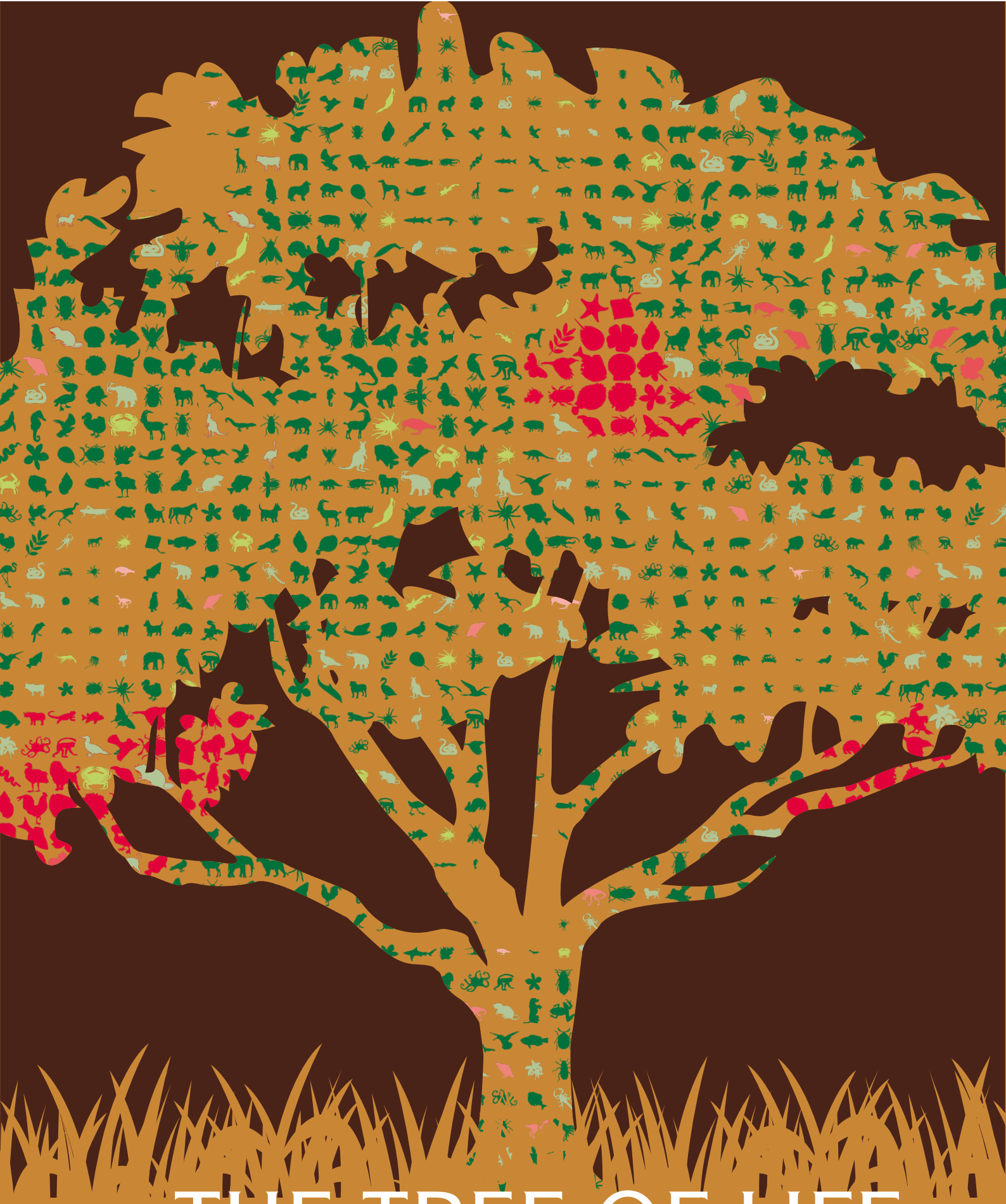

THE TREE OF LIFE

DISCOVERING EVOLUTION THROUGH THE EYES OF CHARLES DARWIN

codice
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THE TREE OF LIFE

DISCOVERING EVOLUTION THROUGH THE EYES OF CHARLES DARWIN

Curated by Telmo Pievani
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EXHIBITION

production by

codice
Idee per la cultura

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THE TREE OF LIFE

DISCOVERING EVOLUTION THROUGH THE EYES OF CHARLES DARWIN

This exhibits collection was born from the exhibition "*Darwin 1809-2009*", produced by Codice. Idee per la cultura in collaboration with the American Museum of Natural History of New York. The exhibition has been travelling all over Italy during 2009, and was in Rome, Milan and Bari; a smaller version was set up in the European Institute of Oncology, Milan.

"*Darwin 1809-2009*", compared to the American edition, involved an extended scientific research and many additions, as well as newly produced models, taxidermies and original exhibits; there comes the idea of an exhibition about the crucial topic of Evolution, that we present and suggest to Italian and international museums interested in building up a specific section about these topics.

Charles Darwin was an inquisitive boy and an attentive observer. We tend to remember him in his old age, with his long white beard, his dark hat and his black coat: an image that has become his icon. But first of all Darwin was a young passionate naturalist. He was born in England two hundred years ago. He was fascinated by the wonderful diversity of life on Earth, from barnacles to butterflies, from ostriches to orchids. He was not a brilliant student, but never tired of looking for new answers to the questions that crowded into his lively mind. He collected specimens, recorded his observations and carried out experiments. He read the works of many fellow naturalists from all over the world, and frequently corresponded with them. He studied nature using simple tools, at times little more than a microscope or a magnifying glass. And he wrote books, like *On the Origin of Species*, published on November 24th 1859, a hundred and fifty years ago, that changed natural science forever. He understood that all living things are part of the same evolutionary history.

Darwin's trip was a physical one, on board the HMS Beagle, but also a fascinating journey of the mind. This exhibition tells the story of Darwin's findings and their enduring importance. Indeed, curiosity is a human trait that continues to drive scientific research.

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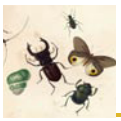
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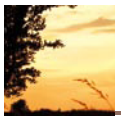
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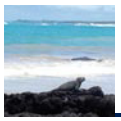
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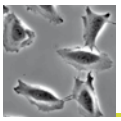
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Happiest at home with his notebooks and his microscope, he shunned the public eye. Controversy made him ill. This **brilliant observer of nature** kept his most original and revolutionary idea under wraps for decades. Yet today, two centuries after Charles Darwin's birth, nearly everyone knows his name. **What did Darwin do**, and why does he still matter so much?

Keenly observing nature in all its forms - from fossil sloths to mockingbirds, primroses to children - Darwin saw that we all are related. **Every living thing shares an ancestry**, he concluded, and the vast diversity of life on Earth results from processes at work over millions of years and still at work today. Darwin's explanation for this great unfolding of life through time - the theory of evolution by natural selection - **transformed our understanding of the living world**, much as the ideas of Galileo, Newton and Einstein revolutionized our understanding of the physical universe.

Darwin's theory of evolution by natural selection underlies all modern biology. It enables us to decipher our genes and fight viruses, and to understand Earth's fossil record and rich biodiversity. Charles Darwin, reluctant revolutionary, profoundly altered our view of the natural world and our place in it. His human and scientific adventure is worth an exciting tale!

Birds' eggs and sea shells, Beetles and coins, moths and minerals - as a child, Charles Darwin collected all of these and more. Born in 1809 to a wealthy family in rural England, he spent hours watching birds. He was **an indifferent student**, though, and school bored him. But he **never tired of studying the details of the natural world**.
Impatient with Charles's lack of progress, Darwin's father pulled him from the school and sent him to Edinburgh University in Scotland to study medicine, like his father and grandfather before him. When **Charles showed no interest in becoming a doctor**, Robert exploded, "*You care for nothing but shooting, dogs, and rat-catching, and you will be a disgrace to yourself and all your family.*" He next sent Charles to the University of Cambridge to prepare for a career in the church. Charles had no objection. A quiet country parish might be just the place to pursue his interest in natural history. While at Cambridge, though, **Darwin was singled out by an elite circle of academics** who recognized his potential. Finally, his true talent for natural history blossomed.
At Edinburgh University he wrote his first scientific papers and at Cambridge he became so devoted to botany that he took the sole botany course three times. One scientific hobby, however, stood out above all: **collecting beetles**. Darwin got into a heated rivalry with another Cambridge student, Charles "Beetles" Babington, over who would acquire a new species first. And when he wasn't collecting beetles, he was writing excited letters to his cousin William Darwin Fox, confessing, "*It is quite absurd how interested I am getting about the science*".

Displayed objects: entomological box plus butterflies or similar collections from Museum


A VERY SMALL VESSEL

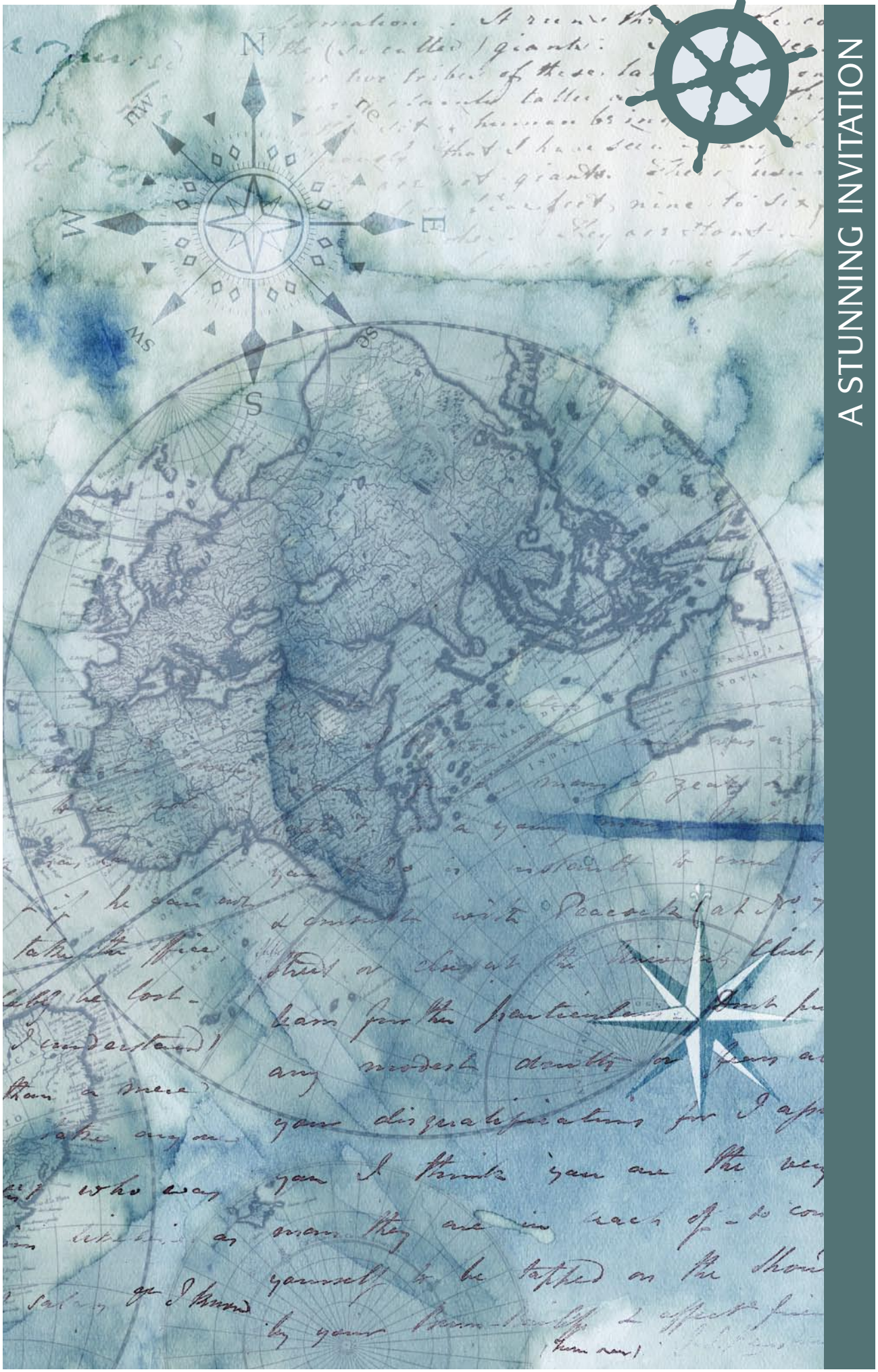
Darwin knew that life would be cramped aboard the Beagle, but it was still a shock to see how small the ship was: only 90 feet long. The poop cabin measured just 10 feet by 11 feet. The ship's library lined one wall, and a large table filled most of the remaining space. To sleep, Darwin hung a hammock over the table. He lay just two feet from the ceiling, looking up at the stars through a skylight.

