many leaves have fallen (gone extinct) during the wild growth of this incredible tree; probably 95% of all leaves that ever greened on Life's tree have fallen away.

We know that there were five periods when the Tree lost many of its leaves. But the roots and trunk were never in danger.

When leaves do fall, the Tree just keeps branching and twigging and making more leaves. Right now there are probably some 100 million species of living organisms on Earth. And they are each unique, different from all the other species.

Mutation

How does all this variation or difference happen? The answer is mutation.

Organisms grow and reproduce by copying their genetic material, their eggs and sperm.

Mutation is a continual process of changes that happen as cells copy themselves. When genetic material is copied within the cell, little changes sometimes happen, so the copy is not quite perfect. Amazingly, mutation can turn out to be a good thing. Little copying errors in the reproductive cells can add up to create variation within the species, so what look like mistakes turn out to be the differences that allow a species to adapt. On the other hand, many mutations are deadly.

Mutation is a natural and inevitable process. Some mutations are triggered by cosmic radiation which permeates the universe. Some are the result of copying errors

Mutations can be triggered within the cells in unnatural ways, however. Many human made chemicals cause mutation. Such substances are called mutagens. Chemical pollution, increasingly widespread, is responsible for many mutagens.

Mutation as a result of human activity is usually a bad thing, which leads to deformities, disease, and death.

In contrast, mutation that occurs naturally is for the species a good thing that gives it the variation that enables it to survive and flourish in response to changes in its living conditions.

This process of change to better fit new circumstances is called **adaptation**.

Adaptation

Let's look at two examples of how this process of adaptation works.

1) Ozone and Frog Eggs

Many kinds of frogs are in trouble right now because of human activity. One trouble they have is about ultraviolet radiation from the sun.

Human activity has reduced Earth's ability to filter out most of the harmful ultraviolet radiation—we have damaged Earth's natural filter in the atmosphere, which is called the ozone layer.

Most frogs lay eggs which float on the surface of shallow water. They float in almost transparent "egg masses" of hundreds of eggs held in a kind of gelatinous jelly.

Right now, many of these eggs are dying. We suspect that they die because of too much harmful ultraviolet radiation from the sun, which happens because of a depleted ozone layer in Earth's atmosphere. Further, scientists suspect that a whole array of chemical changes humans have accidentally made in the general environment make many combined reasons for frog's' dying.

Thought Experiment: Let's look now at an **imaginary** frog species, the "fernfrog".

Fernfrogs are supremely adapted to their wetlands–lowlands habitat. But like every species, fernfrogs are variable, that is, they have differences in their reproductive cells. Now let's imagine that some fernfrogs have a little difference (or variation) in them that makes their egg mass jelly darker than usual.

Let's say that the darker jelly protects the egg mass from ultraviolet radiation. The darker-jelly-egg-masses hatch better than the clear jelly egg masses.

So, in time, as the "darker jelly" tadpoles grow up into frogs, and reproduce in their turn, gradually more and more fernfrogs will lay eggs in darker egg masses. The trait of darker egg-jelly will eventually be found in all fernfrogs.

So the species will continue. The species will have adapted to a changing environment. The species will have evolved.

Of course, we know that within the various actual frog species, there are bound to be a host of small differences. But we don't know yet if any of those variations will actually protect the eggs from too much ultraviolet radiation. If such variations exist and spread, then the frogs will survive. If such differences do not exist, the frogs will all die; their many species will become extinct.

2) Industrial Melanism

In Britain for thousands of years lived a light gray moth with a few black spots on its wings called the **peppered moth**. In 1848 near a large industrial city, a black-winged mutant form of this moth was found.

Biologists began to study this moth and found that by the year 1898, only fifty years later, 99% of the peppered moths in that industrial area had black wings instead of the formerly universal peppered gray wings.

To understand what happened here, we need to look at what eats peppered moths, and where. The moths are typically eaten by insectivorous birds that catch the moths as the moths rest on tree bark.

For thousands of years, when the moths rested on light-colored tree bark with lots of lichens living on it in patches, they looked very much like another patch of lichen, so the birds did not see them. The moths had **cryptic coloration**. Their wing pattern **mimicked** lichen.

But when the trees in industrial coal-powered England began to be blackened by air pollution, the light gray moths were suddenly easy for the birds to find and eat.

The lichens on the tree bark had all died from pollution., and the bark was black with soot.

Any moths that were even slightly darker had a better chance of staying alive than the standard gray ones did.

The moths had relied on mimicry to avoid being eaten by birds. When the color of the tree bark changed, the color of the moths had to change too, for the protective coloration to work.

