United Nations
Educational, Scientific and
Cultural Organization

Convention on
Biological
Diversity

Biodiversity Learning Kit

Volume 2

Activities

Biodiversity Learning

Kit

Volume 2

Activities

Published in 2017 by the United Nations Educational, Scientific and Cultural Organization
7, place de Fontenoy, 75352 Paris 07 SP France

ISBN 978-92-3-100178-9

Editing and coordination: Salvatore Aricò
Scientific and technical supervision: Bernard Combes (education and pedagogy), Victor Scarabino and Gilles Bœuf (biodiversity)
Drafting: Hélène Gille
Iconography and additional contributions to the text: Bárbara Ávila and Marine Wong
Editing: David McDonald
Administrative coordination and partnerships: Nataša Lazić
Quality control: Carl Vannetelbosch
Layout and cover design: Mirian Querol and Marie Moncet

Composed and printed in the workshops of UNESCO
The printer is certified Imprim'Vert ®, the French printing industry's environmental initiative

Printed in France

Table of contents

Foreword

Biodiversity is the essence of life: it provides essential products such as food, textile fibres and building materials, maintains ecosystem services such as soil fertility, and underpins societies, cultures and religion.

The UNESCO/CBD Biodiversity Learning Kit uses text, illustrations and practical methods to help secondary school students and teachers understand the multiple dimensions and complex processes related to biodiversity through innovative learning pathways and hands-on activities. It also explains the status of biodiversity and how it is affected by prevailing attitudes and behaviours and by consumption patterns.

Education is essential for the sustainable and equitable use of biodiversity and its conservation. We therefore hope that teachers and students will find the Kit to be a useful and interesting resource to deepen students' knowledge of biodiversity and thus develop an understanding that its conservation is pivotal to the future of our planet.

This publication is a contribution to the United Nations Decade of Biodiversity (2011-2020). It is consistent with the main objectives of the Convention on Biological Diversity (CBD) Action Programme on communication, education and public awareness, to which UNESCO has contributed over the last 15 years, and the Global Action Programme on Education for Sustainable Development, coordinated by UNESCO. The Kit was pilot tested by secondary schools of the UNESCO Associated Schools Project Network (ASPnet).

The Kit was developed within the framework of a joint initiative between UNESCO's Education and Natural Sciences Sectors and the Convention on Biological Diversity (CBD).

We would like to offer our sincere thanks to the Secretariat of the Convention on Biological Diversity (CBD), to the Government of Japan, to UNESCO Extea, to Beraca and to the French MAB National Committee, who have provided resources for the development of this Learning Kit in support of UNESCO.

Flavia Schlegel
ADG/SC

Qian Tang
ADG/ED

Preface

'Go take your lessons from nature, that is where our future lies.'

Leonardo da Vinci

This educational kit is the result of the joint work of experts from various disciplines including education, pedagogy, biological sciences, ecology, languages and cultural diversity. The project favours interdisciplinarity because, by definition, biodiversity – the central theme of this manual – traverses all sectors of our society. Biological diversity encompasses the past – the evolution of life on earth – the present – the contribution of biodiversity to human wellbeing – and the future – the crucial need to preserve biodiversity as it undergoes erosion and loss at local, regional and global levels.

Why produce an educational kit on biodiversity? The answer lies in the results of the Global Biodiversity Outlook *(GBO)* and the work of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), which should be brought to the attention of all, not just decision-makers. Indeed, the future of biodiversity will depend on the global collective action of an educated society, including a moral obligation to promote traditional and indigenous knowledge of biodiversity.

UNESCO has developed this kit in close collaboration with the Secretariat of the Convention on Biological Diversity (CBD) and the UNESCO Associated Schools Project Network (ASPnet). We want this kit, which will be freely available upon publication in three languages (English, French and Spanish), to serve as a reference allowing the concept of biodiversity, often seen as difficult to grasp, to be understood and applied in terms of its essence and its impact on our lives and the sustainability of our planet. Ultimately, biodiversity, beyond encapsulating the natural evolution of life on earth and in the oceans, represents the result of our interaction with nature around us. If we lead lives that reflect the objectives of sustainable development, we can continue to benefit from biodiversity and its vital ecosystem services. These services affect our food security and access to water, contribute to our health and wellbeing, offer protection against natural disasters, and provide renewable energy and key components for our habitats, as well as climate regulation.

Activity 1

A preliminary inventory of biodiversity: animal and plant projects

1. Introducing taxonomy

At the outset of the activity, the teacher explains that our planet is shared with millions of other species. This abundant biodiversity encompasses individuals, organisms and life forms, as well as a variety of relationships between different species and between species and their environment.

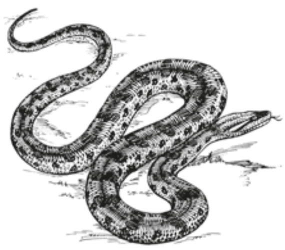
It is this pattern of relationships that shapes the natural habitats and landscapes around us.

Humans, like all other species, are part of this living fabric and exist because of it.

The teacher then explains that a series of activities are planned on this topic.

Biodiversity in fact presents us with a double paradox:

Avocet



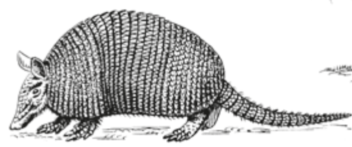
Anaconda

Almond plant

Albatross

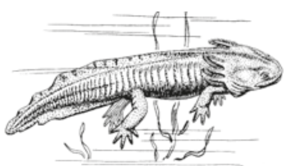
Antelope

Agouti



Armadillo

Baltimore oriole



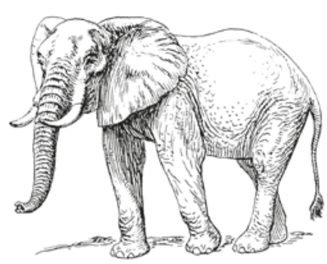
Axolotle

Anteater

Artichoke

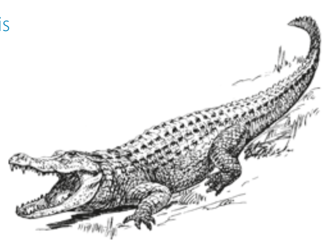
Baboon

Amaryllis



African elephant

Banana tree



Alligator

1. We make use of biodiversity on a daily basis, but know very little about it. The number of potential species is vast, estimated at between 5 and 30 million, however most are still unknown to science.

2. These species potentially offer interesting qualities and characteristics, but are now disappearing at an increasing rate before we have had the chance to learn anything about them.

- The teacher then offers to shed some light on what science tells us about biodiversity. He or she briefly introduces taxonomy within the context of the traditional classification of species, at the same time pointing out how it has been improved on in recent decades.

- The teacher next outlines the classification inherited from Linnaeus which divides living organisms into six kingdoms: bacteria, archaea, protists, fungi, plants and animals, and illustrates by means of examples how organisms are arranged in groups of decreasing size, from kingdom to species.

> *Example: lions*
> *Kingdom: animals; Phylum: chordates; Class: mammals; Order: carnivores; Family: cats; Genus: great cats; Species: lions.*

- The teacher then demonstrates that the hierarchy of taxa or conceptual units established between groups allows us to group living organisms in a way that indicates the degree of relatedness between species.

> *Example:*
> *All chordates develop a dorsal nerve cord. All the great cats roar.*

- The teacher goes on to explain the important role of the scientific name distinguishing each species. Because of its precise nature, the name allows us to identify, name and single out each species. This classification system enables us to situate each species and understand its place in the fabric of biological life and how it is connected or linked to other species.

  This classification system, especially the cataloguing of species and their relationships, is known as systematics. It is a key tool for understanding biodiversity, allowing a deeper appreciation of ecosystems and the biosphere, and their functions and interactions.

- At this point, the teacher adds that our scientific knowledge of biodiversity is incomplete, with 1.7 million species recorded out of a plausible estimate of between 10 and 30 million. Large pieces of the jigsaw are therefore still missing, even though important theories about their probable nature have been developed:

  It is thought that these species include an extremely high proportion of invertebrates (especially insects and arachnids) and micro-organisms (protists such as single-cell algae, fungi, bacteria and viruses).

2. Encourage the creation of projects involving plants and animals

At this stage, the teacher encourages pupils to start their own plant and animal projects, highlighting the concept of species.

He or she explains that 'species' is a practical and useful concept that allows us to distinguish between organisms by accurately identifying them on the basis of their physical characteristics: morphological, anatomical and physiological.

As they work on their plant and animal projects, the pupils first focus on the characteristics peculiar to certain families of species (since they cannot all be tackled), then examine the characteristics within each family peculiar to individual species, thus highlighting the disparities between families and species.

- The class is divided into groups to focus their attention on species found in the local environment, often including larger species such as vertebrates among the animals and terrestrial plants. Possibilities may also include domestic animals, trees found in the region, flowering plants (angiosperms) from among the wild flora, edible plants and insects.

  If the pupils live in a coastal area, one group can choose molluscs (gastropods and bivalves).

3. Refine the research and tools according to the species

Pupils can develop their plant or animal projects with a view to capturing the characteristics of families and species. They can use a variety of recording methods depending on the available school resources. These may include photography, sketching, painting, collages, collection of samples, dried plant specimens, observation of animals in real life or from printed sources, and study of anatomical drawings. Moreover, Media allowing access to relevant Internet information including pictures and videos of species will be utilized whenever feasible.

> *Example:*
> *In the case of canines (the dog family), pupils can observe pet dogs and study materials on dingoes, jackals or wolves, recording their bodily attitudes during play or when they are being submissive (in the case of dogs) or defensive (bared fangs). This will enable them to discern the supple, agile bodies of canines, their elongated limbs which make movement so effortless, and their meat-eating jaws with their pointed teeth.*

In the same way, pupils can identify the characteristics that make caprines (the goat family) such agile climbers.

- In regions with temperate or boreal forests, a group of pupils on the advice of a tracker may attempt to lie in wait for animals in the hope of observing wild species in their natural surroundings, for example members of the weasel family.

  With luck, such glimpses will allow pupils to draw the elongated snouts and slender bodies of burrowing animals, distinguish the more thickset, wedge-shaped bodies of badgers, given to excavating spacious galleries, or the neater, lithe, cylindrical forms of weasels and stoats, with their tendency to merge into their background and steal up on prey from behind. Afterwards, pupils can use printed and online sources to identify another fearsome predator of the weasel family, the otter, whose hydrodynamic form enables it to swim under water with ease.

- Pupils may also explore the symbolic dimension of animals. For example, animal projects might examine the symbolic aura of ermines – feared and respected predators that grow a pure white coat in winter, resulting in an association with purity. Historically, ermines have had a central place in many Western cultures: icons and portraits of kings, emperors and high-ranking dignitaries often show them ermine-clad or at least wearing an item made from ermine.

  In the case of flowering plants, the first task is to determine which of the two traditional classes a plant belongs to – monocotyledons or dicotyledons. Monocotyledons are plants whose seeds germinate from a single seed-leaf such as wild irises, orchids and banana trees, while dicotyledons germinate from two seed-leaves and encompass a large number of families ranging from the Rosaceae to the Fabaceae, Asteraceae and Crucifers.

  The monocotyledons are easier to recognize, as they have linear, ribbon-like leaves with parallel veins.

  The teacher uses the distinction between the two plant classes to explain to pupils that monocotyledons represent an important phase in the evolution of the plant kingdom, interpreted as an irreversible evolution stemming from the genetic variability of a dicotyledonous plant. Returning to the fixed hierarchy of taxa in traditional classification, the teacher goes on to point out that this has been abandoned in favour of a more recent classification based on the notion of common descent, according to which all species are the result of speciations – in other words, divergences or genetic variabilities given substance by the evolution of species that preceded them.

The plant projects can explore shapes, the morphology of plants according to families (e.g. the fruit of the Fabaceae are all pods and their leaves are always compound) and the anatomical structure of different plant organs. For example, plant families such as cacti have adapted to drier climates and drought and are no more than stems that they store water, euphorbia have developed thick fleshy leaves that hold water known as 'succulents', and crassulaceae (e.g. houseleek) or saxifrages grow in the shape of rosettes or cushions to protect themselves from icy mountain winds.

The plant project group should note a variety of shapes and colours in their effort to study and draw the flowers. The same elements or organs – carpels, stamens, petals and sepals – are often found arranged around a central axis for a wide variety of inflorescences within families and from species to species, encompassing inflorescences in spike, cluster or capitulum forms (a single flower balanced at the end of a peduncle or stalk).

Moving beyond differences in inflorescence, pupils will discover that elements in flowers of the same family follow similar constructions, such as in the cases of Fabaceae (for petals) and Liliaceae (the bell-shaped flowers of lily of the valley recall the shape of tulips). All of these flowers have adapted in diverse ways to degrees of brightness or amounts of sunlight, or to specific methods of pollination or reproduction.

The plant drawings are then painted or coloured (using pencils or crayons), depending on availability, using flat monochromes tints for large petals, long thin brush strokes for the spikes, and delicate brushstrokes for the clusters and capitula.

It is useful for pupils to observe flowers from the same family whose corollas have opened (e.g. Ranunculaceae in the northern hemisphere) to identify disparities between species on the basis of visual details such as range and depth of colours, and the size and shape of petals. Examples may include high-altitude (anemones or columbines), aquatic (marsh marigolds) or horticultural (clematis) species.


Aster


Bachelor's Button

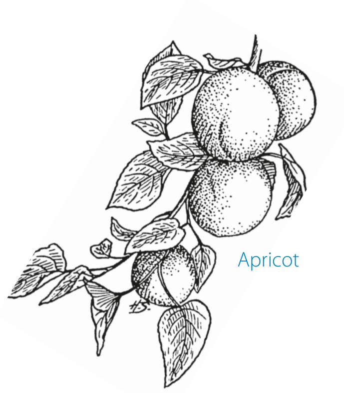

Aconite


Alder


Acacia


Alfalfa


Alyssum


Apricot

4. Organize a presentation of the plant and animal projects

In the final stage of the activity, the groups present their animal or plant projects to the whole class, taking care to situate the species studied in the classification according to their membership of a phylum, class, order and family.

Although it is important to emphasize the characteristics and disparities of species in terms of their differences in shape, size and lifecycles, with accompanying drawings and notes, the idea is also to relate each species to the fabric of biological life.

All species share the same vital functions that keep them alive and enable them to form part of this fabric of biological life. These functions which drive biodiversity are respiration, the release of energy from food, the absorption of nutrients and the expulsion of waste, growth, locomotion and reproduction.

As part of the presentations, each group must also establish how their species reproduces, locates the raw material needed for energy and growth (by absorbing food or sunlight through photosynthesis), and regulates their energy flow through respiration or evapotranspiration.

How do species individually ensure that these functions of feeding, respiration and reproduction occur?

During the presentations the pupils will examine a variety of issues relating to the species being studied. Key questions include: What does the diet of animal species consist of? Which organs of the plants are involved in photosynthesis and which are needed to make glucose? Does photosynthesis occur only in terrestrial plants? Which species breathe through lungs, which through tracheas (windpipes) and which through branchiae (gills)? What is the precise function of stomata in plants and which gases are exchanged through them? Do plants expel waste matter? In enabling plants to breathe, do stomata also promote a form of feeding through the take-up of nutrients from the soil? How do the plants presented reproduce? What acts as their pollinating agent? What kind of fruit do they bear? How do they disperse their seeds? Does this process also require a dispersing agent?

Eglantine

Dogtooth violet

Decurrent

Decussate

Dandelion

An illustrated diagram of the fabric of biological life

1. Explain the concept of biological life

The teacher starts by reviewing the concept of biodiversity.

- She or he summarizes:

Biodiversity encompasses all forms of life including those at the microscopic level to entire organisms and their natural habitats. It is found at every level of biological life and forms part of systems that consist of genes, species, ecosystems and biomes.

Above all, it covers the totality of relationships and interactions that link these living units. Biodiversity constitutes the living fabric of our planet. This image can be understood by examining a vital function that maintains these units of life: the flow of energy from food.

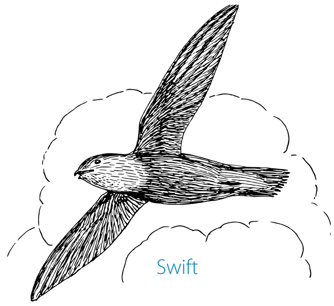
Living things that exist within the same space are interdependent. Together, they form a network consisting of nodes each of which corresponds to a species. These are linked to one other through interactions that make up the food chain.

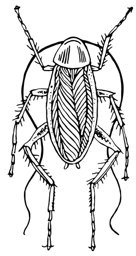
These interactions are responsible for the flow of organic matter from the species that is eaten to the species that consumes it.

Many species consume different kinds of food and thus belong to several food chains, all of which form part of a **trophic network**.

The teacher concludes:

The relations between species make up food chains and trophic networks, which enable the circulation of matter and energy necessary for every living thing. This process sustains the dynamic complex known as the ecosystem.

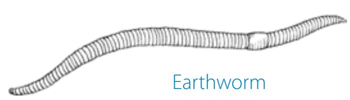

Swift


Cockroach


Cedar


Toad


Coyote


Earthworm

2. Create a pyramid-shaped diagram illustrating the fabric of biological life

- After this explanation, the teacher asks the class to create a large diagram illustrating the fabric of biological life.

- She or he points out that representing biodiversity in this way can show how trophic networks play a part in the functioning of ecosystems. Different options include diagrams resembling spider webs, circles crossed by networks of arrows linking species located at the periphery, simplified diagrams showing the multiplicity of connections between species, and a pyramid of energy featuring different species according to their trophic levels, with the pyramid narrowing towards the top (big consumers) indicating the loss of energy during transmission.

- The teacher then suggests to the class that they opt for a large, pyramid-shaped chart to illustrate the fabric of biological life. The chart should show the links within biodiversity, the food chains and the transfer of energy.

- A large, vertical sheet of paper is used and securely attached to the wall. It is important to allow space to add further sheets alongside to chart additional developments. Pupils are asked to think once more about the food chains that link the dominant species in their own environment, recalling the group discussions during the previous activity (1.2).

- Next, the pupils identify the various food chains, trying to be as accurate as possible. The food chains generally involve fewer than six species.

Examples:
In temperate mountain regions:
Alpine bistort (seeds) (Polygonum viviparum) ➧ Snow vole (Chionomys nivalis) ➧ Stoat (Mustela erminea) ➧ Golden eagle (Aquila chrysaetos)
In the grassy steppe regions of South America:
Fescue grass (Festuca orthophylla) ➧ Domesticated cow (Bos taurus) ➧ Human being (Homo sapiens)

- Once the food chains have been identified the teacher asks for volunteers to practise drawing species to be included in the diagram.

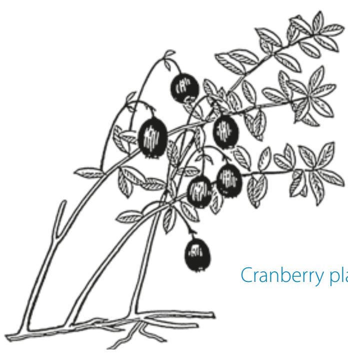
- If a decision is taken to use photos to represent species featured at each node in the network, or to alternate between drawings and photos, other pupils are given the task of collecting the material.

- The conventions for interpreting the diagram are then established:

  Arrows are used to indicate the links between species that serve as food for other species. The arrows always indicate the direction of the transfer of matter and energy, and not the direction of predation.

Example:
Bistort ➧ vole ➧ stoat ➧ eagle


Chinchilla


Cranberry plant


Adder


Bandicoot


Eagle


Butterfly

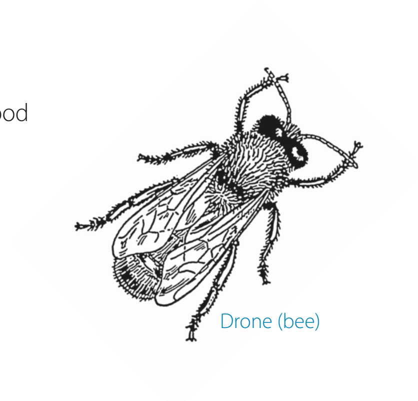
3. Fill in the details of the pyramid diagram

Before starting at the base of the pyramid with the first trophic level, the teacher explains that one category of living things cannot satisfactorily be classified within the trophic networks, because they are active at several different levels. These are **decomposers**. These organisms and micro-organisms transform dead organic matter into mineral compounds, and are found in soil, water, the litter under trees, detritus, septic tanks, or next to carcasses or excrement.

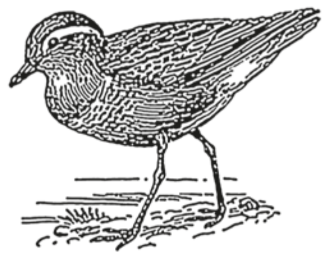
- Decomposers play an essential part in the flow of matter and energy in living things and are found throughout the biosphere, wherever the remains of organic matter need to be broken down.

- The teacher then gives the class some guidance:

Since decomposers are virtually impossible to locate, they cannot be accurately inserted into food chains but must appear at several levels in the pyramid of biological life. They can be shown in a separate box at the base of the pyramid or in boxes or sidebars arranged alongside.


Drone (bee)

Decomposers consist mainly of micro-organisms and invertebrates. This teeming diversity is often hidden or invisible to the naked eye. In the separate boxes below or next to the pyramid, the pupils paste cut out or copied images of decomposers. These may include detritivores found among invertebrates in the soil (e.g. ants, iules, earthworms, centipedes, beetles of the Crustacean family), the larvae of diptera or decomposer micro-organisms present in the soil (e.g. unicellular fungi or yeasts such as ascomycetes, mycorrhiza, bacteria of the *acidianus* or *acetobacter* type, or unicellular algae of the *chlamydonomas* type – a genus used in biofuel production).


