Natural History Museum of Venice Giancarlo Ligabue

ENG | Booklet to visit the Museum

Get ready for a suggestive and engaging experience... and discover the secrets of nature and living beings...

THE BUILDING

The Museum is housed in the Fontego dei Turchi, a palace built by the Pesaro family in the first half of the 13th century. It was then purchased by the Republic of Venice and, over the years, it was alternately used as an official site intended to accommodate foreign nobility, as well as used by various rich families. From 1621 it was used for about two centuries as a dwelling place and business site by Turkish merchants.

From the 1860s onwards, it was totally rebuilt, architecturally inspired by the double loggia plan in the so-called Venetian-Byzantine style derived from the 16th century plans of Jacopo de' Barbari. The Fontego today is one of the most characteristic buildings overlooking the Grand Canal, where it is easily recognizable because of the two side towers and crowning battlements.

THE HISTORY

The Museum was established in 1923 to house several local scientific collections, particularly those of the Correr Museum and the Istituto Veneto di Scienze, Lettere e Arti. Over time, this material has increased through acquisitions and donations, to make up the present heritage numbering over two million natural objects, which includes zoological, botanical, paleontological and ethnographic collections.

SCIENTIFIC ACTIVITIES

The Museum carries out scientific research activities, often collaborating with other prestigious scientific institutions. Especially important are the studies on the environment of the Venice Lagoon, the creation and implementation of biodiversity databases, field- and museum-based studies and scientific assessments. The Museum also houses some naturalistic associations that collaborate to both research and educational activities.

EDUCATIONAL ACTIVITIES

To promote the spread of natural sciences and the scientific culture, the Museum offers educational services directed to students, teachers, adults, trainers and technicians. Educational activities for students of all levels are carried out by professional operators, representing a true reference point for local schools and other institutions.

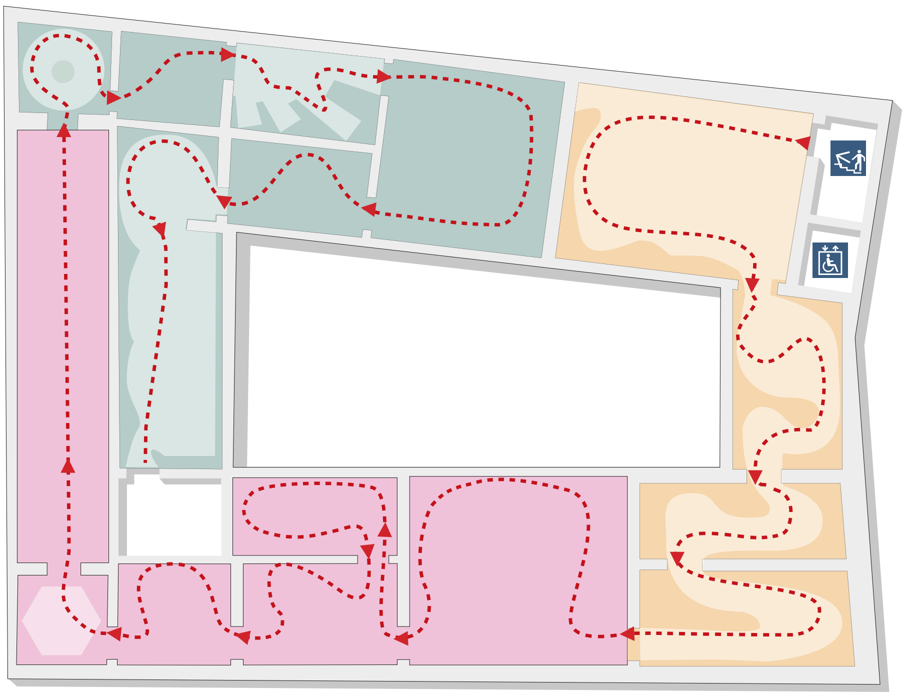
THE LIBRARY

The Museum vast scientific library is unique in Venice, rich in over 44.000 monographs and 2.500 periodicals. It also contains numerous 16th and 17th century publications, and 19th century manuscripts.

THE NEW MUSEUM

A stimulating, enthralling, and structured exhibit.
On the **ground floor** are the Cetacean Gallery and the Marine Aquarium that reproduces the extraordinary ecosystem of the "tegnùe" (natural rocky formations off the Venetian coast) and illustrates their rich biodiversity.

The **second floor** is organized into three main sections:
ON THE TRACKS OF LIFE. Dedicated to fossils and palaeontology, it spans along four rooms, following fossil traces, to portray the birth and evolution of life on Earth, from the origin of earlier organisms, almost 700 million years ago, to the appearing of man, "just" 40,000 years ago.
COLLECTING TO ASTONISH OR COLLECTING FOR RESEARCH. It tells the evolution of natural history collecting and the origin of scientific museology. Spanning from aesthetically organized displays to the proper scientific classification, it focuses on the explorers of yesterday and today, the history of collections and their formation, the Natural History Museum of Venice as well as on natural science museums in general.
THE STRATEGIES OF LIFE. It offers a novel perspective of the complexity of nature and living organisms, revealed through the survival strategies developed by animal and plant species in the course of evolution. Species of today or extinct, micro and macro-forms, inhabitants of waters, lands and the sky: a journey in the diversity of living forms, marked by profound differences as well as surprising similarities.

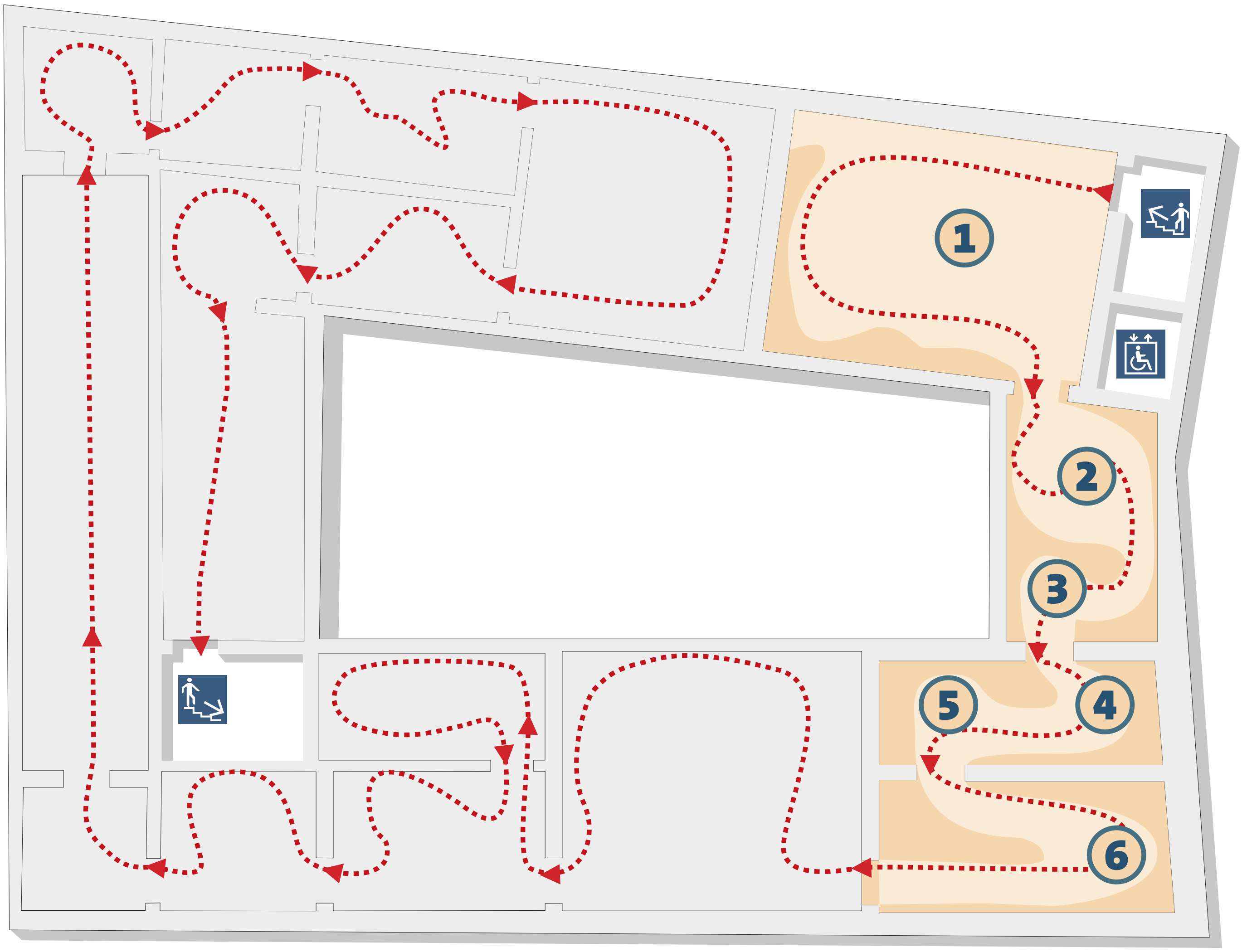


MUSEUM ITINERARY
Second floor

- **On the tracks of life**
- **Collecting to astonish, collecting for research**
- **The strategies of life**

ON THE TRACKS OF LIFE
(SULLE TRACCE DELLA VITA)

Fossils are all that remain of only a small number of the species that lived on the planet. Traces of a journey that lasted millions of years that are brought to light by researchers both to understand the past and to imagine the future.



1

SEARCHING FOR DINOSAURS (ALLA RICERCA DEI DINOSAURI)
Palaeontology and the Ligabue's scientific expedition

Searching for and studying fossils (Cercare e studiare i fossili)
Buried for millions of years, fossils can be admired and studied thanks to the work of palaeontologists, who are constantly searching for tiles from the vast mosaic of the history of life. It was in this spirit that Giancarlo Ligabue organised an expedition to the Téneré Desert in 1973. Going after the huge skeletons that are rising above the Sahara sands, he uncovered the fossil remains of animals and plants dating back over 100 million years, which included a dinosaur and a giant crocodile.

Palaeontology and the study of the past (La Paleontologia e lo studio del passato)
On the borders of biology and earth sciences, palaeontology studies the organisms that lived in distant ages. Through their study of fossils, palaeontologists play a fundamental role in understanding the evolution of species, environments, climate and the geography of the past. Very often fragmentary and dispersed, fossils can only be studied after a lengthy, painstaking process of research, excavation, cleaning, consolidation and carriage to a laboratory for fossil identification. In the Veneto region, palaeontology boasts a tradition dating back to the XVI century if not earlier, and reached its height in the 1800s with outstanding scholars such as Giovanni Battista Brocchi, Tommaso Antonio Catullo and Abramo Massalongo. Studies are currently ongoing with expeditions and research projects using the most up-to-date technologies.

The Ligabue's expedition (La spedizione Ligabue)
In February 1973, Giancarlo Ligabue and Philippe Taquet from the National Museum of Natural History in Paris organised a palaeontological expedition to the desert of eastern Niger. Excavation started on November 17th in the site of Gadoufaua and lasted around a month. The vastness and abundance of the deposits made it possible to extract a huge amount of fossils that, once consolidated by the expedition technicians, were taken to Europe where they were restored and studied at the Museum of Paris. Amongst these finds was the almost complete skeleton of an *Ouranosaurus nigeriensis*, which Giancarlo Ligabue donated to Venice together with other fossils from the same site. The fossils were then mounted in the Museum of Natural History of Venice and displayed to the public in 1975.

From legend to research: towards the Sahara (Dalla leggenda alla ricerca: verso il Sahara)
The protagonists of the Italo-French expedition sum up their venture and preparations as follows: *"the legends of the Tuareg, the mysterious blue men of the Sahara, describe enormous stone snakes coming out of the golden sands and ancient buried treasures. Geologists and French mining specialists working in the area of the Ténéré (southern Sahara) have seen huge fossil remains. Different kinds of specialists are needed for the expedition: palaeontologists, geologists and mineralogists, archaeologists and palaeo-histologists, cartographers, photographers, organisers, drivers, interpreters... Finally, the team is complete, the itinerary and timing defined, supplies and instruments ready, and the means of transport have been chosen. We set out on November 4th 1973".*

The bones emerge (Affiorano le ossa)
"The route to reach it is complex and tiring: the departure base is in Agadés (Niger), the ancient city of clay in Sahel, on the borders of Teneré. Tents are put up in the base camp, the work is organised and the territory to be explored divided up. Links with Agadés will be guaranteed by a small plane to guarantee logistical needs and supplies. One of the largest dinosaur deposits in the world is located in Gadoufaoua, 170 km south-east of Agadés: 180 km long, and two km wide. The action of the wind on the sand has already brought the fossil remains to light: at last, the "stone serpents" from the Tuareg legends!"

The excavation and discoveries (Lo scavo e le scoperte)
"The scientists' work has begun: surveys and maps, measurements, photographs before the fossils can be freed from the sediments holding them prisoner, all of which is done with the greatest caution using hammers, scalpels, brushes, trowels and spatulas. The bone fossils are impregnated with consolidating substances; once they have been freed they are wrapped in gauze and plaster so they can be removed without the risk of fracturing and, later, they will be packed for transport. All stages are carefully described in the excavation "notebooks" that will be the basis for the final scientific reports. The results of the expedition are surprising: In addition to the large skeleton of the Ouranosaurus nigeriensis numerous other fossils of various animals and plants have been discovered, including the enormous crocodile, Sarcosuchus imperator, which is over ten metres long."

