

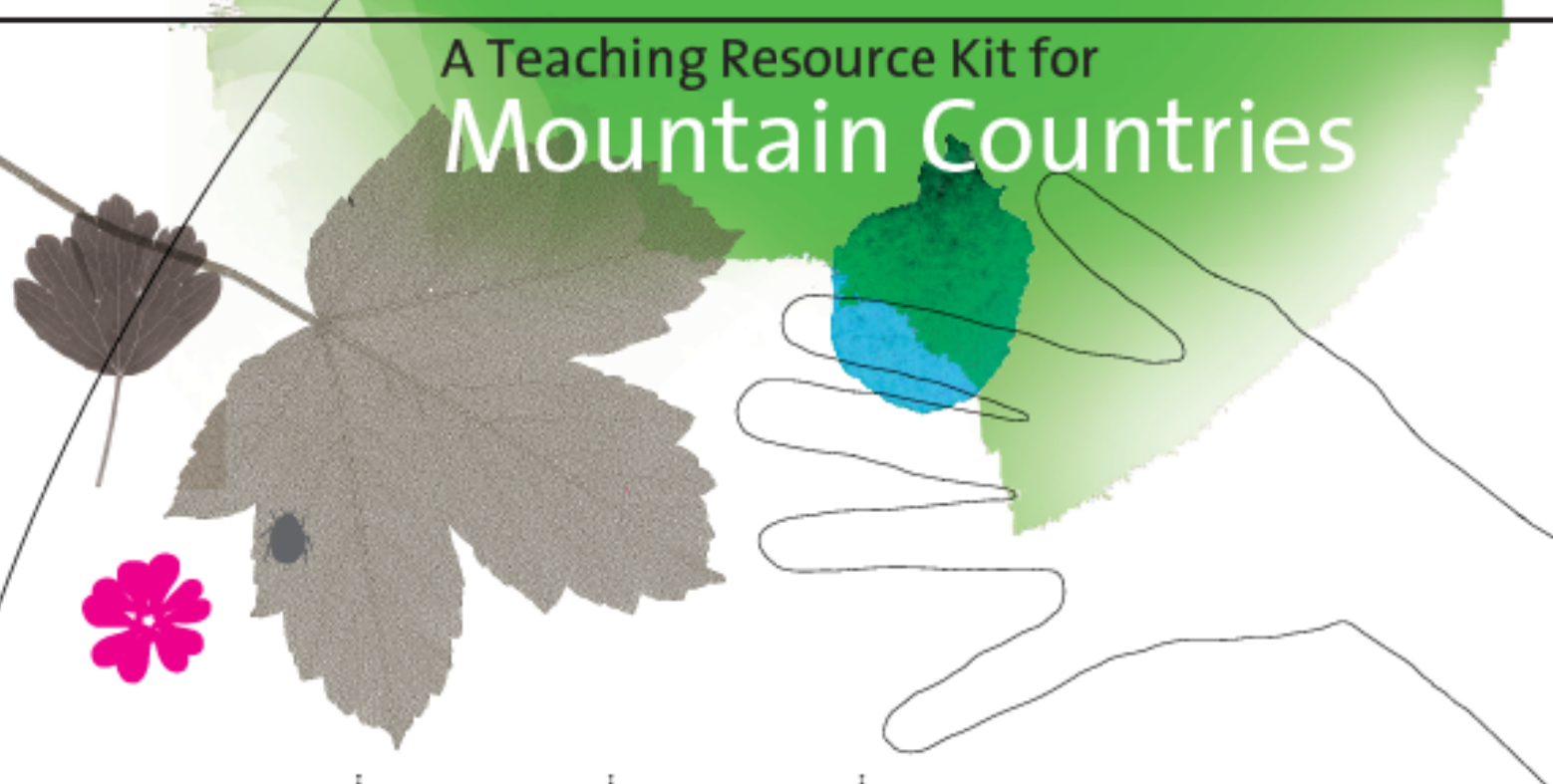


Teacher's Manual



A Creative Approach
to Environmental Education

A Teaching Resource Kit for
Mountain Countries



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Cultural Organization

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Programme



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Associated
Schools



A Teaching Resource Kit for Mountain Countries

A Creative Approach to Environmental Education

“The breath of my mountain is my heart”

Maori chief Hepi te Heuheu, Ngati Tuwharetoa tribe

Officer-in-charge:

Thomas Schaaf, UNESCO

Editor and project designer:

Hélène Gille

Scientific advisers:

Michel Le Berre, Thomas Schaaf

Graphic design:

Mecano, Laurent Batard
assisted by M. Malpeyrat et de C. Sayous

Translation:

Paul Reed

Coordination and iconography:

Hélène Gille

With the collaboration of:

Greg Thaler

Administrative assistance:

Natasha Lazic,
Rosanna Karam

Cover:

Basgo Monastery,
Ladakh, India

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1, rue Miollis
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Email: mab@unesco.org
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Preface

This environmental education kit for mountain countries was developed as an initiative of the Programme on Man and the Biosphere (MAB) of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Entitled: *A Teaching Resource Kit for Mountain Countries*, it is a new environmental education kit similar to the *Teaching Resource Kit for Dryland Countries* published by UNESCO in 2008. It is based on the same innovative approach appealing to the creativity and artistic sensibility of pupils aged around 10 to 15, and is intended for secondary-school (and late primary-school) teachers and their pupils, this time living in mountain ecosystems, where climate and environmental conditions are harsh, often varying between extremes, and which are subject to the problems of erosion.

As an educational tool, the kit offers a practical and attractive way of helping teachers and their pupils towards a better understanding of the environmental problems of their region and to stimulate their quest for possible solutions. In this respect, its content is a further contribution to the United Nations General Assembly's resolution proclaiming 2002 the International Year of Mountains and is also consistent with the activities developed as part of the United Nations Decade of Education for Sustainable Development (2005-2014), the promotion of which is UNESCO's responsibility.

The kit is being distributed by the UNESCO Associated Schools Project Network (ASPnet), which comprises a total of 8,000 schools in 177 countries, and benefits from the support of the United Nations Decade of Education for Sustainable Development through activities organized in the different countries involved.

We invite teachers interested in the kit or requiring information about how to use it to contact UNESCO's regional offices in their respective countries and refer them to the Internet and email addresses of the project organizers: www.unesco.org/mab and mab@unesco.org, and to the Internet sites of partner programmes at UNESCO in the field of education: the UNESCO Associated Schools Project Network (www.unesco.org/education/asp) and the Decade of Education for Sustainable Development (www.unesco.org/education/desd).

We should like to extend our warmest thanks to the Flemish Government of Belgium, which financed the entire process of developing this teaching resource kit as part of its broad support for the Natural Sciences Sector, demonstrating that environmental education is as much a part of science as it is of education.



N. Ishwaran

Director, Division of Ecological and Earth Sciences
Secretary, International Coordinating Council
of the Programme on Man and the Biosphere

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Introduction

The objectives of the teaching kit

In mountain ecosystems, all sectors of the population are affected by the harsh weather and environmental conditions prevailing at high altitude, compounded by active erosion problems that result in land degradation and constrain their ability to live in a mountain environment.

Environmental education and awareness are vital and must begin early if they are to have an impact on the individual. With a view to giving secondary school pupils (and older primary school pupils) a better understanding of mountain ecosystems, this teaching resource kit offers a creative approach to environmental education designed to arouse pupils' curiosity, capture their attention and help improve the transmission of scientific information and environmental knowledge.

The primary objective of the kit is to help teachers transmit the scientific information contained in it in an entertaining and appealing way.

The longer term objective of the kit is to develop the ability of pupils and the community as a whole to combat the instability and degradation of the soil that cause erosion in mountain areas, while endeavouring to preserve biodiversity.

The concept of sustainable development is at the heart of the activities proposed in the kit: as they implement them, the teachers or educators, with the help of resource people, local partners and environment professionals, teach the pupils to critically evaluate local practices linked to land use and natural resource management. They identify the practices that may be harmful to or non-viable for the ecosystem and in this way gradually deepen their understanding of the impact of human activities on their environment. By engaging in practical activities, the pupils then gain a better knowledge of sustainable development in mountain ecosystems.

Structure of the kit

The kit has two components:

- the teacher's manual;
- the class notebook.

The central component is the **teacher's manual**. It is divided into three chapters, each with its own theme:

- Discovering the ecosystem and its biodiversity;
- Maintaining plant cover;
- Preserving water resources.

The first two chapters each contain five activities and the third chapter contains three, ranked according to their level of difficulty in terms of content and implementation. Each chapter begins with "easy" activities, followed by "intermediate" and then "advanced" activities.

The teacher may choose to carry out the activities with the class sequentially, in the order proposed within each chapter, or alternatively may conduct one or more of the activities separately, in accordance with the themes being studied in class, the school timetable and the ability level of the pupils.

The **class notebook** is used by the pupils and is designed to accompany the teacher's manual.

The notebook contains a double-page spread to be filled in for each activity. The pupils are split into groups, and, in turn, each group works together to fill in the pages set aside for the activity being carried out. They use their own words, their understanding of the activity objectives, their visual and sensory memories of the exercise, and their ability to draw and preserve something of what they have experienced and learned.

The class notebook is printed in just two colours so that it can be easily photocopied, making it simple for the teacher and pupils to exchange class notebooks with another school in the UNESCO Associated Schools Project Network, located in a different mountain region of the world.

