

LIFE

# THE WONDERS OF LIFE ON EARTH



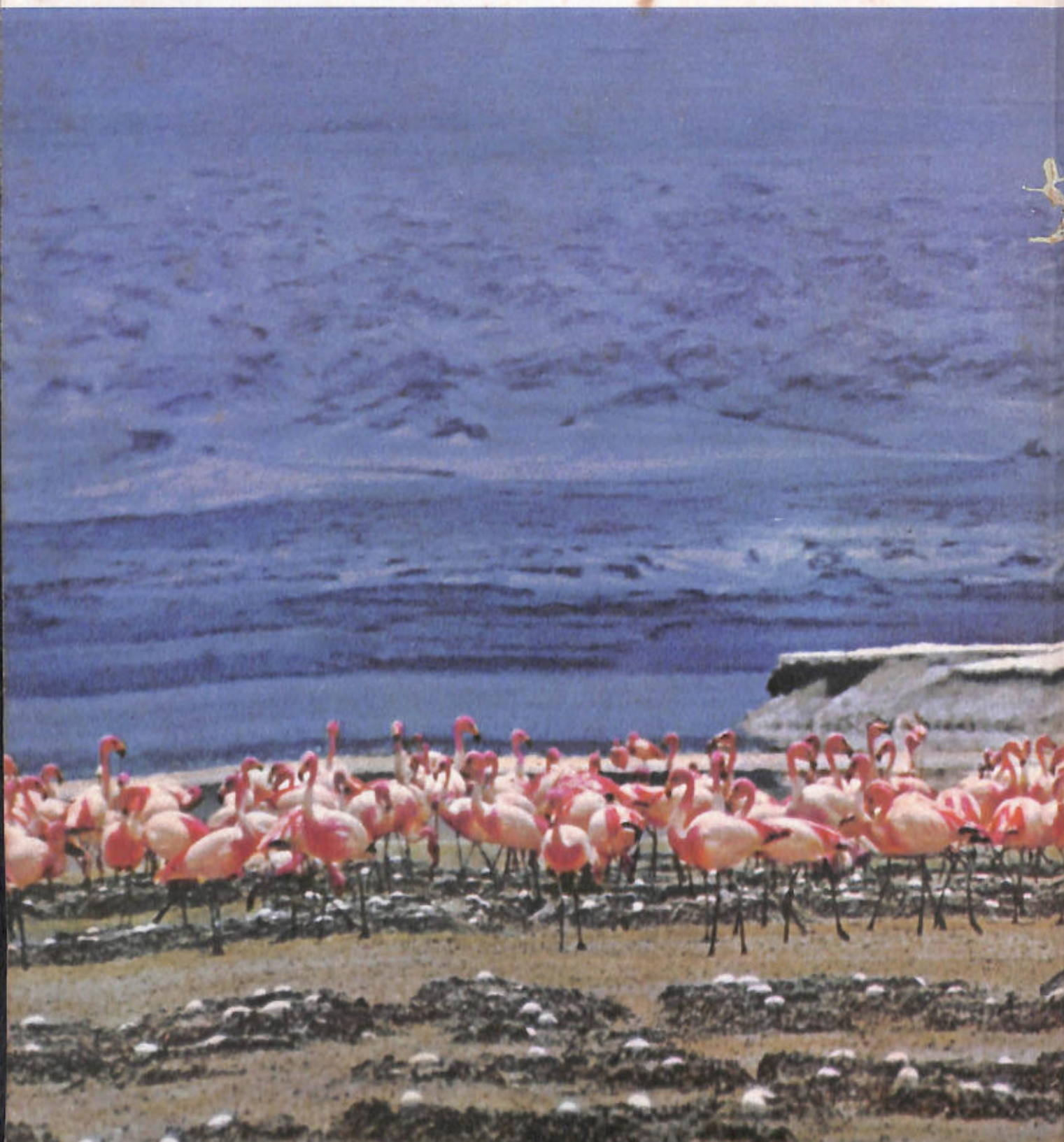
IAL DE LUXE GOLDEN BOOK EDITION

THE WONDERS  
OF LIFE ON EARTH



**LIFE** SPECIAL EDITION FOR YOUNG READERS

# THE WONDERS





# OF LIFE ON EARTH

By The Editors of LIFE and Lincoln Barnett

Text Especially Adapted by Sarel Eimerl  
from the Original Version

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*Morganucodon, a shewlike creature, may have been the first mammal.*



*Ichthyostega, the first amphibian, lived on earth about 300 million years ago.*

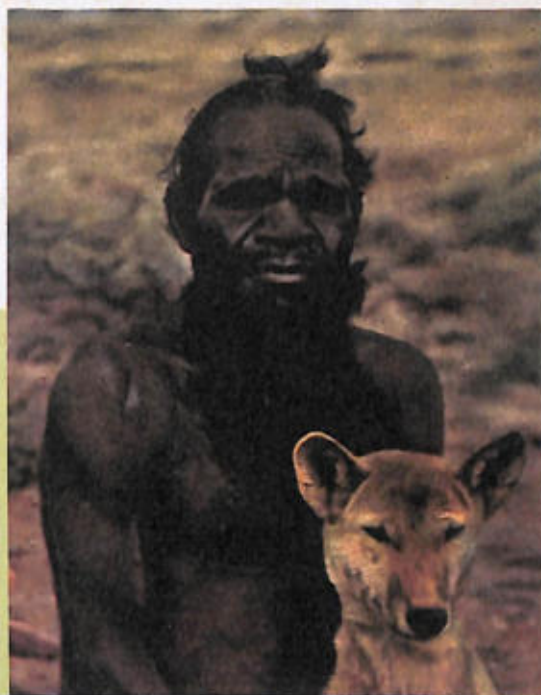




*The ring-tailed lemur is a member of the most primitive order of primates.*



*Australopithecus, an African "ape man," may have come from the common line from which both men and apes evolved.*



*An Australian aborigine and his yellow dingo dog are still nomadic hunters.*

*Staphylococcus aureus bacteria, subjected to penicillin, gradually resist the drug by evolving mutations.*



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## DARWIN'S LEGACY TO MODERN MAN

A little over a hundred years ago, a British naturalist named Charles Darwin came up with a startling new theory. It was an explanation of how all living creatures had come into existence.

Darwin's theory was that all creatures have descended from either one or a very few simple forms of life. Over a period of millions of years, these original forms of life branched out. Gradually they developed new characteristics that helped them to survive. As a result of these changes, reptiles, fish, insects, birds, and animals came into existence. The highest of all these forms of life is Man. This explanation of how new kinds of creatures have developed by natural selection is called the theory of evolution.

Darwin first explained his theories to a group of scientists in London. His ideas were so new and startling that few of the scientists accepted them. But a year later, in 1859, Darwin explained his ideas more fully in a book called *The Origin of Species*. In this book he showed that plants and animals could not possibly have been created in their present form. They must have gone through a long process of development. Evolution was, therefore, a fact.

But that was not all. In *The Origin of Species*, Darwin also described the method of evolution.

*Darwin's study at his home in Downe, England, is packed with books and specimens, much as he left them. Here he wrote all but two of his 17 books.*

He showed not only that it was a fact but also how evolutionary processes actually worked.

As the years passed, more and more scientists came to see that Darwin was right. Today almost all scientists accept his theory of evolution. Later discoveries have confirmed his belief that all present-day creatures have descended from either one or a few original species. These discoveries have also proved that new species do not come into existence quickly. They develop very slowly, over periods of thousands of years—just as Darwin said.

Darwin's whole life was devoted to scientific research. His interest in science started in his youth, when his hobbies were hunting for beetles, collecting minerals, and watching birds. As a student at Cambridge University in England, he went on field trips to examine plants, and he studied geology among the mountains of Wales.

Darwin's father wanted him to become a clergyman and Charles consented to do so. But shortly after his graduation from Cambridge, Darwin received an offer that was to change his whole life. He was invited to go on a trip around the world on the British Royal Navy ship H.M.S. *Beagle*. The 242-ton *Beagle* was making the voyage to survey little-known areas of the world, and Darwin was offered the job of naturalist.

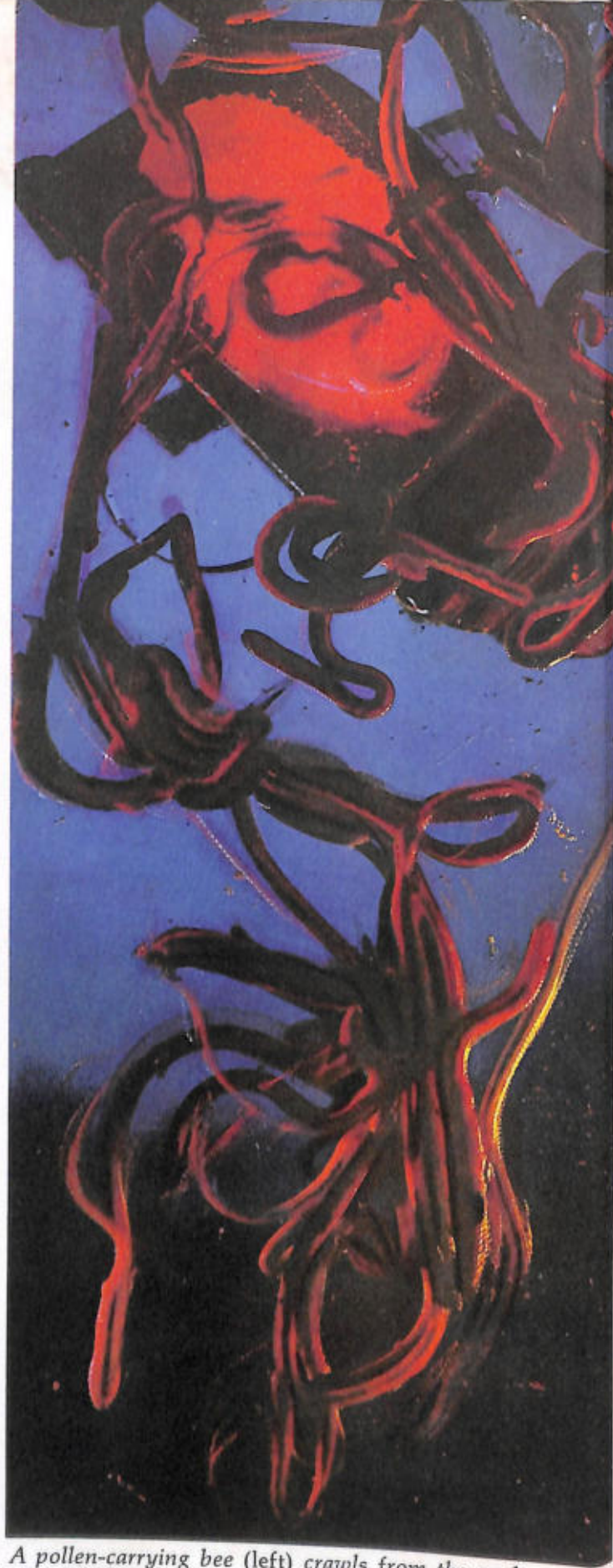
Darwin was 22 when he sailed on the *Beagle* from Plymouth, England, on December 27, 1831. He returned to England on October 2, 1836. The voyage was a revelation to Darwin. It enabled him

to study vast numbers of creatures that he had never known existed. Pressed in the rocks of out-of-the-way countries, he discovered fossils of species which had long since become extinct. These fossils showed Darwin that forms of life went through many changes. The patterns of life he saw around him and in the rocks had a profound effect on Darwin. They made him think that gradual changes in life took place over many thousands of years.

Darwin first began to formulate his ideas of evolution in the Galápagos Islands in the Pacific. When he returned home his notebooks were filled with his observations and his boxes were filled with specimens. For the next twenty years he continued his studies of evolution. Then, when he had digested his material, reached conclusions, and formulated theories from them, he wrote down his ideas in *The Origin of Species*.

Darwin produced seventeen books on a large variety of scientific subjects. He wrote all but two of them in the study of his home in the village of Downe, 20 miles from London. His study, shown on page 8, was packed with books and papers, stuffed animals, and specimens from his voyages.

Darwin conducted endless experiments in his study and in the greenhouse in his garden. He



A pollen-carrying bee (left) crawls from the neck of a Malayan orchid. The adaptations of orchids for attracting bees help keep the species constant.



*Darwin's experiments proved that earthworms react only to bright lights. Here night crawlers (upper left) held on a glass plate, ignore a lantern's glow.*



*The sundew, a meat-eating plant, traps a fruit fly in its sticky sap. Next, longer tentacles under the leaf will arch up to enclose the fly and digest it.*

studied the way in which orchids attract bees and the way sundew plants trap fruit flies. Watching colonies of earthworms in the dead of night, he discovered that the worms react to light, but only if the light is bright. His interests covered every kind of living creature and substance. He wrote books on a variety of subjects ranging from earthworms to coral islands, including one four-volume work on barnacles.

But Darwin's most influential work was his theory of evolution. It revolutionized the sciences of botany, biology, and medicine. It brought new ideas into the study of religion and astronomy, of history and psychology. The truths about the history of life which Darwin perceived have affected every branch of science. Every one of them has benefited from his work.





*Jagged hunks of black lava strew the shore of James Island where Darwin lived for a week of studies.*

such as the Galápagos pelican, were quite similar to birds and animals on the American mainland. Yet the Galápagos lie more than 600 miles from the mainland. How, then, had these mainland creatures managed to reach the islands?

Darwin's first idea was that a land bridge might once have connected the Galápagos to the mainland of South America. If this theory were true, then the animals could have reached the islands by crossing the bridge.

But Darwin soon gave up this notion. He recalled that there were very few mammals and no toads or frogs on the islands. If there had been a land bridge, toads and frogs, as well as many mammals, would have reached the Galápagos.

Darwin's conclusion was that life had been brought from the mainland to the Galápagos haphazardly, through the sea and air. This would explain why there were so many lizards on the islands, but no frogs. For lizards' eggs are protected by shells while frogs' eggs are only covered with a jellylike substance. Lizards could have survived the ocean journey while frogs would have died.

Darwin performed countless experiments to test his theory that life had reached the Galápagos in a hit-or-miss fashion across the ocean. His object was to discover which kinds of eggs and seeds could survive after a long journey through air or water.

He kept seeds in water for several months and found that some would still germinate. He grew plants from seeds dropped by birds and from seeds embedded in the mud that had stuck to birds' feet. The results of these experiments confirmed his belief that life had come to the Galápagos from the distant mainland.

The Galápagos are rich in birds. There are hawks which are afraid of nothing, not even of men. There are pelicans which are closely related to the brown pelican of the United States. With its wing span of six to seven feet, the Galápagos pelican is the smallest member of the pelican family. It obtains food by diving into schools of fish with its bill opened wide; the catch is then scooped into its throat.

One place in the Galápagos where birds and animals thrive especially well is the island of Nar-



mates to the islands on the equator. Herds of tame and playful sea lions sport and splash in pools along the shore. Penguins sprawl on the rocks and strut along the beaches. The Galápagos penguins are the northernmost members of the penguin family. The baby penguins have soft brown fur, but when they grow older they shed it and take on the black and white colors of the adult penguin.

The scarlet rock crabs provide a flash of color as they scramble over the rocks, hunting for food. Although they look clumsy, they are surprisingly nimble. Their greatest enemies are predatory birds. When they see the shadows made by the wings of an approaching bird, the crabs scuttle hurriedly into the safety of crannies in the rocks.

Darwin remained on the Galápagos Islands for only five weeks. They were, however, among the most important weeks in his life, for he realized that these isolated islands held the key to the whole mystery of evolution. Because the Galápagos were isolated from the rest of the world, he was able to study the creatures that lived on the islands as if he and they were in a laboratory. He called the Galápagos, "a little world in itself."

Darwin was puzzled by the fact that living creatures inhabited the Galápagos at all. Most of the animals were unique and could not be found anywhere else on earth. But as the islands were of volcanic origin, he was sure the animals had not originated there. Besides, some of the island creatures,

The route of H.M.S. Beagle (shown by the dotted line) took Darwin to four of the Galápagos Islands. He spent a month observing animal life and noting how creatures differed from island to island. This map, which gives both Spanish and English names of the islands, shows the animals which Darwin saw on his trip. Their appearance and behavior have changed little from his day to ours.





*Jagged hunks of black lava strew the shore of James Island where Darwin lived for a week of studies.*

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One place in the Galápagos where birds and animals thrive especially well is the island of Nar-



*One-month-old baby penguins (left) sprawl on a rocky roost on Albermarle. These birds, the northernmost members of their family, have soft brown down. When mature, they take on the black-and-white colors of adults.*

*This tortoise (below), which weighs more than 500 pounds, has sensed danger and draws in its head with a hiss of alarm. It measures 96 inches around the waist and 53 inches down the length of its back.*

borough. This island has remained a sanctuary for them. Men have never settled there, nor have they brought along their dogs and other animals which have disturbed the balance of nature in other parts of the world. Untouched by outside influences, Narborough's birds and animals have been allowed to breed undisturbed, and some have taken on many strange forms. One unusual bird is the flightless cormorant which, as its name implies, has lost the use of its wings. But the inability to fly has not proved detrimental to the Galápagos cormorant. It is the largest member of its species in the world, and breeds on the island in enormous numbers.

The fur seals of the Galápagos have had less success in protecting themselves against their enemies. The biggest threat to their existence is the men who hunt them for their fur. Today there are only a few hundred Galápagos seals left alive and they, too, may soon die out.

The reptiles are the strangest of all the creatures on Narborough and the other Galápagos islands. Nowhere else on earth have reptiles developed into so many unusual species. The most common of Galápagos reptiles, the lava lizard, is found everywhere on the islands, even inside the homes of men. Although they feed mostly on insects, lava lizards sometimes eat smaller members of their own species. When they get angry, they puff themselves up and spit their displeasure.

Perhaps the most extraordinary reptiles are the sea-going iguanas. With their sawlike teeth and knifelike talons, the iguanas look rather like dragons. They fit perfectly into their surroundings. The scales that cover their heads and spines are shaped like volcanic cones, and their black and gray skins reflect the colors of the lava and the surf. The primeval appearance of the reptiles makes the Galápagos look like a scene from the age of dinosaurs.

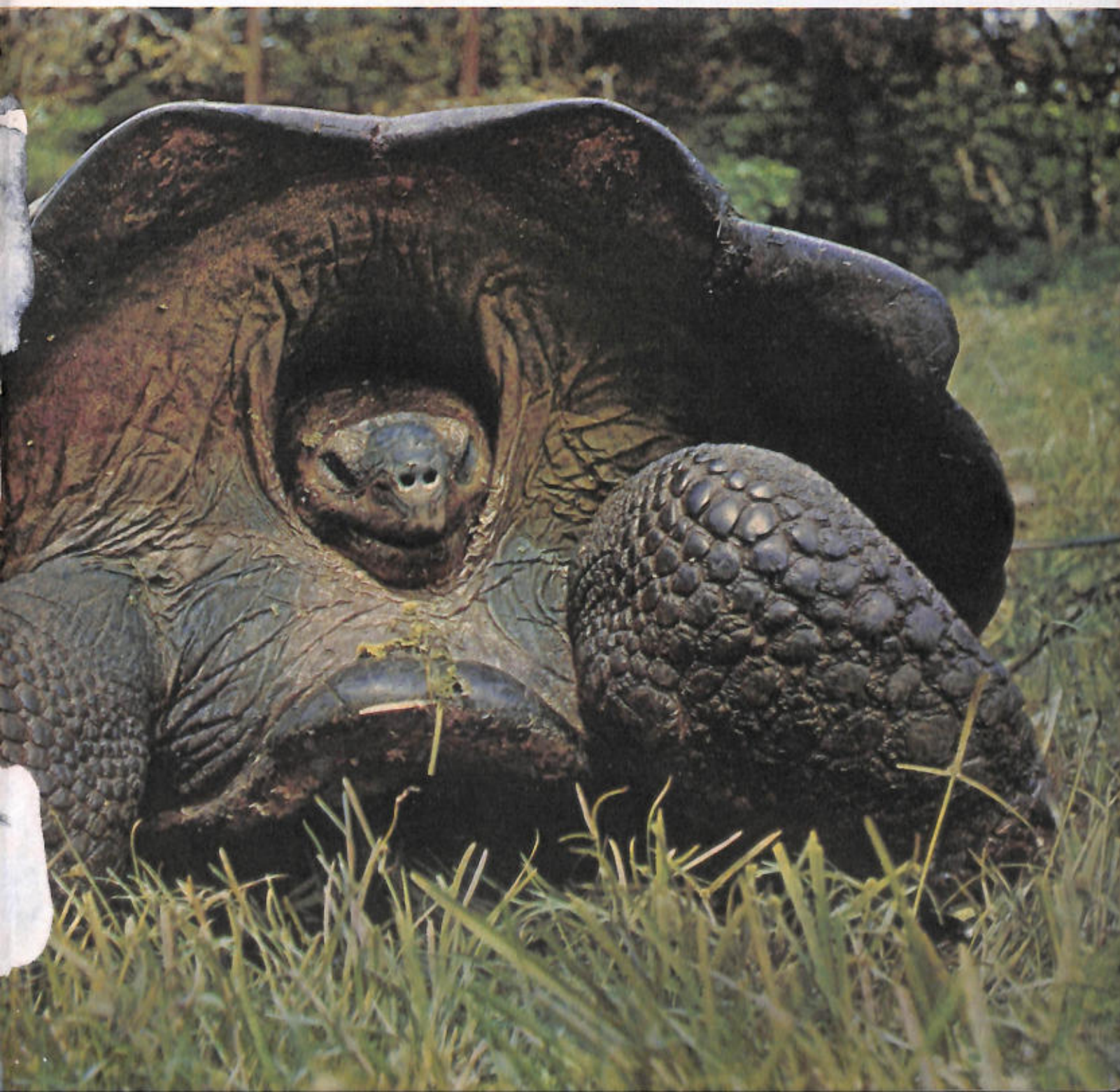
During his visit to the Galápagos, Darwin was particularly impressed by the enormous number of different kinds of reptiles that he found on the islands. He also noticed that there were almost no mammals there.



Mammals are the most highly developed of all animals, and in almost all other parts of the world they have eventually outnumbered the reptiles. But although Darwin hunted tirelessly for mammals in the Galápagos, he found only two. One was a mouse which, he decided, had bred on the islands. The other was a rat which he believed had come to the Galápagos on a ship.

Darwin noticed that none of the birds and animals on the island of Narborough fought with each other, and that none of them were afraid of each

other, or of men. Once Darwin got so close to a hawk that with the muzzle of his gun he was able to push the bird off the tree branch on which it was perched. He was astonished by the tameness of the birds. From his observations, he decided that birds do not have any instinctive fear of men. Instead, their instinct of fear is developed only after they have lived near men for several generations and have learned by experience to fear them. After fear is learned, succeeding generations of the birds are born with the instinct.





*A wild cucumber (above), related to the garden variety, produces a seed pod which bears bright red seeds. The seeds are eaten by vegetarian finches.*

Darwin's visit to the Galápagos Islands provided him with his first and vital clue to the solution of the great mystery of how new forms of life came into existence. He obtained this clue after brooding for a long time over a question which had haunted him during his stay on the islands.

The individual types of various species of creatures differed, often radically, from one island to the next. But since the climate and terrain on the different islands were similar, all these creatures seemed to be living under the same conditions. How then had the differences among them arisen? A perplexing problem, one which Darwin called "the great difficulty."

*A lava lizard (below) eats a smaller lizard. This is unusual since lizards normally live on insects. Lava lizards are found throughout the Galápagos.*



It was the vice-governor of the Galápagos who first called Darwin's attention to the way in which animals inhabiting different islands varied from each other. He remarked that by looking at a tortoise he could tell which island it came from. Darwin overlooked this observation at first. "I did not," he related, "for some time pay sufficient attention to this statement." For, as Darwin confessed, he did not at first realize that islands which were only 50 to 60 miles apart and had a similar climate could be inhabited by different animals.

In the end it was not the tortoises but the finches which put Darwin on the track that led him to the discovery of how different species of creatures come into existence. He remembered that he had observed thirteen different varieties of finches on the Galápagos. He theorized that these finches must all have descended from one bird which had either migrated to the islands or had been blown there by a storm.

There were no other land birds on the Galápagos. Therefore, without enemies or rivals, the finches were able to develop freely into many different species. On each island the special characteristics that were best suited to their environment were transmitted in successive generations. In some finches, slender curved beaks for probing flowers had evolved; in others, strong parrotlike beaks useful for cracking seeds had survived.

It was this discovery which gave Darwin his first clue to the central part of his theory of evolution. In his book, *The Origin of Species*, he explained that there were two main factors which decide how creatures change and develop. The first is the physical surroundings they live in, for creatures that have survived have gradually developed over successive generations the characteristics they need to exist in their environment. The second factor is the other creatures living in the environment. Surviving creatures develop characteristics needed to conquer their prey and avoid their enemies.

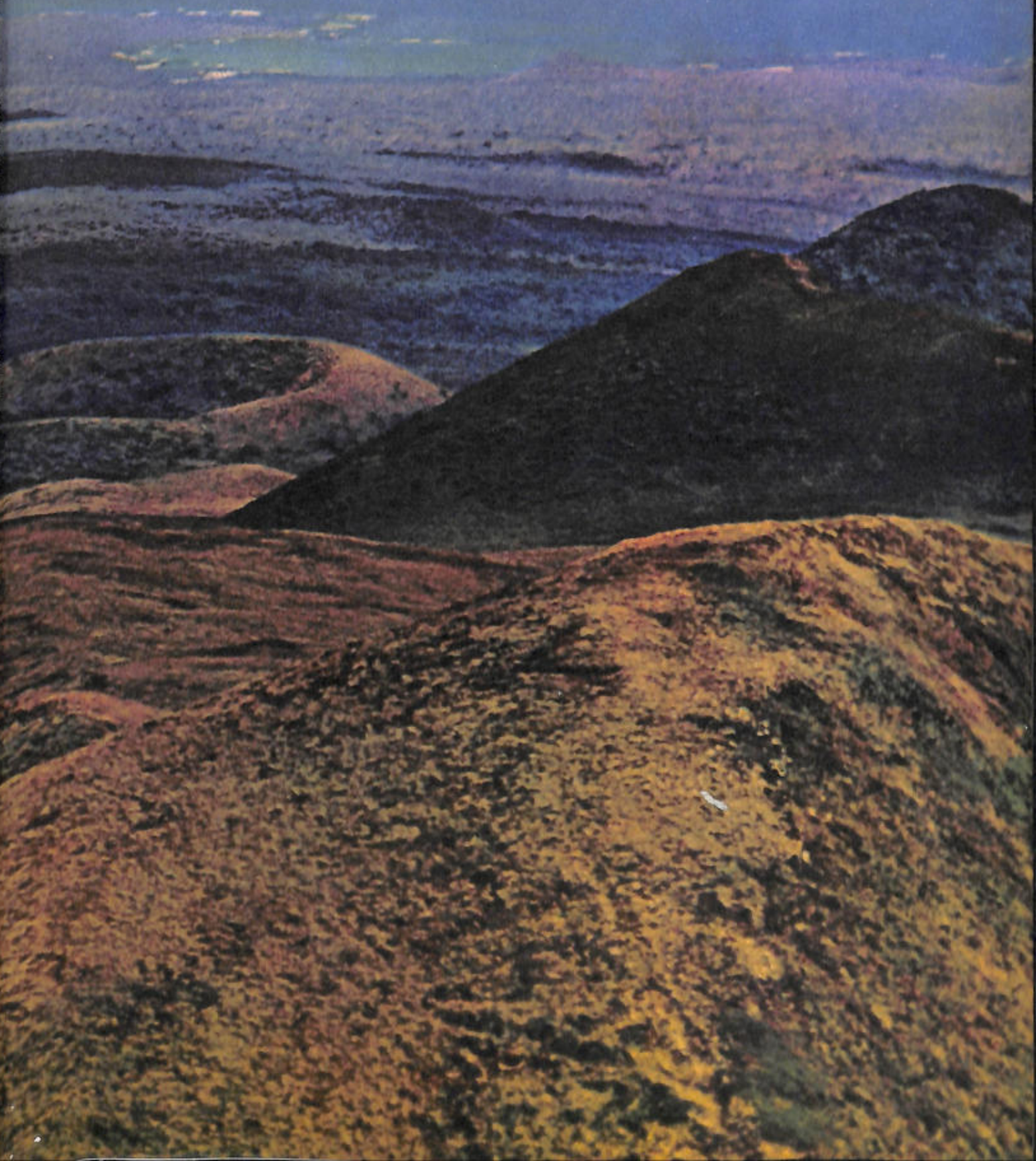
Although the climate and terrain were similar on the Galápagos Islands, the animals had begun to develop differently. Each slight change in one led to changes in the others. So the process of evolutionary change continued until the differences had become so great that Darwin was able to make one of his most important discoveries.



*A Galápagos pelican nests in a clump of mangroves with two fledglings at its feet. It is closely related to the familiar brown pelican of the United States. With its wing span of six to seven feet, it is the very smallest member of the pelican family. It feeds by diving into schools of fish with its bill open, and scooping them into its pouch.*



*The green, grassy highlands of Indefatigable Island roll down to the blue Pacific, 15 miles away. It is only inland on such treeless slopes of the highest volcanoes that grass and leafy plants can grow in the Galápagos Islands.*





*Ancient, prehistoric kinds of creatures are best preserved on Narborough Island. In this painting all the main species are shown as they exist today, living peacefully together on the spray-blown cliffs beneath Narborough's live volcano.*

*The time is November, the start of the mating season for marine iguanas, when the males take on their courting colors. The big crested iguana on top of the rock at left is defending his females against possible intruders. But there are not likely to be any*



fight. Despite their formidable claws and scales, iguanas dislike bloodshed. The closest they come to actual fighting is to glare at each other and butt their heads together like goats until one gives way. They are vegetarians and usually ignore the crabs

which scuttle over their bodies, hunting for ticks. The crabs live mainly on algae and seaweed which they nibble from exposed rocks at low tide (center foreground).

On the white rocks at the right, a young flight-



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On the white rocks at the right, a young flight-



less cormorant is eating fish from its mother's throat. In the lower righthand corner, beneath a clump of cactus, a Galápagos snake (one of the few predators on the island) is eating a lava lizard. In the middle distance are pelicans (upper left), sea

lions and penguins (front center), more iguanas and cormorants (right). In the far distance a pair of blue herons perch on mangrove trees. Overhead, frigate birds soar on powerful wings scanning the sea for fish.



1 MEDIUM GROUND FINCH

2 CACTUS GROUND FINCH (FEMALE)

3 CACTUS GROUND FINCH (MALE)

LAND IGUANA



10 TOOL-USING FINCH

11 WARBLER FINCH

12 LARGE INSECTIVOROUS TREE FINCH

Three years after his return to Britain Darwin published an account of his trip around the world in a book called *The Voyage of the Beagle*. In it he mentioned the significant questions which had intrigued him during his trip. But he continued to collect information and evidence in support of his theories for another 20 years before he finally disclosed them in his great work, *The Origin of Species*.

Among the 13 different species of finches on the Galápagos, Darwin noticed that some hunted

*Thirteen varieties of the finches that Darwin found on the Galápagos vary in their beak structures, plumage, and diet. In the center of the picture at the left is a land iguana.*

INSECT EATER



WARBLER FINCH

PRIMARILY INSECT EATERS PLUS SOME PLANTS



LARGE INSECTIVOROUS TREE FINCH

MEDIUM INSECTIVOROUS TREE FINCH

SMALL INSECTIVOROUS TREE FINCH

TOOL-USING FINCH

MANGROVE FINCH

PRIMARILY PLANT EATERS PLUS SOME INSECTS



LARGE GROUND FINCH

MEDIUM GROUND FINCH

SMALL GROUND FINCH

SHARP-BEAKED GROUND FINCH

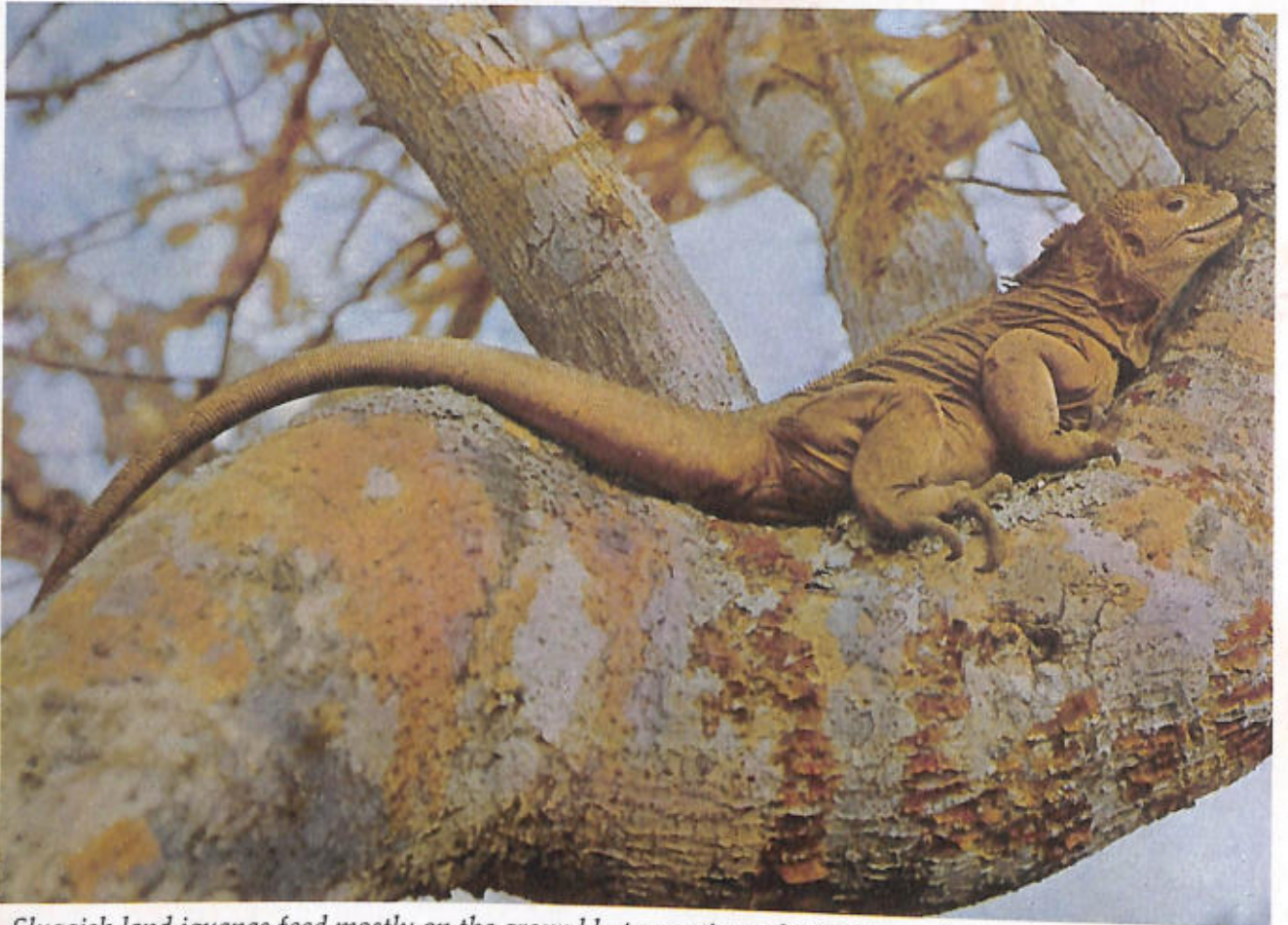
CACTUS GROUND FINCH

LARGE CACTUS GROUND FINCH

PLANT EATER



VEGETARIAN TREE FINCH



*Sluggish land iguanas feed mostly on the ground but sometimes climb low acacia trees in search of leaves.*

seeds on the ground or insects in the trees. Some fed on fruit and flowers. Each species had a differently shaped beak, depending on the kind of food it ate. The birds' plumage also varied, depending on where they lived. The finches that lived on the lava cliffs were black. Those that lived among the trees were gray and green.

The most conspicuous animals on the Galápagos Islands are the land and sea iguanas. Sea-going iguanas have not been found anywhere else on earth. They dislike bloodshed and do not attack other creatures. The closest they ever come to fighting among themselves is when they glare at each other and then butt their heads together until one gives up. They spend most of their time basking peacefully in the sun.

They are vegetarians and make no effort to eat the crabs which scuttle over their bodies hunting for ticks. Instead, they live on seaweed which they nibble from exposed rocks at low tide.

The sea-going iguanas are graceful swimmers,

but they avoid the sea when they are frightened. Darwin proved this by heaving one into a pool several times in succession. Each time the iguana swam straight back to the shore and to him.

Darwin reasoned that iguanas, which have no enemies on shore, are sometimes attacked by sharks at sea. They had, therefore, developed an instinct that told them the shore was a safe place.

The land iguana is similar to its sea-going relative. It is also a vegetarian and lives on plants and leaves. It is both lazy and sluggish and feeds mostly on the ground. But occasionally it crawls up the low, stunted acacia trees to eat the leaves.

The land iguana also has a peaceable nature. One day Darwin saw one digging a burrow and pulled it out by the tail. "At this it was greatly astonished," he wrote, "and then stared me in the face, as if to say, 'What made you pull my tail?'"

*Sea iguanas sprawl along the coast of Narborough Island where they breed in the greatest numbers.*





*A giant block of lava stands surrounded by crumbling rocks amid a great crater lake on Narborough.*

No one knows exactly when the Galápagos were lifted by volcanic forces from the sea floor. As the lava gushed from smoking volcanoes, it piled up until the level of the hot mass finally rose above the surrounding seas. The volcanic eruptions have left more than 2,000 craters on the islands. Lakes of black lava and hot sulphurous water lie inside many of these craters.

Some of the volcanoes rise thousands of feet above the sea. Cool, moist breezes from the sea are heated as they cross the parched lowlands; then the air rises and forms clouds and mists around the mountaintops. Watered by this moisture, lush meadows of ferns and grass cover the ridges of lava. The moisture also collects inside some of the craters and forms clear, fresh-water pools where flowers bloom and insects and birds make their homes.