2

STONE CREATURES (CREATURE DI PIETRA)
Testimonies of a lost world

Fossils (I fossili)
The work of the devil or creations of the gods? A joke of nature or the remains of dragons and giants? These "stone creatures" have never ceased to arouse both curiosity and concern, fuelling myths, legends and fanciful hypotheses.

In actual fact, fossils are all that remains of countless animal and plant species that followed one another in succession on Earth from the beginnings of time until a few thousand years ago. The fossilisation process is, however, extremely rare and is linked to particular environmental conditions. Fossils are therefore a precious source of information about the natural environments of the past.

What becomes a fossil? (Cosa si fossilizza)
Generally speaking, once they have died, organisms decompose very quickly leaving no trace of their existence. In the rare cases when this does not occur, the remains, as well as the traces of their activities such as dens, imprints (ichnofossils) and excrements (coprolites) become fossils. However, not all the parts of an organism are preserved as a fossil. “Hard” parts such as shells, bones and teeth, as well as trunks and seeds, are more likely to be preserved than “soft” parts such as skin, muscles and leaves, which decompose much faster. Chemical substances such as coal and petroleum also have organic origins (chemical fossils) and are the remains of the existence of ancient plants and animals.

Pseudo fossils and… fake fossils! (Falsi fossili e… fossili falsi!)
Just because it looks like a fossil it does not mean it actually is: in the rock world many natural processes produce shapes and structures that are vaguely similar to animals or plants. Typical pseudo fossils are the dendrites, which result from mineral infiltrations in the rock and are similar in shape to plants; another example is strange shaped silica nodules. However, there are also fake fossils, made for the purpose of deception; mostly destined for souvenir markets, they may also enter the scientific field at times. These are either simple rocks that have been painted or engraved or real fossils that have been deliberately changed, and are sometimes the result of combining different parts of organisms.

How fossils are formed (Come si forma un fossile)
During the fossilisation process the remains of an organism and the sediment they are in undergo radical changes: the sediment becomes compact rock and the organism is transformed into a fossil, changing its composition while preserving its general shape. Once the mineral substances that are in the water circulating around the sediments (calcite, dolomite, silica, and pyrite) have replaced the organic compounds completely, replacement mineralization takes place; when they are deposited in the empty cavities of the soft tissues, as is the case with bones, permineralization takes place. However, very often plant remains undergo a carbonization process in which all that remains of the plant is carbon in the form of coal. When the remains of plants or small animals near hot springs full of salts are covered with salt deposits, encrustation fossilisation takes place, which is very common in the sedimentary rocks known as travertine.

Not just stone (Non solo pietra)
In very rare cases, at times even when they are still alive, organisms can be engulfed by materials such as bitumen, ice or resin so that they are preserved without any great changes. The presence of bituminous ground led to the outstanding preservation of large-sized animals as well, in which even parts of the fur and soft tissues were preserved. In colder areas, on the other hand, animals and plants may quickly be covered with snow and ice, and are therefore preserved inside the thick layers of frozen ground. Parts of plants and small animals can also be completely absorbed in dense fluids such as resin: amber is the result of a particular fossilisation process of resin, in which the entire organism in it is preserved almost completely intact.

Fossils and rocks (Fossili e rocce)
Nearly all fossil deposits are found in the rocky layers of the ground, from which they can emerge as a result of natural erosion processes, caused for example by wind or rain. Fossils are not to be found in all rocks: with few exceptions, they are present only in sedimentary rocks, formed by the settling and later consolidation of sediments in environments such as the bottom of the seas, lagoons, lakes, swamps, and much more rarely on land. Since the forces behind them usually destroy any organic remains, it is highly unusual, though not impossible, to find fossils in magmatic rocks, which are created by the cooling down of melted magma inside the Earth, or in metamorphic rocks that result from sedimentary or magmatic rocks that have been transformed by high pressure and temperatures.

What a fossil is made of (Com'è fatto un fossile)
A fossil is made of both the petrified remains of an organism and their negative imprint on the external rocky matrix. The original material, including the hard parts, is preserved very rarely; more often than not, what comes to light is an accurate model of the original, made up of material that filled the cavities created in the rock as the animal and plant remains gradually dissolved. If the cavities are not filled, only the external imprint is preserved and perhaps, as is the case with molluscs, the internal mould created by the sediment that initially penetrated the inside of the shell.

The long walk of life (La lunga marcia della vita)
Fossils are proof of the existence of different life forms, at times strange and unusual, that are now extinct; but they are also proof of certain animal and plant species from which today's forms are derived, and are thus testimony to the small and large changes in shape and size owing to evolution. Unfortunately, this "reconstruction" is only possible in very few examples, so a large number of empty spaces still remain in the puzzle of life. However, there are some organisms that have not much changed for dozens or even hundreds of millions of years and these are regarded today as real "living fossils".

The geography of the past and the passing of time
(La geografia del passato e lo scorrere del tempo)
During the lengthy history of the Earth, the inclination of the rotation axis, the geographical position of the continents and oceans, and the composition of the atmosphere have undergone continuous changes, while entire groups of animals, plants and micro-organisms have appeared and disappeared. The effects of these changes have been partially "recorded" into the rocks. On the basis of these important events and the radiometric dating of rocks, it is possible to divide the past into time intervals of various lengths; these are organised into eras, periods, and epochs and constitute the entire geochronological scale of time. On the one hand, fossil dating makes it possible to compare ancient biological communities in different areas of the planet, and on the other, to interpret the evolutionary pathway of extant species and communities.

3

THE PATH OF LIFE (IL CAMMINO DELLA VITA)
The long and complex course of evolution

The Precambrian (Il Precambriano)
This was both the longest and the oldest age, beginning with the origins of the planet itself until just over 500 million years ago. Life rose and developed in the Precambrian: the oldest known fossils, the stromatolites, are around 3.7 billion years old and are the evidence of the activity of primitive single-cell organisms. The first multi-cell beings instead, somewhat similar in shape to modern invertebrates, date back to not more than 670-700 million years ago and are represented by the so-called Ediacara biota.

The Palaeozoic (Il Paleozoico)
The Palaeozoic began with the Cambrian period, around 540 million years ago. In fact, a myriad of different life forms, some of which were already highly specialised, suddenly appears in the rocky layers of that age. Most marine invertebrates developed during this period, while the lands above sea level, originally deserted, were colonized first by plants and then by invertebrates, amphibians and reptiles. Towards the end of the Palaezoic, the movements of the continental masses resulted in the formation of one large continent called Pangaea, with the rise of many mountain chains.

The Palaeozoic sea (Il mare del Paleozoico)
The most famous fossil from the Plaeozoic period are the trilobites, which were widespread on all sea beds with an enormous variety of species. Graptolites, small colonial animals with soft bodies protected by hard capsules, were widespread as were brachiopods, organisms with mollusc-like shells, very few species of which still survive. Other organisms include jelly fish and corals, echinoderms (starfish, sea urchins and sea-lilies), bryozoa and molluscs. The larger sized invertebrates include the eurypterids, big-clawed predators that were similar to today's scorpions and could grow up to three metres long. Ostracoderms, the first vertebrates, appeared during the Ordovician; these were fish-shaped but had no jaws and were protected by numerous bony plates. The Silurian then saw the rise of the placoderms, which had a mobile jaw and paired fins, while true fish did not appear until the Devonian, slightly over 400 million years ago.

The conquest of land (La conquista delle terre emerse)
Towards the end of the Silurian, over 400 million years ago, the first plants began to appear on land, along the shores of lagoons and coastal pools. These plants had no roots and were small vertical stems that reproduced by spores. Over several million years, plants were responsible for a key transformation in the terrestrial atmosphere and it was thanks to this change that animals were also able to colonise the land above sea level. The first traces of amphibians appear in Devonian rocks. This group developed from archaic fishes living in swampy areas subject to desiccation, which developed the ability to breathe oxygen from the air and to move on land. *Ichthyostega*, the oldest known amphibian, had well-developed limbs but still had some of the typical features of a fish. The amphibians became widespread during the Carboniferous with the order of labyrinthodonts, now extinct, which included some 'gigantic' species such as *Eryops*.

The forests of the Carboniferous (Le foreste del Carbonifero)
During this period, extensive forests of ferns, lycopods and horsetails grew in tropical areas, where the climate was constantly hot and humid, and later gave rise to today's vast coal deposits. The first conifers appeared towards the end of the Carboniferous. This widespread development of plant life facilitated the proliferation of the fauna on land, including many arthropods such as spiders, centipedes, millipedes, scorpions and insects. The first fossil remains of winged species also date back to this period, some of which were of considerable size such as Meganeura, a huge dragonfly with a wing span of around 70 cm.

Early reptiles (I primi rettili)
The first reptile fossils also come from the Carboniferous deposits. These animals were completely independent of water thanks to two important evolutionary innovations: their skin was covered with corneous scales, thus guaranteeing the total control of transpiration, and their eggs were protected by a shell, so that embryos would not dehydrate. These changes made it possible for reptiles to colonise almost any land habitat, no matter how inhospitable, even deserts. Very cold areas were the only exception, since their body temperature still depended on the external environment.

4

The Mesozoic (Il Mesozoico)

Known as the "Reptile Era" because of the great development of these vertebrates, the Mesozoic was also the age in which modern dominant groups, such as birds and mammals, originated. The unbelievable similarity among fossils discovered on lands separated by oceans is due to the former existence of one vast continent, the Pangaea. It was only with its later fragmentation that flora and fauna began to differentiate.

The sea in the Mesozoic (Il mare nel Mesozoico)
Thousands of species of ammonites, coiled-shell molluscs, and squid-like belemnites, with an inner shell, are found in Mesozoic rocks. Bivalve molluscs replaced the brachiopods, occupying their ecological niche, and new groups of corals and echinoderms arose. The formation of huge cliffs dates back to this period, including those that formed part of today's Alps, and are a result of the building capacity of calcareous algae, sponges, corals and rudists, typical cone-shaped bivalves of the Cretaceous. Arthropods were especially widespread during the Jurassic, with a considerable number of decapod crustaceans and the presence of various species of horseshoe crabs, the general shape of which has remained unchanged up to today. Among aquatic vertebrates,
modern fishes, the teleosts, developed and began to replace the earlier groups of bony and cartilaginous fishes.

The Reptile era (L'era dei rettili)
The Mesozoic Era was one of the most important periods in the evolution of vertebrates. The geological layers of the Triassic reveal both the traces of the first dinosaurs and of many other reptiles, now extinct, such as the pterosaurs, first flying vertebrates, the ichthyosaurs, marine reptiles similar to modern-day dolphins, and the armoured placodonts, which had a mollusc-based specialised diet. However, alongside these groups that have now disappeared, were also primitive crocodiles and turtles. In the following Jurassic and Cretaceous periods, dinosaurs became the dominant group, inhabiting nearly all lands, while plesiosaurs and mosasaurs, deadly predators with fin-shaped limbs, appeared in the seas.

The origins of mammals (L'origine dei mammiferi)
The remains of a new group of vertebrates, characterized by diversified teeth and a more efficient skeleton, also appear for the first time amongst Triassic fossils. These were the first mammals, descendants of the synapsid reptiles of the Permian. Throughout the Mesozoic, in other words until dinosaurs disappeared, they remained very small in size, although they soon developed into the three groups known today, monotremes, marsupials and placental mammals, all of which already existed in the Cretaceous.

Compared to their reptile forerunners, mammals show morphological and physiological innovations that were the key to their success. Covered with fur and able to self-regulate their body temperature, they could cope with considerable changes in temperature. They also developed mammary glands that allowed the female to nourish her young.

First birds or last dinosaurs? (Primi uccelli o ultimi dinosauri?)
Discovered amongst the rocks of late Jurassic, the remains of *Archaeopteryx lithographica* showed a combination of reptile and bird characters, so that the species has long been regarded as a link between the two groups, significantly contributing to the hypothesis that birds derived from reptiles. However, new deposits have brought to light older feathered fossils that allows to date the appearance of feather-like structures, probably for thermal insulation, to early Jurassic. These latter were found also in small theropod dinosaurs, the coelurosaurs, which were probably able to regulate their own body temperature. The first true bird with a toothless beak, *Confuciusornis sanctus*, dates back to early Cretaceous and was discovered in large numbers in north-east China.

The Great extinction (La grande estinzione)
The end of the Mesozoic saw the disappearance of a great number of organisms: the second largest mass extinction in the history of the planet. All of a sudden, the large dinosaurs vanished, as well as the flying and marine reptiles, with the exception of seaturtles, while among the fossils of invertebrates ammonites, rudists and nearly all planktonic organisms also disappeared. The first great extinction had taken place at the end of the Palaeozoic Era, when entire groups were wiped out, marine invertebrates in particular. Such global crises seem to have been caused by drastic imbalances in the climate, probably due to the effect of a combination of causes about which there is no agreement yet among scientists.

5 6

The Cenozoic (Il Cenozoico)

At the beginning of the Cenozoic, the land arrangement was basically the same as we know it today and the fossils that go back to this period indicate that the climate was relatively hot, with zones characterized by tropical or warm temperate fauna and flora, even in those areas where the climate is much colder today.
The disappearance of most of the Mesozoic reptiles created a considerable number of open ecological niches, which were quickly occupied by birds and mammals.
The first traces of hominids appeared in the second half of the Cenozoic Era.