Who is the kit intended for?

The kit is designed for secondary-school teachers of subjects as varied as geography, biology and visual arts.

It may also be used by teachers of older primary-school children and, more generally, by any educator wishing to carry out an environmental education project, either alone or as part of a team, in a formal or non-formal educational setting.

In terms of raising public awareness, the kit may also be used to promote the efforts of local decision-makers wishing to take environmental issues into account when drafting development policies.

Most of the activities in the kit, which require very little in the way of equipment, involve an element of environmental discovery (or rediscovery) based on observation, collection, drawing, imagination and meeting with local resource people. The activities thus take into account the shortage of resources and the often difficult working conditions of educators in the sometimes remote areas typical of mountain regions.

In summary, the form the educational project takes, depends mainly on the educators' and teachers' motivation and their ability to organize themselves and pool their efforts.

They may use the kit to develop an environmental education project on a particular theme (along the lines of a themed class) or conduct activities in the kit as part of educational or pedagogical innovation projects. They may also use the kit as an education for sustainable development resource through various ideas that it proposes:

- cross-disciplinary learning objectives that extend beyond the scope of a single subject;
- methodology based on the development of critical thinking;
- participation of resource people, local stakeholders and environment specialists in educational activities, supporting and enriching the teacher's contribution.

A creative approach to environmental education

All of the activities contained in the teacher's manual have been developed in accordance with a creative approach to environmental education.

Initially, this approach encourages the pupils to use their senses to discover the environment.

Often living in rural areas, children growing up in mountainous countries develop a close relationship with the mountains; they have practical, pragmatic experience of their natural environment.

In order to carry out the activities, they go outside and look afresh at their natural surroundings, accompanied and guided by their teacher.

They learn how to observe, to "read" their environment better, to examine it in detail and to see things they may never have noticed before.

They describe an object within reach on the ground or a species in its natural habitat and, always on the basis of practical observations, learn new terminology and concepts.

The pupils may rediscover an object by placing it next to or comparing it with others in collections and compositions that the class produces together.

On certain occasions, when circumstances warrant it, the teacher may ask the pupils to draw what they observe, since this often helps them to see and understand better. The aim is not to develop their drawing skills, but to help them become better observers of nature. They draw in order to remember a detail or capture a particular scene.

In other activities, the class learns to recognize and describe the smells and tastes of plants, and of preparations and dishes derived from them. Others still invite them to rediscover the relief of the land by placing themselves in the environment and to use certain exercises to compare the human scale with that of the landscape.

In short, the aesthetic and inspiring qualities of the environment are used to arouse pupils' curiosity and keep their attention. They can understand better what they have observed from close quarters, what they have experienced in an intimate kind of way, what they have made their own and, to a certain degree, learned to love.

In the second phase, scientific information and environmental knowledge are passed on to the pupils in activities that rely on local and everyday knowledge placed in a scientific context. These activities encourage exchanges with those members of the community who have an expert knowledge of their locality, such as herders, foresters, crop and livestock farmers, trackers, medicinal plant experts and craftspeople.

Frequent reference is made to a triangular relationship between the teacher(s), resource people in the community and the pupils, which is incorporated in the methodology of the activities.

At various stages in the activities, the teacher may choose to create a forum for discussion with local experts in the classroom so that the links between the ecosystem and local culture can be explored.

The transmission of knowledge, practical skills and even of the oral tradition (through stories and anecdotes) is thereby facilitated.

The teachers then place this knowledge in a scientific context: how can indigenous knowledge be combined with scientific data on the fragile ecosystems found in mountain areas? How can it be used to improve knowledge of species conservation? How can it be linked to the sustainable use of natural resources?

The pupils are thus led to develop their ability to think critically and the teacher helps them to consider the impact of human activities on the environment.

In the activity *Shape and design: the anatomy of trees and shrubs*, for example, the object is to study the shape and growth of plants, particularly trees, and to learn how to identify them, to judge their condition from their habit and to assess the degree of deforestation in the surrounding woodland areas.

The teacher draws on the practical knowledge of the local inhabitants and community elders: what are the external factors that act on a plant's habit? Which shapes are the result of genetic adaptation and which the result of deformation caused by the mechanical action of the weather or the adverse impact of human activities? How can pupils learn to identify those factors that lead to destruction: signs of overgrazing, the constant gathering of firewood, elimination by burning or by trampling, or else signs of the impact of wind, frost and snow?

The activity prompts the pupils to reflect on a larger scale, the surrounding mountains providing the starting point for their observations: is there any evidence of mass deforestation of the slopes? What do the slopes look like in the absence of plant cover? Are there any visible attempts to replant trees? In what way is every part of a tree valuable to the soil?