Dotterel

- The pupils then focus on the first section at the base of the pyramid, which represents the trophic level of plants or **producers**.

- This section should emphasize the astonishing diversity of these species by highlighting the different parts of plants (e.g. leaves, seeds, fruits, cones, flowers, stalks) according to whether they are the favourite food of species at the next trophic level.

Pupils should not forget certain examples of producer organisms among the aquatic plants of their environment, such as the microscopic algae that form phytoplankton.


Mosquito

- The teacher then returns briefly to the term 'producers':

Plants rely on a 'suction' effect created by the loss of water through evapotranspiration to draw water and vital nutritious elements from the soil.

They also rely on **photosynthesis** to ensure their own growth process and make their own food:

Photosynthesis is the process whereby plants make direct use of the sun's energy to convert water and carbon dioxide contained in their leaves into glucose. Plants use this glucose as a source of energy and convert it via a chemical transformation into cellulose, starch (seeds) and plant matter, which is usable by other living organisms. Plants therefore produce not only their own food, but also matter and energy made available to other species.

- Next, the pupils move up the pyramid to the **primary consumers**, which feed on plants. These phytophagous animals rely on a source of biochemical energy obtainable from plant matter.

They species are easy to identify, and their food is very widespread.

- The pupils select herbivores on the basis of the specific nature of their diet and explain the corresponding morphological adaptations.

> *Examples:*
> *Depending on the latitude, zebras and giraffes, plains bison, chamois and ibexes found on mountain slopes, all survive on a diet of grass and shoots. Their digestive organs are adapted to maximize the intake of food, which is ingested in large quantities but is of little nutritional value.*

The diet of granivores is rich in starch, and also requires the morphological or anatomical adaptation of certain organs, such as a powerful beak in the case of the spotted nutcracker *(Nucifraga caryocatactes)* or the European greenfinch *(Carduelis chloris)*, and developed mandibles among granivorous ants *(Messor barbarus)*.

- By transporting, eating, ejecting and even swallowing seeds – the reproductive elements of plants – granivorous animals contribute to their dispersal.

  Pupils can present ecological functions linked to the diets of herbivores in separate side panels, parallel to the main diagram.

> *Example:*
> *The red-rumped agouti* (Dasyprocta leporina)*, a fruit-eating rodent of the tropical rainforest, eats the drupes of the moriche palm* (Mauritia flexuosa)*, then breaks the kernels to eat the seeds, thereby promoting the dispersal of the plant, sometimes to excess in the case of some specimens.*

- Regardless of the natural environment of the class, it is important not to neglect the primary consumers that feed on aquatic plants. These often correspond to the larvae of insects (e.g. mosquitoes) and planktonic crustaceans.

- The next trophic level can pose a challenge, as it is more difficult for pupils to determine whether a predator is a **secondary** or a **tertiary consumer**.

  A carnivorous animal seeking a source of biochemical energy from animal matter can feed on an herbivorous animal. For example, a frog may eat grasshoppers that feed on plants. In this respect, the frog is a secondary consumer.

  In comparison, a grass snake that feeds on frogs that eat grasshoppers, which feed on plants, is a tertiary consumer.

- In cases where predators link to several types of prey simultaneously, pupils will need to introduce more arrows.

  For example, the brown bear (*Ursus arctos arctos*) is an omnivore, and eats not only berries, roots and shoots, but also fish, moths and rodents. Conversely, the polar bear (*Ursus maritimus*) is exclusively carnivorous and feeds on fish and seals, including the ringed seal (*Puda hispida*), which is itself partial to Arctic cod and planktonic crustaceans.

- Pupils and teachers should now attempt to clarify the notion of a **super-predator**.

  The brown bear, as an omnivore, sits at the top of the food pyramid. Once it has reached adulthood, it is no longer preyed upon by other animal species, and can only be consumed after its death by decomposers.

- The pupils then work to identify the super-predators in their own environment. These are placed at the top of the pyramid.

- The pupils highlight the usefulness of super-predators by using the appropriate food chains to underline their crucial role in regulating populations of potentially harmful species.

> *Examples:*
> *In many parts of Africa, the Nile crocodile* (Crocodylus niloticus) *helps to regulate populations of catfish such as the giraffe catfish* (Auchenoglanis occidentalis) *and species of cichlids. In Europe, the long-eared owl* (Asio otus) *helps to keep down the number of land voles and field mice.*

- Pupils must remember to include aquatic carnivorous animals, which select their prey from among other aquatic animals. Examples include herons that feed on loach in lake environments or certain super-predators in marine environments, such as whales. These masters of their biological communities often die a natural death and play an important role thereafter in sustaining marine biodiversity and the expansion of deep-water species.

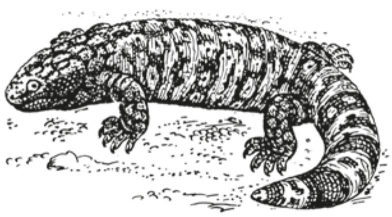
- On completion, the illustrated diagram of the fabric of biological of life should contain an abundance of species. It should also a large number of clearly drawn arrows representing the links between species in the networks.

4. Locate the energy flows in the pyramid

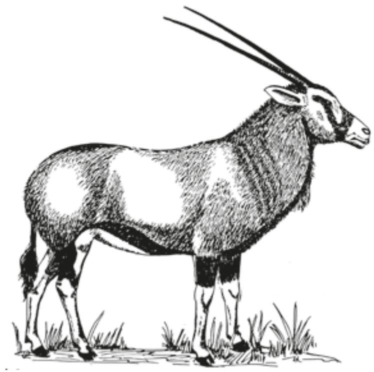
- Finally, the teacher asks the class to focus on the narrowing of the pyramid of biological life towards its summit.

  At the base, the producers are plentiful in number.

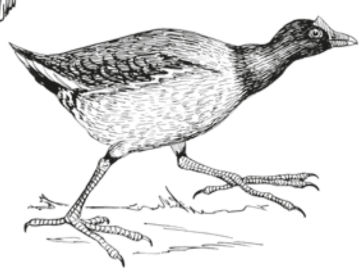
  At the summit, the tertiary consumers and super-predators are few in number and only contain a small amount of energy.


Gila Monster

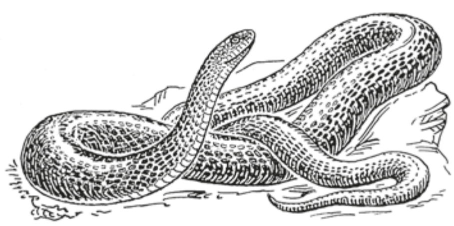

Hornbill


Gemsbok


Gecko


Moorhen


Genet


Black snake

- The teacher explains that the illustrated diagram of biological life also functions as an energy pyramid. The flow of energy corresponds to the amounts of energy that move through the ecosystem. The pyramid shows that at each trophic level or stage in the food chain as much energy is lost as transmitted.

- The teacher now makes use of the examples present in the diagram:

  For instance, when an aquatic predator (of the seal type) absorbs a large number of individuals in a shoal of fish (e.g. mackerel), the energy captured in the form of food is no longer available. It is lost and cannot be re-used.

  In ecology, the energy pyramid is used to represent the energy entering the trophic level (to increase the mass of an organism) and the energy lost or degraded (through assimilated matter, unconsumed matter in remains, and the loss of heat through cellular respiration or digestion).

- The teacher explains that such lost energy is constantly being replaced throughout the ecosystem by energy trapped in the remains of organisms that have died.

  By breaking down dead matter, decomposers, earthworms, fungi and bacteria release and recycle its nutritious elements and, at the same time, reinitiate the flow of energy and matter, which then moves through all the organisms that make up the whole of biological life.

- The pupils use side panels to present the important role of decomposers:

  For example, at the upper trophic level, the bodies of super-predators are broken down by necrophages, a category of 'specialist' decomposers of carcasses that include the griffon vulture *(Gyps fulvus)*, the hooded vulture (*Necrosyrtes monachus*) and certain species of ants, depending on the region.

  These species, whose organisms are adapted to swallow large amounts of saprophyte bacteria, function as 'grave-diggers' within the ecosystem, working with these same bacteria to break down dead matter.

  Life is therefore intrinsically linked to death throughout our biosphere.

Bittersweet

Hummingbird

Bittern

Blueberry

Horehound

Who lives where?

1. Goals and summary

The teacher guides the pupils or trainees through the stages of an activity aimed at relating the plants, animals and micro-organisms of a community of species to their respective habitats in the ecosystem.

The examples set out below, based on temperate and dryland regions, can be a useful starting point. The aim is to train the group to work outdoors with a view to discovering local biodiversity and pursuing an activity in relation to their own environment.

With this in mind, the teacher selects an area in the local environment as an example of an ecosystem. The class then sets about making an in-depth study of the area: defining the environment, locating the habitats and cataloguing the species that live in them.

Once back in the classroom, the group uses the catalogue to produce a display consisting of photographs, or pencil or coloured drawings of the chosen area.

They start with the background consisting of a landscape representative of the environment in the selected area (relief, open spaces, soil and climatic features). Next, they add detailed drawings or photos of the chosen area, including depictions of species in their habitats.

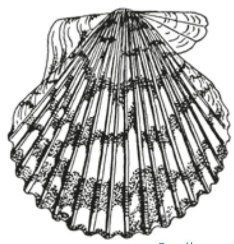

Starfish


Coral


Polyps


Anemone


Hermit crab


Scallop

2. Methodology

- The area selected should be as representative of the ecosystem as possible without being too large, and should present a variety of features.

> *Examples:*
> - *In bocage landscapes in temperate regions, the chosen area could be a closed environment (woodland, undergrowth) or an open one (grassland, fields).*
> - *In dryland regions, the group could select an area of sandy or rocky desert on the edge of a pond or guelta.*
> - *In karst landscapes, pupils could study a dry limestone plateau overlooking a river valley.*

- Once the group arrives at the chosen destination, the teacher asks the pupils to face the designated area and locate the best viewpoint. This could be a point overlooking the site or a view from a distance.

- The group then makes a number of sketches to capture the physical structure of the landscape, including its surface and relief.

  Key questions to ask include: How does the relief shape the landscape? Where is the selected area located? Does it get much sunlight? Which way is north and south? Is water present? What is the chemical composition of the soil (limestone or siliceous) and what texture does it have (sandy, silty or clayey)?

- To answer these different points, the teacher can draw on information and expert advice from key resources in the area, including agricultural, environmental and forestry professionals.

- Back in the classroom, the group spreads a large sheet of paper on a horizontal surface and draws the landscape using the preliminary sketches made at the site.

  The landscape drawing should include the broad outlines of the relief, the division of space into its surface elements, any water present, the cardinal points of the compass, and the composition and texture of the soil.

- Next, the class analyses the selected area again and list the species that make up the **biocenosis**.

- The class then identifies the dominant species of each different sub-environment.

> *Example:*
> *Forests in temperate regions of Europe are home to numerous tree species that vary according to the soil. Dominant species include examples of the Fagaceae family: the pedunculate oak* (Quercus robur)*; the cork oak* (Quercus suber)*, which thrives only in siliceous areas; the beech* (Fagus sylvatica)*, which typically grows at mid-altitudes and has a preference for brown soil and siliceous scree; the chestnut* (Castanea savita)*, a majestic tree that shuns limestone soils; and the downy oak* (Quercus pubescens)*, which prefers them.*

- Animal species are harder to spot. Accordingly, the group will have to undertake further outdoor study to locate traces.

  Sighting of mammals such as rabbits, deer or rodents in the undergrowth are rare.

  However, objects and tracks can provide clues. These may include feathers or bones, droppings, abandoned shelters, scents, half-eaten fruit or cones and leaves with holes in them. All of these clues allow us to determine an animal's presence, passage, behaviour and relationships in an environment, and so help to determine its living space.

- Once species have been identified, it is useful to refine the notion of 'habitat' by introducing the concept of 'micro-habitats' and the horizontal stratification of habitats.

  These terms can be applied to closed environments, such as woodlands, independent of the richness of the biodiversity present in the chosen ecosystem.

> *Example:*
> *In temperate woodlands, for instance, it is possible to distinguish fauna living in the soil, such as woodland snails, woodlice and millipedes, wood-boring insects, such as iuli, that live inside the bark of trees (and whose galleries are easy to spot), and leaf insects such as beech and oak weevils, which attack leaves by making small, easily recognizable holes in them.*

- The teacher should take care to avoid presenting habitats as isolated spaces with defined boundaries. Instead, he or she should emphasize that habitats are spaces lived in by organisms that carry out a variety of vital functions involved in eating and reproducing, including moving from place to place and interacting with other organisms. The notion of a habitat encompasses the existence of these organisms and areas with important functions essential to their life cycles (feeding areas, resting areas, nests, burrows and breeding areas).

- The teacher should also guide the pupils towards a wider conception of habitats:

  A species that no longer finds the conditions necessary for its survival in a given area will unfailingly move to a different area. It may choose to return to the old area after a time, and so exhibits a high level of mobility over a vast territory.

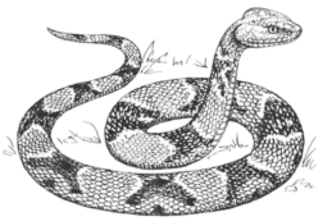
  Species vary in terms of the distances they are able to cover. For this reason, their habitats vary in size.

In addition, some species are specific to particular localized conditions, while others can tolerate a wide variety of conditions. The latter are said to be 'ubiquitous'. Examples include certain butterflies in temperate regions, among which are the Small Heath (*Coenonympha pamphilus*), which feed on a range of plants of the Poaceae family in various sub-environments.

- Pupils can convey this information using the landscape backdrop, for example, by indicating the re-appearance of particular species at different points in the landscape.

- Back in the classroom, the pupils compile a catalogue of the species they have encountered, regardless of whether they have actually seen them or merely identified them. The teacher can use available documentation resources to aid with identification (books, photos, the Internet).

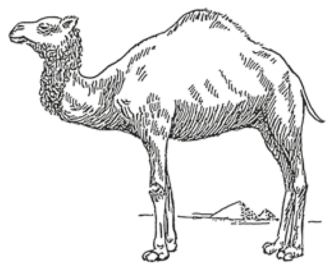
Finally, the pupils indicate the species present in their habitats by taking their detailed drawings or photos of species taken in the wild and placing them on the backdrop. They should take care to provide a detailed description for each species using drawings, colour and adding details, where necessary, in the case of the photographs. They should be equally painstaking in their presentation of the habitats, and can use windows and close-up images to present descriptions of small-scale habitats.

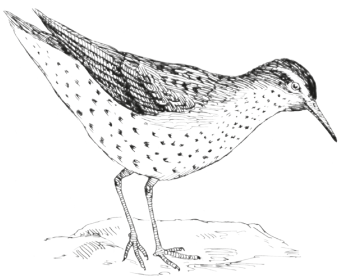

Copperhead

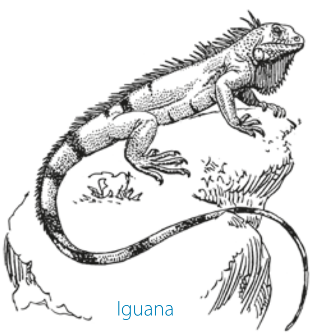

Date palm

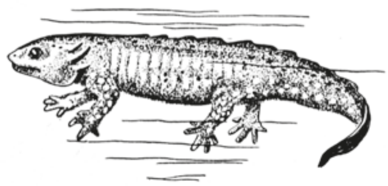

Camel


Cactus


Dromedary


Snipe


Iguana


Salamander


Giant Cactus

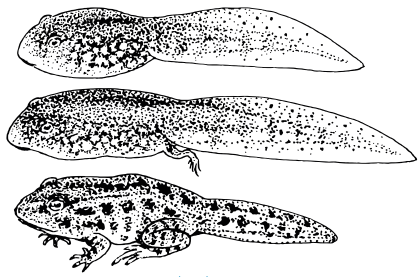
Activity 4

Species in their ecological niche

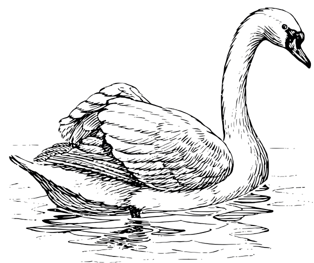
1. Explain the concept of an ecological niche

To introduce the concept of the ecological niche, the teacher returns to the image of biodiversity as a living fabric and the web of life.

Drangonfly



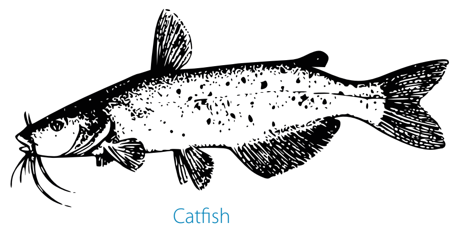
Tadpole



Swan

Egret

Aloe



Catfish

- The teacher continues:

Every node or stitch in the fabric represents a species and forms a link with other species. When a stitch in the fabric is 'dropped', the damage is not limited to the disappearance of a species. That disappearance creates a 'hole' and causes discontinuities among subsequent stitches in the fabric, hence in the interactions between different elements of biological diversity. The stitches begin to unravel and the hole gets bigger. The disappearance of a single species thus has consequences for the entire system.

For example, when a flowering plant disappears from an ecosystem, it has an impact on the populations of bees, butterflies, spiders or grasshoppers that depend on it, and subsequently on the birds that feed on those insects or their larvae. All of this undermines the pollination and seed dispersal functions performed by these same animals as they go about their daily tasks.

Each species within an ecosystem has its place. This is called an **ecological niche**.

This refers both to the space occupied by the species and the role it plays. The concept of the ecological niche is an active and dynamic one.

- The teacher illustrates this point:

There is a close relationship between the morphology of species, their physiology, and the niche they occupy – between their physical characteristics, the space where they occur and the function they fulfil within it.

Examples:
At altitude, many flowering plants (anemones, dryas, poppies, gentians) deploy large corollas of bright, dazzling colours, 'nurtured' by the strength of ultraviolet rays at high altitudes and long periods of sunshine. Conversely, the inflorescences of undergrowth species are much more 'modest'. These high-altitude flowers also produce biomass where little exists and hence deploy strategies (their remarkable colours) to attract pollinating insects that live at these altitudes.
Members of the weasel family provide another example. They are first and foremost burrowing animals, whose long snouts enable them to turn over and aerate the soil which constitutes their habitat.

- The teacher sums up:

Ecological niche is a concept related to the space occupied by a species. It refers to the resources and conditions of the space in question, which enable the species to live and breed, as well as to the impact made on the space and surrounding area by the species' activity in terms of food (predation, feeding dependencies), competition and symbiosis.

2. Illustrate the concept of an ecological niche

- At this point, the teacher makes the analysis more explicit by taking a specific example.

He or she gathers together detailed materials (photos, drawings) relating to specific species:

Example: the saguaro:
- *The saguaro cactus* (Carnegiea gigantea) *is a candelabra-shaped cactus of the Cactaceae family. It is a dominant species in the cactus scrubland of the Sonoran Desert in Mexico.*
- *Its ecological niche reflects the climatic conditions of its environment: high, sometimes extreme, temperatures all year round, a very high degree of aridity and low rainfall at infrequent intervals. The saguaro favours warm, south-facing slopes and would not survive 24 hours of frost (nights can be very cold in this desert).*
- *However, its ecological niche is also a reminder of the precious associations it maintains with companion plants such as the ocotillo* (Fouquieria splendens) *and the Joshua tree* (Yucca brevifolia). *These provide shelter allowing the cactus to germinate, become established and take in nutrients from the soil, in addition to promoting photosynthesis in its stem.*

- The teacher illustrates these different points using relevant illustrations or projections.

- The teacher continues to illustrate the concept of the ecological niche using examples:

  - The saguaro is host to numerous species that help to define its ecological niche. For example, it provides a home for the Harris's antelope squirrel *(Ammospermophilus)* and the northern flicker *(Colaptes auratus)*. The holes the latter leaves behind are reused by numerous small owls and elf owls *(Micrathene whitneyi)*, which also feed on the saguaro. All of these animals are **commensals** of the cactus, a Latin term which translates as 'table companions'.
  - As the host, the saguaro provides these animals with food and shelter without receiving anything in return. However, it lives and evolves without being harmed by their presence. This process is known as **commensalism**.
  - Among other examples of biological interaction involving the saguaro, the teacher can mention a mutually beneficial association or symbiosis with the Gila woodpecker *(Melanerpes uropygialis)*. This species eats the fruit of the saguaro, which contains a large number of seeds. These are scattered undigested, thereby contributing to the dispersal and conservation of the species. This process is known as **zoochory**.
  - This relationship is an important one since it influences plant dynamics, allowing saguaro populations to become stronger. These, in turn, have a regulatory effect on the dryness of the air and, by extension, on the local climate.

- The teacher emphasizes that ecosystems function through the interactions between different living organisms (biotic factors) linked with the totality of physico-chemical factors that influence the biocenosis (abiotic factors).

- He or she stresses that when studying the ecological niche of a species, it is important to consider the impact of its biological parameters on the local environment.

    - The saguaro feeds and shelters elf owls, which as predators regulate populations of insects that could otherwise become invasive and upset certain ecological balances in the ecosystem.
    - While its stem goes on living and growing, it sheds its needles. These attract large numbers of detritivores such as ants and termites, which break down the dead matter, thereby helping to recycle nutrients in the soil.

- The concept of an ecological niche encompasses cycles that interlink with one another.

- This allows the teacher to frame the interplay between species and the circulation of matter and energy generated by them within a wider mixing process between organic substances and the mineral substances absorbed by living things. This recycling of elements corresponds to the flow and transformation of chemical compounds or major elements (carbon, oxygen, nitrogen and water) that sustain the conditions for life within the biosphere during major biogeochemical cycles.