The vessel that carried Darwin around the world was originally a two-masted Royal Navy ship weighing 235 tons and outfitted with 10 guns. The Beagle's maiden voyage in 1826 was to survey Patagonia and Tierra del Fuego, the tip of South America. The region was desolate, the voyage difficult, and the solitude too long. The captain committed suicide. The ship came under the command of a 23-year-old lieutenant, Robert FitzRoy, who completed the survey work and returned the vessel to England in 1830.

The following year the Beagle was refitted again and returned to South America with Captain Robert FitzRoy again at the helm and Charles Darwin joining as naturalist. Captain Robert FitzRoy had **extremely high standards** for any ship he intended to command. The cabins were outfitted in mahogany, the deck was raised to make more room to walk below and the hull was covered in copper. FitzRoy was especially **demanding about scientific instruments**, in which he was an expert. To prevent the ship's iron cannons from interfering with his precision compasses, he replaced them with brass cannons at his own expense. And after the Admiralty provided more than a dozen timepieces, which were used to measure longitude, FitzRoy insisted on buying six more.

The Beagle returned home in 1836, set off on a third voyage to Australia within months, and upon her return remained in England as a coast guard vessel. She was eventually moved ashore and sold as scrap in 1870. In 2004 a British team announced that it had maybe located the ship's remains lodged in the mud in a marsh in Essex, in the southeast of England.

Displayed objects: model of the Beagle



A STUNNING INVITATION

In August 1831, Darwin rushed home from a geology trip to Wales, eager to begin two weeks of partridge shooting. But a letter was waiting for him from his Cambridge professor and mentor J. S. Henslow. It contained **a chance of a lifetime**: an invitation to go on a trip around the world as a naturalist on the HMS Beagle. Darwin was elated - he was longing to travel and explore natural history in tropical lands.

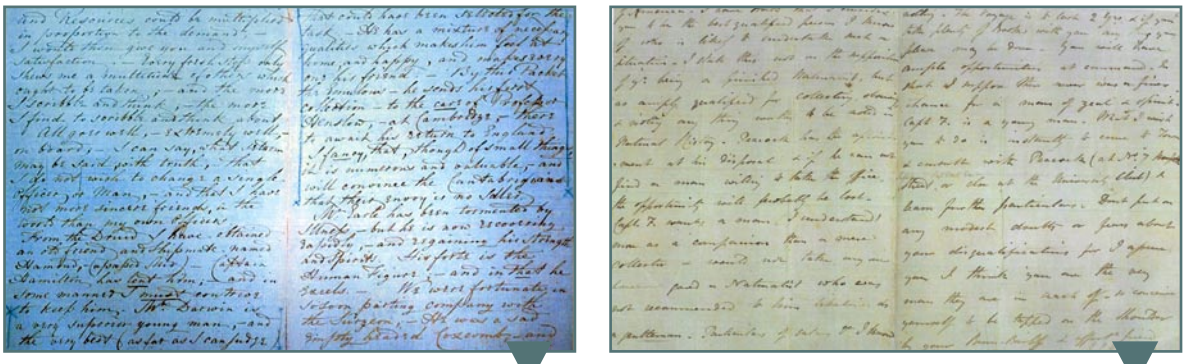
His father, however, threw cold water on the idea. It was time for Charles to settle down, he said, not go dashing off on some "*wild scheme*". Charles sadly turned down the invitation. **But his father had left one ray of hope**: "*If you can find any man of common sense who advises you to go, I will give my consent*". No one was more sensible and respected by his father than Charles's uncle Josiah Wedgwood, a wealthy and pragmatic potter. Fortunately Josiah sided with Charles, and together they crafted a point-by-point response that changed his father's mind - and Charles Darwin's future.

A LIFE-CHANGING LETTER

Henslow had been tempted to go on the voyage himself, but he had a wife, a job and a new baby. So Henslow turned to the inexperienced, 22-year-old Darwin. He reassured his former pupil, "*I consider you to be the best qualified person I know of who is likely to undertake such a situation - I state this not in the supposition of yr. being a finished Naturalist, but as amply qualified for collecting, observing, & noting, any thing worthy to be noted in Natural History.… In short I suppose there never was a finer chance for a man of zeal & spirit*".

"A VERY SUPERIOR YOUNG MAN"

In this letter penned some nine months after the Beagle had set sail, Captain FitzRoy describes how pleased he is with Darwin, who had proved to be good-natured, energetic and industrious. Writing from Montevideo on August 15, 1832, FitzRoy told the Admiralty's office, "*Mr. Darwin is a very superior young man, - and the very best (as far as I can judge) that could have been selected for the task. - He has a mixture of necessary qualities which makes him feel at home, and happy, and makes every one his friend*". However, as the months went by, a combination of Darwin's permanent seasickness and the short and disagreeable temper of Captain FitzRoy, whose way of thinking was very conservative, led to moments of tension and incomprehension.



Displayed objects: facsimile of letters from Henslow to Darwin and from FitzRoy to Beaufort

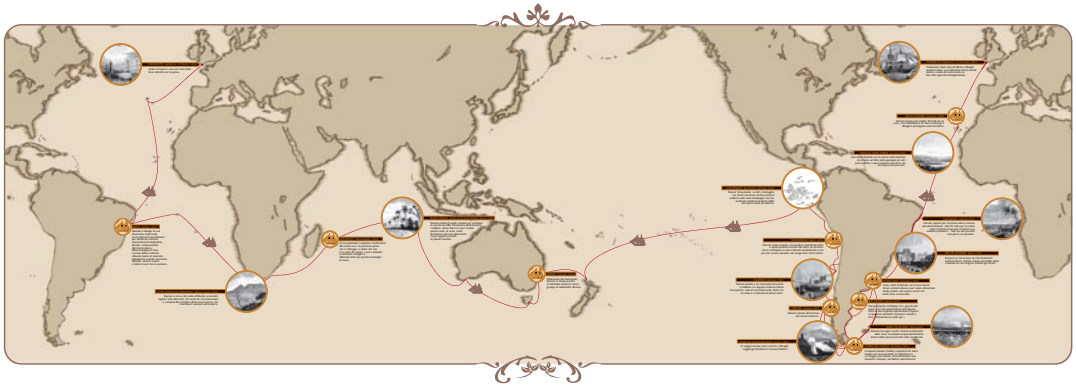
A TRIP AROUND THE WORLD

"BY FAR THE MOST IMPORTANT EVENT IN MY LIFE"

The captain and crew of the HMS Beagle originally planned to spend two years on their trip around the world. Instead, **the voyage took nearly five years**, from December 1831 to October 1836. The primary purpose of the trip, sponsored by the British government, was to survey the coastline and chart the harbors of South America, in order to make better maps and protect British interests in the Americas.

In addition to the ship's official mission, however, it was understood that Darwin was to make scientific observations. So while the ship systematically measured ocean depths, Darwin went ashore to explore and collect specimens. In fact, **two-thirds of Darwin's time was spent on dry land**, largely in the wilderness of Brazil, Argentina, Chile and remote areas such as the Galápagos Islands. By any measure, Darwin's labors were hugely successful. He brought back specimens of more than 1,500 different species, hundreds of which had never before been seen in Europe. He filled **dozens of notebooks with careful observations on animals, plants and geology**.

In the Autobiography, Darwin later called the Beagle voyage ***"by far the most important event in my life".*** When he set out, 22-year-old Darwin was a young university graduate, still planning a career as a clergyman. By the time he returned, he was an established naturalist, well-known in London for the astonishing collections he'd sent ahead. He had also grown from a promising observer into a probing theorist. The Beagle voyage would provide Darwin with a lifetime of experiences to ponder - and the seeds of a theory he would work on for the rest of his life.



Displayed objects: map of the trip

"A CHAOS OF DELIGHT"

In the year before his voyage, tantalizing pictures of lush South American jungles and the thrilling writing of Alexander von Humboldt had instilled in Darwin a longing to travel. But even the most vivid descriptions could not match his ecstasy at seeing the rain forest for himself: "*The delight one experiences in such times bewilders the mind, - if the eye attempts to follow the flight of a gaudy butter-fly, it is arrested by some strange tree or fruit; if watching an insect one forgets it in the stranger flower it is crawling over….The mind is a chaos of delight*".

From his very first stop in South America, Darwin was overwhelmed by the splendors of the Brazilian jungle. Among the marvels he saw there were large green iguanas peering down at him from tree branches, and colourful majestic parrots like the macaw. The blue, yellow and red of their feathers impressed him so much that back in London he called his first house with its glaring furniture "*Macaw cottage*".

His observations would soon lead him to the first hypotheses explaining, for instance, the connection between extinct and living species. Was there some sort of relationship between the extinct large mammals of South America whose fossils could be unearthed, like the megatherium (or giant sloth) and the glyptodont, and modern mammals like sloths, armadillos and anteaters? Similarities and differences between giant sloths and modern three-toed sloths, and also among armoured mammals, seemed to leave no doubt…

Displayed objects: models or taxidermies of Amazonian animals from Museums

SPACE, TIME, DIVERSITY: A GREAT IDEA IS ABOUT TO BE BORN

ARMOURED ANCESTORS?

Throughout his trip, Darwin saw ample evidence that **Earth had undergone vast changes**. Mountains had risen from the sea. Climates had changed. Many species had gone extinct, leaving fossils as evidence. But how, Darwin wondered, had these changes occurred? Darwin's geological studies left him increasingly convinced that most of these changes had happened over a very long time. He climbed high into the Andes and found his proof: fossil tree trunks, still upright. Long ago, a forest must have been buried and slowly petrified. Then, in a long series of earthquakes, the land had been uplifted to form the Andes Mountains. **Geology was the key part of Darwin's experience**, and it remained his primary scientific competence for years after his return.

During that time, Darwin was delighted by the armadillos he saw scurrying about in Argentina. But most intriguing was the striking similarity of these small, armoured mammals to some of the fossils he was unearthing. One such fossil was a glyptodont, an immense shelled animal that looked like a giant armadillo. Actually, among Darwin's most dramatic finds was the "*armour of a gigantic armadillo-like animal, the inside of which…was like a great cauldron*". In fact, to Darwin, **many ancient, extinct species seemed to be giant versions of living species**.

The young naturalist linked these observations on the "*deep time*" of fossil species to the ones on the distribution of current species in geographical space: why so many living things that were different in some ways and similar in others lived in adjacent areas? Why the Rio Negro river, in Patagonia, separates two species of rhea, one smaller and one bigger, that live apart without mixing?

Displayed objects: armadillo from Museums

ARMADILLOS FOR BREAKFAST

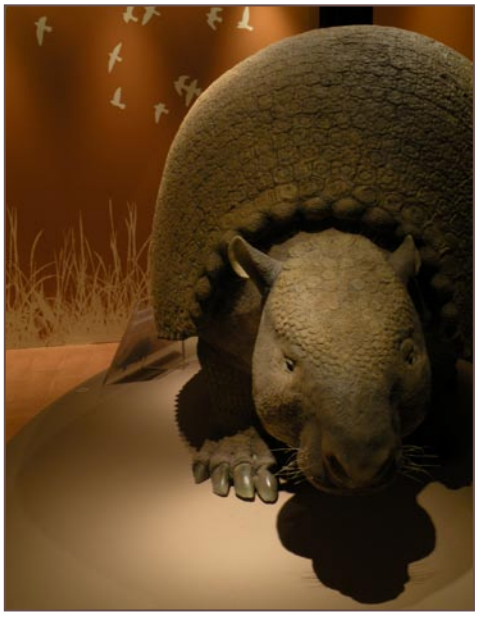
Why, Darwin also wondered, had so many species gone extinct, only to be replaced by similar ones? And not just once, but again and again? Perhaps the newer species were better suited to the changing environment, he reasoned. If Earth's changes were slow and gradual, what did that mean for the changes in species? Back in England, Darwin would ask himself: **Over long periods of time, could older species have evolved into new ones?** Though Darwin was charmed by the armadillos' behavior, he was equally interested in having a fine meal.