Through a precise, scientific study, the class examines the ecological functions a tree fulfils from its roots to its crown and reaches a better understanding of the true ecosystem represented by a single tree, together with the need to preserve it in its entirety in an environment where the ecological balance is fragile.

In *An inventory of useful plants*, the ecosystem is seen as a source of crops and other benefits, and is likened to a garden from which the community gathers fruits: a nourishing garden (edible plants), a healing garden (medicinal essences and plants) and a protecting garden (use of plants to build houses or make clothing).

How does a population, in return, preserve natural resources?

The class begins by reflecting on the relationship that exists between plants, cultural traditions and conservation. Since local plants provided the initial impetus for the development of cultural practices – in terms of taste, cooking, medical care, aromatherapy treatments and house-building – and are often associated with rituals linked to worship and spiritual well-being, they have given rise to numerous uses that define or improve our living conditions and enrich our culture.

However, the class is quickly steered towards the following questions:

What agricultural and forestry practices are detrimental to the availability of these plant resources and contribute to a decline in their diversity?

How can one overcome the problem of having to use trees as a source of instant income by felling them more quickly than they can be replaced?

Through being encouraged to talk to the local actors, the class comes up with practical solutions and becomes aware of the importance of maintaining or revitalizing local knowledge.

How can the livelihood of the local population be diversified through a wider range of activities? How can additional income be generated and agriculture improved on the basis of valuable knowledge about wild plants and biodiversity? How can local knowledge be improved through greater accuracy in the present state of knowledge and by scientific advances? How can the diversity of resources be maintained to meet the different needs of the community and the possibility and advantages of choice (in terms of building materials and furnishings, for example) be promoted so as to maintain this diversity?

Finally, in *The experimental garden*, a team of teachers develops a practical educational project based on a garden. The activity includes an element of sustainable development, since it encourages the pupils to take long-term action, for the benefit of future pupils and generations and not just themselves.

The choice of the garden site is linked to the pilot projects in environmental protection of the local actors and decision-makers. In creating the testing ground of the experimental garden, the pupils are constantly guided by the advice and experience of professionals and by full-scale areas cultivated by professionals such as farmers, foresters, smallholders and environment experts. They learn to note the characteristics of those plants that are indicators of soil quality; they discover the advantages of self-propagating plants, of messicole and ruderal plants, they learn how to use green manure, to spread fertilizer and to use intercropping methods by exploiting the virtues of leguminous plants. The particular advantage of an experimental garden in mountain areas is that it allows a wooded area to be discovered and exploited. The latter can initially be cleared, restored and enriched, subsequently becoming the testing ground for a collective and consultative method of management for non-wood forest products.

How to use the teacher's manual

The layout of the teacher's manual is designed to be clear and appealing, reflecting the spirit of the project.

The clearly marked colour coding of green and navy blue makes it easy to identify the division of the manual into three chapters and thirteen activities.

The green on the cover is also found on the dividing strip between chapters and again on the header of each numbered activity.

This header includes the **title** of the activity as well as several graphic symbols that enable the teacher to identify and use the pedagogical material. The following information is indicated:

The **level** of the activity: its level of difficulty in terms of content and implementation: Easy, Intermediate or Advanced;

The **place** where the activity should be conducted: outdoors, or in the classroom;

The **number of sessions** required in order to complete the activity: the length of a session, two to three hours on average, may be modified by the teacher according to the time available.

The **objectives** are also set out at the start of the description of each activity, under the title header.

The teacher can therefore easily identify the objectives of the activity, which are usually defined in terms of discovery of the environment, knowledge to be transmitted and pupils' comprehension.

Some advanced activities, in addition to transmitting knowledge, aim to develop certain aptitudes and skills.

The **methodology** to be followed for each activity is clearly indicated by the division of the activity into several sequential stages.

Each stage is summarized by a verb indicating a specific action ('collect' or 'classify', for example) or a subheading in which the action is described ('observe the action of the wind and the signs of erosion', for example). This provides both a sense of dynamism and a clear order of progression.

Throughout the **description** of each activity, the subheadings are coloured green, the colour used to organize the manual, and are therefore easily identifiable in the text. Examples illustrating each stage of the activity are shown in navy blue, the colour which, along with green, forms the colour code used throughout the teaching resource kit.

The titles and subheadings also appear in the manual's table of contents, which, from the outset, provides an overview of the content and methodology of each activity.

Finally, scientific and technical terms relating to ecology and the environment are clearly identifiable: they are highlighted in pink and refer the reader to a **glossary** at the end of the manual.

In this way, the teacher's knowledge base is strengthened and the requisite knowledge specified.



Chapter 1

Discovering the ecosystem and its biodiversity



01 Collecting treasures

Level 
easy

Place  
classroom
and outdoors

Duration 
2 sessions

Objectives

1. Discovery of the environment

By collecting natural objects in their own familiar landscape, pupils become aware of biological diversity in their environment. The exercise often generates a sense of wonder.