In the lowlands around the island coast, there is little moisture. Only plants like the cactus, which can stay alive with little rain, are able to survive in the lowlands. Some of the plants reach tree size. They provide almost the only source of food and drink for the tortoises and iguanas which consume them, prickly spines and all.

The volcanoes and craters, the parched lowlands, and the lava cliffs make the Galápagos Islands a dismal place for visitors. After his first walk in the interior, Darwin wrote that "nothing could be less inviting." The novelist Herman Melville also vis-

*The main crater of Narborough's biggest volcano (right) rings a lake measuring 11 miles around. The outer walls soar 4,900 feet above the sea.*

ited the Galápagos and reported that "little but reptile life is here found . . . no voice, no low, no howl is heard; the chief sound of life here is a hiss."

But Darwin ignored the discomfort. He made repeated trips into the gloomy interiors of the islands. On these trips he counted 185 species of plants and observed that 100 of them were kinds he had never seen before. For endless hot hours he studied the habits of the tortoise. He timed its rate of progress and found that it moved 360 yards an hour, or four miles a day.

Darwin also made intensive studies of all the other kinds of life on the islands: the lizards and birds, the insects and the trees, the shrubs and the flowers. These studies showed him that the species of living things varied from one island to the next. The general characteristics of each kind of animal and bird were the same on all the islands. Yet every island had its own special variety of such creatures as the tortoises, the finches, and the mocking thrush.

This fact, Darwin wrote, "strikes me with wonder." It was also to lead him to one of his most important discoveries about the way evolution works over the ages.

In 1957, a group of scientists working with international conservation groups and *Life* magazine recommended that some of the islands be set apart as sanctuaries so that the creatures who lived on them would be protected from harm. The scientists also recommended that a center for biological research be set up on the islands.

These proposals have since been carried out. Today several of the Galápagos Islands are nature sanctuaries. A unique "laboratory" of evolution is now being completed on the islands. When finished, the Charles Darwin Memorial Station will be the first international biological research center.

Scientists from many nations of the world will try to resolve the questions which are yet to be answered, including those concerning the arrival of the creatures which now breed and thrive on the Galápagos. Science has discovered how some of the species reached the islands, but the exact method used by others is still unknown.





*A Blue Morpho Butterfly, most brilliant of all the insects that enchanted Darwin's eye, spreads its wings.*

are also insect-eating snakes, lizards, monkeys, and other animals. Each insect has developed its own camouflage to hide from its most dangerous enemies. Over a period of many thousands of years, the insects which have survived are those which have inherited the particular disguises that enable them to hide most successfully from their enemies.

Many insects have other methods of keeping their enemies from attacking them. Some have the appearance of other insects which their enemies are afraid of. Some have developed an unpleasant smell that repels their enemies. Some have become so unpleasant to taste that predators do not find them worth eating.

To some insects, heat is a more dangerous enemy than other creatures are. One such insect is the morpho butterfly, which lives among the treetops. Its bright blue coloring reflects the sun's rays and thus guards its fragile body from the heat.

In Brazil Darwin noticed that certain insects were attracted by certain plants. He had observed the same process in England. This led him to conclude that insects and plants in the same general families react similarly wherever they live.

But the teeming insects of Brazil taught Darwin something far more important. They gave him his first real insight into the continual struggle for survival that takes place in nature. By studying them, he began to understand how living creatures manage to avoid or overcome their enemies.

He did not begin to see how evolution actually took place until he reached the Galápagos Islands. But in Brazil he found the first clues to the mystery of why some creatures are able to escape from their enemies while others are wiped out. He later called the explanation of this mystery the "survival of the fittest." It was to become one of the most important parts of his whole theory of evolution.



*The male Rhinoceros Beetle (above) wears fearsome horns which look as if they are intended for fighting. Since Darwin never saw these beetles fight, he decided that their horns were merely ornamental and served to attract females. However, the male rhinoceros beetles do sometimes fight over females.*

*Parasol Ants live on leaves. A group of the ants (below) are carrying sections of leaves to store in their underground labyrinths. Darwin wondered at the tireless labors of what he described as the "never-ending foragers, burdened with pieces of green leaves often larger than their own bodies."*





The wasp and the spider are two of nature's most relentless enemies. They frequently engage in fights to the death like the one witnessed by Darwin.



Usually the wasp is the victor, as in the fight shown here. The wasp begins the fight by attacking the spider and evading its legs (top). Then it implants its deadly sting on the underside of the spider's thorax (center). This paralyzes the spider. Finally (bottom) the wasp drags its paralyzed victim away.



cells and stuff them full of paralyzed spiders and caterpillars. Then they lay their eggs in the cells. After the eggs have hatched, the grubs feed on the still alive but paralyzed insects in the cells.

Darwin observed and recorded these facts. They were to help him develop his theory of how nature's creatures use their enemies in order to survive.

The pressure of life in the tropical forests is fiercer than anywhere else on earth. Insects fill every corner of the dank, green masses of plants, vines, and trees. They swarm through the forests, from the ground to the topmost leaves of the trees.

All these insects are constantly threatened by their enemies. At every moment they face possible destruction from some sharp-beaked bird or long-tongued lizard, and from snakes and toads. In order to survive, the insects have developed an enormous collection of defenses to deceive the creatures that hunt them.

In 1958, an English scholar named Dr. H. B. D. Kettlewell retraced the journey taken by Darwin through Brazil's forests in order to analyze insect adaptations in the light of modern knowledge. Possessing scientific equipment which Darwin had lacked, Dr. Kettlewell was able to identify 5,000 different varieties of insects.

The most common means of self-defense used by insects is camouflage. The stink bug and the longhorned beetle both copy the appearance of lichen, a plant which grows on tree barks. The giant moth *Thysania agrippina* also imitates the appearance of lichen. Stretching 12 inches from one wing tip to the other, it is the largest moth known to science today.

The sphinx moth's broken coloring makes it look like the splotchy patterns on the bark of a tree. There are green moths which are practically invisible against green leaves.

Other moths have developed wings with irregular, cutout patterns which make them resemble dead leaves with holes. Another kind of moth, called the cossid, looks like a fallen flower. The phasmid stick, which is long and thin, has the appearance of a dead twig.

Two other insects have taken on a particularly curious kind of camouflage. The wily weevil has developed a whitish shell spotted with brown that gives it the appearance of bird droppings. The leaf

This picture shows the camouflage, or defensive coloration, used by insects in the Brazilian forests. (Far left) The Stink Bug and the Longhorned Beetle both blend into the lichens on the tree. So do the giant moth, *Thysania Agrippina*, and the other moths around it. The Phasmid Stick impersonates a dead twig, while the Cossid Moth (top, right center) looks like a fallen flower. The green wings of the Leaf Blemish Katydid (right center) simulate blotches of tree blight. The Brown Leaf Katydid (lower right) copies a dead leaf, but can also startle its enemies with a sudden flash of color.

- 1 LICHEN-COLORED STINK BUG
- 2 LONG-HORNED BEETLE
- 3 WORLD'S LARGEST MOTH, *Thysania Agrippina*
- 4 DISRUPTIVE WHITE-MARKED MOTH, WINGS FOLDED
- 5 TRIANGULAR-WINGED DISRUPTIVE NOCTUID MOTH
- 6 LARGE JEWEL BEETLE
- 7 PRAYING MANTID
- 8 DISRUPTIVE-STRIPED NOCTUID MOTH
- 9 WAVY-PATTERNED BUTTERFLY
- 10 HUGE BROWN PHASMID STICK INSECT
- 11 GIANT GRAY HAWK MOTH
- 12 DISRUPTIVE-PATTERNED COSSID MOTH, WINGS FOLDED
- 13 GREEN AND WHITE PATTERNED MOTH
- 14 RUST AND WHITE PYRALID MOTH
- 15 BROKEN TWIG MOTH, WINGS FOLDED
- 16 GREEN SPHINX HAWK MOTH
- 17 GREEN-SPOTTED GEOMETRID MOTH
- 18 GRAY-GREEN TREE GRASSHOPPER
- 19 FOUR-SPOTTED LEAFLIKE MOTH
- 20 WINDOW-WINGED MOTH
- 21 FLOWERLIKE COSSID MOTH
- 22 GREEN AND YELLOW VARIEGATED LEAF HOPPER
- 23 BROWN-BLACK DISRUPTIVE MOTH
- 24 ORANGE-COLORED DEAD LEAF MOTH
- 25 DARK-SPOTTED TWIG-HOLDING MOTH



- 26 GRAY SPHINX HAWK MOTH
- 27 BROWN LEAF MANTID
- 28 RED-BODIED FOUL-SMELLING MOTH



29 WEDGE-SHAPED MOTH, ON TWIG  
 30 GREEN LEAF BLEMISH KATYDID  
 31 BROWN LEAF KATYDID

32 YELLOW AND BLACK FLASH MOTH  
 33 TAN SATURNID MOTH, CAMOUFLAGED  
 34 BRIGHT TROPIC BEE



29 WEDGE-SHAPED MOTH, ON TWIG  
 30 GREEN LEAF BLEMISH KATYDID  
 31 BROWN LEAF KATYDID

32 YELLOW AND BLACK FLASH MOTH  
 33 TAN SATURNID MOTH, CAMOUFLAGED  
 34 BRIGHT TROPIC BEE



35 TAN SATURNID MOTH IN EYE SPOT DISPLAY  
36 YELLOW-WINGED WARNING MOTH  
37 RED-FLASH GRASSHOPPER

38 SNOUDED MOTH  
39 BROWN LEAF KATYDID IN FLASH DISPLAY  
40 HAIRY-BODIED MOTH



Some insects use mimicry to confuse their enemies. A swarm of black and orange butterflies flicker in the center of this painting. The two topmost specimens are the Distasteful Heliconian and the Distasteful Model. They have an unpleasant taste. The other butterflies are edible but imitate the distasteful Model.



tasteful species, thus confusing their enemies. Between the butterflies are two big orange and black insects. The one at the left is the harmless Mydas Fly, which impersonates the venomous Pepsis Wasp to its right. At the lower left, the Headlamp Click Beetle bears eyelike spots intended to



29 WEDGE-SHAPED MOTH, ON TWIG  
 30 GREEN LEAF BLEMISH KATYDID  
 31 BROWN LEAF KATYDID

32 YELLOW AND BLACK FLASH MOTH  
 33 TAN SATURNID MOTH, CAMOUFLAGED  
 34 BRIGHT TROPIC BEE



- 1 GOLD-MARKED WARNING SYNTOMID MOTH
- 2 YELLOW WARNING GEOMETRID MOTH
- 3 BLACK AND YELLOW GRAY HAWK CATERPILLAR
- 4 RED AND BLUE LEAF HOPPER
- 5 TWO-SPOTTED SYNTOMID MOTH
- 6 HEADLAMP CLICK BEETLE
- 7 BIG-WINGED MASKED LANTERN BUG
- 8 MALE WHITE BUTTERFLY
- 9 ORANGE AND BLACK LEAF HOPPER
- 10 YELLOW-SPOTTED BLACK LEAF HOPPER
- 11 SMALL TWO-SPOTTED NOCTUID MOTH
- 12 FEMALE WHITE BUTTERFLY
- 13 ORANGE-WINGED MYDAS FLY
- 14 ORANGE-WINGED PEPSIS WASP
- 15 GRAY TWO-SPOTTED ARCTIID MOTH
- 16 TRICOLORED LYCORID BUTTERFLY
- 17 BLUE MORPHO BUTTERFLY
- 18 TRICOLORED DISTASTEFL HELICONIAN BUTTERFLY
- 19 TRICOLORED NYMPHALID BUTTERFLY
- 20 RED-BEAKED TRUE WASP
- 21 BLUE-BLACK TARANTULA HAWK WASP
- 22 TRICOLORED DISTASTEFL MODEL BUTTERFLY
- 23 TRICOLORED MELINIID BUTTERFLY
- 24 TRICOLORED MECHANITIS BUTTERFLY
- 25 TRICOLORED EUEIDES BUTTERFLY
- 26 RED-BEAKED WASPLIKE SYNTOMID MOTH
- 27 RED-WHITE-BLACK SWALLOWTAIL BUTTERFLY
- 28 ORANGE-BANDED WARNING SYNTOMID MOTH
- 29 BLUE-BLACK ASSASSIN BUG
- 30 ANTLIKE BUG
- 31 ORANGE-BANDED WARNING LYCID BEETLE
- 32 WAXY-STREAMERED CICADA
- 33 HORNED TREE HOPPER
- 34 KNOBBED MEMBRACID BUG
- 35 CRESTED TREE HOPPER
- 36 THORNLIKE TREE HOPPER
- 37 ORANGE-BANDED LONG-HORNED BEETLE
- 38 SPIDERLIKE MOTH
- 39 KNOB-LEGGED GNATLIKE MOTH
- 40 GIANT HORNED BEETLE
- 41 SCORPION-TAILED MOTH
- 42 WEEVIL-LIKE MOTH
- 43 GRAY-WINGED BEETLELIKE MOTH
- 44 LEAF-LEGGED SQUASH BUG
- 45 PALE BUGLIKE CICADA
- 46 PALE BUGLIKE MOTH
- 47 HAIRY BLUE-GREEN NOCTUID MOTH
- 48 HORNED SCARAB BEETLE

scare its enemies. In the upper left corner the Lantern Bug reveals its scary markings: huge eye marks on its hind legs and the likeness of an alligator, complete with teeth, on its head.

blemish katydid has green wings with blotches on them, similar to the spotted leaves on trees which have been stricken with blight.

Other insects resemble the patterns of light which filter through the treetops into the forest. One kind of caterpillar has diagonal stripes with patches of blue-green and white. These markings are so like the effects of light and shadow playing on the leaves that the caterpillar is scarcely visible. The mottled moth is covered with light oval markings which resemble flashes of sunlight.

The draconia moth also has found a way to take advantage of the sun. It does not rest with its wings folded, as most moths do. Instead, it stands erect when resting, with its wings spread out at right angles to the sun. By doing so it exposes only its thin wing edges and its long body to the sun's rays. Its shadow is thus kept as small as possible and it is not so noticeable to hungry birds.

Some insects have developed extraordinary tricks to confuse their enemies. The acrobatic moth throws its abdomen over its head when resting so that it doesn't look like an edible moth at all. The hairy legged moth avoids looking like a moth by spreading out its large black forelimbs. In some positions this defensive behavior gives the moth the look of a spider.

*The Pseudo Spider below is actually a kind of hairy caterpillar with eight false, leglike appendages.*



There is also a kind of hairy caterpillar which impersonates a spider. It has eight false appendages which look so much like a spider's legs that the caterpillar is called the pseudo, or imitation, spider. If the false legs are nipped off by an enemy, they quickly grow back again.

One silk moth that flies at dawn has developed what is perhaps the cleverest trick of all to deceive its most dangerous enemy, the dawn-flying bat. Bats hunt by following reflected sounds. The silk moth has long wing tails which make a slight rustling noise in flight. The bats hear the wing tails and attack them. But the wing tails come loose, allowing the moth itself to escape.

If discovered, some insects that use camouflage to conceal themselves also try to frighten their enemies away. The brown leaf katydid looks like a dead leaf, but if it is discovered, it unfurls its wings and startles its attacker with a sudden flash of color. The saturnid moth resembles a faded leaf when it is resting. But when threatened, it displays spots which look like bloodshot eyes and these seem to scare the birds away.

Still other insects rely on their possession of a horrible smell or taste to keep them safe. These include the red-bodied foul-smelling moth and the orange-black pseudo-sphinx caterpillar. Birds

*The Acrobatic Moth is able to disguise itself quite effectively by throwing its abdomen over its head.*





*A camouflaged caterpillar is protected from detection by its stripes and splashes of blue-green and white.*

which have once smelled the moth or tasted the caterpillar will leave them alone in the future. Many insects that use this kind of defense are brightly colored and are easily recognized.

Nature's tricks are limitless. Some insects use mimicry instead of camouflage to defend themselves. They confuse their enemies by looking like other insects which are less attractive prey.

Among these impersonators are a group of black and orange butterflies. Two of them, the distasteful heliconian and the distasteful model, have such an unpleasant taste that no bird wants to attack or eat them. The other butterflies although resembling the bad-tasting ones, are quite edible.

Some insects have survived by developing the appearance of completely different and dangerous insects. The harmless mydas fly impersonates the vicious pepsis wasp. And moths have taken on the appearance of spiders, weevils, beetles, and scorpions to prevent their enemies from attacking.

Still other insects have developed special terrible-looking features that frighten their enemies. The lantern bug is a harmless creature and can hardly be seen when at rest. But in flight it exposes huge eye marks on its hind wings and a head that looks like a tiny alligator with savage teeth. As a final defense, its body is coated with an unpleasant-tasting wax.

Darwin noticed that even the shape and form of the insects, and the way they held themselves, were designed to help them escape their enemies. He believed that originally insects may have resembled objects such as twigs or leaves. This first resemblance was probably accidental. But gradually the insects began to change and take on new characteristics. If the changes made them look more like twigs or leaves, they became harder for their enemies to see. They were, therefore, less likely to be attacked and had a better chance of surviving.

Other insects took on characteristics which made them look less like their background. These insects became easier for their enemies to see. They were more likely to be attacked and destroyed. So, as time went on, the insects that grew to look more and more like their surroundings had a better chance to live to adulthood, and to reproduce their own kind. Those which failed to do so were gradually wiped out.

Because Darwin lacked the equipment of modern science, he was not able to identify all the thousands of different kinds of insects which swarm among the Brazilian forests. But he saw

enough to help him develop the theory which he was later to term simply "Natural Selection," or "the Survival of the Fittest."

Darwin observed that because of a limited food supply, far more creatures are born than can possibly survive. Life in its natural state is therefore a constant battle for survival. As the generations pass, all creatures develop new and different variations, just like the insects in Brazil. Some of these variations help the creatures to get the food they need or to avoid their enemies. These creatures continue to breed. Other creatures develop characteristics which do not help them in the struggle for survival. These creatures eventually die out.

This theory of the survival of the fittest was part of Darwin's explanation of how evolution works. With it he was able to provide an answer to the question of why some creatures continue to exist while others die out.

The process of natural selection moves slowly. Under normal conditions it takes birds, animals, and insects many generations to develop the new characteristics that help them to survive. But if a creature's environment is changed suddenly, the process of natural selection may be speeded up and new characteristics may develop rapidly.

In the past hundred years men have made great changes in natural conditions. They have replaced fields with houses and factories, and they have built highways and railroads across the open countryside. Once-clean air has become filled with smoke from automobiles and factory chimneys. This smoky air has, in turn, darkened the leaves of trees and plants that remain in the area.

England is one of the most heavily industrialized of all countries. The insects which live in England's industrial areas have adapted rapidly to the new conditions. The moths are a good example. A hundred years ago most of the 780 varieties of English moths bore light colors. These colors blended with the light tree trunks and lichen-covered rocks where the moths rested during daylight hours. But 70 different varieties of English moths are now darker colored.



*Long wing-tails worn by this silk moth produce a rustling noise. The noise probably decoys bats and other predators away from the moth's body.*

The peppered moth presents a particularly striking example of how quickly this darkening process can take place. The black variety of peppered moth was first seen near Manchester, England, in 1848. At that time only one out of every hundred peppered moths was dark. But Manchester is an industrial city. As new factories sprang up, the smoke-filled air darkened the tree trunks where the peppered moth made its home. Those moths which kept their light colors were gradually destroyed because their enemies could easily spot them against the darkened tree bark. Only those peppered moths which developed a darker color were able to survive and to reproduce. By 1895, ninety-nine out of every hundred peppered moths in and around Manchester were a dark color.

This evolutionary change in the peppered moth took place during Darwin's own lifetime. It was a perfect example of his theory of natural selection, for it showed quite clearly that in the constant struggle for existence, only the "fittest," those who adapt to the changing characteristics of their surroundings, are able to survive.

*The Wily Weevil has a whitish shell touched with brown, which copies the droppings of birds.*



*Pseudo-sphinx Caterpillars (above) bear orange and black colors to show enemies they are foul-tasting.*

*The Mottled Moth (below), camouflaged by its oval markings, rests on the surface of a leaf.*

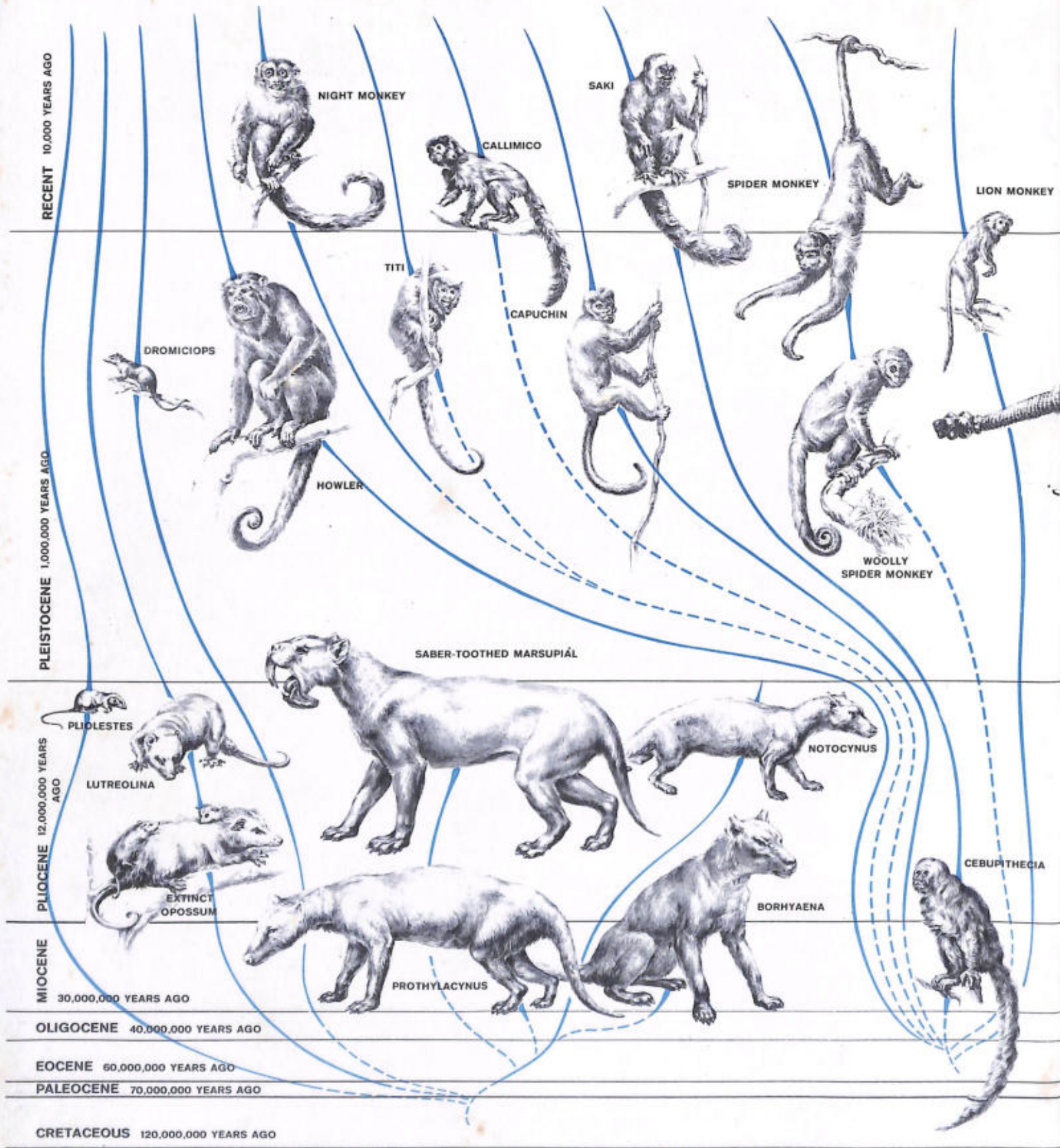




## THE ENORMOUS MIGRATION

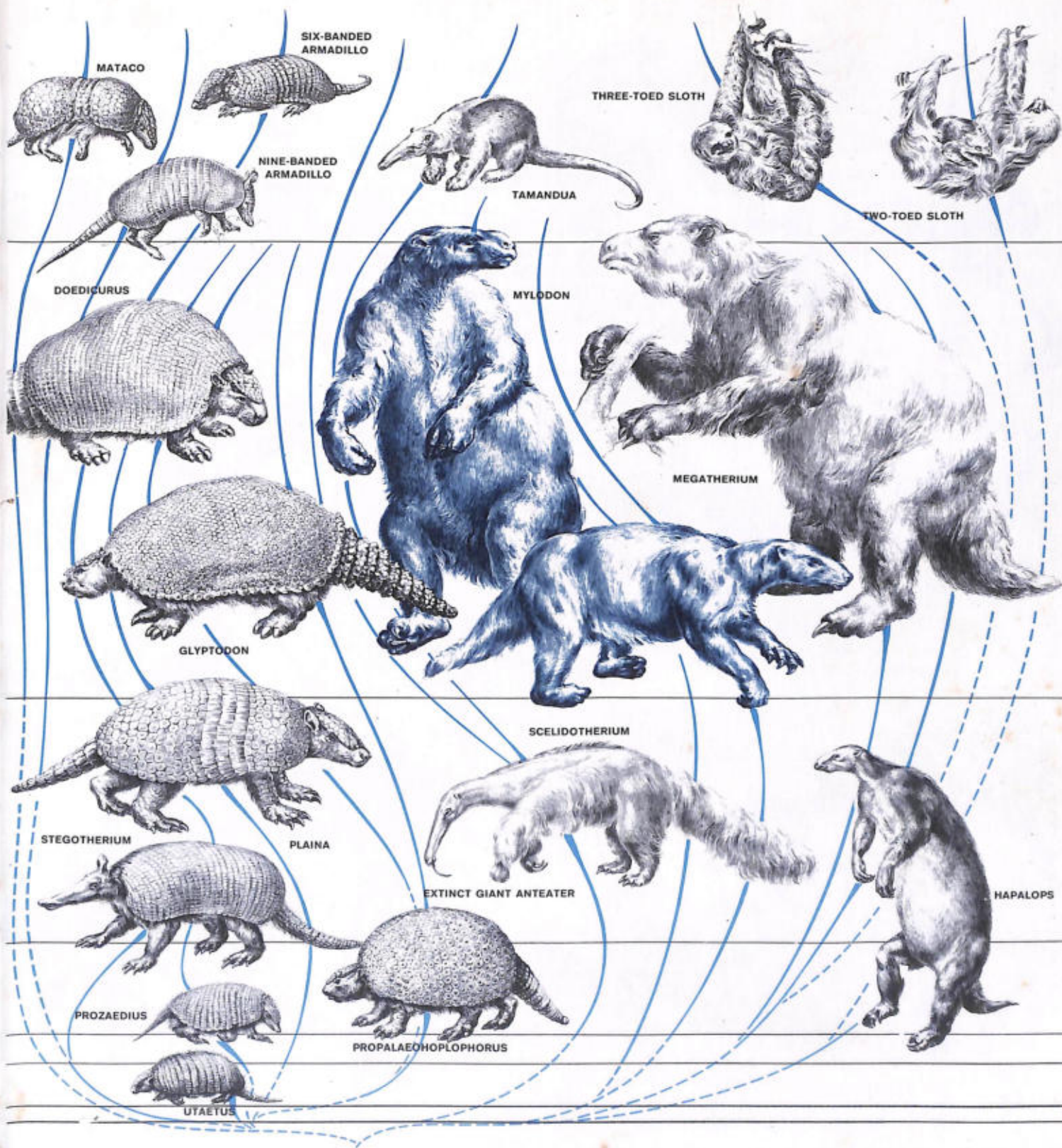
The animals of the Americas are products of the greatest migration in the recorded history of the world. Since the Age of Dinosaurs the two continents had been separated by the sea. About one million years ago the Isthmus of Panama arose, creating a land bridge from north to south. Animals streamed across in both directions. From the north came the varied species indicated on the map by blue arrows. From the south came those indicated by white arrows; those which got no farther north than the forests of Central America are indicated by yellow arrows. Many of the migrants became extinct in the great dying of the Pleistocene Age. Others, like the spectacled bear of South America and the porcupine of North America, survive today only in their adopted homes.

TOXODONT



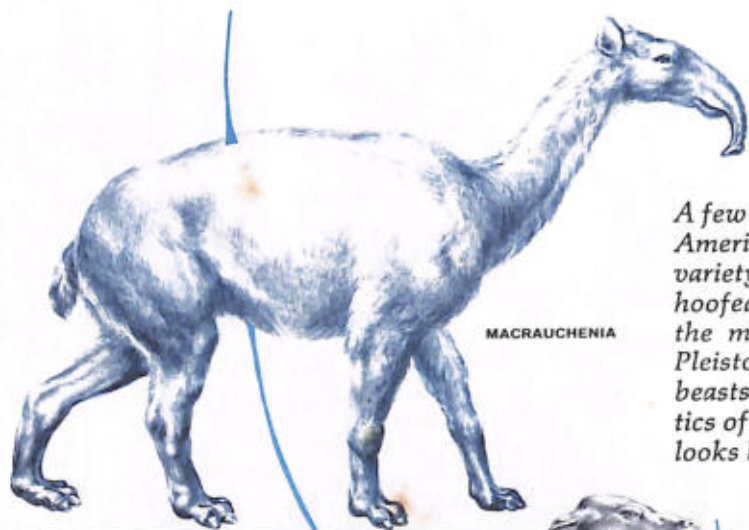
Many strange species of animals evolved in South America during its millions of years of island isolation. Only a few descendants of these ancient species still survive and all have undergone some change. The charts on these pages show the evolutionary development of South American animals.

On these charts history flows from the bottom up. It begins at the end of the Cretaceous period when the giant reptiles died out and mammals became dominant. The curved lines show how different species have evolved from distant common ancestors. Where the lines are solid we have a



complete fossil record of the animals' evolution; dotted lines indicate that the record is incomplete. Where the same line actually touches two animals, those animals are closely related. Solid lines which reach the top of the page indicate that a related species still exists today; examples are the mon-

keys, sloths, armadillos and small marsupials at the far left. Lines which end farther down indicate that the species became extinct at that point. The two giant mammals shown in color on the chart above are the ones whose bones Darwin discovered in the Argentine pampas.

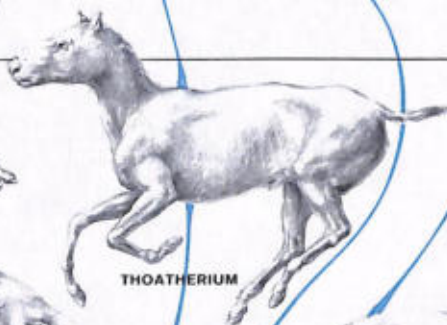
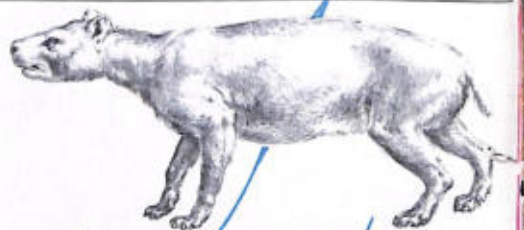


MACRAUCHENIA

A few of the ancient animals which arrived in South America 75 million years ago later evolved into a variety of hoofed mammals. Not one of these hoofed mammals is still alive. Only two of them, the macrauchenia and the toxodon, survived the Pleistocene invasion from the north. Some of these beasts show how species may develop characteristics of a different species. For example, pyrotherium looks like an elephant and thoatherium like a horse.



THEOSODON



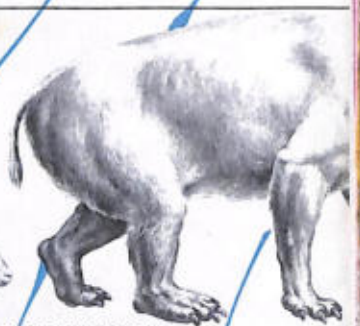
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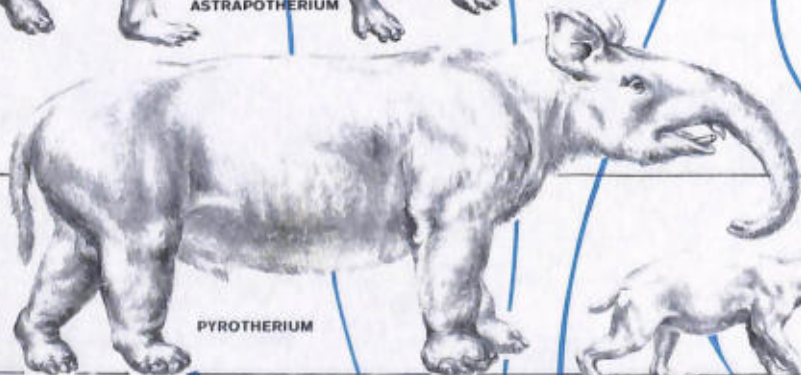
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PROTYPOTHERIUM



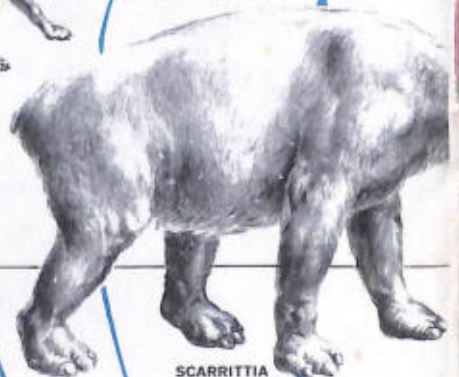
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PYROTHERIUM