The Cenozoic sea (Il mare del Cenozoico)
In the seas, the vast gap created by the disappearance of many Mesozoic forms allowed the development of new species of corals, molluscs, echinoderms and fish, which were similar in appearance to modern forms. On the other hand, nummulites, single-cell organisms with shells that could reach more than 15 cm in diameter, were to be found in the Palaeogene only, before they became extinct at the end of the Oligocene. One of the most spectacular Cenozoic deposits is the area of Bolca, a locality near Verona that became famous for its fossils as early as the middle of the XVI century. Fish, crustaceans and marine molluscs, as well as large-sized land plants, were preserved in excellent condition inside the rock.

The fossils of Bolca (I fossili di Bolca)
Generally known as the "Bolca fossils", they actually come from several adjacent Eocene sites, which apparently differed from each other in period of formation and habitat. The prevalently marine fauna, represented by fish and invertebrates, come from the "Pesciara" and Mount Postale deposits and are representatives of a sub-tropical coastal marine environment. The fossils extracted from the lignite mines in the "Purga di Bolca" and Mount Vegroni include outstanding examples of large palm trees, crocodiles and terrapins that seem to indicate a continental swampy environment. One of the most surprising characteristics of these finds, regarding fish and crustaceans in particular, is their close similarity to today's marine fauna typical of both the tropical barrier reefs and the sandy, shallow-water beds covered by seagrass meadows.

The age of Mammals (L'era dei mammiferi)
During the Cenozoic the disappearance of the large Mesozoic reptiles made way for new, more advanced species of mammals. From the Eocene onwards, most of the ecological niches were occupied by a multitude of species highly diversified in morphology and size. These also included aquatic and winged species, which allowed the mammals to conquer the marine environment and part of the aerial space. The largest terrestrial mammals that ever existed, sometimes over 5 m tall, date back to the Oligocene, whereas the first carnivores, rodents, primates, cetaceans, artiodactyls and perissodactyls, orders that still exist today, all appeared already during the Eocene. Anthropoid apes and hominids developed only during the Miocene and the following Pliocene.

The climate during the Quaternary (Il clima nel Quaternario)
The beginning of the Quaternary was characterized by drastic cyclic variations in the climate. Very cold periods, with glacier expansion and a decrease in the sea level, were followed by intervals with a warm temperate climate, during which the increase in temperature resulted in the melting of most of the glacial masses and an increase in the sea level. These climatic changes, together with the consequent modifications of the coast line, left an indelible mark on both the morphology of the landscape and on the flora and fauna. The wide changes in the distribution range, the massive phenomena of migration and the ensuing alternate phases of isolation and reunion of species and populations had important consequences on today's life forms.

The glacial faunas (Le faune glaciali)
The characteristic environment of northern hemisphere during the glacial period is the steppe. The arid, cold plains of Europe were covered mainly by grassy vegetation and were inhabited by bison, reindeer, woolly rhinoceros and mammoths. The woods were the dominion of deer and wild oxen, while the caves were the home of large carnivores such as the cave bear. Around 10,000 years ago many cold-climate species became extinct, whereas others moved towards the poles or higher altitudes; so ended the last Ice Age and began the Olocene, the time in which we live today.

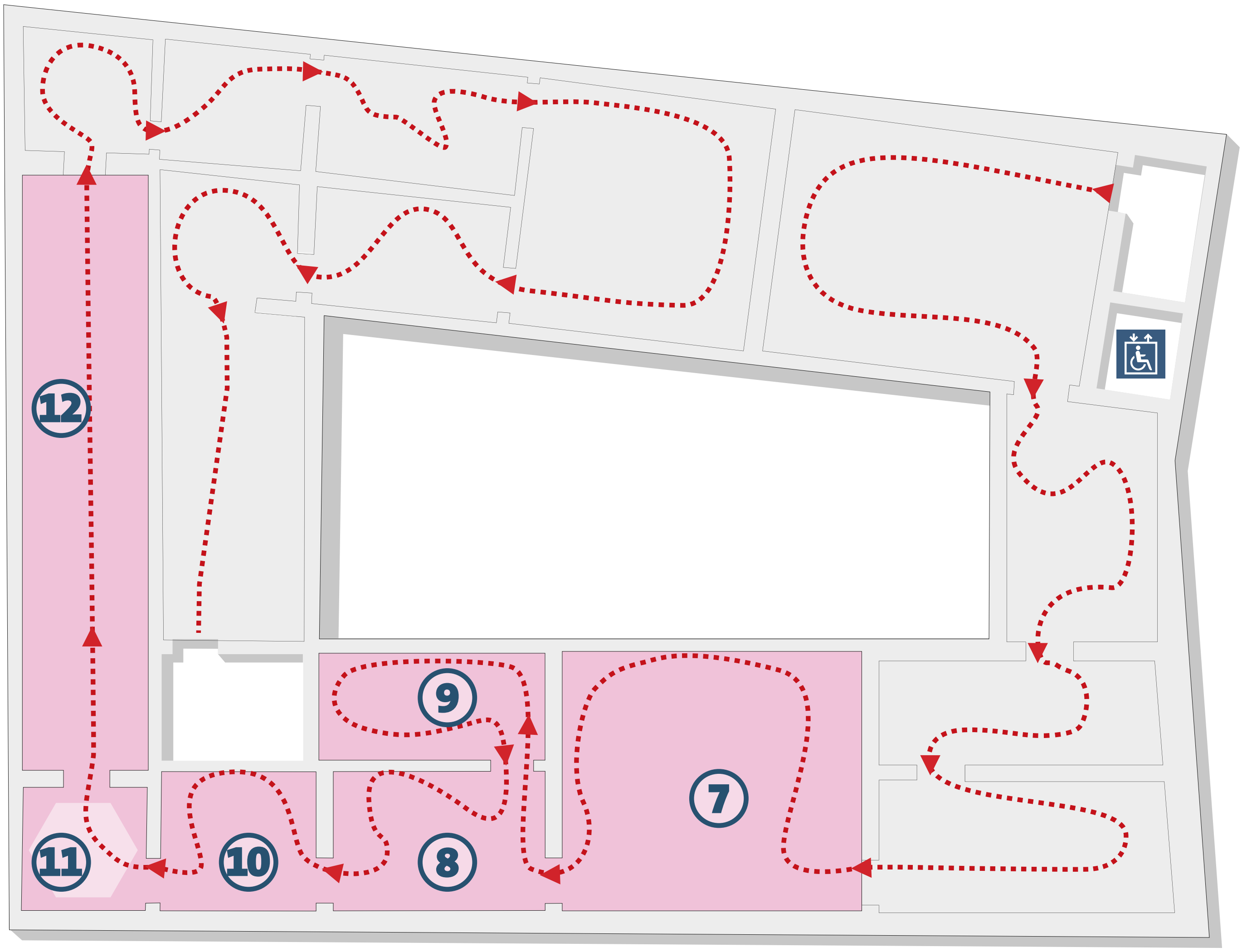
The origins of man (L'origine dell'uomo)
There is no doubt that the most important fossils from the Quaternary are those that document the origin and evolution of the genus Homo. Although well-defined at the general scale, the precise evolutionary course of our species is partially lacking in details since the continuous discovery of new finds brings into question earlier interpretations. However, there is general agreement that the African origin of hominids, together with the contemporary presence of different species in southern and eastern Africa and the following diffusion on other continents, lays upon solid foundations.

Hominids or apes? (Ominidi o scimmie?)
Based on palaeontological remains that are relatively scarce, often fragmentary and of an ambiguous nature, the actual boundary between apes and hominids is still a controversial subject. However, palaeontologists do agree on the definition of the australopiths as hominids, whereas other large primates, such as *Proconsul africanus*, clearly belong to anthropomorphic apes. So far, all known species of australopiths come from Africa, where they inhabited the savannah 5-6 million years ago. Of these, the most famous is *Australopithecus afarensis*, of which numerous skeletal remains have been preserved, including the famous "Lucy", as well as outstanding fossil footprints. The skeleton structure and the way this small hominid was able to move provide irrefutable evidence of a fundamental step in human evolution: the acquisition of the upright posture.

Homo (Homo)
Although australopiths also used natural objects as tools, it was their actual production that distinguished the first true representative of the human genus: *Homo habilis*.
The African *Homo ergaster* and the Asian *Homo erectus* seem to have originated from the latter and, having a stronger build and more developed brain, were able to create more advanced tools and used fire. Although the earliest remains that can be attributed to Homo sapiens appeared in Africa, the largest finds come from Europe and central Asia, and go back to the last glaciations. This was the Neanderthal man, *Homo (sapiens) neanderthalensis*, who took shelter in caves and left behind traces of a primitive cult of the dead. Modern man, *Homo sapiens sapiens*, appeared towards the end of the Neanderthals' course, for which it may be directly or indirectly responsible, leaving behind testimonies of dwellings, artefacts, rock paintings and carvings.

COLLECTING TO ASTONISH OR COLLECTING FOR RESEARCH
(RACCOGLIERE PER STUPIRE, RACCOGLIERE PER STUDIARE)

Rare, curious and precious objects, not only from travels and expeditions to distant lands, but also from everyday life. Natural History collections between aesthetic displays and a carefully ordered scientific tool



EXPLORERS FROM VENICE (ESPLORATORI VENEZIANI)
Tales of travels, studies and expeditions

7

Giovanni Miani
Autodidact, musicologist, poet, patriot and exile, Giovanni Miani adopted Venice as his native city and sought fame in his African explorations. In 1859 he organised an expedition in search of the sources of the Nile which, in 1860, after various vicissitudes, took him further up the river than any other European had ever been. Despite his perseverance and courage, he did not fulfil his aim: the sources were discovered later by the Englishmen Speke and Grant in 1862 and Miani died in Africa ten years later. The exhibits on display come from the 1,800 finds he collected during his first expedition, almost all of which he then donated to the city.

Biography of an explorer (Biografia di un esploratore)
Giovanni Miani was born in Rovigo in 1810. When he was fourteen he moved to Venice to stay with the patrician Pier Alvise Bragadin, believed by some to be his natural father and from whom he received a considerable inheritance that allowed him to cultivate various interests. A complex character, throughout his life he felt he was not really accepted by society and, as a result, strived for glory and honour in all his actions. After his debut as a musician, he took part in the 1848 rebellions in Rome and Venice, thus resulting in his political exile. It was not until much later, when he was over forty, that he decided to set out in search of the sources of the Nile. In 1859 he undertook his first expedition, which he was forced to give up. He made further attempts but in the meanwhile the sources were discovered by others. In 1871 he set out in search of rare, unknown animals in Central Africa, where he was to die in Monbuttu in 1872. His remains lie in the *Accademia dei Concordi* in Rovigo.

The conquest of Africa and the search for the Nile sources
(La conquista dell'Africa e la ricerca delle sorgenti del Nilo)
Following the industrial revolution, around the middle of the nineteenth century European countries began carrying out highly aggressive polices to expand their markets, resources and profits. Practically unknown until then, *Black Africa* became one of the main objectives of explorers and armies, evangelizers and merchants, driven by adventure and scientific curiosity, bullying and a missionary spirit. Since its course was still partly unknown, from 1840 to 1870 the Nile was at the centre of European interest. The feasibility of the Suez Canal was under study and the control of this area was seen as strategic matter; therefore, a better knowledge of central-east Africa became fundamental.

The search for the Nile sources, which had always been shrouded in mystery, not only posed a fascinating challenge for many explorers, whether independent or sent by the Geographical Societies of various countries, but above all was a serious economic and political issue.

The expeditions (Le spedizioni)
In 1858 Miani presented the French Geographic Society with the "Nouvelle carte du bassin du Nil" with notes regarding his project for exploring the river.
Once he had received the support of Napoleon III, the following year he formed his first expedition, hiring a captain, drawer, surveyor, chemist, interpreter, soldiers and bearers. For one reason or another, many of them proved unreliable and were ultimately a hindrance to the project's success.
However, Miani went up the Nile as far as Galuffi, in today's Uganda, the southern-most point of his travel; here he engraved his initials on a large tree but then, exhausted by disease and led astray by wrong directions, was forced to give up. With the support of the Egyptian Viceroy Mohamed Said Pascià, he tried once more but again without success at the end of 1860. He thus returned to Italy to rally support for a third expedition.
Although he was beaten by Speke and Grant, he refused to resign himself immediately and tried to refute their result more than once.

Travel diary (Diario di viaggio)
When in Africa, Miani kept careful note of not only his adventures and vicissitudes but also his bitter disappointments, notes he was then to rework in Venice between 1862 and 1865, turning them into a handwritten diary embellished with evocative drawings in pencil. Conserved in the Museum library together with letters, manuscripts, plates and drawings, his journal offers a passionate portrayal of the route and the ups and downs of the expedition, together with detailed descriptions of the peoples he met and their lifestyles.
This therefore represents a formidable source of information that both integrates and completes the finds on display with extraordinary coherence.

The history of the collection (Storia della collezione)
Amassed between 1859 and 1861, Miani himself brought the collection to Italy where it was put on display first in Florence, which was then the capital of Italy, and later in Turin. Donated to the City of Venice in 1862, at first it was arranged in the rooms of the Casa d'Industria in accordance with Miani's precise indications.
The collection was formally entrusted to the Museum in 1866 and put on display, on the ground floor of the *Fondaco dei Turchi* that had just been restored, in 1880. In 1930 it was moved to the room we can see today, which is a careful reproduction of the original layout Miani illustrated in a signed lithograph sketch.