2. Knowledge and comprehension

The teacher gets the pupils to classify the objects they find and to assemble them in collections, so that their first acquaintance with the concepts “biotope”, “biocenosis” and “ecosystem” is a visual one.

Methodology

1. Discover the lower slopes of the mountain together

- ▶ In mountain areas, the landscape is often varied and picturesque; at the same time, access is difficult, owing to the steep, often very steep, slopes, climatic conditions are harsh and erosion is rife. Most pupils who live in daily contact with the mountain are familiar with this hilly terrain, since their relationship with their environment is often a functional one.
- ▶ The teacher begins by suggesting to the class that they discover for themselves, with help, the exceptional beauty and richness of mountain ecosystems.
- ▶ The teacher gets the class to explore the immediate environment during walks on the lower mountain slopes, where the permanent habitats are found, and to distinguish different environments where biodiversity exists in various forms.
- ▶ The teacher introduces the concept of **biodiversity**¹: a general term denoting the variability of plants, animals and micro-organisms existing on Earth, their variability within a single species and also the variability of the **ecosystems** to which they belong. Broadly speaking, biodiversity covers genetic diversity, the diversity of species and the diversity of **habitats** and ecosystems.

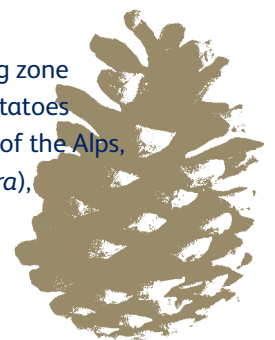
2. Learn to identify different environments

- ▶ The teacher lays emphasis on discovery in two or three distinct landscape areas, characterized by a specific type of **plant cover**.
- ▶ In most regions, the option can be a comparison between a closed environment (forest, wood or understorey) and an open one (grassland, meadow, crops or terracing).

Examples:

In the Bolivian Andes, the topic could be a rain forest zone or a high-altitude farming zone where quinoa, for instance, is grown; in Central Himalaya, a zone where wheat or potatoes are grown in terraces and an oak grove of *Quercus lamellosa*; in a temperate region of the Alps, a bocage zone and a deciduous forest of, for example, sessile oak (*Quercus sessiliflora*), beech, chestnut, ash and hornbeam.

¹ Terms highlighted in pink are defined in the glossary on p.164





1

1. Mountainous landscape,
Taganana massif, *Tenerife*,
Canary Islands
© Michel Le Berre

2. Mosaic of forests and meadows,
Mont Laitmaire region, Switzerland
© UNESCO/Olivier Brestin

2

► The class learns to detect changes in plant cover in their part of the world by moving between the two selected zones on the lower slopes of the mountain. The pupils note in particular the richness of species and the marked stratification of forest environments, consisting of an arborescent stratum (in fact, two), a shrubby stratum and an herbaceous stratum.

Example:

In the temperate deciduous forests of Western Europe, the oak may occupy the highest stratum of the forest, at the collinear stage, closely followed at a lower altitude by beech or pine, in turn followed by bushes such as bramble, by smaller shrubs such as heather or bilberry with their angular stalks and by a stratum of ground vegetation, consisting of herbaceous plants as tall as perennial fern or shorter ones like spring ephemerals such as bear's garlic or arum lily.

► In the same way, pupils can take pleasure in identifying the stratification of vegetation typical of a more open environment, if the topic is a meadow or pasture, by distinguishing between an aerial stratum of tall grasses or stubble and a ground stratum consisting of herbaceous plants, or even of a subterranean layer.

► Assisted by the teacher, they relate the vegetation stages in the environments they have visited to the wildlife likely to be living there and try to detect traces of its presence or its passage.

3



3. Young false helleborine plant (*Veratrum album*),
Château d'Oex region, Switzerland
©UNESCO/Olivier Brestin

4. Cluster of fungi,
Pelling region, Sikkim, India
©UNESCO/Olivier Brestin



4



5

5. Fir branch, *Etivaz*,
Château d'Oex region, Switzerland
©UNESCO/Olivier Brestin

6. Globe-flowers (*Trollius europaeus*),
Château d'Oex region, Switzerland
©UNESCO/Olivier Brestin



6

Examples:

The ground stratum of herbaceous plants in meadows is home to hosts of locusts, grasshoppers and beetles, and also to voles.

In forests, the dust mite lives off the carpet of moss, the warbler off bushes, the squirrel off the trunks of trees and a bird like the crossbill off the buds in the treetops.

3. Distinguish microenvironments among the environments visited

► The teacher takes the discovery exercise a step further to include identification of types of "microenvironments" among the different environments explored.