"I*n the morning we had caught an armadillo, which, although a most excellent dish when roasted in its shell, did not make a very substantial breakfast and dinner for two hungry men*".

GLYPTODONT - ARMORED GIANT

What were these ancient, extinct animals? It was difficult to tell, since many bones were often mingled together. Darwin at first thought the shell of a glyptodont went with the skeleton of a megatherium - a giant sloth that in fact had no armor. He shipped them all back to London for more seasoned scientists to sort out.

Darwin tried to figure out each fossil's age from the age of the rocks and shells around it, and his new quest topped even his former passion: "*There is nothing like geology. The pleasure of the first days partridge shooting … cannot be compared to finding a fine group of fossil bones, which tell their story of former times with almost a living tongue*".



Displayed objects: Glyptodont model

EVIDENCE FOR EVOLUTION: ISLAND SPECIES

The five weeks spent on the Galápagos, in 1835, were a key moment in the trip. The strange plants and animals of the islands puzzled Darwin. **Many lived only on the Galápagos** - and sometimes only on one specific island. How had these species gotten there? And why weren't they the same as those on similar islands around the world?

Instead, in countless details, **they were more like species from the mainland of South America**. That would make sense if they were migrants. But while many birds, plants, insects, reptiles, and even mollusks on the Galápagos resembled South American species, they were also slightly different. Before the Beagle reached home, Darwin began to wonder if species from the mainland had **reached the Galápagos, and then changed - as they adapted to this new environment**. Was it possible? Over time, could species change?

STRANGE NEW WORLD

Of all the exotic new worlds that Darwin saw on his travels, none was more alien than the Galápagos Islands: "*Nothing could be less inviting than the first appearance. A broken field of black basaltic lava, thrown into the most rugged waves, and crossed by great fissures, is everywhere covered by stunted, sunburnt brushwood, which shows little signs of life*". Darwin noticed that many species seemed a perfect match for their environment, even down to their coloring. Describing "*most disgusting clumsy Lizards*" that were "*as black as the porous lava rocks over which they crawl*", Darwin mused, "*They assuredly well become the land they inhabit*".

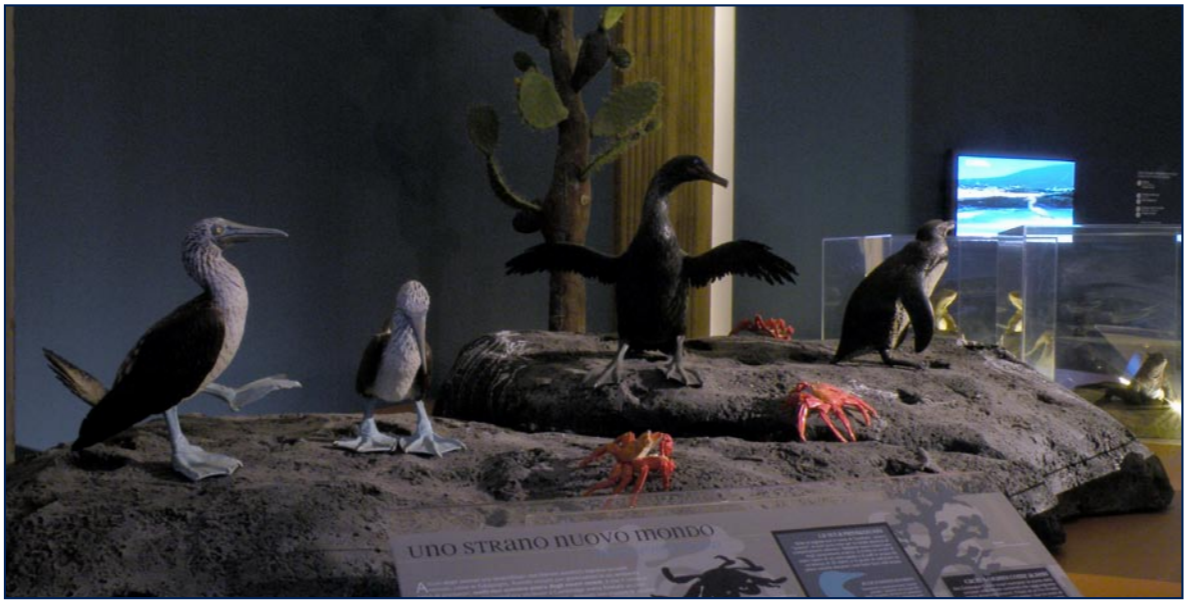
Having lived for generations in a land free from hunters, many had **no fear of humans**. This made them easy prey. Darwin, who as a student at Cambridge had formed a club dedicated to eating animals "*unknown to human palate*", cheerfully sampled the iguanas. He concluded, "*These lizards, when cooked, yield a white meat, which is liked by those whose stomachs soar above all prejudices*".

Unfortunately, the delicious taste of reptiles meat became fatal also for the huge Galápagos tortoises, that were doomed to being used as food and a source of oil by pirates for decades. They too had diversified on the archipelago, and their stately appearance and

slightly different shell from island to island drew Darwin's attention. Today, the populations of the subspecies of giant tortoises still present on the Galápagos have become a symbol of the danger of extinction and the necessity to preserve such a unique environment.

BLUE-FOOTED BOOBIES

Named for a word meaning "*foolish person*", boobies are known for their complete absence of defensive behavior. Though awkward when walking, blue-footed boobies are swift-flying seabirds that can dive from 80 feet and snatch a flying fish out of mid-air.



A TREE SIZED CACTUS

On the Galápagos, Darwin found that normally smaller plants could be found in enormous sizes. The stems of some prickly pear cactus, Darwin noted, grew six to ten feet high and one foot in diameter.

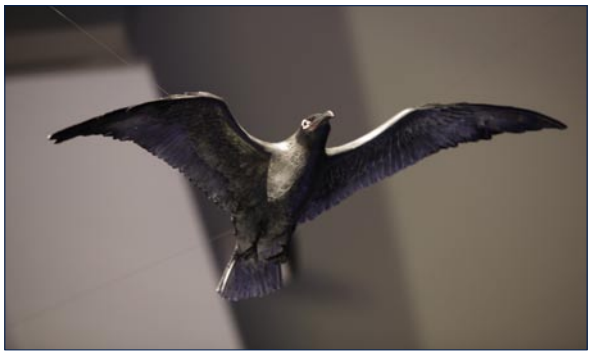
SWIMMING WITH THE WINGS

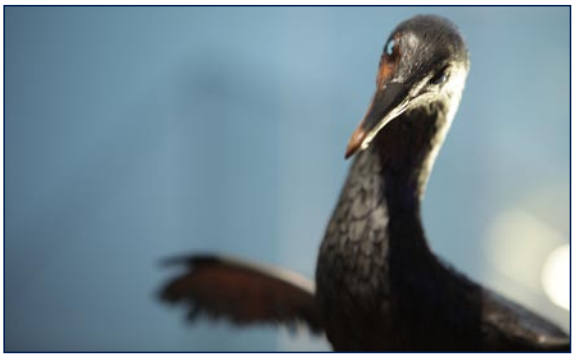
Though it is related to the 35 other cormorant species around the world, the flightless cormorant lives only the Galápagos Islands. And **while all other cormorants can fly, this**

one cannot. Its wings are, however, perfectly suited to swimming - much more useful than flying when searching for octopus, its favorite food.

Before humans arrived on the Galápagos, **the cormorant had no natural predators, so it had no need to fly**. It was wonderfully adapted to its isolated environment. But when people came - bringing dogs, cats, pigs and other "*invasive species*" with them - the defenseless birds were at their mercy. Their numbers have dropped dramatically, and now they are rare.

The only cormorant species that cannot fly is the flightless cormorant of the Galápagos Islands; all others, including the great cormorant (*Phalacrocorax carbo*) are able to fly.





PENGUINS AT THE EQUATOR

When most people think of penguins, they think of Antarctica, where these flightless seabirds waddle over the ice and dive for fish and krill. But some penguins live on the coast of South America, thanks to a cold, north-flowing ocean current, and **one tiny penguin lives in the tropics**. Instead of huddling for warmth, it must battle the blazing heat of the sunbaked Galápagos Islands.

The Galápagos penguin is not only the smallest penguin, and the only one found near the equator, but it is probably the only penguin that has to hold its wings outstretched over its webbed feet to prevent sunburn. Once again, **Darwin had found an example of a unique species that lived only in the Galápagos, but which seemed to be a modified version of a species from somewhere else** - as if it had somehow become specially adapted to its island environment.

Displayed objects: Opuntia, scalesia, rocky environment, crabs, boobies, penguin, cormorant, frigatebird, gulls. Plus iguanas and tortoises from Museums.

LONDON: THE “TREE OF LIFE” TAKES SHAPE

Within months of stepping off the deck of the Beagle, Darwin settled in London, where he spent a few years absorbed in intense and feverish research. Here he made a name for himself in science as a geologist and became famous for his book *The Voyage of the Beagle*. Here he married and had his first two children. Here, with the ambition to join the "*real naturalists*", he entrusted his finds to the best experts of the time and plunged into the work of writing up his Beagle research. **A huge idea was taking shape** in his mind. Had those first shipboard insights been right? Could new species arise from old? If they could, how did it happen? In London **he began another voyage - this one inside his mind**.

PECULIAR PLANTS

Darwin never claimed to be a botanist. "*I knew no more about the plants I had collected than the Man in the Moon*", he wrote his old Cambridge mentor, John S. Henslow - humorously overstating his ignorance, as he often did. In fact, Henslow had taught him well, and Darwin was a very systematic plant collector. He plucked, pressed and brought back to England a specimen of every species he found in flower on the Galápagos.
Darwin suspected that many of his specimens were "*peculiar*" to the Galápagos - that is, existed nowhere else - and he was anxious for Henslow's analysis. Close study of the plants might have provided a clue that they were related to those on the mainland and that their differences were a product of geographic isolation.

Here caption: scans of Beagle herbarium sheets Galápagos plants collected by Charles Darwin, Various species 1835

DARWIN'S EVIDENCE: FOSSILS

While in Argentina, Darwin had collected the bones of a large, extinct South American animal and shipped it back to England - a neck bone is displayed here. When he arrived in London paleontologist and anatomist Richard Owen told him his find belonged to a sort of giant camel. This fit with what Darwin was thinking: a small camel-like animal, the guanaco, still lived in South America, so perhaps the extinct and living animals were related. Owen later decided the Macrauchenia was really closer to an elephant - also an error - but by that time it didn't matter. Although he had the details wrong in this instance, Darwin correctly grasped the big idea: that fossils are often the ancestors of living species.

«I THINK...»

Darwin relied on his notebooks. In them, he jotted private ideas, questions and fragments of conversations related to his thinking on "*transmutation*" - what we now call "*evolution*". **The notebooks reveal a great mind homing in on a great idea**: plants and animals are not fixed and unchanging. Instead, **all species are related through common ancestry, and they change over time**. This is the link between extinct and living species, and also among species that diversified on adjacent islands from a common ancestor: they are all part of a single genealogical history.

Once Darwin started thinking seriously about evolution, he grasped its essentials with astonishing speed. Only a month or so elapsed between the time he opened the first full transmutation notebook, in about July 1837, and the time he drew a crude - but unmistakable - "***evolutionary tree***". This drawing, with the most ancient forms at the bottom and their descendants branching off irregularly along the trunk, reveals that Darwin understood all plants and animals are related. Above his tree Darwin wrote firmly, "*I think*". This is the key moment for the shaping of his theory.

Just one year later, in September 1838, reflecting on the individual differences that emerge between generations of living organisms, Darwin drew on the idea of a "*struggle for existence*" due to the constant lack of resources, by economist Thomas Malthus, to link he essential aspects of this process into what he later termed "*natural selection*".