Miani and music (Miani e la musica)
Before fulfilling his true passion as explorer, in search of "glory for himself and his homeland", Miani tried his hand as a composer. For many years he also worked on a Universal History of the Music of all Nations, of which, however, he only managed to publish the first volume, at his own expense. In the original plates conserved in the Museum, depicting instruments and musical scenes from all over the world, his passions as musicologist and explorer are intertwined, as it is evident from the numerous musical instruments he collected during his African explorations, as well as in certain passages from his diary on this subject: *"(...) these peoples have an unbelievable amount of wind instruments, strings and percussion. Trumpets both large and small made of elephants' teeth, zithers made of tortoise shell and two horns (...). Drums of all kinds, even made of ivory, skilfully hollowed out like their bracelets."*

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Giuseppe de Reali

A passionate "big game" hunter, Count Giuseppe de Reali (1877-1937) put together an impressive collection of hunting trophies and other colonial style items during his various safaris to northern and equatorial Africa. Mainly made up of large animals but also ethnographic material and evocative photographs, when he died his collection was donated by his heirs to the City of Venice. Although it had no scientific objectives, together with the materials brought to Europe by other travellers and explorers of the same period, de Reali's collection contributed to the knowledge of ethnographic and naturalist knowledge of the African continent.

Biography of a "great hunter" (Biografia di un "grande cacciatore")
Giuseppe de Reali was the last descendant of a Venetian family of landowners with vast stretches of terrain between the Lagoon and the surroundings of Treviso. An eminent political and financial figure in Venice, senator of the Kingdom of Italy as well as mayor and podestà of the municipality of Casier, he was made count by King Vittorio Emanuele III at the end of the '20s. De Reali loved art, as can be seen in some of his sculptures still present in his Villa of Dosson, as well as in the many archaeological finds from his lands in Altino, but his true love was big game hunting. It was to this purpose that between 1898 and 1929 he set out on no less than twelve expeditions, mainly to northern and equatorial Africa. He died unexpectedly in 1937, without leaving any direct heirs, and was buried in the family tomb on the island of San Michele in Venice.

Colonialism and big game hunting (Colonialismo e caccia grossa)
The process of imperialist colonisation of Africa took place from the nineteenth to the early

twentieth century. As was the case in the rest of Europe, in Italy colonial policy went hand in hand with the belief of the supremacy of the "white man" and his duty to civilise the entire world, as well as with his right to dominate and conquer nature, the animal kingdom and local populations. Widespread amongst European nobility and the middle class, the delight in trophies and big game hunting was part of this cultural climate. Mainly carried out in the African continent, the safaris were organised down to the smallest detail and often with a great profusion of means and resources. Typical equipment included diverse weapons and ammunition depending on the type of game being hunted, photographic equipment to immortalise the hunter with his kill, and whatever was needed for the on-site preservation of the trophies.

Villa de Reali and the trophy rooms (Villa de Reali e le sale dei trofei)
Upon his return home from hunting expeditions with the remains of the specimens he had killed, de Reali began transforming part of the family home in Dosson into a permanent exhibition of African animals and objects. He not only preserved classical trophies, but also used parts of the animals, such as bones, skin, horns and hooves, to create bizarre furnishings. The original lay out of the objects can be seen in various photographs that were taken in the villa, including some the director of the Natural History Museum had taken in 1938, before the collection was moved to the *Fontego dei Turchi*.

From private collection to public heritage (Da raccolta privata a bene pubblico)
De Reali's collection was donated to the City of Venice by his heirs, immediately after the Count's sudden death, and it was to be housed in the Natural History Museum. Numbering over 300 finds, it was reordered and arranged in two rooms, where we can still see it today, in accordance with the original aesthetic style. Opened to the public in 1939, from 1996 to 1998 it was the subject of detailed revision and cataloguing and was completely restored in 2000. De Reali left no written testimonies of his travels and the only document we have is "Some notes about my travels in Congo" that was left by his wife Amelia Pigazzi, who accompanied her husband on at least five of his safaris. Nevertheless, a systematic study of the materials, as well as archive and bibliographical sources, has made it possible to outline the itineraries of these expeditions and define the origin of some of the most important specimens.

Africa and its fauna: a paradise almost lost (L'Africa e la sua fauna: un paradiso quasi perduto)
Very few of the species in De Reali's collection are still as numerous in the wild as they were in the early 1900s. Some are now extinct, others are endangered and the rest are now to be found in much smaller areas. Although hunting certainly played a key role in this situation, other human activity that was often a direct result of colonialism also played its part. Today, the creation of large parks and nature reserves, together with the enactment of national and international laws regulating the capture, killing, use and trade of wild species have all made it possible to monitor African flora and fauna, and thus promote conservation. Using the information from their own collections and with special research programmes and environmental education, natural history museums also take an active part in the conservation of endangered species all over the world.

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Giancarlo Ligabue

A successful Venetian entrepreneur, for over thirty years Giancarlo Ligabue devoted himself with great passion to both exploration and scientific research, organizing many expeditions to five continents, often yelding the most amazing results. He is also the founder of the Study and Research Centre that bears his name. The ties between Ligabue's discoveries, research and collections and the Museum of Natural History of Venice are very close, also thanks to his considerable donations, first and foremost the Ouranosaurus nigeriensis on display in the first room of the Museum.

Biography of a today's explorer (Biografia di un esploratore di oggi)
Giancarlo Ligabue was born in Venice on October 30th, 1931. After attending the Secondary School in Venice and specializing in economics, his whole time was soon shared between his entrepreneurial activities and his great passion for scientific research and exploration.
A scholar of archaeology and palaeontology, he completed his doctorate in palaeontological studies at the Sorbonne in Paris (1974) and later received several international awards. In 1978 he founded the *Ligabue Study and Research Centre* that, with a scientific board made up of teachers and scholars from the most important Italian and foreign institutions, organised excavations and explorations throughout the world.

Activity of the Ligabue Study and Research Centre
(Le attività del Centro Studi e Ricerche Ligabue)
Conceived by Ligabue as a *"school of fieldwork experience, open to young researchers from all over the world, aimed at the sciences of Man and the Earth"*, the LSRC was founded in 1978, as the completion of a research path that had already produced great results, in particular the discovery of the Sahara deposit of dinosaurs in Gadoufaoua. The Centre's studies can be divided into four lines of research: anthropology, archaeology, palaeontology and natural sciences.
In the course of over one hundred and thirty missions, six deposits of dinosaurs, five of Hominidae fossils, various ethnic groups facing extinction or unknown in the western world were discovered, as well as buried cities, necropolis, settlements, megalithic centres, rock paintings and graffiti, seven new species of animals and fossil footprints.

Anthropology (Antropologia)
Researches carried out by the Centre in the ethnographic field concentrated on the study of religious beliefs of primitive peoples, focusing on the music-dance-ecstasy relationship in particular. The figure of the Shaman and Amero-Indi curanderos was studied and documented, including the last shamans in Chile, Peru, Ecuador, Bolivia, Mongolia and Kazakhstan. The origins of shaman secrets and art were also analyzed in further depth thanks to the study of signs discovered in ancient hidden sanctuaries, identified in the Peruvian Andes.

In addition, a 1995 expedition to Mount Borradaile (Australia) discovered unique rock paintings from an aboriginal ceremonial centre dating back to over 15,000 years ago.

Archaeology (Archeologia)
Driven by his tireless curiosity in history, Giancarlo Ligabue also studied other mysteries of the past, such as the disappearance of the lost army of King Cambyses that, according to Herodotus, had been swallowed by Sahara's sands over 2,500 years ago, as well as the search for the mythical Eldorado and its lost cities. Hence his expeditions to Iran (1975-1978) and Belize (1979-1982), where ancient settlements were discovered; to Turkmenistan (1991-1994), which revealed a vast necropolis from the III century BC; to Peru (1987-1994), with the discovery of mausoleums, caves, rock drawings, sacrificial altars and tombs, including that of a pre-Incan shaman; to Easter Island, where he carried out no less than three excavations. Then he went once again back to Turkmenistan (1995-2010), where he not only discovered two new cities and a necropolis but also proved the existence of a new civilisation from IV-II century BC, the "Civilisation of the Oases", regarded by experts as one of the greatest contemporary discoveries in archaeology.

Palaeontology (Paleontologia)
Besides the famous discoveries of the remains of African dinosaurs in Niger and other Cretaceous sauropods from South America, which had then stimulated the creation of the LCSR, other findings characterized his activity in this field, such as the identification of previously unknown fossil species, some of which were then named after Ligabue (the small cretaceous dinosaur *Ligabueino andesi*, the oligocene creodont *Masrasector ligabuei,* the cretaceous pterosaur Cearadactylus ligabuei and the cretaceous scorpion *Araripescorpius ligabuei*). The Centre also carried out research in the field of Paleoichnology, discovering new dinosaur tracks in the Andes, the Amazon forests, Bolivia (*Ligabueichnium bolivianum*) and in the sedimentary rocks of Turkmenistan, in central Asia. In the Gobi desert (Mongolia) research focused on the variegated fossil fauna of the Cretaceous period, and resulted, among others, in the discovery of dinosaur egg nests and a new reptile species. Further discoveries included new species of sauropods in Patagonia (*Agustinia ligabuei* and *Giancarlosaurus leanzai*), as well as an Early Jurassic deposit in Morocco, rich of bones and tracks of a new quadruped herbivorous dinosaur.

Natural Sciences (Scienze naturali)
Each of the Centre's expeditions relay on expert naturalists as well, who study the habitats and ecosystems in which the research takes place. It is thanks to this interdisciplinary approach that new animal and plant species could be discovered even during palaeontological, ethnographic and archaeological missions. These include two contemporary dipteran insects: *Paralimna ligabuei* (from Sudan, 1980) and *Asmeringa ligabuei* (from Maldives, 1980). The Centre organizes also expeditions with purely naturalistic aims: in the coral atolls of the Maldives (1980), in search of possible surviving thylacines in Australia (1984) and to study the Aye-aye, a rare lemurid that was believed extinct, in Madagascar (1985).

MUSEUM AND SCIENCE (MUSEO E SCIENZA)
from the "cabinet of curiosities" to scientific museum

11

Wunderkammer: the room of wonders
(Wunderkammer: la stanza delle meraviglie)

The Renaissance saw the flourishing of the arts, sciences and culture while the study of new commercial horizons encouraged explorations beyond known borders. European scholars in the XVI century therefore came to possess an incredible variety of objects, plants and animals, some of which had already been the subject of legends in Mediaeval bestiaries and travellers' tales in times long past. This is how the first collections that adorned scholars' private cabinets originated, transforming them into real rooms of wonders, more alchemistical than scientific in nature. In the first half of the 1700s these wunderkammer began to be opened to the public, thus paving the way for the future scientific museums.

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Museum and Science (Museo e Scienza)

As a result of the experimental scientific method introduced during the seventeenth century, trust in reason and the primacy of science were established during the enlightened eighteenth century. The tendency to amaze with a wealth of shapes and sizes and the abundance of finds was replaced by the need to study the extraordinary variety of organisms and natural products adopting a common and ordered method of classification. As did their counterparts in other countries, naturalists in Venetia undertook systematic studies throughout their territory and created outstanding collections. Together with publications, manuscripts and scientific correspondence, many of these represent the initial nucleus of the considerable patrimony of the Museum of Natural History in Venice.

The natural history collections (Le collezioni naturalistiche)
Often gathered by scholars during their own studies, rocks, fossils, plants, animals and their parts all form the heart of the finds preserved in natural history museums. Each of these finds is ordered, classified and given a label bearing the scientific name, as well as when and where it was found, the name of its collector and other relevant data. Without this information the *natural object* is of absolutely no scientific importance. It is the museum's fundamental task to make sure the find is preserved together with this information.

This is even more important for the so-called types, i.e. the reference specimens that provide the basis for the description of a species, which are of incalculable scientific value. Nevertheless, all finds in a museum are important since they are testimony to the appearance of new species, the extinction of others and the transformations of the territory with the passing of time.

A Natural History museum in Venice (Un museo di Storia Naturale a Venezia)
The initial idea for the creation of a naturalistic museum in Venice came from Gian Domenico Nardo, who presented the Viceroy of the Lombard-Venetian Kingdom in 1834 with a project for a "*central collection of all natural and industrial products from the Venetian provinces to be kept in their capital*". Scientific collections thus began to be assembled in various institutions in the region. In Venice, the most important were those of the *Museo Civico e Raccolta Correr* [Civic Museum and Correr's Collection] and of the *Istituto Veneto di Scienze, Lettere e Arti* [Royal Venetian Institute of Sciences, Letters and Arts]. Owing to either the vast amount of materials so far accumulated, the lack of resources and the demise of many of the scholars who had been in charge of them, in early twentieth century these collections were pooled together in a single public scientific institution. Thus, in 1923 this led to the foundation of the *Museo Civico di Storia Naturale di Venezia* [Civic Natural History Museum of Venice], located in the *Fontego dei Turchi,* finally fulfilling Nardo's original dream.

Teodoro Correr (1750- 1830)
Heir of an ancient patrician family of Venice, Teodoro Correr, once he had completed his studies, held various public positions and took part by hereditary right in the *Gran Consiglio* since 1775. His passion for collecting was already evident when he was young but it was not until 1779 that he methodically began to collect art, historical and natural history objects related to Venice and its past. In 1789 Correr left his political posts to become abbot, devoting all his time to the expansion and organisation of his collections, which were displayed in the family's palazzo, next to the *Fondaco dei Turchi*, and open to scholars and men of letters twice a week. At his death, he left everything to the city, including the palazzo and the necessary resources to create a true museum to be open to the general public: the *Museo Civico* e *Raccolta Correr*, the original core of today's *Musei Civici di Venezia* as a whole.