- Thanks to the abundant explanations and illustrations provide by the teacher, the pupils grasp the concept of an ecological niche, and understand that a single species, however small, plays a part in the functioning of the biosphere. Each link in the biodiversity chain counts as part of the great fabric of biological life.

Beetroot

Horseradish

3. Prepare an oral and visual presentation

The teacher is now able to present the living world as a series of embedded ecological units, from the smallest to the largest: from ecological niche to biotope to ecosystem to biome and finally to the entire biosphere.

The concept of species can be applied to all of these units.

Beech tree

- Each pupil selects a single species that he or she will situate in an environment or biotope, then in an ecosystem and finally in a biome. Each biome is a vast landscape with a distinct character consisting of a complex of ecosystems, whether located in temperate steppes or grasslands, northern forests or tropical savannahs.

- The pupil then maps out the living conditions of the chosen species, before attempting to describe its ecological niche in an oral presentation.

- Each stage of the narrative is prepared in advance and researched under the teacher's guidance:

  The pupils, working individually, begin by focusing their attention on how their species adapts to the resources and physical and climatic conditions of its environment (which may be very harsh).

  Factors to be considered include sunlight, space (from the macro to the micro level), soil, relationship to water, temperature range, precipitation, seasonal cycles (rainy season, dry season), microclimates and so on.

- The teacher then supervises study by pupils of species' adaptation to their environment. He or she guides the research on anatomical adaptations, which presuppose a gene pool and gradual adaptation to the environment throughout the course of evolution (see Vol. I, p. 23).

> *Example:*
> *Plants found high up in the mountains grow close to the ground. Over time they have adopted a squat, curled structure in order to survive the cold and violent winds at these high altitudes.*

- The dynamic discussion and research process turns next to competition between species and the relentless struggle for survival. The best adapted and sometimes the best 'armed' species occupy a particular ecological niche, tolerating its constraints. Natural selection is invoked whenever environmental conditions have eliminated the least resistant species.

- The teacher takes the opportunity to refer to specific adaptations of certain organisms to extreme environments.

> *Example:*
> *Weddell seals* (Leptonychotes weddelli) *have adapted to survive in very deep water and tolerate the lack of oxygen and enormous water pressures.*

- The teacher asks the pupils to pay attention to species whose ecological niches vary in terms of their amplitude. He or she introduces the specific term **narrow ecological niche**, applied to very specialized species that exhibit low adaptability when ecological factors change in their particular habitat.


Horse's head

> *Example:*
> *The Pyrenean desman in Europe is a semi-aquatic insectivore that seeks out waterways free of anthropogenic pollution and usually feeds on the larvae of mayflies, which are sensitive to the smallest variation in the acidity or temperature of water.*


Horns

- The teacher also introduces the contrasting term **ecological valence**, which refers to the possibility of a species populating different environments.

  A species with a broad ecological valence or broad ecological niche can live in a variety of environmental conditions. It is capable of developing in biotopes where ecological factors may be subject to significant variations.


Hooked beak

> *Examples:*
> *The large yellow underwing* (Noctua pronuba), *one of the European moths, is found in many open and closed environments.*
> *The tilapia* (Tilapia nilotica) *is a similarly robust species of African freshwater fish belonging to the Cichlidae family.*

- At this stage, the pupils synthesize the information they have gleaned about the habitat of the species they have chosen.

- Once they have a fuller understanding of this habitat in terms of its resources and conditions, and have more closely identified the needs of their chosen species, the pupils need to provide an image of the species. This may take the form of a photograph they take themselves (if the biotope is located in the neighbouring area) or a drawing.

- This image can then be embedded in larger photos or drawings portraying the ecological units at higher levels. This is an effective way of situating the ecological niche of the selected species.

Framing the habitat of their selected species in this way will provide the pupils with a backdrop for their oral presentation.

- The ecological niche is the expression of a functional relationship linking the species to its ecosystem. However, the habitat and the species' adaptation to it are not sufficient to define the species.

- Under the guidance of the teacher, the pupils focus on feeding and breeding conditions, with a view to identifying interactions with other members of the same species.

  Sample questions include: What is the prey of carnivores? What are the plant's 'food' requirements? How much space does the species occupy? What is its temporal reproductive rhythm? Does it hibernate? Is it active during the day or at night?

  With which species does it compete?

  Example:
  In Europe, nightingales and robins nest and hunt in competition with one other.

  With which species can it live in harmony?

  If two species with ecological affinities have different requirements on a single point they are able to co-exist peacefully.

  Example:
  Chamois and ibexes in many mountain areas are able to live together at the same stage of montane vegetation, because they have slightly different food preferences.

- The teacher now comes to the functional characteristics of certain species, by virtue of which they fulfil essential ecological functions and make a vital contribution to the functioning of ecosystems.

  These functional characteristics of species define valuable ecological niches and services from which human communities derive huge benefits:

  For example, the structure and biochemical composition of the leaves and roots of certain plants help to retain nitrates in the soil. The reproductive characteristics of seeds, including their mass and number, contribute to primary production (biomass).

- The teacher points out that the role of biodiversity in providing support services and regulating ecosystems that benefit us and our societies is increasingly valued by scientists and political decision-makers.

- As well as valuing species that provide us with provisioning services (food and wood), it is important to consider species that allow this provisioning to take place.

- The teacher then draws attention to species that function as the keystone of ecosystems and their living communities. Despite an occasional reduction in their biomass, these species fully realize the meaning of the term 'ecological niche' by performing a central functional role in the ecosystem. If these species were to disappear, their loss would result in dramatic changes to the ecosystem.

  Example:
  The starfish keeps down the numbers of its prey in coastal ecosystems, including sea urchins, mussels and other shellfish, and has no other predators. It is a keystone species. If the starfish were to disappear from these ecosystems, the mussel population would explode uncontrollably, driving away most of the other species, while in tropical coastal areas the sea urchin population would annihilate the coral reefs.

4. Present species in their ecological niche

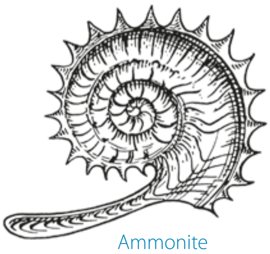
- The pupils now bring together all the characteristics relating to each of the selected species: environmental resources and conditions; morphological, anatomical and physiological qualities; behaviour and main biological interactions; and role and function in the ecosystem, especially with regard to the most useful species (although all species are useful in some way). The pupils then get ready to present their species in its ecological niche.

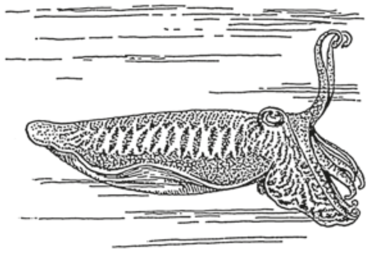
- Each pupil gives their presentation in front of their composition (photo or drawing) of the living environment of their species, which they created earlier. This illustration provides the visual context and setting for the oral presentation.

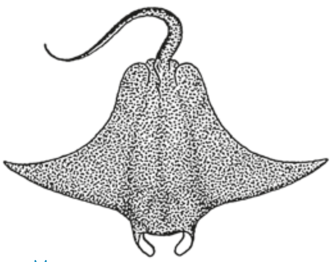
- In order to animate the presentation, the pupil can choose to personify the species: 'I am a young larch', 'a grass snake' or 'a fully grown female giraffe'.

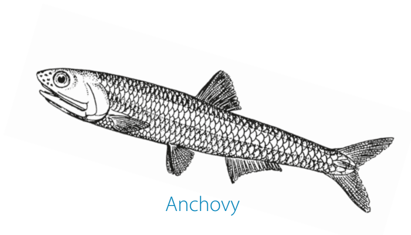
- This approach does not include miming but focuses on personification – allowing the imagination to run free, while simultaneously respecting the body of information and knowledge that has to be imparted.

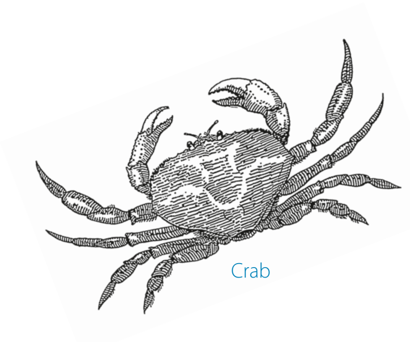
  Each presentation should aim to show how each species strives to fulfil a role, some more modest than others, but all equally necessary. They should highlight the competition between plants and the variety of ways in which animal species exploit the environment, as well as the struggle of each organism to create its ecological niche, the conditions in which it breeds best, its evolution towards an inevitable end as it is absorbed by other organisms, and the constant return of life and new organisms.

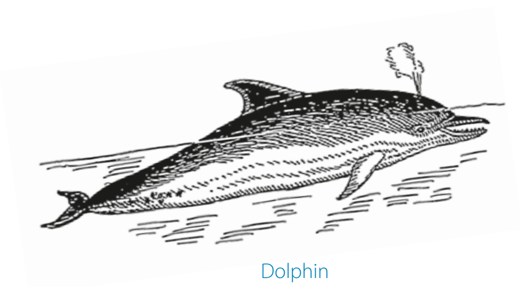

Ammonite

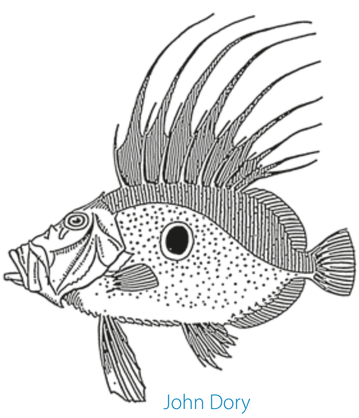

Cuttlefish


Manta ray


Anchovy


Crab


Dolphin


John Dory

Activity 5

A global map of biomes

1. Introduce the idea of a biome

The idea of biomes offers an alternative way to explore the diversity of ecosystems. By identifying biomes, especially terrestrial ones, the teacher can explore how the class and the community are linked to the local landscape or territory.

- The teacher explains that a biome is a community of interconnected ecosystems, forming an immense landscape that has a unified character, such as tropical savannahs, tundra or northern forests.

  He or she explains that these biomes are designated and characterized as such by scientists on the basis of their predominant plant and animal species.

- The teacher then reminds the class that the local environment forms part of an ecosystem that is itself located within a biome.

  This notion may seem a little abstract, since a biome tends to convey the image of a large formation of plants and their associated biocenosis. In fact, it consists of a mosaic of ecosystems, which themselves comprise a wide variety of environments, natural habitats, and communities and populations of species.

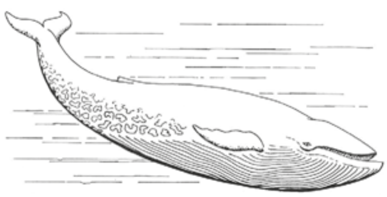
- The teacher explains further:

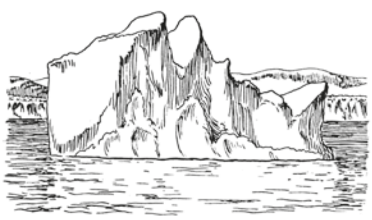
  The abiotic conditions in a bio-geographical area – essentially the climate and the soil – determine the type of biome (characterized by its vegetation) to which an area belongs.

  Referring the pupils to the previous activities, the teacher reminds the class that climate and soil determine the conditions and resources of an environment and simultaneously decide the composition of the environment's biocenosis, since only species adapted to these conditions can live there.

Example:
Biomes consisting of arid steppes and cold deserts only contain plant and animal species adapted to severe cold and aridity.


Penguin


Blue whale


Iceberg


Seal


Dogsled


Polar bear

- The teacher adds:

  Biomes are determined by analysing zonal divisions based on the latitude of bio-geographical areas in combination with climatic conditions.

  Water and temperature are two fundamental factors in determining climate. The distribution of these two factors is conditioned on a global scale by the rotation of the Earth on its axis, and varies according to latitude.

  This distribution is reflected in homogeneous belts of vegetation.

  Species diversity in terms of both plants and animals decreases as we move away from the Equator towards the poles. The biome with the highest level of biological diversity is tropical rainforest.

- The teacher provides an important piece of complementary information:

  The division of the living world into biomes that are shaped by the climate highlights a key fact: the landscapes and the main characteristics associated with these biomes exist at different points on the planet.

Example:
A large part of Europe is characterized by a biome consisting of temperate deciduous forests, especially in regions where there is sufficient rain to permit the growth of tall, broad-leaved trees. For the same reason, this biome occurs in eastern parts of China and in most parts of the United States.

2. Learn to identify the great terrestrial biomes and locate them correctly

The pupils now learn to locate the great biomes of the planet by plotting them on a world map. The latter is made as simple as possible by drawing or tracing just the outlines of the landmasses on the Earth's surface onto a large sheet of paper. This map comprises the first part of a two-part mural.

(For the second part, see Activity 6: People, landscapes and *terroir*).

The landmasses are left blank.

A list is then made of the main biomes. This is not an easy task to perform, as the biomes are often called by different names. In any case, fourteen biomes can be identified and an attempt can be made to simplify their names:

1. Tropical rainforests
2. Temperate deciduous forests
3. Temperate and subtropical rainforests
4. Taiga or boreal forests
5. Mediterranean sclerophyllous forests
6. Temperate grasslands
7. Tropical savannahs, grasslands and scrub
8. Tropical dry or deciduous forests (tropophilous forests)
9. Warm deserts and semi-deserts
10. Cold deserts and arid steppes
11. Tundra and polar deserts
12. A mixed system of mountains and high plateaux

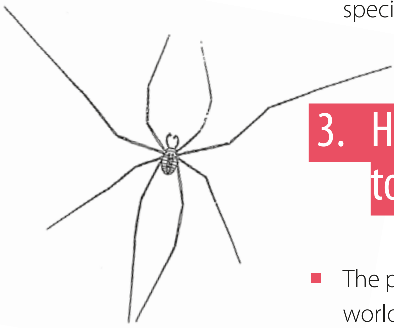
To these terrestrial biomes can be added two coastal or aquatic biomes:

1. Lake and river systems (a biome that characterizes the wet zones of Gabon or the Canadian Great Lakes region)
2. Mixed island systems (a biome that characterizes the larger islands of Sumatra, Java and Borneo and the Caribbean islands)

The pupils now mark the position of the biomes on the world map with the aid of existing biome maps and a conventional globe to locate the regions.

The pupils represent the distribution and geographical extent of the biomes by colouring the blank landmasses on the world map (e.g. light yellow for warm deserts, orange for the Mediterranean biome, light brown for savannahs, blue-green for taiga and so on).

The teacher explains that assigning environments to biomes provides an important advantage: it enables the study of biodiversity at the level of the biosphere. It therefore allows the comparison of different species on different continents because they belong to the same biome.



Daddy-longlegs

3. Highlight the distribution of biomes and their relationship to biodiversity

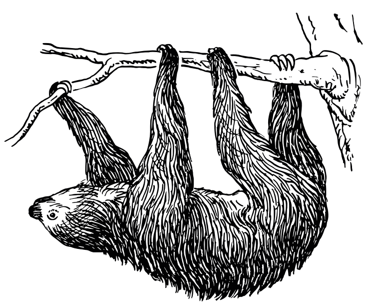
- The pupils identify the main species of the different biomes, continent by continent, and add them to the world map, gradually filling in the chart.

  Emphasis is placed on the different species found in each region, and occasionally endemic species (whenever these are distributed over an area limited to a given region of any size).

- The teacher explains:

  Within each region of the same biome, the peculiarities of climate and geology give rise to distinct plant species, among which equally diverse biological communities live and develop.

Frog



Sloth

Panda

Beaver

Badger

Examples:
Sclerophyllous Mediterranean forests are populated by holm oaks (Quercus ilex)*, typically accompanied by their southern companions: the rockrose and the strawberry tree. Sclerophyllous forests of south-western Australia, also belonging to the Mediterranean biome, are less dense and consist of jarrah, a species of eucalyptus* (Eucalyptus marginata)*, commonly accompanied by species of sundew (drosera) and Banksia, such as Scarlet banksia* (Banksia coccinea).

- The pupils learn to identify plant species and draw them. They capture the form of each species and reduce their outlines to the bare essentials, before finally transferring these simplified shapes to the world map.

  The pupils should also add the most typical animal species of these biomes, according to the region.

  Once they have completed this task, the global map of biomes will reflect the extraordinary diversity of species that make up the fabric of biological life, as well as the equally extraordinary diversity of ecosystems that comprise these biomes, found in places far removed and different from one another on the surface of the Earth.

- Pupils who wish may complement the global map of biomes with 'biome scrapbooks' containing photos gathered from various sources showing the different versions of the same biome from region to region. Such photos can help to provide insights into landscapes that are related in terms of their formation and structure, but which differ profoundly when examined more closely.

People, landscapes and *terroir*

1. Introduce the relationship between people and the local landscape

The previous activity (which is devised and can be conducted in tandem with the present activity) enabled pupils to discover different landscapes around the world, and reveal the extraordinary diversity of biomes and their ecosystems.

- The teacher and the class now examine their local landscape, which represents the most direct and everyday form of contact they have with nature and the ecosystem (and with the biome of which that ecosystem forms a part).

  With the teacher's help, the class considers the following questions:

  - What aspects of this landscape do you prefer?
  - Which places in particular?
  - How do they relate to the local landscape?

- If the pupils live in a rural environment:

  Is their relationship with the local environment rooted in everyday practice? (Examples of activities include games, working in the fields, harvesting and hunting.)

- If they live in an urban environment:

  When do the pupils experience the natural landscape? Are these times tied to specific occasions? When do they feel they are in nature? Which local landscape for them best reflects their region's ecosystem? To which biome does this ecosystem belong?

- Pupils and teacher between them agree on an aspect of the local landscape – one which is tended and maintained – that they would like to explore. They agree on a precise location to study that reflects this aspect.

- The teacher gives some guidelines:

  The chosen landscape should reflect a practical relationship, based on use, between the people who live there and the natural environment. The idea, initially, is not to focus on how the landscape is represented or the recreational, aesthetic and spiritual functions it fulfils, but rather to concentrate primarily on the relationship of management, exploitation and production that local people maintain with the natural environment.

- The teacher explains further:

  The availability of resources and constraints on the environment have always shaped the uses we make of nature. Throughout history we have adapted to the available resources and environmental constraints. The relationships developed with nature are therefore based on the uses we make of it.

  Uses such as gathering, fishing, hunting, agriculture and animal farming have been shaped by the opportunities and constraints present in our environment since the earliest times.

- By maintaining our relationship with nature, we have learnt to adapt the biological resources of our surroundings to our needs and have gradually modified our environment by making the best use of its biological resources.

  This union of nature and culture gave birth to the concept of ***terroir*** (see section 2 for an official definition proposed by UNESCO).

- The notion of *terroir* is important because it embodies knowledge of natural environments and their biodiversity. Each *terroir* reflects a balanced and harmonious relationship based on adaptation and management of natural environments.

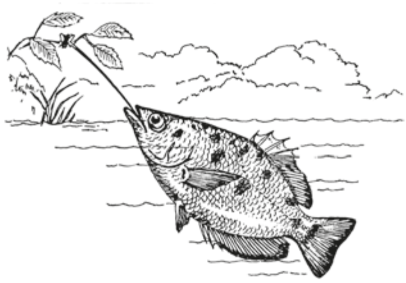
2. Expand on the concept of *terroir*

- The teacher provides more explicit detail:

  Terroirs encapsulate several elements and aspects. They encompass development of the landscape in relation to farming and breeding practices, and the harmonious management of natural resources, including vineyards, salt marshes, palm groves, terraces, foggaras, forestry and so on.

  Terroirs also embody a detailed knowledge of species and environments, technical know-how, practical skills, materials, crafts, tastes, flavours and smells.

  UNESCO and the association Terroirs et Cultures have proposed a definition of terroir: A geographical limited area where a human community generates and accumulates along its history a set of cultural distinctive features, knowledge and practices based on a system of interactions between biophysical and human factors. The combination of techniques involved reveals originality, confers typicity and leads to a reputation for goods originating from this geographical area, and therefore its inhabitants. *Terroirs* are living and innovating spaces that cannot be reduced only to tradition.'


Archerfish


Bas-relief


Barrage


Screech owl


Edelweiss

- The teacher uses the collected documentation to show the pupils photos or descriptions of different *terroirs*.

- She or he emphasizes the homogeneity of the *terroir* in terms of resources (the environment and the biocenosis) and production (arable, agricultural and forestry practices, techniques, tools and products of all kinds).

- The teacher helps the pupils to understand the extent to which the development of the *terroir* confers on those involved a cultural identity that subsequently leaves its imprint on the landscape.

  It is this relationship with nature and biodiversity that defines and enriches cultural identity.

3. Visit and survey a local *terroir*

Before organizing a visit to the selected *terroir*, the teacher approaches local experts. Depending on the particular case, these may be arable farmers, livestock farmers, winegrowers, shepherds, market-gardeners, trackers, hunters, fishermen, foresters, oyster farmers, salt workers and so on.

- Together, they organize the key points of the visit:

During the visit, the pupils carry out a survey. They examine in detail the ecological dimension of the *terroir*. The aim is to get them to measure the extent to which the *terroir* expresses an advanced understanding of the diversity of environments and species.

Examples:

- *Depending on the part of the world in question, the construction of terraces (terraced farming) reflects a specific knowledge of landforms. The shape of the terraces reflects the angle of the slope and the closeness of the contour lines.*
- *Terraced farming in the Andes is extremely diversified and depends on an appreciation of micro-climates at different levels and expert knowledge of the ecological niches of species: Which species can be combined? Which species exclude other species? Which genetic improvements can be made to certain seeds in relation to altitude?*
- *Accordingly, hundreds of sub-species are selected from classic vegetables such as the potato, bean and tomato.*
- *The diversity and selectivity of production (especially from local and wild species) and the exploitation of fifteen levels of different ecosystems makes the Andean terraces an agronomic laboratory appreciated and valued throughout the world.*

- The teaching team and the experts highlight other aspects of the *terroir*.