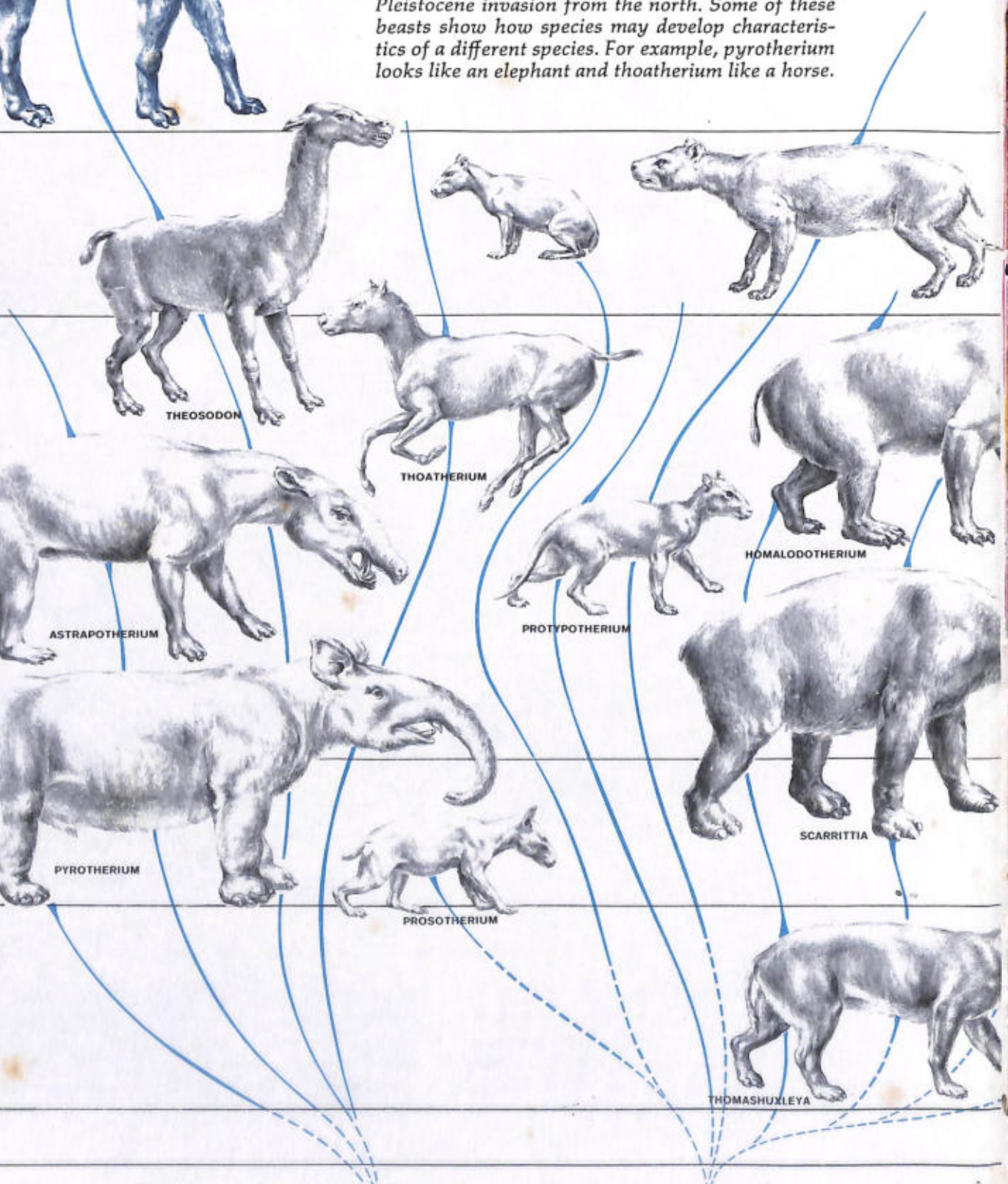
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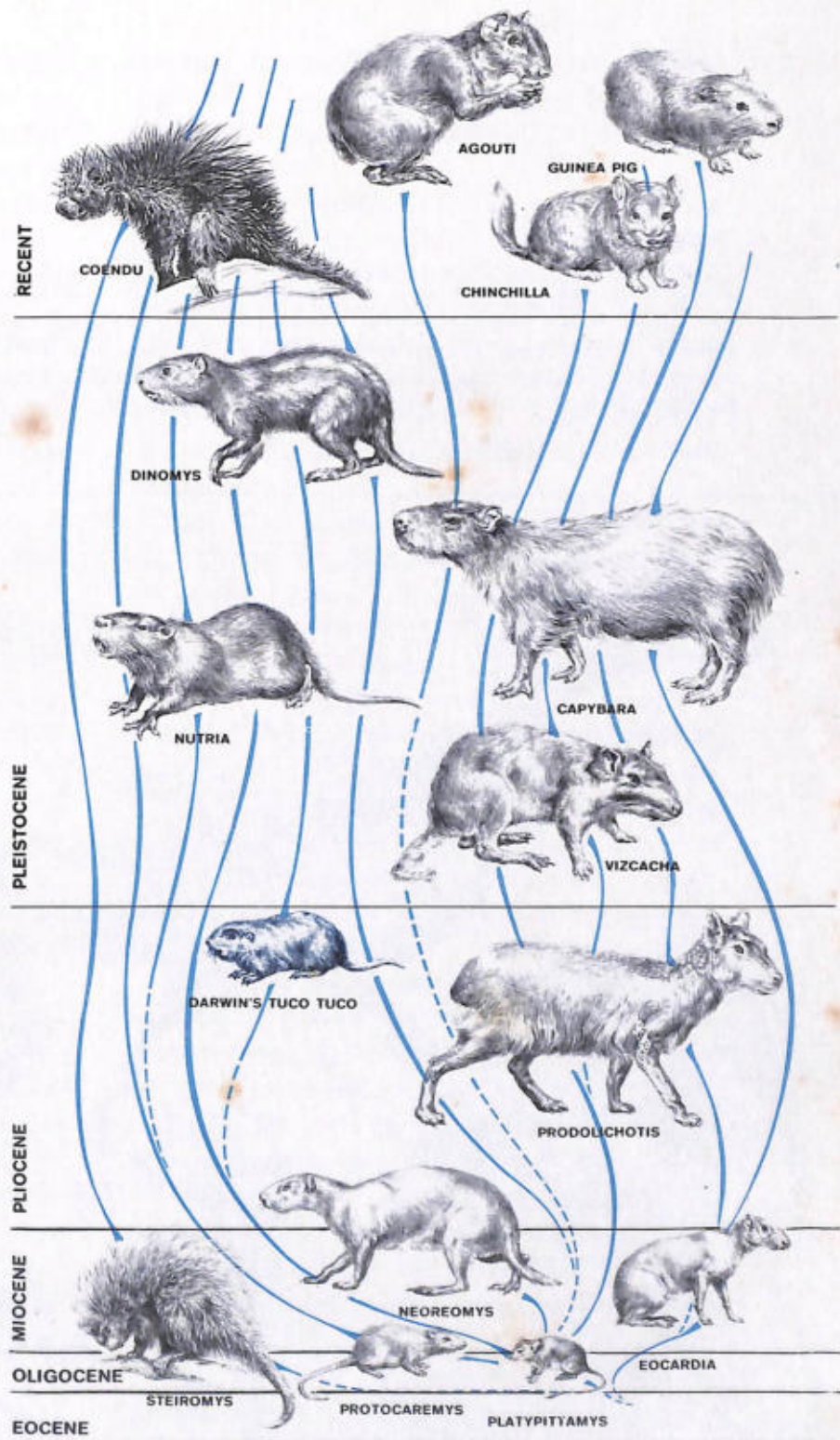
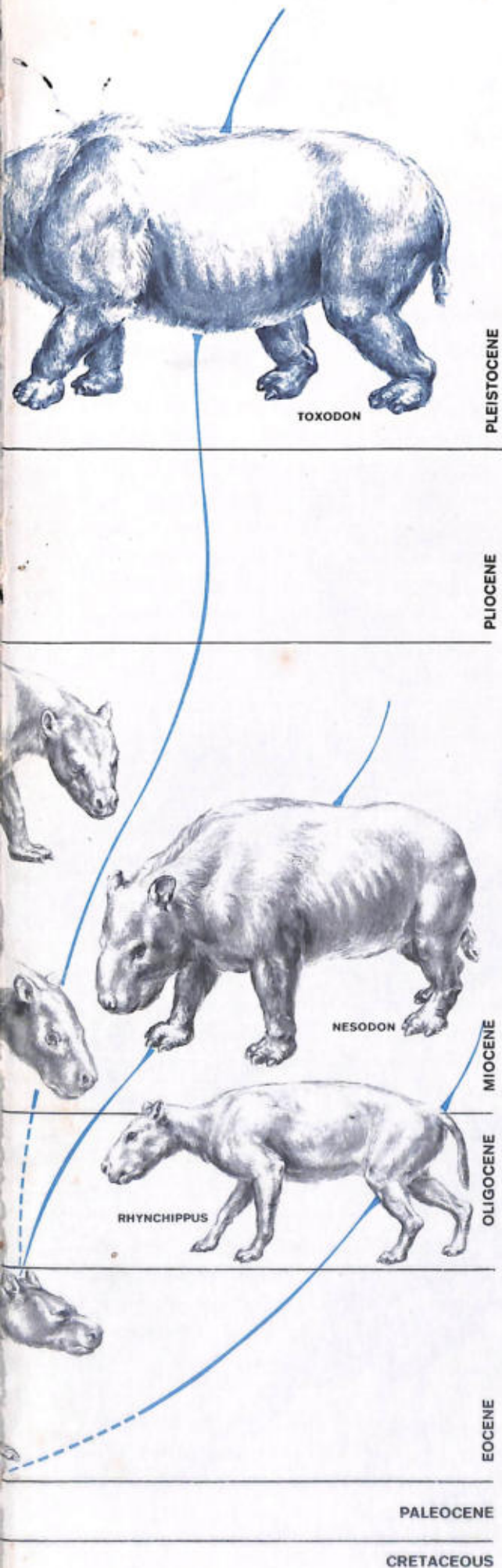


SCARRITTIA



THOMASHUXLEYA



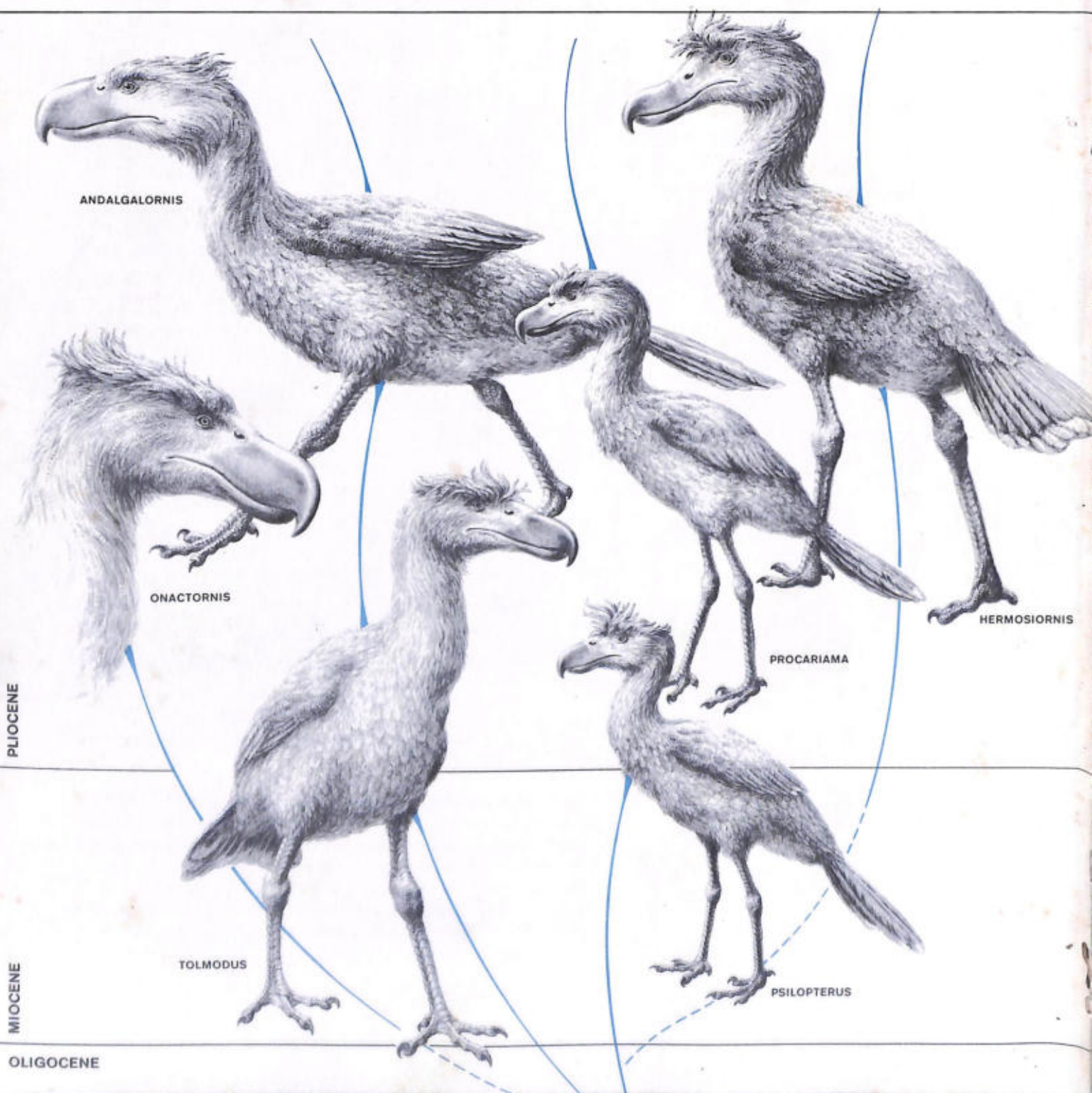


The order of rodents survived the upheavals of the Pleistocene more successfully than any other animals. Rodents from South America migrated north and rodents from North America migrated south. They intermingled so closely that the rodents of present day America are a mixture of both stocks. However, some species of rodents have died out. One of them was the tucos, whose remains were unearthed by Darwin.

*These flesh-eating birds were unique. Nothing quite like them has ever existed anywhere else. Eventually they all died out, leaving only one surviving relative. This is the stately cariamo which stands two feet high. Unlike its fearsome ancestors, it can fly short distances. Unlike them also, it is quiet and peace-loving.*



CARIAMA



ANDALGALORNIS

ONACTORNIS

PROCARIAMA

HERMOSIORNIS

TOLMODUS

PSIAPTERUS

PLIOCENE

MIOCENE

OLIGOCENE

Rodents survived the upheavals of the Pleistocene Age more successfully than any other animals. North American rodents such as the squirrel and the meadow mouse settled in South America; southern rodents such as the porcupine went north. The rodents which live in the Americas today are a mixture of both the original North and South American species.

On the whole, the North American animals were the more successful in the Pleistocene struggle for survival. The puma, the peccary, the deer, and the tapir have hardly changed from that day to this. In South America, the normally timid guanaco still survives in its original form. But its most dreaded enemy, the vicious saber-toothed tiger, has long since died out.

Perhaps the most fantastic creatures that ever lived in South America were the huge, flesh-eating birds. Some were five feet tall, some even taller. The tallest was the onactornis, an eight-foot-high giant with a massive bill 15 inches long.

These birds were ferocious. They could not fly, but they could run very quickly across the vast treeless plains in pursuit of their prey. For millions of years they dominated the other animals of South America. But finally they gave way to more efficient killers like the puma and the jaguar, which came down to South America during the Pleistocene invasion from the north.

In April, 1958, an international team of scientists, following in Darwin's footsteps, went to Argentina. They collected almost five tons of bones of ancient reptiles, fish, and amphibians. These creatures had lived in the Triassic Age, about 180 million years ago.

The Triassic was one of the most eventful periods in the history of life on earth. During that period the first dinosaurs appeared. They were the giant creatures that would rule the earth for more than 100 million years before finally dying out during the Pleistocene Age. The ancestors of crocodiles also appeared during the Triassic. Dinosaurs and crocodiles both belong to the reptile family, once the most dominant group of creatures on earth.

Reptiles were eventually supplanted in dominance by mammals, which are more intelligent. Mammals are distinguished from other groups of

creatures by two characteristics. Instead of laying eggs, they all produce living offspring inside their bodies. And they produce milk with which to feed their young.

Skeletons unearthed by the 1958 expedition showed that some reptiles of the Triassic period were more advanced than their predecessors. They had more energy, and it is possible that they may have been warm-blooded like mammals. These reptiles also possessed other mammal-like characteristics. They may have been a kind of living link between pure reptiles and the mammals which developed later.

Many South American mammals became extinct during the Pleistocene Age. Some of them resembled mammals from other parts of the world. One, called the pyrotherium, had a trunk like an elephant's; another, called the rhynchippus, had a head like a horse's. Some scientists, including Darwin, believed that the pyrotherium must have been related to the elephant, and that the rhynchippus must have been related to the horse. But they were wrong, for there are some animals which just accidentally take on the same characteristics as other animals of completely different species.

The mammals of South America developed in isolation. But other very ancient South American creatures seem to have been related to creatures on other continents. These include the reptiles of the Triassic Age. No one knows how the relationship between the reptiles of different continents occurred. Perhaps, millions of years ago, South America was connected with many more lands than it is today and reptiles may have been able to move freely across many countries now separated by oceans.

There are quite a few questions about the ancient animals of South America which still remain unanswered. No one knows exactly how mammals replaced the dinosaurs, nor does anyone know why so many species of mammals died out during the Pleistocene Age. One possible explanation is that they were destroyed by floods or some other great catastrophe of nature. Darwin did not accept this explanation. Like most modern scientists, he was convinced that major changes in evolution take place only over very long periods of time.



About 350,000 years ago, migrating animals from the north crossed the new land bridge over the Isthmus of Panama. South of it they met and intermingled with the ancient animals of South America. During flood periods when the ground became swampy, many animals were buried in the clinging

clay. This painting shows how a valley in Bolivia may have looked when the intercontinental migration was in full swing.

The most drastic effects of the invasion from the north are seen in the activities of predators like the giant dogs at left. They are harrying a glyptodon



whose armor plating makes it practically invulnerable. At the right of the picture a northern saber-toothed cat is successfully attacking a guanaco. Curiously enough, descendants of the timid guanaco still survive, while the fearsome saber-toothed cat has perished.

Many creatures died out during the Pleistocene. Among them were the mighty mastodons and the native American horse. All the ancient plant-eating animals and marsupials that had thrived in the island isolation of South America also perished from the continent.



*The macrauchenia (above left), perhaps the most grotesque of all native beasts of South America, had the neck of a camel and the trunk of an ele-*

*phant. Yet even the macrauchenia was dwarfed by the megatherie (center). It was a kind of ground sloth which sometimes towered 20 feet high.*



*All the animals above are now extinct, but many, like the large armadillo (lower left) have descendants which still exist today.*

*The opossum, one of the oldest animals in the world, first appeared 75 million years ago and still flourishes in both North and South America.*



# THE ANIMAL HEIRS OF PAST AGES

Charles Darwin's explorations into the heart of South America were both adventuresome and dangerous. He risked capture by marauding Indians, and death by gunfire during the revolutions which were constantly breaking out among the insecure governments of the South American states. In addition, he endured great physical hardships, suffering through extremes of heat and cold, fatigue, hunger, and thirst.

On one occasion Darwin and a native guide found themselves crossing an arid plain. Their horses became so weak from lack of water that Darwin and the guide had to dismount and walk. After going for 24 hours without water, Darwin himself became very weak from thirst but, to his amazement, his guide showed no sign of suffering. He had grown used to going without water for long periods. Some of the native inhabitants, Darwin observed, could endure two or three days under such conditions.

As he traveled down the coast of South America, Darwin passed through many different kinds of country. He explored the forests and grasslands of Brazil and, farther south, he rode for hundreds of miles across the treeless pampas of Argentina and Uruguay and over the wild uplands of the Patagonian plateau. In these wastelands, he studied the fossil remains of certain kinds of armadillos, sloths, and guanacos which had died out, comparing these fossils to types of armadillos, sloths, and guanacos which still existed.

From these comparisons, Darwin learned how life takes on new forms over long periods of time.

*A jaguar swims in a plant-clogged pool. Descended from Old World cats, it is one of the most dangerous flesh-eating animals in the New World.*

For, as conditions change, new generations of animals assume new characteristics. Therefore, in any given area on earth, as the ages pass, animals have descendants which are similar to themselves but not completely the same. Darwin called this process of change "the succession of types."

Darwin observed that changes in an animal species can also be produced by a change of location. During his travels along the South American coast, he was struck by the subtle differences between related types of animals which lived in different areas. He applied the principle of the succession of types to these differences too. As animals move to different environments, their descendants gradually develop new characteristics.

These two parts of his theory led Darwin to a further conclusion. This was that many different inhabitants of the plains and the mountains, of the forests, marshes, and deserts are all related to one another. They are also linked to the extinct species that once inhabited the same continent.

A striking illustration of Darwin's theory is provided by the huge cat family. The jaguar, one of its members, is one of the largest and fiercest flesh-eating animals in South America. It is a descendant of the jungle cats of the Eastern Hemisphere which crossed into the Americas from Asia during the Pleistocene Age. The jaguar has been described as "the tiger of South America." Darwin himself noticed that it was related to the tigers of the East Indies. But the jaguar is also related to the common house cat.

The puma is another member of the cat family. Swift and strong, it has been called "the lion of South America." Pumas crossed into South America from the north during the Pleistocene migration and have flourished there ever since.

Like jaguars, pumas prey on weaker animals, but there are several differences between the two cats. Except when they are cornered or are with their young, pumas normally flee at the slightest noise. Jaguars, on the other hand, are more likely to stand their ground and attack. Like other cats, both pumas and jaguars have cushioned feet. But while the puma prowls stealthily through the forest, the jaguar is a noisy animal. At night its deep roar resounds fearsomely through the trees. One of its prey is the tapir, a slow-moving creature about the size of a pony. Shy and gentle, it is one of the most ancient of American animals.

The animals of the South American forests are split into two groups. Some search for food on the open pampas during the day. Others are night animals that sleep during the day and only appear at sundown. Some of these nocturnal animals are timid creatures that wait for the shelter of the darkness before going to look for food. At night, otters fish in the darkened rivers while raccoons carefully wash their crab victims before eating them. Armadillos, which occur in various sizes, also welcome the shelter of the night. They are happiest in dry country and feed on insects, roots, and snakes. When in danger, they either burrow into the ground or crouch for safety beneath their armor of small bony plates.

*Darwin visited the areas shown on the map below during his visit to South America in 1832-34.*



Other night animals are hunters, like the sharp-clawed pampas cat and two members of the weasel family, the grison and the tayra. There are forest birds, too, that hunt their prey at night. The most powerful of them is the great horned owl. The night is also hunting time for the forest bats which are guided to their prey by sound. There are many different kinds of bats, including one which feeds on nectar, the bulldog bat which eats fish, the white bat which is only three inches long, and, biggest of all bats, the false vampire.

The hawk eagle, which looks very much like an owl, patrols the South American forests from Brazil to Paraguay. It soars lazily above the trees until it spies a snake, lizard, or rodent. Then it darts unerringly to capture and eat its prey.

The vulture family includes the largest flying birds in the world. The most brilliantly decorated member of this family is the king vulture. Its eyesight is so keen that it can spot food from great distances. When one king vulture swoops down on its prey, other vultures quickly notice and gather from miles away to share in the feast.

The burrowing owl gets its food on the ground. It nests in tunnels drilled into the earth by armadillos or rodents, and lays its eggs at the very bottom. It feeds on mice, snakes, and insects.

Perhaps the most unpleasant of all South American birds is the Brazilian caracara. It is a member of the falcon family, but, unlike its hunting kin, it lives mainly off the flesh of dead animals as vultures do.

Most of the forest animals remain quiet so as not to reveal their presence to their enemies. But at dawn and dusk the harsh voices of the macaw, the guan, and other birds shatter the silence.

Periodically throughout the day the quiet is also disturbed by howler monkeys. These small monkeys are dizzily acrobatic, and are seldom seen as they swing through the trees. But they are often heard, for they are among the noisiest creatures in existence. The purpose of their screams is to scare away such predators as ocelots and eagles, and also to warn other kinds of monkeys not to invade their territory.

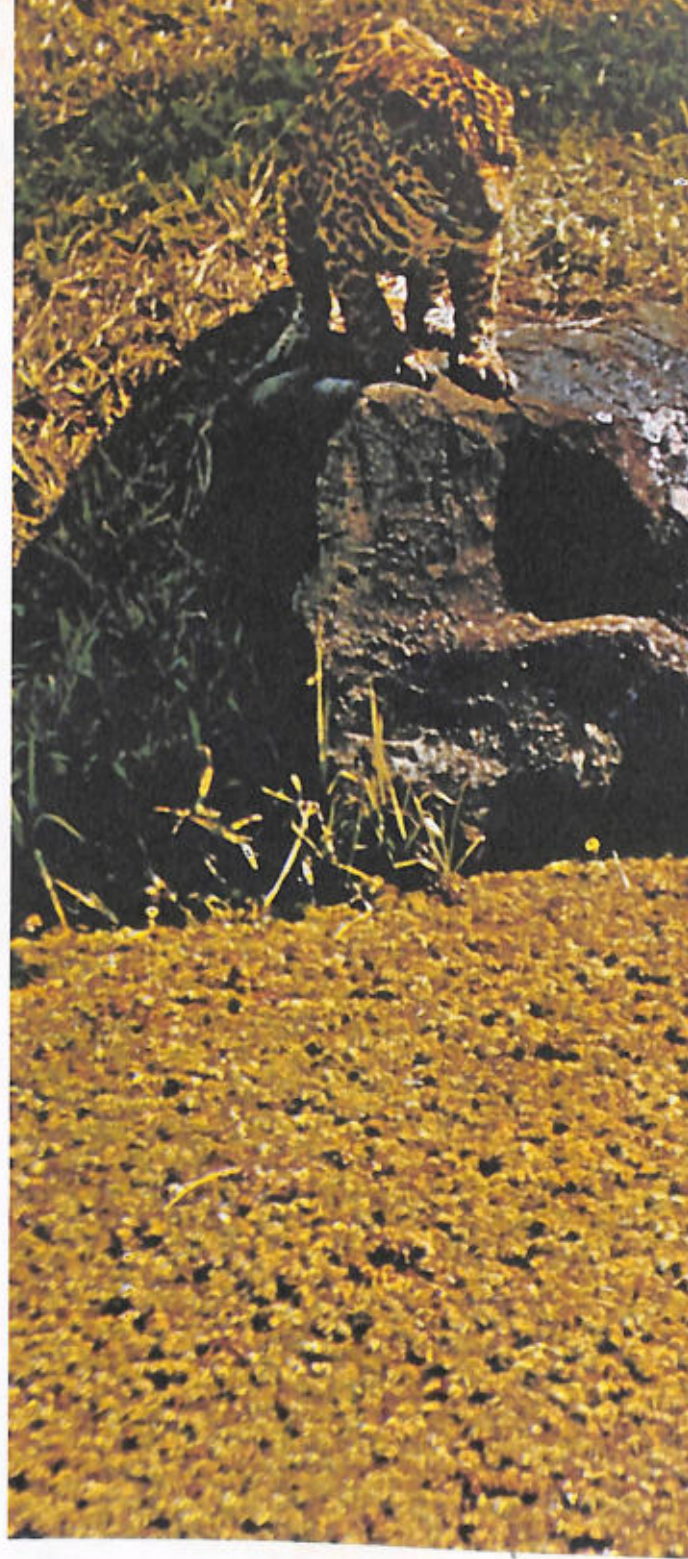
*The puma, swift and stealthy, came to South America from the north during the Pleistocene migration.*





*The three-toed sloth (above) is one of the dullest mammals on earth. Nevertheless, it is very powerful and uses its claws to climb from branch to branch.*

*The tayra (below), a wily marauder, can with equal ease invade a beehive for honey or climb a tree and plunder a bird's nest of its eggs and young.*



But despite all their noise, howler monkeys are peaceable animals and rarely get into fights. They move through the trees in groups. The mothers carry their babies on their backs and sometimes straddle the open spaces between trees, making a bridge so that their babies can cross over. Howler monkeys rarely move more than a quarter of a mile in a day. The whole group moves at the speed of the slowest member, and the cries of distress of one will bring all the others to a stop.

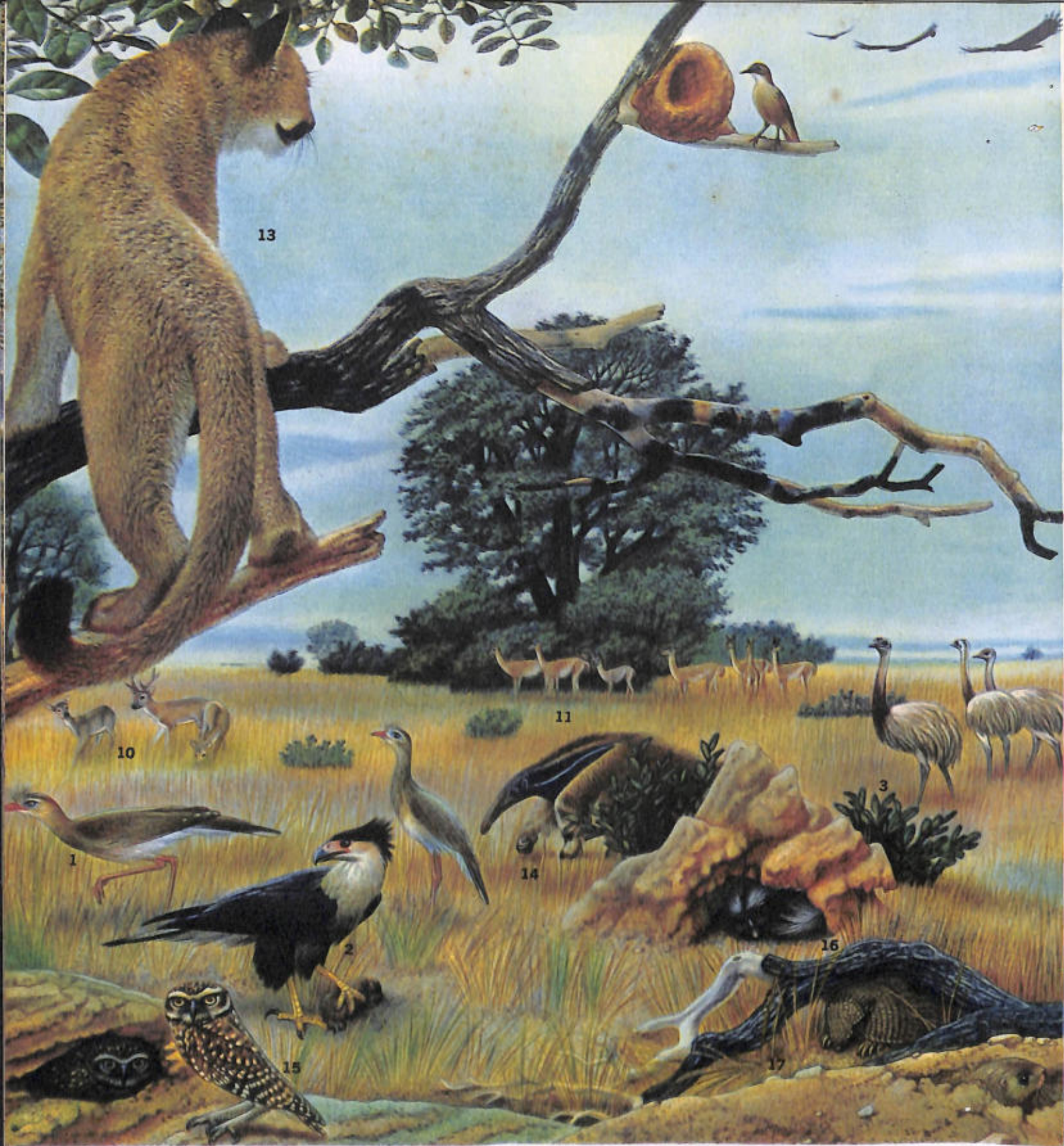


*The jaguar is a noisy killer. Its deep, defiant roar resounds fearfully at night throughout the forests.*

The savage jaguar is a night hunter. It measures from six to eight feet long and weighs up to 260 pounds. It is an excellent swimmer and can cross rivers without difficulty. Sometimes it feeds on fish which it scoops out of the water with skillful strokes of its paw. It is also an agile climber and often hides in overhanging tree branches so that it can leap down upon its prey from above.

Like the jaguar, the wily, weasel-like tayra also hunts at night. The tayra is about four feet long, half of it taken up by its tail. It can invade a wild beehive for honey, or climb a tree to steal the eggs and young from a bird's nest with equal ease.

The night monkey is also active in the dark. It sleeps during the day, and at night it hunts for various edible insects.



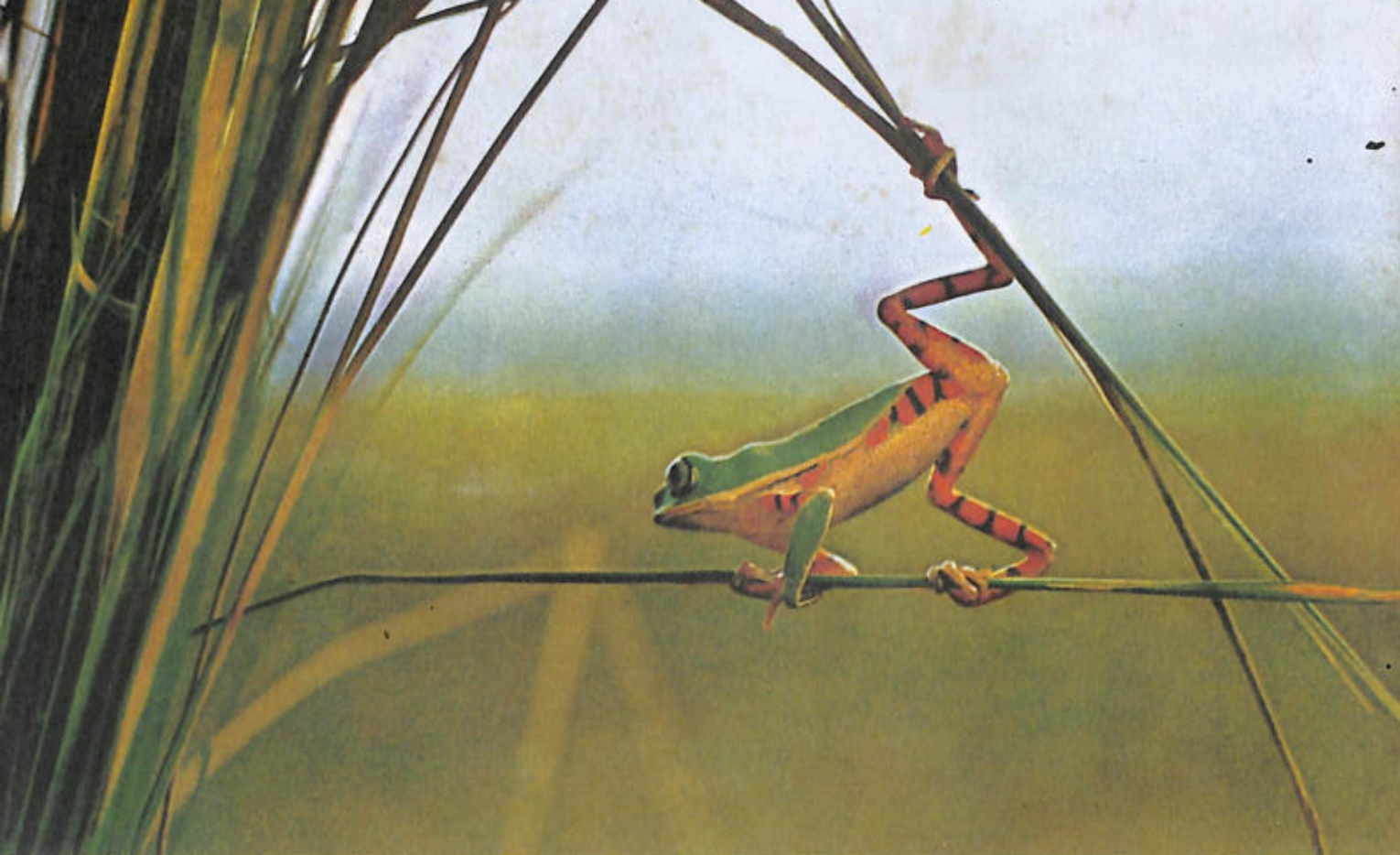
On the Argentine pampas, Darwin found an abundance of life, as shown in the painting above. His eye was caught by the birds: the stately caracara (1.), the carrion-eating caracara (2.), and the ostrich-like rhea (3.). He saw black vultures (4.), wheeling overhead, and sociable toco toucans (5.), perched in

the leafless tree. He listened to the noisy green parakeets (6.), and the irritable tero teros (7.), screaming against trespassers. And he watched the southern green kingfisher (8.), and the South American stilt (9.), wading near the water's edge, patiently waiting for fish.



The tall grass was stirred by shy creatures such as pampas deer (10.), guanacos (11.), and the maned wolf (12.), which is actually a timid animal that eats rodents, frogs, figs and sugar cane. But through this peaceable land two predators strode in safety. One was the puma (13.), the other was the giant

anteater (14.), slow but strong, toothless but equipped with claws. Taking cover are the burrowing owl (15.), a zorrino (16.), a hairy armadillo (17.), and a three-banded armadillo (18.). Three capybaras (19.), looking like huge shaggy hamsters, emerge placidly from the water.



*The green tree frog prefers to live in trees or reeds over the water rather than in it. Suckers on its toes help the frog cling to its precarious perch.*

During the summer of 1833, Darwin spent a month on horseback, camping out with South American cowboys on the open pampas. He enjoyed studying the less secretive animals that lived out in the open. He was extremely fond of these animals and wrote with great interest and affection about many different species.

One of his favorites was the ovenbird, which gets its name from the shape of its nest. The Spaniards called this bird the *casara*, which means "housemaker," because its nest is sturdily built and is out in the open. Darwin also liked the rhea, known also as the American ostrich. Standing four feet tall, it is the largest bird in the Western world. It is quite courageous, and if threatened by men on horseback, will attack them.

Life teems in the streams which flow across the pampas. Colonies of rare and beautiful scarlet ibis dwell in the marshy grasslands. The ibis have curved bills which enable them to dredge up worms, shellfish, and vegetable matter from the mud under the shallow waters.

The largest rodent in the world also lives in the pampas streams. It is the capybara, or water hog. It is about four feet long and weighs around 130 pounds. Unlike most rodents, capybaras are very tame. Darwin found that even though they are quite easy to capture, men don't bother to hunt them because their skins are of little value, and their meat is not very tasty.

The green tree frog is an amphibian; it can live on land or in the water. But it prefers to make its home in trees. Unlike other frogs, it seldom hops. It has suction cups at the end of each toe which help it to keep a firm foothold on branches or reeds when it searches for insects.

Most amphibians lay their eggs in water. But the female green tree frog lays hers on the leaves of branches which hang over the water. The eggs are attached to the branches by a jellylike substance. They hatch during the rainy season and, as the tadpoles emerge, the rain washes them into the lake or stream below where they develop within two months into full-grown frogs.

Everywhere he went in South America, Darwin encountered hummingbirds—near the cities, in the mountains, on the plains, and in the forests. Male hummingbirds are particularly beautiful, some having bright patches of color on their heads, others on their breasts or bellies. It is now known that these colors are not produced by pigment, but by the refraction of light from the prismatic shapes of the birds' feathers.

Hummingbirds fly in a curious darting, hovering way that requires 80 wing beats every second. To produce so many wing beats, hummingbirds use up more energy than any other warm-blooded creature. To provide all this energy, they need 50 to 60 meals a day. They live on nectar, which they sip through their long, tube-shaped tongues, and also eat insects. They build complicated nests lined with down, decorated with lichen or fern, and bound together with spiders' webs. Some of these nests are no bigger than walnut shells. Inside them the birds lay their eggs, which are about the size of peas. (See pages 72-73.)

The South American continent has changed greatly since Darwin explored it more than a century ago. But one huge region of the continent still remains almost unchanged. This is the state of Mato Grosso, an enormous green wilderness which covers half a million square miles in the heart of Brazil. Mato Grosso means "great, thick

forest land" in Portuguese. But the Mato Grosso also has vast dry prairies, arid grasslands, and marshy plains, too.

Modern man has made few changes in Mato Grosso. Trees that flourished in the Pleistocene Age still exist there. Native Indian tribes still lead the same kind of primitive existence that their ancestors did in the Stone Age. Since Darwin's visit to South America, many scientists, explorers, and rubber prospectors have ventured into the interior of Mato Grosso. Some perished from starvation and disease; others were killed by the Indians' poisoned arrows. In 1925, a British colonel, Percy Fawcett, led an expedition into the interior searching for gold and a fabled ancient civilization. The expedition vanished without a trace and the vast reaches of the Mato Grosso remained closed.

Following World War II, a German ornithologist, Dr. Helmut Sick, accompanied a Brazilian government expedition across 750 miles of uncharted wilderness. Over a period of nine years, the expedition advanced through forests, rivers, and swamps and through land inhabited by savage Chavante Indians. Finally reaching the Amazon, Dr. Sick discovered 84 new kinds of plant and animal life. Ten were new varieties of plants and flowers; 74 were various species of birds, lizards, insects, spiders, snails, and worms. One of the last unexplored areas of the earth had opened to science.

*The armadillo comes in various sizes. This seven-banded one attracted Darwin's interest in Patagonia.*





Hummingbirds exist only in the New World. Nine varieties that Darwin encountered are shown here: 1. Brazilian Swallow-tail, 2. Amethyst Hummingbird, 3. Cayenne Wood-nymph, 4. Emerald Hummingbird, 5. Rufous-throated Sapphire, 6. Angela

Star-throat, 7. Frilled Coquette, 8. Ruby and Topaz Hummingbird, and 9. Brazilian Violet-ear.