Nicolò Contarini (1780-1849)
Son of a wealthy noble family, Nicolò Bertucci Contarini was born in Venice and at a very young age was already showing considerable interest in the natural sciences. He studied in Udine where he learnt the scientific method without, however, following any real studies in natural sciences; this knowledge he later acquired by himself, partly thanks to his direct observations of nature. Initially focused only on collecting and drawing zoological and botanical materials, it was not until 1830 that he began to publish the results of his research, including several studies on the biological control in agriculture. By 1840 he had made his name as a scientific expert and was welcomed as a member of the Istituto Veneto.

Thanks to his connections with Italian and foreign scholars, during this period he also published important studies on marine biology, entomology and ornithology, which reveal an original ecological approach. When he died, he left the *Museo Correr* his substantial library and collections, with countless Venetian specimens.

Giandomenico Nardo (1802-1877)
Although he was born in Venice, Nardo spent most of his life in Chioggia and was introduced to the natural sciences by his uncle, an abbot, who taught him the techniques to prepare biological samples. He deepened the study of naturalistic subjects at the secondary school in Udine and then went to study medicine at University of Padua: in both institutions he was made responsible for the zoological cabinets, which he expanded and rearranged. In 1832 he helped to reorganize the collections of marine invertebrates in the Imperial Museum in Vienna and in 1840 was made a member of the Istituto Veneto. He had multiple interests and published numerous papers on medical and social sciences, philology, technology, physics and, above all, Venetian and Adriatic zoology. He devoted himself to marine biology in particular, with a variety of subjects ranging from invertebrates to fish and marine turtles. Nardo not only bequeathed his invaluable collections and publications, but also a vast collection of manuscripts and notes that is still a valuable source of information about the natural aspects of Venetia in the mid nineteenth century.

Giovanni Zanardini (1804-1878)
An esteemed doctor and surgeon, the Venetian Giovanni Zanardini studied medicine in Padua and Pavia, where he also learned the notions of natural sciences. He worked as a doctor in various institutes in Padua and Venice but, as a passionate naturalist and floriculturist, he spent all his spare time on studying botany, particularly algology, and soon made his name in this field. He focused especially on the collection and study of algae from the Adriatic, Venice and Dalmatia, although he was also interested in species from exotic locations such as the Red Sea and south-east Asia. He identified many new species of algae, previously unknown to science. He left his botanical collections to the Istituto Veneto, of which he was made a member in 1843, and his algae collection to the Museo Correr. Today, both collections are still a significant part of the Museum's botanical heritage.

Alessandro Pericle Ninni (1837-1892)
An eclectic Venetian naturalist of Greek origins, Count Alessandro Pericle Ninni devoted most of his life to zoological studies, and to the Venetian fauna in particular. In 1863 he studied the fauna of Greece and participated in the rearrangement of the Museum of Athens as well. He was also interested in fisheries and pisciculture, ethnography and linguistics also related to the Lagoon of Venice and Venetia. The main beneficiaries of Ninni's collections were the Museo Correr and, to a lesser extent, the Istituto Veneto, of which he was a member, as well as many naturalists and scientific institutions with whom he had collaborated and exchanged samples in Italy and Europe.

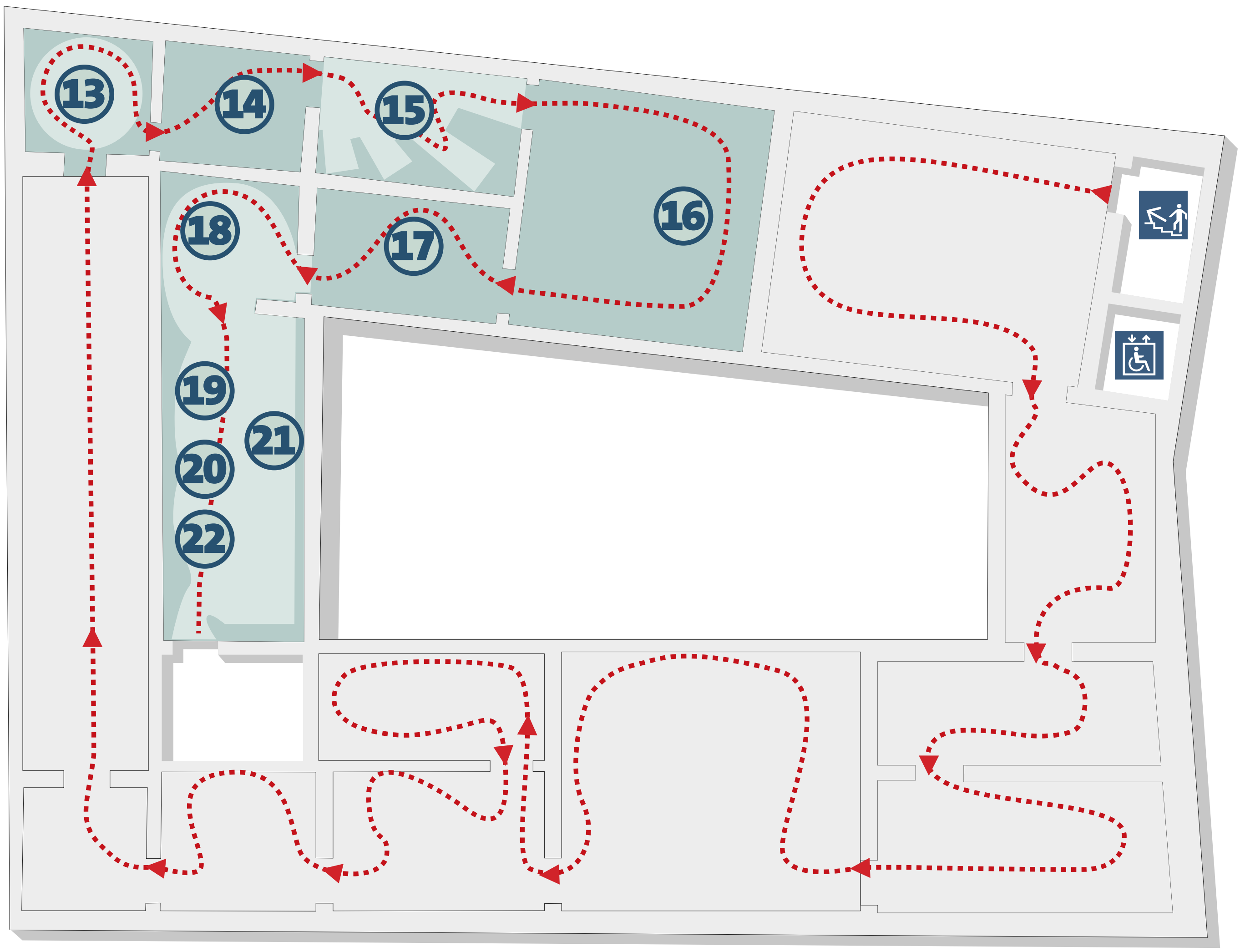
Ninni donated the core of his zoological collections to the Museum in 1876 but he continued to expand them throughout his lifetime; the last lot was added after his death, together with a vast library, by his children. Together with those of his son Emilio, A. P. Ninni's collections still represent a substantial part of the Museums' patrimony.

Enrico Filippo Trois (1838-1918)

Born in Venice, Enrico Filippo Trois studied chemistry and pharmacy. However, being a passionate lover of natural sciences, he soon became Gian Domenico Nardo's pupil. In 1865 he was the keeper at the Museo Civico in Trieste but in June 1866 he was summoned back to Venice by the Istituto Veneto, which appointed him curator and preparer of their Scientific and Natural Collections, a post he was to keep until he died. Besides starting an extensive systematic collection of the Venetian fauna, he made an impressive series of liquid and dry anatomical preparations, many of which were displayed at international exhibitions in Vienna (1873), Paris (1878) and Milan (1883), and for which he received numerous awards. Upon Trois' death, the Istituto Veneto came to an agreement with the Municipality of Venice and its scientific collections were moved to the *Fontego dei Turchi*, the premises of what was to become the *Museo Civico di Storia Naturale*.

THE STRATEGIES OF LIFE
(LE STRATEGIE DELLA VITA)

Present-day and extinct species, inhabitants of waters, lands and the air, gigantic to microscopic in size. A journey in the complexity of living forms, marked by profound differences but also by surprising similarities.



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FORMS AND FUNCTIONS (FORME E FUNZIONI)
The manifold looks of biodiversity

The complexity of nature and living forms
All living creatures share some basic features, such as the capacity to reproduce and that of using external resources as energy and as raw materials to grow. In order to find a partner, food, a suitable place to live, as well as to escape from a predator, organisms have to move, be able to perceive their surroundings and communicate with each other. So unicellular organisms, plants and animals have developed a vast number of adaptations, behaviours and strategies in order to survive. However odd and complex the form of an organism is, it is an evolutionary response to the particular needs of a species in a certain environment. All together these forms, extinct and present-day, gigantic or microscopic, aquatic and terrestrial, constitutes the incredible biodiversity of the planet Earth.

LOCOMOTION (IL MOVIMENTO)
Living space in a dynamic world

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WITHOUT MOVING (NON MUOVERSI)
Adaptations to feeding and breeding staying motionless

Filter feeders (Filtratori)
There are not many animal groups that are able to spend all or most of their life cycle remaining more or less motionless: these are all aquatic organisms that live on the seabed, anchored to floating objects or rocks, which therefore had to devise how to reproduce, defend themselves and reach their food without moving. The difficulties related to motionless feeding were overcome by sponges, bivalve molluscs, sea squirts and other marine invertebrates by making use of filtering structures, which strain the many organic particles present in the water as dissolved or suspended matter.

Filtering is such an efficient solution that not only it has been retained over time by many groups of invertebrates, but it has also been adopted by some of the biggest creatures in the world, such as whales. Other sessile animals, like corals, get hold of their food by capturing the particles suspended in the water with their moving tentacles. On the contrary, there are no land animals that live by filtering the air because, compared with water, it is poor in suspended particles, so that air-filtering would be too exacting and not very effective.

Parasites (Parassiti)
Many parasites live on or within the food which they feed upon, so that all nutrients they need to grow and reproduce are always to hand, without having to move much. Unlike what happens in other types of communal life, they profit from the union with another organism but cause harm to the host species, slowing down its growth, development and moving capability. Parasitism, a very clever solution, is widespread among the most diverse systematic groups: bacteria, fungi, plants and animals such as worms, insects and crustaceans. They can vary much in size, therefore, being from microscopic to a few metres long, like the tapeworm. They may live inside or outside their host organism and have different degrees of host specificity, while some need hosts of more than one species in order to complete their life cycle. Many systems and their functions underwent profound modifications in these organisms, in order to adapt to parasitic life. Most of them are equipped with fastening structures that allow a firm grip to their host, whereas their locomotion system is generally poorly developed.

Predators (Predatori)
There are few sessile or poorly mobile animals that feed on prey: among the organisms anchored to the substrate, nearly all belong to the group of the sea anemones, which immobilise their prey with paralysing poison. More numerous, on the other hand, are terrestrial and marine animals that are not truly sessile but lie in ambush for periods that may even be extremely long, while waiting for their prey. They catch their food using a wide range of strategies: some use poison, others have appendages that work as baits and/or camouflage on the surroundings, whereas others build real traps. Some evolved structures to seize their prey rapidly, like the spines of the mantis or the chameleon’s sticky tongue. Also falling within “motionless predators” are the several species of carnivorous plants, varying in shape and preying strategy, which supplement their nutrition needs by capturing tiny animals. Some have cavities into which small organisms fall, others have hinged leaves, which close the moment the prey rests on them, or secrete sticky substances to which animals remain trapped.

Getting carried (Farsi trasportare)
Plants do not need to move to get their nourishment, however, in order to reproduce and to spread new individuals, they developed special strategies to scatter pollen, spores and seeds, making up for their immobility. Similarly, some animals with poor movement ability have

also adapted parts of their bodies to be carried by water, by air or by other organisms, often over long distances. When one animal is transported by another often both species benefit from the association, such as the remoras that attach to the body of large fishes, meanwhile cleaning them of parasites. Some plants have hooked fruits and seeds to attach to the body of animals, others have fleshy fruits that are attractive to birds and mammals that, eating them, spread their seeds later with excrements, or seeds are carried away and buried as food reserves. Most plant species, however, rely on the transport capacity of air, developing very small, light or wing-like structures. The flow of water, on the other hand, though used also by fruits and seeds, it is harnessed especially by animal organisms, either large as a jellyfish or small like plankton, which depend on currents for dispersal and large distance voyages.

15

WALKING, RUNNING, JUMPING... (CAMMINARE, CORRERE, SALATARE...) **And other ways to move about on a surface**

Moving on a plane (Spostarsi su una superficie)

The capacity to move from one place to another is one of animals' most obvious characteristics: in this way they can procure food, escape from predators or catch up with a partner to mate. Some unicellular forms or phases of fungi and plants can also move actively, as can some bacteria and other prokaryotes. On land, movements generally take place in two dimensions, since the force of gravity holds the body down onto the ground. Planes of movement, however, are not always horizontal: they are often inclined or even vertical, as on rock walls or trees. Even under water some animals have adapted to bidimensional habitats, like the seabed or the surface of other organisms.

