CHAPTER 10

MECHANISMS OF SPECIES EVOLUTION

10. 1. ORIGIN OF SPECIES; NATURAL SELECTION; AND CHARLES DARWIN

10. 1. 1. Introduction

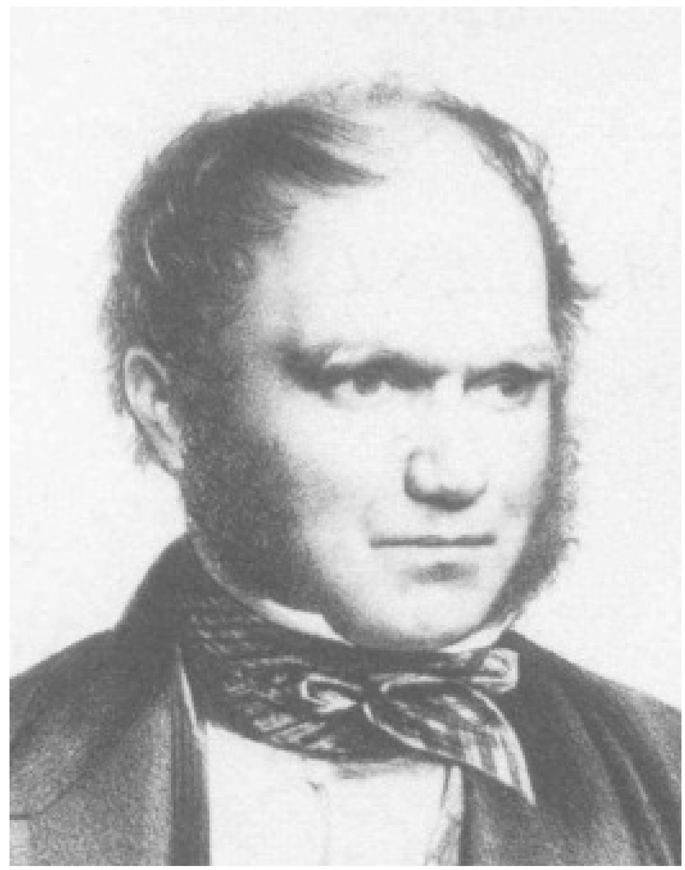
In addition to **biological classification**, two other fundamental concepts must be understood by all ecologists. The third concept, **limiting factors**, we will discuss in our next chapter. In this one, we discuss the second: the mechanisms of species **evolution**.

Regarding this subject—this chapter—as in others we are sharing, we describe only a concept introduction. There are advanced mathematics-oriented explanations on the mechanisms of species evolution. These we do not discuss. We do encourage our readers to learn about and master these when each has the opportunity to do so.

We also focus on the special nature of island life and how the study of island species helps to illuminate the evolutionary process.

10. 1. 2. Charles Darwin's Voyage

Much of our knowledge about the mechanisms of species evolution comes from the pioneer work of a young man named **Charles Darwin**. Darwin sailed around the world while in his early twenties. He and his shipmates visited several continents and many islands over a five year period. Darwin was college-educated and was appointed "Chief Naturalist" for the voyage. The ship he sailed on was called the *H.M.S. Beagle*.

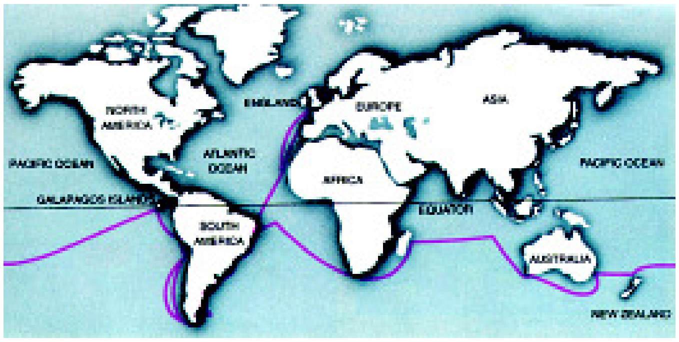


Much of our knowledge about the mechanisms of species evolution comes from the work of Charles Darwin.

Darwin made and recorded many important scientific observations during his journey. He collected numerous specimens for later classification and study.

On the voyage, Darwin carried with him (and diligently read), Charles Lyell's then newly published book *Principles of Geology*. Lyell's book suggested the earth was much, much older than was earlier thought. [Our studious readers will recall Lyell's (and Hutton's) two great geology ideas, the **Principle of Uniformitarianism**, and the **Law of Superposition**.]

From these concepts and perspectives, Lyell had determined that the earth was very, very much older than previously believed. [Note: At the time, it was felt that the earth was not much more than 5,000 years old]. Lyell figured the earth's age to be in the millions, and, very likely perhaps, billions of years.



The route of the H.M.S. Beagle, the ship Charles Darwin sailed on as the Chief Naturalist.

Darwin's observations of limestone at a place very high (over 10,000 feet) in the Andes Mountains of Peru strongly supported Lyell's great earth-age concept. It certainly would have taken a very, very long time for marine-formed rocks to rise up that high.

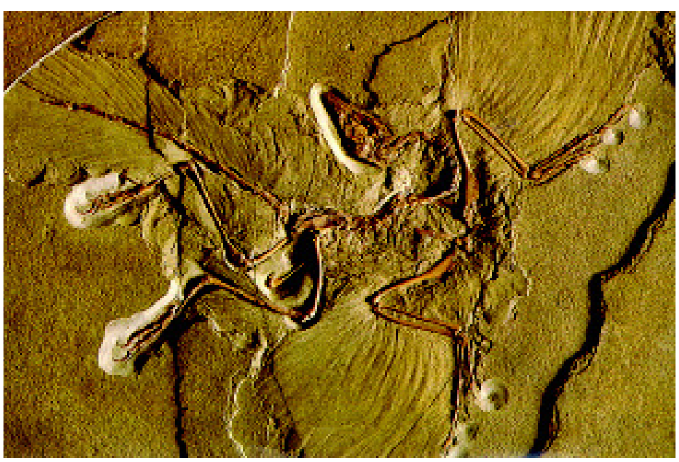
Darwin was inquisitive and keen-minded. He sought, and eventually figured out, many answers to questions which earlier biologists, including his own grandfather, had wrestled with for years. These were mostly "Why?," and "How?," questions.

For instance, why are there so many species on our planet? How did they get to the places where they are? Why had so many others gone extinct?

How are the species alive today different from previous life forms? If current species came from past life forms, how did this happen? Why are animals and plants found on offshore islands sometimes different from those on continents?

After his trip Darwin conducted experiments to test a possible explanation he developed during his travels. That hypothesis, it turned out, was this chapter's title "Mechanisms of Species Evolution."

Based on his unique observations, Darwin took a position against what most everyone else thought at that time. Darwin felt that species could colonize new areas. Darwin determined that, once there, with time, a new species could evolve from an older one.


Fossils, such as this Archeoptrex, the earliest known bird, are key to understanding the progression of evolution.

Furthermore, he felt that different organisms of the present were related to each other through a long chain of ancestors. The driving force of biological change and **speciation** was something Darwin eventually called **natural selection**.

After his voyage, Darwin's experiments served to provide support to his theory of the **origin of species** by means of natural selection. The changing of species over time is called evolution, or, sometimes, **organic evolution**.

10. 1. 3. A Bit Different Type of Presentation

This chapter is laid out a bit differently than the others in this book. At times we discuss some principles everyone should know. At other times we focus on Darwin's experimental observations. This is intentional and meant to be somewhat intellectually challenging.