So twenty years before On the origin of species he had already found the sap that nourishes the tree of life, the mechanisms that cause the change of species.

THE "CORAL OF LIFE"

Here, Darwin uses the image of a growing tree to represent evolutionary descent. The ancient founding group - marked "1" in the drawing - is at the base. Branches represent related groups of descendants. The large gap between branch A and branch D signals a distant relationship. "*For instance*", Darwin writes several pages later, "*there would be great gap between birds & mammalia*". Branches without letters, such as those just above A and to the left and right of the main trunk, are extinct.

Few pages before, Darwin was writing that maybe, in order to better represent both the irregularity of branching and the distinction between extinct and living branches, the metaphor of "*the coral of life*" would be more effective than the "*tree*", that still retained a hierarchical and progressive feel.

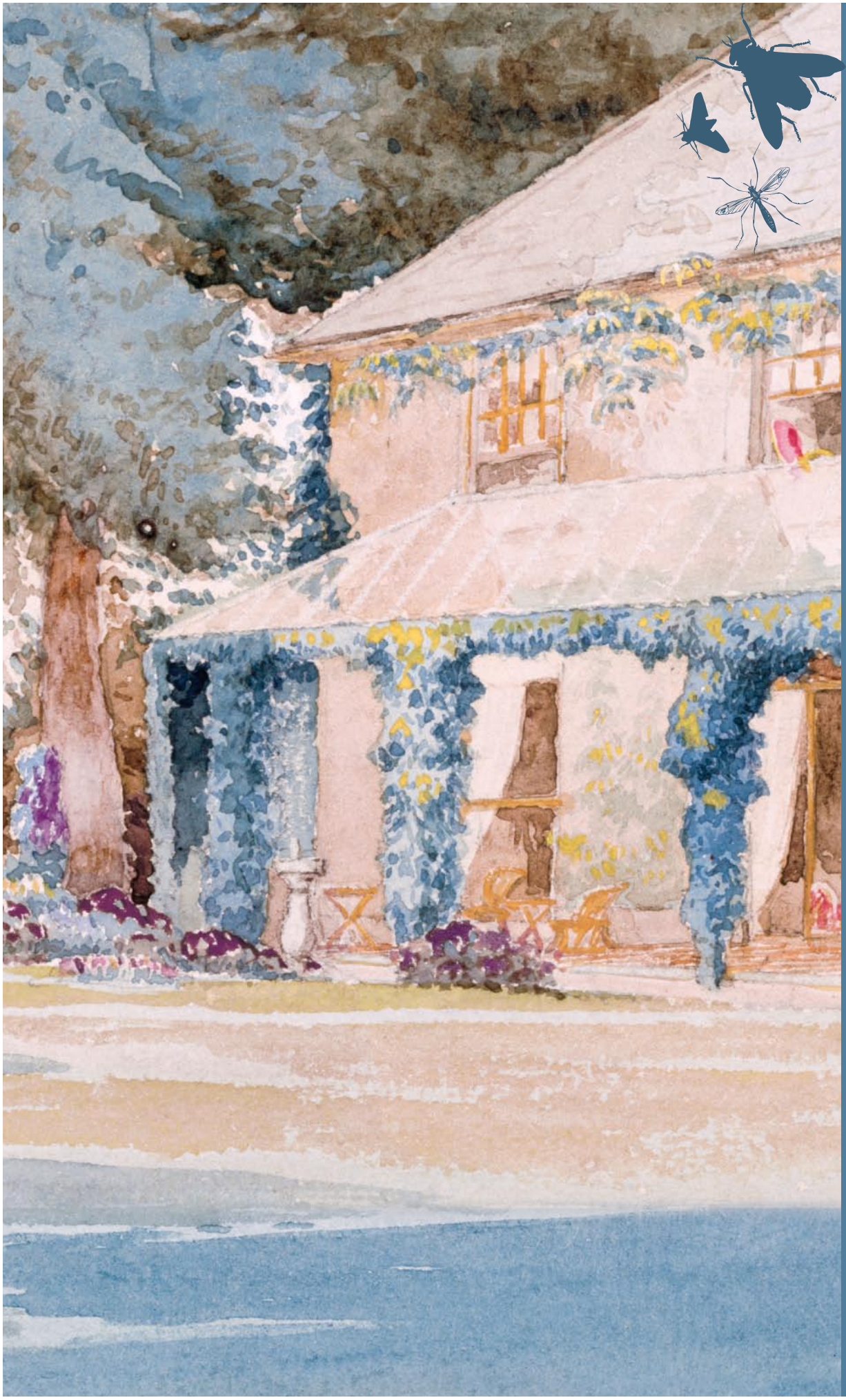
Graphics of tree of life here

"SUCH ARE MY REASONS..."

In the 1842 Sketch, Darwin points to Asian rhinoceroses as powerful evidence for common descent. Java, Sumatra and the Indian subcontinent are each home to a different species of rhino; that is, though these animals look similar, they do not interbreed.

To Darwin, the existence of these three different species in the same part of the world means one of two things. Either the animals were separately created with a "*deceptive appearance of true... relationship*", or they are genuinely related.

Displayed here is the "death mask" of a Javan rhinoceros.



In 1842 **Charles Darwin and his family fled London in search of peace and quiet**. They found it in a tiny village 16 miles outside the city, and for the next 40 years their home - called Down House - was Darwin's **retreat, research station and the hub of his vast scientific network**. Working in his study, greenhouse and garden, corresponding with scientists around the world, Darwin patiently completed the puzzle of evolution by natural selection, described in the Sketch (1842) and in the Essay (1844), that he never published.

In fact, for nearly two decades Darwin **kept his secret from the world**. Why so much reluctance? There are several reasons. Darwin's theory was still incomplete; he wanted to think more, gather more evidence. Other writers, with other evolutionary schemes, were being ridiculed. His own ill health and the tragic loss of his beloved daughter Annie interfered with his work. Imagining **the reaction of the public and the established church** filled him with dread. Yet gradually, over a decade or so, Darwin began letting a few trusted friends in on the secret. To divulge his findings would be like "*like confessing a murder*", he wrote to his friend, botanist Joseph Hooker, in January 1844. It took a letter from the Malay Archipelago to push him into print.

Displayed objects: Darwin's study

STRANGE CREATURES

Darwin planned to do a few months' work on barnacles, collected in Patagonia and Chile, before starting his planned big book on "*Natural Selection*". But he found the tiny and so diversified sea crustaceans so fascinating, and such a good case study of evolution, that he spent eight years studying them

Displayed objects: barnacles

AT LAST...

The letter delivered to Down House in June 1858 was as **shocking as a thunderclap**. Sent by the young naturalist Alfred Russel Wallace, who was in the Molucca Islands, it outlined a theory of evolution by natural selection eerily like Darwin's own. Wallace even cited the passage of Malthus that Darwin had cited in his notebook nearly 20 years before. **Darwin was distraught**: after all the years of work and worry, someone else would get the credit. He hated being scooped - and he hated himself for caring. But Darwin's friends Joseph Hooker and Charles Lyell sprang into action. They knew Darwin had written an essay containing those ideas nearly 15 years ago, so clearly **he had developed the theory first**. Hooker and Lyell **arranged a compromise**: Wallace and Darwin would both have papers on the theory presented at the Linnean Society in London, on July 1st 1858. Wallace was satisfied. He readily accepted the priority of Darwin's findings and acknowledged the greater completeness of his theory, and Darwin - finally - decided to put it into print without further delay. In little more than a year, on November 24th 1859, he published a summary of his twenty-year work that would become his greatest book: *On the Origin of Species by Means of Natural Selection*. This book, together with *The Descent of Man, and Selection in Relation to Sex* (1871) and *The Expression of the Emotions in Man and Animals* (1872), would gain an immediate and wide interest, and would spark a scientific revolution. They would also make Darwin the most revered, and controversial, scientist of his time.

CARNIVOROUS PLANTS, ORCHIDS AND EARTHWORMS: WHAT A "GRAND AMUSEMENT"

During the years at Down House, Darwin produced an immense amount of work despite suffering from a mysterious illness probably contracted on his trip (possibly Chagas disease). He wrote books on subjects ranging from orchids to climbing plants, variation of domestic plants and animals, and earthworms, and innumerable papers.

He maintained this pace partly by limiting interruptions and keeping to a strict routine. At Down, life had a predictable pattern, looked after by the attendance of his wife Emma. Darwin rose early and walked in the garden before breakfast. He worked until 9:30, when he spent an hour in the drawing room, listening to family letters being read. He resumed work in the study, then at noon walked, rain or shine, around the Sandwalk, the "*thinking path*" that he had laid out behind his house. Afternoons Darwin generally devoted to maintaining his vast correspondence, to reading and to the company of his seven children.

With typical understatement, Darwin once described his plant experiments as "*a grand amusement*". But the work was the furthest thing from a hobby; it was an **ambitious, innovative research program** that Darwin conducted at Down House for decades. Darwin looked at plants in a fresh way, fascinated by the intricate details of their structure and behavior. Above all, Darwin's **plant research demonstrated the power of evolution by natural selection**.

Darwin was searching for bog orchids when he stumbled on his first carnivorous plant. Enchanted by the unique adaptation of these tiny meat-eaters - they survive in nutrient-poor soil by trapping and digesting insects with their leaves - he began a series of experiments. Boyishly enthusiastic, first in the kitchen and later in his study Darwin fed his little sundews and Venus flytraps with bits of meat, gnat's wings, human hair and string.

Displayed objects: carnivorous plants

WHERE ALL IT HAPPENED

In this comfortable, cluttered study - part library, part laboratory - Charles Darwin **spent most of his days** at Down House. Rising early, working here for several hours in the morning and several in the afternoon, Darwin produced here an enormous amount of work, including one of the **most influential scientific books** of all time: ***On the Origin of Species by Means of Natural Selection***.

The study reflects the character of the man, unpretentious and intensely focused. Everything here was set up for **comfort and efficiency**. Darwin wrote on a cloth-covered board set across the arms of his battered but comfortable upholstered chair. Wheels had been attached to its legs so Darwin could **reach everything without getting up**. Plagued by a lifelong series of illnesses, Darwin felt the cold; he often draped a shawl around his shoulders, even in warm weather. His dog Polly - immortalized by a reference in the *Expression of the Emotions* - dozed in her bed by the fire while he worked.

This detailed re-creation of Darwin's study includes many objects used by the scientist during the period in which he wrote many of his works.

A DAY IN THE LIFE

Though Darwin was often ill during the years at Down, he produced an immense amount of work. He wrote books on subjects ranging from climbing plants to earthworms, and innumerable papers. He maintained this pace partly by limiting interruptions and keeping to a strict routine. Darwin's wife, Emma, did her part: as one son recalled, she "*shielded him from every avoidable annoyance*".

At Down, life had a predictable pattern. Darwin rose early and walked in the garden before breakfast. He worked until 9:30, when he spent an hour in the drawing room, listening to family letters being read. He resumed work in the study, then at noon walked, rain or shine, around the Sandwalk, the path behind his house. Afternoons Darwin generally devoted to maintaining his vast correspondence and to reading. "*My life goes on like clockwork," he wrote*".

A PLACE IN THE COUNTRY

The Darwin house was about a third of a mile from the center of tiny Downe village, home to perhaps four hundred people. (Village officials added the "e" to the village name in the mid-1800s, but Darwin kept to the old spelling for his home.) Though only 16 miles from London, Down House felt remote, in part because the nearest train station was eight miles away and the roads were poor. "*We are*," Darwin wrote a friend, at the "*extreme verge of the world*".

THE WIDESPREAD EVIDENCE OF EVOLUTION, TODAY

UNITY IN DIVERSITY

A century and a half ago, Charles Darwin offered the world **a single, simple scientific explanation for the diversity of life on Earth**: evolution by natural selection. Although he didn't know the genetic mechanisms of variation and inheritance, his explanation proved correct. The English naturalist firmly based his theory on the convergence of different types of empirical evidence: the palaeontologic one offered by fossils, the anatomic one resulting from the comparison of the morphologies of human beings, and the ethological one deriving from the comparative study of behaviours.