The peppered moths did survive, because some of them (in the variability natural to the species) carried a mutation for black wings.

The black-winged forms survived because the birds could not easily see them against blackened bark, while the lighter colored forms were eaten and could not reproduce.

So the peppered moth adapted to a change in its living conditions, much like our imagined fernfrogs.

The moths evolved in a very short time, although fifty years in moth terms is like fifty generations (1,000 years) in human terms.

This darkening of wings and bodies happened to many insects as air pollution darkened vegetation in industrial areas of Europe.

This adaptive process of evolution became so common it earned its own name: **industrial melanism**. The **selective agent** (the thing that put adaptive pressure on the species) was the moth-eating birds.

This 19th century discovery was our first clue to how rapid evolution could be when an insect species (or any species) was under great selective pressure. Change or die was the choice for the peppered moth, and it changed.

Note: some of the industrial melanism early studies, it was recently discovered, used debatable techniques for data analysis. It is possible that an early researcher faked some data. However, the fact of Industrial Melanism is well-established. For graphics of mimicry on this site, go [Here](#).

Artificial Selection

Artificial selection is the selection (for breeding) by humans of individuals best suited for a specific purpose. It is common in plant and animal breeding.

Humans began selecting which animals would be the parents in their flocks long ago. If they wanted sheep with longer wool, they would make sure that long haired rams mated with long haired ewes, generation after generation.

Breeders of corn plants wanted to get the largest possible yield of corn oil from the plants, so in 76 generations they were able to increase the oil yield from 5 % to 19%.

Thirty years of selection for high egg production in a flock of White Leghorn chickens increased the average yearly production of a hen from 126 to 250 eggs.

Virtually all of the plants we grow for food and fiber, and all the animals we breed for food are the results of age-old or modern-day artificial selection. The **selective agent** in artificial selection is humanity.

Natural Selection

The natural process of reproduction has a parallel to artificial selection, called **natural selection**.

Nature is an abundant breeder—for most species, many more offspring are born than the environment could ever support.

So those offspring must struggle to survive long enough to reproduce. This struggle within a species is **competition**.

The members of a species that have the best survival combination of traits are **naturally selected** to survive and pass along their superior traits. (traits such as speed, size, and disease resistance).

Favorable variations among members of the same species are transmitted to the survivors' offspring, and over many following generations, spread to the entire local population and sometimes the entire species.

Those organisms better adapted or fitted to the environment (that is, those having favorable differences or variations) survive and reproduce, while those least fit do not.

Natural selection suggests that the origin and diversification of species results from the **gradual accumulation of individual modifications**.

Appearance, abilities and behavior of the species may alter strongly. It may change so much it becomes a new species, a “daughter” species.

Specialization

When a species becomes extremely well-adapted to a particular “niche” or way of making a living in a community, we say the species is specialized.

Natural selection can work so powerfully on a species that its natural level of variation

becomes reduced. If a highly adapted (highly specialized) species encounters sudden changes in its environment, it sometimes cannot adapt to them rapidly enough to avoid extinction, or species death.

Most species do eventually disappear because life conditions have changed faster than they can adapt to them, or because the species has become too specialized in its way of making a living and thus too vulnerable to environmental change.

- Mountain Gorillas are a very specialized species; they are so highly adapted that the loss of any of their rare natural habitat means that their number will be reduced. They are over-specialized.

In times of environmental stability the specialized animal enjoys many advantages, but in a rapidly changing world it is the less-specialized animals that are more likely to survive and flourish.

Humans are a very *generalized* or un-specialized species. We don't do any physical thing supremely well, compared to highly specialized animals, but we do most things pretty well.

We can't run like the cheetah, but we can eventually, with our endurance, run down the best runners in the animal world.

We have fingernails instead of the eagle's talons, so we stun our prey with tools instead.

We are highly flexible, and our built-in variability allows us to make our livings in situation wildly different from the environments in which we evolved.

We routinely live in climates much colder than those we evolved in.

We routinely live at great altitudes, and when we do, our bodies grow bigger lungs and chests, and our feet develop thicker soles with more blood vessels.

Our specialty is that we are not specialized; that is, we have great flexibility of behavior.

We can change our behavior to accommodate new situations, so we adapt to change better than most organisms. Other successful animals that are highly unspecialized include the rat, the house sparrow, and the cockroach.

Some Sources for Transformations in Geologic Time Scale

Darwin, Charles, *Origin of Species*

Encyclopedia Britannica

Gould, Stephen, *The Flamingo's Smile : Reflections in Natural History*

Gould, Stephen, *Fossils: The Evolution and Extinction of Species*

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