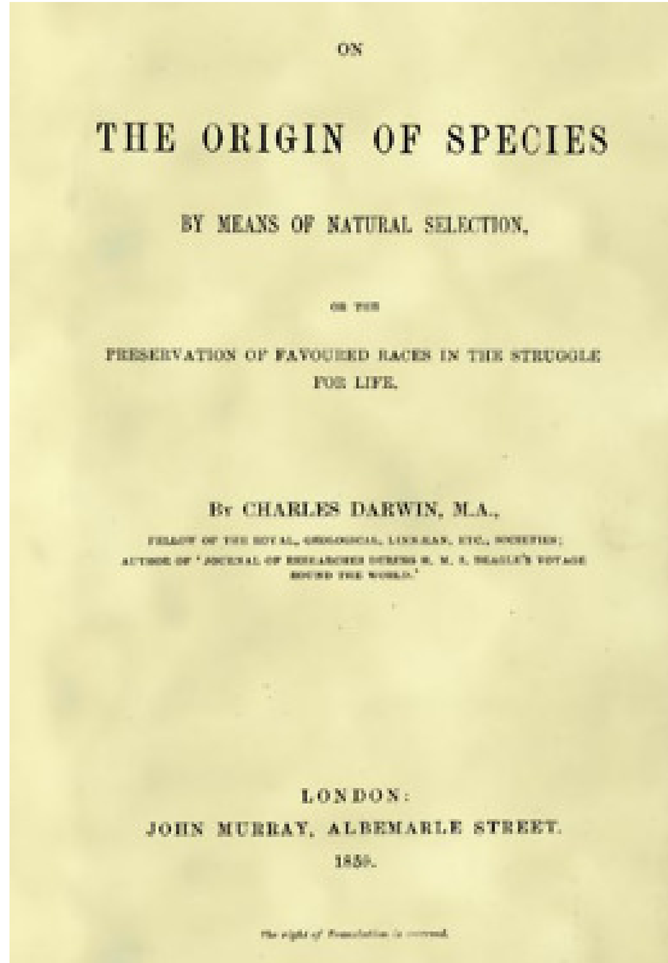
This book's authors and editors encourage you, our readers, to think about and to try to apply *reason* to the principles and information presented. Some questions are added at some section endings. Discuss these amongst yourselves and with your teacher.

10. 1. 4. Try to Imagine or, In Fact, *Just Do It* for Yourself

Remember that Darwin was young (24) when he traveled. He was not much older and perhaps was younger than you yourself. As you read this chapter, try to imagine being in his shoes, traveling the world, experimenting, discovering new species and formulating new ideas.

Read about and, if you wish, try to reconstruct some elements of his later experimental research. Remember this might take quite a bit of time. Darwin worked long and hard. In fact, his experimental efforts lasted for more than a twenty year period before he finally published his findings.

The full title of Darwin's book which explains his ideas on evolution is *On The Origin of Species by Means of Natural Selection, Or The Preservation of Favoured Races in the Struggle for Life.* In Darwin's day, books were often given long titles. Nowadays the book is referred to as *The Origin Of Species*. Your library most likely has a copy. Check it out. It's even available on the Internet.



ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

By CHARLES DARWIN, M.A.,

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1859.

The full title of Darwin's book which explains his ideas on evolution is "On The Origin of Species by Means of Natural Selection, Or The Preservation of Favoured Races in the Struggle for Life."

10. 1. 5. The Importance of Evolution Theory

There is no idea in science that has changed the world's outlook more, or been more subject to dispute, than Charles Darwin's theory of evolution. No idea has been more thoroughly tested and scientifically upheld at every challenge.

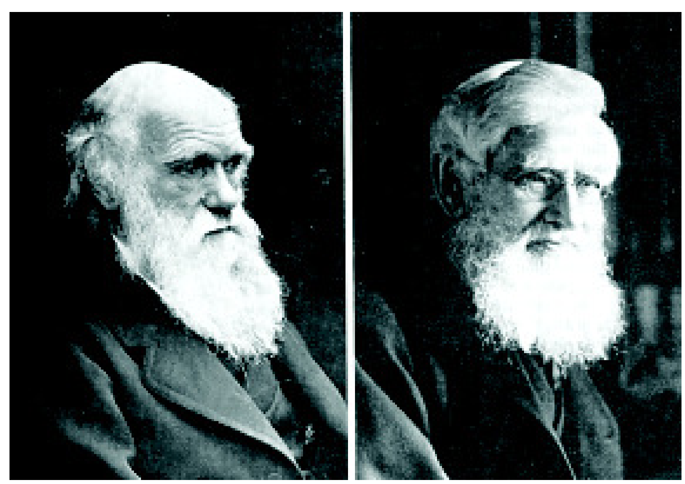
His principal concept lies at the heart of almost all ongoing biological research—from human anatomy and pathology, to agriculture and pest control, to wildlife and fisheries management.

10. 1. 6. Darwin and Alfred Wallace

Here we should note that Darwin's work was shared with the world, jointly, along with that of another great tropical island-focused biologist, Alfred Wallace.

It turned out that just at the time Darwin was completing his 20 year long, post-trip experiments, and was preparing for their publishing, another biologist, Alfred Wallace, wrote to Darwin.

In his letter, Wallace asked Darwin for his opinion about some ideas which Wallace had developed from his own research trips to the tropics. Wallace had been to Malaysia and several of the numerous (over 17,000) islands of Indonesia. Amazingly, the ideas Wallace shared with him (the mechanisms of evolution), turned out to be exactly what Darwin was getting ready to publish.



Both Charles Darwin (left) and Alfred Wallace agreed that they should present their ideas to the world together.

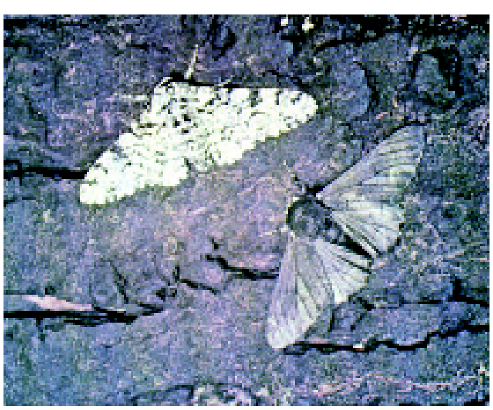
10. 1. 7. Scientific Credit

Formal credit for discoveries in science goes to the first publisher. In a formal sense, Wallace's letter came before Darwin's major publication in which Darwin shared the entire results of his observation and experimental works, *The Origin of Species* book.

After discussion, they both agreed that they should present their ideas to the world together, which they did. Due to the background support that *The Origin of Species* gave, Darwin has historically received the major credit for the species evolution by means of natural selection theory.

This 19th century cartoon lampoons the then new theory of evolution.

Examples of camouflage: Light and dark moths on light bark and...



...light and dark moths on dark bark.

Wallace nevertheless was highly regarded in his day. Additionally, he has left a great legacy of island biodiversity and evolution contributions to all students of island ecology.

10. 2. RELIGION AND DEBATE

10. 2. 1. Not Biblical

The Darwin/Wallace theory, when first proposed, was subject to tremendous discussion and debate amongst the general public.

It was vehemently downplayed by that day's Christian religious leaders who, in essence, declared that since evolution was not discussed in the Christian *Bible,* it never legitimately occurred, no matter what proof was offered. Dogma for many of the Christian faiths held that anyone who said otherwise was blasphemous, or at the least, irreverent.

10. 2. 2. Humans, Included Too?!!!

The major difficulty several religious leaders had with evolution was the assertion that humans, like all other animal life forms, had evolved from earlier species; through ape-like ancestors, through earlier mammals, through reptiles, through amphibians, through fishes, and through even earlier invertebrate species, all the way back to single-celled plankton organisms.

The fossils of the earth, found in underlying rock layers, strongly suggested this indeed had occurred. One particularly revealing fossil strata location, being explored scientifically at just about that same time, is the 1,600-meter-deep Grand Canyon, in the US Southwest.

Darwin and Wallace not only stated that evolution occurred, they revealed *how* evolutionary changes happened.

10. 2. 3. Application of Reasoning; Always to be a *Theory*

Interestingly, because the Darwin-Wallace theory of organic evolution:

that from lower life forms evolved higher life forms over very long periods of time,

is not able to be put exactly to a deductive experimental test or direct observation, (since, at least at the time of this book's writing, we cannot go back into time to observe it happening) and we can only interpret the fossil record, our concept of organic evolution will always be referred to as a *theory* rather than a determined *fact.*

A great deal of deductive and inductive reasoning has, however, given an overwhelming degree of support to the concept/theory.

10. 2. 4. Generally Accepted Today

As stated, when first introduced, the idea of evolution was controversial. A famous judicial trial on the subject once even occurred in the United States, referred to as the *Scopes* trial.

After extensive and wide-spread public debates; after many decades of social and scientific discussion; applied logical reasoning; and both field observations as well as laboratory experimental science; most all of the evolution mechanism principles Darwin and Wallace published have been scientifically re-confirmed and upheld.

10. 2. 5. Natural Selection Demonstrated
Natural selection, once thought to be un-demonstrable in the brief span of modern times, was first scientifically shown to actually occur at a later date. Biologists did this when studying a population of moths many years ago in the country of England.

Today, watching and recording natural selection happen and developing a response to it, is at the heart of many of our food supply regimes. Agriculturists and entomologists engage themselves daily in a constant struggle with the ongoing evolution of insects and plant diseases. Populations of these organisms continuously change and develop new resistance to pesticide applications.

Most Christian religions, including Catholicism, have now officially adjusted their dogmas to incorporate their acceptance that organic life forms *may* have changed and evolved over time, including human beings.