Humans, gorillas, whales, bats, moles, giraffes, polar bears, albatrosses and kangaroos are very different types of animals that use their forelimbs in very different ways, as necessitated by their environment. But beneath the skin, **the forelimb bones of these animals are startlingly similar**. These likenesses in structure, called **homologies**, are the result of descent from a common ancestor, a four-legged animal - a tetrapod - living over 365 million years ago.

Displayed objects: homologies

A COMMON BEGINNING

As adults, zebrafish, chickens, turtles, Homo sapiens and dolphins are very different animals. But surprisingly, all five look very similar in their early stages of development. As Darwin realized, such **developmental resemblances hint at common ancestry**, with more closely related animals following more similar paths of development. Today we understand better than Darwin could the reasons for these early resemblances.

Animals, including humans, share many nearly identical genes, involved in building the body. Different animals develop along similar pathways because **they all have inherited the same genes** for building limbs, or eyes, or heads. In fact, swapping the gene that triggers eye development in one organism with the corresponding gene in another has little effect - it's the same gene! Differences arise among various species because of changes in when and where such genes become active during development. Ultimately those variations in timing and topology spell the difference between fish, chickens, turtles, dolphins - and us.

Displayed objects: models of embryos

TWO WINGS TOO MANY

Nearly all animals share a set of genes that, when repeatedly switched on and off at precise moments during embryonic development, control the formation of different body parts. **And sometimes mutations produce bizarre results**. Hox genes - a set of developmental genes - turned on or off at the wrong time or place have been known to cause one body part to grow instead of another, or extra body parts to grow where none were before. For instance, a normal fruit fly has a single pair of wings, but mutations to a Hox gene can result in a fly born instead with two pairs, the condition in most living insects as well as in the ancestors of fruit flies.

TIMING IS EVERYTHING

All zebras have stripes. But the number of stripes and the particular stripe patterns of the three zebra species are different. Such differences depend on the precise timing of stripe initiation during development. A common zebra's 26 stripes are "*turned on*", or initiated, at 21 days; a mountain zebra's 43 stripes at 28 days; and a Grevy's zebra's 80 stripes at 35 days.

VARIATION, INHERITANCE, SELECTION: THE CORE OF EVOLUTION

Natural selection is **a demographic mechanism that causes populations of living things to change over time. The driving force of selection is individual variation**. Members of any given species are seldom exactly the same, either inside or outside. Such variation is often the result of random mutations, or "*copying errors*", that arise when cells divide as new organisms develop. When organisms reproduce, they pass on their DNA - the set of instructions encoded in living cells for building bodies - to their offspring. And since many traits are encoded in DNA, **offspring often inherit the variations of their parents**.

Environments cannot support unlimited populations. Because resources are limited, more organisms are born than can survive: some individuals will be more successful at finding food, mating or avoiding predators and will have a better chance to thrive, reproduce and pass on their DNA. **Small variations can influence whether or not an individual lives and reproduces**. Differences in color, for instance, aid some individuals in camouflaging themselves from predators. Sharper eyes and claws help an eagle catch its dinner. And brighter coloration improves a male peacock's chances of attracting a mate.

In generation after generation, advantageous traits are passed on to greater and greater numbers of offspring. After just a few generations or after thousands, depending on the circumstances, such traits become common in the population. **The result is a population that is better suited - better adapted - to some aspect of the environment than it was before**. Furthermore, adaptations of a species depend often on adaptations of others, for mutual advantage or "*arms races*" between predator and prey or parasite and host.

These butterflies, for example, are all very similar, but a closer look reveals noticeable variations, particularly in color and wing markings. They all have eyespots on their wings to scare off or confuse predators, but some eyespots work better than others. Small variations in eyespot size, shape or color can spell the difference between life and death.

HOW LONG DOES EVOLUTION TAKE?

Evolution has no single pace. Sometimes, new species or varieties arise in a matter of years or even days. Other times, species remain stable for long periods, showing little or no evolutionary change. However, the characteristics of organisms that reproduce every few hours, such as bacteria, can potentially evolve much faster than in organisms with generations that are measured in months or years, such as horses.

THE HORSE, AN ANCIENT HISTORY

The evolution of the horse is well documented by **a lengthy fossil record extending over 55 million years**. During this time, episodes of relatively rapid modification were interspersed with long periods of little change. And it is clear that horses adapted to many different environments and pressures. Careful dating and analysis of fossils shows a clear succession of forms, from the dog-sized *Hyracotherium* to *Equus*, the modern horse.

Hyracotherium, *Merychippus* and *Equus* represent stages in the evolutionary path to living horses, a sequence that shows species becoming larger through time. But not all ancient horses evolved into larger forms; members of some extinct groups were actually smaller than their ancestors. Indeed, **there are no universal trends in evolution**. Over time, a population can demonstrate a trend in one direction, but over smaller intervals, some subgroups might evolve differently.

Displayed objects: foot casts and skeleton of horse

THE EVOLUTIONARY "BUSH"

Of the many groups of horses living over the past 55 million years, some went extinct relatively quickly, while others initially thrived. But only Equus ultimately persevered, a group that today includes modern horses, zebras, donkeys and onagers.

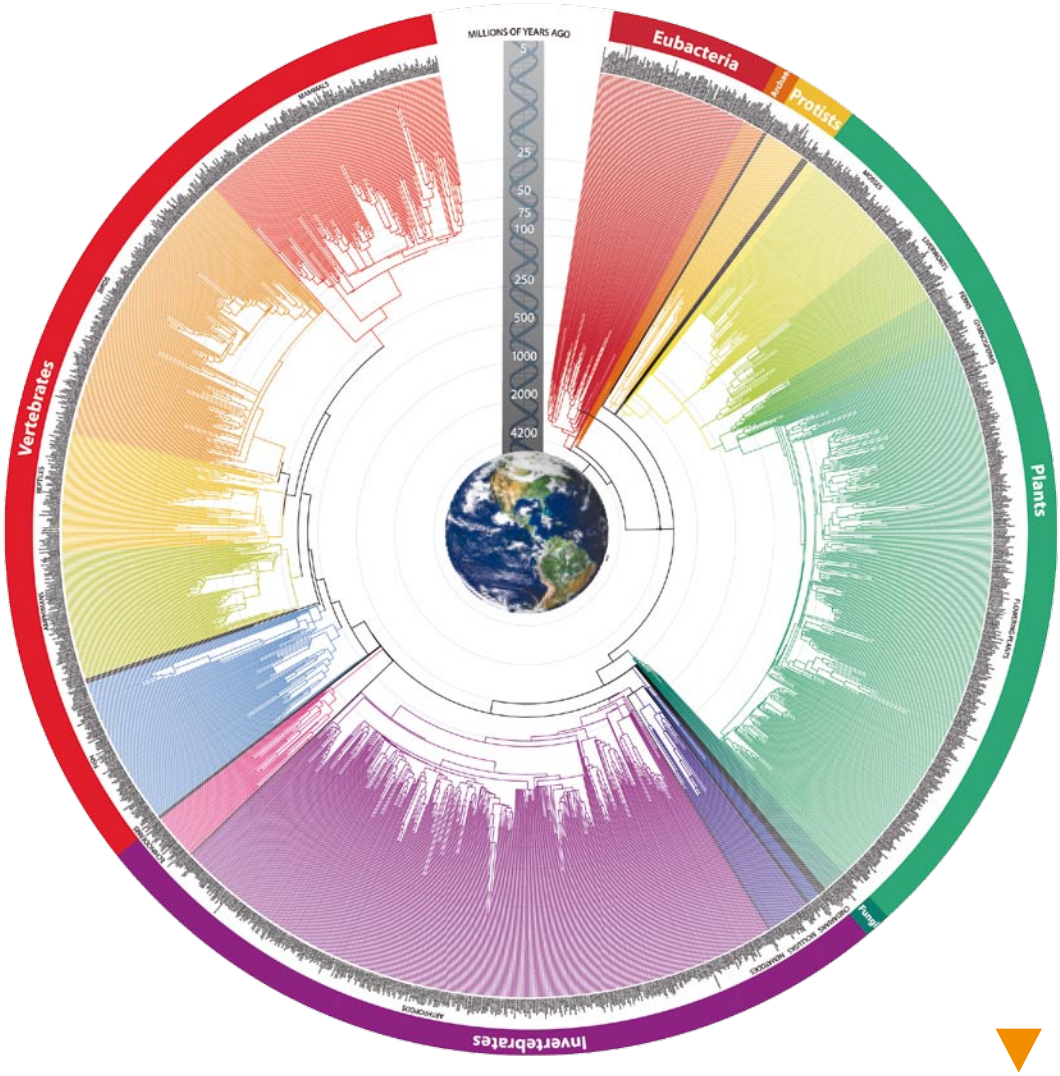
EVOLUTION BY ARTIFICIAL SELECTION

In nature, evolution can take a very long time. **But humans have learned how to speed up the evolutionary process** by breeding only individuals with desirable traits. In the world of horses, for example, Clydesdales are the product of programs that, over about 300 years, singled out and bred only the largest and strongest horses. Thoroughbreds, on the other hand, were bred for speed, also over about 300 years.

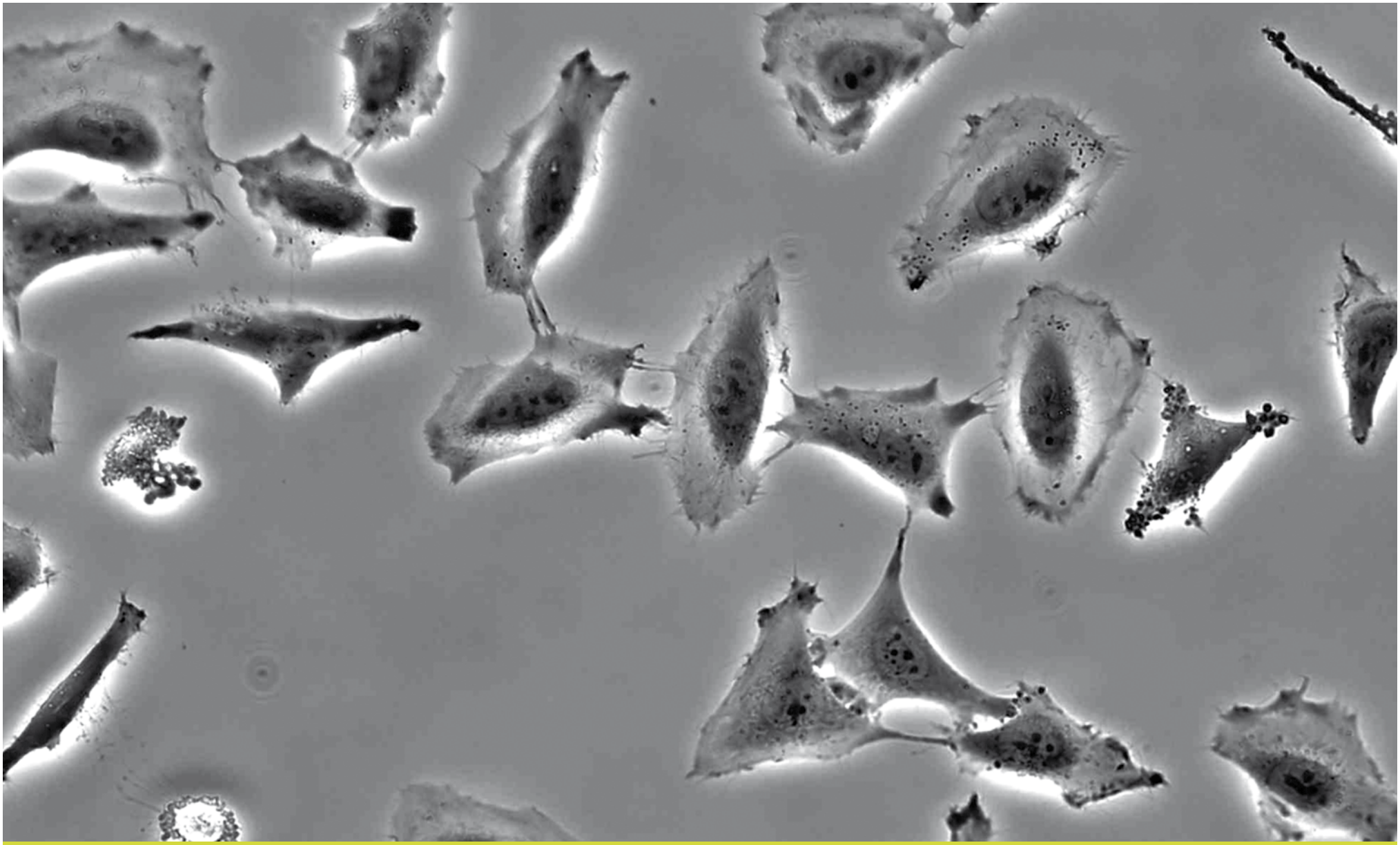
THE BIG TREE OF LIFE TODAY

Modern scientists - focused on fighting viruses, decoding DNA or analyzing the fossil record - can now **answer questions about the natural world in ways Darwin never could**. New tools and technologies, such as DNA analyses, can reveal unexpected relationships between seemingly dissimilar groups. Accurate fossil dating methods show that evolution proceeds at variable rates at a geological timescale and is not always gradual. Darwin would be amazed - and delighted - to see how our new knowledge has helped advance his theory.