Slithering (Strisciare)

The slithering motion is the most primitive way in which living beings move actively. No limbs or appendages are needed in order to slither, and many forms of life are able to move about by just undulating or contracting and extending their whole body. Most slithering species are in aquatic environments: nearly all flatworms, ringed worms and marine gastropods move by crawling, as well as present-day land species, which have evolved from aquatic forms. In vertebrates, adaptation to slithering is a secondary specialization: snake-like reptiles, amphibians and fishes all descend from ancestors with well-developed legs or fins. Indeed, limbs are excellent tools for movement, but can be a hindrance for animals that make use of narrow recesses and natural cavities, or that live in tangles of thick vegetation.

Jumping (Saltare)
Jumping is a very specialised way of moving that requires the development of special anatomic structures, such as particularly long and powerful limbs that act as springs.
Even if many animals that make use of other movement strategies are able to jump, there are not many true jumpers: they belong to the species that use the jump as their primary method of movement or that have specific anatomic features even if they also move about in a different manner. In most cases adaption to jumping is highly visible in the hind limbs. In other cases anatomic changes are less obvious, as in jumping spiders, which leap using the third pair of legs that are externally similar to the other three. There are also species whose entire bodies act as springs, like water fleas and click beetles.

Running (Correre)
Moving quickly is an imperative for most animals: to be faster than one's pursuer is often the only possibility of survival, while for many predators the only guarantee of a meal is to be able to catch up with a fleeing prey.
This is why in some vertebrates limbs have become increasingly long and powerful during the course of time and skeletons have become more and more flexible. In runners, beside rigid structures that lengthen the stride, special anatomic and physiological adaptations have taken place, enabling some species to keep up a constant speed for long periods and others to put on very fast spurts but for a short time. Typical runners are found among mammals, but there are also some among reptiles and birds.
Many invertebrates are also specialist runners, such as certain insects, spiders and centipedes, which are also equipped with limbs that are very long in comparison with their body size.

Walking (Camminare)
Walking is one of the simplest ways of moving on land with the minimum contact between body and ground. It is the most primitive kind of legged movement in terrestrial vertebrates, adopted from the time of the first tetrapods, which could not move very quickly owing to the structure of their limbs, inserted horizontally into their trunk.
This condition is still found in many present-day amphibians and reptiles. Walkers are also very numerous indeed among invertebrates, especially among arthropods that move on land or on the seabed, but also “skaters”, whose habitat is the water surface. In the eternal race between pursuers and pursued, evolution has led many species to increase their speed, but others have taken a different course: untiring walkers, they became equipped with armours, stings and other forms of defence against predators.

Climbing (Arrampicarsi)
Moving on a vertical surface is a challenge to the force of gravity, but it may be worthwhile to get at hanging food such as leaves and buds, flowers and fruit, honey, insects or eggs.

High places, in addition, are safe from many predators and are good look-out sites, as well as suitable places for raising offspring. Some animals have adapted themselves to living on vertical surfaces, while others only venture on them in certain circumstances, but all need special adaptation in order to keep their hold and remain in equilibrium, often considerably above the ground. Limbs with opposable fingers are typical of climbers, some of which also help themselves with other appendages like prehensile tails or curved beaks. Tough nails are sometimes enough to get a good hold on a rough surface, extreme specializations are needed on smoother surfaces, such as fingers and toes with adhesive pads or closely packed lamellae that are able to get a grip on the slightest unevenness.

Moving underground (Muoversi sottoterra)
While most animals move on the ground, some are able to live underneath it: the underground environment is an excellent hiding place for an animal itself and its brood, ideal for storing food and to shelter during unfavourable periods of time. Some species merely enter the subsoil occasionally, while others only emerge if they are forced to. Nevertheless, almost all of them dig their own dens and complex networks of tunnels using specialised anatomic features as tools. Often, also the whole form of their body has adapted so that the animal can slide along more easily, as well as avoid the excavated soil from entering their mouth, ears and breathing system. Among the most extreme adaptations is the earthworm, which excavates by swallowing the soil in front of itself, then expelling it from behind once digested.

16

MOVING IN THE WATER (MUOVERSI NELL'ACQUA)
Forms and strategies to swim and float

Moving in water (Il movimento nell'aqua)
Organisms that move about in a fluid, whether air or water, are free to progress in the three dimensions but must fit in with the physical characteristics of the element in which they are immersed. The high density of water has the capacity to keep up the weight of the body, which almost finds itself in a state of absence of gravity, especially in salt water, but at the same time it offers resistance to movement. All swimmers, therefore, have worked out adaptations that enable them to exploit these features, developing hydro-dynamic forms and propulsive structures. The group of organisms most adapted to movement in water is, of course, fish, whose fins, different inshape and position, are specialised organs that provide thrust, regulate direction and allow control.

The rear or caudal fin, together with a more or less extensive part of the body, generally provides thrust, while the unpaired dorsal and anal fins have the function of keeping the fish vertical; the paired fins (pectoral and pelvic) act as stabilizers and brakes and are sometimes used for slow, precise manoeuvres.

Varieties of form in fishes (La varietà delle forme nei pesci)
The enormous variety of fish forms allows them to move and feed in different ways, adapted to different environments. They divide into two big groups based on their anatomic structure and skeleton type. Cartilaginous fishes have gills that open directly to the outside through slits at the side of the head, the mouth is in ventral position and the caudal fin is usually asymmetric (heterocercal) with the upper lobe larger.
Scales, which are shaped like microscopic curved teeth making it rough to the touch, protect the surface of the body and may have a role in reducing attrition while swimming. Instead, the gills of bony fishes are protected by a bony operculum and most species have a swim bladder, a sac-like organ that they fill with and empty of gas to control buoyancy.
Many bony fishes have developed a symmetric (homocercal) caudal fin in order to optimize the propulsive force, whereas the scales, and sometimes the mucus, that cover their bodies contribute to reduce the attrition.

Different shapes for different environments (Forme diverse per ambiente diversi)
Body shape and movement pattern underwater are closely related and depend on the living environment. Species living near cliffs and coral reefs generally have an oval or elliptical, laterally compressed body. The caudal fin, highly developed, is made up of soft rays that are efficient at providing a flexible and variable thrust; dorsal fins are generally very well developed, as are the pectoral ones.
All such features aim at providing the broad manoeuvrability necessary to slip into narrow cracks or dart among the rocks of the seabed.
Their body shape allows them to feed while motionless in the water column, however they are able of flashing away like lightning in case of danger. Species that are strictly pelagic, on the other hand, have long bodies and a series of hydrodynamic adaptations that enable them to swim for long periods of time in the open sea.
Other forms are found in species living near the seabed, like mullets, whose pectoral fins are modified so that they can “walk” on the soft seabed, stirring it in search for food.

Some fishes have discarded swimming as their main life strategy, instead remaining motionless on the seabed surface.
This adaptation has led to a typical body structure: very flat shape, prominent eyes, both on the upward side, and different colouration between the two sides of the body, the one laying on the bottom being lighter and the other camouflaged, capable of changing its colour. Such

features are found in both bony and cartilaginous fishes, but in spite of the overall similarity in form, structure and function, there is one substantial difference.
In cartilaginous fishes, like rays, the flattening happens in dorsoventral direction, therefore the fish lies at the bottom on its belly and bilateral symmetry is preserved. In bony fishes, on the other hand, such as the sole, flattening takes place laterally, thus the fish rests on one side and it appearance is asymmetrical.
One eye, which would have been useless on the side lying on seabed, has migrated to the top side, slightly behind the other, while the pectoral and pelvic fins retain their original position.

They swim but they are not fish (Nuotano ma non sono pesci)
Several animals, belonging to the most diverse zoological groups, have evolved similar morphological structures in order to move easily in the water, such as hydrodynamic body shapes and thrust structures to overcome currents and wave motion. Swim-adapted limbs are found in many crustaceans, but also in insects such as water-beetles, which have an oval, flattened body and strong, hair-covered legs that they use like oars.
Tadpoles swim with undulating movements of their flattened tail, while adult amphibians make use of various techniques: frogs and toads push their strong hind legs backwards simultaneously, while newts and salamanders swim undulating their body and the wide, flat tail. Among the most efficient swimming reptiles we find extinct forms such as the ichthyosaurus, as well as the sea turtles, which swim with limbs that have changed into flattened flippers that they move like wings.
Many birds are able to dive and swim easily in order to find food but those that have most adapted to the marine environment, undergoing substantial structural changes, are penguins.

Most mammals are able to move in the water, but only some groups have adapted completely to marine life, developing a hydrodynamic shape, fin-like appendages, ways to prevent heat loss, the ability to hold their breath for long periods and the capacity of underwater reproduction. Among them, seals developed large, rigid lower limbs and no auricles, while dugongs and manatees have no hind limbs but a strongly developed fin-like tail. Cetaceans, which are totally independent of land, are certainly the mammals that have adapted most to aquatic life.
Their body has undergone profound, radical changes: fore limbs have turned into pectoral fins, hind limbs have disappeared, the neck is indistinct from the trunk and they have no auricles, hair or other uneven parts in order to be as much hydrodynamic as possible.
The caudal fin, in which their spinal column is inserted, is on a horizontal plane and is their main propulsion organ; a dorsal fin with stabilizing function has developed in the fastest species.

Other ways of moving in the water (Altri modi di muoversi in acqua)
The physical characteristics of water allow other methods of movement in addition to regular swimming, such as floating and reaction swimming.

Plankton, mostly composed of microscopic organisms, have developed special structures and forms to help floating, small-scale movements and the transport by currents and wave motion. Jellyfishes, which belong to the macro-plankton, are able to make active movements of a certain extent by waving their tentacles and swelling up their bell.
Cephalopod molluscs, such as squids, move through jet propulsion: water ejected forcefully through a siphon provokes a reaction movement the opposite way; it is used also for sudden changes of direction. Other cephalopods, provided with shell such as the nautilus, the extinct ammonites and partly cuttlefish, can regulate their buoyancy by acting on the quantity of gas in the shell cavities. Some macro-algae have also developed gas-filled vesicles, called aerocysts, so that the fronds are better exposed to light and are also able to spread more efficiently.

Fish in the depths (Pesci negli abissi)
Marine abysses, some more than 10,000 metres deep, are an extreme environment where the light of the sun is already absent at 200 metres down, the temperature is low and the pressure enormous. Organisms that live there evolved special forms and strategies: often blind or with reduced eyes, many have luminescent organs (photophores) located in various parts of the body, almost all are carnivorous and some feed on the remains of organisms living at the surface, which fall into the depths after death.
Among the most characteristic of these organisms are small deep-sea fishes with monstrous shapes. Many developed an enormous mouth with extremely long teeth to be efficient predators, as well as long, branched fins not to sink into the soft, muddy seabed.
They almost all have photophores used to illuminate their surroundings, to attract their prey or partners and as a defence. Among the inhabitants of ocean depths is also the coelacanth, a fish of primitive appearance that was only known as fossil until 1938, when it was first found alive off the coast of South Africa.

Big swimmers (Grandi nuotatori)
Fishes living in the open sea have slender, hydrodynamic, very smooth shapes, which are perfect to slide into a liquid mean.
Among cartilaginous fishes, the best swimmers are sharks, with their rigid, fixed pectoral fins acting as stabilizers during their permanent swimming. In large bony fishes, thrust is almost exclusively generated by the caudal fin, which is strong and rigid, made in the form of a crescent moon and joined to the body by a narrow element, which is often strengthened by lateral keels, able to sustain the vigorous thrashing of the tail.
Pectoral fins, in such an environment where no special manoeuvre is required, are slender and kept adherent to the body during swimming, without protruding from the outline.
The high energy consumption due to strong muscular activity means that a lot of oxygen is required, therefore gills are wide and efficient, in order to oxygenate the powerful muscles, and rich in the typical respiratory pigment (myoglobin) that colours them in deep red. The fastest cartilaginous fishes is probably the mako shark, while among bony fishes are tunas, mackerels, marlins and the swordfish.

Group swimming (Nuotare in gruppo)
As on land and in the air, also in the aquatic environment several animal species take advantage of the potential of being in a group in order to escape predators. The hundreds or even many thousands of fishes that make up a shoal move in perfect synchrony, so much so that to a predator's eyes they have the appearance of a single organism of huge size. Moreover, a shoal's flight reaction, with fish escaping and dispersing in all directions, creates a confusion-effect that disorientates the predator. Within the complex three-dimensional structure of the shoal, all members tend to behave together in the same way, so that direction changes appears as agreed, simultaneous actions on the part of all. This is made possible by the fish sensory system, especially the "lateral line": a series of mechanical receptors placed along the sides of the animal that provide the information needed to maintain position and rhythm within the group. Each individual can thus adjust its position, avoiding confusion or collisions in the event of sudden changes of direction or unexpected acceleration.

17

MOVING IN THE AIR (MUOVERSI NELL'ARIA)
The conquest of flight

Conquering the sky (Alla conquista del cielo)
Most animal species are able to fly. However, in order to keep hovering in the air, substantial adaptations in the body structure and considerable expenditure of energy are required. What are the advantages of flying, then?
Moving in the air provides access to food resources and, more generally, to ecological niches that are not available to other animals. It makes it easier to escape from predators or pursue prey more effectively, as well as to use the hind limbs as weapons. The conquest of the aerial space also gives the possibility of moving quickly even between places far apart from each other, overcoming obstacles like mountain chains and stretches of water with relative ease.

The flyers (Il popolo volatore)
During the course of evolution, the ability to fly has emerged in four different animal groups, constituting a clear example of adaptive convergence. The first to achieve flight, more than 350 million years ago, were insects. It is likely that this acquisition contributed to their great success: in fact, there are more than 900,000 living species of flying insect. Later on, flight was developed by three groups of vertebrates.