Birds...

10. 2. 6. A Focus on Islands
Interestingly it was both Darwin's and Wallace's biology observations on islands which began this knowledge revolution. Here, on islands, to the trained eye, evolution is more easily discernible than on continents. Why?

10. 3. COLONIZATION

10. 3. 1. Introduction
When an island is first formed, there is no life on it. With time, animals and plants move to the island from other places.

We now know there are five ways that plants and animals can move to an island. The first four *natural* ways are by flight, or by transport by birds/bats, by water, or by wind. Another way for an organism to get to an island is by transport by humans.

and bats both play important roles in natural transport systems.

10. 3. 2. Natural Transportation Systems

Flying
The first organisms to come to a new island are usually birds. Birds have the power of flight. Many can fly for thousands of miles.

Sea birds, like boobies and frigate birds, travel the world in search of new islands to nest on and feed near. Sea birds do not have to depend on land for food, since they eat fish. Other animals that can fly to new islands include bats and insects.

Bird and Bat Transport
Birds carry many plants and animals to islands. Some seeds cling to the feet and feathers of birds. When a bird grooms or cleans itself, these seeds fall off and some may have the chance to grow.

Another way that birds transport seeds is by eating the fruit which contains them. Many fruits' seeds can not be digested. These pass all the way through the bird's digestive tract and are excreted in the bird's droppings. The seeds start to grow in this natural fertilizer and establish a new plant on the island.

The animals, usually insects, that move with birds are usually small ones that get caught in their feathers. These animals may find a suitable habitat and thus get a foothold onto the island. Birds unintentionally transport many organisms to an island.

Bat transport occurs as well. Fruit bats are credited with dispersing even larger seeds than birds.

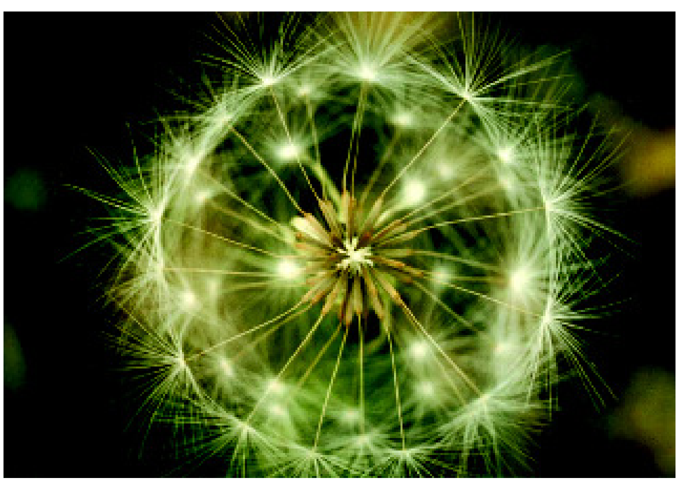
Coconuts float from island to island before sprouting.

Floating and Rafting
A third way for plants and animals to get to an island is by floating on the water. They depend on ocean currents to move them from one place to another. Organisms can get to an island by floating themselves or by floating in a way called **rafting**.

The life forms that float are usually seeds of plants or are animals that live in the sea water when they are young. The coconut crab and the land hermit crab have young that live in the water and float to new areas where they become adults.

Organisms found floating on rafts of logs and dead plants are usually small animals like snails, millipedes, spiders, other invertebrates, and sometimes reptiles.

The seeds of many species of plants have been adapted to being moved by water into new areas. Just take a walk along a beach after a storm to find some of these seeds. Some are large and others are small, so look closely. Sometimes using a one half-inch or smaller wire screen helps.



Some seeds have small parachute-like structures that allow them to float in the air.

For example, coconuts have seeds that float because the thick husk around them provides a buoyant, water-proof covering. The husk and shell of the coconut help the seed float and can keep it alive for up to four months in saltwater. This is enough time for the seed to float several hundred miles, landing on a remote beach.

Once on the beach, the coconut's husk rots. This helps the young coconut grow by adding organic matter to the sand in which the coconut is growing. Many plants along a beach have seeds that work like the coconut to keep them alive while they float to a new island.

Wind Transport
The fourth natural way that organisms arrive on an island is by being blown there by the wind. Many plants have seeds that have small parachute-like structures that will allow a seed to float in the air.

Other plants and fungi often have seeds or spores so small that they will float on the air without a parachute. Mosses, ferns, orchids, and mushrooms are examples of these. Winds can blow these seeds to new areas to grow. Spiders can *'balloon'* to new places by secreting out and holding onto a fine strand of wind-buoyant silk.

Very strong winds, like those of a typhoon, can even blow small birds and insects to a new island.

Here in the Marianas, wind moved many organisms to our islands from the relatively nearby continent of Asia. Even though our surface winds generally blow from the east, at high altitudes there is a reverse wind that blows from the west. This high western wind could have picked up organisms and blown them to the Mariana Islands to settle.

Wind, water, birds and even bats have each moved life to our islands.

10. 3. 3. Human Transportation of Organisms

Once life has started on an island, humans tend to become the main way that new plants and animals are introduced to an island's environment. Humans selectively bring useful animals and plants to new places with them.

Some of the organisms intentionally brought here to our islands include flame trees, bougainvillea plants, bananas, papayas, tapioca, pigs, cows, dogs, and cats. These plants and animals were brought to our islands because humans enjoy them or have uses for them.

Unfortunately humans also have accidentally introduced the weeds, rats, and brown treesnakes that have been found here. Even several intentionally introduced species are now considered pests.

Today humans move organisms to islands by two methods, boats and airplanes. In the time before airplanes, boats were the principle vehicles through which organisms traveled with humans. Now air travel, via planes, jets, and helicopters, has become the main way that organisms move with humans.

The time it takes a plane to go from one island to another is much shorter than by boat, and an organism has a greater chance of surviving until it reaches a new place.

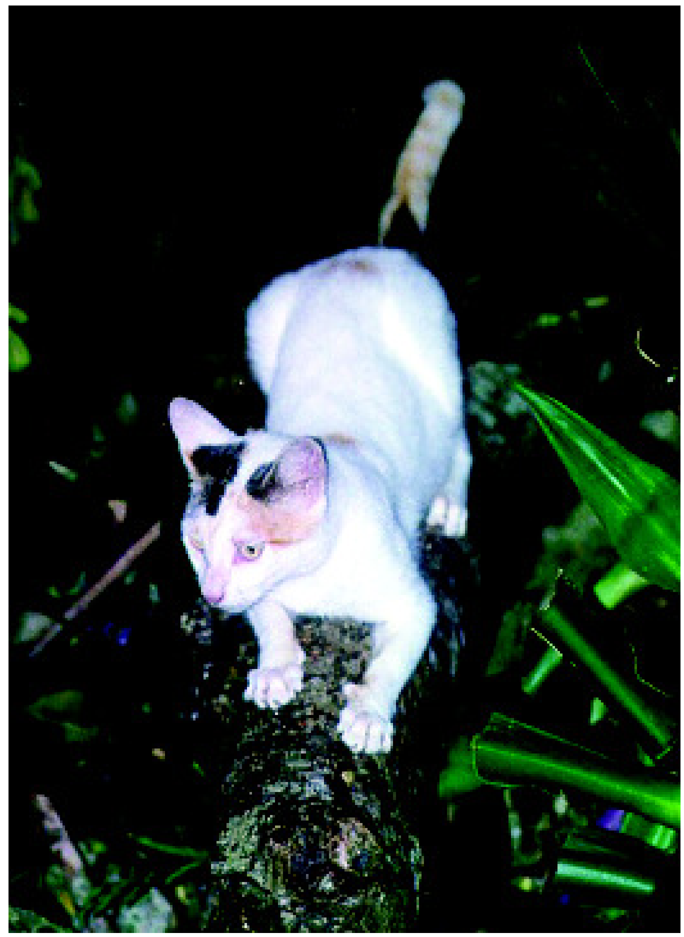
Even today, boats still move organisms, like log rafts, from one place to another. So, humans use boats and airplanes, intentionally and unintentionally, to move organisms to new areas on the earth.

To understand the effect humans have had on the population of animals and plants on our island, we can use the example of the number of plant species found in our islands.