Owing to their distinct features these locations seem to stand out from the rest of the environment, like a clearing in the forest, where the brightness comes as a sudden surprise, or the immediate surroundings of a spring or torrent, where the humidity encourages the growth of certain plants, a profusion of greens from delicate to deep. The zone in question can be an area of scree, ranging from fine to coarse, colonized by a number of pioneer plants forming a multicoloured flowerbed.

► This specific exercise in discovery makes pupils more aware of the existence of certain resources (like water and soil composition) and certain conditions (like exposure to the sun) that give rise to these microenvironments; just as other resources and conditions are conducive to the emergence of the environments studied earlier. These microenvironments fit into a mosaic of environments at higher levels, all of which combine to form the landscape of the low mountain stages.

7

8



9

10

4. Collect natural objects from the various environments explored in the surrounding area

► Split into groups, the class explores the various environments (or microenvironments) visited in turn, collecting as many different natural objects as possible and placing them in different bags, one for each zone. Those objects may include fragments from rocky strata, unusual stones, soil and mud samples, small containers of sand samples, bush and shrub branches and, depending on the season, leaves, stalks and tufts of grass, leaves and flowers of herbaceous plants (except the most fragile and the rarest), all kinds of fruit and seeds (acorns, beechmast, achenes, samara), cones, exposed bulbs and tubers (daffodils, wild garlic in Europe, lilies such as *Lilium medeoloides* in the Japanese Alps), root fragments, pieces of bark, fungi, lichens and mosses, fossils, dead insects (beetles, springtails, woodlice), empty cocoons, bones and teeth of mammals (weasels, fieldmice, foxes, squirrels, martins, sables, peccaries and lynxes, depending on the continent), wood, antler fragments (deer), bird feathers (oak jays in Europe, grouse in boreal forests, macaws and birds of paradise at the lower levels of tropical mountain areas), eggs that have fallen out of nests, shells (molluscs and snails), regurgitated pellets, skins shed by reptiles or other animals. What a surprise! These objects are like hidden treasure, revealed when it is in your hand.

5. Store the plants

► The class can bring in old newspapers or magazines and preserve the plants collected by inserting them between the pages in order to keep them flat and preserve their shape as they dry out.

6. Clean dirty objects

► Where necessary, the pupils clean the objects carefully, making sure not to damage them.

7. Observe

- ▶ Back in the classroom, each object is studied individually: it is interesting to learn about them by examining them from different angles, noting the smallest detail and comparing objects of the same type (two kinds of fruit, for instance).
- ▶ The teacher asks the class to identify any similarities in shape, texture and colour between objects.

8. Identify

- ▶ Only then are the objects identified: what do they belong to? Do they belong to a plant or an animal species? Do any belong to the same species? Have they come from land-based resources (from the soil, for instance)?

9. Classify

- ▶ The pupils classify their finds, pointing up certain distinctions: does it belong to the plant kingdom? Does it belong to the animal **kingdom**? Is it living matter? Is it a non-living form (the rock fragments, for instance)?

10. Put concepts together

- ▶ The teacher takes the class outside again to consider each object individually back in its natural setting. The teacher can also take the objects one by one from the pupils' collections.
- ▶ The idea is to start with the individual object (the smallest unit) and work on a progressively bigger scale towards the species, the natural environment and, at the next stage, the ecosystem.

Example:

A particular object selected by the teacher points to the species, whose natural habitat is then described. Where was it discovered? How does it fit into its habitat? Is it found in large numbers in this habitat? Is it confined to a small area? Does it travel long distances, as animals do when they migrate from one mountain vegetation belt to another, according to the seasons? What does it feed on?

- ▶ This is how the teacher introduces the concept of **biocenosis** – a community of living things (animals, plants and micro-organisms) that coexist in the same natural habitat.
- ▶ The teacher then introduces the concept of **biotope** – a defined natural area, characterized by specific conditions, that supports animal and plant species adapted to those conditions.

Examples:

At the side of a mountain stream in temperate regions, in its lower reaches, where the bed widens out, plant species such as alpine butterwort, starry saxifrage and mealy primrose – associated with laiches (*cyperaceae*) – are a common feature anywhere at the water's edge or on marshy land. Amphibians, too, namely the common frog and the fire salamander are found here, as are insectivores, such as the water shrew; birds such as the grey wagtail and the white-throated dipper fly over and frequent this zone, as do numerous insects, the mayfly – a common species of ephemeroptera – and the *trichoptera caddisfly* among them. These species all coexist in, and so share, the same biotope.

Much higher up, in a pastureland zone dominated by larches, it can equally be said that sheep, larches, grasses such as sheep's fescue or wavy hair grass, along with certain birds that are typical of the larch's avifauna, for example the ring ouzel or the song thrush, all share the same biotope.