The glittering colors of the hummingbirds' plumage are produced by the effects of light refracted through their feathers. The birds' darting, hovering



*flight requires an enormous amount of energy and, to maintain this energy, the birds eat 50 to 60 meals a day. Their food consists of insects, and of nectar which they sip through long, tube-shaped tongues. Hummingbirds are fearless and will defend their*

*territory against trespassers as large as robins and crows. They are also skillful architects and build delicate, complicated nests which are sometimes no bigger than walnut shells. In them they lay eggs the size of peas.*





*Though not a hunter, the Brazilian caracara (left) is a member of the falcon family. It lives on carrion.*

*The king vulture (above) is a decorative member of a family which has produced the largest flying birds.*

*The Hawk eagle, which looks very much like an owl, patrols the forests from Brazil to Paraguay.*

*The hawk-eyed parrot (below) is a popular bird which may easily be tamed and taught tricks.*





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Most of the animals which inhabit the South American forests are shy and secretive. They do not want to reveal their presence to enemies. However, at dawn and dusk the voices of the macaw (1.), the guan (2.), and other birds indicate the richness of

forest life. And throughout the day the silence is broken by the resounding din of the howler monkeys (3.). Their noise is intended to warn off predators like the ocelot (4.) and harpy eagle (5.), or the rival monkey tribes on the right.



*Social and restless, the howler monkeys range through the trees. For all their loud noise, they seldom fight. The mothers carry infants on their backs and provide living bridges across open spaces. The monkeys rarely travel more than a quarter of a*

*mile a day. The cries of distress of a single monkey will halt the entire band. But the howlers do not disturb the quieter inhabitants of the forest, such as the tailless agouti (6.), the toothless tamandua (7.), or the red-coated coati-mundi (8.).*



Two kinds of creatures inhabit the forest. Some go out by day to hunt for food on the open pampas; others sleep during the day and come alive at sundown. The night is the hunting time for the savage jaguar (1.). With the jaguar go many smaller flesh-

eaters: the untameable jaguarundi (2.), the savage margay (3.), and the sharp-clawed pampas cat (4.). Above them the great horned owl (5.), and many varieties of bats also hunt for prey under the cover of the black forest night.



But night protects prey as well as predators. In the dark many timid creatures go out to feed. The giant tree frog (6.) croaks in the trees, the river otter (7.) fishes in dim waters, and the crab-eating raccoon (8.) carefully washes its food before eating.

The armadillo (9.), opossum (10.), and paca (11.) also go their peaceful ways at night. But below them the motionless boa constrictor (12.), the largest of all land reptiles in the western world, lies waiting to seize and strangle.



BLUNTHEADED TREE SNAKE

ABANDONED BIVOUAC

MAJOR WORKER

EMIGRATION COLUMN

OWL BUTTERFLY



CLICK BEETLE

NOCTURNAL TREE FROG

MAIN EMIGRATION COLUMN

QUEEN

MAJOR WORKER

MINOR WORKERS

GUEST BEETLE



SOLDIER FLY	TORTOISE BEETLE	SOLITARY WASP	HELICONID BUTTERFLY	PARASITIC FLY
CHRYSOMELID BEETLE	HELICONID BUTTERFLY	LEAF BEETLE	BLOWFLY	
ARBOREAL TARANTULA		STINGLESS BEE	SCORPION	STINK BUG
				VELVET ANT



ANT BIRD  
GIANT WORKER ANT

PARASITIC FLY  
VELVET ANT

ANOLE LIZARD  
EUGLOSSA BEE  
THREAD-WAISTED WASP



LARVA-CARRYING SUBMAJOR WORKER  
MAJOR WORKER

NEW BIVOUAC

WHIPLESS WHIP SCORPION

LARVA-CARRYING INTERMEDIATE WORKER

ANT LARVAE



VESPID WASPS' NEST  
TROPICAL FLY

WOLF SPIDER

HELCONID BUTTERFLY

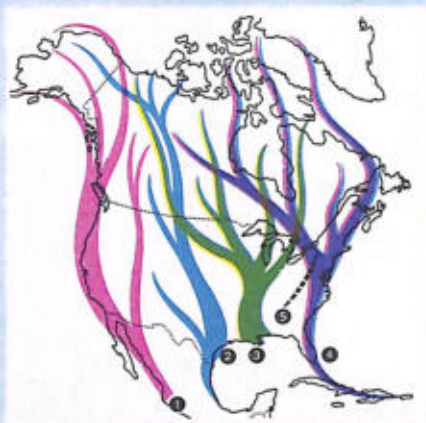
wasps. In these battles, enormous numbers of insects are killed on both sides. While the major ants are fighting, the minors carry the bodies of dead insects back to the previous night's resting place, where they serve as a feast for the queen, the new brood, and the nurse ants which have remained behind.

Darwin observed the army ants during his trip to South America. He was baffled at first by the make-up of the ant colonies, because he could not understand how the process of evolution could have produced neuter ants, which are unable to reproduce themselves. But he finally discovered the answer. Ants operate not as individuals but as members of a group. They must, therefore, be considered as part of a group, just as an arm must be considered, not by itself, but as part of the entire human body.

Darwin concluded that the evolutionary process has worked for the benefit of the ants as a group. It has produced different kinds of ants which are specially equipped to do their own particular job that facilitates the life of the community. Darwin also noted the complexity of the ant colonies and compared them to societies of human beings in which everyone has his own special job to do. A comparison of this sort is not completely justified, however, for human beings run their societies by their individual intelligence, while ants are guided only by instinct.

Darwin was also puzzled by another fact. Although worker ants from the same brood all have the same parents, they grow to different sizes. Scientists have since found the reason for this. The first eggs in each brood laid by the queen are normally the first to hatch. They are given the most food by the nurse ants and, therefore, tend to develop into big majors. The last eggs to hatch receive less attention and food, and tend to become the smaller minors.





**FLIGHT SOUTHWARD  
IN THE AUTUMN**

- 1 Red-throated Loon
  - 2 Red-necked Grebe
  - 3 Black-footed Albatross
  - 4 Great Shearwater
  - 5 Cory's Shearwater
  - 6 Fork-tailed Petrel
  - 7 White Pelican
  - 8 Gannet
  - 9 Double-crested Cormorant
  - 10 Pelagic Cormorant
  - 11 Egret
  - 12 Little Blue Heron
  - 13 Whistling Swan
  - 14 Canada Goose
    - a. Cackling
    - b. Hutchin's
    - c. Greater
  - 15 Brant
    - a. Eastern
    - b. Black
  - 16 Snow Goose
    - a. Greater
    - b. Lesser
  - 17 Blue Goose
  - 18 Mallard
  - 19 Black Duck
  - 20 Pintail
  - 21 Blue-winged Teal
  - 22 Baldpate
  - 23 Shoveler
  - 24 Redhead
  - 25 Canvasback
  - 26 Lesser Scaup
  - 27 Oldsquaw
  - 28 Eider
  - 29 White-winged Scoter
  - 30 Surf Scoter
  - 31 Black Scoter
  - 32 Ruddy Duck
  - 33 Sharp-shinned Hawk
  - 34 Broad-winged Hawk
  - 35 Swainson's Hawk
  - 36 Ferruginous Rough-legged Hawk
  - 37 Gyrfalcon
  - 38 Pigeon Hawk
  - 39 Whooping Crane
  - 40 Sandhill Crane
  - 41 Sora
  - 42 Pomarine Jaeger
  - 43 Glaucous Gull
  - 44 Heermann's Gull
  - 45 Laughing Gull
  - 46 Franklin's Gull
  - 47 Kittiwake
  - 48 Brunnich's Murre
  - 49 Rhinoceros Auklet
  - 50 Short-eared Owl
- M-male F-female Imm-immature  
In other species plumage of sexes is alike





27M

15a

43

47

13

16b

14b

16a

17

31M

48

28M

28M

42

13

29M

19M

25M

26M

24M

33

32M

30M

8

50

29M

19M

34

15a

29M

18M

18M

33

2

16a

5

34

14c

9

45

40

11

16b

17

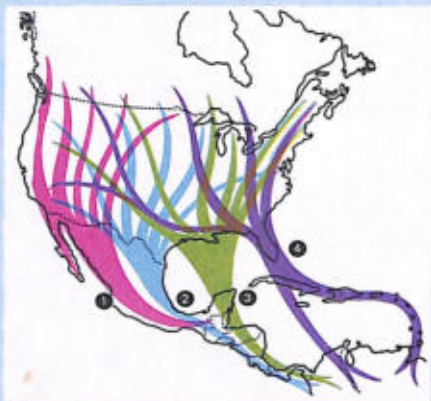
38

21M

34

41

Guy Wood



## A RETURN FLIGHT FOR THE SPRINGTIME

- 1 Piping Plover
- 2 Golden Plover
- 3 Black Turnstone
- 4 Long-billed Curlew
- 5 Greater Yellow-Legs
- 6 Knot
- 7 Least Sandpiper
- 8 Dunlin
- 9 Dowitcher
- 10 Wandering Tattler
- 11 Western Sandpiper
- 12 Marbled Godwit
- 13 Avocet
- 14 Red Phalarope
- 15 Arctic Tern
- 16 Black Tern
- 17 Black-billed Cuckoo
- 18 Nighthawk
- 19 Rufous Hummingbird
- 20 Red-shafted Flicker
- 21 Sapsucker
  - a. Yellow-bellied
  - b. Red-breasted
- 22 Western Kingbird
- 23 Scissor-tailed Flycatcher
- 24 Olive-sided Flycatcher
- 25 Horned Lark
- 26 Bank Swallow
- 27 Cliff Swallow
- 28 Red-breasted Nuthatch
- 29 House Wren
- 30 Catbird
- 31 Gray-cheeked Thrush
- 32 Mountain Bluebird
- 33 Northern Shrike
- 34 Yellow-throated Vireo
- 35 Red-eyed Vireo
- 36 Black-throated Blue Warbler
- 37 Hermit Warbler
- 38 Blackburnian Warbler
- 39 Northern Water-Thrush
- 40 Connecticut Warbler
- 41 Redstart
- 42 Bobolink
- 43 Bullock's Oriole
- 44 Western Tanager
- 45 Scarlet Tanager
- 46 Rose-breasted Grosbeak
- 47 Lazuli Bunting
- 48 Hoary Redpoll
- 49 Savannah Sparrow
- 50 Clay-colored Sparrow
- 51 Fox Sparrow
  - a. Sooty
  - b. Eastern

M—male F—female

In other species plumage of sexes is alike





Guy  
TUDOR

Darwin also observed that the migrating impulse was so strong that it sometimes even overcame birds' maternal instinct. In such cases, when the time for migration arrived, female birds abandoned the young birds if they were not yet strong enough to make the trip, leaving them to die in the cold northern winter. However, Darwin thought that the migratory instinct only became stronger than the maternal instinct for very short periods during certain seasons of the year.

Darwin incorporated his observations on the power of the migratory instinct into his system of evolution. He suggested that at certain times migrating must have benefited birds more than the maternal instinct and so the migratory instinct had been passed on through the process of natural selection. In other words, the birds which had originally possessed the strongest instinct to migrate probably survived and raised their young with the same instinct, while those which felt it less strongly must have died out.

Men had been fascinated by the migrations of birds long before Darwin's time. Although he was intensely interested in the subject, Darwin lacked the equipment and the techniques needed to figure out how it worked. After his death, however, other scientists discovered new ways to study migration. One method was to fasten marked bands on the birds. This enabled observers to check the routes taken by different types of birds, to note the times of year they traveled, and also the speed of their flights.

These new methods uncovered some astonishing facts. Scientists found that every year the tiny, ruby-throated hummingbird flies from the northeastern part of the United States to Panama, a distance of 3,000 miles. The great shearwater, a sea bird, covers the enormous distance from the North Atlantic to Tristan da Cunha, a group of islands in the South Atlantic. But perhaps the most remarkable flight of all is that made by the golden plover, a shore bird which breeds in the Arctic and spends its winters in the Southern Hemisphere. It can fly for days over thousands of miles of open ocean without food or water.

A question which has taken scientists a long time to answer is how birds are able to navigate unerringly over strange lands and trackless seas. It

was found that some birds travel by day and some by night. Some fly in groups; others fly separately, without a leader. Strangest of all, some adult birds set off on their migrations before their young. They leave the baby birds to make their way alone over unbelievably long distances. These young birds have never made such flights before, but somehow they manage to find their way. And when spring comes, they retrace their flight path right back to their original nesting places.

Until recent years no one got any closer to the answer to this question than the German scientist Werner Rüppell did in the 19th century. All he could say was that migrating birds depended on an inexplicable "sense of direction." But Rüppell did make one useful suggestion. He thought that birds, like sailors, might get their sense of direction from the position of the sun.

In 1949 the first real progress toward solving the mystery was made by another German scientist, Dr. Gustav Kramer, who carried out a series of experiments with starlings. His first step was to train the birds to fly always in a certain direction, for example, toward the north. To train the birds to do this he built a birdhouse with twelve feeding stations around it. At each lesson only the northernmost feeding station contained food. The birds that were being trained learned that only if they flew to the north would they be able to find something to eat.

Within a month most of the starlings were trained. Those that had been conditioned to fly north always went to the northernmost station for their food. They found their way there by guiding themselves by the position of the sun. On cloudy days when the sun was obscured, even the trained starlings lost their way.

His first experiments almost convinced Kramer that migrating birds took their direction from the position of the sun, as Rüppell had suggested. But to make sure, he carried out another experiment. He built a birdhouse with six windows in it through which patches of sky could be seen. Then he covered the windows one by one. The birds inside were able to determine different directions until the last window was covered. After hundreds of similar experiments, Kramer was absolutely sure that starlings guide themselves by the sun.

But the problem of how night-flying birds found their way remained unsolved. If the daytime flyers navigated by the sun, it seemed likely that the night flyers navigated by the stars. In 1956, the German scientist Dr. Franz Sauer began a series of experiments with European warblers, which normally migrate south to Africa every autumn. The most astonishing thing about these long flights is that each warbler makes its way, alone.

Dr. Sauer began his experiments by hatching warblers in glass-enclosed, soundproof cages. The birds were never allowed outside these cages, and they grew up in an atmosphere of everlasting summer. Yet when fall arrived outside, the birds showed definite signs of the migrating instinct. Night after night they flitted restlessly from perch to perch. Their restlessness lasted for about the number of weeks it would have taken them to make their flight to Africa. Then, when the imaginary flights came to an end, the warblers began sleeping at night again.

Next, Dr. Sauer placed the warblers in an outdoor cage covered with a glass top so that they could see part of the night sky. When fall came outside their cage, these warblers, too, showed signs of unrest. They took up positions pointing in the direction of the southern route followed by their species. When spring came, they took posi-

tions pointing the opposite way. But when the sky was hidden from their view, they lost their bearings.

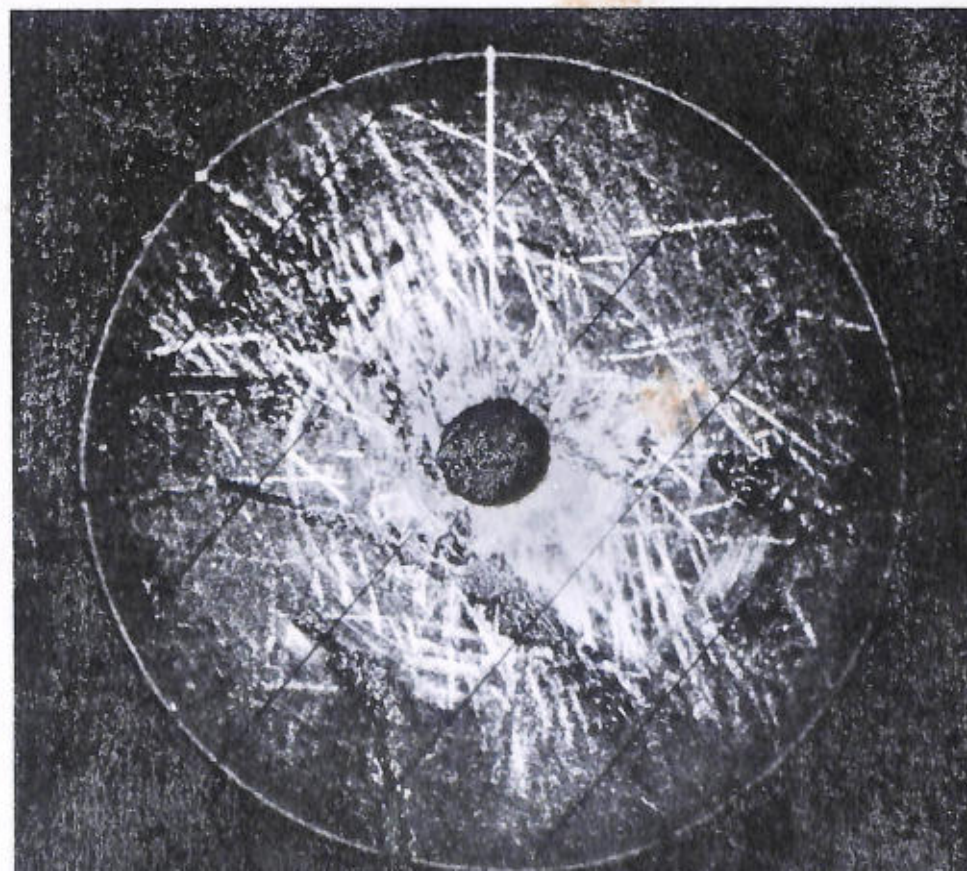
Finally, Dr. Sauer took his birds to a planetarium—a building in which an imitation sky can be adjusted so that it shows exactly how the sky looks in different parts of the world.

The warblers began to behave as if they were out in the open under a real sky. One bird, for example, was flapping its wings as if flying from Germany to the River Nile in Africa. Suddenly the artificial sky was changed so that it looked like the real sky over central Siberia. For almost a minute the warbler paused in doubt. Then it changed direction from south to west, as if it were heading back toward its original migration route.

Dr. Sauer concluded that night-flying birds migrate by following the stars, and his opinion has since been confirmed by radar. Birds navigate successfully on clear, starry nights. But when the stars are obscured by clouds or storms, the birds become confused and lose their way.

Experiments have indicated that birds instinctively know just how the sky looks at different times and in different places. No one knows how birds came to possess this knowledge. Presumably, because originally it helped them to survive, this marvelous sense of direction was developed and passed from generation to generation.

*This radar picture of migration shows the paths of birds flying by night. On a clear and windless night, they can easily navigate by the stars. All flying in the same direction, they form a clearly defined pattern—as shown here. If the wind blows them partly off course, the picture will become more confused. If clouds completely obscure the stars, the birds will lose direction.*





# MAN IN HIS MOST SAVAGE STATE

On his voyage around the world, Charles Darwin visited many bleak and wild lands. But the most desolate of all probably was Tierra del Fuego, at the southern tip of South America. It was discovered by the Portuguese sailor Ferdinand Magellan in 1520. He named it Tierra del Fuego ("land of fire") after seeing the dancing flames from Indian camps along its darkened shores.

Tierra del Fuego is an archipelago, an expanse of water studded with small islands. Few white men had visited the area before Darwin arrived. But such names as Desolation Island, Cape Deceit, Port Famine, and Useless Bay were eloquent testimony of what those first explorers had thought of the forbidding land.

H.M.S. *Beagle* dropped anchor off the coast of Tierra del Fuego in December, 1832. The expedition had come to chart the rocky islands, divided by twisting waterways. Darwin was greatly excited by his first view of the somber landscape; but he was even more excited at meeting the islands' inhabitants—the Fuegian Indians.

At the time of Darwin's visit, the Fuegians were among the most wretched and backward people in the world. Darwin described them as "man in his lowest and most savage state."

Fish was practically the Fuegians' only food. Night and day, summer and winter, they ventured out to pick shellfish from the rocks. The killing of a seal or the discovery of the floating carcass of a whale meant a feast to these half-starved people.

Despite the bitter cold, the Indians went naked for most of the year. Their only clothes were guanaco hides and other skins which they fastened together across their breasts with thongs.

*This 90-year-old woman was, in 1958, the oldest survivor of the primitive Yaghan Indians. By 1950, only nine Yaghans were still alive.*

As they were completely dependent on fish for food, the Fuegians had to go wherever the fish might be. They had no permanent homes. Instead, they moved in canoes from one temporary campsite to another, and lived in crude wigwams. At night five or six Indians slept in each shelter, naked on the wet ground, curled up like animals.

Darwin had asked himself whether modern man could possibly have descended from such savage ancestors. The difference between such savages and civilized men, he said, was greater than the difference between wild and domesticated animals. But during his visit, he was able to see what happened when a group of the Indians were taken to a civilized country and then brought back again to their native surroundings.

This strange experiment had begun some years before Darwin's visit to Tierra del Fuego. During a previous trip, the *Beagle* had stopped at the islands and one of its whaleboats had been stolen. The ship's commander, Captain Robert Fitz-Roy, held four Indians as prisoners until the thieves should return his whaleboat. When the Fuegians failed to return the boat, Captain Fitz-Roy decided to take the four Indians back to Britain and give them a Christian education.

The four captured Indians were all members of the Yaghan tribe. There were two men, a 14-year-old boy, and a 9-year-old girl. During the voyage back to England, the crew of the *Beagle* gave nicknames to the four Indians. They called the men Boat Memory and York Minster, the boy Jemmy Button, and the girl Fuegia Basket.

Captain Fitz-Roy's plan was to educate the Indians and then take them back to their homeland. He hoped that the English-trained Indians would form a link of friendship between their savage fellow tribesmen and future missionaries who would come to the islands.



*A family of Yaghan Indians, the southernmost people on earth, bask in the sun at their camp on Navarino Island. When ashore, they use their boat sail as a tent.*

Soon after the *Beagle* reached England, Boat Memory died of smallpox. The other three were sent to stay in the home of a clergyman. They went to school, soon learned to speak English, and were taught various useful crafts such as carpentry and gardening.

In 1831, two years after the Indians had been taken from their homeland, the *Beagle* set out again for South America. With Darwin and the three Fuegians was a young missionary, Richard Matthews, who was to stay in Tierra del Fuego and work for the betterment of the savage Indians.

Captain Fitz-Roy led his landing party ashore in the heart of the Yaghans' territory. The English sailors carried clothing, tools, seeds, books, and chinaware to improve the conditions of the Indians. Under Fitz-Roy's guidance, a vegetable garden was sown and three wigwams were built. One was for Matthews, one for Jemmy Button, and the third for York Minster and Fuegia Basket, who were married when they got ashore.

Many of the native Yaghans, including Jemmy Button's mother and brothers, paddled up while the wigwams were being built, but they showed no

signs of pleasure at the return of their long-departed fellow Indians.

When the wigwams were finished, Captain Fitz-Roy, Darwin, and the rest of the *Beagle's* crew departed to survey areas to the west. They left the missionary, Richard Matthews, alone with the Fuegians. This turned out to be a bad mistake, for when the sailors returned twelve days later they found that the Fuegians had demanded all of Matthews' possessions, and when he had refused to hand them over, had threatened to attack him. Matthews was robbed of everything he hadn't been able to hide. Captain Fitz-Roy decided that the missionary's life would not be safe if he were left on the islands, so he ordered him to return home to England on the *Beagle*.

About 15 months later the *Beagle* returned once more to Tierra del Fuego and anchored in the same cove as before. All was silence and solitude. Then a canoe, flying a little flag, approached down the channel. In it was a savage with long, disordered hair, naked except for a piece of blanket around his waist. It was Jemmy Button.

Jemmy had a sad story to tell. York Minster and his wife, Fuegia Basket, had fallen back into their old savage habits. They had played a trick on him and stolen all his possessions. But Jemmy refused Captain Fitz-Roy's offer to take him back to England. For he had married a Fuegian girl and was determined to stay in Tierra del Fuego with her.

So the attempt to educate and civilize the savage Fuegians was a failure. In later years, many other missionaries tried to educate the Yaghan tribe but all of them failed and a number lost their lives. The worst tragedy occurred on Nov. 6, 1859, when a group of English sailors and missionaries were massacred while they were holding Sunday service in a half-finished church. And the Indian who planned and led the massacre was Jemmy Button.

But most of the white men who came to Tierra del Fuego were just as savage as the Indians. They took over the Indians' land and slaughtered the natives. Today, the Fuegian tribes have been almost completely wiped out.

At the time of Darwin's visit, there were 5,000 Yaghan Indians. They occupied the lower islands of Tierra del Fuego, near Cape Horn. In recent times only nine purebred Yaghans were left. The

4,000 members of the Ona tribe lived farther inland. They were massacred by white sheep farmers who wanted the land for their sheep. A recent count showed that only seven of the Onas are still alive, living much as their ancestors did.

The third tribe, the Alacalufes, have survived a little more successfully than the other two Fuegian groups. At the time of Darwin's visit to Tierra del Fuego, they numbered almost 10,000. Today there are only about 100 left. But these Alacalufe Indians still retain their ancient culture. They speak their own complicated language. Like the tongues of other primitive peoples, it includes clicks and other unfamiliar sounds which are strange to the ears of modern men.

The few remaining Onas and Yaghans are supported by the Chilean government and the Roman Catholic Church, but the 100 surviving Alacalufes make their own living. The men hunt sea otters, sea lions, and deer. They also dive into the chilly waters in search of sea urchins, mussels, and clams. Although the temperature is close to freezing, they emerge from the icy water without the slightest trace of a shiver. The women also hunt for food, venturing out into the ocean at low tide to collect mussels and sea urchins.

The Alacalufes still roam from one island to the next by canoe, in search of fish. Until fairly recently they made their canoes out of wood and the skins of sea lions, and their stone tools were as crude as the ones used by Stone Age men 300,000 years ago. Later, the Alacalufes took to using the shells of sea clams, for which they dived 20 feet into icy water. It was these tools which gave them their name, for Alacalufe means "the people who use clamshells for tools."

But the savage Alacalufes have been able to benefit from the civilized men who have visited their islands. Today they use modern axes to make their dugout canoes. However, they still make their harpoons and spearheads out of whalebones. These weapons are similar to the ones which European men used in Paleolithic times.

When European travelers first encountered them, the Alacalufes went naked except for otter skins fastened about their shoulders. They smeared their bodies with the grease of sea mammals. But today they wear modern clothes given

them by sailors from passing ships. Their existence is hard but, unlike the Yaghans, they are not vicious or wretched. Instead, they are good-natured people who are quite satisfied with what they have, wanting little more.

Many missionaries struggled to civilize the Yaghans and Onas, and some left accounts of their experiences. But until recently, little was known about the Alacalufes. In 1959, a team of U.S. and Chilean scientists spent part of the winter with them in order to study their culture. These scientists took tape recordings of the Alacalufes' language, and studied the factors which enabled them to survive the bitter cold of Tierra del Fuego.

The Onas slept in open huts winter and summer. But the Alacalufes have always lived in huts covered with skins. They keep a fire burning on the earthen floor and have dogs lying around which provide extra warmth. But during the day they expose themselves to the chilling effects of the snow, the sleet, and rain, and the raw sea winds. They wear no protection for their feet, legs, hands, or arms, and both the men and the women venture out into the icy sea to collect the fish they need to be able to live.

White men could not survive this bitter cold without protection. How then do the Alacalufes survive? To help answer this question, the scientists obtained the services of nine male Alacalufe volunteers and got them to perform an experiment. For eight hours at night the Indians slept underneath a single blanket in an unheated tent. Instruments were taped to various parts of their bodies to measure their body heat and other physical reactions.

The temperature in the tent was very cold; it ranged from 32 to 41 degrees. The experiment showed that the Alacalufes' temperature remained higher than the temperature of white men in milder climates. This proved that the Alacalufes had adapted themselves to cope with the difficult conditions of their existence. This had been Darwin's explanation of how the Tierra del Fuego Indians were able to survive.

The precipitous peaks which thrust up from the islands of Tierra del Fuego are part of the Andes range. All year long these peaks are covered with snow. When the ever present clouds lift, one can

see in many places the snow and ice forming glaciers which, said Darwin, "extend from the mountainside to the water's edge. It is scarcely possible to imagine anything more beautiful than the beryl-like blue of these glaciers, and especially as contrasted with the dead white of the upper expanse of snow." Darwin compared these flowing rivers of ice to "great frozen Niagaras."

Darwin was puzzled by the number of glaciers in Tierra del Fuego, for although the climate is stormy, the temperature is relatively mild. As Darwin noted, it is little colder than the year-round temperature in Ireland. But there are no glaciers in the hills of Ireland.

Darwin concluded that glaciers are not formed simply because the winter temperature is very cold. Instead, they form in places where the summer is cool and cloudy so that the ice which accumulates in winter is not able to melt away before the following winter comes. This theory is now generally accepted by geologists.

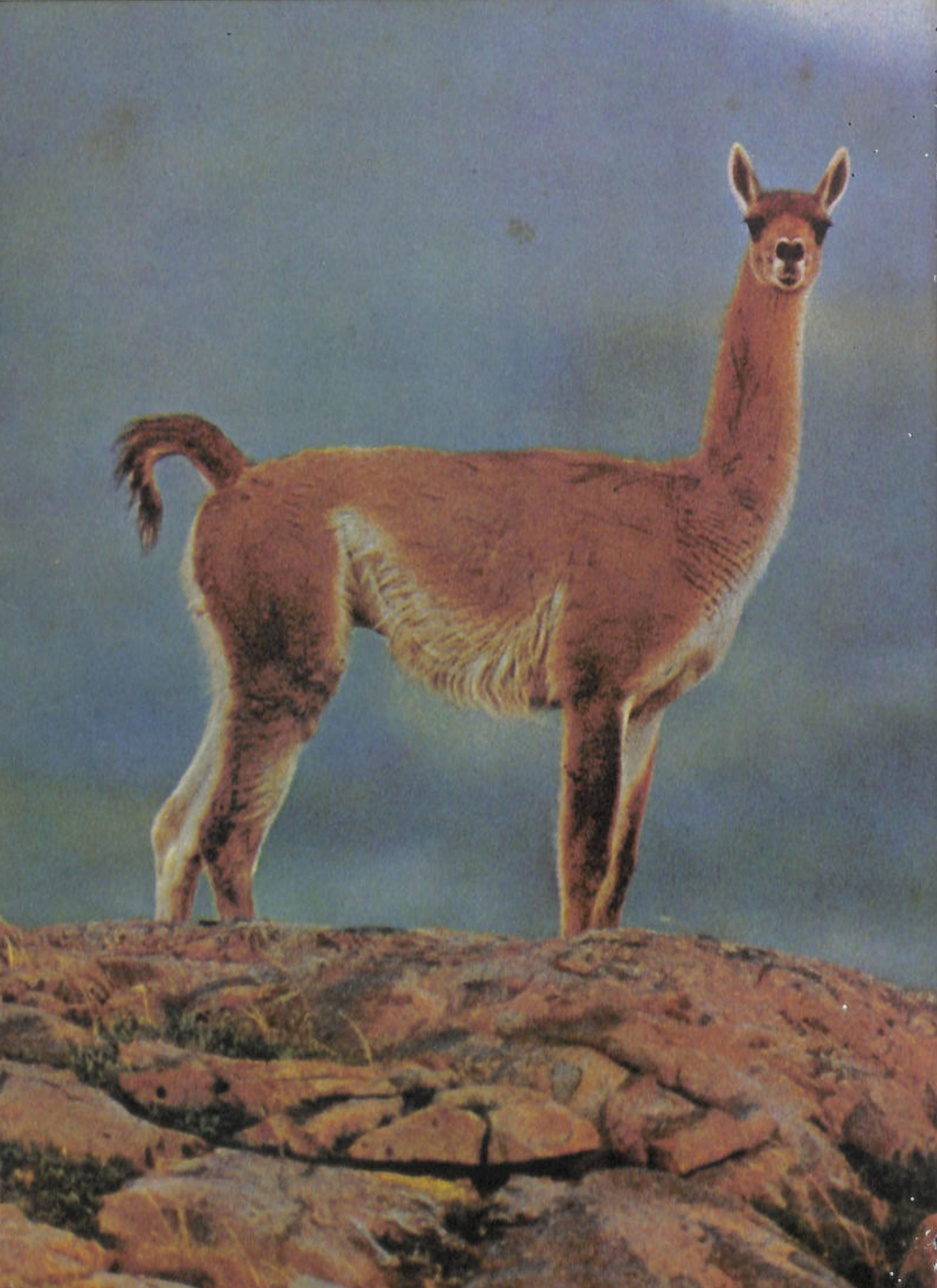
The mountains of Tierra del Fuego are not entirely covered with snow. From sea level up to 1,500 feet, the slopes of the Payne Mountains, north of the Strait of Magellan, are covered with dark, dense forests. Above them a carpet of small Alpine plants extends upward three to four thousand feet to where the snow begins.

An intricate maze of valleys, waterfalls, and streams cover these lower slopes. Wildlife abounds there. It includes the guanacos which swim from one island to another. Darwin admired them so much that he remarked he "could not imagine anything more graceful than their actions."

Geese named "Magellan geese," after the explorer, also thrive on the coastal islands. Some live there all the year round, though others migrate north for short distances during the winter. Darwin noticed that at breeding time the Magellan geese built their nests on small islands far away from the shore. He concluded that they did this out of fear of the foxes which roamed the mainland. It was because of the same fear, he thought, "that these birds, though very tame by day, are shy and wild in the dusk of the evening."

*From sea level up to a height of 1,500 feet, the slopes of the Payne mountains are covered with forests.*





# ANIMALS OF THE MOUNTAIN HEIGHTS

Leaving the tempestuous waters of Tierra del Fuego, the *Beagle* cruised north along the Chilean coast. The mists and raging winds of the archipelago gradually dropped away behind the ship. The climate became milder and the white sands along the coast were clearly visible in the bright sunlight.

But many trips through difficult country lay ahead for Darwin. In 1834 and 1835, he chopped his way through the dense, wet forests which covered the lower slopes of the Chilean Andes. He traveled over 500 miles of barren coastal desert and several times he crossed and recrossed the great Andes range called the Cordillera, making his way along perilous mountain passes more than 14,000 feet high.

On the Cordillera range Darwin made more discoveries which helped to augment his theory of evolution. He found fossil shells embedded in the rocks nearly three miles above sea level. These shells had once lain in the sea and must somehow have been lifted up to where Darwin found them by vast upheavals of the earth's surface.

Darwin compared the plants and animals which lived on the eastern slopes of the Andes with those he found on the western side. Finding considerable differences between the same kinds of living things, he concluded that the mountains formed as much of a barrier between different species of life as the ocean did. As a result, the creatures and plants which lived on different sides of the mountains had probably developed quite independently of each other.

*A guanaco stands guard as its companions graze high up in the Andes. It is one of many creatures which have learned to survive at high altitudes.*

Darwin also found that some animals which lived at high altitudes had evolved the special characteristics needed to survive the cold and thin air of the mountain heights. The guanaco is one of these mountain animals. It is descended from a camel-like ancestor. But this ancestor has died out while the guanaco became adapted to mountain conditions and so was able to survive.

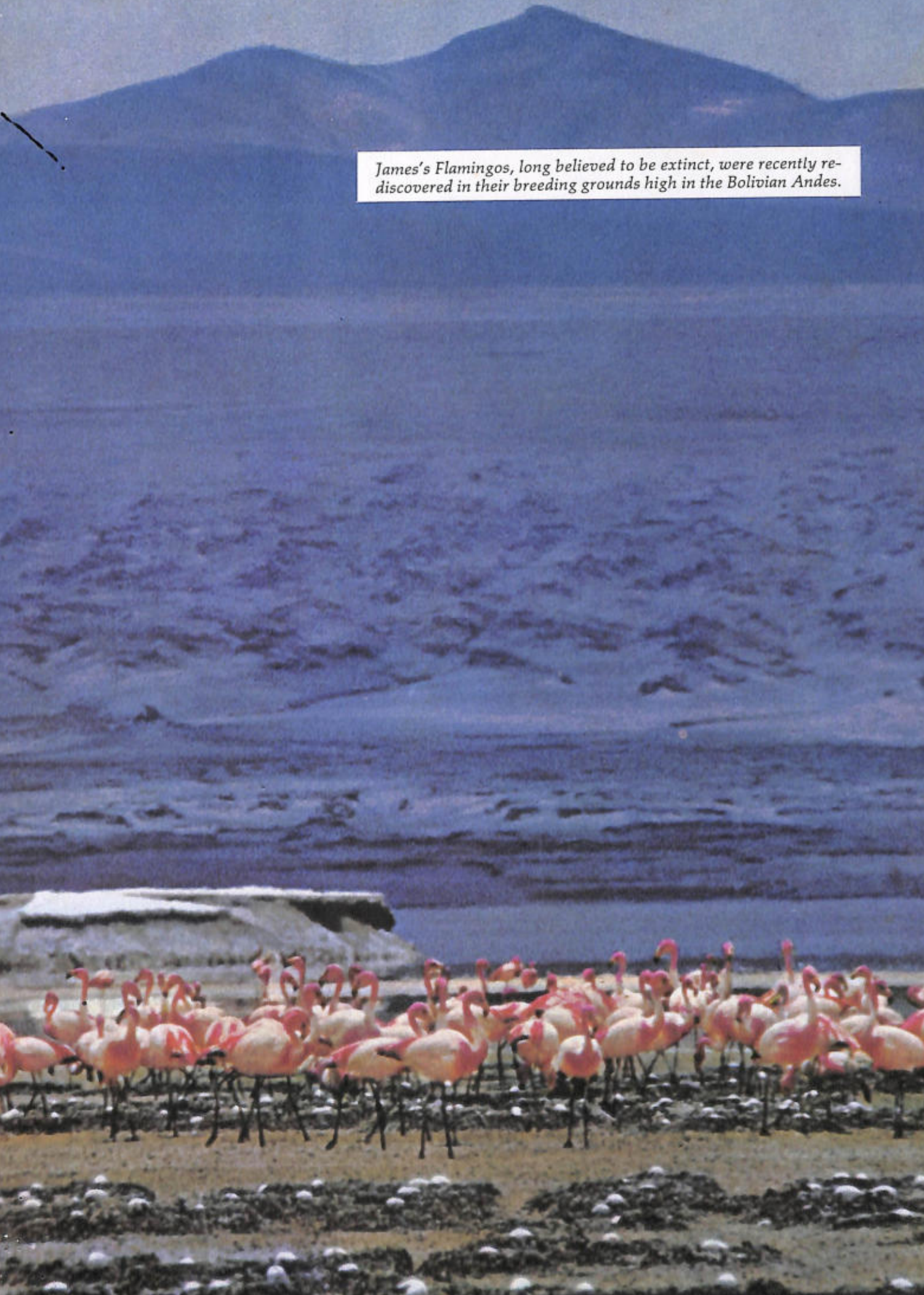
The South American condor also lives on the mountain heights. It is the largest flying bird in the world with a wingspread of more than 12 feet. Birds of prey, the condors nest in rocky eyries high up on the mountainside. When looking for food, they hover high in the air until they spot their prey and then plummet down upon it. When desperate for food, they will sometimes attack lambs or even full-grown llamas. Darwin was fascinated by the condor's ability to soar on currents of air, and wrote: "Except when rising from the ground, I do not recall ever having seen one of these birds flap its wings."