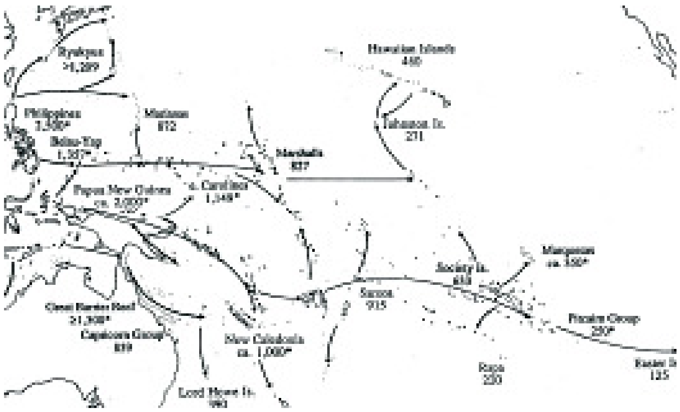
Assuming our plant flora matches those of Guam, by the year 2000 there were 931 documented species of plants living here. Of these 931 species, humans introduced 585 types. Three hundred eighty-one of these are crops or ornamental plants, and 204 are weeds and plants that escaped into the wild environment.

It is not known how 19 nonnative plant species got here. So, this leaves only 327 species as native to the Northern Marianas and not having been introduced by humans.

We can see humans brought over half of all plant species now present in our islands. Humans play an important role in moving plants and animals to new places around the world.



Cats are one of many destructive organisms imported by man.



Estimates of inshore fish species by area and likely route of colonization. (illustration by Robert Myers used with permission)

Many of the plants and animals found in the Marianas, such as the marine toad Bufo marinus, have come from the Americas.

10. 3. 4. Sources of Organisms for the Marianas

When organisms arrive at an island, they usually come from land that is nearest to that island. Here in the Northern Mariana Islands, the nearest large land mass is Southeast Asia. Most of the native plants and animals present when humans arrived likely came from Asia, island hopping all along the way.

We call these organisms **indigenous species**, meaning they were here when people first arrived. Note that indigenous species are also found elsewhere, too. A species found here and nowhere else is called an **endemic species**. These are discussed later in this chapter.

Many of our native plants and animals have relatives that can be found in Asia or on islands near it, including the Philippines. To see how organisms spread out from Asia into the islands in the Pacific, we can gain some appreciation from the map to the left on the distribution of nearshore fish (sometimes called inshore fish).

Nearshore fish are good for the study of the natural distribution of organisms. This is because humans usually do not move them into new areas and it is hard for nearshore types of fish to move across the open ocean. Their planktonic larva, however, do.

In the Philippines (close to Asia) there are over 2,500 species of inshore fish. Next to the Philippines, Belau and Yap have about 1,357 species of inshore fish. After Yap, come the eastern Carolines with about 1,149 species. From the Carolines, the number of inshore fish drops to 872 species in the Marianas, north of the Carolines, and 827 in the Marshalls, east of the Carolines.

By the time we reach Hawaii, the number of inshore fish species drops to 460. (Note: although Hawaii is closer to the Americas than to Asia, due to prevailing winds and currents, most life forms arriving there, including inshore fishes, come from the west.)

Many of these nearshore fish species can also be found in the waters of Southeast Asia. This distribution of inshore fish shows that the further an island is from a continental mainland, the lower the number of species on or near an island. This finding confirmed a prediction that the Darwin/Wallace natural selection theory had presented.

Because of human movement, however, many plants and animals have had even a greater chance to move to our islands from a greater distance away. The brown rat, found here, started in China, then it moved to Europe. After Europe, it traveled with the sailors to the New World in the Americas, then finally to the CNMI.

Since many ships and airplanes have come from North or South America to the CNMI, many of the plants and animals found here have also come from the Americas. For example, the marine toad comes from Central America, as do the papaya and the guava. Humans can move organisms over a greater distance than nature can.

The plants and animals found in the Northern Mariana Islands can be traced to four major starting points. The two most common points of origin for living things here are the Philippines and Mexico. The third point of origin is called the Indo-Malayan-Pacific area. The Indo-Malayan Pacific area forms a triangle from New Guinea, north to the Philippines, and west to India.

The last point of origin really does not have one place from which organisms came. This last starting place could be named **Pantropica**—although this term is not in any dictionary. *Pan* means "all," so here we refer to "coming from or present naturally in all areas between the tropics of Capricorn and Cancer." Pantropical organisms can be found almost any place where the environment is tropical.

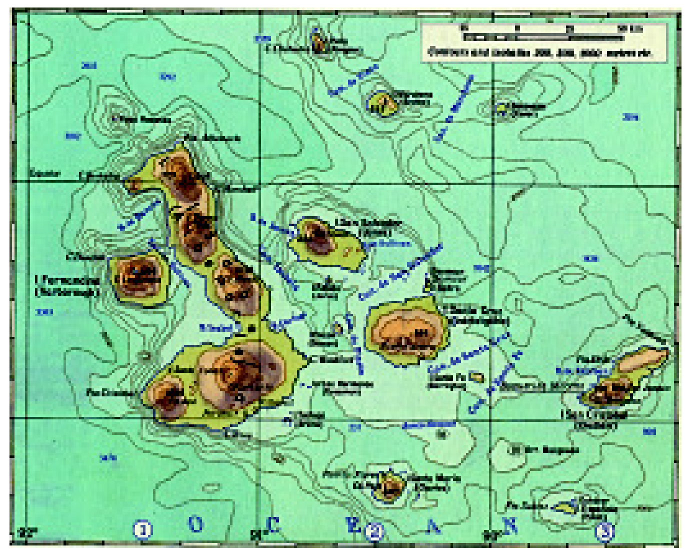
From these four major *areas*, the majority of organisms that came to our Mariana Islands were carried by birds/bats, water, wind, flying themselves, or humans.

10. 4. GEOGRAPHIC ISOLATION

During his travels, Darwin observed that sometimes there were new and different species on offshore islands when compared to a continental mainland. On islands just offshore of a mainland, the species matched those of the continent, though fewer in number. However on islands far off a mainland's coast, entirely different species were present.

Darwin hypothesized that the further distances away from a mainland area helped new species to develop. He calculated that the complete separation from a main population by a smaller group of organisms assisted in the development of new species.

Isolation helped allow for species evolution to occur. How? We now know that **geographic isolation** keeps a remote sub-population from interbreeding with its original population group. Why is this important?



The geographical isolation of island groups like the Galapagos keep a remote sub-population from interbreeding with its original population group.

10. 5. OVERPRODUCTION OF OFFSPRING

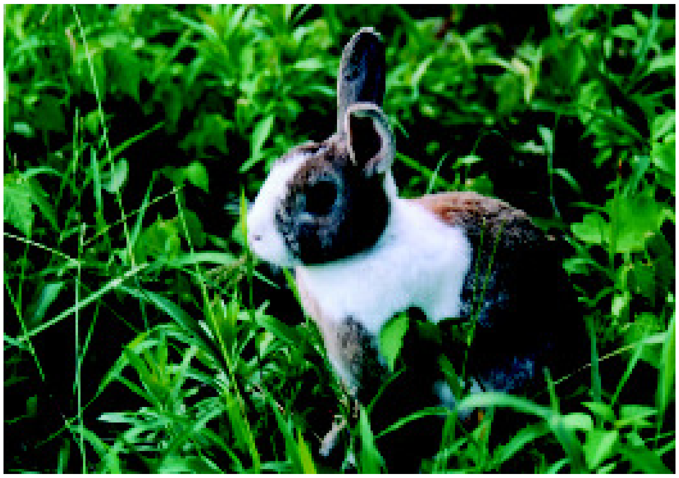
After his global travel experience, Darwin's experimental research showed him that species could produce many more offspring than a habitat could support.

He experimented with a wide variety of plants and animals, both domesticated and wild. One female domestic cat can produce upwards of 70 kittens in its lifetime.