Examples:

- *In Costa Rica, certain terroirs given over to pastoral and forestry practices rely on the maintenance and improvement of pastures based on cross-managing herbaceous plants, species of shrub forage, the maintenance of species that function as living barriers, and specific breeds of cattle. The balance of these ecosystems is often fragile.*
- *In Portugal, ancestral agrarian systems intersperse field crops with cork oaks to provide shade for the growth of cereals. These systems are still maintained in some places and are being improved.*
- *Traditional oases and palm groves depend on a limited but regular supply of water, determined by the heat and sunshine. Algerian foggara, khettaras in Morocco and the quanat in Iran enable the irrigation of land by means of a system of water collection based on gravity and adapted to groundwater reserves. These systems are also being maintained and improved. Concerning the growing practices in oases, the palm tree – often the date palm* (Phoenix dactylifera), *but also other species of the same family – is the pivotal link in crop cultivation. In addition to the produce it generates, it provides shade and protection for the sub-strata of plants, from citruses to cereals, while at the same time allowing enough light to filter through.*

- The pupils then examine the nature and adequacy of changes to the natural environment, and take photos, make sketches and take notes. Their research also profits from the information and informed advice of the local experts.

- After exploring the management of the natural environment, the pupils extend their research to distinctive cultural aspects of the *terroirs*. These traits often relate to habitat and gastronomy, as well as to the ecological and organic harmony established between the local population of a *terroir* and their environment.

- For example, in terms of gastronomy the produce from harvests gives rise to a wide variety of products and a diversity of tastes and flavours.

Example:
The date palm alone (Phoenix dactylifera) produces fresh dates, fermented dates, dried dates, date preserve, dates in the form of confectionary, vinegar extracted from fermented dates, roasted palm seeds as a substitute for coffee, palm wine, palm oil and so on.

- Cultivated plants give rise to other uses beyond purely agricultural ones.

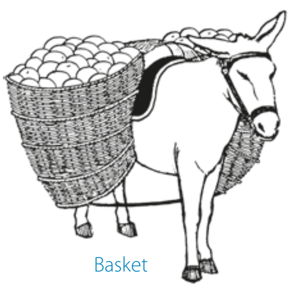
Example:
Parts of the date palm are exploited for their specific characteristics in traditional African handicrafts and dwellings: the juxtaposition of date palm rachis allows air to circulate freely and to keep the interior of houses fresh.
They are found in the walls of Touareg shelters, in furniture, shutters, baskets and other wickerwork items, and also in the form of thatch assembled for the roofs of huts in Senegal and Mauritania.
The stipe produces a hard wood, resistant to rot and to termites, especially in the case of the ron palm (Borassus aethiopum). *It is highly valued in the manufacture of rafters, timber frames and doorposts.*

4. Create a *terroir* mural

- Back in the classroom, the pupils reproduce their findings on large panels, which are used to construct a vast mural of the selected landscape.

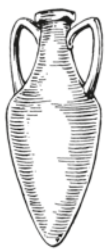
- The pupils share out the work:

  In the first panel, they illustrate the development of the *terroir* landscape emphasizing the ecological significance of these developments. In the second panel, they show and describe the production and products that derive from the *terroirs*. Together, both panels create a large mural, which complements the world map of biomes produced in the previous activity.

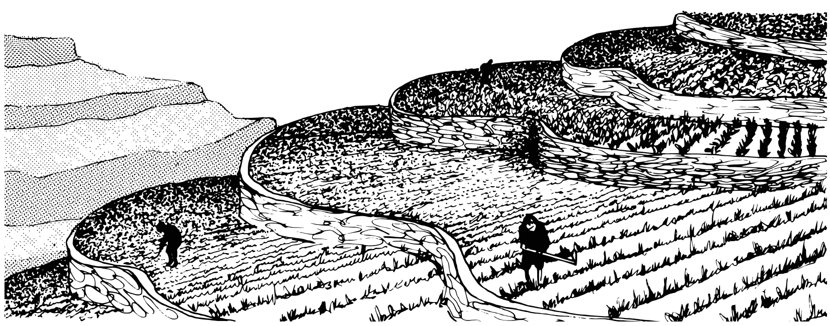

Basket


Blackberry


Fagot


Amphora


Carrot


Terrace


Wheat

- The teacher then emphasizes that landscapes represent an form of diversity that is difficult to classify because of the close association between biological diversity and cultural diversity.

  Although the landscape is both a natural and a cultural heritage, it is above all a living heritage, as distinct from an unchanging one.

  The landscape is alive and constantly evolving, for two fundamental reasons:

  1. This is the result of the combined action of the living world (animals, plants, fungi and micro-organisms), the abiotic environment and human societies.

  Nature can never be taken for granted. This point has been amply demonstrated by the impact of natural disasters.

  2. As human beings discover more about the living world and make further scientific and technological innovations, they can enrich and develop their interaction with nature within the context of the *terroirs*. These innovations in different fields (ranging from species conservation to energy management or hydrology) are converted into management practices that shape the way we use nature and make our mark on it.

  They can also transform and improve lifestyles that extend over vast territories (e.g. from nomadic Bedouin communities in the Middle East to reindeer breeders in the Siberian taiga).

  In summary, our bond with the landscape is constantly evolving. This revelatory process sustains and drives our relationship with life and with biodiversity.

  In this respect, this bond is essential to each and every one of us as human beings. How can this bond be maintained? The following activity provides information on the interplay between populations and ecosystems.

5. Understand the consequences of neglecting *terroir* and degrading the landscape

- To conclude, the teacher draws attention to the numerous areas of the environment where the landscape is not maintained.

  He or she explains the distinction between greenfield and degraded landscapes. The former often consist of abandoned wasteland and brownfield sites on the periphery or in the centre of towns where the natural ecosystem is gradually recovering. The latter consist of nondescript land often characterized by a reduction in the productive agricultural landscape, and suburban areas or built-up rural areas, where natural zones are being eroded and the territory is being blighted by urban sprawl.

- During an outing to point out these changes, the teacher highlights the extent of the proliferation of infrastructure and the carving up of land by roads and major routes, the impact of the growing uniformity of building materials including their non-degradability and the resulting pollution, the wholesale introduction of urban areas far away from town centres and the lack of attention to landscaping.

- The teacher emphasizes the damage caused by such neglect of the landscape both to biological diversity and to cultural diversity. Species do not survive, or do so only with difficulty, confined to tiny pockets or to fragmented or polluted habitats, and we no longer recognize ourselves in these landscapes and gradually lose the sense of what defines us.

Alyssum

Adder's tongue

The interplay of species, services and products

1. Identify the direct services provided by ecosystems to populations

- The teacher begins by reviewing the important role played by ecosystems in the life and wellbeing of humans and the local community.

  The teacher reminds the class that populations have long relied on natural resources to build our societies – resources from which we derive a great deal of benefit. Now the natural systems that provide these resources are showing signs of becoming exhausted. These include soil degradation, shrinking freshwater reserves, increased pollution (nitrogen excess and nitrogen leaching) and climate change. There is an urgent need to better understand the common resources we extract from nature and the manner in which we extract them.

  What natural resources are we in the process of losing or endangering? What systems do we rely upon and do we understand how they function and their importance?

- The teacher explains that ecosystems can be understood as units that provide local populations with services that are often taken for granted. This approach allows us to learn more about and analyse the natural processes encompassing resources, the environment and production mechanisms on which communities depend to develop societies.

  The *Millennium Ecosystem Assessment*, a pioneering United Nations report, defines four types of services: provisioning services, cultural services, regulating services and supporting services.

Ice floe

Breaker

Gorge

Promontory

Glacier

Fjord

- The teacher uses a wall chart (or similar) to lay out in detail the services provided by ecosystems, using a different colour for each service (e.g. red for provisioning services, orange for cultural services, turquoise for regulating services and green for supporting services).

  He or she starts with **provisioning services**, which offer direct benefits to human populations. These include tangible goods and other products supplied by ecosystems: food, timber for construction, drugs and molecular compounds, energy resources ranging from firewood to biofuels, and natural fibres.

- The class are then asked to provide their own examples in order to give a fuller picture.

  For example, items of clothing can be used to identify natural fibres such as cotton, linen, wool, cashmere and so on.

- Leather accessories can be added to the list of products, but with the caveat that certain objects, such as snakeskin handbags and tortoise-shell combs, threaten the survival of animal species.

- The range of food items on the list can be extended beyond crops and livestock products to include derived and processed products (jam, oil and bread), forest products gathered in the wild (mushrooms and berries) and game.

- To the list of ecosystem products can be added other non-wood forest products (NWFPs), such as exudates (resin, latex and gum), which are used by the biochemical industry, natural dyes, and products harvested or extracted directly from nature (cork or essential oils).

- Regarding medicinal products, the pupils can be asked to list local medicinal plants and renowned pure substances and chemical compounds, which are used by the international pharmaceutical industry for healthcare or research purposes.

- The teacher expands on the examples given by referring to standardized products that contain an active ingredient derived from plants. These range from the products of folk medicine and phytotherapy (plant powders, capsules taken internally and oils inhaled or breathed in naturally) to cosmetic products (shampoos, oils and creams).

- The teacher then moves on to the section on the wall chart relating to **cultural services**. These correspond to the intangible benefits we derive directly from ecosystems.

  He or she begins by discussing the aesthetic and spiritual benefits that nature provides. Since time immemorial, human societies have mirrored aspects of nature. This relationship acted as the source of our primal emotions and feelings, and later of our thought and belief systems.

Navigate

Hike

Acropolis

- The teacher explains that over the course of human history, humankind has tamed nature, and developed ways of adapting and making use of its resources. Our ability to recognize certain situations and experiences led to representations of nature, which we communicated to our fellow humans. Examples include hunting scenes painted on cave walls, mountain motifs in traditional Taoist Chinese engravings, frescoes of outdoor pagan rituals in Antiquity, monastery gardens in medieval Europe, tranquil landscapes glimpsed through a window in fifteenth-century Flanders, short poems or

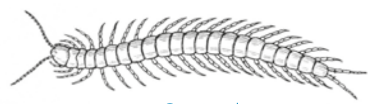
Japanese haiku poems celebrating nature, and universal collections of fables and stories set in the heart of forests which recount the lives of species.

Fungus

- The pupils now participate by relating pleasurable and aesthetic experiences from the natural world. Examples might include regional or familiar landscapes they enjoy (lakes, forests or rocky coastland) and landscapes shaped by human beings (cultural systems).
- The teacher asks them to talk about their visual experiences of nature and its different moods (e.g. dawn, a storm, a sunset or a harbour in the early morning), natural smells (e.g. undergrowth and scrubland) and flavours (e.g. meals prepared for festivals or made with fresh market produce).

Protozoan

- The pupils then brainstorm references to art works that form part of their heritage including pictorial works, cave paintings, and works of a musical, literary or sculptural nature. They should consider works directly inspired by nature, as well as historic, cultural and heritage sites located in natural settings.
- The teacher turns to the subject of sacred natural sites – areas in nature revered by communities. Such sites may include forests, sacred mountains, springs, rivers, lakes or caves that are imbued with meaning and importance, and associated with some form of divine presence venerated by local animistic traditions. They may also be reserved for ancestor worship.

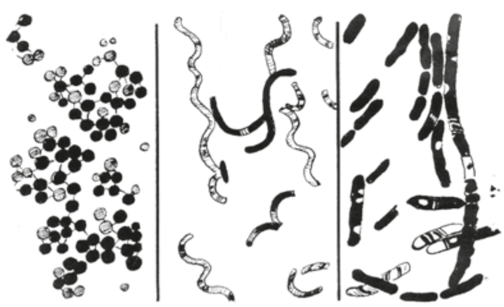


Centipede

- The teacher summarizes: nature has long been associated with religious belief and expressions of veneration, often born of a feeling of reverence and gratitude for the resources and benefits it bestows.
- Among the list of cultural services that feature on the chart, the pupils could make mention of natural divinities such as Gaia, Mother Earth and Vishnu, who in Hindu cosmogony is associated with water on which he floats and sleeps.
- Depending on their region, the pupils can also identify sacred natural areas, such as the forests of the Sherpas in Tibet or the high-altitude páramo regions in the Andes Mountains, as well as mythical natural areas such as the Garden of Eden in the Bible or the 'garden of delights' in the Qur'an.
- Compiling such a list of cultural services often produces surprises and discoveries. It makes the class aware of the references and links to nature that permeate our cultures, and the extent to which our cultures act as vehicles for meanings directly inherited from the natural environment.
- To complete the list of cultural services, the teacher turns to the recreational functions of leisure, relaxation and personal development enabled by ecosystems.

  For example, the recreational activities provided by nature allow us a means of release from stressful and restrictive urban lifestyles – a consequence of the laws that govern market forces, competition and financial profitability.

- Natural ecosystems thus allow us to escape, give us the chance to extricate ourselves from the pressure of our daily existence and, discover new sensory experiences such as walks or treks in remote deserts or mountains, or enjoy fast-paced outdoor activities such as skiing on mountain slopes.
- Other recreational functions of ecosystems allow us to experience a feeling of peace – of being at one with our immediate surroundings – and to 'recharge our batteries' by being reconnected with the living natural world. Outings, excursions and country walks all define our personal relationship with nature, providing opportunities to reflect, to relax and also to be surprised



Bacteria

– to 'blow away the cobwebs' and 'empty our heads'. These are all perhaps vestiges of links with nature that allow us to adjust to the physical and biological reality of the natural world.

2. Identify the indirect services provided by ecosystems to populations

- After cultural services, the teacher moves on to describe the regulating services and supporting services of ecosystems, from which we benefit indirectly. These services ensure that provisioning services are efficient and possible, and underlie the cultural services described above.

- The **regulating services** provided by ecosystems are benefits derived from the maintenance and regulation of natural systems linked to ecosystems. For example, the teacher can refer to the natural water purification functions of wetlands and depolluting plants; the regulation of the climate at local and global levels by forests and oceans through the capture and storage of carbon dioxide; and the role of oceans as huge providers of dioxygen via photosynthesis in cyanobacteria, algae and phytoplankton.

- He or she can also add the role of forests in combating erosion and preventing avalanches. Another vital service is the pollination of plant species by 'pollinating agents', which include not only bees and bumblebees, but also butterflies, spiders, coleoptera (beetles), diptera (flies), hummingbirds and bats. Without these agents, crops could not be sown and harvests could not bear fruit.

- In addition to these regulating services, the teacher explains the importance of anti-parasitic agents to control harmful organisms such as pests and invasive species.

- He or she draws attention to the natural processing of waste, specifically the decomposition and recycling of organic waste by soil fauna and microflora. Certain of these services, such as the recycling of waste, can be regarded as both regulating and supporting services.

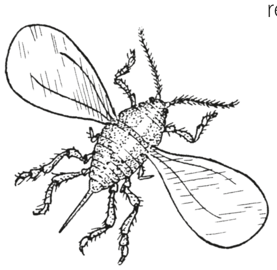
- In parallel, the teacher gives an account of the **supporting services** provided by ecosystems. These are essential to life on Earth and to the production of all the other services.

- These supporting services include the initial formation of soils in which biochemical erosion plays an important part. They also include the recycling of necromass or dead organic matter, with such matter playing a major role in soil fertility, the trophic base of ecosystems and the nutrient cycle, by permitting mineralization and the release of mineral compounds.

- The teacher goes on to describe the nutrient cycle, which is driven by ecosystems, and the nitrogen and carbon cycles, without which the planet's grand biochemical cycles could not take place.

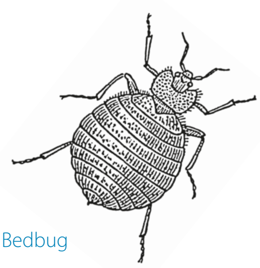
- He or she then turns to the production of biomass through photosynthesis and the conjunction of related biological interactions, before discussing the genetic diversity generated by ecosystems, which represents a formidable gene bank.

- The teacher now takes a look at the provisioning of human beings with drinking water. This occurs thanks to the water cycle, which is generated by the climate and the reciprocal action of plant species. These allow surface runoff to infiltrate into the soil and slowly percolate down through the ground, where it feeds and replenishes the water table.



Cochineal

Queen bee



Bedbug

- He or she concludes by emphasizing the interaction that exists between regulating services and supporting services.

> *Examples:*
> *The planet's grand biogeochemical cycles (concerning macro-elements like nitrogen and carbon) rely on care and correct maintenance. Excessive concentrations of nitrogen in the soil and plants, in combination with increased deposits of nitrous oxide in the atmosphere, which are beyond the capacity of ecosystems to regulate, can alter the long-term performance of these cycles.*
> *Scatophagous insects such as dung beetles decompose cowpats (up to eighteen a day), thereby regulating waste. In addition to this role as 'cleaners', these insects also contribute to the functioning of the nutrient cycle by recycling dead organic matter.*

3. Create a set of pictograms to symbolize ecological services

- Using the colour codes allocated to each type of ecosystem service as a background, the pupils now create a set of pictograms to illustrate the different aspects of each service.

  For example, the pictograms related to **provisioning services** all have a red background. The individual signs that compose the pictograms are self-explanatory images, which convey and differentiate the different aspects of services such as:

  - food
  - fibres
  - medicines
  - personal care products
  - fuel
  - construction materials
  - materials for industry (biochemistry, manufacturing).


Potter's wheel

- The pictograms for **cultural services** all have an orange background and distinguish between:

  - aesthetic benefits, inspiration, creation, amateur pursuits
  - spiritual and religious benefits
  - knowledge systems, educational value
  - recreational value, leisure, pleasure, games, relaxation
  - sharpening of the senses (taste, smell, hearing)
  - nature tourism.

- The same method is now used to illustrate **regulating services** and **supporting services**.


Anvil


Alembic


Observation of the sky

4. Emphasize the link between biodiversity and ecosystem services

- The teacher now emphasizes the link between preserving biological diversity and ensuring thriving ecosystems that provide the services described above.

- He or she reminds the pupils of the pyramid-shaped diagram of biological life (Activity 2) and asks them to imagine the extent to which an ecosystem's productivity – in terms of energy transmitted and energy used to produce organic matter – is linked to a closely-knit pattern of relationships between species and their interactions.

  The teacher explains that behind each product, tangible good and benefit obtained from an ecosystem lies a network of interwoven strands, and hence species, which form part of the web of biological life. On a more general level, each service corresponds to a set of intra-species and inter-species relationships, and a set of processes between species and their environment.

- The teacher concludes:

  The proper maintenance and, where necessary, regeneration of these interactions and processes, generated by biological life and biological diversity, guarantee the functioning and productivity of an ecosystem. Biodiversity is therefore both the source and the basis of the services provided by ecosystems, which themselves constitute the foundation of our wellbeing.

- Biodiversity is a pre-existing and essential form of 'capital'. It can be used to produce new goods, but on condition that the biodiversity is maintained, its condition and functioning are regularly checked, and it has the space and time (and assistance, where necessary) to regenerate.

  Biodiversity that is maintained and well cared for constitutes real sustainable development.


Fagot


Log


Adz


Wheelbarrow


Bungalow

5. Use the pictograms to highlight the species-services-products relationship

- In this final part of the activity, the class demonstrates the relationship between biological diversity, the functioning of ecosystems, and the services they provide for our wellbeing.
- With this in mind, the class agrees on a tangible good obtained from an ecosystem.
- This can take the form of a simple product, for example, a T-shirt.
- The teacher reminds the class that this concrete good is the end product of several ecosystem services, which are themselves upheld by various species at different functional levels within the ecosystem.
- The activity has two stages. First, the class draws a series of diagrams on the board or a wall chart. These begin with the tangible good (the T-shirt) and show all the production stages, highlighting the biological chain that produces the good in question and the related ecosystem services. The unique pictograms created earlier are used to represent each of the ecosystem services. The class then uses other pictograms to identify the kinds of benefits conferred on human beings by the end product.
- The teacher should ensure that attention focuses on the key species and ecological functions indispensable to each stage in the production process.

Example:
A t-shirt has its origins in a cotton plant.
- *Cotton crops deliver to the community a provisioning service in the form of natural fibres, meeting the community's need for clothing.*
- *The cultivation of cotton flowers is dependent on a group of species from among the pollinators (bees and bumblebees), which drive the regulating service of pollination.*
- *It is equally dependent on a group of species from among the natural or anti-parasitic predators (ladybirds), which drive the regulating service provided by scavengers.*
- *Lastly, it is dependent on irrigation, as the water needs of cotton crops are huge. These are in turn dependent on the water purification services provided by depolluting plants and the water cycle, which is reliant on forests (among others) for infiltration.*
- *The end product, the t-shirt, fulfils a provisioning function for human beings in more than one respect. It constitutes a clothing supply for individuals and a commercial product for the textile industry.*
- *It also fulfils a cultural function: t-shirts have an aesthetic value and constitute an expression of fashion, thereby feeding creativity. They also have a recreational value in terms of leisure pursuits and relaxation (comfort and ergonomics).*


Fringe


Scarf


Sarong


Sari

A notebook for studying nature as a source of inspiration

The teacher suggests to the pupils that they concentrate on the cultural services provided by nature by undertaking a thematic study of the local ecosystem. This can be conducted in several stages and recorded in an exercise book (sketchbook, research notebook, logbook).

The activity should begin by examining biodiversity as a force that awakens the senses and heightens perception, then explore its spiritual, aesthetic and symbolic values, before finally devising an artistic and creative process around these aspects of biodiversity.