Perhaps the strangest of all the creatures which dwell high up in the Andes is the flamingo. Flamingos breed in salt lakes. They are lovely, delicate-looking birds with rosy-red plumage and long, thin legs. But despite their fragile appearance they are amazingly adaptable. South American flamingos can endure in temperatures only a few degrees above the freezing point, yet African flamingos thrive in the blinding heat which beats down on the salt lakes of Central Africa.

The beautiful flamingo has delighted man's eyes since earliest times. Six or seven thousand years ago an artist painted a picture of a flamingo on the wall of a cave in Spain. In the picture-writing used by ancient Egyptians, a flamingo meant the color red.



*James's Flamingos, long believed to be extinct, were recently re-discovered in their breeding grounds high in the Bolivian Andes.*



Some ancient peoples even believed that the flamingo possessed magic qualities, for it became associated with the phoenix, a legendary bird that was believed to burn itself up every 500 years and then rise up alive again from its own ashes. The Phoenicians, who traded with the Celts of ancient Britain and Europe, claimed that the immortal phoenix wore flamingo plumage. The phoenix's gift of immortality might therefore be passed on to people who wore the dried flamingo skins that the Phoenicians were trying to sell. Early in the Christian era, the concept of the undying phoenix was attached to the flamingo, perhaps because the flamingo in flight etches the sign of the cross.

American ornithologists divide flamingos into six varieties. Three of them live in the Eastern Hemisphere and the other three in South America. One of the South American varieties is the Chilean flamingo, which has gray legs with red joints. Another is the Andean flamingo, which has yellow legs. The third and smallest variety, with dark red legs and eye patches, is the James's flamingo. This small, elusive species was named for H. Berkeley James, a British financier who organized an expedition which first identified the James's flamingo as a separate species.

Several specimens of James's flamingo were found in Chile and were sent to the British Museum more than a hundred years ago. More specimens were found late in the 1800's. But in the first decade of this century the James's flamingo disappeared from sight and some ornithologists believed that it might have died out.

However, an American naturalist named Robert Porter Allen was not so sure. In 1956 he suggested that the rare birds might still be alive in some isolated place. He called the question of whether or not the James's flamingo was still in existence somewhere in the world, "one of the outstanding mysteries of the avian world."

These words led to the launching of three expeditions to search for the mysterious red-legged flamingo. The first group set off in 1957. Just across the Bolivian border from Chile the expedition came upon Laguna Colorada, a shallow salt lake with red-colored water. It is 14,800 feet high and ringed with volcanic mountains. Here, thousands of Chilean and Andean flamingos were feed-

ing. Among a group of about 30, the ornithologists noticed one flamingo which seemed to be smaller and to have a whiter back than the others. It also had brick-colored legs and a wide yellow band on its bill. At last, the long-sought James's flamingo had been found.

There turned out to be thousands of James's flamingos on Laguna Colorada, for the lake is their breeding ground. Despite their isolation, the birds suffer from being hunted by the Andean Indians who raid their nests for eggs. In winter when the lake is locked in ice, the flamingos migrate. But no one has yet discovered where they go.

A second expedition in 1957 took photographs of the flamingos at Laguna Colorada and Laguna Verde, another salt lake further to the south. Then, in January, 1960, a third expedition set out. It was led by Luis Peña, a Chilean scientist, and William G. Conway, curator of birds at the Bronx Zoo in New York. The two scientists were determined to catch some of the James's flamingos alive.

The expedition encountered great hardships. Every day, even in summer, rain and hail, sleet and snow fell. Gale winds swept across the lake; at night the temperature was close to the freezing point. And many members of the expedition suffered from splitting headaches and nausea caused by the thinness of the air at that high altitude.

To catch the flamingos, Conway and Peña had to venture out across the salt lake. As the water was too shallow for rowing, the two scientists had to struggle with layer upon layer of mud. The freezing water made their feet ache with cold. Frequently they fell, bruising themselves on the rough salt crystals. "Progress," wrote Conway, "became a series of short struggles punctuated with rest periods while we stood covered from head to foot with mud and gasped at each other."

But somehow the two men managed to overcome their difficulties. They succeeded in laying snares and capturing 19 of the timid flamingos. Eighteen of the birds survived the trip by air back to the Bronx Zoo.

*The South American condor, largest flying bird in the world, has a wingspread of more than 12 feet. Beautiful in flight, condors can soar on air currents without apparent movement of their wings.*





*The Chilean parakeet, which dwells high in the Andes, has adapted itself to mists and cold.*

Since their arrival at the zoo, the birds have once again shown the flamingo's amazing ability to adapt itself to a new climate and new living conditions. They share their pond with members of the five other known varieties of flamingos. They can no longer live on their usual diet of tiny lake creatures so instead they are given baby food, poultry feed, assorted vitamins, and also carrot oil to keep their plumage red. Thus far, they seem contented and show every sign of staying alive.

Darwin's explorations in Chile included several trips into the rain-drenched forests along the lower slopes of the Andes. There he encountered a tangled mass of dying and dead tree trunks covering the forest floor. "I am sure," he wrote, "that often our feet never touched the ground. At other times we crept one after another on our hands and knees, under the rotten trunks."

*The Valdivian forest covers some 4,000 square miles of hills with a steaming growth of plants and trees.*





The great Valdivian forest was among those which Darwin explored. It covers some 4,000 square miles of rain-soaked hills with a steaming growth of ferns, plants, and mossy trees. Here Darwin discovered a long-nosed frog which has since been named after him. Darwin's frog has two strange characteristics. It has a pointed nose, and the male of the species looks after the eggs. When they hatch, the male Darwin's frog takes the tadpoles into his mouth and keeps them there until they are ready to hop out as froglets.

Darwin also discovered a parakeet in the Valdivian forest that nests in stunted trees and hunts for seeds on the ground. Most members of the parakeet family live in hot, tropical climates, but the Chilean parakeet has managed to adapt itself to the mists and cold of the Andes.

After describing the discomforts of this wild, harsh land, Darwin added, "Yet . . . I cannot forget how sublime is the silence of the forest." However, it was not entirely sublime, for during Darwin's

*Darwin's frog is unique because of its pointed nose and the fact that it is the male which tends the eggs.*





*An Andean waterfall, the Salto del Laja, cascades down from the snow-covered Cordillera mountain range.*

visit a violent earthquake occurred. "A bad earthquake," he observed, "destroys our oldest associations: the earth, the very emblem of solidity, has moved beneath our feet."

Only in central Chile is the climate favorable to civilized man. Northern Chile is a desert, while southern Chile is one of the rainiest regions on earth. Darwin found central Chile much to his liking and he made some important discoveries there.

One day on the Cordilleras he saw what he described as "some snowlike columns." They turned out to be the remains of trees like the araucaria (opposite page), which had turned into a solid substance.

Darwin quickly worked out the awesome story of how the remains of the trees had come to stand high on the Cordillera mountain range. Originally, the trees had grown beside the shore of the Atlantic Ocean when, thousands of years ago, it had flowed right up to the foot of the Andes moun-

tains. As many years passed, the land sank below the ocean. But later the surface of the land was heaved up by the movement of forces deep inside the earth, and what had once been the ocean bed eventually rose up to form a mountain range more than 7,000 feet high.

The jagged Andes Mountains stretch along the length of South America from the Antarctic to the equator, forming the rocky backbone of the continent. These mountains are a difficult place to live. The temperature is cold, the air is thin, and high winds whip along the mountainsides. There is little food on the sparse, scrubby slopes or in the chilly mountain pools. Yet there are many hardy animals which have managed to adapt themselves to these conditions and to thrive in the high altitudes of the Andes ranges.

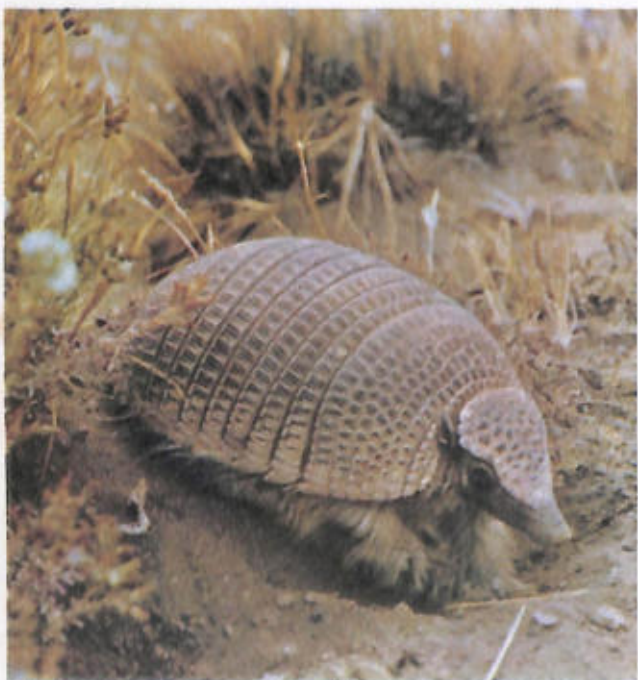
*A hillside (right) is studded with the towering araucaria trees which grow in only two areas of South America—the Andes and the east.*





*The hardy, nocturnal pampas cat is not much larger than a house cat. But it is a coldly efficient predator.*

The graceful guanaco has been particularly successful in adapting itself. It is equally at home swimming through the icy waters of Tierra del Fuego or stepping over jagged crags in the mountains of Chile and Peru. The guanaco is related to the vicuna, the alpaca, and the llama. It was domesticated many hundreds of years ago and was the main American beast of burden until the explorer Cortes brought horses from Europe to America in 1519.



Men still use guanacos as beasts of burden, but the male guanaco can be a dangerous animal. It is temperamental, wary, and tough, and will fight jealously, using its feet and its teeth, to guard its females against marauders. The male guanaco has another weapon which it may make use of in some emergencies; with deadly accuracy it can shoot a blinding, bad-smelling jet of saliva at its enemies.

Darwin was delighted by the guanacos and also by many other animal residents of the Chilean uplands. He liked the black-necked swans, which live only in southern climates. In summertime they breed in the streams and estuaries of Tierra del Fuego and the Patagonian plateaus; when winter comes, they migrate northward up the coast and into the pampas of Argentina. The young swans are born white and only develop their high black collars as they grow into adulthood.

*The hairy armadillo which dwells on the pampas and in the Andes, sleeps by day and feeds at night.*



(Left) A male guanaco leads a female down a ridge in the Andes. It is completely at home in the uplands, stepping surely among high, jagged crags.

The fresh-water otter (below) is hunted by the Indians both for its meat and its skin. But this one is safe, floating on its back in a state of complete relaxation.



The little pampas cat is another sturdy animal of the heights, though it also lives in lower areas along the South American coast. Its fur is soft but warm and hardy. Although not much larger than a house cat, it is a coldly efficient killer. It does its hunting at night on the ground but when frightened, it takes refuge in trees.

The fresh-water otter also has adapted itself to mountain living. It is hunted by Indians both for its meat and its skin. The hairy armadillo thrives high up in the Andes, too, as well as in the lower areas of the pampas. It sleeps by day and feeds at night and, when frightened, burrows for safety into the ground.

Darwin noticed that the hairy armadillo often tried to escape being seen by squatting close to the ground. He reported that to catch an armadillo, it was almost necessary to fling oneself upon it as soon as one saw it. "In soft soil," he wrote, "the animal burrowed so quickly that its hind quarters would almost disappear before one could alight."

Black-necked swans live only in the south. In summer they breed in the streams and estuaries of Tierra del Fuego and Patagonia. In winter they migrate northward into the pampas and up the coast.





# BIRDS THAT CANNOT FLY

Birds developed originally from reptiles. Instead of being covered with scales like their reptilian ancestors, they grew feathers. They first took to the air during the Jurassic period, about 135 million years ago.

As time passed, birds took on the new characteristics needed for flight. The act of flying calls for great energy; so birds developed warm blood and high body temperatures to produce that energy. They acquired powerful chest muscles and superb eyesight, and developed the sections of the brain which control balance. They also learned to build nests and to care for their young.

It took millions of years for birds to become adapted to life in the air. Yet there are some species which seem to have developed backwards. These are birds like the penguin, the ostrich, and the kiwi which were once airborne but have long since lost the ability to fly.

The penguin has wings but uses them as fins when swimming. The ostrich spreads its wings like sails to help it run along the ground. And although the kiwi has wings, they serve no purpose whatever. The cassowary is another bird that can't fly. It is the fiercest of the flightless birds and has saberlike talons that can tear a man to pieces.

Why did these birds lose their ability to fly? Darwin offered an explanation which today is accepted by most ornithologists. There are some birds, Darwin reasoned, which got their food and built their nests on the ground. Such birds as the emu, the moa, and the cassowary had only one use for their wings: to flee from danger.

But these birds lived in places like Australia, New Zealand, or Madagascar where there were no big, dangerous, predatory animals. The birds were big and tough enough to defend themselves against any potential enemies. Therefore they did not need to fly to escape danger. So gradually their wings shrunk and atrophied from lack of use, their legs grew longer and heavier, and they lost their ability to fly.

Other birds, like the African ostrich and the South American rhea, went through a similar process. There are many dangerous beasts of prey in Africa and South America, but the ostrich and the rhea lived in open country, where they could not be taken by surprise. They developed very keen eyesight and the ability to run quickly, and were therefore able to remain safely on the ground.

Some birds which both ate and nested on the ground lived on islands in the middle of the ocean. To them, wings were a positive disadvantage. For when flying, they were liable to be caught by a sudden storm and to be swept out to sea. Those that gave up flying were more likely to survive. In accordance with the law of the survival of the fittest, the birds that gave up the use of their wings were more apt to live long enough to reproduce their own kind.

Flightless birds were safe on the ground as long as they could keep clear of stronger or more cunning enemies. Because no dangerous predatory animals came to Madagascar, Australia, and New Zealand, the flightless birds flourished there for a long time, perhaps for millions of years.

But there was one predator that finally came to these hitherto safe refuges. That predator was man. Early in the 16th century, Portuguese sailors landed in the Mascarene Islands in the Indian

*In this painting of a morning in New Zealand 2,000 years ago, a flightless giant moa reaches down from its 12-foot height in search of gizzard stones.*

Ocean, home of the flightless dodo. The sailors brought dogs and rats with them. The dodos could not defend themselves against these new enemies, and within 100 years they were completely gone.

Perhaps the strangest of all flightless birds was the giant moa of New Zealand. The story of its destruction is still wrapped in mystery. From moa bones which have been dug up, we know that they lived in New Zealand as long as two million years ago. In the absence of predators, they flourished and spread over the islands. Scientists believe that they developed into as many as 37 different species, and the largest of them stood taller than any other creature of modern times, except for the giraffe and the African elephant.

Darwin visited New Zealand in December, 1835. He stayed there for only nine days but in that time he was able to hear many stories about the great, vanished moa. From these stories he deduced that moas, like many other flightless birds, had been able to flourish in New Zealand because of the absence of dangerous predators.

But when did the moas die out? And why? Before white men came to New Zealand, the islands were occupied by a race of natives called Maoris. The Maoris had many stories about the giant bird. They described moa footprints, moa mating calls,

*A male cassowary (right), fiercest of flightless birds, tears at a rival with its three-pronged claws.*

and moa habits, and they described methods of killing moas. One way, said the Maoris, was to toss a moa a red-hot stone. The moa would swallow the stone and so grill itself to death from inside.

After listening to these stories, some scientists came to believe that it was the Maoris who had killed off the moas. But in the past few years archeologists have discovered that other people had come to New Zealand before the Maoris. These earlier settlers are known as the "moa hunters." They hunted and slew moas. They caught fish with hooks made from moa bones and shaped the hooks with chisels and knives made from moa bones. They wore moa necklaces.

No one is sure whether the giant moas were wiped out by these settlers. But the most recent moa known to have existed lived around A.D. 1290, which means that after surviving for some two million years, the giant birds were destroyed at some period shortly after men arrived in New Zealand. Like the flightless dodo, the moa remained safe as long as it existed without human disturbance. But the flightless moa was unable to survive the attacks of men.



*The tailless, nearly wingless kiwi of New Zealand (left) waddles through the woods by night.*





*A male North African ostrich, the largest of all living birds, drops to the ground to court a female. First he rocks back and forth, showing off his tail feathers and wings; then he repeats his courtship call of two short "booms" followed by a long-drawn "boo-oo-oo-om." With most species of flightless birds, it is the males that have the job of sitting on the eggs until they hatch, but the male and female ostrich take turns.*



*A pair of Australian emus watch over their brood of fledglings. Standing five to six feet tall, emus are second in size only to the ostrich.*





*This small rhea (above), found from Bolivia south through Argentina, was discovered by Darwin. Each male mates with half a dozen females.*



*The crested tinamou (above) is a tasty game bird hunted for sport in both western Argentina and Patagonia. It has some ability to fly but weak wing muscles limit its flying range to only half a mile.*

*These "noble rheas" (right), as Darwin called them, are the largest birds in the New World. One stands entangled in bolas thrown by a gaucho.*





TUPOR



# EARTH'S MOST PRIMITIVE MAMMALS

The process of evolution is one of change. In the struggle for existence, the creatures who survive are the ones that can adapt themselves to new conditions. The ones that cannot adapt themselves die out. But there are some backwaters where primitive animals have remained exactly as they were millions of years ago.

The biggest of these backwaters is Australia, land of the marsupials. A marsupial is a primitive animal which carries its young in a pouch. The young marsupials remain inside their mother's pouches because they do not develop fully enough before they are born, to survive on their own.

Marsupials spread out over the earth at the beginning of the Age of Mammals. No one is quite sure how they reached Australia. One theory is that they crossed to it over a land bridge from Asia, which later, about 60 million years ago, sank back into the sea.

Marsupials have very small brains, and they are much less intelligent and efficient than more advanced mammals, which remain longer inside their mother's body before birth, and so have time to develop more fully. On other continents higher types of mammals became dominant and destroyed the marsupials. The only marsupial to survive outside the Australian continent was the American opossum.

Marsupials presumably survived in Australia because the land bridge to Asia was destroyed before the more advanced mammals could cross over it. Higher mammals did not come to Australia until man arrived there a few centuries ago. So the marsupials were left free to breed and develop.

*A little koala clings to a eucalyptus tree with its baby on its back. Koalas were once ruthlessly killed for their fur, but now they are protected by law.*

Australia also houses another species of animals which are even more primitive than the marsupials. These animals are called monotremes. They came into existence perhaps 150 million years ago, toward the end of the dinosaur period.

At that time some reptiles were beginning to evolve into mammals, and on the evolutionary scale, the monotremes came halfway in between. Only two varieties of monotremes still survive, both of them in Australia. They are the duck-billed platypus and the echidna, or spiny anteater. Both in form and habits they very closely resemble their ancestors who lived millions of years ago.

The duck-billed platypus and the echidna possess characteristics which are half reptilian and half mammalian. They lay eggs, like reptiles and unlike mammals. But, like mammals, the monotremes feed their young with milk from their bodies.

The monotremes hatch their eggs in a unique way. The female platypus curls up in a ball and clutches the eggs to her breast for nine or ten days. The echidna puts her eggs in her pouch, where they hatch, and carries the young until their spines begin to prickle. Then out they go.

The first man to realize that monotremes came halfway between reptiles and mammals was a French scientist named Lamarck. He came to this conclusion in 1809, and classified the monotremes as "pre-mammals."

In 1836, Charles Darwin arrived in Australia and set to work studying the marsupials and monotremes. He came to the same conclusion as Lamarck had. Marsupials, Darwin said, were survivors of the earliest types of mammals which had once lived in many areas of the world but had died out almost everywhere except in Australia.

The monotremes were even more primitive. They had evolved from reptiles and had then given way





*The golden possum (above), a nocturnal prowler, surveys the morning sky before going to sleep.*

to marsupials. In their turn the ancient marsupials had given way to the more advanced mammals, which had finally destroyed them.

The biggest group of marsupials belongs to the possum family. One of them is the koala. Although it looks like a teddy bear, it is a marsupial that lives in trees.

At its birth, an infant koala is barely an inch in length. It wriggles immediately into its mother's pouch, where it remains for about six months. When fully grown, at four years, koalas weigh up to 30 pounds. They dine on the leaves of gum trees, particularly the eucalyptus.

Koalas are almost completely unable to defend themselves. Their fur is valuable and great numbers of them have been killed for it. But the almost defenseless little animals are now protected by law.

The golden possum also lives mostly in the trees, using its long, bushy tail to help keep its balance.

*An Australian koala (left), its baby clinging to its breast, leaps boldly from one gum tree to another.*

It is a nocturnal animal that sleeps during the day and comes alive at night to search for leaves, flowers, and honey.

The possum family of marsupials spans a wide range. They vary in size from the big brush-tail to the pygmy possum which weighs barely an ounce. The pygmy possum's body is only two-and-a-half inches long but it also has a two-inch tail, which it wraps around branches in its nocturnal travels amid the trees. It eats nectar and the pollen of flowers. It also lives on insects, including butterflies which are sometimes as big as itself.

Possoms breed in great numbers and can adapt themselves to almost any conditions. Some possums are as acrobatic as any animals except perhaps monkeys. The sugar glider is completely at home in trees, where it finds insects to eat, but it also can fly. It has membranes shaped like parachutes between its limbs which enable it to glide 100 to 150 feet from the treetops. The sugar glider gets its name partly from this ability to glide and partly from its liking for honey.

*A pygmy possum, hanging by its prehensile tail, fixes an eager eye upon a monarch butterfly.*

The ring-tailed rock wallaby is another marsupial that can move gracefully through the air. Wallabies are dainty, attractive creatures that are often as small as rabbits. They live in the plains regions of southern Australia. In the mornings and evenings, they roam widely, feeding on leaves, bark, roots, and grass. During the hottest part of the day they find shelter from the sun's rays in rocks and caves. Although small, they can leap 12 feet from crag to crag, for they have padded soles on their hind feet which keep them from slipping.

The ring-tailed wallabies' main enemies are foxes and wild dogs which were brought to Australia by native settlers hundreds of years ago. If they are hotly pursued, wallabies sometimes take refuge in trees. They cling to the branches with their middle toes which are so shaped that they are especially useful in gripping or wrapping around branches.

*The sugar glider, another member of the possum family, nibbles on a grasshopper in a she-oak tree.*







*Wallabies have rough, padded soles on their hind feet which keep them from slipping on the rocks.*

The ring-tailed wallabies are related to kangaroos, the best known of all marsupials. The first white man to see a kangaroo may have been the English explorer Captain James Cook, who discovered Australia in 1770. On June 24 of that year, Cook described this extraordinary animal in his journal. "It was of a light Mouse colour," he wrote, "and the full size of a grey hound and shaped in every respect like one, with a long tail which it carried like a grey hound . . . but for its walking or running in which it jumped like a hare or a deer."

Cook and his fellow sailors did not notice the kangaroo's pouch. Perhaps the one they saw was a male. But by listening to the chatter of the natives who lived in Australia, Cook noticed that they referred to the strange animal by a word that sounded like *kangaroo*. That is how the kangaroo was named by its first Western observer.

Kangaroos originally lived in trees, like many other marsupials. But at some unknown time they left the trees and descended to the ground. Although one species later returned to the trees, the others remained on the ground.

Kangaroos have no homes. They range over the countryside as the spirit moves them. They move by bounding along on their powerful hind legs, sometimes using their tails to help. Taking leaps of up to 20 feet, they can race along as fast as 30 miles an hour. They continue to grow as long as they live and an elderly male may stand seven feet high and weigh 200 pounds.

The tree kangaroos are smaller. They are about three feet tall and their fore and back legs are more nearly the same size. But the tree kangaroos

also have very powerful tails. Using their tails as rudders, they can leap 70 feet to the ground.

Like the offspring of other marsupials, a baby kangaroo gropes blindly for its mother's pouch when it is born. The unlucky ones that miss are not picked up; they are simply left to die. A baby kangaroo is known as a joey. The ones that do get into the pouch stay there for about six months before they are ready to venture out on their own.

But the baby kangaroos do not remain in the





*A ring-tailed rock wallaby springs gracefully through the air in a 12-foot leap from crag to crag.*

pouch all the time. As a joey develops toward independence, it spends more and more time out of the pouch. And when a kangaroo mother is in danger, it often ejects its baby, leads the enemy away from the spot, and only returns to pick up the baby when the danger is past. Though apparently a tight fit, the pouch is elastic and stretches as the joey noses its way back in to receive the mother's warmth and protection.

There is one marsupial which used to live in

Australia but now survives only in Tasmania, an island a few miles to the south. It is called the Tasmanian devil. Clean as a cat, it lives in a burrow, and can swim long distances underwater.

The Tasmanian devil got its name because it has a dark color and a bad temper and occasionally makes raids on domestic hens and chickens. But actually it is no more wicked than any other meat-eating animal. Usually it hunts rats, mice, and frogs, and only occasionally invades chicken coops.

*At full speed two great kangaroos (below), largest of the kangaroo species, bound across the open plain. With leaps of 15 to 20 feet they can move at 30 m.p.h. Their speed is produced by their muscular hind legs.*



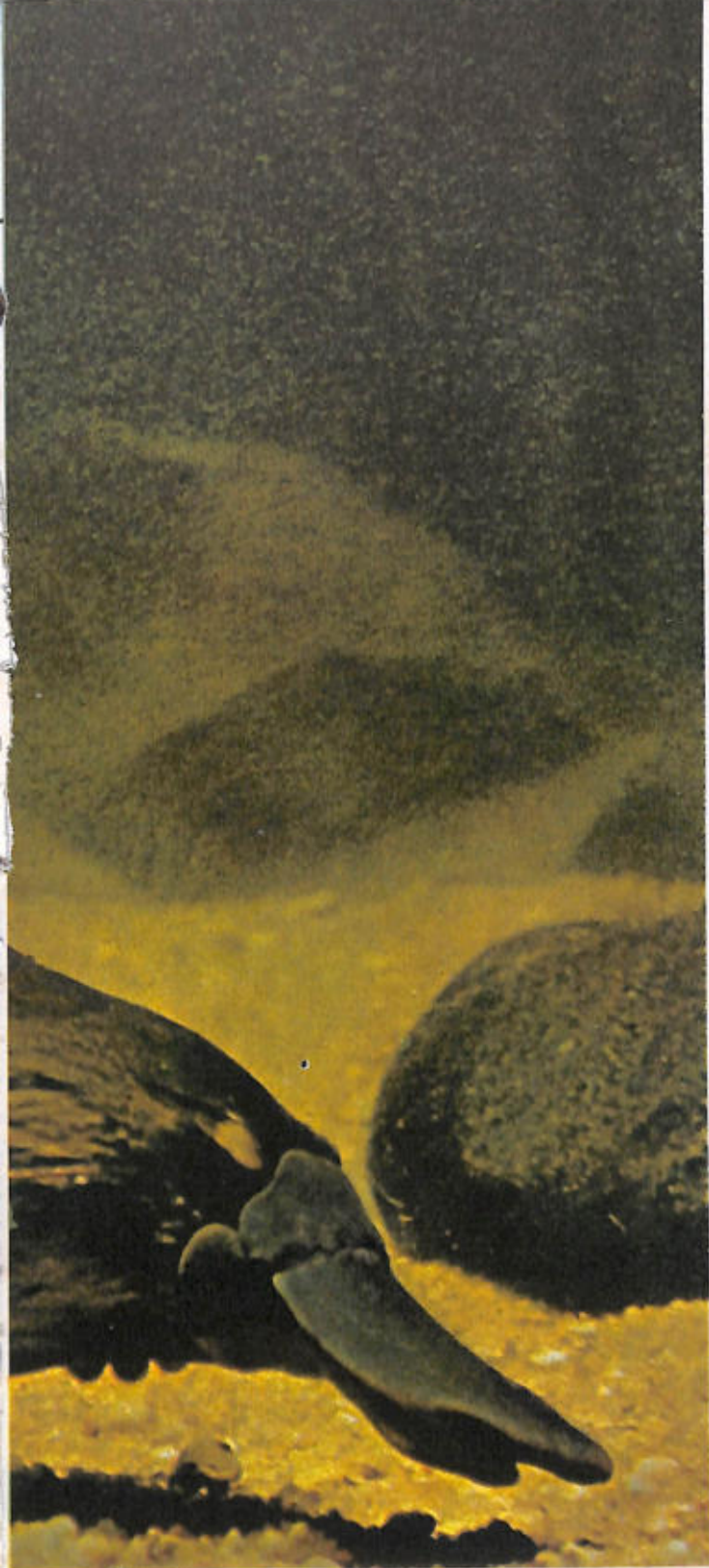


The duck-billed platypus is an expert swimmer and diver. It lives on worms, crayfish, and grubs which it dredges up from the river bed with its flat, capacious bill. It closes its eyes underwater and finds its food by smell and touch.

A platypus' bill is not hard but is soft and leathery and it contains very sensitive nerves. The young

platypus uses its bill to press on its mother's body to make the milk come out; then it scoops the milk up with its bill.

The echidna lives on ants and other insects which adhere to its long, sticky tongue. When threatened, it burrows quickly into the earth but leaves its quills exposed to defend itself.



*The duck-billed platypus (above) snuffles along the pebbly bottom of a stream. With its flat bill, it is dredging for worms and other tiny water creatures.*

*To evade an enemy, the spiny anteater (top to bottom, right) burrows into the earth within a few seconds. However, it leaves its quills exposed for defense. Coiled in its thin beak is a foot-long sticky tongue to which ants and other insects adhere.*



The existence of the Australian marsupials and monotremes was not generally known until about 1800. In the 13th century an Arab merchant named Ali Abul Hassan Masudi brought back stories of an odd little animal which, he said, "lives for six months in its mother's belly and always goes back there to feed." In 1640 a Dutchman reported that he had seen "a creature as large as a man with the head of a deer and a long tail, which stands on its hind legs like a bird, but can hop like a frog." This was presumably a kangaroo. Later explorers noticed kangaroos carrying their young in pouches. But the reports of these explorers were not generally believed.

Toward the end of the 18th century, immigrants from England began to settle in Australia. They sent specimens and drawings of the marsupials back home. In 1790 a group of zoologists met in London and noticed that every one of the newly discovered animals had a pouch, called a marsupium. They were forced to admit that the marsupials were a completely new kind of order, different from any other creatures they had ever seen.

*The rabbit bandicoot has long, rabbit-like ears and can dig a burrow faster than a man with a spade.*



A few years later, specimens of the platypus and echidna were sent to London. They seemed so strange that at first the scientists in Britain thought the Australian settlers were playing a joke on them. But in 1803 the platypus and echidna were officially recognized as members of a completely new order of animals—the monotreme.

It was difficult for scientists to study the platypus in its home in Australian streams, and those specimens which were kept in captivity quickly died. For many years zoologists were unable to be completely certain that this extraordinary animal both laid eggs and fed its young with milk from its body. Lamarck and Darwin both realized the platypus' place in the history of evolution. But it was not until the end of the 1800's that most scientists accepted the platypus for what it was: a kind of living fossil that had survived in the isolation of Australia for 150 million years.

Not all the marsupials that once lived in Australia still survive. In 1830 an Englishman named George Ranken found the enormous bones of some unknown beast buried in a cave. The bones

*The fearless and intelligent marsupial cat looks rather like the common house cat kept as a pet.*





*Jerboas, or jumping mice, dart about the Australian scrublands searching for insects to eat.*

showed that it had been six feet high at the shoulders and ten feet long. At first it was thought that the bones belonged to an elephant that had been drowned in a flood.

But further examination showed that the animal had been unlike any now left on earth. It was a giant marsupial which vaguely resembled both a gigantic guinea pig and a rhinoceros. It had two huge chisel-shaped teeth in its lower jaw, and the shape of its legs indicated that it could sit back and graze for food in the lower branches of trees.

The animal was named the *diprodoton*, which means "two front teeth." For years no one knew

whether any *diprodotons* still survived or whether they had all died out. But the remains of other *diprodotons* which were found later showed that they had been cooked and eaten. This discovery helped to prove that the *diprodotons* had finally been wiped out by a higher mammal—man.

But more questions about the marsupials remain unanswered. No one is exactly sure how they reached Australia. No one is sure either of the exact process by which marsupials and monotremes descended from reptiles. Only more explorations in the heart of Australia, the world's least-known continent, may provide the answers.



JOSEPH SIBAL

# THE EVOLUTION OF COURTSHIP

The evolutionary course taken by any species is decided by two factors. One is the struggle for survival; for only the creatures which triumph in the fight for survival are able to produce offspring. The second factor is sexual selection; for offspring can only be produced by those creatures which are able to find mates.

Among some kinds of animals, it is the females which try to lure males to mate with them. Does pretend to run away so that bucks will chase them. Female giraffes invite males to go after them by cantering with a special swaying kind of gait. Female gnus show that they are ready to mate by dropping to their knees and nudging males as they stroll past. Tigresses display their readiness by pacing up and down in front of tigers, flicking their tails and drawing them across the males' muzzles. Female gorillas simply stand in front of the males and wait.

In most cases, however, it is the males which compete for the right to mate with females, and so to produce offspring. Sometimes the strongest males win the courtship struggle, but other times it is not the strongest but the most attractive males which win.

Darwin's studies showed that male animals, birds, fish, and insects have developed many techniques to make themselves attractive to females. But, as he recognized, the fact that a creature has developed a complicated method of courtship does not necessarily mean that it stands high on the ladder of evolution.

Insects, fish, and amphibians are among the less advanced of creatures. Yet some have more ad-

vanced methods of courtship than other, more highly developed species. Jewel fish, for example, put on elaborate displays to attract females. They quiver, change color, dig into the sand, and stand on their heads. Salamanders dash about furiously, poking, nudging, biting, and exuding exciting smells. Frogs and toads perform stately dances.

The most striking techniques of courtship have been developed by birds. Where courtship is concerned, birds fall into two classes. The males of some species mate with only one female, live with her, and help to feed and raise her young. Many of these birds do not bother with courtship ceremonies. The males win the right to mate with the female by being with her constantly and helping to build a nest and provide food. The songs of such monogamous birds serve not to attract the females but to keep male rivals away from the area.

The males and females of other species of birds come together only briefly—to mate. The male members of these species compete fiercely to win the females. They have, therefore, developed various ways of making themselves attractive.

The methods each species adopts depends on its physical make-up. The blue-footed booby has brightly colored feet, and the male booby struts to show off his feet. The fulmar has a startling purple lining to his mouth; the males open their mouths wide to show off this splendid lining.

Apart from the peacock, the most strikingly decorated of all birds is the bird-of-paradise. The male has developed a most elaborate ceremony for courting females. He begins by uttering loud, raucous cries. Then he goes into a dance, usually along the branch of a tree. He starts the dance by lowering his head and swinging it gently from side to side. Then, gradually, he opens his wings and lifts the long plumes along his flanks. At last, he suddenly

*Beginning a courtship ceremony, a magnificent male bird-of-paradise does acrobatics on the branch of a sapling for the benefit of a plain-looking female.*

leans forward, lowers his wings, and, to climax the display, he reveals the sprays of plumes that circle his head like a crown.

One species of bird, the maypole-building and avenue-building bowerbirds, prepares a special area for its courtship. These birds are called bowerbirds because they build a bower, a kind of shelter or enclosure, usually surrounded by leaves.

One of the oddest of the bower-builders is Sanford's golden-crested bowerbird. To attract a female, the male makes a mat of ferns and builds a curtain of ferns and bamboo around it. He decorates the mat with shells, insect skeletons, and berries, moving them around to catch the sunlight.

Another group of bowerbirds is called maypole-builders. Every spring the male begins to build his bower by clearing a small, circular space on the forest floor at the foot of a sapling. He covers this space with moss gathered high in the trees, and then collects dead twigs and twines them around the sapling. When the bower is finished, the bird flutters around the sapling to show off his fine feathers and his bower to his chosen female.

The short-crested bowerbirds have a less attractive plumage than the flame-crested variety. Perhaps to make up for this, they build more elaborate bowers. In addition to the bowers, the male attaches a small tepee of twigs to the top of the sapling, and on the cleared ground, he scatters colorful shells and flowers.

The male crestless bowerbird has an even less attractive plumage, barely distinguishable from the female's. This variety makes even greater efforts to make his bower attractive, decorating it with insect skeletons, seeds, and charcoal as well as shells and flowers. As the flowers fade, he keeps adding new ones. To help attract the female, he also bobs and weaves around the bower, holding some colorful object, usually a flower, in his mouth.

When the female finally enters the bower, the birds mate. Then the female flies away to build her own nest where she will lay and hatch her eggs. Male bowerbirds mate with only one female each season, but even after she has come and gone they continue to look after their bowers.

Avenue-builders make up another branch of the bowerbird family. Living on the edge of the forests in New Guinea and Australia, they have devel-

oped a completely different kind of bower. Instead of twining sticks together to form a maypole, they use sticks to make a long, rectangular mat on the ground. Then they construct walls on two sides of the mat by thrusting sticks into the ground, giving the effect of a treelined avenue.

The male avenue-builder gathers pounds of ornaments to decorate his avenue. Then he proceeds to paint it. He makes the paint by chewing colored berries and charcoal, and he does the painting with his bill. Some males spend up to half a year building and decorating their avenues. At the height of the courtship season many males work in pairs. They hunt out a piece of bark and use it like a paintbrush to apply colors to their mating grounds.

Lauterbach's bowerbird, the least colorful of the avenue-builders, constructs the most elaborate bower of all. He adds walls along the third and fourth sides of his mat. Some of these birds use over 3,000 sticks to build their bowers and construct them so firmly that the bower can be lifted up and carried away like an orange crate.