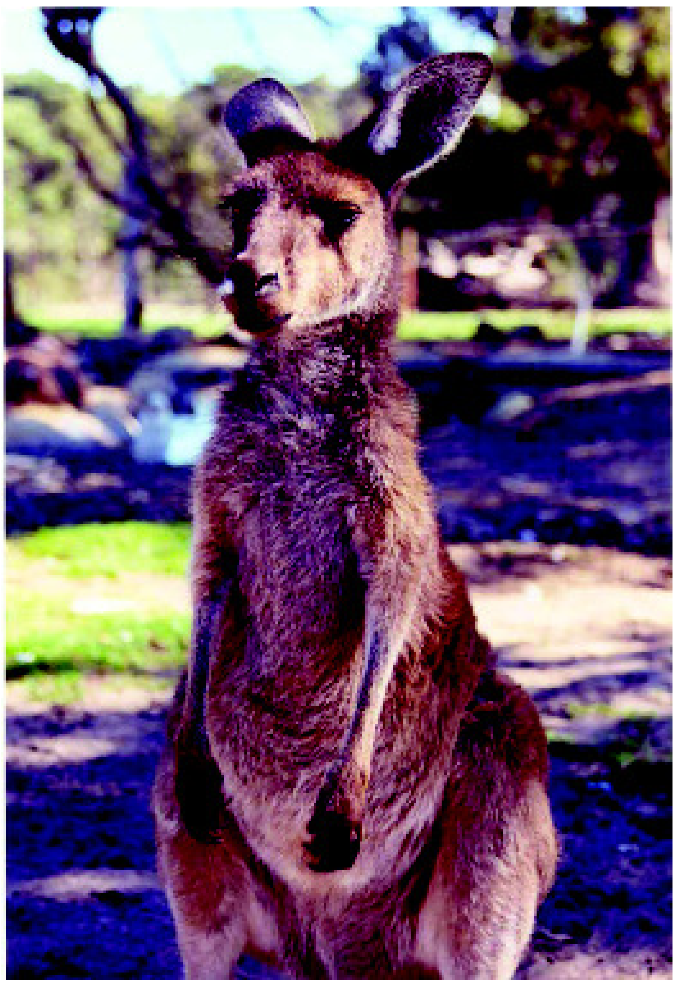
Darwin calculated that from an original pair of elephants, a species that is relatively slow to reproduce, some 19 billion offspring could be produced in just 750 years. This is a little more than three times the amount of people alive in the year 2000 AD. The world would be a very crowded place if only *all* the cats and elephants born were to survive and reproduce.

Each of our TANGANTANGAN trees (*Leucaena leucocephala*) produces tens, perhaps hundreds, of thousands of viable seeds. Many oceanic animal life forms, including fishes, and some terrestrial animal life forms, including insects, can produce millions of eggs, each a potential offspring.

Of course, not all seeds germinate and grow to full-sized plants and not all offspring of animals live to adulthood. Why not?



In the 19th century, rabbits were introduced to Australia...



leading to a decreased kangaroo population due to resource competition.

10. 6. SLIGHT DIFFERENCES AMONG OFFSPRING

From his experiments Darwin found that not every offspring of a parent was exactly the same. Seeds of a plant, although at first looking much the same, were always found to be of slightly different shapes and weights.

Puppies and kittens each can be told from one another with due attention to their details. This aspect of slight differences among family groups and populations is called **variation**. Planted seeds do not grow in exactly the same manner nor do animals always exhibit exactly the same behaviors. Again, why not?

10. 7. COMPETITION FOR RESOURCES

10. 7. 1. Competition for Resources

In nature, all offspring from one set of parents do not survive, and of those that do, each is slightly different from one another. All surviving offspring must compete among themselves and with other organisms to survive. If an organism does not adequately compete, it dies.

Competition happens when the use of a *limited resource* by one individual reduces the availability of that resource to another individual.

If an organism controls or uses a resource, it is no longer usable by other organisms. For example, if a fruit bat eats a mango fruit, another fruit bat cannot eat that same fruit because it no longer exists. Resource use is a constant activity—the air breathed, the ground walked on, the shade taken advantage of, etc.

It is impossible to list all of the resources each organism competes for. However, some general categories of resources which plants and animals may compete for include food, water, space, light, and reproductive mates.

Competition may not seem good for an individual because of the costs. The costs of competition are time, effort, and, sometimes, death. During competition, an individual may be hurt or not win the resource. This wastes time and effort. On the other hand, the benefit of competition is continued survival (life).

Individuals must weigh the costs against the benefits before competing for a certain resource. Even if competition is not always good for an individual, it is a major part of that individual's ecology.

10. 7. 2. Competitive Exclusion Principle

An individual must compete for limited resources with both other individuals of its own species and, occasionally, individuals of other species.

When competition is between two species for a resource, there are two possible outcomes. One species may *exclude* the other from using the resource, or the two species might *share* the resource somehow.

If one of the two species is somehow kept from using a resource, and if this resource is needed for reproduction or growth, the species which is not allowed to use the resource may become extinct. This illustrates the **Competitive Exclusion Principle**.

This principle states that two species cannot exist at the same time on the same limited resource. One must die. In nature, it is possible to see competition between species happening when the population of one species decreases while that of another increases. For example, rabbits were introduced to Australia in the early 1900's. When this happened the population of kangaroos decreased, while the population of rabbits increased. They were competing for the limited resource of grass.

At the time of this book's writing, humans, and an accidentally human-introduced rabbit-killing virus, are controlling the rabbit population. The native kangaroo population is increasing.

Both hawks...

10. 7. 3. Resource Sharing

The second possible outcome when species compete for a resource is that they share the resource. Biologists have discovered that many species have found ways to divide a resource. They may divide the resource by time or by space.

For example, in many parts of the world (though not here), both small hawks and owls eat mice. The hawks hunt during the day, and the owls hunt during the night. Thus, the two species divide the resource, mice, by time.

An example of a division of a resource by space involves two species of cormorants. Both the great cormorant and the shag cormorant are ocean diving birds that feed on small fish. They both live in the same place and feed at the same time.

Through careful observations, **ornithologists** (biologists who study birds) found that the great cormorant feeds on fish from well above the bottom of the water, while the shag cormorant only feeds on fish very close to the bottom. They divide their food resource, fish, by space.

When species compete, either one of the species will go extinct, or one will change its habits, or they will find a way to share the resource.

and owls share resources, since hawks hunt by day and owls by night.

10. 7. 4. Indirect Competition

When individuals of the same species compete with each other, they do it by one of two methods. The first method is **indirect competition**. Everyone uses the same limited resource, but there is less available for the next one to use.

For instance, when plants compete for light, the taller plants get the light first. Thus, the shorter plants get less light.

10. 7. 5. Direct Competition

The second method is **direct competition**. This is when one individual claims a resource and does not allow another individual to use it. Direct competition is very common when animals compete for space by forming hunting or nesting **territories**.

The traits of the Rota subspecies of bridled white eye (nanaso) are being carefully evaluated to see if it should be re-classified as a separate species of bird.

The Galapagos marine iguana (Amblyrhynchus cristatus) has adapted to eat algae from rocks both above and under the ocean.

On islands, competition plays an important role in the survival and change of species. Because of the limited resources on islands, competition is even more severe than on continents.

Biologists find that organisms have a high extinction rate on islands. This is partly because of both limited resources and competition from other species.

10. 7. 6. Survival of the Fittest

One reason for a high extinction rate is that a resource needed for life may not be available on an island. Then, the population dies. If one resource is not available, but another is, some members of a population may have characteristics that allow them to use the other resource.

We use the term *natural selection* to indicate that nature has selected these *better adapted* individuals to survive. We also say that the surviving individuals are *better fit* to the new environment.

An **adaptation** is a physical or behavioral characteristic that allows an organism to better compete in its struggle for life. Natural selection is often referred to as **survival of the fittest**.

Through **inheritance** (discussed below), the **characteristics** (also called **traits**) are passed along to the next generation. Those without the survivable trait die out and the population as a whole is changed to target the new resource.

The change may be so great as to eventually cause a population to be recognized as an entirely different species. Note that it is the *population* that adapts and evolves into new species, not an individual organism.

At the time of this book's writing, the traits of the Rota subspecies of bridled white eye (NANASO) are being carefully evaluated to see if it should be re-classified as a separate species of bird.

10. 7. 7. Galapagos Marine Iguanas

One example Darwin discovered and wrote about is the marine iguana (*Amblyrhynchus cristatus*) of the Galapagos Islands. This iguana eats algae growing on coastal rocks. Sometimes it even swims out into the ocean and dives to the bottom to eat algae growing there.

The marine iguana evolved from the green iguana (*Iguana iguana*) that lives in South America and the Galapogos Islands. The green iguana eats the flowers and leaves of trees and small plants.