1. Form working groups on the various themes linked to biodiversity

- First, the teacher divides the class into groups, with each group choosing a theme to work on.
- Each group focuses on one aspect of biodiversity, this time considered in its widest sense. It can include the great species of land animals (wildlife and domestic animals), a particular group of species (birds or insects), flowering plants (wild flora), 'useful' plants (ranging from vegetable species to plants used for dyes), an area of forest, a marsh, an area of bogs, mangroves, wooded savannahs, an area in a protected zone, a national park, a biosphere reserve, cropping or farming systems, bocage or dry grassland, among others.
- In urban environments, the teacher encourages direct contact with the environment (although the class may also make use of documentation). Pupils can opt for a large green space, a suburban, national or heritage forest, an ecological park in the town, an historic garden, a natural garden, a zoological park, the banks of a river, a wasteland or brownland site, or urban flora, including the flora that grows spontaneously on derelict sites, alongside railway tracks and between paving slabs.
- The class must approach the planned visits with an open, flexible and receptive state of mind.

  The teacher should encourage the pupils to use all their senses to experience their chosen theme. They must be ready to remain perfectly still, listen acutely to sounds, sharpen their powers of observation and remember smells. They must also learn to note down in words the sensations and observations they discover (and rediscover) relating to the biological diversity around them.


Secretary bird


Spotted Sandpiper


Woodpecker


Allspice


Scissortail

The emphasis here is on first-hand experience and collecting information based on facts.

- The teacher plans several visits and, depending on the case in question, seeks the assistance of trackers, forest rangers, botanists, farmers, gardeners, scientists or local officials.

- The pupils are told to travel in groups to the agreed location, accompanied by the professional experts, who provide advice and information during the visit.

2. Explore the sensory and aesthetic dimensions of cultural services

- Depending on the region and the study topic, the pupils comb the various plant formations, walk the length and breadth of grassland or pastureland, enter the undergrowth, approach water sources, scale the summits (closely supervised by adults) or scour the soil in search of insects. They will observe animals, listen to their calls and interpret and record them, look for flowers or specific plant communities, observe the undulation of grass formations in the wind, listen to the creaking of trees, feel their barks, note the shape of the crowns and learn to distinguish between tree species of the same family, such as between a European silver fir (*Abies alba*) and a Norway spruce (*Picea abies*).

Hieroglyphics

- The pupils' preferences for collecting data will be determined by their chosen topics.

  In the case of animals, they may rely on:

  Observation of animals at particular times of day (early morning or late evening) and note-taking.

  Listening and recording sessions to analyse and match calls to situations and emotions (fear, flight, displays, combat), interpret behaviour and ways of occupying space (the distances animals flee, the extent of their territories), and deduce from these analyses facts about their diet, predation patterns and associations between species.

  The use of **drawing** to record animal prints. These can be identified by the number and arrangement of the pads or the size of the hooves, and can help to distinguish between species of the same family (e.g. antelope and buffalo among bovids). The shape of the prints should also be catalogued: star-shaped for birds, trail-like for insects, and elongated for the back paws of hares or rabbits.

  Collection of isolated fragments for use later to create a collage or sketch in the notebook. These may include feathers, teeth, bits of shell, half-eaten fruit and cones, among others.

  The use of **text in the form of narratives or descriptions**. Pupils are not expected to produce literary descriptions, but instead to observe nature, successfully capture a movement and convey an animal's behaviour in words. In the case of birds, this could include the displays it makes and its gait; its appearance including the colour of its coat, the texture of its skin and its wing patterns; and its movement through the air.

Graffito

- The teacher suggests different methods of capturing data, depending on the chosen topic.

- In the case of flowers, the class can build on their earlier experience with interpreting **colour** as a way of capturing the wide range of shapes and structures among plants (see Activity 1).

Scarab

In suitable ecosystems, especially those with a rich diversity of plant life, the pupils can use existing references to describe colours (buttercup yellow, golden yellow, sunflower yellow, pea green, sage green and olive green have equivalents in all cultures). They can make colour charts or create displays of species by colour, varying their sizes, exaggerating certain forms and introducing different shades of the same colour.

If the chosen topic is a plant formation in the Mediterranean ecosystem, such as garrigue or maquis, **collections of smells** provided by fragments collected as specimens can be a useful way to reconstruct a sense-based approach to these environments. Samples of aromatic plants are gathered and sealed in a bottle, capsule or tin (whatever is to hand). These might include thyme, rosemary, lavender, sage, dill, caraway, aniseed, coriander, lemon balm, basilica, marjoram, fennel, cloves, sweet peas, lemon verbena, cistus capsules, fragments of pine needles or cones – duly noting the differences between Aleppo pine (*Pinus halepensis*), scots pine (*Pinus sylvestris),* Austrian pine (*Pinus nigra*), stone pine (*Pinus pinea*) and maritime pine (*Pinus pinaster*) – and the leaves or fruit of oaks, junipers or wild olive trees (open so as to release the scents). Pupils are then put to the test of identifying species by their smell with their eyes closed. Their second task is to describe and differentiate between these olfactory impressions in their notebooks.

3. Explore the spiritual aspects of cultural services

- Once the pupils have strengthened their capacities to observe, listen and capture their impressions, and improved their overall sensitivity to direct contact with biological diversity, the teacher directs them to explore the inspirational, spiritual and symbolic significance of the bio-diverse elements they have selected.

- The teacher structures the lesson in a series of stages.

  She or he begins:

  - Many animal and plant species are actually held sacred and venerated by numerous cultures.
  - Throughout history, populations living in close contact with the natural environment have discovered the importance of species both as a primary resource and as a key factor in the balance of nature.
  - The way of life of these hunters and gatherers was based on interactions and constant confrontation with animal species. Their symbolic representations of nature contain numerous animal figures and references to the lives of animals (often animated through rituals that dramatize key relationships with living things). The teacher can refer to numerous examples:

> *Example:*
> *In Africa, the ritual masks of the Dogon tribe incarnate the forms of antelopes, bovine animals, birds* (kanaga) *and figures from the Nommo ancestral myth. The masks are used in funeral rites* (dama). *The Baga people of Guinea consult totemic sculptures. These include the spectacular figure of Bandjoni, who takes the form of a snake, symbolizing longevity and divine power.*

- If the pupils are in daily contact with these cultures or live in geographical areas nearby, the teacher encourages them to make contact with resource persons in the community. These may include storytellers shaman, griots, nomadic herders, hunters, trackers or fishermen, who can transmit knowledge and personal experiences.

- In line with their original topic, pupils in Western countries can research the oral transmission of knowledge in different cultures, visit museum collections (on naïve art), identify representations of animal species and make sketches of them in their books. They can also find out about sacred texts and past civilizations (e.g. Ancient Egypt), the myths, traditional and modern fairy tales (Brothers Grimm, Andersen, Kipling) and fables (Aesop) of their own culture, and study the symbols, meanings and values they convey through plant and animal species.

  The class records all notes, texts and images in their notebooks.

Next, the teacher describes the relationship between early peoples and species in a wider context:

- Early peoples were constantly faced with problems related to the availability of resources and environmental constraints. As a result, these populations were sometimes nomadic and relied on foundational myths and animistic beliefs and rituals to give structure to their traditional societies. Their representations of the living world were rooted in these myths and beliefs.

- Ancestral myths often express a cosmogony that imposes an order on the world, in which each species is assigned a place.

  This cosmogony is the foundation for a union with nature that establishes and controls access to natural resources in ways that respect populations of species and their interactions with the environment.

- At this stage, the teacher provides some examples:

Examples:
In many cultures, including ethnic groups such as the Pelan in Malaysia, the Asmat in Indonesia, the Kasua or the Bochiman in Africa, the Amazonian Yanomami and the Australian Aboriginals, hunting and fishing are the subject of negotiations with symbolic figures – divinities who control the resources or form part of a cosmogony, such as the Dream Time of the Aboriginals.
Even among the peoples of Greater Northern Siberia (Evenks, Tchouktches), hunters (who also fish and breed cattle) have a strict code for hunting, based on the management of local resources and linked to a cosmogony. Thus, only a certain number of animals in a population of wild reindeer or ducks can be hunted. Traps can only be set in certain places and for certain species, and not all of the eggs can be taken from the same nest.


Boss


Calabash


Cartouche


Howdah


Riding boot


Arabesque

- Pupils for whom these cultures form part of their daily lives can invite into class the professional experts mentioned earlier within a transmission framework.

- In line with their study topic, whether linked to fauna, flora or game, the pupils transfer all the information gathered, anecdotes and sketches to their notebooks.

- In most parts of the world, the teacher can also set up meetings with scientists, anthropologists or ethnologists, to talk about the cultural aspects of biodiversity linked to the beliefs and spirituality of hunter-gatherers in particular, since such aspects highlight the diversity of peoples. Such diversity is threatened by their extinction, so knowledge of its elements is vital to its preservation. Biodiversity does, after all, include the diversity of human beings – of those peoples who first practised methods of management that were themselves diverse in character. All of these things constitute the richly varied expression of a primeval link between humanity and nature, which needs to be rediscovered in the context of conservation.

4. Explore the intangible cultural heritage transmitted by local farming communities

- In line with the topics initially chosen by pupils, such as wildlife or useful plants, the teacher widens the study of the cultural values of biodiversity to include rural communities practising traditional farming. Such traditional approaches are often practised in new, improved organic forms, which differ substantially from industrial or intensive farming.

- The teacher explains that such communities in this context often maintain the ecological balance of biodiversity, as well as the ecosystem's support and regulation services (see Activity 7).

  Their actions are based on mastery of **agro-biodiversity**, an intangible cultural heritage comprising both theoretical and practical knowledge, including a knowledge of species, technical know-how, practical skills, highly developed craftsmanship and sophisticated tools, all frequently connected to rituals and values.

  The teacher discusses communities that practise rice growing, market gardening, horticulture, irrigation farming and itinerant agriculture. Most traditional populations that live off the land are located in South-East Asia or the Andes.

  She or he may refer to specific communities:

  For example, the Malay Kelabit live in tropical mountain areas, where they practise rice growing. They have become masters in managing water on the slopes by diverting streams and constructing irrigation channels in semi-natural forest areas, where they site and maintain their rice paddies.

  Farming communities in the Andes use as many as several thousand species of potato on their terraces, while farmers in Java plant hundreds of vegetable and horticultural species in their kitchen gardens. Harvests are staggered and crops are rotated with some plots left fallow for the soil to rest. Reduced ploughing also revitalizes the fauna and the micro-flora in the soil. In addition, cereal varieties are stored in seed and gene banks. The result is that micro-environments are more efficiently exploited, biodiversity is sustained and sources of income are diversified.

Ginger

Smilax

Grapevine

- The pupils consider these practices from all angles and explore their content in their notebooks. They highlight their usefulness as banks of data and applied knowledge, and as a source of inspiration for their sketches, drawings and paintings.

- They also link them to the associated rituals, which are often based on the farming calendar.

  Plant species are sanctified during harvest festivals and at other festivals linked to the cycle of the seasons.

  > *Example:*
  > *Maize is still highly prized socially in Quecha communities and is celebrated in rituals at the beginning of the harvest that emphasize the precious and sacred character of this resource.*

- The class highlights in this way an entire body of imagery linked to the farming or countryside calendar, including harvest plants and well-known and popular wild plants (poppies, cornflowers, wild chamomile and adonis), which have become standard hosts for crops and human-modified environments. These plants have been tolerated through the ages because of their association with undeniable ecological virtues. Their return could revive the image of farming as a creator of colourful landscapes and diversified environments.

5. Explore the cultural symbolism of plants

- Pupils who have chosen plant-related topics devote this stage of the activity to researching the symbolism of plants in their own culture.

  The teacher could start by introducing the sacred and profane symbolism of plants in Western culture:

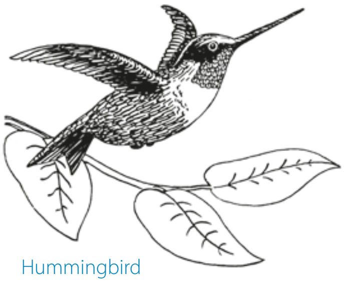
  - The sacred symbolism of both wild and cultivated plants has evolved over time and is present in myths, ancient texts and literature, and in art depicting religious or mythical subjects. The latter includes the blue irises used to symbolize the Virgin's suffering in the paintings of Hugo Van der Goes, the crown of roses in Botticelli's Rite of Spring, the pomegranate and its many seeds that symbolize fertility in the works of Rossetti, the cherries which invoke the passion of Christ in Titian and the contorted cypresses of Van Gogh.
  - Derived symbolism is linked to the history of humanity and confers virtues or is given emblematic status. Such symbolism generally is more profane and domestic. Examples include mistletoe, which is associated with good fortune, the oak, which is a symbol of power, the rose and the thistle, the emblems of England Scotland respectively, and the spruce, which has become the Christmas tree.

- The pupils use their notebooks to work on the shift in meaning of these symbols – from the sacred to the profane – an evolution discernible in other cultures. For example, the lotus is a divine symbol in the Hindu tradition and has become the national flower of India, while the cyclamen is venerated as the sacred flower of love in Japan.

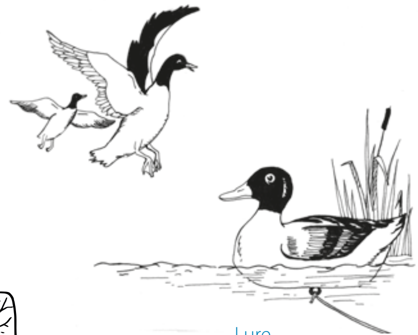
6. Use the completed notebooks as the basis for a creative project

- Finally, the notebooks are displayed and presented for discussion by the whole class. Between them they contain sufficient researched material to inspire a more creative project:

  For example, each group can use a panel to work on a description summarizing their chosen topic – a topic illustrating biodiversity as the subject of multiple cultural interpretations.



Hummingbird



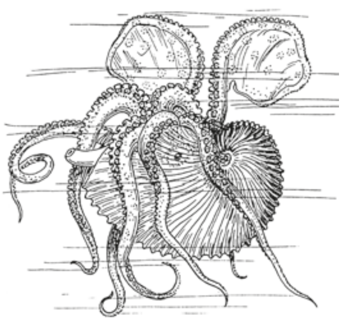
Lure

Hepatica

Deer

Seahorse

Mint



Nautilus

Heath

Speedwell

Moose

Agro-diversity: a sustainable production process?

Following on from the discussion of provisioning services in Activity 7, the teacher asks the class to draw up an inventory of provisioning services in the local ecosystem with regard to food.

With this in mind, the class produces a table of resources to summarize and evaluate the state of services and the impact of production methods on the environment. The pupils also compile a calendar of seasonal fruits and vegetables as an appendix.

Fig

Gourds

Grapes

Apple

1. List food products derived from plants and animals collected, harvested and consumed locally

- The class starts by drawing a table on a sheet of paper divided into six columns.
- The first column is used to present food products derived from plants and animals collected, harvested and consumed locally. These will consist of produce available at market stalls, booths, shops or supermarkets, depending on the part of the world.
- They start with edible plants including plants grown as crops, plants picked in the wild for consumption and those obtained from orchards, and then move on to examples of animal species from livestock and, in some areas, from hunting and fishing.
- One or two examples of ready-to-eat meals, such as pre-cooked dishes and frozen products, can also be included in the list.
- The pupils then list the plants in the first column of the table, classified vertically by scientific category, with no more than two examples of species per category:

Examples:
For vegetables:
- *Garlic or onion (edible bulbs)*
- *Potato tubers, celery petioles or bamboo shoots (stalk vegetables)*
- *Carrot or manioc (root vegetables)*
- *Watercress, spinach, dandelion or amaranth (leaf vegetables)*

For fleshy fruits:
- *Passion fruit, tomato, bilberry or strawberry guava (berries or seeded fruits)*
- *Olive or apricot (drupes)*

For dry fruits:
- *Common caryopses such as wheat, maize, barley or rye, or achenes such as chestnuts or cashew nuts (Indehiscent fruits)*
- *Pod vegetables such as the common bean, black-eyed pea, green pea, azuki bean and siliquae, which include cabbages, radish, mustard and rape (Dehiscent fruits)*

- Among the plants mentioned, the class should include examples of wild plants that have some dietary interest, as well as species of orchard fruits and forest species that can be easily picked or from which edible products can be collected or extracted.

Examples:
Christ's thorn jujube (Ziziphus spina-christi) *and the baobab* (Adansonia digitata) *are species that grow naturally in some dry regions. The walnut and wild apple trees of Central Asia are among the fruit species of semi-natural orchards. Species providing edible, non-ligneous forest products include the sugar maple in Canada (maple syrup), the argan tree in Morocco (oil), the taiga birch (a sweet, acidic drink obtained by drawing off the sap) and the cow-tree in the forests of Venezuela (a milk-like drink derived from the sap).*

- Next, the class focuses on food products obtained from animal species. They draw up a list of livestock species that provide meat and by-products, game caught during hunting, and fish species caught in the wild or farmed. All these products meet the human organism's need for proteins and trace elements.

The pupils then classify the main species or selected varieties in the first column of the table. They start with cattle, sheep and goats bred locally, such as the Aubrac and Holstein breeds of European bovids. The pupils can also widen their study to include other animal products that are eaten. Examples include wild ungulates that provide bushmeat, venison (Africa and Indonesia), and tamarins, lemurs and birds hunted in Madagascar. In coastal environments, pupils will focus their attention on marine species caught in the wild, which may include overfished species such as swordfish, red tuna, plaice, sole, turbot or hake. They can also include freshwater and farmed species, such as the numerous varieties of carp, as well as saltwater species or species farmed in brackish water, such as molluscs and shellfish.

- For the pre-cooked or frozen foods, the pupils should identify the ingredients constituting the meal. Does the meal include any vegetables? What are the fat, sugar and salt concentrations? Have these been added? Do it contain food additives? If so, what kind?

The packaging is also inspected to ascertain its separate elements (e.g. outer cardboard packaging, foil dish, plastic film lid, vacuum-sealed sachet and plastic cutlery).

2. Identify where and when the foods were produced

- The second column of the table is used to identify and describe aspects of the production of each food item listed and studied.

  Is the item produced locally or nationally? Is it harvested locally? Is it produced at a particular time of year? Is it processed by a local company? What other foodstuffs are derived from the product in its raw state?

- The second column is divided into two half-columns. The left side corresponds to the place where the product is harvested or produced (locally or imported), and the right corresponds to the time of year of production (seasonal basis or all year round).

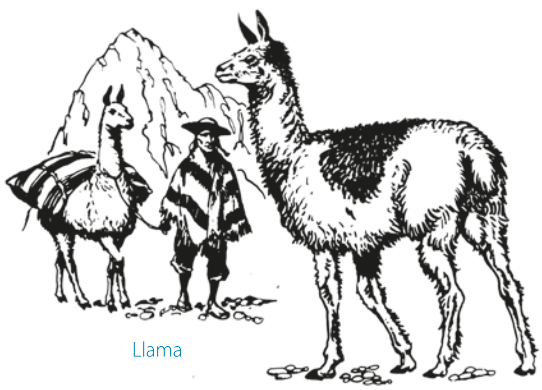
- For each food item, the pupils specify the time and place of production, and add coloured stickers: green for items produced locally and red for imported products; green for items produced in season and red for items produced all year round. Green stickers thus indicate practices that show consideration for the environment and human health, while red stickers indicate more harmful practices.

  Processed foods or by-products based on the original foodstuff are specified in the half-column indicating the place of production.

> *Examples:*
> *Pupils in Europe can easily consume strawberries from Australia, beans from Kenya, beefsteaks from Argentina, apples from the Cape and chanterelles from North America.*
> *These products are imported from around the world and therefore do not qualify as local produce. Pupils can reflect on why goods are transported such long distances when local farmers and producers are able to meet demand from adapted species and local supply includes countless apple varieties, as well as a wide range of livestock species, forestalling any shortage of meat or cheese.*

Hemp

Cranberry



Llama

- The pupils allocate red stickers to these products to indicate that they are not of local origin but involve some form of transport (especially air transport), which requires large quantities of energy and therefore represents a cause of pollution.

> *Examples:*
> *Elsewhere, in Africa or South-East Asia, maize and rice are farmed intensively for export (often from a single species that constitutes the only source of income for the population). This form of farming generates high costs for the local community (due to lack of cost effectiveness, lack of infrastructure, lack of production and packaging facilities, and dependence on the raw material). It also leads to significant impoverishment of the genetic stock of plants and fails to provide an adequate diet for the local population (undernourishment), for whom they are not primarily intended. These crops are given both a red and a green sticker. Although grown locally they mainly 'fuel' the export business, constitute inadequate provisioning services for the local population, and degrade the ecosystem and biodiversity (through soil exhaustion, genetic erosion).*
> *In many parts of the world where fishing is an important activity, the catch is processed locally for export in factories (sardines are canned, while other fish are refrigerated or deep frozen or else turned into terrines, potted meat, purées and sauces). However, such processing results in high costs in terms of energy usage, with associated costs in terms of transport and packaging, without providing a sustainable means to feed the local inhabitants. Accordingly, these products are allocated both a green sticker and a red sticker.*

- The teacher encourages the pupils to visit markets, read labels and note the origin of products on sale. Their investigations should aim to obtain as accurate a picture as possible in order to complete the table. Information about frequency of production can be obtained from stallholders, who are often small producers or market gardeners rather than shopkeepers or grocers. Talking to stallholders will allow pupils to find out at what times of year the fruits and vegetables they are studying are fully ripe (which is when they taste best), and details about their natural growth cycle.

- The pupils can also devise their own personal calendar of seasonal fruits and vegetables, which can serve as a useful pocket guide for improving their own eating habits. This research into growing periods helps them to complete the table.

> *Examples:*
> *In Europe, the growing season for strawberries lasts from May to July, while the season for lettuce and lamb's lettuce runs from June to September. These items are produced locally at all times of year in heated greenhouses, which use large amounts of energy.*
> *In the countries of the Maghreb, the season for citrus fruits (oranges, mandarins and grapefruit) is not always respected , with crops in some areas grown intensively and generously irrigated.*

- The different frequencies of production are distinguished in the table with green and red stickers.