11. Create collections

- ▶ Using this knowledge, the pupils will each create a collection based on their own finds in order to present the items collected in a visual form that illustrates the newly acquired concepts of biotope and biocenosis.

A flat box or a simple cardboard surface can be used to present each collection.

- ▶ The pupils recall the spot where each object was found. What are the key characteristics of this landscape unit in the ecosystem?



11. Redstart (*Phoenicurus*) (Turdidae),
Distribution: Europe and Asia
©UNESCO/Olivier Brestin

13. Mountain stream,
Praz Cornet, Switzerland
©UNESCO/Olivier Brestin



12. Mountain arnica
(*Arnica Montana*), Praz Cornet,
Switzerland
©UNESCO/Olivier Brestin



► They set out each group of objects belonging to a specific biotope on the cardboard base. How can the unity of a community of life forms in a single locality be best represented?

► They paint a coloured background representing the soil of the biotope or else glue onto the base mineral elements that have come from the soil in question. For instance, sand could be sprinkled onto a layer of glue, creating an effect that closely resembles the actual texture and substance.

► They then place on the base the objects representing the species present in the biotope, but in a particular order: objects are grouped to represent food chains, families of species or biological kingdoms.

The pupils themselves first suggest a way of representing the ecosystem, on the basis of what they have collected and the initial information they have been given, so as to illustrate the unity and the diversity of a habitat in the landscape.

► The teacher's role is to tweak the collection so that it reflects the reality of the environment. Depending on the diversity of the habitats found locally, the teacher might suggest moving beyond the diversity of the objects collected to take account also of their number and their relative proportions.

Thus the collection could highlight comparisons between objects of the same type (between several different leaves or feathers, for example).

► This allows the teacher to bring in quantitative elements of a scientific nature and to introduce more precise concepts such as the richness and abundance of species or, conversely, their rarity or decline, elements that mark the difference between one biotope and another.

► With regard to the decline of species, the teacher introduces the notion of the impact of harsh climatic conditions on living beings but equally the impact of human activities on the **conservation** of the environment.

► The teacher explains that the ecosystem can be perceived as a dynamic whole, biotopes and biocenoses interacting with one another.

► In this way, pupils can create as many mini-collections as there are identifiable habitats, each collection corresponding to a specific biotope. These are real "collections of places" that allow the pupil to approach ecosystems through displaying them as separate units. This is one of the ways in which ecologists themselves study ecosystems.

02

Plant cover or the mountain as a mosaic

Level 
easy

Place 
outdoors

Duration 
2 sessions

Objectives

1. Discovery of the environment

By representing the mosaic of mountain plants as a vast carpet of vegetation covering the ground – composed of natural objects picked from the mountain slopes at different altitudes – pupils become aware of the diversity of the habitats that surround them.

2. Knowledge and comprehension

Through close observation of this composition, the teacher helps the pupils to understand the conditions that govern the existence of living organisms in mountain areas as well as the relationships or factors that bind them to one another as species and to their environment.

Methodology

1. Choose the site for assembling the plant mosaic

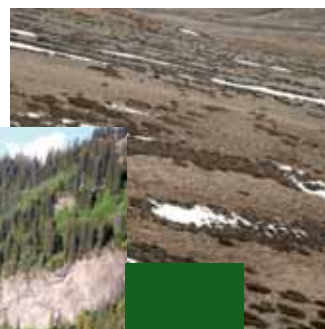
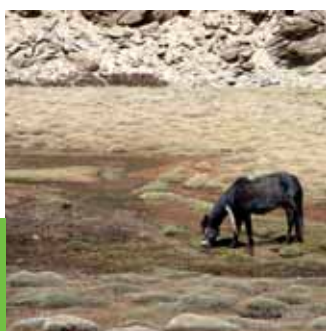
► The teacher chooses an outdoor area near the school, a patch of bare ground – preferably large and clear – that can be raked and tidied up. It is then levelled to serve as the background for the carpet of plants that will represent the mosaic of mountain vegetation. The colour of the site is also important: it should allow these objects from a different location to stand out against their background.

2. Prepare the collection stage

► Using the same format as the previous workshop, *Collecting treasures*, the pupils set about collecting natural objects at several different altitudes on the massif in a way that helps them to understand and to bring out the layering principle of mountain vegetation.

Prior to the collecting stage, the teacher explains the facts below:

- The structure of the vegetation as a series of zones or stages from the base of the mountain mass to its summit is a very important biological feature of mountains.
- The distribution of living organisms (plant and animal species and micro-organisms) on the slopes is controlled by temperature.