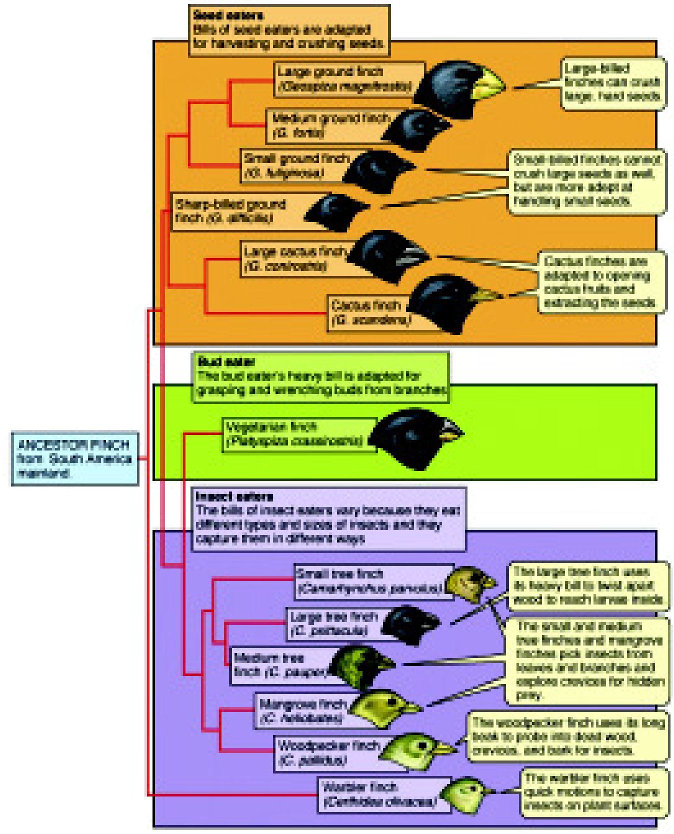
On some of the Galapagos Islands, there are not many land plants. Through natural selection (survival of the fittest), populations of the iguana changed physically.

At first only some individuals displayed the behavior of ocean diving. Since these survived when others died out, eventually, through the natural selection of the better fit individuals, many of the island chain's iguanas were able to dive for algae, a rich resource previously not being used.

Their physical and behavioral changes were so great that they became an entirely different species from the land iguanas which originally colonized from the South American mainland.

10. 7. 8. Galapagos Finches

One important set of observations Darwin made on the Galapagos Islands concerned several groups of birds called “finches.” Darwin identified fifteen different species of finches living in the small archipelago.



Darwin identified fifteen different species of finches living in the Galapagos.

These small bird forms varied only slightly in size and color. A major difference amongst them, however, was in the shape and size of each type’s beak. Darwin could see these beak shapes were vitally important in determining what each bird ate.

These birds are considered different species because they used different parts of the environment and did not breed with each other.

Because the body and color of all the finches were about the same, Darwin reasoned that all these species of finches must have had the same ancestor many thousands of years ago. In South America, Darwin had noticed finches of the same approximate size and color.

10. 7. 9. The Law of Natural Selection

From this information, he *hypothesized* that the finches on the Galapagos must have come from one or more flocks of finches which colonized from South America to the Galapogos, perhaps blown by storms. From his observations, Darwin proposed an explanation which eventually became the **Law of Natural Selection**, on which the *Theory of Evolution* is based.

The Law of Natural Selection states that the environment determines whether or not an organism lives or reproduces. The more fit an organism is to its environmental conditions, the more likely it is that it will survive. Populations of these fit organisms are more able to adapt to changes in the environment and to use resources to the maximum amount.

The factors that control natural selection are:

1. Overproduction of offspring;
2. Differences in species’ individuals;
3. Limited resources;
4. Changing environments.

As a result of these factors, only the fittest survive to reproduce.

10. 7. 10. More Examples of Changes in Organisms on Islands

The changes in organisms on islands can be large or small. These changes depend on how isolated a population is, and how often **mutations** occur (see below). Small changes include variations in the color or size of the members of populations on different islands.

The coloration of the collared kingfisher’s head differs from island to island.

For example, the collared kingfisher on Saipan has white feathers on the top of its head. On Rota, the top of its head is a mixture of white and blue feathers, and on Belau, the collared kingfisher’s crown is completely blue.

Separate species of the fantail exist in the Marianas and Palau.

Most flame trees (Delonix regia) drop their leaves when the dry season starts.

These small differences and changes make our world more interesting. They result in new varieties within a species. However, they are insufficient for a taxonomist to call it a new species.

Greater changes in a group of organisms can lead to a new species. For example, both Yap and our Marianas have a bird called the rufous fantail. It has a dark top and white tips on its tail. In Belau, there is also a fantail, but it is called the Palau fantail. It has a red top and red tips on its tail. These changes are enough to make these two fantails different species.

If enough changes occur within a species, previously *unfilled niches* within an island environment may be exploited, facilitating the development of an entirely new species. Remember Darwin's finding of 15 species of finches on the Galapogos archipelago? He found ten species of finches on just one of the Galapagos islands. Each evolved to fill a previously unoccupied niche.

Individual populations on islands can diverge and become new species that are *endemic* only to that island. "Endemic" means "is only naturally found, and is likely to have evolved at a certain place."

Competition is an important evolutionary force on islands, and must always be considered when looking at how organisms interact and change with time.

10. 7. 11. Environmental Constraints

All plants, animals, and other organisms face environmental constraints. With limited resources, only so many organisms of any particular type can get food and water. The ones that are not able to use a resource, or to adapt, die. The difference in individuals may make some offspring not fit for survival.

An animal might be born blind or not able to move. A plant might not produce any **chlorophyll** and thus not be able to make its own food. These individuals will die. The changing environment selects the fittest plants, animals, and other organisms to survive.

The changing environment works on each member of a species to select the best-adapted individuals. When the environment changes, it puts pressure on an individual. The strongest or best-adapted organisms survive to pass on their **genes** (see below).

For example, in our area, most flame trees (*Delonix regia*) drop their leaves when the dry season starts. Dropping their leaves is an adaptation to retain moisture within their trunks and branches.

If the flame trees were to grow in an environment with no dry season, the individuals that kept their leaves a little longer would have an advantage over the trees that dropped their leaves sooner. They would be able to grow longer and use more of the resources (water, carbon dioxide, and solar energy).

After a long time, this other area's population of flame trees might even quit dropping its leaves altogether. The trees might, instead, grow leaves all year long if the climate stayed wet enough.

Of course, these new flame trees would not be able to compete with the older variety of flame trees in an environment with wet and dry seasons. They would most likely die from **desiccation** (drying out) during the dry season. An individual's fitness depends on the environment to which it is adapted to survive.

10. 8. MUTATIONS AND GENETIC CHANGE

One aspect of organic evolution, which even Charles Darwin could not determine (though he tried greatly), was the internal manner by which the bodies of animals and plants passed on their traits to their offspring. Crossbreeding of organisms within a species to achieve desired breeds was understood, but how exactly did it occur? We now call the passing on of traits, **inheritance**.

10. 8. 1. The Abbott Gregor Mendel

The principles of inheritance were discovered by the eminent botanical scientist and mathematician, Abbot Gregor Mendel. Like Darwin, Mendel was also college educated. But, unlike Darwin's round the world trip, Mendel's great focus area of study were the seeds and plants of his garden.

Abbot Gregor Mendel discovered what he called "factors of inheritance;" now known as genes.

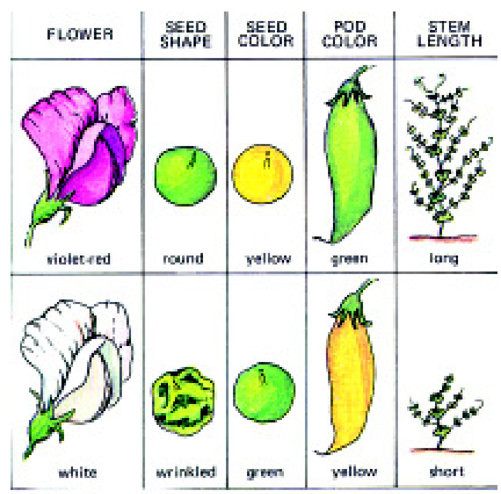
In his garden, Mendel applied the scientific method of careful observation, good record keeping and careful reasoning of the meaning of each experiment's results. Through his work he discovered what he called "factors of inheritance." Scientists now call these *genes*.

Mendel discovered that the genes were passed from the parents to their offspring in the **gametes** (eggs & sperm or pollen) of animals and plants.

He provided precise formulas for predicting the frequency of results of the crossbreeding of organisms having various characteristics. This field of biology, learning about and experimenting with genes, is now called **genetics**.

10. 8. 2. Mendel's Experiments with Garden Seeds

Through his experiments Gregor Mendel discovered the basic laws of **heredity**. He experimented in the 1850's and 1860's. Mendel studied how pea plants transfer their physical characteristics to their offspring. Heredity is the transfer of *traits* from parents to their offspring.