> *Example:*
> *Within the same geographical area, tomatoes are grown in high season as subsistence crops (sometimes in the family garden) are widely exploited in season as a field crop and are grown out of season in heated greenhouses. Different species and varieties are used depending on the practice adopted.*

3. Describe the method of food production and its impact on the ecosystem and biodiversity

- The third column of the table is used to examine the production methods for each foodstuff listed and studied, while the fourth column evaluates its environmental impact.

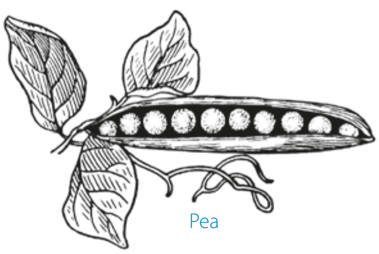
- In the case of vegetable foodstuffs, the pupils should answer the following questions for each product:
  - Is it farmed intensively and by conventional methods?
  - Is it grown under cover as a forced plant in hothouse conditions (to speed up the maturation process)?
  - Is it the result of integrated farming or an improved form of traditional agriculture that seeks high yields but with reduced use of chemical fertilizers and pesticides? (Improved forms of traditional agriculture apply preventative strategies based on natural mechanisms that rely on organic pest control through biodiversity and the presence of natural predators.)
  - Is it produced by organic farming methods that preserve the humus in the soil, maintain its fertility by rotating crops, prohibit the use of synthetic chemical products, and favour cultivated varieties naturally adapted to the climate and resistant to disease?

Examples:
Intensive farming is widespread in the United States. For example, 80% of America's entire lettuce output comes from Salinas Valley in California.
With regard to cereal production in the United States, the mechanized, intensive farming of maize gives rise to one of the highest yields in industrialized countries. Wheat is grown extensively, albeit with fewer inputs per acre than in Europe, for profit on land worn out by the ravages of intensive farming.
Similarly, rice growing in Southern China and wheat production in the north of the country has increased in an effort to produce sufficient food to feed the rising population. However, industrial production of these products produces food of an inferior quality, which is widely exported for commercial ends.

- The pupils specify the features of the production methods in the third column of the table. In the case of intensive farming, they can note the wholesale use of fertilizers and pesticides, the selection of seeds, the use of large-scale machines, the monopolization of water sources for irrigation, and the distortion of world markets through the granting of export subsidies.

- The class then evaluates these aspects using the corresponding stickers (in this case, red).


Guava


Pea


Eggplant


Cauliflower


Brussels sprouts

- The pupils now use the fourth column of the table to evaluate the environmental impact of food production methods for each product listed, in terms of gains and losses for the ecosystem and biodiversity. The pupils should state the precise consequences of each of these production methods.

- To do this, they need to carry out some preliminary research. With the help of the teacher and members of the local scientific community, they gather information on pollution rates and the percentage of degraded sites. They then locate the sites and assess the impoverishment of the region's genetic stock, the reduction in the populations of species and the decline in water reserves.

- The pupils highlight these losses for the ecosystem and biodiversity by means of the appropriate stickers (again red, in the cases examined).

> *Examples:*
> - *The residues from synthetic chemical substances (biocides and fertilizers) are a major cause of air, soil and water pollution. The pesticides and insecticides present in the atmosphere degrade the scents of flowers, hormones and pheromones and affect numerous species as well as pollination and reproduction (coldblooded animals). An excess of fertilizer creates a surplus of nitrogenous matter in the soil rendering it saline. The nitrates then find their way into the surface water or seep down into the water table, polluting the water supply. Residues may be detected in food products, with toxic substances sometimes found in aquatic organisms and in fish in rivers as a result of bioaccumulation.*
> - *Other consequences can include a diminution of the organic content of soils, which has not been replenished or maintained due to intensive farming or soils becoming impermeable as a result of compacting by heavy machinery.*

- The pupils next turn their attention to livestock produce.

  They highlight parallels between the intensive farming of crops and the intensive breeding of livestock, which is aimed at increasing productivity by shortening the phase of an animal's growth.

- They list the characteristics of this production method including: the concentration of a large number of animals in confined spaces resulting in a lack of comfort, poorer product quality along the length of the chain from the feeding of animals to the end product (meat and by-products of livestock farming), and the use of antibiotics.

- The pupils then determine the corresponding losses for the ecosystem and allocate red stickers to indicate their impact. Examples of losses include intensive livestock farming, which leads to wide-scale deforestation in certain regions of the world (South America, South-East Asia); lack of sufficiently large areas for pig-breeding, which leads to quantities of animal waste too large for the land to absorb and subsequent pollution of runoff water (Brittany in France, China); and increasing numbers of cattle bred for beef that generate large quantities of methane (a gas animals produce during digestion), which accounts for 18% of all greenhouse gases.

- The pupils also focus on areas where the ecosystem benefits from certain methods of production.

> *Example:*
> *A principal focus of organic farming is maintaining soil fertility in a sustainable manner. Practical measures are used to renew the organic and living components of the soil. These include rotating crops, spreading leguminous plants and growing green manure for short periods (rye or legumes, as appropriate). See Vol. I, Part 2.*

- In the table, the pupils highlight the value of these measures as **benefits** to the ecosystem.

> *Example:*
> *In regions of the world where the topsoil is particularly vulnerable to climatic conditions, farmers opt for approaches that reflect improved forms of traditional farming or agro-ecology. Examples include reduced tillage and direct sowing under vegetation (instead of traditional slash and burn agriculture).*

- The pupils award green stickers for the growing or breeding methods examined, which should reflect as diverse a range as possible.

4. Make a final evaluation of food provisioning services in the local ecosystem

- The pupils' final task is to count the green and red stickers and assess the degree of degradation or conservation of provisioning services in terms of the goods produced from crops, livestock, hunting and gathering.

- They must also include in their evaluation products derived from wild plants and wildlife – traditionally a valuable and direct source of food. The exploitation of these products is often governed by codes of behaviour and management methods respectful of the ecosystem, which tend to be neglected or ignored in favour of practices aimed at quick and easy profits.

- Once the pupils have totalled the total of green and red stickers they make a final evaluation of provisioning services in the fifth column. Dividing the column into two semi-columns, the pupils assess the following:
  - Is the service profitable? Is its yield maintained? Or is it unprofitable? Is it showing signs of degradation and exhaustion (overfishing or land erosion)?
  - Is the service sustainable in the context of the local and wider environments?

- Finally, in a sixth column, the pupils decide whether the provisioning service fulfils its primary function, which is to feed the local inhabitants.

  Does it provide enough food for the community? Does it maintain a balance in the food supply? Does it contribute to public health?

- This assessment should highlight the impact of production methods for plant and animal foodstuffs on human health, for example, the health risks created as a consequence of the food and medication given to animals. For example, intensive fish-farming, just 1 tonne of farmed salmon is produced for every 5 tonnes of wild fish ground into fish meal. In addition, the antibiotics and chemicals used in processing techniques, result in pathogenic, carcinogenic and mutagenic substances in the food we eat.

Ear of corn

Cultivators

Barrow

Scenarios based on supporting and regulating services

In this activity the pupils create scenarios focused on the role of **keystone species** (see Activity 4, section 3) in the functioning and maintenance of the supporting and regulating services of ecosystems.

The pupils collaborate in groups to create different scenarios that identify the scope and stages of the ecological role of these species.

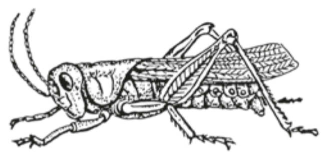
- It is imperative that the class, guided by the teacher, take care to choose species whose functional characteristics directly enter into the provision of supporting and regulating services. Among the soil micro-organisms, for example, fungi contribute to the recycling of necromass, the natural processing of waste and the nutrient cycle, while pollinating and seed dispersing agents influence the production of living matter, the evolution of species populations (capacity for reproduction, density and distribution) and demand for natural habitats.

  Other candidates include the species that form the basis of phytoplankton and coral reefs, which are crucial to photosynthesis in ocean environments and to the combined oxygen and carbon cycles, as well as 'engineer' organisms such as earthworms or beavers that directly influence the development and transformation of environments, thereby creating favourable living conditions and habitats in specific biocenoses.

Vorticella

- Once they have selected a keystone species, the pupils collaborate on the first scenario.

  The following example of **soil fungi** suggests a methodology and sequence for the composition of a scenario.



Grasshopper

Mushrooms

Snail

1. Create a scenario describing the maintenance of supporting and regulating services based on favourable conditions

- Creating a scenario will require some preliminary research under the guidance of the teacher. This may include printed material as well as fieldwork, where the pupils will they come into contact with these photosynthetic organisms, which are found close to trees in forest, savannah or wet woodland.

  The object of the exercise is to gain a better understanding of the characteristics of the various categories of soil fungi (mycorrhizal and saprophytic), as well as their interactions with plants and their associations with numerous species (invertebrates, micro-organisms and bacteria), which are often beneficial for the productivity of ecosystems and the maintenance of ecological services.

- Once the information and approach have been explained by the teacher and clearly understood by the pupils, collaborative writing of the scenario can begin. The aim is to produce a text that is inventive, lively and appealing, but which reflects the knowledge acquired by the pupils.

The context:

- First, the pupils establish the main components of the scenario. The location will be the base of a tree, so they need to determine which type of tree as species differ according to the region. In addition, different categories of fungus are associated with each woody species. The pupils identify these categories of fungus at the outset and note the fungal species that can occur in the location chosen. Some fungi such as saprophytes are ecosystem 'cleaners'; they break down a range of dead matter, from plant litter to cellulose. Other fungi have a greater impact on the nutrient cycle because they are symbiotic, growing in association with living plants; these are mycorrhizal fungi.

- In accordance with the woody species chosen, the pupils describe the context – the atmospheric conditions, plant litter and odours.

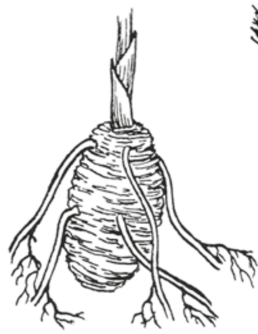
> *Examples:*
> *In mountain or temperate regions, pupils may select dark spruce stands for their scenario, where saprophytes such as scaly wood mushrooms* (Agaricus sylvaticus) *specialize in breaking down conifer litter. Alternatively, they may choose the harsher setting of beech stands (known as 'cathedral forests'), with decomposers of beech litter and lignin including the whitelaced shank* (Megacollybia platyphylla) *or lighter, more airy woods consisting of oak mixed with broadleaved species like chestnut along with the saprophytes affiliated to these species, such as the beefsteak fungus* (Fistulina hepatica).

- Next, they describe the microclimatic conditions and resources in the immediate area: temperature, conditions for shelter (fungi like warm, snug conditions), humidity, light, altitude, and the season or time of year.


Puffball

The organisms present:

- The class turns the spotlight on the actors in the scenario by describing the keystone species – fungi, in this instance – together with other companion species that are indispensable to the action of fungi.


Rhizome

- Fungi come in all forms – from single-cell micro-organisms such as yeasts and multi-cellular organisms like moulds, to forms visible to the naked eye. The most common have caps visible above the ground. The relevant ones for the pupils (saprophytes and mycorrhizas) have different kinds of caps ranging (in temperate regions) from the dome-shaped caps of cep mushrooms to the honeycombed caps of morel mushrooms. However, they all share the same branching, threadlike feeding system (the mycelium). During the fieldwork stage, the pupils take notes and make drawings of these fungi.

- At this stage, the pupils also scour the plant litter, turn over the soil, dig down to a certain depth and uncover the filaments of the fungi, together with the companion species that populate the surface layer of the soil: earthworms, woodlice, ants (especially in savannah regions) and springtails.

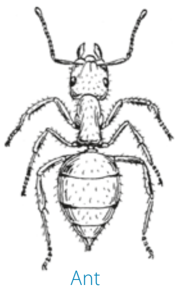

Pyxidium

- With the teacher's assistance, the information gathered on site is revisited with a view to highlighting the activity taking place in the surface soil, as witnessed by the pupils themselves. The pupils focus on the main 'actors', using their own words, and the teacher reviews the result.

- The idea is to convey the activity that takes place in the dynamic matrix constituted by the soil. This area of exchanges covers several dozen centimetres and is influenced by the roots, decomposing organic matter, rock erosion and the combined actions of fauna, microflora and micro-organisms in the soil.

  - How do these exchanges bring about chemical reactions that favour the development and metabolism of a wide variety of bacteria? How do the roots catalyzes microbial and bacterial activity? How do colonies of bacteria assist fungi to decompose litter, release minerals and biodegrade pollutants?
  - How is the soil oxygenated? How is the decomposition process encouraged? How is aerobic bacteria generated? The answer to these questions is found in the actions of earthworms, which also play other roles in the ecosystem. Earthworms produce small mounds of waste that contain aggregates of modified soil, which disseminate patches of nutrients thought to regulate the diversity and distribution of micro-organisms in the soil.
  - Other 'companion' species play key roles in specific ecosystems as 'engineers' and 'cleaners' (without which an ecosystem would fall apart) and are equally indispensable to the ecological action of fungi. Examples include fossorial (burrowing) invertebrates, such as dung beetles, which burrow through tonnes of organic matter in the planet's livestock-farming regions, as well as ants found in bush formations in the savannahs of the Australian Mallee, which tirelessly carry leaf debris and twigs back to their fungus-bedecked burrows, to chew and regurgitate, thereby producing the perfect compost for fungus growth.


Elm (leaf)


Ant

- The scenario assembled by the pupils and supervised by the teacher should be lively and contain surprises, but above all should illuminate the mysteries of microscopic life found at the rhizosphere level, which still remains largely unknown to us.

  It should also show that ecosystems consist of dynamic organisms, whose actions produce effects that are often underestimated by humans.

2. Highlight the functional role of fungi in ecosystem services

- The pupils continue the scenario by focusing on the **ecological functions** of fungi in ecosystems.

  They emphasize the capacity of a group of organisms to maintain an ecosystem and improve its productivity – a capacity that has given rise to numerous studies seeking to analyse and quantify the economic and ecological value of this functional role.

- As a first step, the pupils demonstrate the capacity of **saprophytic fungi** to mobilize the soil's resources by breaking down organic matter – a process that also decomposes mineral matter. The fungi secrete powerful enzymes, which can decompose plant litter (leaves and twigs) and even the most resistant organic matter (cellulose and lignin) found in dead wood. Their association with bacteria is a key factor, since only fungi and bacteria can decompose these substances.

- The pupils also consider the capacity of species to work together to penetrate and decompose organic matter. The pupils should emphasize the succession of fungus species involved in the different stages of decomposition of an organic body.

  From the leaves to the lignin, the whole tree is recycled and its chemical elements are incorporated into the trophic chain. Finally, humicola fungi (humus specialists such as the Marasmius and Collybia genera) refine the dead material by recycling nutrients in the soil (see Vol. I, p. 135).

  Through their numerous roles in recycling necromass, establishing the trophic base of the ecosystem, cycling nutrients, maintaining humus fertility and processing waste, saprophytic fungi contribute to the successful delivery of regulating and supporting services by ecosystems.

- Next, the pupils describe the functional role of **mycorrhizal fungi**.

  They demonstrate the extent to which these fungi improve plant nutrition and the significant part they play in promoting the production of biomass.

  As a starting point, they explain that fungi cannot move or synthesize their own energy in the form of carbon compounds, unlike plants, which produce these elements as a result of photosynthesis. Needing an external source of carbon, mycorrhizal fungi colonize the roots of a plant, in particular trees. A symbiotic association develops between the fungus (myco) and the roots (rhize) of the tree, otherwise known as a mycorrhiza. Through this symbiosis, the fungus extracts sugars (carbon compounds) from the plant, which in return receives numerous nutrients thanks to the fungus.

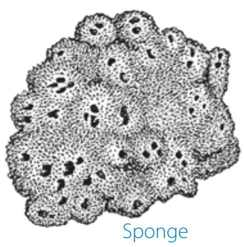
- The pupils highlight the importance role played by fungi in the exchange of nutrients between plants. This remarkable process takes place underground, where it remains largely hidden from human eyes. A good example of this exchange is carbon – a high proportion of photosynthesized compounds produced in plants are available to micro-organisms, including mycorrhizal fungi. As soon as a single fungus colonizes the root systems of several plants, an exchange of carbon can take place between them with the fungus acting as an intermediary. For example, a stunted fir growing in a shady spot can benefit from the carbon produced by a neighbouring birch, which is exposed to the sun.

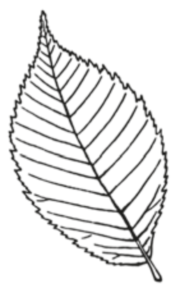
- By focusing on this exchange of nutrients, the pupils can identify the 'complete menu' that fungi serve up for trees. They can also draw on visual materials and comparisons for this part of the scenario.

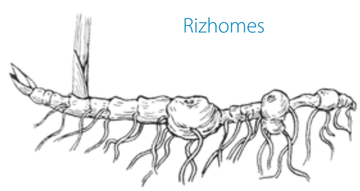
  Mycorrhizal fungi have a feeding apparatus consisting of a network of hyphae made up of thin strands, which be quite long. These strands infiltrate the roots of trees, cloaking them in a mass of hyphae that form a kind of sleeve or fungal mantle, inside which symbiotic exchanges occur at the intercellular level.

  Hyphae function as an extension of the tree's roots, covering a huge area, which enable the roots to access nutrient deposits that would otherwise be inaccessible.

  In this way, fungi supply conifers (especially pines and firs) and broadleaf forest species such as birch and beech with macro-elements that are difficult to obtain. These include phosphorus, nitrogen, oligo-elements such as iron and manganese, and water.


Sponge


Serrulate leaf


Rizhomes


Serrated leaf

- The pupils register the importance of the role played by fungi in establishing dynamic interconnections at different points within the ecosystem as a whole. Fungi modulate or increase the efficient flow of minerals (nitrogen and phosphorus) in the ecosystem, contribute actively to the planet's biogeochemical cycles, supply young and developing plants with carbon matter thereby influencing the composition of plant communities, serve as intermediaries between plants, and multiply, diversify and even interact with other networks (the same tree can grow in symbiotic association with several mycorrhizas). Fungi therefore play a vital role in sustaining the regulating and supporting services of ecosystems. They even protect plants from pathogenic organisms and pollutants through the bio-accumulation or retention of elements such as heavy metals.

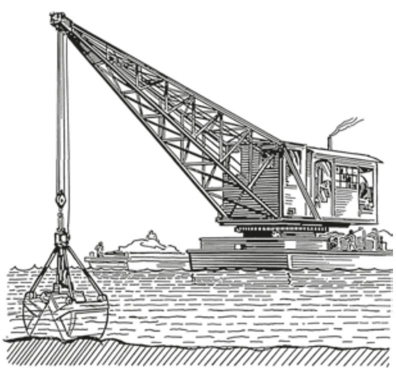
Throughout the scenario, the pupils work to interpret the processes of soil mechanics through the actions and functions of these types of fungi.

3. Construct a second scenario describing the degradation of supporting and regulating services based on the decline of fungi

The pupils now create a second scenario in which they imagine a series of adverse conditions that could disturb and eventually destroy the context in which fungi survive, as well as the organisms they contain and the beneficial action of fungal organisms.

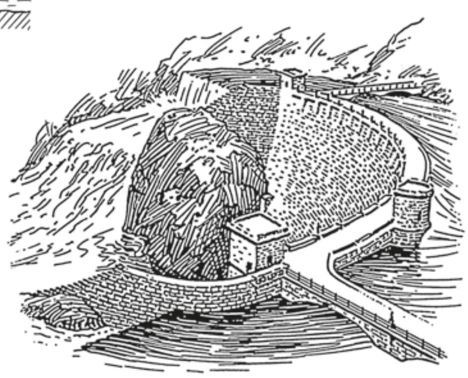
Among the possible causes of disturbance, they can select ploughing, drastic changes to the soil that disturb the environment and affect species, compaction of the soil by machinery, intensive farming, overgrazing and trampling of the soil by cattle.

In a forest context, they can reference the impact of clear-cutting, which results in disruption of the biochemical, climatic and microclimatic parameters of the local environment.



Dredge

Riddle



Dam

Log

- The pupils describe the effects on the communities of species.

  There may be radical modifications to physico-chemical parameters such as acidity, alkalinity, the presence of dioxygen and carbon (via the soil), temperature, which is important for the development of bacteria, and accordingly, bacterial communities. Harmless, beneficial bacteria that often play a useful role in environmental regulation processes (rhizobia or aerobic bacteria) may become rarer or even disappear.

- Whatever the region, the class provides a full account in its scenario of the disastrous effects of nitrogen fertilization on agriculture and forestry, the nitrogen surpluses created, and the acid and nitrogen deposited in forest areas.

  On the basis of studies, the pupils qualify the effects of these pollutants (oxides of nitrogen) on the number of carpophores and saprophytic fungi, and on the processes of plant litter decomposition and humus fertilization. They explain that these pollutants are directly linked to erosion of mycorrhizas diversity and an appreciable reduction in the capacity of these organisms to fulfil their function. They also have a biological impact on the very formation of mycorrhizas structures.

- The pupils then imagine a forest depleted of mycorrhizal fungi and its corresponding effect on the health of trees and the overall vitality of the forest, where species now exchange fewer nutrients. In the case of certain species, such as the Austrian black pine which grows in limestone soil, growth is reduced to virtually nil without the contribution of mycorrhizas. For other trees, such as the sugar maple, precious exchanges with herbaceous plants disappear. In general, networks deteriorate, species vegetate and the appearance of the forest as a whole changes. It is important to remember that in temperate regions all the roots of forest trees exist in a symbiotic relationship with fungi.