Bowerbirds belong to the same family as birds-of-paradise, but they are more highly developed. Because a bower can be made more decorative than a bird's plumage, the bowerbirds are able to put on a far better display. The more highly developed birds use external decorations to attract females. Birds with bright plumes are more easily seen by their enemies and so are more likely to be destroyed. The dull-colored birds are harder to see and therefore are more likely to survive.

The battle for survival has also influenced birds' choice of places to do their courting. All birds-of-paradise used to do their courting high in the trees. But the more advanced varieties now do their courting on the ground. Birds which make their courtship display in the trees are more easily seen by their enemies and so are less likely to survive.

All bowerbirds do their courting on the ground. The males probably started to build bowers to conceal their mating from enemies. The elaborate decorations may have evolved from this early device.

In recent years men have come to live closer to the wild places where bowerbirds do their courting. The birds have taken advantage of their arrival, using bottle tops, car keys, coins, teaspoons, and even a glass eye for decoration.



*A male Sanford's golden-crested bowerbird (foreground) tries to entice the female perched above him into his bower that he has elaborately decorated with shells, berries, and insect skeletons. The courting spectacle has attracted other birds, too.*



*The male flame-crested bowerbird (above) is one of the most primitive of the maypole builders. Because of his elegant orange plumage he can attract the female just by parading in front of her. However,*

*he adds to his charms by building a bower. He builds it around a small sapling and decorates it with special mosses and dead twigs. Then he flutters around the pole, displaying his fine feathers.*



The most elaborate bowers are built by a branch of the bowerbird family called the avenue-builders. Instead of twining sticks together to form a maypole, they use them to make a long, rectangular mat. Then they thrust twigs into the mats to form

parallel walls, giving the bower the appearance of an avenue, and decorate the mats with pounds of attractive ornaments. The most brightly colored of the avenue-builders is the regent (above). It builds the simplest avenue.



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*Satin bowerbird (above, center) also builds an alley of twigs. Like other male bowerbirds, he comes up and down his alley for weeks on end, singing and preening. During his maneuvers, the female shows only occasional interest by perching*

*on a nearby branch; then the male flashes one colored object after another in his bill to attract her. Finally the female enters the bower. Before mating, the satin bowerbirds engage in a courtship fight, as shown in this painting.*



*The male short-crested bowerbird (center) has less attractive plumage. Sometimes it is as short and drab-colored as the female's. The male therefore depends more on his bower to excite a female,*

*and so builds a more elaborate one. In addition to the lawn and maypole, he adds a small tepee of twigs to the top of the sapling. On the lawn beneath he scatters many colorful flowers and shells.*



*The male crestless bowerbird (above) is completely drab. His plumage is indistinguishable from the female's. His bower has therefore grown more elaborate to take the place of colorful feathers. He*

*gathers insect skeletons, shells, seeds and charcoal, and arranges them in neat piles in his bower. While bobbing about to attract the female, he holds a colorful object, usually a flower, in his bill.*



The satin bowerbird (above, center) also builds an avenue of twigs. Like other male bowerbirds, he marches up and down his alley for weeks on end, posturing and preening. During his maneuvers, the female shows only occasional interest by perching

on a nearby branch; then the male flashes one colored object after another in his bill to attract her. Finally the female enters the bower. Before mating, the satin bowerbirds engage in a courtship fight, as shown in this painting.



...uterbach's bowerbird is the least colorful of  
...venue-builders, and his bower (above) is the  
...elaborate. After building one pair of parallel  
...he adds a third wall in front of them and a  
...h behind. Frequently he uses over 3,000 sticks

to build his bower and decorates it with up to 1,000  
stones which he piles neatly against the walls. To  
help lure the female, he also adds colorful berries  
to the bower every day. After mating, the female  
leaves the bower to build a nest for her eggs.



# THE CORAL ISLES

For many generations before Darwin's day, sailors had been baffled by the mystery of the coral reefs and islands which lie scattered across the oceans. These are formed in the warmer waters of the world by the skeletal remains of countless generations of tiny creatures called coral.

How do corals adhere together to form islands? And how do the islands manage to survive against the unrelenting buffeting of powerful ocean waves? These were questions which no one before Darwin had been able to answer.

In the autumn of 1835, H.M.S. *Beagle* completed its survey of South American shores and headed across the Pacific, where Darwin was to see coral formations for the first time. In the early spring of 1836 he made a brief stop at the Cocos Islands in the Indian Ocean. There he found solutions to the questions about coral islands which had remained unanswered for so long.

During the 17th and 18th centuries, voyagers and explorers had tried to explain how the coral islands had been formed. Some thought that coral animals built the circular-shaped coral reefs by deliberate design, in order to protect themselves from the fury of the ocean. In both prose and poetry, nature writers had described the "coral insect" building its "home," and had praised its "skill" and "industry."

Darwin knew that this talk of "skill" and "industry" was nonsense. He was sure that corals

could not have constructed the islands deliberately, in the same manner that bees, for example, build beehives. He was also sure that coral reefs did not serve to protect living corals, because the active coral builders flourished only on the seaward side of the reefs. They could not live in the protected lagoons behind the reefs. Therefore the reefs were no protection for them.

One problem particularly puzzled Darwin. The outer walls of the coral reefs and islands plunge precipitously to enormous depths beneath the ocean. But living corals can only exist in the lighted upper levels of the sea, extending no further than 180 feet below the surface. If the reef builders could not survive at great ocean depths, on what did they base their massive structures? What held the coral islands up on top of the water?

As he studied coral formations, Darwin saw that they are of three kinds. Some are atolls. An atoll is a ring of coral islets enclosing a sunken lagoon. Some are barrier reefs. A barrier reef is a rampart of coral which surrounds a volcanic island but is separated from it by a channel of water. The third kind consists of fringing reefs which are similar to but smaller than barrier reefs, and also stand closer to the shore.

When Darwin began his studies, it was already known that coral atolls were in some way connected with underwater volcanoes. Some people believed that atolls actually rested on the rims of submerged volcanic craters. But Darwin dismissed this theory. He pointed out that some atolls were five times as long as they were wide, some were shaped like loops, and one atoll in the Indian

*In the calm reef waters of the Cocos Islands dainty damselfish flash their turquoise scales. They usually swim in large schools close to their coral home.*



Ocean was 88 miles long. Obviously none of these atolls could rest on the rim of a circular volcanic crater.

Nonetheless, Darwin's explanation of how coral structures are formed was based on the relationship between coral and volcanoes. During his visit to South America, he had realized that over great periods of time, parts of the earth's crust rise or

fall. Sometimes a section of crust is elevated into a mountain range; sometimes a section subsides beneath the ocean. Studying the three kinds of coral formations, Darwin concluded that they followed an evolutionary sequence; that one must come first and the others follow. The first stage, he reasoned, occurs when a movement of the earth's crust thrusts an active volcano above the



*A coral barrier (foreground) protects West Island, the largest island of the Cocos, from the sweeping surge of the sea. Behind is the atoll's lagoon, seven miles wide and encircled by scattered islets.*

But new corals continue to build on the old foundation. As the original island formed by the volcano grows smaller, the lagoon between it and the coral formations grows wider.

During the third stage, the volcanic island settles lower and lower in the ocean while the coral reefs continue to grow larger. Corals flourish best out amid stormy waves and crashing surf; so the coral reef tends to expand outwards. As it does so, the lagoon behind grows steadily bigger. The shrinking slopes of the volcanic island contain less and less room for vegetation, but on the sand-covered coral reef a rich covering of palms and other plants will continue to grow.

In the fourth and final stage, the original volcano disappears completely beneath the ocean. Only the coral reef is left, now become an atoll—a ring of islets enclosing a lagoon. Dotted across the shallow waters of the lagoon, clumps of coral rise like frozen flowers above the surface. The outer walls of the atoll fall as sheer as mountain precipices into the ocean depths, reaching as far as a mile below the surface. For the atoll may have risen this high above its original base in the million years that it takes to reach its final form.

Coral islands teem with life under the surrounding water, on the ground, and above the ground—in the air. In the Cocos Islands Darwin noticed that birds thrived particularly among the shrubs and palms of the islands' wooded areas. The red-footed booby is one of the Cocos Islands' aerial inhabitants. It cannot take flight from the ground but must first climb onto a bush. But once in flight over the water, it can sight fish from a distance of 50 feet or more, and dives after them.

The white fairy tern also lives in the Cocos Islands. It has a particularly light and airy way of flying when it soars, with its slender body clearly silhouetted against the blue sky.

But coral islands contain another world which is far more colorful than any realm of land or air anywhere on earth. This is the world of coral beneath the water. Here tree- and shrub-shaped corals form elaborate coral gardens. Brilliantly colored

surface of the ocean. Gradually corals adhere together around the shores of this volcanic island. As countless numbers of more corals come together, they form a fringing reef.

Then comes the second stage. Gradually the fringing reef changes into a barrier reef. By this time the volcano has ceased to be active; cold and extinct, it has begun to sink back into the sea.



*The history of the formation of a coral atoll is shown here in four stages. In the first stage, a still active volcano rises above sea level—which is represented by the white line. Black lines show the lava flow. The fringing reef of coral has begun to grow larger around the volcanic island.*

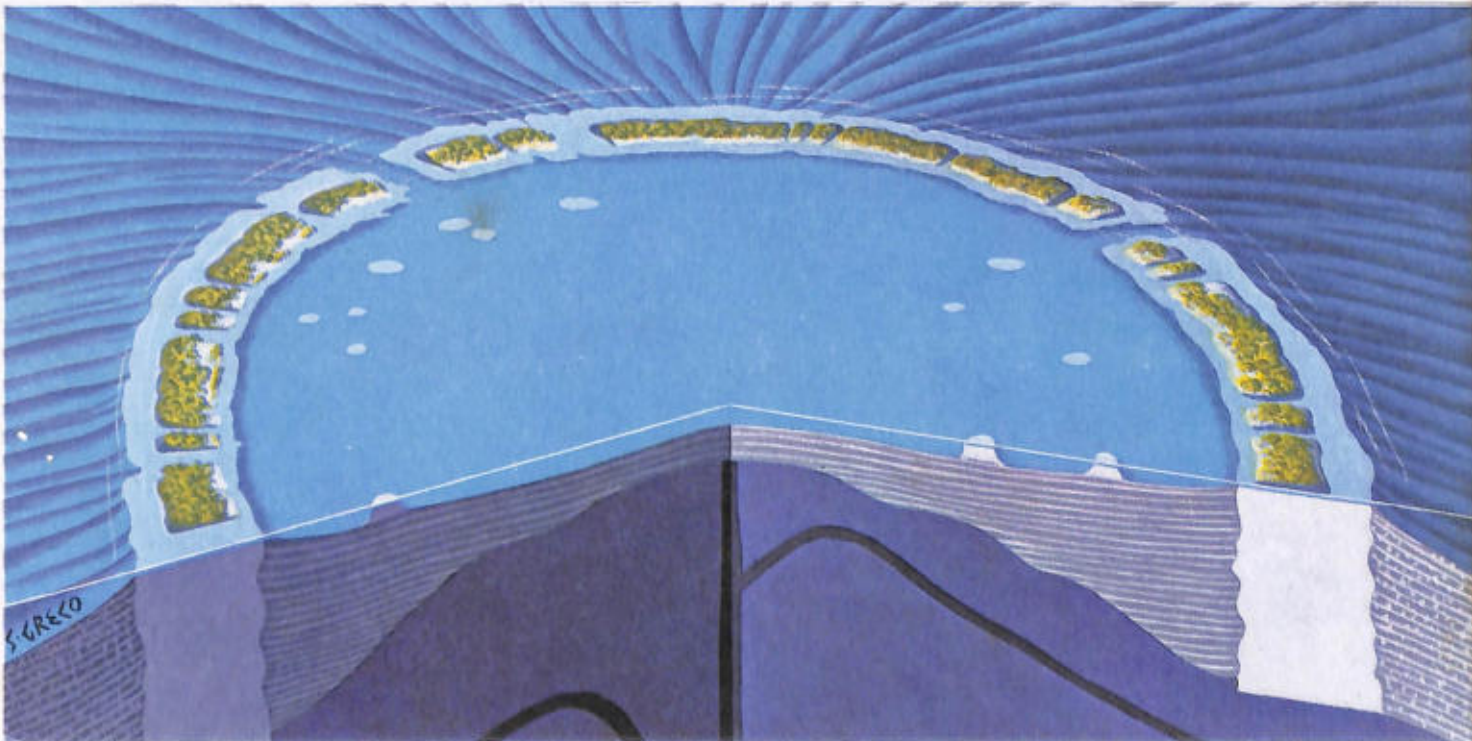
*The third stage: as the volcano settles lower in the sea, the barrier reef spreads outward and the lagoon continues to grow bigger. On the shrinking slopes of the volcanic island there is less room for vegetation. But the sandy surfaces of the coral reef develop a rich covering of palms and plants.*





The second stage: the fringing reef changes into a barrier reef. The now cold and extinct volcano has begun to sink back into the sea. Meanwhile the corals continue to build on their old foundations. As the volcanic island grows smaller, the lagoon becomes wider. Vegetation appears on the reef flats.

The fourth stage: the atoll is now complete. The original volcano has disappeared beneath the ocean. Only a ring of coral isles remains, encircling a turquoise lagoon. The living corals stand nearly a mile above the original volcanic base and their outside walls fall as sheer as precipices.







*In hovering flight, the white fairy tern is clearly silhouetted against the brilliant blue sky.*

coral fans and whips wave in the wash of the tides, and coral spines and boulders loom among the multi-shaped coral crags.

Many varieties of coral have been known for a long time. Throughout the ages collectors in every land have prized coral specimens. But only recently have scientists been able to study coral in its underwater home.

There, some surprising discoveries have been made. One of the most interesting concerns the color of coral. The color of an object depends in part on the light that plays on it. Light is transmitted in waves of different lengths. Below a certain depth, water filters out all wavelengths of light except the very short waves which are known as "ultraviolet waves."

In 1958 divers descended into the ocean off the coast of the island of New Caledonia in the Pacific, and reached a depth where only ultraviolet waves of light operate. Here they made a startling discovery. They noticed that certain unfamiliar types of coral glowed with a lovely inner light.

With great care the fragile corals were brought to the surface, each one carried in a separate basket. The corals were then placed inside tanks. At once their colors faded and they turned drab and

brown. But when an ultraviolet lamp was turned on them, the corals once again glowed with a mass of color.

Some insects such as fireflies and glowworms, possess a similar quality; they, too, glow with light in the darkness. Darwin had wondered why insects did this and decided that they might have developed their glowing abilities to frighten off enemies or to guide females to the males.

He noticed that some insects which have an unpleasant taste also glow in the dark, and thought that the glow might serve to warn predators of their distastefulness. Some deep-sea fish also give out light in the underwater dark, perhaps for similar reasons. But no one has yet explained satisfactorily why the corals should glow in the obscure ocean depths.

Amid the coral life of the Cocos Islands, Darwin found plenty of evidence to support his theories of evolution. He saw how crabs and clams, among other creatures, had adapted themselves to their ocean environment.

There are about 100 different varieties of crabs on the Cocos Islands. Darwin's interest was most taken by the robber crab, which eats coconuts. It begins by tearing off the coconut husk, fiber by fiber, with its enormously strong claws, until it has made an opening. Then it turns around and extracts the coconut meat with its rear pincers.

*Roosting in a tree, the red-footed booby rests between the flights out to sea where it catches fish to eat.*



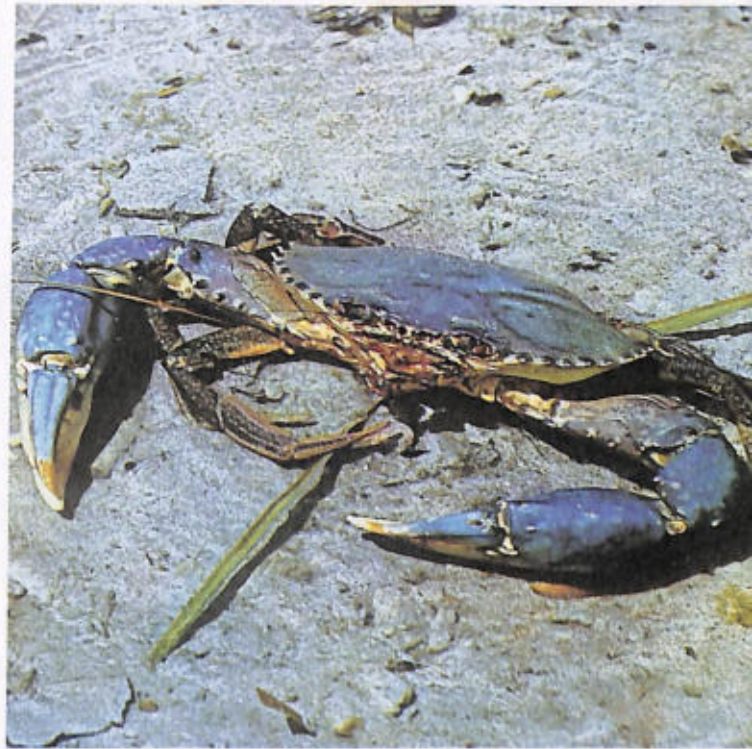
*The timid ghost crab (above) creeps out at night to feed. When burrowing it hurls sand three feet away.*



Darwin was struck by the amazing way in which a crab had learned to make use of the coconuts that nature had placed in its environment. "I think," he wrote, "this is as curious a case of instinct as ever I heard of."

It is the unnumbered different kinds of corals which transform the waters around coral islands

*The robber crab (left) has strong claws. Darwin told how one escaped from a tin box by bending the metal.*



*A blue mangrove crab (above) searches the shallow flats for food. The soft-bodied hermit crab (left) has sheltered itself in an old snail shell.*

*This giant clam (below) measures a foot across. Some clams, four times as big, weigh up to 600 pounds.*



into a multicolored fairyland. But the seas are filled also with a marvelous variety of strange fish. Some are brilliantly decorated, like the gaudily striped wrasse or the carmine-colored damselfish. The wrasse has blue teeth with which it crushes the shellfish it feeds on. Damselfish are tiny creatures which usually swarm in large schools and stay close to corals that protect them. But sometimes they venture out among other groups of corals, such as the *Alveopora*, which are dangerous. For these



*A Chinese fish (left) hovers over a golden cluster of deep-sea coral. Scientists have not as yet been able to explain why it swims in an almost vertical position.*





*A feather star (above) flutters gracefully through the water like some strange, lazy bird. When feeding, it attaches itself to a rock or shell by means of its claws. It lives off microscopically small marine creatures, some alive and some dead.*

*This cling fish (below) is hanging on to a rock by means of a sucker pad on its fin. Being a weak swimmer, it is almost helpless in strong currents or heavy seas. To survive, it developed the ability to cling to rocks, by which it got its name.*





*A slate-pencil sea urchin scuttles silently across the sea bottom in search of prey.*



coral possess extended, writhing tentacles which they use to seize any fish that are rash enough to venture within range.

The yellow chaetodon fish sometimes falls victim to the corals' tentacles. The chaetodon is practically invisible in intense light. But its colors brighten with darkness and at night it becomes brilliantly luminous. The anemone shrimp has a luminous tail. Even more curious, it is practically

*A striped goby nuzzles into the sea bottom. It is collecting sand which it will carry away for a nest.*

transparent, so that its internal organs can be seen quite clearly from outside.

Another coral island fish, the striped goby, has one habit that is more common among birds. It builds a nest for itself. It makes the nest out of sand which it bulldozes into its jaws from the ocean floor and then carries over to the nest. The striped goby is a timid creature and makes sure that it is unobserved each evening before diving into its sandy home.

The slate-pencil sea urchin is a vegetarian and finds its food on the ocean floor. Like other sea urchins, it has a hard shell. It moves with difficulty on spines that protrude from the hard plates which surround its soft body. Its mouth is located in the middle of its body and contains five sets of teeth.

The slender pipefish also rely on body armor for protection, because they are slow swimmers. Pipefish have a particularly strange way of mating. The male and female meet very briefly, just long enough for the female to lay eggs in a bag under the male's body. There the young fish emerge a week or two later to begin active life.

One of the rarest and most beautiful swimmers in coral waters is the Chinese fish, which has only recently been discovered. The Chinese fish has one remarkable characteristic; it swims in an almost vertical position. Scientists have so far been unable to provide any explanation for this extraordinary habit.

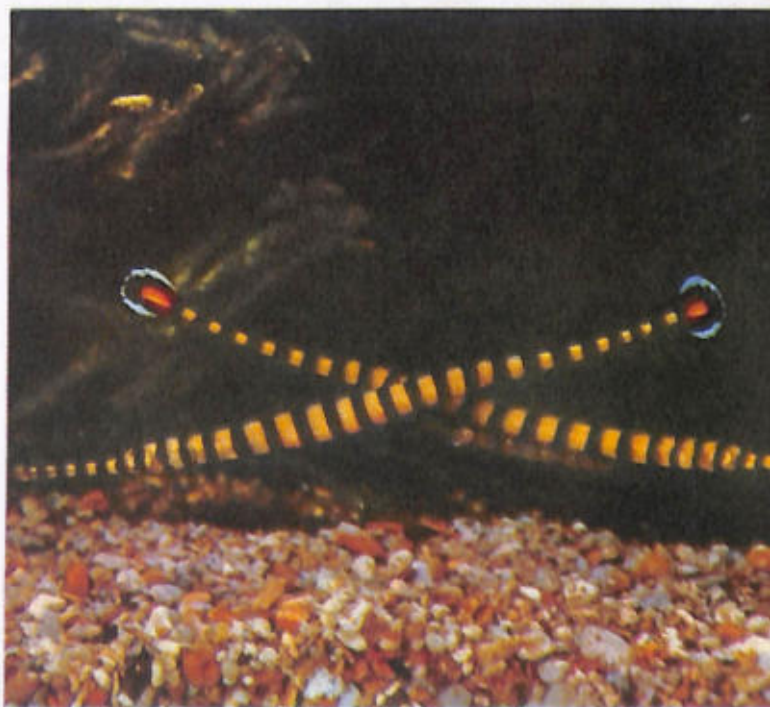
The feather star, a relative of the sea urchin, is also very graceful. It flutters through the water like some strange lazy bird. The feather star lives on tiny ocean creatures and plants, and, when feeding, attaches itself to a rock or shell by means of its claws. Another very curious inhabitant of coral waters, the cling fish, also attaches itself to rocks. Because it is fragile, has no scales, and only small fins, it is a weak swimmer, and finds itself practically helpless in strong currents or heavy seas. In order to survive, it hangs on to rocks by means of a sucker pad attached to one of its fins.

In recent years scientists have been studying the ways in which the different kinds of creatures that live on or around coral islands react on one another. It has long been known that coral attracts fish, some just passing through and some of them permanent residents of the coral waters. However,



*An anemone shrimp sways by a rock, occasionally flicking its tail. The shrimp is nearly transparent, so its insides can clearly be seen. Its markings indicate that this shrimp is a female.*

*Two slender pipefish glide past each other. Because they are slow swimmers they depend on bony armor for protection. They mate in a brief meeting when the female lays eggs in a bag below the male's body.*





*A Colonial Reef coral, with fingerlike tentacles and three central mouths, is drab brown in natural light.*

scientists have only recently discovered that fish are extremely important to coral. Indeed, the health of coral depends on the presence of enough fish. For one of coral's worst enemies is seaweed, and many varieties of fish eat up the seaweed as soon as it begins to form along the ledges of the coral reefs.

Other scientists have been investigating with great thoroughness the question which Darwin set himself to answer: how coral formations come into existence. Much recent information has been collected which has confirmed the truth of Darwin's explanation.

During World War II, the U.S. Navy found submerged, flat-topped, volcanic mountains scattered throughout the depths of the Pacific Ocean. On these underwater mountains pebbles were found that had obviously been shaped by the action of waves. Therefore the submerged plateaus must have once protruded above the surface of the sea where the waves could sweep over them. This discovery helped confirm Darwin's theory that coral formations grew originally from volcanic islands which have since subsided into the ocean depths.

Darwin himself realized that he did not possess enough information about coral to thoroughly sub-

stantiate his theories. "I wish," he wrote, "some doubly rich millionaire would take it into his head to have borings made in some of those Pacific and Indian atolls."

In recent years Darwin's wish has been realized, for very deep borings have been made at three places in the Pacific. The deepest hole was bored in 1952 at Eniwetok atoll in the Marshall Islands. This hole penetrated 4,600 feet and reached the foundation of the original base on which the coral reef was laid down.

The boring showed that the foundation of the Eniwetok atoll was an underwater volcano rising two miles above the ocean floor. At one time the volcanic island had projected above sea level. Then, when volcanic action ceased, the volcano slowly sank. As it returned to the depths, corals and other forms of life began to build on the submerged slopes. Fossils found near the foundation of the volcano date as far back as the Eocene period, 60 million years ago. Oceanographers estimate that the Eniwetok atoll has since been subsiding eight hundredths of an inch every century.

This discovery confirmed Darwin's theory of subsidence. However, it is now known that subsidence can work in two ways. The level of the ocean can remain constant and an island can sink below it; alternatively, the level of the island can remain constant, and the ocean may rise above it.

Changes in the level of oceans have occurred frequently in the world's history. These changes were caused by the freezing or melting of the huge icecaps which cover enormous areas around the North and South Poles. At some periods of history the world's climate turned colder and vast quantities of water were transformed into snow and ice, thereby decreasing the volume of ocean water. At these times, known as the ice ages, the general level of the oceans fell. Then the climate became warmer, the newly formed icecaps melted back into water, and the level of the oceans rose again.

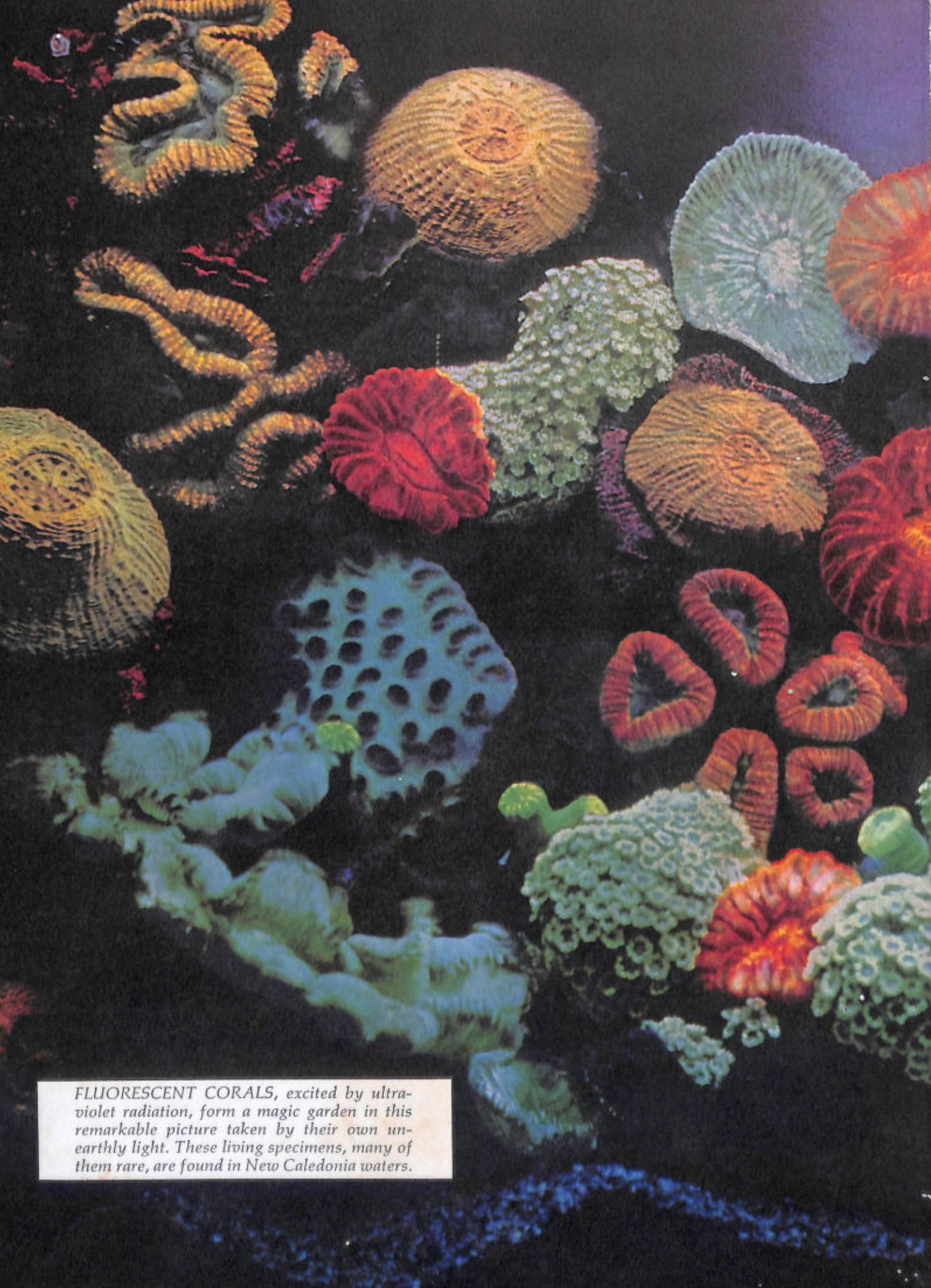
Darwin did not realize that some coral formations might have developed from changes in the level of the oceans. But today most scientists believe that this may sometimes have happened. They also believe that some coral islands may have been lifted above the ocean's surface by movements in the earth's crust.

Many questions about coral remain unanswered. Perhaps the most interesting are the unsolved mysteries of the corals which glow with light far below the ocean. Why do they only reveal their colors when exposed to short wavelengths of light? And why do only certain corals possess the extraordinary ability to glow?

Darwin, profoundly moved by the fabulous world of coral, wrote, in his book *On The Structure and Distribution of Coral Reefs*, that the vast dimensions of the pyramids and other great ruins were "utterly insignificant . . . when compared to these mountains of stone accumulated by the agency of various minute and tender animals."

*Under ultraviolet light, the same coral shown on the opposite page turns a glowing emerald green.*





*FLUORESCENT CORALS, excited by ultra-violet radiation, form a magic garden in this remarkable picture taken by their own unearthly light. These living specimens, many of them rare, are found in New Caledonia waters.*





# THE MOST PRIMITIVE PRIMATES

At some time in the distant past, most of the small, secretive mammals which lived in trees descended to the ground. This happened perhaps 75 million years ago. But some keen-eyed and agile mammals continued to live in the trees. As time passed they eventually gave rise to the great order of primates.

Primates are the most highly developed of all creatures. The order of primates includes apes, monkeys, chimpanzees, and the most intelligent of all living beings—man. But it also includes a family of more backward creatures. They are the various types of lemurs, most of which live on the island of Madagascar, off the southeast coast of the African continent.

Lemurs are the most primitive of all primates. They are shy, silent, secretive animals with staring eyes that make them look like sleepwalkers. Probably they got their name from their quietness and the expression of their eyes, for it comes from the Latin word *lemures*, which means "ghosts of the dead," or "nocturnal spirits."

Lemurs came into existence before any of the other primates. They once ranged throughout the world. But as the later and more intelligent primates developed, they gradually forced the backward lemurs from most continents. Great numbers of the lemurs became extinct but some survivors took refuge on the island of Madagascar.

*The woolly avahi, a wistful-looking lemur with wide eyes, is about a foot tall. Its hands have fingers of unequal length and huge, opposing thumbs.*

Madagascar lies in the Indian Ocean and it covers an area equal to France, Belgium, and Holland put together. It is the fourth largest island in the world; only Greenland, Borneo, and New Guinea are bigger.

An immense, rocky dry plateau runs the length of Madagascar's 995 miles with an occasional mountain peak here and there towering 10,000 feet above sea level. In the lower parts of the island, the landscape is more varied. It includes open grasslands and coastal plains, deserts, and forests. It is in these forests that the lemurs have found their last stronghold on earth.

Madagascar is separated from the coast of Africa by the Mozambique channel, which is from 250 to 500 miles wide. No one knows how or when lemurs crossed the channel. Whatever the answer might be, lemurs were the only primates, except for men, to make the crossing. They therefore found themselves free from the competition of their more intelligent and aggressive relatives.

Their secretiveness makes lemurs hard to find and study. Nevertheless, more than 200 different varieties have been discovered. Almost all have the same shy and gentle nature, and some can be tamed and taught to live with men.

Safely hidden in the Madagascan forests, the lemurs have evolved into many different forms. Some have shrunk to the size of a small mouse while others have reached the size of setter dogs. Some live alone and only venture out at night; others live in groups and go out during the day. The males of some varieties mate with only one



*The ring-tailed lemur is the most common member of its family, and is an excellent acrobat.*

it tail. The macaco lemur is another tree dweller, living in the deeper forests of Madagascar. Because the male is dark colored, the macaco is sometimes called the black lemur. But the female macaco is shaded with russet and brown and has light-colored ruffs on its ears and chest. Unlike some lemurs which live by themselves, the macacos are very sociable. They travel through the trees in noisy groups of 12 to 15, eating, sleeping, and singing.

The woolly avahi is yet another tree dweller. It is a wistful-looking creature, barely one foot tall, with wide eyes. At night it grazes for food among the tree leaves; during the day it sleeps curled up in the fork of a tree with one or more companions. Up in the trees the woolly avahi is as agile as a trapeze artist. It makes enormous leaps through the branches. But on the ground it hops along in an ungainly fashion with its hands held high.

The ring-tailed lemur is equally at home up in the trees, down on the ground, or among the rocks where it nests during the day. There are more ringtails than any other kind of lemur. Although it spends most of its time on the ground, the ringtail is as acrobatic as most other lemurs. It, too, can make tremendous leaps from branch to branch. When jumping, it uses its long, bushy tail for balance; at night it wraps its tail around its neck for extra warmth. Ringtails make good pets. They are tame, neat, and clean, and they respond to human affection by making a purring sound like a cat.

The sifaka lemur is another acrobatic animal and lives mostly in the trees. But it is also at home on the ground, where it comes to play, and leaps around with surprising agility on its long, springy, hind legs. When frightened, it gives a little growl that sounds like "shi-fak," and that is how it got its name. But it is sometimes called the "monkey" lemur because it has a white cowl around its face which makes it look like a monkey.

Sifakas are spread over most of Madagascar. They call to each other with a series of hiccups and move around in family groups, feeding on fruit, flowers, leaves, and sometimes tree bark. Baby sifakas have some especially strange habits. They hang on to their mothers by curling around

female while the males of others mate with several females. Some lemurs have tails which are mere stumps and others have grown tails so long that they can be thrown around their owners' necks. Their diets also vary enormously and include the bark of trees, buds, fruit, flowers, insects, nuts, roots, and, occasionally, young birds.

Many lemurs live in trees. One of them is the red-ruffed lemur, which is four feet long, much of



*Macaco lemurs are also called black lemurs although only the male (center) is dark. The female is usually russet or brown, with lighter ear ruffs.*

their waists or clinging to the silken fur of their mothers' chests or bellies. When they grow a little older, they ride piggy-back.

The smallest lemur—and the smallest of all primates—is the lesser mouse. Its body is barely five inches long although it also has a six-inch-long tail. This tiny creature is very secretive. During the day it hides in hollow stems or in the holes of trees and gives a shrill cry of annoyance if it is disturbed. At night it emerges from hiding to hunt for insects and fruit among the trees. Even in the darkness it can leap unerringly from branch to branch.

Lesser mouse lemurs are hard to see or capture and they are unhappy in captivity. Unlike most of the bigger lemurs, they have mean tempers and are likely to bite, though without serious damage.

Roman sailors and Arab traders observed lemurs

*The lesser mouse lemur is the smallest of primates. It is barely five inches long but has a six-inch tail.*

many hundreds of years ago. But the first man to give a reliable description of a lemur was a French doctor who visited Madagascar in 1768. He saw a strange animal sitting upright on a branch like a





*This three-month-old baby sifaka (left) clings to its mother. When it is older, it will ride piggyback.*

small human being, eating fruit with its hands. It was later found that this particular animal was an *Indri Indri*, the largest of the lemur family.

Some years later the rarest and most primitive of all lemurs was seen for the first time. This was the aye-aye, which comes out only at night. The aye-aye, seldom seen, probably got its name from the strange "aye-aye" cry it utters. The natives of Madagascar regard it as an omen of death.

In the middle of the 1800's, several aye-eyes were captured. Two dead specimens were sent to Paris and Berlin, and a living aye-aye was sent to the London zoo. European zoologists were very interested in these aye-eyes. At the time very little was known about lemurs and some of the zoologists did not believe that the aye-aye was a primate at all. They thought it belonged to an unknown and completely distinct order of mammals.

In 1813, however, a young Dutch naturalist named François Pollen went to Madagascar to investigate the lemurs. He stayed on the island for three years and later wrote the first detailed information ever collected about lemurs.

Darwin concluded that lemurs once existed in many other parts of the world, but many had been wiped out by stronger and more intelligent primates; the survivors were only the remnants of a once great family.

We now know the lemurs' first ancestor was an insignificant tree creature called *plesiadapidés*, about the size of a rat. It probably lived on insects and flourished in many places, including the western plains of the United States. All primates may have descended from the *plesiadapidés*.

The lemur-type descendants of *plesiadapidés* branched out into different forms and spread across vast regions of the earth. From fossil remains which have been found there we know that considerable numbers of lemurs lived in Europe, North America, Indonesia, and Ceylon. Some lived as long as 75 million years ago.

*The sifaka lemur (right) is sometimes called the monkey lemur because the white cowl that circles its face is suggestive of the capuchin monkey.*





*The tenrec is a spiny insect-eater. When frightened it curls up like a hedgehog and remains quite still.*

Gradually lemurs were destroyed or driven from their habitations by the more advanced primates. By the end of the Eocene Age, 45 million years ago, they had disappeared from Europe and America. The only lemurs which survived were those that took refuge in out-of-the-way places. Apart from the ones in Madagascar, only five varieties of lemurs are known to exist today. One kind, the large-eyed loris, lives in Ceylon and Malaya; the other four types live in Africa. All five are secretive, nocturnal animals.