Scientists can compare DNA to help determine evolutionary relationships: in general, the greater the difference in DNA between two species, the more time must have passed since the two groups were one, since they diverged from a common ancestor accumulating different mutations. **The tree of life**, also called a phylogenetic tree, is a graphic tool that biologists use today (and Darwin used in his private notes already in 1837, we have seen) to portray evolutionary relationships among plants, animals and all other forms of life. **The tree reveals evolutionary histories**: each "fork in the road," or branching point, indicates a common ancestor splitting into two descendants. And the fewer branching points there are between any two species, the more closely they are related - a feature that has great predictive value. **The history of evolution is recorded in DNA**.



Here an updated chart of the universal tree of life



EVOLUTION, RIGHT BEFORE OUR EYES

Sometimes evolution happens overnight. Unlike most larger organisms, viruses and bacteria reproduce very rapidly - they simply split in two every few minutes or hours, with both offspring continuing to divide and multiply. Such **short spacing between generations can help speed up the evolutionary process**. These organisms have an enormous potential to acquire advantageous adaptations quickly. A mutation that gives an advantage in reproduction can dominate a population in a few days.

Like all viruses, influenza, or "*the flu*", can evolve very rapidly. Each year scientists study flu viruses from around the world in order to predict how they might evolve. Scientists then create a vaccine designed to help the body's immune system ward off the most dangerous of the upcoming year's varieties, a process that has saved countless lives. But since **any one vaccine can help immune systems fight only some varieties of flu**, others survive, reproduce and evolve. Thus, new flu vaccines are issued every year not because the old ones have worn off, but to fight newly evolved or re-emergent varieties of the virus. This is a clear evidence of evolution by natural selection today in action and experimentally verifiable.

KILLER FLU

Sometimes, viruses can change so dramatically that human immune systems are nearly powerless to fight them. In 1918, an unfamiliar flu swept the globe. Despite precautions, such as those taken by U.S. Army soldiers in Seattle, that flu virus killed between 25 and 50 million people worldwide.

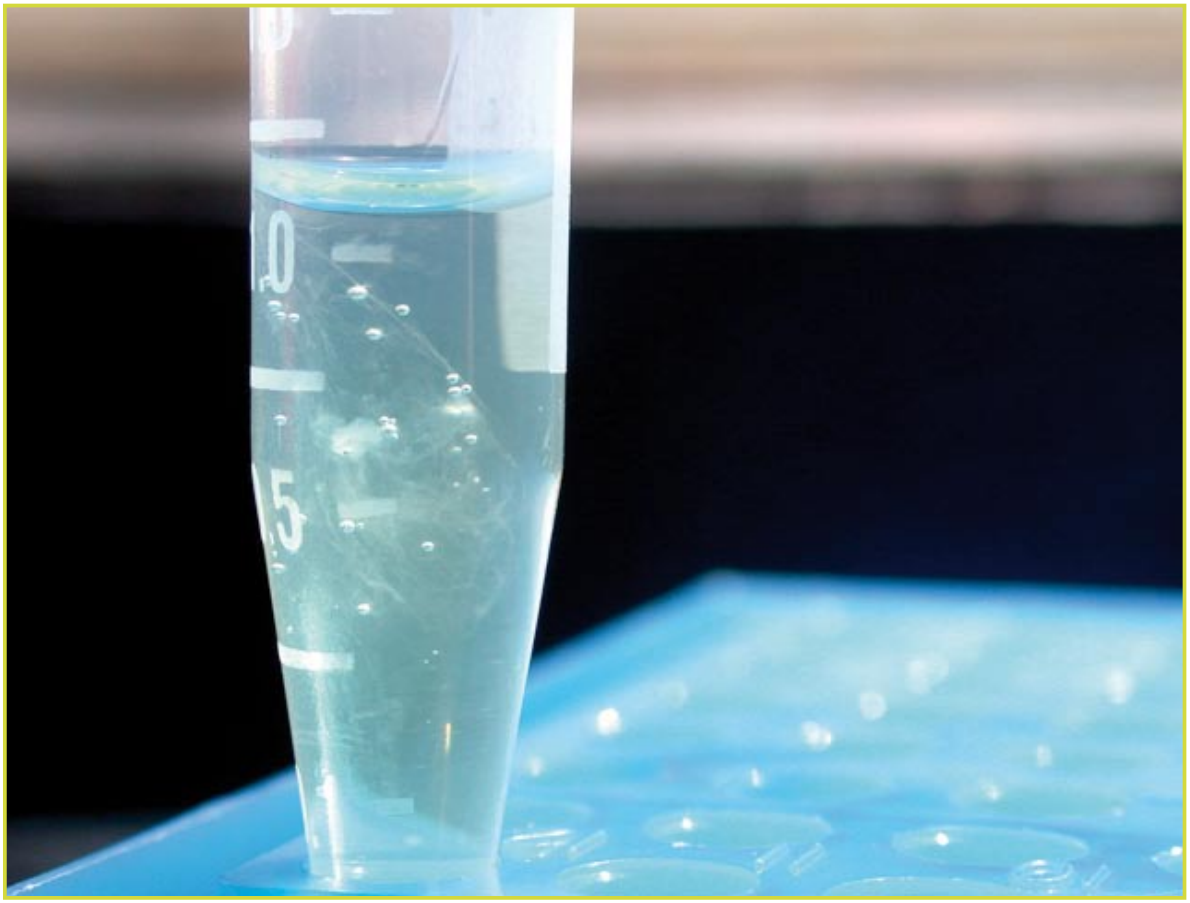
Photo of flu precautions

AN ANTIBIOTIC ARMS RACE

Antibiotics such as penicillin became widely available more than 60 years ago, so you might think infections and bacterial disease would be problems of the past. Think again.

When people or animals take antibiotics, most bacteria cells in their bodies die. But of those millions of bacteria, a few might have mutations that make them resistant to any one particular antibiotic. It is those cells that survive and multiply - **a dramatic example of natural selection in action**. Over time, resistant bacteria strains replace nonresistant ones, and soon that initial antibiotic becomes ineffective. So researchers are forced to develop new ones. But the bacteria evolve in response to these new drugs - creating in effect an antibiotic arms race. To combat quickly evolving bacteria, many doctors prescribe multiple antibiotics to be taken at the same time. Such drug "*cocktails*" greatly reduce the chances that any bacteria cells will survive and multiply.

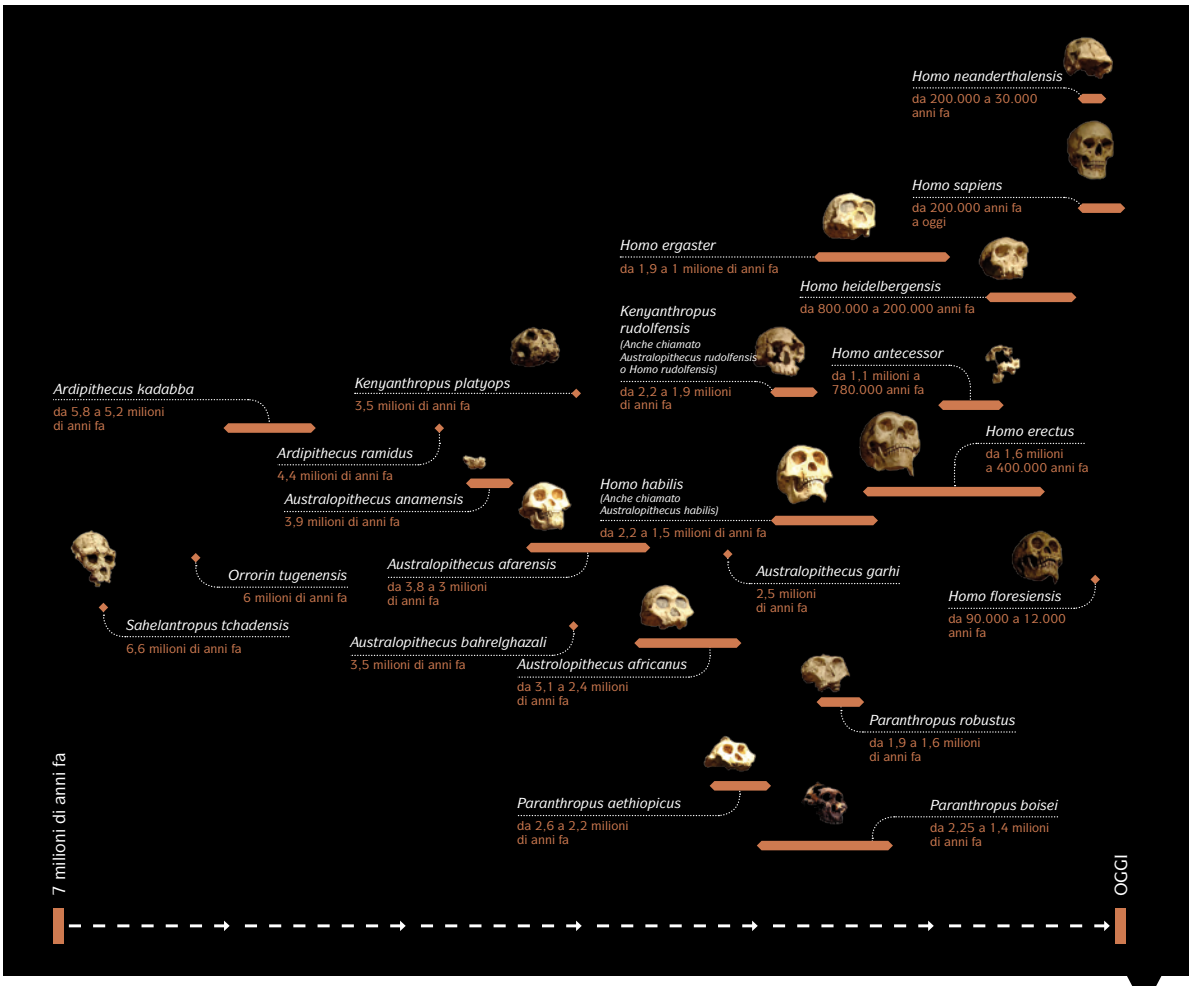
So, our bodies are themselves a field of action for evolution. The enterprise of trying to find evolutionary explanations for vulnerabilities to disease is named "***darwinian medicine***". The evolutionary understanding of a disease can refer to defences, infection, unusual environments, genes, design compromises or evolutionary legacies.