Pterosaurs, reptiles of the past that became extinct together with dinosaurs, began to fly more than 220 million years ago.
Birds, which appeared 150 million years ago, are the vertebrates that still rule the skies today, with more than 9,000 species living in even the most extreme environments. The last group to fly was that of the chiropterans (bats): the first fossil remains of these mammals date back to 60 million years ago.

Equipping for flight (Attrezzarsi per volare)
In order to keep up in the air, load-bearing structures are necessary, and these are common to all flyers: wings. Each group, however, has developed these structures trough a different way. In vertebrates, wings are always derived from the modification of the fore limbs: the conquest of the air, therefore, implied giving up some agility on land.
Pterosaurs and chiropterans used the bones of the hand as the main support for the wing, whereas in birds the whole arm acts as supporting framework.
While vertebrates have had to sacrifice a limb in order to acquire the capacity to fly, insects have evolved a wing structure that is independent of their other appendages, which keep their original locomotor function. Alone among all flying creatures, they also have four wings instead of two.

As light as a feather (Leggeri come una piuma)
Beside developing wings, flying requires some adaptations to reduce body weight.
Hollow bones and a fenestrated cranium lighten the skeletons of pterosaurs and birds, but the latter have worked out other efficient solutions: they have a horny beak instead of bony jaws with teeth, and a feathered tail without any bones.
The most obvious adaptation to lightness is in fact feathers, structures composed of thin filaments interwoven into a network that is so dense as to behave like a membrane. Even if they are independent of each other, feathers overlap tightly to form the continuous surfaces of the wings and tail. Insects have adopted a similar solution: feathered wings appear in very many species of tiny butterflies, wasps and flies, further reducing the weight of the original membranous wing that is already light.

Leathery wings (Ali di pelle)
Chiropterans are the only mammals that have the capacity of active flight.
Their name means “winged hand”, in that it is the bones of the hand above all that support the patagium, the elastic wing membrane crossed by bundles of muscles, nerves and blood vessels. Thin but strong, this is the feature that enables them to fly with an extraordinary manoeuvring ability, as well as to keep their body weight down at the same time.
A leathery wing of skin also characterized pterosaurs, whose patagium was mainly supported by the enormously elongated fourth finger of the hand.
For a long time, it has been common thought that these reptiles were able to glide only, but today’s most credited theory regards them as very skilled, active fliers.

Imitating flight (Imitare il volo)
Flight is such a useful skill that several animals have tried to imitate it even if they do not have wings. These are mainly arboreal species bearing structures that get extended during their jumps, acting as parachutes and allowing them to glide among the branches.
Skin expansions at the sides of the body have appeared in flying lizards and various groups of mammals, the best known of which are flying squirrels.
There are also gliding frogs, which move in the air by means of their wide foot webbings, and flying snakes that, bending in zig-zags and flattening their bodies, manage to glide for considerable distances. In the aquatic environment there live flying-fishes and even flying-squids, which succeed in escaping from predators thanks to an initial propulsive thrust that allow them to "fly" for tens of metres above the water surface.

Eating on the fly (Nutrirsi al volo)
Many animals manage to capture their prey while flying. Some do it only in this way, like dragonflies and many bats. Among birds, excellence is achieved by diurnal predatory birds, which fly above the land to locate a prey and then swoop down on it; some of them, such as the peregrine hawk, even specialize in hunting flying preys.
Like other birds, they can also hang in mid-air, flapping their wings against the wind, using the so-called "Holy Spirit" technique, while looking carefully at the ground below.
The trick of staying suspended in mid-air is also exploited by some animals that feed on flowers: among the best known are hawk moths and hummingbirds, which can feed without propping themselves thanks to their hovering ability.

Saving strategies (Strategie per risparmiare)
Since flying requires an enormous expenditure of energy, birds have worked out some strategies to do so economically. Some stop flapping their wings from time to time, closing them and carrying on in flight by inertia: this entails a loss of height, so that they need to resume motion after a few seconds.
The result is a characteristic undulating trajectory. Such strategy does not work for large, heavy birds, which, however, if their wings are wide enough, can keep them open and still to glide. In general, this is done by exploiting either updraughts, as raptors do, or the wind, like many pelagic birds.
Flying in formation is also labour-saving: each bird in a flock exploits the slipstream of the bird ahead; since the flock leader is not in the position of doing so, time to time another bird takes its place.

Good flyers and poor flyers (Grandi volatori e volatori scarsi)
Some animals are so well adapted to flight that they spend most of their time in the air.
The primacy goes to swallows, which even manage to sleep and couple in flight.
Albatrosses fly for days on end without landing because they can freeze their wings in a gliding position, keeping them open with little exertion.

Many other birds can stay in the air over long distances: they do so during migrations, a behaviour shared also by insects and bats.
Flying without having the best tools, however, may be a tiring activity to be limited to the bare minimum, as for birds with a heavy body and small wings that are only able to sustain short journeys.
Some animals even only fly once in their lives, like ants and termites, whose reproducing adults fly away from their original nests: once they have landed their wings fall off or are torn away, since they will not be needed any more.

NUTRITION (LA NUTRIZIONE)
The energy cycle and the strategies to get food

18

FEEDING ON LIGHT (NUTRIRSI DI LUCE)
Photosynthesis at the root of life

Photosynthetic organisms (Gli organismi fotosintetici)
Unique among all living beings, plants build up the organic matter that forms their body from a small number of inorganic substances by means of a process called photosynthesis.
An abundant, easily available source of energy is needed to transform simple substances into other complex substances: this is the sun, or rather the part of solar radiation that makes up visible light.
This process can only take place thanks to special pigments, the most common of which are chlorophylls, that are present in very simple organisms like bacteria, as well as in more complex ones such as algae, mosses, ferns and all higher plants.
During photosynthesis, glucose is produced from water and carbon dioxide, while oxygen is released as a “waste” from the reaction.
Indeed, during the history of life on Earth, the percentage of the latter essential element in the atmosphere has increased thanks to photosynthetic activity, initially carried out in microscopic organisms, such as unicellular algae and cyanobacteria, and later on also by terrestrial plants.

The leaf (La foglia)
In higher plants, all the green parts are able to carry out the photosynthetic process, but the organ truly specialised to this function is the leaf, a very ancient structure that first appeared about 400 million years ago. In order to perform its task, a leaf must capture sunlight into its tissues; in addition, it must allow gaseous exchanges, also controlling water loss at the same time in order to prevent dehydration. So leaf blades are generally flat and thin, protected by waterproof coating of variable thickness, in which, however, there open small pores called stomata. In most plants, leaves are organs in which two other important functions take place: respiration and transpiration. During the first one, as in animals, oxygen is used to produce energy by “burning” sugars, whereas in transpiration the release of water vapour is regulated by the stomata, by that also allowing fluids to climb up from the roots to the highest part of the plant. A large number of modified leaves is present in plants, which have transformed to carry out the most diverse tasks. Petals, sepals and bracts protect the flower and can be useful in attracting pollinating insects, squamae protect the stem and buds, thorns reduce transpiration and defend the plant from herbivores, cotelydons and succulent leaves are reserves of nutrients and water, whereas tendrils hold up the stem by winding around surrounding objects. Distinctive leaves exist also in carnivorous plants, in which they form special structures for prey capture. When transformation is so extreme not to allow photosynthesis, this function is carried out by other green parts of the plant, such as the stem in many cacti, whose leaves have become thorns.

Variety of forms (La varietà delle forme)
The leaf is one of the most versatile and variable organs ever conceived by nature. Its most common appearance is that of a flat lamina which varies in form, type of margin and veining organisation. The margin may be smooth, as in the magnolia, serrated as in the chestnut or variably incised up to the point of being divided into leaflets, as in leguminous plants, in which case they are called compound leaves. The network of vascular tissues forming the venation is clearly to be seen on the lamina. In gymnosperms (pine, larch) there is generally only one venation, while in angiosperms there are many, laid out in various ways: most dycotyledons have feather-veined leaves with a central vein from which the lateral ones branch off obliquely as in a bird feather (oak, rose), while in others the leaves are palm-shaped with veins arranged like the fingers of a hand (plane tree, ivy); finally, in monocotyledons the leaves are generally parallel-veined, with veins running in parallel lines along the entire lamina (orchid, maize).

Plants and biomass (Piante e biomassa)
Starting from luminous energy and simple inorganic molecules, plants manage to produce large quantities of matter: indeed, by means of chlorophyll photosynthesis, a small plant that has just bloomed will reach the huge size of a great tree. Organisms without chlorophyll cannot make organic matter from inorganic molecules, and must therefore provide themselves with the organic substances from other living beings.

The capacity of plants to capture solar energy, therefore, is the basis for life on Earth: plant matter consumed by herbivores, and indirectly by carnivores, is thus the basis of every food chain and in any ecosystem most of the biomass, which is the mass of all living organisms, consists of plants. By means of photosynthesis, plants fix vast quantities of atmospheric carbon dioxide. In the history of life, this process accelerated with the appearance of terrestrial vegetation. Especially in the Carboniferous, when environmental conditions such as temperature and humidity were particularly favourable to the development of plant life, luxuriant forests took shape, vegetation attained its fastest speed of growth and the biomass its highest values.
Tree trunks, piled up one on another in enormous quantities for millions of years, thus generated immense deposits of coal and petroleum that are still exploited today as sources of energy.

Plants and habitats (Piante e ambienti)
Leaves have a wide surface facing the outer environment and, being very versatile organs, they can transform to allow the plant to fit best the outside conditions.
Sometimes such modifications are so specialised that just watching a leaf we can easily tell whether it belongs to a plant from a dry or humid climate, or to a plant growing in full sunlight or in the shade. In arid climates, plants have to adopt certain strategies in order to survive where water is scarce. They are generally short and compact in shape, may have succulent stems that act as water reserves and their root system may be extremely developed in order to intercept as much water as possible.
The leaves of these plants also show signs of special adaptations: to cut down on evaporation they reduce their surface, becoming small and narrow (rosemary, heather); if broad, they are protected by thick waxy cuticles (bay leaf, ilex), or they may be coated with silvery hairs that reflect sunrays (olive, edelweiss). They may be provided also with supporting tissues, in order not to wilt when water lacks, or they can turn into spines without any photosynthetic activity, which is then carried out by the stem.
The stomata only open at night, when evaporation is low, and the plant creates a temporary reserve of carbon dioxide, which it then uses for photosynthesis during the day. Vegetation is usually luxuriant in damp environments, but precisely because they are tightly packed together, plants may face the problem of not getting enough light. For this reason, the leaves on lower or inner branches (shade leaves) have a very thin cuticle and in some cases all their cells contain chlorophyll, in order to absorb as much light as possible; often they are also thin and delicate, any particular supporting tissues being unnecessary. Such adaptations do not involve the leaves on higher branches (sun leaves), as they are fully exposed to light.

Into the leaf (Dentro la foglia)
The inner structure of a leaf consists of specialised cells, which are generally organised in horizontal layers. The upper and lower surfaces are made up of covering cells (epidermis), protected by a waxy cuticle that is poorly permeable to gas and water.

Between these two layers is the proper foliar tissue (mesophyll): cells in the upper portion are generally elongated, closely packed and rich in chlorophyll (palisade layer), whereas in the lower portion cells are rounded, leaving broad gaps between each other to facilitate gas exchange (spongy layer). The mesophyll is crossed by nervation, consisting of the veins that bring water and minerals from the roots (xylem) and those distributing the products of photosynthesis to the sites where they are used or stored (phloem). The leaf bears also many microscopic pores (stomata), usually on the lower side, functional at supporting gas exchange with the outside, particularly allowing carbon dioxide to enter and releasing water vapour and oxygen.

Photosynthesis and symbiosis (Fotosintesi e simbiosi)
The photosynthesis process is so effective that some organisms, unable to carry it out by themselves, have developed close relationships with photosynthetic life forms, taking indirect advantage of it. Such strategies belong to mutualistic symbiosis, tight relations that organisms often very different from each other establish in order to derive reciprocal benefits. One of the best known examples of symbiosis is the lichens, which manage to colonise extreme environments, being made up of the association between a fungus and a photosynthetic organism (a cyanobacterium or an alga). The fungus survives thanks to the substances produced by the plant, which, in its turn, receives protection, minerals and water. In marine environments, an example of a symbiotic association is represented by corals that cohabit with certain unicellular algae, the zooxanthellae.
Algae give the coral most of their nourishment and receive elements in exchange that are essential for the photosynthetic process. For this reason most corals depend on sunlight and live in luminous, shallow waters; indeed, when there is not enough light they become pale and die.

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VEGETARIAN DIET (ALIMENTAZIONE VEGETARIANA)
Specializations and strategies

Plant eaters (I fitofagi)
The second link in the food chain consists of vegetable-eaters, the phytophagous organisms, a category that includes not only animals that feed on grass (herbivores) but also those that eat wood, seeds, flowers, fruits and other vegetal tissues. They are the only organisms able to exploit cellulose as food, converting it into substances that can be assimilated. To feed efficiently, phytophagous organisms have adapted in various ways, among which by evolving particular mouth structures.

Mammals, for example, share a common dental structure: well developed incisors, canines that are either incisor-shaped or growing smaller until they disappear and massive molars. An extensive diastema, a toothless space where many mammals accumulate the food to be chewed, is often present between incisors and molars. A similar type of mouth architecture is also found in other plant eaters: a gap is recognizable both in the jaws of some insects and in the mouths of ancient vegetarian reptiles, between the incisor-like and the molar-like sections.