The world's most outstanding authorities on lemurs are two French zoologists, Dr. Jean Jacques Petter and his wife, Arlette. In 1956 French authorities asked the Petters to make an intensive study of the lemurs in Madagascar. For a year the Petters roamed the Madagascan forests, studying the lemurs in their natural surroundings. They also collected about 30 live lemurs and brought them back to Paris. Among these specimens were some tiny lesser mouse lemurs, and from them the Petters made a particularly important discovery.

Lesser mouse lemurs must have exactly the right conditions of food and climate before they will breed, and those brought back by the Petters were the first ever to give birth in captivity.

In preparation for the birth, the mother lemur

made a nest of leaves and grass in the hole of a tree. There the babies were born. Then the mother lay flat across the tiny bodies to feed them, allowing the babies to suck in milk from underneath her. The mother also carried the babies in her mouth, like a cat, from place to place. And, just like a cat, she carefully washed each of them with her tongue.

But the most important thing the Petters noticed was that at certain periods of the year the lesser lemurs went into hibernation. During their hibernating period, the lesser mouse lemurs awakened about once every 15 to 20 days in order to eat. Then they went back to sleep again.

Many animals hibernate. But none of the more highly developed primates do so. The fact that the lesser mouse lemur does hibernate helps to prove that lemurs are indeed the very lowest kind of primates. They are, in fact, only a little more advanced than the four-legged mammals from which they descended.

Even in their Madagascan stronghold, the lemurs are fast dying out. Until 1958 the island of Madagascar belonged to France and the French government made some effort to preserve animal life on the island. It passed laws to make reservations out of some of the forest areas where lemurs live. No one was supposed to enter the reservations. However, the laws were not generally obeyed.

In October, 1958, the French colony of Madagascar became an independent country called the Malagasy Republic. This change has made things worse for the lemurs, for the new government has had a difficult job running the new country and has had little time or money to spare for saving the unfortunate animals.

The greatest threat to the lemurs comes from the destruction of the forests where they live. Every year the natives burn large areas of trees to provide more grazing land for their cattle. Year by year more and more of the magnificent Madagascan forests are turned into grassland. Today only about one tenth of the original forest trees are still standing and the lemurs have far less space in which to live and breed.

The natives of Madagascar also hunt the lemurs for food. When the French zoologist Dr. Petter visited Madagascar, he was asked to make recom-

mendations on how the island's lemurs could be preserved. Dr. Petter suggested that an international organization be set up to help protect the lemurs. If this was not done, he warned, the lemurs would gradually die out.

If the lemurs are allowed to die out, we will lose an important link with our own ancestry, for man has derived some of his most valuable characteristics from the ancestors of the little lemurs. Some common ancestor of all primates first developed the kind of eyes that enable man to see the world in three dimensions. Some common ancestor also developed the marvelous hands which have helped lift man and the other primates above the rest of the earth's animals. It was because man possessed such wonderful eyes and hands that he developed a brain big enough to direct them.

Madagascar is like a giant sanctuary, and lemurs and other small, weak creatures can live there free from attack from bigger and more aggressive animals.

Most of the animals which shelter in Madagascar's forests or on the warm coastal plains are shy and peace-loving. Many also are ancient in form.

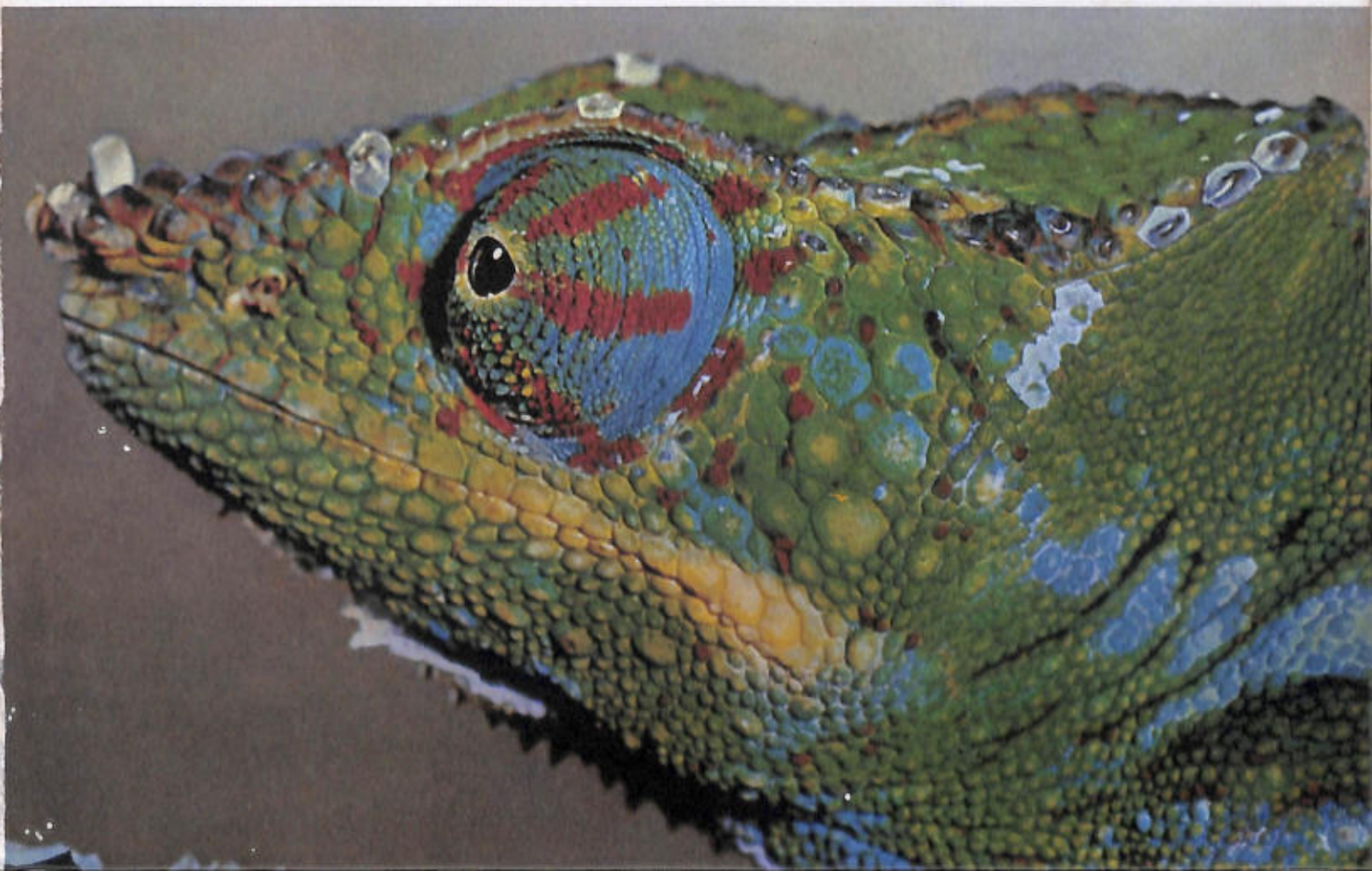
One of these ancient-looking creatures is the fossa, which lives only in Madagascar. It looks something like a wildcat. It has short legs and puts its heels down first when walking, unlike most other animals except bears and men. The fossa preys on lemurs, birds, and domestic fowl.

The tenrec is another curious inhabitant of Madagascar. It lives throughout the island, feeding on caterpillars, beetles, and certain kinds of worms. It is covered with spines and, when frightened or disturbed, it curls up like a hedgehog.

Madagascar is the home of 300 different kinds of birds, half of them found nowhere else on earth. There are innumerable insects, including 800 varieties of butterflies. And the island also contains crocodiles, tree frogs, and lizards.

The chameleon is perhaps the most interesting of the lizards. Sluggish and slow-moving, it protects itself by camouflage, changing its color to copy the appearance of whatever place it happens to be resting. But the strangest thing of all about the chameleon is its eyes. They can revolve either forward or backward, and each eye can focus independently of the other.

*This slow-moving chameleon has protruding eyes which can revolve either forwards or backwards, independently of each other. It traps unwary insects with its long, sticky tongue.*





# STRANGE PARTNERSHIPS AMONG ANIMALS



In his great works on nature, Charles Darwin repeatedly commented on the mutual interdependence which binds all living things together. Some are linked by enmity in the common struggle to survive. But there are others which are linked in mutual assistance. For example, bees carry pollen between flowers, and birds scatter the seeds from which new trees grow.

The strangest of these partnerships are the ones linking creatures that are completely different from each other. This kind of mutual assistance partnership is called symbiosis — a Greek word which means “a living together.”

Symbiosis is a partnership which benefits both participants. One example of it is the herding together of ostriches and zebras. Because ostriches have far-seeing vision and zebras have sharp hearing and smell, they can assist each other in warning of danger. The African rhino and the tickbird provide another example. The bird lives on the ticks embedded in folds of skin on the rhino's back. In return, it chirps excitedly at the approach of other animals and so alerts the short-sighted rhino to possible danger. The rhino does not appear to object to the bird's presence.

Sometimes an animal and a plant share a symbiotic relationship. The lazy South American three-toed sloth has coarse hair in which tiny plants called algae grow. During the dry season, the algae are brown; during the wet season they turn green. Thus, in return for living off the sloth, the algae provide excellent camouflage for their animal host as it hangs motionless in the leafy trees.

*The three-toed sloth has a symbiotic relationship with tiny algae plants. The algae live in the hair of the sloth, providing camouflage protection in return.*

Sometimes the relationship benefits only one partner, though without hurting the other. It is then known as synoecy. The African rhino shares this kind of relationship with a bird called the cattle egret. The bird walks behind the rhino, feeding on insects stirred up by the big animal's massive tread. But it performs no service for the rhino in return.

Tiny fish called remoras have a similar relationship with sharks. They attach themselves to sharks by sucker discs on their heads and, protected from other predator fish by the presence of the shark, they feed on the leavings of its kills. The sharks gain nothing from the relationship, and no one knows why they never kill and eat the remoras.

Sometimes one partner becomes completely dependent on the other, and lives on it. Such creatures are called parasites. Bacteria and viruses which live on men are examples of parasites.

As Darwin pointed out, there is no evidence to show that any animal ever performs any action just to benefit others. But every creature tries to take advantage of other creatures' instincts and needs. Perhaps the most striking example of this is the process known as symbiotic cleaning. This occurs when one creature removes (and eats) substances such as bacteria, undesirable particles of food, or damaged tissue which are harming another creature. Through this process, the cleaner obtains its food, and the cleaned creature is freed from the presence of harmful substances.

In 1892, just ten years after Darwin's death, another English scientist reported one of the first cases of symbiotic cleaning ever to be observed. It concerned a tiny, South American insect, the pseudoscorpion, which feeds on mites that infect the body of a larger insect—the long-horned beetle.

In 1924 an American scientist, William Beebe, reported another case of symbiotic cleaning. He observed red crabs foraging for red ticks on the leathery hides of sea-going iguanas that were sunbathing in the Galápagos Islands.

Symbiotic cleaning is particularly common among fish. The most extensive studies of cleaning fish were made by a German scientist named Dr. Irenäus Eibl-Eibesfeldt. Investigating the cleaning process in both the Atlantic and Pacific oceans, he discovered that almost all free-swimming fish participated in it. Twenty-one different species of highly specialized fish are known to act as cleaners, as well as at least six kinds of shrimps, one bird, one crab, and one worm.

The cleaning process differs in certain details, depending on which fish are taking part. But basically the process is the same wherever it takes place, whether in the Caribbean, the Mediterranean, or the South Seas. First, the cleaning fish performs certain actions to show that it wants to go to work. In reply, the fish that wishes to be cleaned (known as the client fish) makes signals to indicate that it is now ready.

In the colder waters of the north, the ceremony by which the cleaner and client fish come together is usually a simple one. But in tropical seas the ceremony sometimes becomes very elaborate. The cleaner fish may start the performance by darting forward, turning sideways, or dancing around the client fish until they both finally slow down. Or they may nibble, extend their fins, or beat their tails up and down. Certain cleaner shrimps even have extremely long white antennae which they wave like signal flags to halt the fish which they want to clean.

The client fish react strongly to these advances. They approach the cleaner, pause, and then take up awkward positions as though they are in a hypnotic trance. Some client fish show that they want to be cleaned by floating at odd angles. Some stand on their heads while others roll over on their sides. Occasionally the client fish that want to be cleaned outnumber the cleaners. Then they jostle each other and sometimes even start vicious fights, snapping and thrashing around in their eagerness to be first.

When the cleaning process begins, the client

often slumps into what looks like a coma. The cleaner carefully forages along its entire body from head to tail. With its sharp, pointed teeth, it nibbles away at the troublesome bacteria and tiny shellfish, at the particles of food, and at the pieces of sore or damaged tissue.

Frequently the cleaner fish enter the large client fishes' mouths and disappear completely as they work their way along the insides of the jaws and down into the clients' throats. The most vicious fish, such as barracudas and sharks, allow cleaners to enter their mouths without making any attempt to harm them.

Some client fish change color while they are being cleaned. One species which inhabits the Indian Ocean changes from near black to light blue. Another species turns pale. A kind of discus fish which is especially troubled by growths of fungus turns almost black. By doing so, it makes the light blotches of fungus show up clearly so that the cleaner can see them more easily.

Some places in the ocean have become cleaning stations where fish assemble regularly to clean or be cleaned. At one such station in the Indian Ocean, Dr. Eibl-Eibesfeldt discovered that a certain species of fish turned up at the same time every day. All the different kinds of client fish which came to this station summoned the cleaners in the same way. They opened their mouths, spread their gill covers, and turned their lips inside out. When they had been cleaned to their satisfaction, they closed their mouths, flipped their tails, and swam off.

Another scientist, Dr. Conrad Limbaugh, studied a cleaning station in the Bahamas Islands. He found that in a six-hour period, one fish cleaned 300 clients. Some of the clients, especially ones that were sick or injured, returned to be cleaned many times during the day.

To test the effects of the cleaning process, Dr. Limbaugh removed all the known cleaners from two small, isolated reefs in the Bahamas where fish were particularly plentiful. The results were startling. Within a few days the number of fish was

*A small carmine bee-eater rides on the back of a kori bustard. The bee-eater will fly off, snap up insects flushed by the larger bird, and return to its perch.*





*During its larval period, the blue English butterfly shares a symbiotic relationship with ants. The butterfly larva feeds on ant grubs; the ants stroke the larva which then yields honey to the ants.*

drastically reduced; within two weeks practically all the permanent residents of the reefs had disappeared. Many of those that remained developed blotches, swellings, sores, and damaged fins.

Cleaner fish need to be clearly visible so that the clients will notice them. In keeping with Darwin's law of natural selection, the cleaners have developed characteristics that enable them to be seen easily. All over the world their characteristic sign is a bar running around their bodies. In the Indian and Pacific oceans most cleaner fish are blue with black side bands. In the Caribbean, they tend to be yellow but also with a black side band.

As in other domains of life, other fish have learned to mimic the cleaners for their own advantage. One such mimic is the vicious predatory fish *Aspindontus taeniatus*, which has long, saber-like teeth. It has acquired the precise colors and patterns of the most common cleaner fish which share its home in the Indian Ocean.

Copying the seesaw, flipping motion of the cleaner, the predator approaches an unsuspecting client. But when the client presents itself for cleaning, the vicious *Aspindontus taeniatus* promptly goes into action, tearing large chunks of flesh from the duped victim's body.

But this is an exception. On the whole, symbiotic cleaning is a process of mutual assistance. Its existence shows that there is a place for cooperation amid nature's ceaseless and unrelenting battle for survival.

The large, blue English butterfly has a curious and complicated relationship with ants. In return for honey, the ants provide the butterfly with a home and food while it develops into maturity.

The butterfly's life cycle begins in June, when it hatches into the form of a wingless, wormlike larva. For about 20 days it feeds on flowers and other larvae. Then it casts off its outer skin, and stops eating.

At this point ants gather around the larva. They stroke its honey gland with their antennae, and drink the sweet drops of honey it gives off. Finally one ant picks the larva up in its jaws and carries it underground to the ants' nest.

Here the larva feeds on ant grubs; in return it continues to give off honey whenever the ants stroke it. By winter the larva has grown to four times its original size and has gone into hibernation. The following spring, it becomes active again and encases itself in a cocoon.

In May, the now mature butterfly emerges from the cocoon and makes its way above the ground. There, it spreads its wings and flies away to lay eggs.

Some species of birds participate in symbiotic relationships with completely different kinds of creatures. One is the honey-guide bird, so named for the part it plays in the relationship.

*A hornbill follows a group of chattering guenon monkeys as they move through the high trees.*





*A honey-guide bird leads a ratel to a beehive, then eats the wax combs after its partner has fed on the honey.*

The bird's purpose in forming the partnership is to get at beeswax, which it likes to eat. But beeswax is found inside beehives, which the bird can locate but cannot break open. It therefore forms an alliance with an animal which likes honey and can break the hive open.

This other animal may be a man or a baboon, but most often it is the badger-like ratel. The honey-guide bird leads the way to the hive by flying ahead of its partner and giving out repeated calls. When the ratel reaches the hive, it rips it open and noses out the honey. The honey-guide bird waits until the ratel has finished its meal and then settles down to feed on the wax combs that have been left scattered about.

The hornbill is another bird that benefits from an association with animals. It follows guenon monkeys as they move through the trees (see p. 175), staying at least six feet below them. The monkeys stir up beetles, moths, and other insects in their progress, and the hornbill promptly snaps them up.

Some birds, such as the small South African carmine bee-eater, benefit from their relationship with other birds. The bee-eater hops on the back

of the three-foot-tall bustard (see p. 173) and rides along until the bustard flushes an insect. Then the bee-eater flies off, snaps up the insect, and returns to its position on the bustard's back. The bustard gets nothing from the bee-eater but nonetheless tolerates its presence.

The black-crowned night heron also benefits from its relationship with another, larger bird—the fierce, sharp-eyed osprey. The osprey builds a ramshackle, platform-sized nest on rocky cliffs or at the top of trees. A foot or two underneath, the night heron builds its own fragile nest (see p. 180). The osprey's nest shelters the night heron from the wind and rain; and by its presence, the osprey also protects the smaller bird from other predator birds.

The sphinx moth is one of many insects which have a symbiotic relationship with plants; in this case, with honeysuckle. The moth has a long, sucking organ which is specially adapted for getting nectar from the honeysuckle. To get its food, the moth flies from flower to flower. As it does so, it also distributes the honeysuckles' seeds.

*A sphinx moth approaches a honeysuckle for its meal; in return it will spread the flower's pollen.*





Many curious relationships exist in the ocean, too. The long-snouted trumpet fish (upper left) conceals itself behind a bulky parrot fish, then darts down on its prey. The anomalops (far left) and the sepiola (lower left) house luminous bacteria. In return they use the bacteria's light for defense or to blind their prey.



The *Melia tessellata* crab (lower center) carries two small anemones in its claws; the hermit crab (right center) attaches anemones to its shell. The anemones have stinging cells which ward off predators and help the crabs capture food. Unable to move by themselves, the anemones can thus catch more food.





*Under the nest of the fierce fish-hawk, or osprey, the night heron has built its own home, sheltered from wind and rain; also, the osprey's presence guards the heron against attack from other birds.*

*The rufous woodpecker lives inside an ant's nest. The ants would attack any other bird but they leave the woodpecker alone. Normally, the woodpecker eats ants but it does not eat any of its hosts.*



# MAN'S INFLUENCE ON EVOLUTION

On Oct. 2, 1836, Charles Darwin ended his voyage on the *Beagle*. During the next two years he lived mostly in London, studying the notes he had taken. As he did so, he became convinced that the vast number of different kinds of living creatures could not all have been created separately, but that they must have developed from a smaller number of ancestors. •

Most of these variations have developed through the process which Darwin called "natural selection." But, as Darwin came to see, many variations have been caused deliberately—by man. For their own purposes men have made amazing changes in plants and flowers, and in horses, sheep, and other domestic animals. Starting with a single type of plant or animal, they have caused it to develop into many different varieties.

Darwin decided to study man's power to bring about changes in animals and plants. With astonishing industry he set about tracing widely different breeds back to their origins. He studied sheep, cattle, pigs, dogs, cats, poultry, rabbits, pigeons, peacocks, canaries, goldfish, bees, and silk moths. He also studied cabbages, peas, beans, potatoes, fruit and nut trees, roses, dahlias, and pansies. He interviewed breeders and gardeners and read great numbers of books on agriculture and horticulture.

At the beginning of 1868 Darwin revealed his conclusions in his second great work, *The Varieties of Animals and Plants under Domestication*. Its two massive volumes contained more than 1,000 pages. They dealt with virtually every plant and animal cultivated or domesticated by man.

*The "La Fleche" French cock is famous for its white meat. Like all modern breeds of poultry, it is a descendant of the jungle fowl of Southeast Asia.*

In this book Darwin explained how man had managed to make changes in different creatures. These changes occur when a plant or animal takes on some new characteristic—known as a mutation. If the creatures which have developed the mutation continue to breed, the mutation will be passed on; if they are destroyed, the mutation will disappear and the original species will continue unchanged.

Man cannot prevent these natural mutations from occurring. But by selecting the animals which will be permitted to continue breeding, he can decide which mutations are to be passed on and which are to be wiped out. And by breeding creatures with different characteristics together, he can create new variations. These processes are known as "selective breeding."

The variations which take place in any one generation are very small. But over a period of many generations they can become considerable. By selective breeding over many generations, man can greatly alter animals or plants in the direction he wants. For example, by selective breeding of cattle, he can develop cows which give the maximum amount of milk.

Darwin also proved another and very important fact—that all the various types of any one general species, such as sheep or goats or roses or cabbages, are descended from one ancestor. The different variations may evolve haphazardly through natural selection, as in the case of wild animals or plants. But they may also be created deliberately by careful selective breeding.

One example of this is the special type of French cock, called "La Flèche" because of its famous white meat. La Flèche and every other breed of modern poultry, as Darwin pointed out, have descended from the jungle fowl of Southeast Asia.



*These silkworm cocoons are a few of the more than 1,000 varieties all descended from one silk moth ancestor.*

The same thing is true of insects. In order to get silk, man has developed more than 1,000 different types of silk moths. Some have been bred for the special strength of their silk; others for its length or color. But all have descended from one original, common ancestor.

Darwin devoted special attention to the development of pigeons. He became a breeder himself and a member of two pigeon clubs in London. Delving into the past, he discovered that domestic pigeons had been bred in Egypt as far back as the year 2500 B.C.

The tremendous variety of pigeons dazzled Darwin. They range from high-flying, acrobatic types to the parlor tumbler, which can barely flutter off the ground, and to the jacobin, which cannot fly at all. The jacobin, long bred for its beauty, has a hood of plumes around its head, but it also has lost the ability to fly. The nun pigeon, named for the

black veil across its face, has also been bred for its beauty. So has the fantail, which has 48 tail feathers instead of the usual 12.

Yet all these different pigeons come from one common ancestor, the wild rock pigeon, which they closely resemble. Today, of all the many varieties of pigeons, the ubiquitous striped-winged gray-blue street pigeon which roosts on the cliffs and ledges of cities all over the world, most closely resembles its ancient ancestor.

Most of Darwin's fellow naturalists accepted his theory that the many varieties of each species of domestic plants and animals had descended from one ancestor. But many of them refused to believe that different varieties could develop through the process of natural selection. Their opposition to

*Fancy pigeons flutter around a street pigeon, which most resembles the ancestral wild rock pigeon.*





*The nun pigeon (below), prized for its coloring, is named for the black veil across its face and throat.*

*Most pigeons have 12 tail feathers, but the fantail (above) has 48 which it spreads in display.*



Darwin arose partly from their reluctance to accept his revolutionary new ideas. But it arose also from lack of knowledge.

As Darwin explained, natural selection works very slowly. If his theory of evolution was true, then animals must have been in existence for tens of thousands, perhaps millions, of years. But in Darwin's time, most people did not believe that the world was that old. The general opinion was that the earth had only been in existence for about 6,000 years.

The discovery of fossil remains of extinct animals seemed to indicate that the earth must have existed much longer than 6,000 years. But people who opposed Darwin's theory produced an explanation of how animals could have developed and perished within a comparatively short period of time, saying that periodic catastrophes struck the earth destroying whole species.

But during Darwin's own lifetime, scientists were beginning to prove that the earth had been in existence for a very long time. One of these scientists was a geologist and friend of Darwin's named Sir Charles Lyell. He believed that mountains, valleys, and other features of the planet must have been formed slowly by internal pressures deep within the earth's crust and by the external effects of rain, ice, and snow. These processes, Lyell concluded, must have taken many millions of years. Lyell's studies therefore showed that there had been enough time for animals to evolve in the way Darwin suggested.

Another branch of science which began to flourish during Darwin's lifetime proved that not only the earth, but also man and other animals had been in existence for a very long time. This new science was archeology—the study of history as revealed by the relics and buildings left by ancient peoples.

Toward the end of the 19th century, archeologists discovered proof of the existence of ancient peoples in many lands. In Egypt they began to decipher the hieroglyphics on the tombs of the ancient Pharaohs. In Switzerland they found traces of people who had lived tens of thousands of years ago. In England they unearthed the remains of ancient animals and the axes and spears made of flint that men had used to hunt them.

In more recent years archeologists have dug deep into the ground by the Rivers Tigris and Euphrates in the Near East. There they have discovered the homes where people lived in Biblical times. Other archeologists have uncovered the caves where the earliest men lived during the Paleolithic Age.

But the period that most interested Darwin was the Neolithic Age, which came between Paleolithic and Biblical times. It was during the Neolithic Age that early men gave up hunting as a way of life and turned to farming and herding. This change was one of the most important turning points in human history, for as farmers and herders, men began to win control of their environment for the first time.

Modern archeologists have been trying to piece together the history of the Neolithic revolution. But the task is enormously difficult. In ancient



*Unlike its high-flying relatives, the parlor tumbler pigeon can barely flutter from the ground. In its struggle to fly, it somersaults, as shown above.*

times men used to build new homes on top of old ones, so that, as the years passed, villages rose on the ruins of old villages, towns on former towns, and cities on former cities. In some cases twenty or more layers would rise on one spot. To get down to the early Neolithic settlements, archeologists have therefore had to clear away enormous masses of dirt and rubble.

Some of the most striking discoveries have been made by archeologists of the Oriental Institute at the University of Chicago. In northern Iraq they have found the remains of one of the world's earliest farming villages. There, some 150 people made their home between 7000 and 4500 B.C.

In such early settlements it is hard to tell whether animal bones are the remains of domestic or wild animals. But the scientists of the Oriental Institute agree on one point. They believe that man first began to cultivate plants and domestic animals in the Near East, in the area between the present-day countries of Jordan and Iraq. Here, wild wheat and barley grew in rich soil, and here,

wild sheep, wild goats, wild cattle, and wild swine wandered freely over open land. Nowhere else in the world were all these elements found together.

The discoveries of modern archeology have therefore helped to confirm Darwin's theory that cultivated plants and domestic animals have evolved from wild species and have been improved and varied through the process of selective breeding.

The first farm animals to be domesticated probably were sheep and goats. It was in Neolithic times, perhaps 7,000 years ago, that Near Eastern peoples began to tame certain sheep that were running wild around them. Most zoologists believe that the first domesticated sheep were Anatolian Moufflons, which still run wild in the hills of Iraq, Iran, and Turkey. They also believe that sheep were first domesticated for their meat and hides. Only later did men discover that a sheep's soft underfur could be turned into wool.

About 200 different breeds of sheep have been developed from their first ancestors, and each variety has its own special advantages. Some, like the Rambouillet and the Zackel, are valued for their fur. The Rambouillet was first bred by King Louis XVI of France, and its wool is used for making delicate clothing fabrics. The Zackel is bred in southeastern Europe and its long, rough wool is used to make rugs and peasant clothing.

Other sheep have been bred for both their wool and their meat. One such type is the Scottish Blackface Highland, which provides mutton and long wool. The Blackface was once called the "col," and some people believe that its name was passed on to the collie dogs which was used to herd the flocks.

The so-called Lop-eared sheep of North Africa supplies milk and leather as well as meat and wool. But perhaps the strangest of all sheep is the Fat Tail of far eastern Asia whose tail was turned into tallow. Its tail used to be so huge that a small cart was needed to carry it round the barnyard. But such huge tails are now rare. Breeders now prefer sheep that can carry their own tails and so have selectively bred animals with smaller ones.



*This ancient bull, bred in Chillingham Park, England, is a link with the wild cattle of prehistoric times.*

Some domestic animals, like horses, cattle, and swine, were dangerous and formidable in their wild state. Scientists have therefore wondered why they allowed themselves to be caught and tamed. One answer is that the process of domestication began with the capture of young colts, calves, and piglets. These young animals, brought up in captivity, grew up tame and accustomed to men.

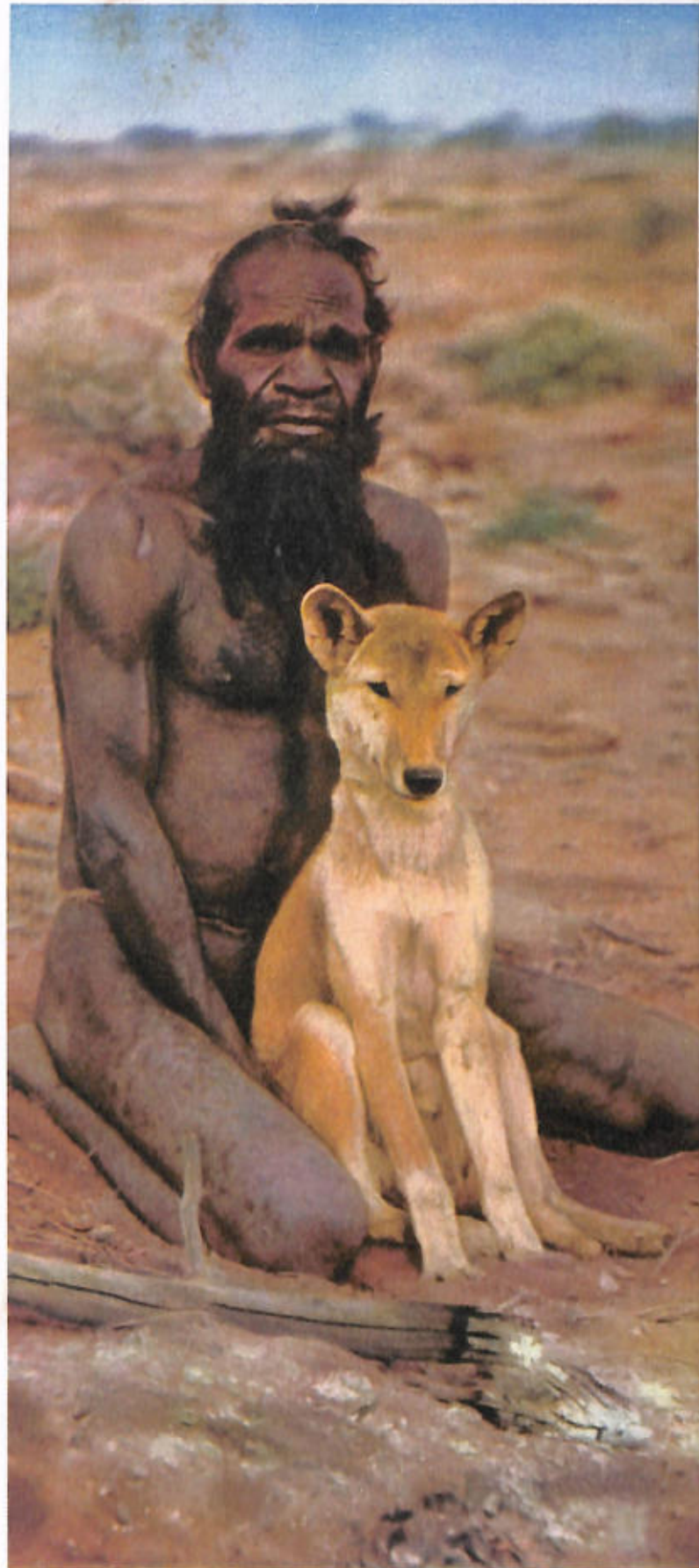
Discoveries made by archeologists suggest the order in which the larger animals were domesticated. Either pigs or cattle were the first to follow sheep and goats into the barnyard. The wild ancestors of the modern domestic pig ranged from Europe to the Far East, and two varieties still survive. One is the common wild pig of Asia. The other is the common wild boar, which stands three feet high, and is armed with four tusks and 44 teeth that can inflict fearsome wounds. During the Middle Ages these wild boars were hunted in Britain, with spears and dogs. They are now extinct in Britain but still flourish in parts of Europe and the Near East.

Long-horned wild cattle roamed the grasslands of Europe and the Near East for countless millions of years. They were known as aurochs. We know what they looked like from discoveries of their skeletons, and from paintings made of them by Paleolithic cave men.

Some of the aurochs were domesticated by Swiss lake dwellers about 2500 B.C., but cattle still ran wild in Europe in the time of Julius Caesar, about 2,000 years ago. At Chillingham Park in England, direct descendants of the ancient aurochs have been preserved since 1220 A.D., and more than two dozen still graze there.

The horse was the last of man's major animals to be domesticated. It was probably tamed by nomads who roamed Central Asia about 4,000 years ago. We also know what the ancient wild horses looked like from skeletons and paintings. In recent years scientists have mated Icelandic ponies with horses descended from wild herds discovered in Asia in 1882. By doing so, they have produced horses similar to the tarpan, a wild horse of the Middle Ages.

Some of Darwin's fellow scientists criticized his belief that prehistoric men had been able to influence the evolution of animals. They claimed that



*An aborigine and his yellow dingo dog squat beside their campfire in the Australian wasteland.*

primitive peoples had not possessed enough intelligence to practice selective breeding.

Darwin, however, had noticed that savages were fond of taming animals and suggested that if these animals proved useful, they would naturally have been domesticated. Moreover, it would be natural for even the most primitive men to preserve the most valuable individuals and destroy the less valued ones. As generations passed, the breeds must consequently have improved.

Darwin found that the same principle applied to plants. It was natural, he said, for man to cultivate the best varieties known and to sow their seeds. Then, when a slightly better variety happened to appear, they would naturally select it. He called this process "unconscious selection."

Darwin's belief that prehistoric savages had made use of animals is confirmed by the habits of primitive peoples who survive today. The aborigines of Australia are extremely primitive nomadic hunters but they have a domestic animal—the yellow dingo dog. The tie between man and dog is a loose one. The dingo joins the aborigines in their hunts and then, if times turn hard and food runs short, he returns to the wilds.

It was probably in this way that dogs first entered man's service, perhaps 20,000 years ago. Darwin believed that we shall probably never discover exactly how dogs became domesticated. But discoveries made by archeologists indicate that originally man domesticated dogs because they helped him hunt, and in good times ate his leavings; in bad times they probably served as his food.

In recent years the musk ox has been added to the list of man's domestic animals. The name is misleading, for the musk ox is actually a member of the sheep-goat family. Vast herds of musk oxen once roamed across North America but so many were killed by men that only a few thousand still survive. They live deep within the Arctic Circle.

Musk oxen are protected by law. But in 1954 an American anthropologist was allowed to capture two calves to start an experimental herd in Vermont. In 1958 two calves were born to them, indicating that the musk ox might thrive in captivity. It could be valuable both for its meat and for its long, fine wool which it sheds every year and grows anew.





*A few musk oxen, transported from their Arctic homeland, are now living in a farm in Vermont. They are tame and playful and responsive to human affection. On hot days they cool off with frequent dips in the farm pond. The musk ox is extremely tough and when full grown may weigh up to 1,400 pounds. It is valuable for its meat and wool. The wool, which it sheds and grows anew every year, is as fine as cashmere.*



# THE MYSTERIES OF HEREDITY

All living things inherit their characteristics from their parents or from their more remote ancestors. These characteristics (or traits) are passed down through invisible factors called genes, which are so small that they cannot be seen even through a microscope. The genes are contained inside threadlike bodies called chromosomes, which in turn are contained within cells.

It is the genes which shape each living creature into an elephant or a rose, a chipmunk or a man. They determine the colors of flowers, the shape of a tree's leaves, the length of a giraffe's neck—in fact, every physical and mental trait which a living thing possesses. They determine the color of a man's eyes, his I.Q., and the size of his feet.

A creature's genes are a combination of the genes of his male and female parents. So are the genes of plants. Sometimes a parent's traits are exactly repeated in the offspring; sometimes the act of combination produces characteristics that lie midway between those of the two parents. If pure white and pure blue delphiniums are bred together, the flowers which result may be pure white or pure purple; or they may be some intermediate shade. But they can never be a color totally unconnected with blue or purple.

The study of heredity, of how living things come to be born with certain characteristics, is known as genetics, from the word "genes," the name given to the tiny organisms by the Danish

botanist, Wilhelm Johannsen. Because genes cannot be seen, we cannot be absolutely sure that they exist. But scientists have only been able to explain the way heredity works by assuming the existence of the mysterious genes.

Much research into genetics has been done with fruit flies. The fruit fly reproduces itself every 17 days, so the effects of crossbreeding experiments can be traced through many generations of these insects in a very short time.

These experiments have shown that there are widely separated bands along the length of every threadlike chromosome. Each band marks spots inside the chromosome which play a part in controlling one specific trait, such as the color of the eyes. A single band may control many traits or it may control only one. We do not know exactly how this control is effected. But we do know that the controlling is done by some complex chemical structure within the chromosome.

The modern science of genetics was founded by an Austrian monk named Gregor Mendel. He carried out his studies in a monastery garden in the years between 1854 and 1866.

Experimenting with the crossbreeding of flowering peas, Mendel noticed that all the physical traits of each parent remain in their offspring, although they are not necessarily apparent. For example, when Mendel bred smooth peas with wrinkled peas, the next generation of peas were all smooth. However, the genes which produce wrinkled surfaces were also passed down and remained inside the second-generation peas. In later generations, the wrinkled surfaces reappeared.