HUMAN EVOLUTION: ANOTHER STORY OF DIVERSITY

When Charles Darwin published *On the Origin of Species* in 1859, virtually nothing was known of the human fossil record. Nevertheless **he saw that humankind is a very close-knit species, and in *The Descent of Man* (1871) he accurately surmised that the origin of that species was in the continent of Africa.**

Opposite, **the human "family tree" as we understand it today**. Despite the linear patterns of the past, we know now that hominid phylogenesis has nothing exceptional with respect to the evolution of other successful animals. Darwin, in his Notebooks, introduced the metaphor of the "*coral of life*" to represent the apparent irregularity of evolutionary branches. Well, ***a "coral"*** or ***"bushy tree"*** **like this is an effective pattern to understand our past**. Here, Homo sapiens appears as one single terminal twig among many, in a story that sees many species living in the same periods showing a variety of different adaptations. Hominid evolution has been in fact **a story of luxuriant diversity of species**, living in the same periods and geographical regions in Africa and then outside Africa as well, a story of different adaptations and innovations, contingent environmental changes, movements of populations, repeated evolutionary experimentation. Our solitude as a species, the sole representative of the genus *Homo*, has occurred only recently, when our last cousins, *Homo neanderthalensis* in Europe and *Homo floresiensis* in Indonesia, became extinct between 26,000 and 12,000 years ago.



Displayed objects: large graphics with hominids bush

FACE TO FACE WITH LUCY!

Fossils and artifacts may in themselves be objects that are pleasing to the human eye and mind, worthy of exhibition simply for their aesthetic qualities, or for the symbolic attractions they exert. But to complete the story they tell it is necessary to put flesh on the bones and to represent long-vanished forms as they may have appeared in life. No process of reconstruction can be totally authoritative in all of its details; but a careful step-by-step approach can produce remarkable likenesses of our extinct ancestors: images that can bring these forebears to life as truly living, breathing creatures.

Here, **four stages in the process of reconstructing the bust of "Lucy," probably the most famous of all hominid fossils**: a 40% complete skeleton of a female *Australopithecus afarensis* specimen, discovered on the morning of November 24th 1974 by Tom Gray and Donald Johanson at the Hadar formation in the Awash Valley of Ethiopia's Afar Depression. During the merrymaking of the first evenings at the camp after the great discovery, the fossil was nicknamed "*Lucy*" listening repeatedly to the Beatles song "*Lucy in the Sky with Diamonds*". As you might expect of one who lived some 3.2 million years ago, the tiny Lucy, only a meter tall, had quite archaic body proportions. **Still, as an upright-walking biped she had already embarked on the trail that ultimately led to the genus *Homo*. But today only her bones remain. What did she actually look like, out there on the landscape?**

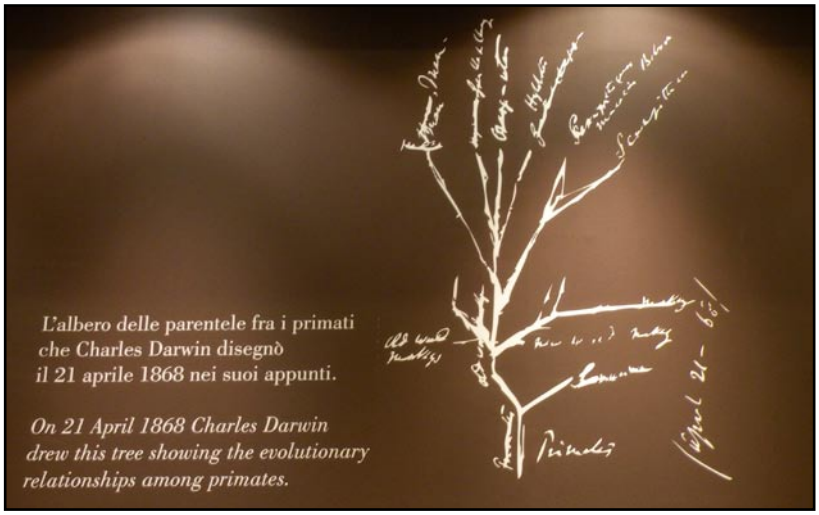
A handful of bony fragments is assembled into a complete skull, on to which the technician applies first the deep and then the more superficial muscles, guided by an intimate knowledge of comparative anatomy. The cartilaginous structures of the nose are reconstructed based on the underlying bony structure, and then subcutaneous fat and skin are applied. The final stage involves adding ears, eyes and hair, and applying color to the skin. Many of these later steps involve educated guesswork; but, without claiming to be a definitive statement, the final result is compatible with the basic bony information we started with. And the viewer has a tangible being to relate to!

Displayed objects: Lucy, stages of reconstruction

AN EXTINCT COUSIN

DNA can be extracted not only from the tissues of living organisms but also from exceptionally well preserved ancient bone. Over the past decade molecular biologists have been able to extract and analyse DNA from several Neanderthal specimens, and to compare it with DNA taken from modern humans all over the world. Neanderthal mithocondrial DNA has been shown to be consistently distinctive, and to differ much more from any modern human DNA than human samples differ from each other. These findings, and initial data coming from fossil nuclear DNA as well, have **confirmed the status of Homo neanderthalensis as a distinct species within the human family**.

Knowledge of Neanderthal DNA is also beginning to yield information of a kind that cannot be retrieved from fossil bones. Researchers have recently found, for instance, that four of four Neanderthal samples possessed the gene variant that determines red hair in modern humans.



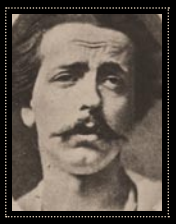
Neanderthal/human/primate tree and red-haired Neanderthal portrait

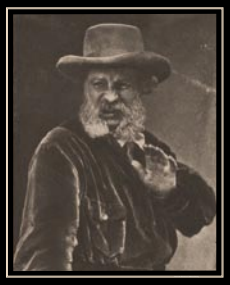
SAME FEELINGS

When Darwin looked at the **expressions on people's faces** - and at the body language of dogs and cats - he saw evidence for evolution. These pictures, some posed and some candid, appeared in his *The Expression of the Emotions in Man and Animals* (1872). What Darwin himself observed, and what he learned from scientists studying cultures worldwide, convinced him that **all humans have the same feelings**. What's more, they show them on their faces in similar ways.

Similarly, Darwin thought, animals had recognizable emotions. Chimpanzees could feel disappointment. When they were disappointed, they sulked; and when they sulked, they stuck out their lips like pouting children. Experts of the time believed, wrongly, that we humans had special muscles in our faces so we could express what they called our "*exquisite feelings*". Darwin's work contradicts this. **Our emotions, and the way we express them, connect us with the rest of life** on Earth.

GLI STESSI SENTIMENTI
same FEELINGS





Quando Darwin esaminò le **espressioni facciali delle persone**, come il linguaggio del corpo di cani e gatti, trovò prove dell'evoluzione. Queste immagini, alcune in posa e alcune naturali, comparirono nel suo *L'espressione delle emozioni nell'uomo e negli animali* del 1872. Sulla base di quanto aveva osservato con i suoi occhi e di quanto aveva imparato dagli scienziati che studiavano le culture di tutto il mondo, si convinse che **tutti gli esseri umani condividono gli stessi sentimenti**. Per di più, li mostravano attraverso il volto in modi simili. Similmente, Darwin pensava che anche gli animali provassero emozioni riconoscibili. Gli scimpanzè potevano provare la delusione. Per mostrarlo, mettevano il broncio, protrudendo le labbra come fanno i bambini. Gli esperti del tempo pensavano, sbagliando, che noi umani avessimo muscoli speciali sul volto che ci permettessero di esprimere quelli che chiamavano i nostri "mirabili sentimenti". Il lavoro di Darwin contraddiceva tale posizione. **Le emozioni che proviamo, e il modo in cui le esprimiamo, ci collegano al resto della vita sulla Terra.**

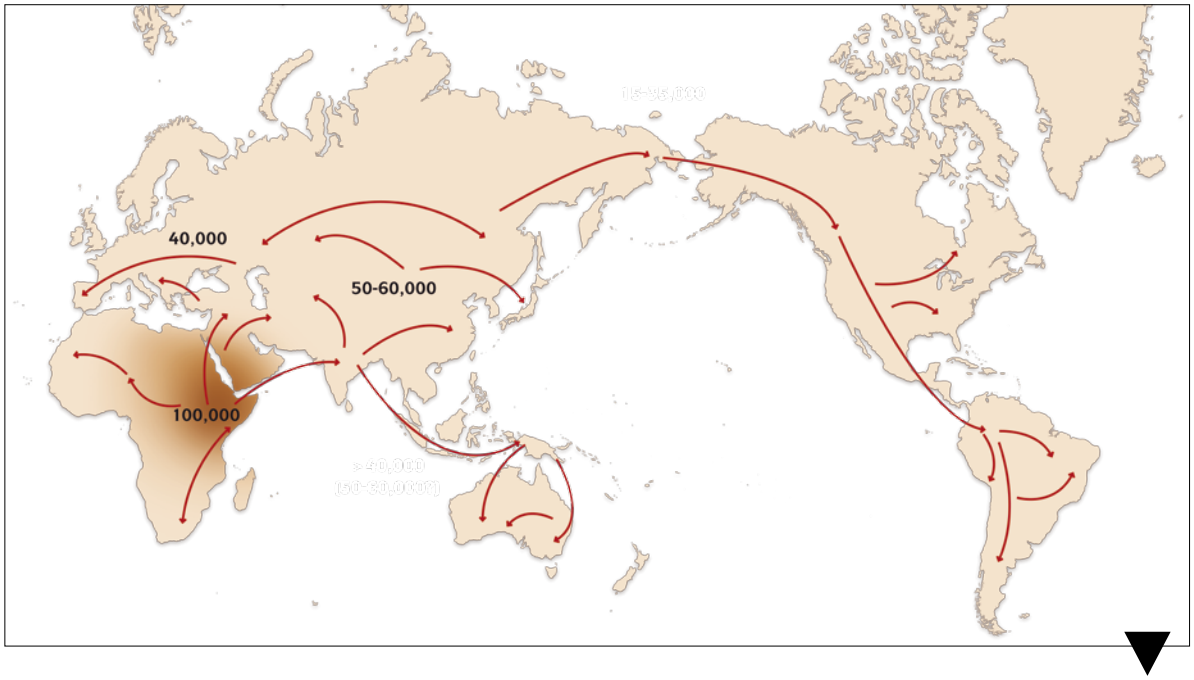
*When Darwin looked at the **espressioni an people's** faces – and at the body language of dogs and cats – he saw evidence for evolution. These pictures, some posed and some candid, appeared in his* The Expression of the Emotions in Man and Animals *(1872). What Darwin himself observed, and what he learned from scientists studying cultures worldwide, convinced him that **humans have the same feelings**. What's more, they show them on their faces in similar ways. Similarly, Darwin thought, animals had recognizable emotions. Chimpanzees could feel disappointment.*
When they were disappointed, they sulked, and when they sulked, they stuck out their lips like pouting children.
*Experts of the time believed, wrongly, that we humans had special muscles in our faces so we could express what they called our "exquisite feelings". Darwin's work contradicts this. Our emotions, **and the way we express them, connect us with the rest of life on Earth.***

emotions panel

ALL OVER THE WORLD: THE GREAT MAP OF HUMAN SPREADING

The best record we have of modern human origins and the spread of our species around the globe is found in our DNA. In 1871 Darwin predicted that the ancestry of humankind would be found in Africa, and now studies of DNA variation among human populations have allowed **geneticists to confirm the emergence of modern humans in Africa**.
It has also permitted them to date the origin of our species Homo sapiens to between 150,000 and 200,000 years ago. Spreading routes are inferred from both the mtDNA, tracing the female lineages, and sequences of the Y chromosome, marker of the male lineages. So, as shown in the map, the spread of humans around the world following about 80,000 years ago is also written in the DNA record.

Putting all lines of evidence together, the following **general scenario** seems reasonable. Homo sapiens had its origin in a tiny population that lived in eastern Africa at some time over 160 kyr ago. Over the next 30 kyr this population expanded to the south and the west and then to the north, where there seems to have been an initial exodus foray out of Africa into the Levant a little over 100 kyr ago. This seems to have been followed by a retreat, possibly due to climatic deterioration, with a fresh exodus, at about 85 kyr, of people whose descendants ultimately populated the entire habitable world. Over the next 10 kyr they moved eastwards along the southern coast of Asia, reaching China by about 75 kyr. Australia may have been reached (by boat) by about 60 kyr ago. Warming of the climate around 50 kyr ago allowed invasion of the Levant and the Fertile Crescent region to its north; and by about 40 kyr *Homo sapiens* was entering Europe and central Asia. By 25,000 years ago northeastern Eurasia had been occupied, all the way to the Arctic Circle. Perhaps as early as 20 kyr ago, and certainly within a few thousand years of this date, populations had entered the New World via a Bering Straits Land Bridge exposed by low sea levels. Indications are that people had reached Chile, possibly following the coastline in boats, by almost 15 kyr ago. Such are the major outlines of how modern humans took over the world, evicting more archaic hominid populations along the way, except in the previously uninhabited New World.