- Next, the pupils introduce degradation factors such as the appearance of disease, invasive species, pests or climatic phenomena such as a prolonged period of drought. In the absence of mycorrhizas, the trees have little defence against pathogenic agents that can infiltrate their roots, and have little resistance to climatic disturbances, heat waves or frost without the water contributed by fungi.

  As a result, the ecosystem's regulating and supporting services no longer manage to maintain or restore its ecological equilibrium. The ecosystem is permanently degraded.

4. Compare the two scenarios and draw some conclusions

- The pupils' final task is to compare their two scenarios and decide which practical steps should be accorded priority to maintain or promote fungal activity in the soil.

- For example, they can assess the importance of preserving the diversity of forests.

  The greater the biologically diversity of forest populations, the greater the variety of mycorrhizal fungi, since each tree species has a symbiotic relationship with these species. Furthermore, the root system of the same tree often hosts several different mycorrhizal species. Biodiversity therefore significantly increases their numbers and optimizes the effectiveness of their actions.

- Pupils can be quite specific about the steps they advocate. For example, during large-scale felling operations in forest areas, it is vital to preserve the young stands by creating adequate approaches for vehicles or marking out the routes they must follow. These young plants will help to re-establish fungi in a new generation of trees, as fungal organisms do not disappear entirely when a tree is felled, but survive for a time in the rhizomes of the stump, owing to its carbon reserves. This allows some of the networks to remain active.

Activity 11.1

Dialogue and action on sustainable agriculture

The activities presented in this kit are designed to help pupils understand the extent to which we depend on biodiversity in our day-to-day existence, and to demonstrate the essential role played by biodiversity in guaranteeing the functioning of ecosystems and the indispensable services they provide.

Activities 9 and 10, in particular, aim to help pupils gauge the consequences of a large-scale decline in biodiversity, especially with regard to food supplies and the degradation of soil quality.

- In this activity, the class discuss and appraise the challenges represented by the conservation of biodiversity in an agricultural context, its sustainable use and the equitable distribution of its benefits, as advocated by the Convention on Biological Diversity.

- To this end, the pupils and the teacher invite relevant local stakeholders to participate in lessons. These would ideally include a farmer involved in conservation efforts, as well as a policy-maker or local politician active on the political and administrative front, or a scientist or environmental officer overseeing conservation work with a good understanding of the local context.

Tool for floating wood

Furrow

Scythe

1. Initiate a discussion on the different aspects of conservation in agriculture

- The pupils lead the discussion using question sheets prepared in advance. Only a few carefully chosen questions are necessary, but these should ensure the discussion progresses smoothly and cover different aspects of the topic.

- A starting point can be the farmer's experience with conservation and, in particular, biodiversity.

- The discussion should start at the landscape level.

What part does the farmer play in the maintenance of the landscape? Does he or she regard the landscape from an inclusive perspective as a single terrain? Are landscaped features such as hedges, strips of woodland (windbreaks) or flora maintained? Is the connectivity between closed and open environments a concern? Are the main features of landscape structures conserved?

The pupils also question the farmer about species typically found in landscaped features. Which species best serve the needs of these features?

> *Example:*
> *In temperate regions, small trees at the foot of hedges may mix with shrubs. For example, in some environments, hazel* (Corylus avellana)*, hornbeam* (Carpinus betulus) *and willow* (Salix) *intermingle with bramble* (Rubus fructicosus)*, while the mountain ash* (Sorbus aucuparia) *grows in association with climbing plants such as bindweed* (Calystegia sepium)*. Such combinations also affect trees that grow to a considerable height, including the common ash* (Fraxinus excelsior) *or the white poplar* (Populus alba).

- The pupils will naturally question the nature of the relationship between landscaped or agro-ecological features and ecosystems rich in species.

  Do these lead to a polyculture of associated species, a patchwork of fields, prairies, pastures and forests, and a diversity of land uses?

  Does biodiversity express itself at the level of territory in terms of landscape diversity?

- By questioning the stakeholders involved, the pupils are able to analyse the relationship between the protection of wildlife and conservation of biodiversity, and between the preservation of biodiversity and improvement of farming practices with lower pollution and integrated farming or organic farming.

2. Concentrate on the conservation of local biodiversity

- The class now attempts to collectively evaluate actions undertaken to protect wildlife.

  What actions, for example, contribute to the well-being of wildlife and enable its protection?

> *Examples:*
> *When an environment is subjected to a disruptive event, such as clear-cutting in forests or ploughing on cultivated land, it is important to limit the effects to the extent possible by conserving, for example, the seedlings or by allowing the land to rest in years when it is not being ploughed. This enables the natural habitats of species (an abundance of forest wildlife and micro-organisms in the soil) to be preserved. Better understanding and characterization of the functional symbiosis between mycorrhizal fungi, microfauna in the soil and forest species is conducive to improvements in tree growth and in forestry generally.*

- The pupils identify actions beneficial for local biodiversity – those that allow for a caring approach and those that regenerate the interactions and processes engendered by species living within the ecosystem. Which species need protecting and preserving as a matter of priority? How should they be preserved? How can the interactions and processes they engender be revived? Can other species play a role in this regard?


Kangaroo

- Working with the stakeholders present, the class draw up a list of the species targeted by actions for their protection and conservation.

- They explore, for example, species capable of creating agro-ecological conditions that permit the return or preservation of populations of natural enemies of pests.

  The class focuses on obtaining details of specific cases:


Kinkajou


Kiwi

- They start with populations of pests that need to be controlled. These include species of spider, Colorado beetles, aphids such as the dusky-veined aphid (*Callaphis juglandis*) found on the veins of walnut tree leaves, or flies such as the olive fruit fly (*Bactrocera oleae*) found in olive groves.

- Next, the pupils identify auxiliary animal species, distinguishing if possible between parasitoids and predators. The larvae of parasitoids develop in contact with pests, as in the case of wasps (hymnoptera), which are used to control aphids, and the European corn borer. Predators eat pests such as ladybirds, lacewings and hoverflies.

- Finally, they explore plant species recommended for bands of flora because they attract auxiliaries and develop their populations. These include messicole plants grown in association with crops such as cornflower (*Centaurea cyannus*), or *anthemis* species such as *Anthemis altissima* or *Anthemis arvensis*, which, by attracting hoverflies and lacewings, are particularly effective at maintaining cereal crops, vines and orchards, including non-irrigated Mediterranean orchards.

- While the pupils take notes, the experts present stress the conservation of biodiversity through targeted actions, the preservation of specific local species, and the strengthening of processes and interactions beneficial for the health, dynamism and, by extension, the productivity of the ecosystem.

- The class now analyses figures and evaluation results reported by actors in the field (including the scientists present). These are studied and interpreted to ascertain:

  What is the actual impact of actions to optimize the functional character of biodiversity on the ecological and economic dimensions of services?

  This approach allows other aspects of biodiversity to be highlighted and evaluated:

  - Which species favour the **action of crop pollinators**, for example?
  - After analysing local species implicated in biological control, the pupils work to identify species associated with the growing cycle and the development cycle of producers.

> *Examples:*
> *Many crop species that provide essential food supplies worldwide, such as oilseeds, fruit crops and crops for processing or industry, are pollinated by bees* (mainly wild bees), *as well as thrips, wasps, flies, beetles, moths and other insects. In Malaysia, oil palm pollination is largely performed by weevils* (Elaeidobius kamerunicus). *In Mexico, papaya crops* (Carica papaya) *are pollinated by the sphinx, a moth of the Sphingid family, while certain species of agaves are pollinated by local species of bat. The yields of horticultural crops, such as orchids, are improved by pollination services provided by hummingbirds and other small birds. It is therefore essential to protect wild pollinators by introducing honey-producing plants into the vicinity of crops, to meet their food needs outside periods when cultivated plants produce nectar or during migrations.Honey-producing and nectar-producing plants that attract or preserve pollinators include several flowers with deep corollas: Fabaceae, Lamiaceae, Scrophulariaceae, Boraginaceae and aromatic herbaceous plants, as well as those that produce honey in abundance such as the borage plant (Borago officinalis) in Europe. Also worthy of mention are cultivated sainfoin* (Onobrychis viciifolia) *and fruit-bearing woody plants, including the wild cherry* (Prunus avium). *The latter is pollinated mostly by bees, while elderberry flowers attract hoverflies.*

- The discussion now moves on to other points: what is the practical value of **genetic diversity**?

- Why is genetic diversity both within the population of a species and between populations of the same species indispensable?

- With the support of the invited participants (e.g. scientists), the class formulates a collective response. Without genetic diversity, species can neither survive nor evolve. They need genetic diversity in order to regenerate, resist disease and compensate for changes in the natural environment.

- Farmers are fully aware of this, as they practise genetic improvements, often via traditional methods. They can therefore highlight the significance of their actions with regard to the following:

How traditional methods of genetic improvement often resort to selection from among local indigenous varieties. How they protect and preserve specific specimens within and across populations. How farmers are able to identify and conserve different rustic varieties within the same species and between closely related species, as in the case of African farmers who are very familiar with species of sorghum, millet, white fonio (*Digitaria exilis*) and teff (*Eragrostis tef*). How improvement consists of introducing selected specimens of different varieties from within a single species to promote cross-fertilization (this is undertaken to obtain specific desired outcomes such as improving the resistance of the species to cold, drought and disease).

- The discussion with stakeholders can also explore the introduction and use of improved cultivars or hybrid varieties obtained through molecular genetics.

- The discussion should remain open-minded, rich and rewarding throughout, and the pupils should continue to take notes.

3. Make the connection between biodiversity conservation and improved agricultural practices

Fennel

- The pupils gradually begin to understand the ways in which local efforts to preserve biodiversity influence agricultural practice, in particular:

- How the preservation of biodiversity necessitates a dramatic reduction in the use of pesticides, herbicides and fungicides. How it entails a better understanding of insects, birds and other predators or pollinating agents and their lifestyles. How it requires an expert knowledge of local wild species of flora and fauna and their use. How it involves knowledge of the conditions for introducing predators or biological agents to reinforce specific processes. And how it calls for knowledge of the operation of diagnostic or assessment tools such as population counts.

- The pupils try to discover just how committed farmers are to improving their farming practices by asking a few questions:
  - Do farmers opt for the practice known as **integrated farming**, aimed at significantly reducing the use of chemical pesticides, and abandoning those that are most toxic for species and the environment?
  - Do they practise mechanical weed control, especially at the base of trees, to preserve mycorrhizae? Do they apply preventive strategies based on natural mechanisms, such as biological control of natural predators to combat crop pests and parasites? Do they use chemical methods only as a last resort to save crop yields?
  - Do farmers make use of the diversity of natural assets, such as the local gene pool, when selecting varieties from typical species that are well adapted (to micro-environments and diseases)? Do they combine and integrate biological and physical approaches, such as taking into account factors such as exposure, shade, sunlight, wind and humidity, to improve farming practice?

Owls

- The class questions the farmer present about his or her intentions and objectives:

  Do these include a move towards **organic farming**, which prohibits the use of chemical fertilizers and biocides and focuses primarily on respecting the soil and maintaining its fertility?

  Permanent regeneration of the natural fertility of the soil depends on the following measures:

  - A system of crop rotation incorporating a fallow period to allow the land to rest, and the possible cyclical planting of green manure depending on the soil's needs;

- Maintenance of the organic component of the soil (humus) with the help of organic fertilizers, either by spreading legumes on the soil surface or enriching the soil with compost.

- The farmer can clarify his or her practice regarding organic farming – the most successful form of sustainable farming – and the use of crop rotation, which involves a form of polyculture based on associations between plants, resulting in a mosaic of land parcels, and thus a diversity of land uses.

  At the level of territory, this translates into a diverse landscape.

- At this point, the scientist present can introduce certain facts, supported by figures:

  The more one promotes polyculture, the more biomass one produces.

  The greater the variety of species an ecosystem produces, the greater its productivity at the agricultural level.

  In addition, the more diversified the environment, the stronger its defences against harmful or invasive organisms.

  The next question for the farmer is how the practice of sustainable farming can ensure adequate yields. Under what conditions does farming provide a secure livelihood?

4. Explore the management of sustainable agriculture and biodiversity by the political authorities

- The class now revisits certain aspects of local farming practice.

  Are the efforts made by farmers to improve genetic diversity supported by local seed organizations and by the establishment of **gene banks** based on the genetic heritage of local biodiversity? Are they based on farmers' genetic expertise and know-how? Are they protected by the public authorities?

- The class now enters into a discussion with a local politician, decision-maker or officer responsible for policy development – whichever is available to join the group within the school context. The pupils may ask some of the following questions:

  - Does the **genetic capital** provided by local biodiversity receive official recognition in terms of its ability to contribute to an annual increase in agricultural production, especially cereal production? To what extent does biodiversity feature in political and administrative decision-making?
  - Is traditional indigenous knowledge of relevance to the phytogenetic exploitation of resources at local, national and international level protected by the authorities? Is there a commitment to FAO's *International Treaty on Plant Genetic Resources for Food and Agriculture*?
  - Is there a right way for farmers engaged in farming practices to improve and preserve the local gene pool (via biodiversity) to equitably share the benefits arising from plant genetic resources (development of cultivars, etc.)?
  - Further to this point, the class can find out about the *Nagoya Protocol*, adopted during the COP (Conference of Parties), held in October 2010 in Nagoya, where States Parties to the Convention on Biological Diversity (CBD) adopted a protocol on access to genetic resources and to the benefits arising out of their utilization, otherwise known as **Access and Benefit-Sharing (ABS)**.

- The pupils ask about the implementation and application of this protocol in their region. Does it define the rules under which an agri-food, pharmaceutical or cosmetic company may make use of a locally originating variety or selected molecule, bring it to market and share the profits with the local community?

- When will the fund provided by the protocol, the *Multilateral Benefits-Sharing Mechanism*, be in place? How does it apply to the protection and remuneration of traditional knowledge stemming from the utilization of genetic resources? Numerous indigenous peoples have maintained and protected plants for centuries, many of which are endemic.*

* For more details see
Activity 11.2, Dialogue and action on sustainable livestock farming (p. 69).

  • The class then questions the member of the scientific community. Which aspects of traditional knowledge are promoted and exploited in research and in the development of integrated ecosystem management projects? Which aspects of this knowledge are updated and improved in the context of scientific and technical progress? Has a methodology been elaborated to remunerate environmental services in the context of conservation projects?

5. Take stock of practical measures supporting agro-biodiversity and initiatives on sustainable agriculture

- The group raises the wider issue of remuneration for the environmental, social and cultural services provided by farmers.

Example:
In maintaining the presence of hedges it can be argued that farmers are contributing to the beauty and quality of the landscape by defining the visual, aesthetic and cultural identity of the territory and its environmental amenities. Are services such as these recognized by the public authorities (political, institutional, administrative)? Some of these services, such as protecting wildlife or managing biodiversity, strictly speaking, fall outside the scope of a sustainable farming enterprise, but nevertheless play a part in keeping the ecosystem healthy for the benefit of all.

- Using questions prepared in advance, the pupils now proceed to learn about the orientation of agricultural policy. If some of the services provided by farmers form part of the common good, should rules other than those of the marketplace apply? Could this put an end to distortions caused by exports subsidies? Could financial incentives be provided to encourage the sustainable management of resources, food security and food quality?

- To conclude, the pupils engage in an open dialogue with the stakeholders present, focusing on ways to secure a strong agricultural policy.

- They also raise this point with the officers responsible for development policy or the local politicians in attendance:


Impatiens


Star of Bethlehem


Henbane


Horse chestnut

- Could increasing the local added value of smallholder farming activities boost agricultural economic profitability? What is the best way to achieve this? Facilitating or supporting the creation of micro-enterprises and local infrastructures (packaging and processing)? Encouraging crop diversification (agroforestry, aquaculture) or the growing of 'value added niche products' intended for food or industrial processing?

Example:
Depending on the region, value added niche products may include olives, argan fruit, palm trees, almonds, soya, pineapples, sugar cane, beetroot, sunflowers, flax, rape, hemp, ricin and fruit crops.

- The class debates these questions exploring a range of different views, including those of the farmer, who can estimate the probable chances of diversifying his or her source of income.

  Should the farmer explore ventures that combine crop production and various other commercial opportunities? Is it worthwhile becoming an artisan, business partner or a member of a cooperative in addition to being a producer?

  How can the authorities support these initiatives?

  Should they strengthen local markets (by stimulating them at the source)?

  Should they develop outlets for products intended to simultaneously meet the needs of the local community and cater for unsaturated, domestic demand, and generate sales opportunities abroad? Should they aim to develop an agricultural and food sector that is viable and sustainable from the local to the international level?

- Following the discussion, the class writes up an accurate summary and sends a copy to all the participants involved.

Black bear

Bohor reedbuck

Zebra

Chimpanzee

Activity 11.2

Dialogue and action on sustainable livestock farming

Depending on the local context, the class may choose to focus on sustainable livestock farming instead of sustainable agriculture (Activity 11.1).

As with the previous section on agricultural farming, the pupils invite a cross-section of local stakeholders to participate in the activity.

- The class can begin by exploring the landscape and its peculiarities before embarking on a group discussion about ways to conserve the biological chain of species with a focus on improvement of livestock farming practices.

- The discussion revolves around the conservation of species recommended for improving degraded pastures.

  Which species of trees or shrubs and bushes are recommended for planting as living fences in and around pastures in a particular region?

- The discussion can also addresses other topics, such as the rich composition of grasslands from a botanical point of view.

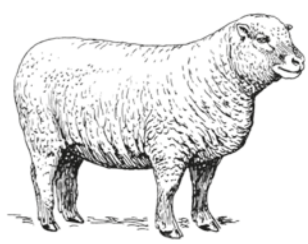
  Which species of herbaceous plants and approaches to farming (e.g. late haymaking) can help to maintain the rich diversity of plant life in grasslands?

  Which animal species contribute to the plant diversity of grasslands? Which species (of birdlife) keep the numbers of insects in check? Which species are good bio-indicators of the presence of other useful species?

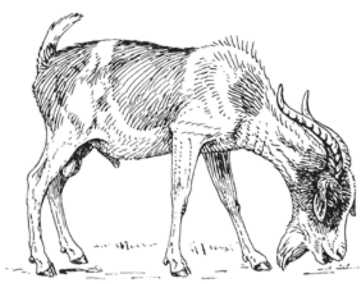
  Do grasslands function as reservoirs of genetic diversity for forage species, providing they are maintained on a sustainable basis? Do they contribute to landscape diversity through the intraspecific and interspecific diversity of herbaceous plants and through the maintenance of hedgerows?

  Can a relationship be established between the richness of the plant life in grasslands and the quality of the related animal products (i.e. milk and meat)?


Heather


Sheep


Holstein Cow


Goat


Argali


Aurochs

- The pupils direct the discussion along the same lines as Activity 11.1 on sustainable agriculture.

- They question the invited stakeholders on improved practices in livestock farming.

  Does enriching the genetic capital lead to better quality in livestock farming?

  Is the extensive system of cattle production in many regions of the world still developed by crossing local breeds for the purposes of meat and milk production (and calf production in the case of species that suckle their young)?

  Do farmers still favour species that are adapted to the climatic conditions of specific regions? Where grazing is concerned, and in places where conditions are sometimes harsh, do farmers prefer hardy species able to withstand the wet and life outdoors at high altitudes (e.g. Aubrac and Salers breeds in Western Europe)?

- How is the genetic capital of breeds and crossbreeds being protected?

  Is there a system for protecting the genetic capital of animals (a gene bank) at regional or national level? Does a similar system exist for fodder crops and plants in general?

  At the level of regional livestock farming, have collections of 'plant materials' been built up from specimens and non-indigenous populations of herbaceous plants (fescue, perennial ryegrass or cocksfoot), as well as from related wild species found especially in mountain pastures, such as wavy hair grass (*Deschampsia flexuosa*), red fescue (*Festuca rubra*) or timothy grass (*Phleum pratense*)?

- Have regional producers been incentivized to adopt sustainable livestock practices through financial compensation for environmental services?

  Do these services depend on the integrated management of agro-pastoral and silvo-pastoral ecosystems?

  Such integrated management could be based on three aspects:

  - Management of the biological diversity of grasslands (genetic flux in species of herbaceous plants, wildlife diversity)
  - Maintenance of hedgerows and living fences consisting of fodder shrubs
  - Conservation of indigenous livestock breeds, some of which are on the verge of extinction despite being perfectly adapted to the various systems of production.

Wolf

Gnu

Goa (Tibetan gazelle)

Activity 11.3

Dialogue and action on sustainable forest husbandry

Remaining with the local context, the class may decide to focus their attention on sustainable forest husbandry, instead of sustainable agriculture or sustainable livestock farming (Activities 11.1 and 11.2).

- As with the two previous sections, the pupils invite a selection of local stakeholders involved in conservation to participate in the activity. These could include a forester, a local politician, a forest engineer, a scientist specializing in conservation, the head of a local company (sawmill) and a self-employed craft-worker.

  The pupils can start the discussion by assembling an inventory of the surrounding landscape and its particular features. They then explore key environmental problems and suggest ways of managing them. Finally, they put together a list of best practices currently in place (or proposed) that aim to preserve the biological chains in forest resources.

- The class proposes an initial assessment of deforestation in surrounding woodland areas, based on observation of the landscape. Are there signs of mass deforestation?

  If so, is this the result of conversion of woodland into farmland or land given over to agro-fuels? Alternatively, is it the consequence of tourist infrastructure development (e.g. for mountain sports)?

  The situation may differ substantially depending on the context. For example, the situations of Brazilian Amazonia, Equatorial Africa, a boreal forest region or a mountain region in Europe vary considerably.