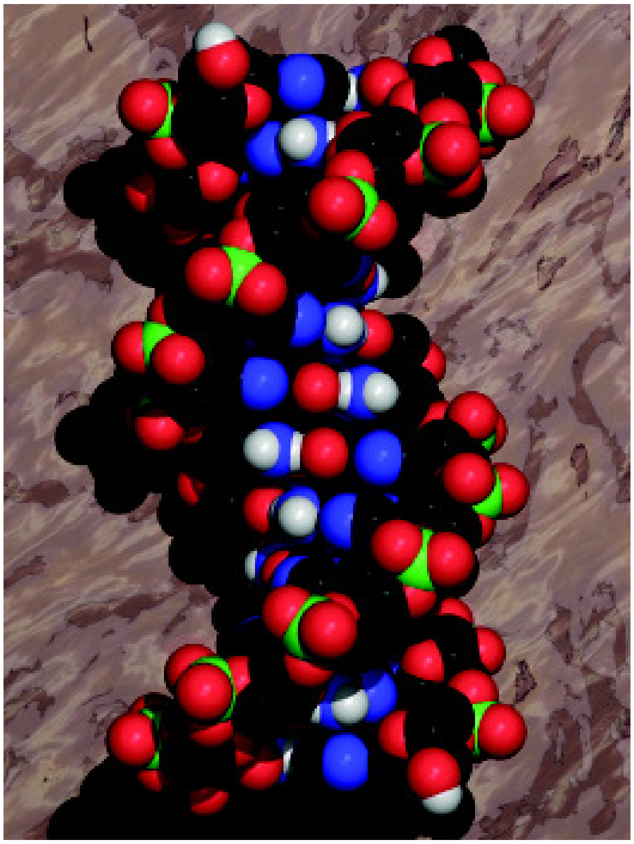
Mendel understood that parents transfer traits to their offspring. The variety of characteristics used in his cross-breeding experiments are shown here.

From his observations, Mendel formulated the **Laws of Inheritance**:

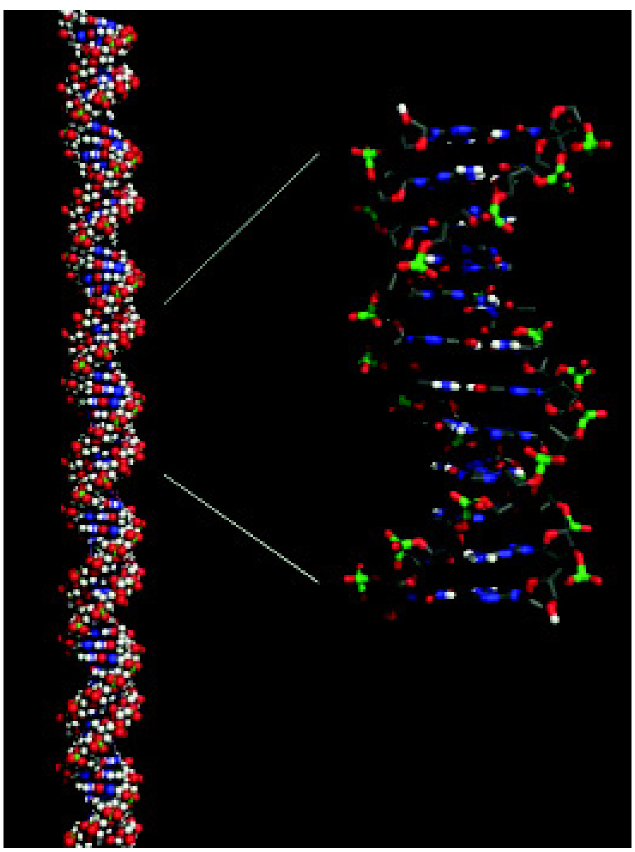
1. *Some inherited traits are dominant. Others are recessive.*
2. *Many traits are inherited in pairs.*
3. *Hybrids do not breed true.*

The first law means that some **dominant traits** will hide others that are called **recessive**.

For example, Mendel's experiments showed that when he interbred tall and short pea plants, all **hybrid** offspring would be tall. He reasoned that tallness in peas must be dominant, while shortness was recessive.



DNA, deoxyribonucleic acid, is a large molecule found in the nucleus of cells.



DNA chains are found on the inside of a chromosome.

10. 8. 3. Predicting Cross-breeding Results

If the hybrid offspring of this crossing were bred together, both tall and short plants would be produced. Mendel was able to predict the percentage of these offspring that would be tall (75%), and short (25%).

Because of his experimental results, Mendel realized that traits must be inherited in pairs. Mendel understood that parents transfer traits to their offspring.

Although he could predict this inheritance, he did not know precisely *how* traits transferred between generations. This was left for other scientists (see below) to figure out.

One final note before leaving the work of the esteemed Abbot. Mendel's work was never widely known while he was alive. Many years after his death, scientists doing research, read and understood the important meaning of his experimental results. (Publishing matters...)

10. 8. 4. Chromosomes and Genes

In the 1930's, scientists discovered how traits transferred to offspring. They found a group of structures called **chromosomes** inside the **nucleus** of each **cell** in an organism. These chromosomes control the functions of a cell.

Researchers found that chromosomes contain the genes that *express* themselves as individual traits in organisms. Genes occur in pairs on chromosomes.

An organism inherits one-half of its genes from each parent. An offspring inherits one of each pair of genes in a parent's chromosomes. Therefore, half of the chromosomes must come from one parent, and the other half must come from the other parent.

This allows the offspring to look like its parents, but at the same time vary enough to be *not exactly* like either parent. How chromosomes and genes could control cell functions and the appearance of traits in an organism was not understood until the 1950's. Then two scientists (see below) discovered the structure and function of DNA.

10. 8. 5. Deoxyribonucleic Acid

DNA, **deoxyribonucleic acid**, is a large molecule found in the center of chromosomes, within a cell's nucleus. It is actually made up of two chains and is partially composed of sugary molecules called deoxyribose. Early on, the molecules were found to have an acidic quality and were thus called an acid.

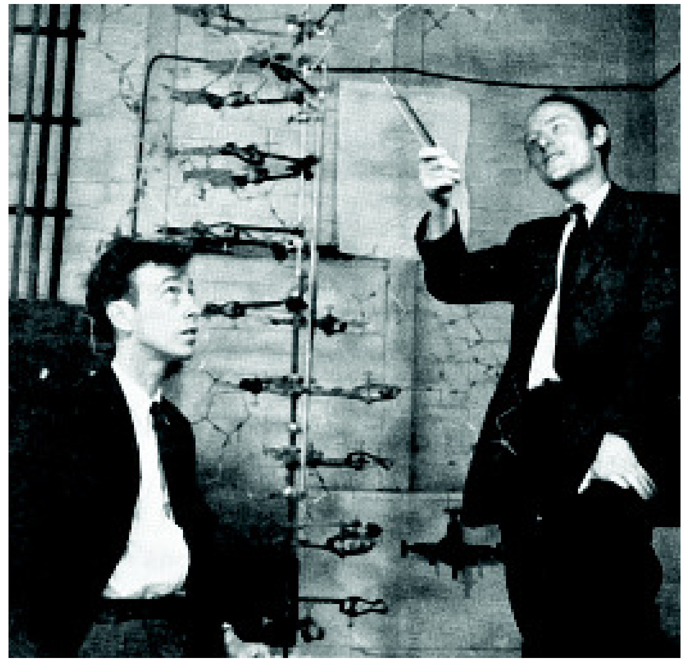
"Deoxyribo" means "a sugary material—ribose—lacking one oxygen molecule"; "Nucleic" means "found in the cell's nucleus"; "Acid" means "acidic in nature". "DNA" for short.

Also part of the molecule, and in fact, its most important part, are four different types of *basic* (meaning like antacid) sub-molecules which occur in pairs called **base pairs**.

As mentioned, DNA chains are found on the inside of a chromosome, which has an outside wrapping of protein. Connected at the base pairs, these chains twist around each other to form a structure called a *double helix*.

10. 8. 6. Watson and Crick

The actual chemical make-up of genes remained a mystery for a long time until two young chemical engineers, named James Watson and Francis Crick, jointly published their work on the structure and function of nucleic acids. This nucleic acid structure and function is now called the **genetic code**.



Watson and Crick discovered the structure and function of nucleic acids.

Through their research, we now can appreciate nature's great inheritance-providing double-helix molecule, DNA. Watson and Crick discovered that DNA can reproduce and make copies of itself. An exact copy can be transmitted to the offspring of a cell.

The genetic code can be found in the sequences of base pairs found along the DNA's double helix. These sequences work to cause traits. A trait could be any of the many identifying things about an individual, ranging from a physical attribute to a behavior.

Several bases along a line, which can cause some trait, are called **codons**. "Codons" are the chemical equivalent of genes. Mendel's sought-for "factors of inheritance" had been found.