*Fruit flies, magnified here 80 times, are useful in research in genetics, the study of how living things come to be born with certain characteristics.*



*These delphiniums were bred from pure white or pure blue ancestors. All are varieties of these two colors.*

In his long years of puttering around with peas in the monastery garden, Mendel discovered two basic principles of genetics. The first was that the characteristics of parents do not blend in the offspring. If a man has blue eyes and his wife has brown eyes, their children do not have eyes that are half blue and half brown. Instead, the traits of the parents are passed down separately, in the form of genes which can produce either blue or brown eyes. But whatever color their own eyes may be, the children possess genes which can produce both blue and brown eyes, and their descendants may be born with eyes of either color.

The second principle which Mendel discovered was that each parent's traits can appear in their offspring in a variety of combinations. These combinations can be worked out mathematically, for a parent's traits reappear in a consistent pattern. If a smooth pea is bred with a wrinkled pea, as Mendel discovered, the next generation of peas will all be smooth. But if two peas of the second generation are bred again, 75 per cent of their offspring will be smooth, and 25 per cent will be wrinkled.

Mendel drew a conclusion from these facts. He decided that there were pairs of factors (one from each parent) which were sometimes of unequal strength. The smooth surface of a pea, for example, has more power to assert itself than the wrinkled surface. So when the two come together, the offspring always bear the stronger trait—the smooth surface.

Mendel gave the word “dominant” to the stronger traits which reappear in the first generation of offspring. He gave the word “recessive” to the weaker traits.

The way dominant and recessive traits combine can also be seen in the case of the fruit fly. The eye color red is a dominant trait while the color brown is recessive. If a red-eyed fruit fly is mated with a brown-eyed fly, the second generation of flies will all have red eyes. But one out of every four of the next generation will have brown eyes.

Modern geneticists have since discovered the process which produces the results Mendel observed. Genes are passed down inside the chromosomes of the male sperm and the female eggs.



*Chromosomes from a fruit fly cell consist of banded strands gathered together at their centers. Each band is associated with some trait. Those marked are related to the color of the eyes.*

When the sperm and eggs meet, they create new cells. These cells continually double themselves and divide as the new creature grows toward birth. As the cells double themselves and divide, so do the chromosomes (and genes) inside them. Thus every cell inside the offspring contains a combination of the traits of both its parents.

Mendel said that it was possible to calculate mathematically which traits any living organism will inherit. In theory it would therefore be possible to predict the exact make-up of any creature. But in practice this is quite impossible, for all highly developed creatures contain vast numbers of cells, and each cell contains many chromosomes. A man has 46 chromosomes in each cell, a fruit fly has eight, an onion has 16, a crayfish has 200. And each chromosome contains perhaps 1,000 genes which are shuffled in the process of evolution. Thus the number of possible genetic

combinations which decide a creature's make-up cannot possibly be counted, and the final result cannot be predicted.

A fungus is a plant that has molted, mildewed, or rusted. Bacteria are tiny and usually one-celled organisms which normally live off other organisms, such as man. Fungi and bacteria are useful in the study of genetics because they reproduce so quickly that a new generation can come into existence every 20 minutes.

Fungi and bacteria are used to study the appearance of mutations. Sometimes an accidental alteration occurs in the chromosomes of an egg or sperm. This produces a change known as a mutation. It is these mutations which lead to the creation of new characteristics. When a mutation occurs, the members of the new generation may be born with a completely new trait that neither of their parents possessed.

Darwin's theory of evolution was heavily assailed from all sides. Members of religious groups attacked the theory because they thought it contradicted the Bible.

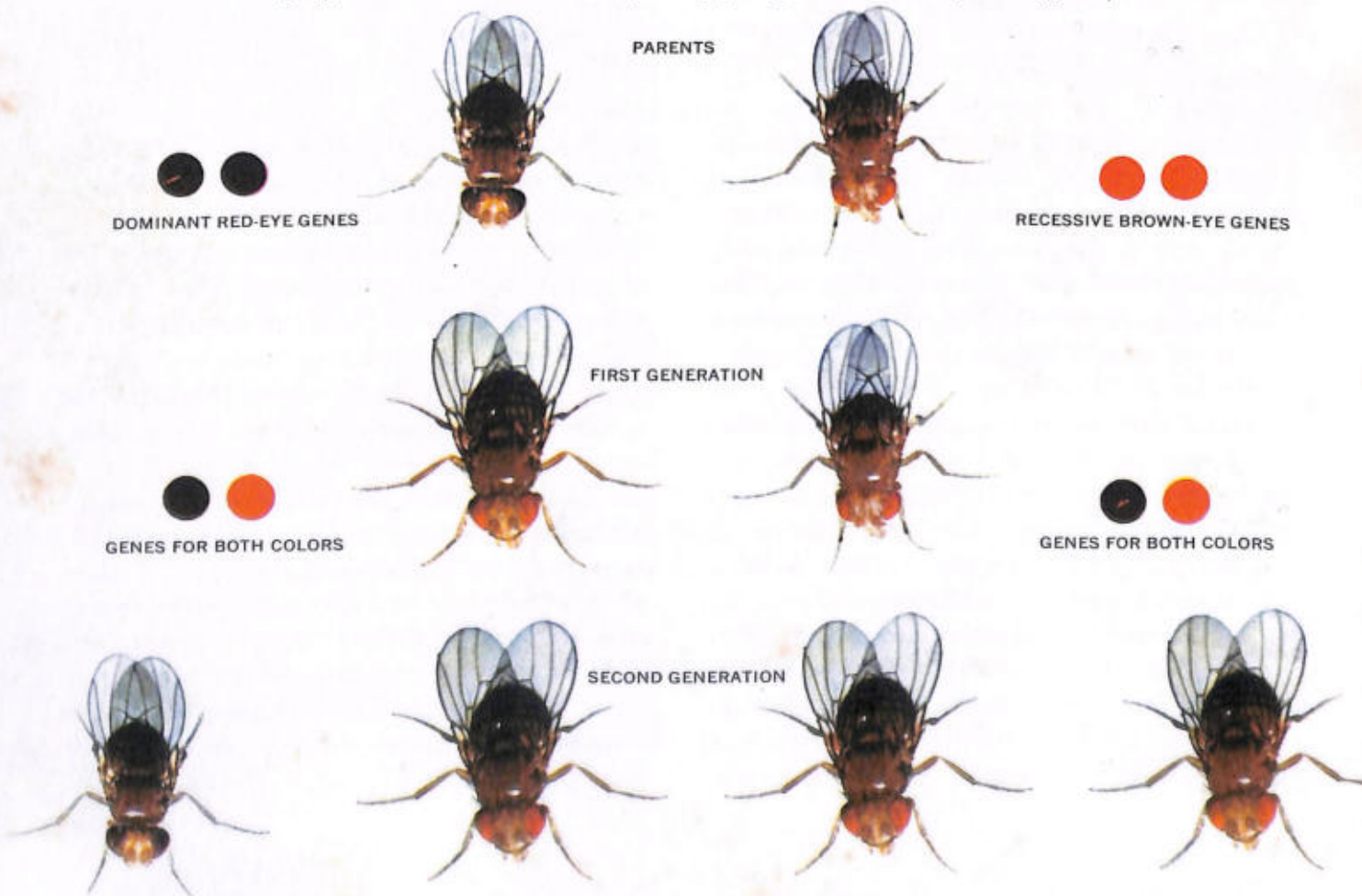
Darwin was also attacked by his fellow scientists. Although his book convinced them that evolution was a fact, it failed to explain the biological process by which new characteristics come into existence. By failing to explain adequately the physical process of heredity, Darwin left his critics unconvinced that natural selection could permanently alter a single species of animal.

Scientists of his day believed that the characteristics of the male and female parent are *blended* together in their offspring, like two liquids being mixed together in a jug. This meant that all one parent's characteristics were mixed up with all the other parent's characteristics. If only one parent possessed a new trait it would soon be lost by being mixed with the traits of all the other individuals who did not possess it. Therefore the new trait would vanish like a drop of water in the ocean.

Darwin admitted the force of this criticism and was unable to provide a satisfactory answer, for little was known about the reproductive process at that time. Until the 17th century no scientist had even begun to make a serious study of the process of reproduction. In 1672 a young Dutch scientist named Regnier de Graaf discovered egg cells inside female rabbits and ewes, and women. This enabled him to perceive that, like birds, fish, and reptiles, mammals also produced eggs—though inside their bodies. However, de Graaf decided that it was the mother alone who produced her offspring's embryo, and that the only contribution of the male sperm was to trigger it into growth.

Three years later another Dutchman, a lens-maker named Anton van Leeuwenhoek, examined the male sperm under a microscope. He was the first man to see the tremendous mass of tiny organisms, called spermatazoa, which make up a male's sperm. Like de Graaf, Leeuwenhoek drew the wrong conclusion from his discovery; he decided that the male sperm contained all the ingre-

*Recurrence of a trait is seen in successive generations of fruit flies. Here, the recessive brown-eye gene will recur in one out of every four grandchildren of the original pair.*



dients of the embryo, and that all the female did was to house and nourish it.

The argument between people who agreed with de Graaf and people who agreed with Leeuwenhoek continued until Darwin's day. It was not until 1854 that a male sperm was seen to penetrate the ovum of a female frog. Then biologists realized that the cells of both parents combined in the reproductive process. But the biologists misunderstood the process of combination. They thought that the male and female cells blended together, lost their individuality, and formed a kind of mid-way compromise.

It was Gregor Mendel whose experiments showed that each parent's individual traits are passed down in separate, indivisible units which are not altered or blended during reproduction. Instead of taking on a mixture of its parents' traits, a creature takes some from one parent and some from the other. Thus, any mutation can be passed down and may remain in existence.

Mendel published his discoveries in 1866. But they aroused little interest and were generally ignored until 1900—18 years after Darwin's death.

Lacking knowledge of Mendel's work, Darwin was unable to answer his critics' attacks. He wondered in vain "why the child often reverts in certain characters to its grandfather or grandmother or more remote ancestor." The answer, of course, lay in Mendel's findings about dominant and recessive characteristics.

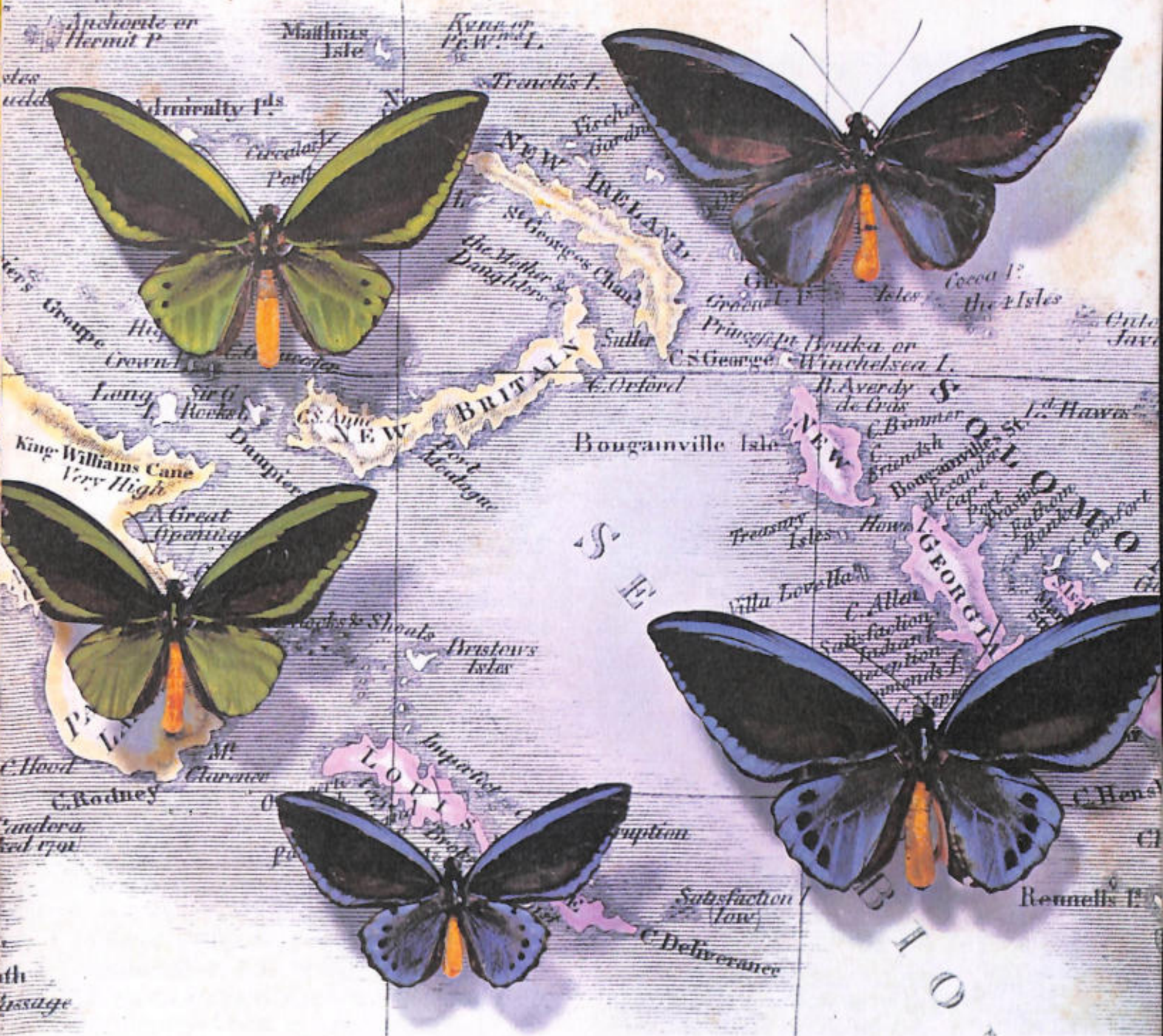
Mendel's studies also suggested how new characteristics are passed down and enable a species to evolve. The answer lay in mutations, those still unexplained variations which take place inside chromosomes and produce new traits.

Advantageous mutations aid in survival and through natural selection over many generations, the process may lead to the evolution of a completely new species. The likelihood of this occurring in isolated places was demonstrated by Darwin when his studies of the origin of species began years before in the Galápagos.

*After one day (top), bacteria used in a laboratory experiment had formed no mutations. After two days a mutation appeared which could eat sugar fed to the bacteria (center). After five days (right) bacteria were crowded with new sugar-eating forms.*







The butterflies have developed many different arrangements of wing spots as well as variations in color.

The swallow-tailed butterflies of New Guinea are a good example of the effects of isolation. At some time in the remote past, the island of New Guinea probably broke off from the Australian land mass. The butterflies of New Guinea and neighboring islands were then cut off from each other. Gradually the ones on each island took on new and individual variations of color, and different arrangements of spots on their wings.

American butterflies of the same type may live

as far apart as Pennsylvania and Nicaragua. But they are not separated by any insurmountable barrier, such as an ocean. So their genes circulate freely among the whole species. As a result, all American butterflies of the same type have the same general appearance.

Largely through the work of Darwin and Mendel, we now know how new species come into existence. But there is a related question which naturalists are now studying. How does each spe-



*A male grasshopper rubs its wings together to produce the high-pitched call to females of its species.*



*The distinctive mating call of the male katydid lures a female of the same species.*

cies maintain its separate identity? How do creatures belonging to one species avoid getting intermingled with others?

Where there is a wide difference between species, the answer is obvious. Giraffes do not mate with antelopes; elephants do not mate with tigers or wasps with ants. However, members of different species do sometimes mate with each other or are mated by man. The mule is one example of such crossbreeding. It is produced by mating a horse and a jackass. But the mule, like the other offspring of mixed animal species, is sterile; it cannot reproduce itself.

Creatures of different species which are very similar might seem likely to make the mistake of crossbreeding by accidentally taking the wrong mate. To prevent such mistakes, nature has arranged ways by which creatures can recognize their own kind.

Some species have one particular method of recognition, such as the mating call. A male grasshopper identifies itself with a high-pitched sound which it produces by rubbing the saw-toothed surface of one wing against the other. Katydid also recognize each other by means of mating calls. These calls, too, are made by the male katydid rubbing its wings together.

Cicadas use distinctive cries as recognition signals. Their mating season takes place during the last six weeks of their lives. At the beginning of the mating season, different varieties of cicadas may be

thoroughly intermingled. But before mating starts, they split up into the proper groups, by calling out and responding to the appropriate cries from mates of their own species.

Grouse use a different method of recognition; the female identifies the male through his plumage. When a male grouse wishes to mate, it drums its wings rhythmically together. This movement reveals the pattern of his plumage, and so allows the female to recognize him as a member of her own species.

The plumage of a male grouse has a very complicated pattern. These complicated patterns have probably evolved because members of many different types live in the same place. Each pattern indicates a different type. Because the female can distinguish between the patterns, she is able to pick out the right mate.

Some fish, such as shield darters, also recognize each other by their markings. The shield darter is closely related to the Johnny darter, which lives in the same waters. The shield darter has developed easily recognizable crestlike markings which apparently help it to avoid confusion. But these are not the only ways by which it avoids crossbreeding. It breeds only in water that runs rapidly over a gravel bottom while the Johnny darter breeds under rocks in quieter water. Moreover, the shield darter begins its mating season in the spring while the Johnny darter waits until the beginning of the summer.

The many varieties of frogs have developed several methods to identify their own kind. The process of recognition is carried out by the female. It is she who must somehow find her way through the grass and water to a male of her own species.

The female has two ways of recognizing her proper mate. One is to pick out his particular mating call from among the peeps and croaks made by all the other males. The second way is to locate the place where he is waiting, for the males of each species select a special site to do their mating.

These sites are very carefully and exactly picked out. There are at least five varieties of tree frogs which come down to a lower level to breed, and each type has its own special spot. The female green tree frog knows she can expect to find her mate beneath some overhanging cover while the female squirrel tree frog knows that her mate will be hanging on to a stick.

It is not easy now to understand the revolutionary effects of the discoveries made by Darwin and Mendel. In their time the science of genetics simply did not exist. The fact that crops and herds could be improved by selective breeding had been known for many centuries. The ancient Greeks had known that mules were the sterile result of crossbreeding. The ancient Romans had noticed that children sometimes resembled one parent, sometimes the other, and sometimes a grandparent. But little progress had been made in putting these and other known facts together and working out their significance.

It was not until the middle of the 19th century that scientists first realized that male and female cells combine in the reproductive process. It was not until 1875 that scientists discovered that cells duplicate and divide during reproduction.

Darwin had no knowledge of discoveries made later from studies of the microscopic cells. But he realized that all traits are passed down from one generation to the next through male or female cells which are too small to be seen by the naked eye. Putting these facts together, he developed a theory that every part of a living being reproduces itself independently.

*Two species of cicadas are intermingled, but when mating starts they will disperse into separate groups.*





*A male grouse courts a female by drumming its wings. The pattern of its plumage is then revealed, enabling the female to recognize a member of her own species.*

Darwin was theorizing in the dark, without any knowledge of Mendel's work. But his theory showed that his wonderful instinct had put him on the right track. The details of his theory were wrong. But he was right in refusing to accept the common belief of his time that new life was produced by blending the various streams of life.

Darwin's instinct told him that reproduction works by somehow combining separate particles. In 1909 his instinct was proved right by the Dutch botanist, Wilhelm Johannsen. He deduced that there must be some physical unit which causes heredity to work, and he called this unit the gene.

Darwin and Mendel did more than anyone else to create the science of genetics. They approached it from two quite different directions. Darwin was interested in change and variation; Mendel was interested in the way biological traits persist and repeat themselves. Darwin was a visionary theorist, concerned with the whole grand sweep of life; Mendel was a patient experimenter who worked by studying small changes in one small organism, the pea, inside a small monastery garden.

Their lives, too, were quite different. Darwin was a famous man and greatly honored in his own lifetime; Mendel remained unknown until long

after his death. Another generation had to pass before his work was recognized for what it was, an epic advance in man's continuous struggle to understand the mysteries of life. But between them, Darwin and Mendel laid the foundations of genetics, the youngest of the sciences which study the workings of nature.

The birthdate of modern genetics is usually fixed at 1900. In that year three biologists working independently in three countries rediscovered the lost paper which contained the discoveries made by Mendel.

After that, events moved swiftly. The development of better microscopes enabled scientists to probe far more deeply into the mysteries of cells. A Dutch botanist, Hugo De Vries, discovered how drastic changes, which he called mutations, take place in living organisms. Then between 1910 and 1920 an American scientist, Thomas Hunt Morgan, carried out a series of experiments with fruit flies and showed how mutations actually work. Morgan made an even more important discovery. He saw how outward changes in the flies' eye colors and wing shapes corresponded to changes in specific areas of specific chromosomes.

Gradually, it was recognized that every trait of every living thing on earth depends on its chromosomes and their genes. In fact, geneticists can now

draw detailed chromosome "maps." They show which parts of a chromosome control particular individual traits.

Geneticists now believe that they have discovered the chemical which makes up genes. It is a giant, complicated, long-chain molecule of deoxyribonucleic acid, which is popularly known as DNA. Every chromosome contains 10,000 to 100,000 of these DNA molecules.

The giant molecule is made up of thousands of components, including sugar and phosphates. Although the gene itself has never been scientifically described, some scientists believe that it is equal to a single DNA molecule. Other scientists believe that one DNA molecule may represent a whole mass of genes.

It is generally agreed today that DNA is the substance which determines heredity and directs the development of life. The patterns for every living organism are contained inside the interlocking spirals of the DNA molecule. These patterns are as complex as the circuits of a computing machine. They are also as exact as a computing machine in shaping the design, behavior, and individuality of the living beings which finally emerge from them. Perhaps on some far distant day, this master molecule may help man to work out the destiny of human life.

*A shield darter with crestlike markings breeds in the rapidly running water of a gravel-bottomed river.*





# THE LONG CHAIN OF EVOLUTION

Darwin's great work, *The Origin of Species*, is now generally accepted as one of the most important books ever written. But when it first came out in 1859, it was both derided and bitterly condemned by scientists and laymen.

Much of the opposition to *The Origin of Species* arose from Darwin's claim that all living creatures, including man, are somehow related. Many people were outraged by the suggestion that man shared a common ancestor with animals such as apes and monkeys. They attacked Darwin for saying that man had descended from the apes.

But Darwin never actually said this. He believed that modern men and modern apes have both descended from the same ancestor. But at some time in pre-history, millions of years ago, men and apes began to develop separately, and ever since have continued to take on different characteristics. Today, almost 80 years after Darwin's death, this is the opinion which scientists continue to hold.

In his works, Darwin described the progression of life from its earliest forms. First came the invertebrates—creatures without a backbone. Then invertebrates evolved into fish; fish into amphibians; amphibians into reptiles; and reptiles into birds and mammals.

Fossil remains found after his death show that Darwin was right. Perhaps the most amazing fact about his theory is that he managed to work it out with the aid of only a few fossil discoveries. The fossil remains of *Archaeopteryx*—the creature that linked reptiles and birds—were only found in 1871, 19 years after *The Origin of Species* was published. The fossil remains of *Pithecanthropus*—the earli-

est creature that was undoubtedly a man—were not found until 1891, nine years after Darwin's death.

Fossil remains were not the only information which we now possess but which Darwin lacked. He knew nothing about Mendel's studies of heredity. He did not know that apes have the same diseases as men; nor that they and men have the same kind of blood. Nor did he know about the modern uses of radiation which enable scientists to tell the age of fossil remains and so estimate the speed at which evolution has taken place.

Lacking all this information, Darwin had to rely on other branches of science. One of them was comparative anatomy—the science which compares the physical make-up of different species. He observed that all vertebrates—amphibians, reptiles, birds, and mammals—possess forelimbs which are basically the same. The limbs may be used for swimming, flying, or walking, but they are all built on the same plan. They contain one bone in the upper arm, two bones in the forearm, several bones in the wrist, and five bones in the hand with finger joints attached.

Darwin marveled at this similarity between such widely differing species. "What can be more curious," he asked, "than that the hand of a man formed for grasping, that of a mole for digging, the leg of a horse, the paddle of the porpoise, and the wings of a bat, should all be constructed on the same pattern?" From this extraordinary fact, he drew the correct conclusion: that different species share the same characteristics because they are descended from the same ancestors. Then, later, they took on the separate traits which helped them most in the struggle to survive in their own local environments.

Darwin also made use of the science of embryology, which deals with the early stages that a crea-

*Archaeopteryx, the first bird, lived about 130 million years ago. It was really an airborne lizard with teeth, a scaly head and a lizardlike tail.*

ture passes through inside its mother's body before being born, or inside an egg before being hatched. He observed that the embryos of fish, birds, and men have amazing similarities. For example, all three have gill slits and tails.

The reason is that in the period before it is born or hatched, every creature passes rapidly through several stages which follow the entire history of its species. A human embryo therefore reproduces the stages when man's remote ancestors possessed gills for swimming and, later, tails for maneuvering among the trees.

Long before birth the human embryo closes its gills and curls up its tail, so that no signs of them appear after it is born. Yet every human carries traces, now useless, of man's distant past. He possesses patches of the hair which once protected his ancestors against the cold, and the beginnings of muscles which his ancestors once used to twitch their ears.

Once again Darwin drew the inescapable conclusion from his observations. Since the embryos of men, fish, and birds possess some of the same characteristics, all these orders of life must have descended from the same ancestors.

Since Darwin's death, discoveries in many different branches of science have helped confirm his theories. But during his lifetime some of his assertions were little more than inspired guesses, and his critics were quick to attack them.

If the theory of evolution was true, they asked, why hadn't fossils of all the successive stages of life been found? Why were there so many "missing links" between different species?

Darwin's answer was simply that the collection of fossils was not complete. Many fossils, he said, remained to be discovered. Some species had probably not left any fossil remains at all. And scientists had not yet learned exactly how to understand the history of fossil remains.

Other questions to which Darwin had no answer continue to baffle scientists. Why did the huge dinosaurs that had trod the earth for 100 million years suddenly die out? Why did many species of mammals disappear just as suddenly at the end of the Pleistocene period? Why did some orders of life evolve with great speed while others have continued unchanged for millions of years?

Darwin did not deal with the subject of man's history and origins in *The Origin of Species*. But in 1871 he published another book called *The Descent of Man*. In this work he tried to answer the question: where did man first come into existence?

To find the answer, Darwin drew on his knowledge of how and where other species had evolved. In every part of the world, he pointed out, the mammals that still exist are closely related to now extinct species which used to live in the same region. Extinct species of apes had probably once lived in Africa, which is now inhabited by gorillas and chimpanzees. These two species are man's closest relatives in the animal world. Therefore, Darwin concluded, man's earliest forbears were more likely to have lived in Africa than in any other place on earth.

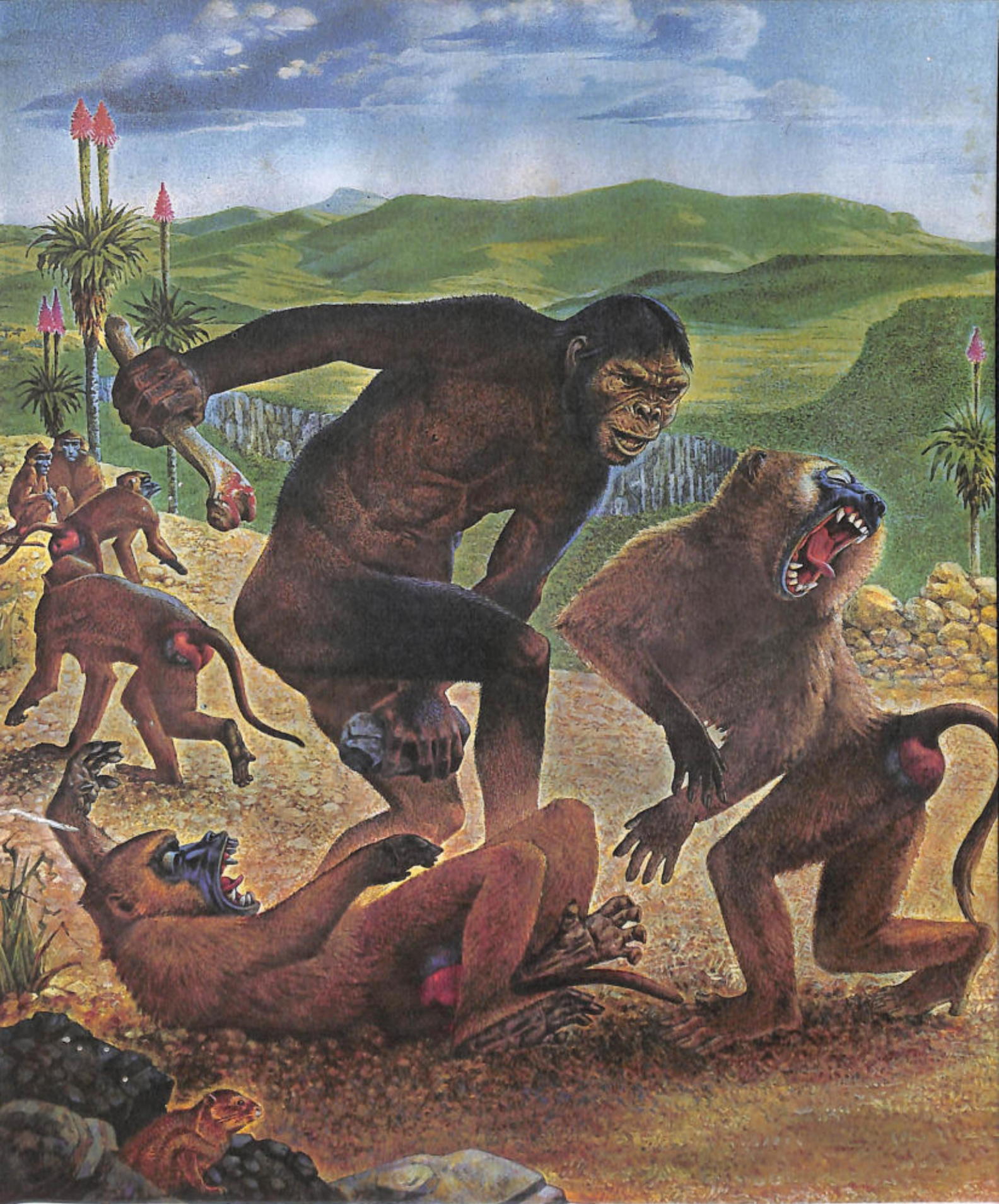
Anthropologists have now succeeded in piecing together the story of man's physical evolution. But they have not yet decided when man took on his peculiarly human quality. Only man possesses a spirit, a personality, an awareness of himself as a separate, thinking individual. But we do not yet know for certain when man achieved these characteristics which distinguish him from all other living creatures.

In recent years scientists have made some progress toward answering this question. One important find was made in 1924 when the remains of a creature called *Australopithecus* were dug up in South Africa. *Australopithecus* was half ape, half man. Although the shape of his face was apelike, he walked upright like a man.

No one has yet decided where *Australopithecus* stands on the evolutionary ladder. He probably lived about half a million years ago, at the same time as other definitely subhuman species. But it is believed that he came into existence much earlier and died out without leaving any descendants.

In July, 1959, a British anthropologist made an even more significant find in Tanganyika, Africa. His discovery was the skull of an extremely primitive but human-like creature called *Zinjanthropus*. He was nicknamed "Nutcracker Man" because of his massive molar teeth.

*An African "Ape Man" (Australopithecus) is shown using an antelope bone to attack a gang of baboons.*





*The coelacanth, the oldest fish known on earth, has existed virtually unchanged for 300 million years.*

The Nutcracker Man differed from Australopithecus in several ways. His larger nose and brain both were closer to those of modern man. But there was an even more significant difference. The Nutcracker Man's remains were found together with typical tools of the Old Stone Age, such as parts of a stone hammer. The bones of animals which the Nutcracker Man had killed and eaten were also found nearby.

*Two of the oldest crawling creatures of the sea are Xenoturbella (top) and Nemertoderma (bottom).*



Man is not the only creature to use tools. For example, one of the finches which Darwin found on the Galápagos Islands uses the spine of a cactus plant to dislodge insects from deep crevices. But only man selects tools for a purpose and trims them to his own design. Most anthropologists agree that man is distinguished from all other creatures by his ability to fashion tools.

The primitive man-ape *Australopithecus* may have used antelope bones and jagged stones to hunt animals. But the Nutcracker Man is the first creature known to have shaped his tools and so crossed

*Hutchinsoniella*, one tenth of an inch long, links modern crustacea with their extinct ancestors.



the threshold which divides man from all other animals. And the remains of the Nutcracker Man were found in Africa, the continent which Darwin had believed to be the birthplace of man.

In the depths of the sea there lurk some creatures which have survived unchanged from distant epochs of the past. Darwin called them "living fossils."

Three of these living fossils are particularly striking. No different from their remote ancestors, they are links between long-vanished forms of life and other, later forms that we know today.

Nearly two billion years ago, single-celled animals evolved into creatures with many cells. Two of the living fossils, *Xenoturbella* and *Nemertoderma*, were links between these stages. Dwelling in the mud at depths of a few hundred feet, they were—and still remain—two of the world's most primitive crawling animals.

But the most famous of the living fossils is the coelacanth, which has remained virtually unchanged for 300 million years. Coelacanths belong to the primitive crossopterygian order of fishes. Other members of this order ventured onto land

and later evolved into the amphibians, from which all land vertebrates arose. But coelacanths remained in the ocean. Until one was caught in a fishing net in 1938, they were believed to have died out 70 million years ago.

The course of evolution has been marked by a succession of vital turning points when completely new types of creatures came into existence. The first living creatures inhabited the sea. Hundreds of millions of years ago, some fish wriggled out of the water onto the land and there developed legs. Later they evolved into amphibians.

The first amphibian, called *Ichthyostega*, was a slow-moving but probably predatory creature about four feet long. It flourished in Greenland perhaps 300 million years ago and is the oldest four-legged animal that we know of. Its stubby legs were certainly developed to carry it on land but the scales on its body and the fin on its tail show that it emerged originally from the sea.

Amphibians lived both in the sea and on the land. But at some stage certain kinds of amphibians succeeded in hatching hard-shelled eggs on land and were thus freed from dependence on the

*The first mammal may have looked like this furry, four-inch long animal—*Morganucodon*.*





*The first amphibian, slow-moving Ichthyostega, is the oldest four-legged animal known to man.*

sea. The order of reptiles evolved out of these amphibians. The first known reptile, which was really a highly developed amphibian, has been given the name Seymouria because its remains were found near Seymour, Texas.

Mammals evolved from reptiles about 160 million years ago. No one is quite certain what the

first mammal looked like. It may have resembled Morganucodon, a small animal about four inches long, which looked like a modern shrew and lived in South Wales. Morganucodon possessed a furry mammal-like skin. But like other transitional forms, it also possessed some characteristics of the order from which it emerged—the reptiles.

*This creature, Seymouria, was not only the first reptile but also a highly developed amphibian.*



The first bird took to the air about 130 million years ago. Because birds are so different from other creatures, many of Darwin's critics used them to attack his theories. They claimed that birds are so distinctly individual that they could not have evolved from any other creatures. Therefore they must have been created as a separate order of life.

But discovery of the fossil remains of the first bird, Archaeopteryx, gave support to Darwin's theory. For Archaeopteryx was basically a reptile; an agile, acrobatic lizard with feathers that enabled it to fly. Its scaly head had teeth instead of a beak and its lizard-like tail was longer than its body.

A few years after *The Origin of Species* was published, fossil prints made by a feathered reptile were found in Bavaria, Germany. This find further confirmed Darwin's belief that birds had evolved from reptiles. And later discoveries have shown that all modern fowl have descended from Archaeopteryx, the first reptile-bird.

As evolution has always been a continuous process, a constant succession of links has joined each species to the next. But some of the most important links are still missing and many will probably never be found. For the history of evolution has not always been one of gradual change; it has been marked by sudden extinctions of whole species. Many species of vertebrates flourished in the Mesozoic era, 75 million years ago, but all modern vertebrates are descended from only eight of those species. All the others were destroyed and have left no descendants.

Life began about two billion years ago, at the beginning of the pre-Cambrian era. The pre-Cambrian period lasted for some one and a half billion years, and during this time life evolved into most of the main forms that exist today. Yet no fossil remains of pre-Cambrian life have been found. The first fossils appear in rocks of the Cambrian period, 500 million years ago.

But life itself had begun long before with the soft-bodied creatures of the sea.

Pre-Cambrian creatures were soft-bodied vegetarians, not possessing the hard body parts which in later ages would leave impressions in the sediment that gradually covered them. Since there were no predators, these animals did not need claws for attack or shells for protection. Aggres-

sion first occurred, it seems, around the beginning of the Cambrian period. In the succeeding struggle for survival, claws and shells developed. So the fossil record of life began.

To find out how life originated, scientists today are trying to reproduce the exact composition of the sea and air as they existed when life first began.

Other scientists are looking into the future. They are trying to foresee the course that human evolution will take. Biologists agree that man's physical evolution has probably come to an end; his body is unlikely to undergo any major changes. For man has conquered his environment. He has been in existence for only one hundredth of the time that dinosaurs ruled the earth but in this comparatively short period he has wiped out many species of animals, and he possesses the ability to destroy any creatures that threaten him.

Yet man faces a terrible danger. He has won the battle for survival over other creatures; but through his control over nuclear power he may wipe himself out. Radiation produced by nuclear explosions could destroy the cells through which man reproduces his kind. If enough radiation escapes into the atmosphere, man and all other forms of life may disappear. But if man avoids self-destruction, he will probably continue to evolve. His body may not develop further but his brain surely will.

Every advance in human knowledge has confirmed the essential truth of Darwin's theory of evolution; yet many scientists are still reluctant to describe evolution as a "fact." They remember how many beliefs which have been called facts in the past were later found to be inaccurate. Perhaps it is better to describe evolution as a "verified theory," and the only interpretation of the natural world which seems able to explain the whole grand history of life on earth.

Darwin's theory of evolution had a revolutionary impact on 19th-century thought. It seemed to show that nothing is permanent, and that change is the rule of the universe. Because his insights were so disturbing, Darwin was often attacked as cold and heartless. But nothing could have been more untrue. Charles Darwin was not only one of the greatest scientists in history; he was also a man filled with warmth and sympathy, and, above all, with a sense of his kinship with all living things.

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