Grazing teeth (Denti per brucare)
Incisors are very well developed in herbivorous mammals. They are chisel-shaped and are used to grasp the grass before ripping it off with a movement of the head, as in horses and bovines. Other mammals use these teeth to slit open even the hardest plant tissue, like seeds or nuts. The incisors of gnawing mammals, such as rodents, hares and rabbits, are subject to intense wearing and, in order not to become too worn down, they keep growing throughout their lives, thus retaining a sharp edge all the time.
This is possible because the enamel, which is only on the front surface, is harder than the dentine of the tooth body behind and wears out more slowly, resulting in a chisel tip.

In some herbivores, including cows and goats, there are no upper incisors: they are replaced by a tooth pad, a kind of tough callosity that carries out their function.

Grazing without teeth (Brucare senza denti)
Some toothless animals have developed unusual adaptations in order to crop plants.
Some sea urchins are an example: their mouth, which is on the lower side, is composed of a very original structure known as "Aristotle's lantern".
The organ, which is peculiarly complex, is composed of five pyramid-shaped calcareous plates, each of which contains a small mobile tooth. The plates are laid out in a circle and the jaws open and close with their tips facing the centre, to pinch and tear up the vegetal fouling.

Teeth for grinding (Denti per macinare)
Herbivorous mammals mainly feed on tough, fibrous plants; to chew properly such food it has to be scraped between teeth with uneven surfaces. In fact they have large molars, whose surface is roughened up by an alternation of slightly projecting enamel plates and depressions created by the wearing of dentine. Such type of molars have evolved in various groups such as rodents, ungulates and elephants. The most long-lived mammals have to face the problem of their molars wearing out. Some, like horses, solved it with very long teeth set in deep sockets, from which they emerge gradually.
While elephants have come up with a different solution: like other large mammals, they have 12 molars, but they only use four at a time so that each of these huge teeth has two in reserve.

Toothless but with a scraper (Senza denti ma con la radula)
A unique mouthpart has evolved in molluscs, which are provided with a scraping organ called the radula. This is a chitinous, ribbon-like structure, covered with minute curved teeth and rooted in the mouth as is the tongue in vertebrates. Vegetarian molluscs, everting the radula back and forth, scrape up leaves and fruits or the algal coating from off rocks and trunks. Like a vertebrate's teeth, the minute teeth on the radula wear out too. This problem is solved by constantly producing new teeth at the rear of the mouth, which come forward gradually to take the place of those worn out.

Toothless but beaked (Senza denti ma con il becco)
Birds and turtles includes vegetarian species, but have no teeth to process food. These animals' bony beak, coated with keratin, may take on a variety of shapes that are suitable for ripping up or cutting off grass and leaves, gathering small seeds or cracking hard nuts. Some beaks are very specialised, like that of the crossbill, whose curved, crossed tips are used to take seeds out of pine cones. Beaks, however, do not allow the animal to chew, so digestion is slower. For this reason birds have developed the gizzard, a muscular sac where food is shredded by horny plates lining its wall or gravel that has been swallowed on purpose. Turtles, on the other hand, have a slow metabolism and, like most reptiles, can take their time to digest.

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EATING OTHER ANIMALS (MANGIARE ALTRI ANIMALI)
Adaptation to preying

Carnivores (I carnivori)
The third link in the food chain consists of the predators, organisms that feed by preying on other animals. It may be more laborious for them to procure their food than for plant-eating creatures, but in their favour is the high nutritional value of meat and its easy digestibility. For this reason a carnivore's body structure, and its dentition in particular, is designed for predation. Among them, several have mouths bristled with sharp teeth, very effective at ripping off pieces of meat that are swallowed whole. This basic pattern, with a wide range of variations, is found, for example, in large preying dinosaurs as well as in present-day mammals, which display a reduction in both teeth number and differentiation. An effective example among invertebrates is the tiger beetles, a group of preying coleopterans. Their jaws, equipped with long pointed teeth, are perfect to pierce their prey on first.

Seizing teeth (Denti per afferrare)
The most primitive predators have a large number of teeth that are similar in shape and size, with sharp points and sometimes keen edges that are suitable for seizing prey and tearing off mouthfuls of food. This is the typical case for many dinosaurs, but also present-day vertebrates of ancient origin such as sharks and crocodiles. In some cases, teeth are only used to hold on to a wriggling prey while it is put in the right position to be swallowed, and they are thus short, conical and alike, as in dolphins.
In other animals, such as sharks and piranhas, teeth are triangular with serrated or sharpened edges that are used to chop off a piece of meat from the prey in one clean bite.

Teeth to help swallowing (Denti per ingoiare)
Many carnivores swallow their prey without either chewing or cutting them off, as when they are much smaller than the predator. Nevertheless, there are also animals that swallow preys that are huge in comparison with their own size. Snakes in particular can swallow animals whose body diameter is greater than their own. In many of these animals, teeth turn backwards to assist in sliding the prey towards the stomach and prevent movement in the opposite direction. This adaptation is very useful for snakes, which may even take hours to finish swallowing a prey, but is also found in other animals like the monkfish, which has hooked teeth inside its throat. Some birds too, like mergansers, have a serrated beak with rear-slanting teeth that help in swallowing fish.

Killing teeth, cutting teeth (Denti per uccidere, denti per tagliare)
Among the mammals most adapted to predation are canids, some ursids like the polar bear and, above all, felids. In these predators dentition has become specialised in killing big preys and cutting off large pieces of meat from them. In these animals incisors are reduced while the canines, conical and of a substantial size, allow them to prey on large animals.
With such teeth, used like daggers, they hold their prey until suffocation, sever vital blood vessels or snap the spinal column. Canines attained a very huge size in some extinct felids, like sabre-toothed tigers. As meat is easy to digest and does not need to be shredded, also pre-molars and molars became secodont, that is cutting-edged teeth acting as shears.
Two pairs of these teeth, called ferine teeth, are bigger than the others and are used especially to break up bones; they are largest in animals that feed also on carcasses, like hyenas.

Venom teeth (Denti per avvelenare)
Venoms are very common in nature, above all as a defence. Some animals, however, also use poison as a hunting tool, injecting it into their prey to kill or paralyse it.
Two big animal groups, spiders and snakes, administer poison by biting.
For this purpose, animals that are so diverse have mouth parts that are similar in function, consisting respectively in jointed appendages and modified teeth.

A tubule connected to venom glands runs inside the acuminate appendages of spiders, called chelicerae. A canal springing form a venom gland also passes through the modified teeth of snakes. According to the species, snake fangs may be located in the rear or front part of the mouth and in the latter case, like in vipers, they may be kept reclined against the palate when at rest.

No teeth but a beak (Senza denti ma con il becco)
There are also many predator species among birds and turtles, sometimes equipped with specially adapted beaks. For example, the pelican has a very large beak with a huge dilatable sac that it uses to capture fish. Birds that lie in ambush for their prey have a long, sharp beak that they use like a harpoon to spike their victim.
This technique is sometimes used by herons and regularly by anhingas, tropical birds whose beak is rough to get a better hold on fish, swallowed whole and often still alive. Birds of prey, on the other hand, developed a short, strongly hooked beak with sharp edges that is not used for prey capture but to tear it to pieces, after they have been seized by their powerful talons.

"Tin openers" (Apriscatole)
Many invertebrates are protected from predators by strong armour-like structures, as insects, crustaceans and especially molluscs, most of which can seal themselves up in a hard calcareous shell. However, some predators have evolved techniques and tools to open such "tins of meat" and feed on their content. Some fishes eat molluscs after crushing their shell: the bull ray especially uses massive grinding plates derived from modified shark teeth, while the gilthead has several rows of palatine molar-shaped teeth.
The method used by some marine gastropods, such as moon snails, is more sophisticated: they couple the use of the radula with an acid secretion to bore through the shell of their prey. Then, they inject digestive fluids through the hole and suck the dissolved body.
The technique used by Licinus ground beetles, which prey on land snails, is again different: their jaws, unusually short and asymmetrical, truly act as a tin opener, with which they patiently cut into the shell until they reach the mollusc's body inside.

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EVERYTHING IS RECYCLED (TUTTO SI RICICLA)
Nourishment from organic remains

Decomposers (I decompositori)
Decomposers are organisms that feed on dead vegetal tissues and dead animals, breaking down their organic substances. These organisms carry out an essential function, making again available to the vegetal world the simple mineral compounds that were transformed into complex substances along the food chain.

A large variety of organisms with different diets and food specialisations belong to the decomposers. They are divided into two groups, which however may merge into each other: while saprophagous organisms feed on animal carcasses and dead plants, coprophagous creatures live on excrements, remains and substances that have already been partly digested. Then, bacteria, acting simultaneously or after such organisms, complete the breakdown of the organic substance into minerals and reintroduce them into the cycle of matter.

There is such a wide variety of decomposers that no shared specialization can be identified. Some are adapted to feed on carrion, like the condor, which can introduce his bare neck into his meal without getting soiled. Animal carcasses are an ephemeral source of food, so that Insects developing into them as larvae, like many fly species, have evolved a very rapid life cycle and a very acute sense of smell, with which they locate carrion at a great distance, like sexton beetles, or even dying animals, as murexes. Animals that feed on dung must also take steps to deal with the ephemerality of their food, therefore many coprophagous beetles put their food in a safe place by burying it for their larvae, which take several weeks to grow. The food source used by decomposer fungi is much more long-lasting; this group is environmentally very important since they digest lignin and cellulose, breaking down even huge tree trunks. Finally, some detritivores feed on soil, digesting the organic matter contained in it.

OTHER WAYS OF FEEDING (Altri modi per nutrirsi)

Filter feeders (I filtratori)
The aquatic environment is like a diluted broth containing small suspended mouthfuls ready to swallow: all that is needed is to separate them from water.
Many animals feed from this
inexhaustible alimentary source by means of systems that allow them to concentrate the scattered food. Some filter feeders are immobile, such as sponges, corals and bivalves, but many fish also filter water using their gills, equipped with very fine denticles covered with adhesive mucus. Among birds, flamingos are the filter feeders par excellence: their beak contains a large number of bony lamellae that retain particles up to one-tenth of a millimetre in size. Some ducks also feed by filtering the water that they pump through the lamellae at the sides of their beak.
Even whales, the biggest living beings that have ever existed, are filter feeders.
Hundreds of baleens, flat plates that wear out fraying into thin filaments, hang from their palate. Their huge tongue, which may weigh more than an elephant, is used to thrust mouthfuls of water through the baleens, which filter the tons of food that such gigantic animals need.

Omnivores (Gli onnivori)
Omnivorous animals have generalist mouthparts that are suitable to process food of both animal and plant origin. This absence of specialization, which is common to all them, gives omnivores a wide choice of food: they can eat soft vegetables, fruit, seeds, tubers, small animals and other easily accessible and digestible food.
They cannot feed on grass alone or hunt big animals: these foods are reserved for the specialists. In omnivorous mammals canines may be small, as in hominids, or take on functions not connected with food, like swine tusks, which are also used as defensive weapons. Molars are bunodont, namely with rounded cusps useful for crushing food.
The beaks of omnivorous birds are generally medium-sized and robust, though they may vary greatly in form. Several animals have become omnivorous in recent times as a result of associating with human settlements, such as seagulls and rats, today typical visitors to dumping grounds.

Specialised tongues (Le lingue specializzate)
Some vertebrates evolved a particular type of tongue as a consequence of dietary specializations. Hummingbirds, for example, feed on nectar like butterflies and get to it inside the deep corollas of tropical flowers with their long filiform tongue.
Predators may have even more surprising types of tongue: those of toads, for instance, are sticky and stretchable, so that they can be projected on their prey, as the even longer tongue of chameleons. To reach preys inside small cavities, some animals have extremely elongated tongues, like that of the anteater, which is hardly more than a centimetre wide but up to sixty centimetres long.
The woodpecker's tongue can be five times longer than its beak and is covered with little hooks to extract insects from their tunnels in the decaying wood; at rest, it lies rolled up around the cranium up to the base of the beak.

Sucking (Succhiare)
Among minute animals some are adapted to exploiting fluid foods, generally not available in sufficient quantities for larger size species. This is the case for many insects: it is for them that flowers produce their sweet nectar, beloved of butterflies.
Their sucking organ, the proboscis, is coiled under the head when at rest, but can measure more than the rest of the body when extended. Very nutritious fluids are also contained inside living organisms, like the blood of vertebrates and the lymph of plants.
To reach these foods, mosquitoes and bugs have an oral system that can not only suck but also perforate; such insects all have a mouth like a straw.
A different structure that has the function of gathering liquids is the short proboscis of the fly, which ends in a pleated pad that can absorb liquids by capillarity, acting as a sponge.

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THE LIFE CYCLE (IL CICLO DELLA VITA)

Microcosm (Microcosmo)
A continuous flow of energy from the sun is the motor of innumerable cycles of transformation of the matter that take place in all ecosystems. In food chains, in fact, carbon, oxygen, nitrogen and other elements continually transfer from the producers (plants) to the consumers (phytophagous and predator organisms) to end up with the decomposers that break down the organic substances, so that the cycle of matter can resume. In a simplified form, the BioGlobe reproduces some of these processes, which have been taking place on Earth for millions of years.
A salt water pool environment has been reconstructed in a glass sphere, where algae, red shrimps and bacteria live in equilibrium, with the fundamental external contribution of light only. Such ecosystem is therefore self-supporting, without needs for further assistance from the outside.