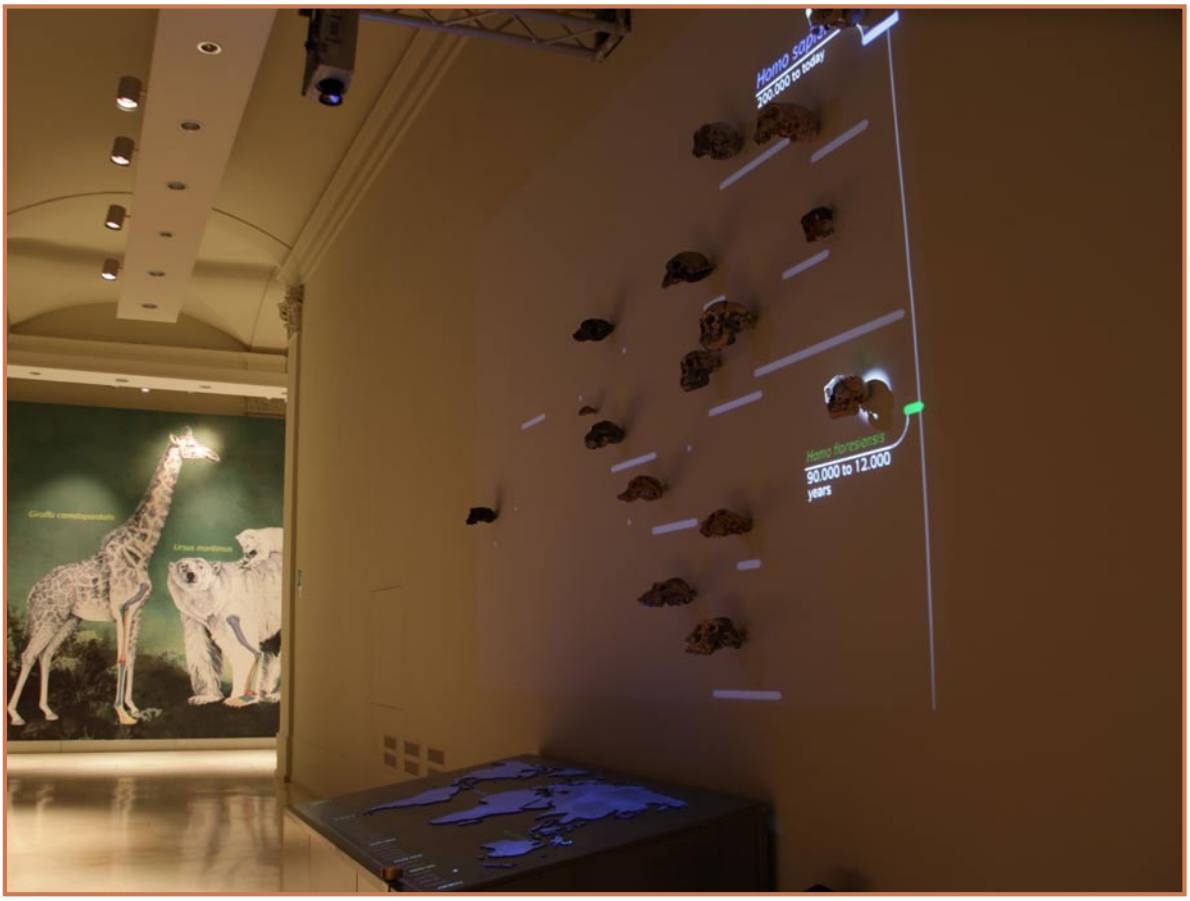
great global map

ONE SPECIES, NO RACES

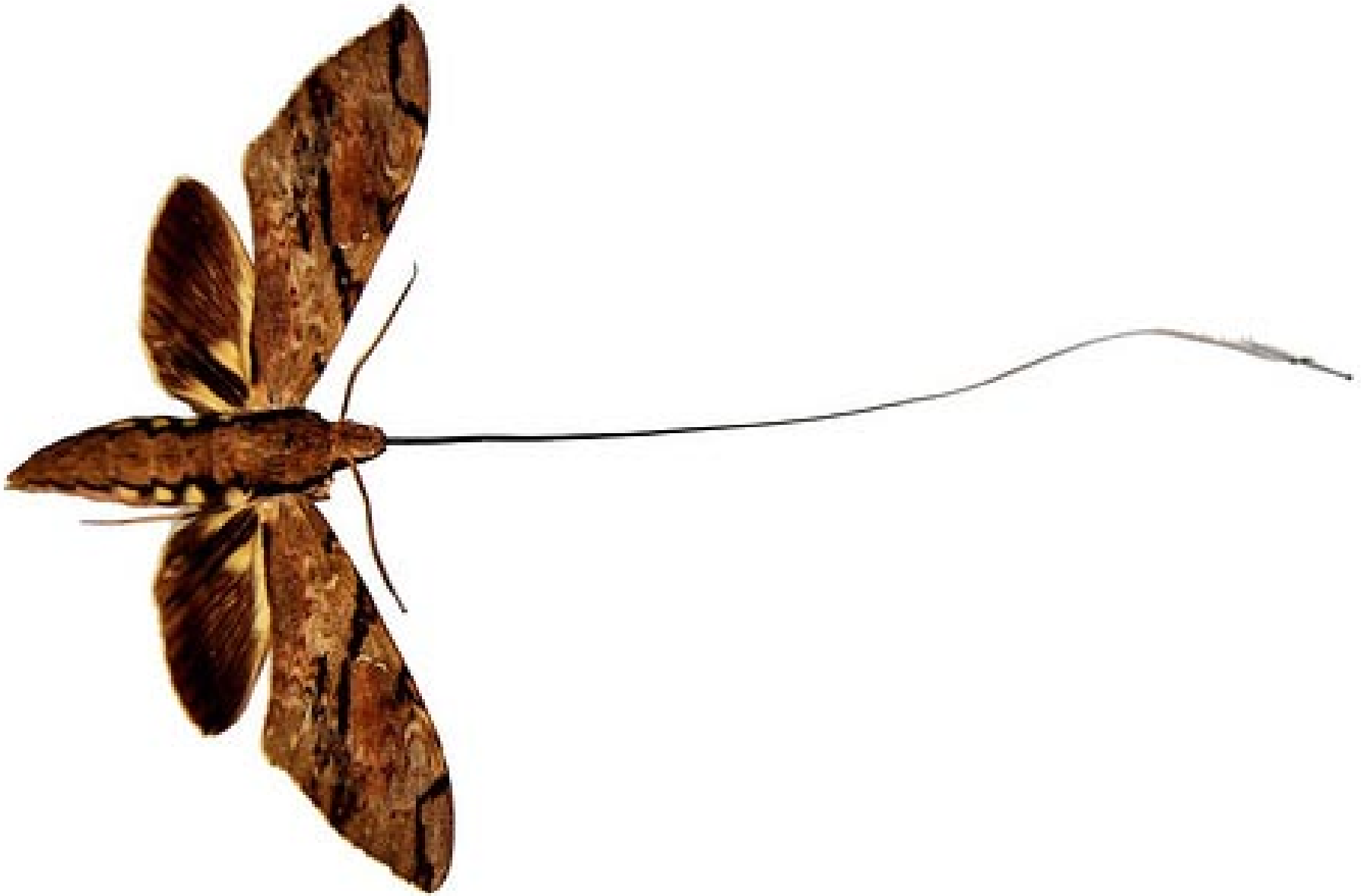
Darwin was a passionate advocate of the abolition of slavery, still a scourge in his day, and was also **a defender of the biological unity of mankind** at a time when this issue was still debated. Modern biology has come down firmly on Darwin's side. As shown in the "bushy" tree of human evolution, several species have typically coexisted throughout the history of the hominid family. Now, there is only one very close-knit hominid species, *Homo sapiens*. DNA studies have shown that in the human species today there is much less variation than can be found among West African chimps alone. Since mutations accumulate with time, this alone is evidence that our species has recent origins, and that any variations we see within it are more recent still. What is more, **the kind of genetic variation that we do see today is ephemeral and continuous**, that is without clear biological boundaries between populations or specific sets of variations characteristic of a population. As a result, while there are clearly minor geographic differences among the populations of mankind in features such as in skin colour and blood group frequencies, **it has proven impossible to classify us into definable "races"**.

races panel

THE HOMINIDS' BUSH: A JOURNEY THROUGH SPACE AND TIME



here interactive hominids exhibit



Darwin first saw this astonishing orchid from Madagascar, *Angraecum sesquipedale*, in 1862. Its foot-long green throat holds nectar - the sweet liquid that draws pollinators - but only at its very tip. "*Astounding*", Darwin wrote, of this strange adaptation. "*What insect could suck it?*" He predicted that Madagascar must be home to an insect with an incredibly long feeding tube, or proboscis. Entomologists were dubious: no such insect had ever been found there.

Charles Darwin died in 1882, and more than 40 years later, his insight was confirmed. A naturalist in Madagascar discovered the giant hawk moth, which hovers like a hummingbird as its long, whip-like proboscis probes for the distant nectar. The moth's scientific name, *Xanthopan morganii praedicta*, honors the prediction of the scientist who never saw it, but whose theory told him that it must exist.

In everyday use, the word "*theory*" often means an untested hunch, or a guess without supporting evidence. We say: "*it is just a theory*". But for scientists, a theory has nearly the opposite meaning. **A scientific theory is a well-substantiated and corroborated explanation of a part of the natural world that can incorporate laws, hypotheses and facts**. The theory of gravitation, for instance, explains why apples fall from trees and astronauts float in space. Similarly, the theory of evolution explains why so many plants and animals - some very similar and some very different - exist on Earth now and in the past, as revealed by the fossil record.

A theory not only explains known facts; it also allows scientists to make predictions of what they should observe if a theory is true. **So scientific theories are testable**. New evidence should be compatible with a theory. If it isn't, the theory is updated, refined or rejected. The longer the central elements of a theory hold - the more observations it predicts, the more tests it passes, the more facts it explains - the stronger the theory.

Many advances in science - the development of genetics after Darwin's death, for example - have greatly enhanced evolutionary thinking. Yet even with these new advances, **the scientific theory of evolution still persists today, much as Darwin first described it, is strongly corroborated by countless and converging evidences, and is universally accepted by scientists.**

Displayed objects: Darwin's moth and Madagascar orchid

ENDLESS FORMS MOST BEAUTIFUL AND MOST WONDERFUL

The orchid plants, members of a vast and ancient family, enchanted Darwin late in life and intrigue us still, more than a century later. With over 20,000 species in the wild today, each astonishingly adapted to its habitat and its pollinator in shape, size, color or fragrance, orchids owe their amazing diversity of shape to the coevolutions with their pollinators and to the ingenious expedients that enabled them to reuse parts that had evolved for other reasons. **Orchids embody life's richness and creativity**. And it is that richness and creativity that Darwin's work allows us to understand.

Displayed objects: live orchids

Two centuries after Darwin's birth his **insights remain fresh and vital**. As a young man, he dared to ask how the natural world came to look as it does. How can we explain the amazing diversity of life all around us? And his answer - through evolution by natural selection - only **increased his sense of wonder**, as revealed in the famous poetic ending of *On the Origin of Species*:

"It is interesting to contemplate an entangled bank,
clothed with many plants of many kinds,
with birds singing on the bushes,
with various insects flitting about,
and with worms crawling through the damp earth,
and to reflect that these elaborately constructed forms…
have all been produced by laws acting around us…
There is grandeur in this view of life,
with its several powers,
having been originally breathed
into a few forms or into one;
and that, whilst this planet has gone cycling on
according to the fixed law of gravity,
from so simple a beginning
endless forms most beautiful and most wonderful
have been, and are being, evolved".