Protein Formation

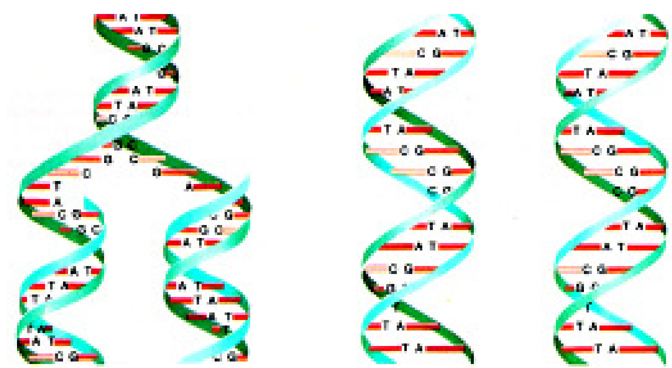
Genetic codons can be read by other **organelles** in the cell. This information is then used to build **proteins**. This is done by a type of organelle called a **ribosome**. In cells, proteins are used for two main purposes. First, they are used to make up different parts of the cell. Second, proteins control chemical reactions.

When a protein controls a cell's chemical reactions, it is called an **enzyme**. Enzymes control just about every function of a cell, from what it is built of, to the amount of food it uses to make energy.

One specialized protein, called a **hormone**, can affect cells very far away from the original cell, but within the same organism. Another, called a **pheromone**, can even affect other organisms. Many of the fragrant odors we smell in our out-of-doors, especially in the early evening, are actually chemical attractants.

10. 8. 7. DNA is Like a Blueprint

DNA is like a blueprint for the cell, while the proteins are like workers. The workers build the physical structure of the cell, following the blueprint's instructions.



DNA is like a blueprint for the cell.

The discovery of DNA and chromosomes helped explain how traits are passed on from one generation to the next. Moreover, researchers soon found that genes can change with time until, under the right conditions, a new species evolves.

10. 8. 8. DNA and Mutations

While individuals in a species are always a little bit different from each other, sometimes more drastic changes happen. These changes occur through a process called *mutation*.

Sometimes the DNA code in a cell is changed. Some of the bases are changed or rearranged. This change can cause a new trait to appear. Most mutations are of no benefit to an individual and many are **lethal** (cause death). However, some mutations are beneficial. They may even help an individual survive harsh environmental conditions or make it able to use otherwise unavailable resources. These survivors, in turn, pass on their newly-ordered genes to their offspring.

Komodo dragons grow to over 10 feet in length, and eat whole goats.

If significant beneficial mutations build up in a population, it may become a new species. On islands, mutations affect populations greatly. Likewise, new species appear on islands far more often than on continental land masses. This is because of the high **reproductive isolation** potential which occurs on islands.

Genetics and the Theory of Evolution explain how changes happen to organisms. They give us an understanding of the reasons for the changes and the reasons for the high level of endemism found in plant and animal species living on islands.

10. 9. CHARACTERISTICS OF ENDEMIC ISLAND LIFE FORMS

10. 9. 1. Large Size

Among the unique features of island-evolved life forms is the predominance of unusually large species. When compared to similar species on a mainland, island life forms are sometimes twice as big as their mainland relatives.

Many endemic island bird species, such as the Guam rail (*Gallirallus owstoni*) and the Micronesian megapode (*Megapodius laperouse*), are large compared to their closest mainland relatives.

The greatest endemic island birds of all were the *elephant birds*, which lived in prehistoric times. These were found on the island of Madagascar, off the eastern coast of Africa.

The giant tortoise (Geochelone elephantopus) is found only on those island groups where we think it evolved.

One particularly large elephant bird, which apparently looked much like a goose, probably weighed as much as one thousand pounds. It likely stood at a height of ten feet. Now fossil eggs and bones are all that remain.

Another group of large birds, the *moas*, potentially grew to two meters at the shoulders, or ten feet height, if their necks were fully raised. One species was *Dinoris giganteus*, a name well worth contemplating its derivation.

Several scientists however, now believe that their necks hung down, heads low to the ground. They weighed from 40 to 600 pounds. These giants lived on the islands of New Zealand. Like the elephant birds, moas are now extinct.

Birds are not the only animals that tend to become large on islands. Reptiles also seem to increase in size when isolated. The giant tortoise (*Geochelone elephantopus*) is found only on those island groups where we think it evolved. Two examples of such islands are the Aldabra Islands in the Indian Ocean, and our now familiar Galapagos Islands here in the Pacific.

Since it evolved, the giant tortoise has been able to travel from island to island within an archipelago by floating and swimming. Darwin learned that each individual island had its own distinct population of tortoises, different from all of the other islands in the Galapogos. By studying the environment of each island, he related their differences to each island's unique conditions.

Lizards also seem to grow bigger on islands. The largest lizard currently known, the Komodo dragon, *Varanus komodoensis*, lives on a group of isolated islands in Indonesia. Our local monitor lizards, *Varanus indicus*, share the same genus name, indicating the two have many traits in common and, it is believed, had a common ancestor. Komodo dragons grow to over 10 feet in length, and eat whole goats.

Sometimes even plants become giants on islands. The largest palm is the coco-de-mer, *Lodoicea maldivica,* that grows in the Seychelles. This palm grows to be more than 100 feet tall. It produces the largest seed in the world. Each seed takes seven years to become mature.

10. 9. 2. Flightlessness

Another unusual island-evolved characteristic is bird flightlessness. Many island birds cannot fly. Due to a lack of need, and sometimes, to an actual disadvantage of flight capability, populations of island birds slowly lose the ability to fly. Birds on islands often lose the ability to fly because there are no predators to hunt them, and it takes many resources to maintain flight.

In birds, twenty percent of the body weight is taken up by the muscles and bones needed for flight. Also, when flying, a bird must use a great deal of energy to stay in the air.

A bird can make better use of its energy if food is available on the ground and no predators are around. Then it can get more food, grow bigger, or do whatever else it needs to survive. Rails commonly give up the ability to fly once they have settled on an island.

Even on the Galapagos, sea-going cormorants (*Phalacrocorax sp.*) lost the ability to fly. They have only very short wings and must jump into and swim-splash out of the sea, much like penguins do in the Antarctic.

When birds quit flying, they have a tendency to grow bigger than related birds that do fly.

Many island insects have evolved into flightless forms as well. Populations of plants whose original seeds were winged and which came to the islands originally by the wind, also adapt to island living by losing their flying capability. After many generations, they begin producing heavy fruits that fall to the ground near their parent plant.

Thus nature selects for flightlessness on islands. Once a distant island has been colonized by airborne seeds, insects, or birds, the very tendency to be carried afar by the winds, which was responsible for their original successful landing, becomes a liability.

In the Galapagos islands, sea-going cormorants (Phalacrocorax sp.) lost the ability to fly and must jump into and swim-splash out of the sea, Seeds blown away from an island are unlikely to settle anywhere but in the ocean, and birds inadvertently carried away on the wind are apt to be lost once they lose sight of land.

10. 9. 3. Susceptibility to Extinction from Introduced Predators, Diseases, and Parasites

An unfortunate result of the loss of the flying ability is a susceptibility for island bird species to be driven to extinction by predators when, and if, they are allowed to be introduced. Cats, dogs, and rats have each caused extinctions, as have other animal introductions.

Both flying and flightless birds often do not react in ways necessary to avoid the predators. The brown treesnake (*Boiga irregularis*) caused the tragic extinction of all of Guam's forest-dwelling bird species, and several lizard and mammal species as well. It is of such great concern that we dedicate an entire chapter (Ch. 28) to encourage its prevention and control.

Introduced diseases and parasites, likewise, have caused extinctions to populations which do not have appropriate defenses or immunities.

One notable example of a large flightless bird driven to extinction was the fifty pound 'Dodo' (Raphus cucullatus).

One notable example of a large flightless bird driven to extinction was the fifty pound 'Dodo' (*Raphus cucullatus*), a relative of the pigeon. Dodos lived on the islands of Mauritius, Réunion, and Rodriguez in the Indian Ocean. They lived until the seventeenth century, when mariners introduced rats and hogs to the islands. These animals, along with the mariners themselves, caused the dodo's extinction.

Another example is the giant moa mentioned earlier, which was unintentionally driven to extinction by the first human settlers of New Zealand, ancestors of the present day's Maori tribe.

10. 9. 4. Conclusion

Because of reproductive isolation and the mutation of genes (such as flightlessness), populations of organisms are able to change relatively quickly on islands. They may change shape or color slightly, or may become an entirely new species. The law of natural selection assures that the organisms best adapted to the island's environment will survive and have offspring.

With all these adaptations and changes amongst our island populations, the Pacific region is a fascinating place to visit and live. Our islands hold special interest to ecologists, botanists, zoologists, and everyone else interested in learning about living things and the natural world in general.