  The class put their questions to the parties present:

  What is the position of the authorities (represented by the politician in attendance) on the adoption of development schemes that grant subsidies for agro-fuel monocultures or agricultural farms that result in the clearing of forest areas?

- Next, the pupils orient the debate towards the issue of loss of diversity and therefore quality in forest ecosystems.

  Is timber extraction among the causes of the degradation of forest ecosystems?

  What is being done to remedy the situation?

  The pupils can evaluate forest development programmes (e.g. ECOFAC in Africa, ONF in France) being devised and implemented to address these problems through calculation of the amount of timber that can be harvested without permanently destroying or damaging the forest ecosystem’s capacity for regeneration.

- The class can also explore another side to the issue. Selective or emergency cuts (for firewood) are often undertaken in an uncontrolled manner either to meet individual needs or as illegal commercial activities. Do these practises also result in the degradation of native forest species?

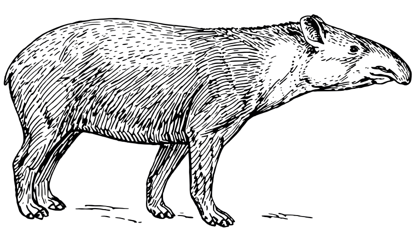
What steps are being taken to counter these debilitating forms of exploitation? What action is being undertaken to discourage them?

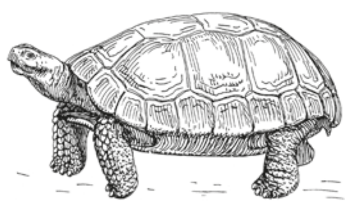
- The pupils challenge the stakeholders about areas for action:

  1. Developing alternative forms of fuel or energy sources;
  2. Increasing the economic benefits of logging for local populations through:
     - management of the labour force and the timber supply chain (organization of the sector);
     - development of local infrastructure: processing, packaging of wood (sawmills, palette factories) and recycling of wood chips.
  3. Integrating the indigenous knowledge of local populations on medicinal biodiversity, for example:
     - How should the international pharmaceutical industry compensate the use of botanical knowledge and its use in traditional medicine?
     - What intellectual property rights should indigenous peoples have?
     - How should the Nagoya Protocol (ABS) be applied in terms of access to benefits from the use and commercialization of plants and molecules deriving from local contexts?
  4. Conserving nature on a broad scale by:
     - conducting biological, plant and specifically forest inventories;
     - transforming vulnerable areas with a high concentration of biological life (biodiversity hotspots) into nature reserves;
     - protecting representative samples of species that are characteristic of the few remaining primary forests;
     - establishing gene banks.
  5. Fighting illegal trading through:
     - the implementation of CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora);
     - the development of timber certification and the application of eco-labels (e.g. the Forest Stewardship Council (FSC)), which guarantee both product certification and environmental, social and economic sustainable management criteria.

As part of an initial assessment of the operational and legislative framework of local forest husbandry, the class question the forester and forest manager about their management practices and methods and highlight initiatives related to sustainability, for example:

- management of dead wood;
- collection and management of forest resources rooted in traditional practices;
- cutting techniques in managed forests (selective cutting, strip cutting and restricted access zones);
- improvement of planted forests;
- enhancement of the subsoil, mycorrhizal fungi and interspecies exchanges through mycelial networks.


Tapir


Tortoise

The school garden: a biodiverse garden

In this final activity, the pupils plant a garden where they apply and promote the body of knowledge they have acquired about biodiversity and its conservation. They also try to make use of the garden to study and test the function of biodiversity itself, and its role in the dynamics and vitality of the ecosystem (fluxes of matter and energy, nutrient cycles, biomass production, crop productivity, and social and economic goods and services).

Hydrangea

The task of constructing and maintaining the garden is spread over numerous sessions, several growing seasons and continues over a number of years, truly becoming a school project.

The tasks of promoting, refreshing and, in particular, maintaining the garden are shared out among the different years.

Cotton plant

1. Decide on the site for the school garden and assess the condition of the land

- The class as a whole decides on the location of the garden with the help of environmental professionals. Ideally, the plot should be situated next to the school and measure no less than 120 m^2, consisting if possible of two contrasting environments in terms of aspect, sunlight and humidity. A nearby water supply for watering the plants is essential.

- The plot must consist of at least partial plant cover and should be a living environment. Soil that remains inactive over long periods becomes dead soil, and thus much harder to improve.

- After visits to several possible sites, the class selects the final location of the garden and accurately determines its perimeter. Next, they inspect the plot and its main characteristics.

- This is done to better understand the mineral compounds in the soil (whether mainly chalky or siliceous) and especially to evaluate its nutrient content.

  Are there any indications of a deficiency in organic matter and, if so, to what extent?

  Can any diagnoses be made on the basis of indicator plants?

- The teacher enlists the assistance of an agronomist, a farmer, a forester and a gardener in making these diagnoses.

> *Example:*
> *In temperate regions, an abundance of certain plants such as couch grass or ragweed implies that the soil is deficient in organic matter and has been decalcified. In rainforest regions, an abundance of moor grass or bent grass is evidence of leaching of the soil and loss of organic matter.*

2. Enrich the soil in preparation for planting

- On the basis of the above specialist advice and diagnoses the class proceeds to enrich the topsoil.
- The pupils realize the importance of the texture and structure of the soil, and accordingly estimate the proportions of sand, silt and clay. The latter is important as it allows water and air to permeate the soil and enables hydric exchanges between the roots and the soil.
- They note that soil that is not dark brown needs enriching. It lacks humus, which normally gives the soil a dark colour.
- After weeding the plot by hand, the pupils can prepare the soil by sowing **green manure** on areas reserved for plants.

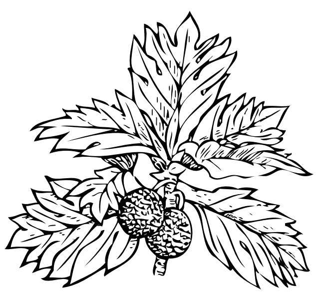
  Green manure is produced by cultivating a fast-growing plant, carefully chosen to suit the conditions of the soil, with the aim of improving its potential yield.

- This method offers several advantages:
  - Green manure can be used on eroded or compacted soil: the roots of the plant penetrate deep into the ground, aerating, structuring and loosening the soil, which resists compaction as a result of frost or drought.
  - Green manure also provides cover to soil, which would otherwise be left bare and exposed to excessively harsh climatic conditions and the leaching of nutrients by rain.
  - Lastly, green manure is used in particular to balance the concentration of nutrients in the soil, ensuring or boosting the supply of nutritional elements for future crops.
- The pupils therefore choose a plant that retains any excess nutrients in the soil or, conversely, select one that adds nutrients to the soil such as nitrogen-fixing leguminous plants.


Sycamore


Thistle


Vine


Breadfruit


Thuja

Example:
There are symbiotic systems in which plants of the legume or Fabaceae family (lucerne, lupin, clover, acacia, soya, groundnut) grow in association with bacteria called rhizobia, which settle on the deep roots of these plants and induce the formation of nodules in which they fix nitrogen.
The bacteria supply the plant with nitrogen compounds; the powerful root system of the legumes diffuses the nitrogen through its roots, pumps it to the surface and makes it available for future crops.

- Following the advice of experts, the pupils sow clover or lucerne. They first familiarize themselves with sowing techniques learnt from the farmers and then broadcast the green manure.

  Once the plants are tall enough, the pupils dig them well into the soil using mechanical assistance. The buried green manure will add a layer of organic matter to the surface and produce humus, which enhances the structure of the soil.

- As a way of reviving the biological functions of the soil, the class can also choose to mix in organic fertilizer. This stage requires some preparation. A few weeks earlier, the pupils, advised by the augmented pedagogical team, apply themselves to the technique of composting:

  - They dig a pit (a large hole) not far from the school and the garden site, and make the compost to suit the degree of organic enrichment required.
  - They fill the hole with piles of dead leaves, sludge from sediment deposits or water-treatment plants, waste matter from household rubbish such as fruit and vegetable peelings or leftover food, and garden waste from plants that have been dug up or cut down, with the exception of slow-decaying plants such as couch grass, herbaceous plants that have run to seed or highly poisonous species like monkshood, hemlock or digitalis.
  - They add, as appropriate, specific types of organic waste. These can include goat or sheep droppings, slurry (animal excrement) and dung (animal excrement with straw), as well as the bark of ligneous plants, peat, wood shavings and other types of cellulose waste or thatch.
  - They completely cover the mound with a layer of earth and leave the mixture to stand for several weeks, remembering to turn and water it regularly, so as to accelerate decomposition.
  - Before sowing or planting the crops, the pupils spread the compost over designated areas; they turn the topsoil over, which aerates it, and mix it with the compost in equal proportions.
  - This process is intended to remedy certain deficiencies. Compost made predominantly with household waste improves the structural stability of the soil and acts as a source of nitrogen and potassium, sewage sludge has the same effect as fertilizer and functions as a source of phosphorus, animal dung is a source of nitrogen and again substitutes for fertilizer, and the use of peat or cellulose waste enhances the soil's retention of water.

3. Introduce ligneous plants into the plot

In the early stages of creating the garden, it is a good idea to think about siting and planting one or more trees to provide shade and maintain the soil's fertility.

- The pupils make sure to select eco-friendly species well known for their revitalizing effect on the ecosystem.

Examples:
In dry regions, the acacia is a possible candidate for promoting revitalization. Its exceptional root system enables it to draw water from deep in the soil (hydraulic lift) or supply nitrogen to an annual surface crop – such as cereals (wheat or barley) established nearby at a sufficient distance – by drawing it to the surface or injecting it back into the ground through excretions from the roots.
In forested regions or regions with high rainfall, the pupils take advantage of the action of mycorrhizal fungi in the undergrowth. They plant in the garden types of forest trees that shelter several species of mycorrhiza in their root systems, and are thus able to exchange nutritional elements via mycelian networks. If a beech is planted near a douglas fir, for example, and the two are exposed to different light conditions, the beech will, via the fungi, supply the less exposed fir with a sizeable amount of carbon, which the fir will fix by means of photosynthesis.

- The class can exploit other known associations in the garden and highlight the role of biodiversity in the dynamics of ecological services, such as nutrient cycling (plants-soil-microorganisms).

- When the decision is made to plant a new tree in the garden, the pupils clear the area and transplant a seedling raised in the nursery that is already well developed.

- As a complement to ligneous plants, which are endowed with unquestionable ecological qualities, the pupils can decide to introduce into the garden a minimum of two trees or fruit shrubs (two trees of the same species but of different varieties have to be introduced if they are to bear fruit). As well as eventually providing tasty, full-flavoured fruit, fruit trees attract many living species (pollinating and dispersing agents) and thereby allow a dense and diverse concentration of biological interactions to take place on the site.

- The pupils will need to be patient and wait several years before they can taste the first almonds, pistachios, cherries, apples, plums or apricots, depending on their particular region.

- In the meantime, they can ask a forester to help them plant from a scion or half-standard (obtained by grafting). They will need to maintain and fertilize the orchard area on a regular basis to encourage the growth of the young plants, avoid disturbing the ground cover and shady conditions, which are indispensable to sexual reproduction during the first flowerings, and restrict the amount of fruit they pick from the young trees the first time around.

4. Establish crops in the garden

- The preparation of individual patches of the plot and the planting itself provide the pupils with a chance to put into practice the maintenance of a dynamic, healthy and viable ecosystem, in which biodiversity plays a vital role.

- Several aspects must be addressed simultaneously including: the choice of cultivated species, crop protection, the scale of the work involved and the plot environment, the maintenance of auxiliary plants, and the conservation and management of pollinators.

- On all these points the class can seek the advice of environmental specialists.

Sugar maple

Subulate leaves

Pumpkin

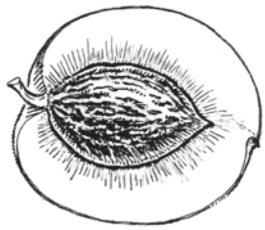
Sugar cane

The pupils adopt a comprehensive strategy in consultation with the farmer, engineer and gardener, with whom the pupils exchange ideas and collectively monitor each initiative as part of the larger framework.

- Their work on previous activities will have made the pupils aware that living species form a biological association with other species whose needs complement their own. These species become **companion species** and may even help one another (see Activity 4). The pupils now use this knowledge to identify plant associations and adapt them to the context of the garden.

Bundle

> *Example:*
> *Tomato crops benefit from the close proximity of marigolds, nasturtiums and French marigolds, which attract pests (greenfly, flea beetles and Colorado beetles), thereby protecting young tomato plants from these organisms.*



Endocarp

- The pupils organize the plot in accordance with the crop rotation method, which will influence the association between species. Growing the same plant on the same patch of garden over years in successive years can be harmful to the soil. By consistently drawing nutrients from the same depth, plants permanently rob the soil of mineral compounds and other elements.

Emblem

- To avoid this scenario, the class alternates leaf vegetables with root and leguminous crops, so as to take advantage of complementarities between organic matter and minerals in the soil. On the same patch the pupils first sow Fabaceae or legumes (e.g. broad beans, French beans or peas, depending on whether the garden is situated in the Andes, Africa or elsewhere). These enrich the soil with nitrogen. The following year they sow leaf vegetable crops such as cabbage, which benefit from the newly available nitrogen. The cycle ends with root vegetables, which draw their nutrients from deep in the soil, even when these have been leached by rain. The pupils then begin the cycle all over again, enriching the soil by sowing legumes or green manure.

- To make the most of the plot, the pupils learn more about co-existence between species and accordingly organize the growing area to ensure better yields.

- They avoid growing tubers such as potato in association with deep-rooted plants such as carrot or other solanaceous vegetables like aubergine, which have the same needs; or growing a popular plant such as the tomato, which requires a rich, constantly fertilized soil, in association with other plants that require plenty of nitrogen, such as cabbage. Conversely, they may choose to plant tomato next to basil, as the former will benefit both in terms of fertility and taste.

Some plants are not very compatible with others because of the substances excreted by their roots. One such plant is garlic, which inhibits the growth of leguminous plants such as beans or peas. However, garlic is an excellent fungicide and its odour keeps insects like aphids and spiders away from tomato crops.

- In addition to acquiring information about similar plant needs and obvious antagonisms, the pupils learn about plants that rid the soil of noxious organisms or diseases, since parasites specific to certain plants tend to become entrenched, especially if the plant has occupied the same spot for several years.

> *Example:*
> *Horsetail helps to fight against mildew and oidium, while onion peels or a decoction containing onion keeps carrot fly at bay (it may be advantageous to sow alternate rows of carrots and onions).*

5. Use auxiliary organisms to control pests

The pupils next undertake efforts to control pathogenic agents in the garden. These include pests that attack plants (termites and flies), parasites that degrade the life cycle of plants (dust mites and plant bugs) and, in particular, pests that can cause significant harm to the food they produce (greenfly, Colorado beetles, slugs and pierids, which are all found in various parts of the world).

- To achieve this, the pupils do not resort to chemical products or pesticides, but instead try to control these agents biologically within a conservation context.

- They take into account both the garden and its relationship with the surrounding landscape and encourage the establishment and development of auxiliary organisms naturally present in the environment, rather than introducing or releasing new ones.

- Emphasizing the role of indigenous biodiversity, they pupils seek to establish a balance between crops, phytophagous organisms and garden auxiliaries, without eradicating pests. As the main auxiliary organisms are insects, including coleoptera (ground beetles), hymenoptera (wasps and larvae), mites, spiders, bats and birds, the pupils maintain or install facilities that offer protection or shelter to these populations. These could include the introduction of tree stumps or nesting boxes, the use of low walls or partitions, the planting of hedges, flower borders or grass borders, or the maintenance of ditches, embankments or covered micro-environments.

  The pupils also maximize the chances of sparrows using the nesting boxes as temporary shelter by locating them in the orchard area of the garden.

- In addition to the aforementioned aromatic plants which repel noxious insects and can be planted next to crops (e.g. borage drives away Colorado beetles and lavender keeps greenfly at bay) the pupils select melliferous plants to create **flower borders** that attract auxiliaries, so as to aid biological pest control.

- They also introduce aromatic herbs of the umbelliferae family, carrot or fennel, sweet clover, viper's bugloss, phacelia or alfalfa, which attract bugs *(Orius)* and predatory dust mites, as well as hoverflies and lacewings, which feed on nectar and pests. Micro-hymenoptera parasitoids (see Activity 11), which in many parts of the world combat greenfly, are particularly attracted to bird's foot trefoil and acillea in Europe and by umbellifers in North Africa.

- Although more research is needed on the dynamics of auxiliary plants inhabiting plots, it is clear that auxiliaries make significant use of **hedges** as shelters on a temporary and a permanent basis.

- The pupils next start work on planting a hedge. As with the construction of the garden as a whole, this is a slow process. It takes time for shrubs to reach a certain height, for species to occupy their ecological niche and for the micro-ecosystem represented by the hedge to achieve a measure of ecological balance.

  In every region, the class should work with professional experts to establish the hedge at the earliest possible moment, so it can fulfil its functional role.

> *Example:*
> *In temperate regions, the pupils start by planting basic species such as hornbeam, hazel or willow (low-growing trees), which they supplement with shrubs like guelder rose, broom or bramble, depending on local conditions. Next, they add multipurpose herbaceous species, such as garlic mustard and comfrey, as well as climbing species like old man's beard or honeysuckle, which will need to be carefully controlled. The resulting tangle of branches will make an excellent habitat.*

- This approach can be replicated and adapted to all other regions.

> *Examples:*
> *In the Maghreb, fruit trees of the pistachio variety form the base of the hedge, laden with nectar to increase nesting opportunities in arid regions and diversified with aromatic plants. In sub-Saharan Africa, the fruit-bearing Indian jujube* (Ziziphus mauritiana) *may be used in conjunction with other multipurpose ligneous plants, such as the Faidherbia albida acacia, which are valued for their shade (reverse phenology), and to which are added low-growing plants such as balsamiferous spurge* (Euphorbia balsamifera).

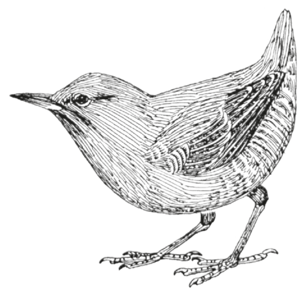
- Over time, the class observes the appearance of a diversity of wildlife and take notes.

- The pupils pay special attention to the **connectivity** of the hedge with the plants they wish to protect. They introduce a herbaceous layer between the crops and the hedge to encourage arthropods (spiders, dust mites, coleoptera, including invaluable ground beetles and ladybirds) to circulate and propagate from one place to another.

- They make sure that the hedge does not become overgrown or overrun by perennial species, which could themselves attract species that do more harm than good.

- They also take care not to choose crops that belong to the same family as the plants used for the hedge, so as to avoid the propagation of noxious species or pests.

6. Ensure the protection and conservation of wild pollinators



- To heighten the productivity of the garden both in terms of quality and abundance – while ensuring high yields are not the sole objective – the pupils incorporate practices geared to the protection of pollinators.

  Among their experimental crops are many (fruit-bearing, oleaginous, horticultural, vegetable, fertilizing) species that do not produce seeds either for sowing or at the fruiting stage (and therefore fruit) unless pollinating agents transfer pollen from the male anthers of their flowers to the female stigmas of the same flower or to another flower of the same species. The transfer of pollen to the female stigmas, from where it penetrates the ovary to fertilize the immature seeds, is entirely due to the intervention of these pollinating creatures.

Sparrows

- Drawing on professional knowledge, the class lists the pollinating agents of plants growing in the garden (vegetable, fruit, horticultural, aromatic and medicinal).

- In many parts of the world (and especially at the scale of a garden) these will consist mostly of insects including wasps, bees, bumblebees, flies, coleoptera, moths, butterflies and arachnids, as well as small animals generously endowed with hair to which the sticky balls of pollen easily attach themselves. However, in rare cases, and in relation to specific species, the pupils can focus their attention on more unusual pollinators such as certain types of squirrels or arboreal weasels (nectarivores), or birds such as hummingbirds or sunbirds.

- When selecting from approaches to protect wild pollinators in gardens, the pupils avoid the use of insecticides and pesticides.

- They choose the greatest possible range of plants for the plot, especially in arid and mountainous ecosystems, so as to attract diverse populations of highly adapted pollinators.

- They pupils carry out a series of comparative studies over time to measure the benefits of pollination. These reside not only in the quantity of fruit or seeds obtained, but also in the variety and quality of the products.

Example:
Even though scientists still lack sufficient information on the pollination needs of plants, it has nevertheless been demonstrated in the case of many fruits, such as watermelon, that more frequent visits by pollinators invariably produce fruits with better flavour.

- The pupils also learn to measure the extent to which exposing plant species to wild pollinators preserves and enhances the genetic diversity of cultivated plants:

  Although many plants have flowers that are both male and female (hermaphrodite) or have separate male and female flowers on the same plant (monoecious), and can thus self-fertilize, the norm is for living species to deploy strategies aimed at enriching themselves genetically and, in the case of plants, at promoting cross-fertilization.

  Certain plants cannot survive without insects because their unisexual flowers require a visit from pollinators for fertilization. This is the case with **cucurbits**, which are found on every continent. The pupils perform another series of tests to try to ascertain the extent to which such plants can hybridize, after being fertilized over time by pollen from different plant varieties (albeit within the same species). This process occurs everywhere, leading to a wide variety of marrows, courgettes, squashes, cucumbers, gherkins and pumpkins, and calabashes (in Africa), all of which are the result of a varied community of pollinators.

- Over time, the pupils amass an extraordinary seed bank consisting of seeds obtained from the plants, but also as a result of the multiplicity of biological interactions at work in the garden.

UNESCO Global Action Programme on Education for Sustainable Development

UNESCO Associated Schools

United Nations Educational, Scientific and Cultural Organization

Japan Funds-in-Trust

BERACA

9 789231 001789