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14. Fescue (*Festuca orthophylla*) (Poaceae), *Socaire* plateau, *Atacama Desert*, Chile
©UNESCO/Olivier Brestin

16. Conifers and evergreens on grassland, *Mont Laitmaire* region, Switzerland
©UNESCO/Olivier Brestin



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- Boundaries between vegetation stages can be blurred, for in each of the world's massifs, plants are subject to the massif climate and even to its microclimates rather than being organized exclusively by altitude.

- Even so, the higher the altitude, the colder the temperature because:

- atmospheric pressure decreases with altitude since the atmosphere contains less water vapour, carbon dioxide and dust particles;

- as a result, the atmosphere no longer provides the same thermal mass as a screen between the sun's rays and the earth;

- very intense solar radiation during the day heats up the soil and natural elements to a considerable degree, while at night, as nothing prevents the loss of this heat, the ground cools down significantly: heat loss is intense and the temperature plummets;

- in short, the higher up the mountainside an organism lives, the more resistant it must be to the cold.

- ▶ In order to carry out the multi-altitudinal collection stage, the teacher plans the logistics of the activity.

The teacher divides the class into groups, according to the number of stages of vegetation to be visited and studied.

- ▶ With some human help (a driver, a mountain guide), the teacher organizes transport to take the groups to several high access points, either by road (if it is passable) or on foot, arranging overnight stops if necessary.

Note:

Depending on the height of the massifs and the steepness of the slopes, reaching the alpine stage will be more or less ruled out, since it is sometimes situated at a very high altitude (in Central Himalaya, it is at about 3,900 metres). Whenever it is possible to reach the tree line and the **alpine grasslands** (part of the journey can be made by transport), pupils are encouraged to do so, since these zones in the ecosystem are very interesting, often rich in microenvironments and in undulations: in the Himalayas, alpine grasslands are a zone where yaks, goats and sheep are raised, while in the Bolivian Puna, the livestock consists of ovines and bovines.

17. Mosaic of forests and grassland,
Mont Chevreuil, Château d'Oex
region, Switzerland
©UNESCO/Olivier Brestin

18. Thaw, Paray Dorénaz,
Switzerland
©UNESCO/Olivier Brestin



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The same applies to tropical regions, where certain zones containing thickets of giant bamboo and some mountain forest zones are impenetrable.

In any case, the main thing will be to highlight two or three concentric belts of vegetation that are a recurrent feature of many massifs. From the bottom upwards:

- a zone of hills and low slopes conducive to human settlement and terrace farming which have altered its character;
- a thick forest belt;
- alpine grassland or a lush herbaceous carpet of grasses located above the tree-line.

► The pupils must remember to take old newspapers with them to store the plants that they have collected between the pages (see previous activity).

3. Collect natural objects on different stages of the mountain

► Pupils make several collections of natural objects at different altitudes on the massif, all at the same time (for this to happen, some pupils will have to make an early start...).

► Within each vegetation stage, pupils scour several different units with distinct types of vegetation and fauna.

These might be:

- at the collinean stage in the Alps, an oak grove mixed with a wood of Scotch pine and a zone of vine cultivation;
- at the **subalpine** stage in the Tien-Chan Range in Asia, a tree-line zone, composed of stunted trees like spruce with creeping branches, and willow and dwarf birch;
- at the **alpine stage**, a high alpine valley, strewn with boulders, the site of striking contrasts between microenvironments such as:
 - a ridge on the south-facing slope (**adret**), warmed by the sun, alive with buzzing insects and blossoming purple gentian;



19. Arid hills (1,600 m),
Samarkand region, Uzbekistan
© Michel Le Berre

– on the other side of the massif, on the **ubac** or northern slope, a deep depression or snow **combe**, cold and in shadow, and sheltering herbaceous willow.

► For each zone, the pupils sort their finds into different bags (not forgetting to include a sizeable number of stones and pebbles of every size and hue, those found in the rocky conditions of the alpine stage, for example).

4. Construct the mosaic of mountain environments on the chosen site

► On returning to their chosen site, the pupils create their carpet of plants for the various horizontally-occurring habitats of the mountain ecosystem:

► They collect stones and use them to make an outline of the mountain on the ground, then divide the shape into stages (horizontal strips), again using pebbles to mark the boundaries.

► Within each horizontal strip, they create subdivisions (kinds of boxes or squares) according to the number of units representing each stage of the ecosystem.

Example:

If a group of pupils has identified three different biotopes at the collinean stage (see types of plant mentioned earlier), then the group will mark off three boxes or squares for this stage, on the basis of items collected from each biotope.

► The class choose their day carefully: it should be bright, with no humidity and no wind so that the objects will not be blown away.

► The pupils set about constructing their mosaic, paying particular attention when arranging objects in the appropriate square on the ground; these should be of a convenient size.

Example:

In temperate regions, the horizontal strip corresponding to the subalpine stage could be divided into three boxes, as in the following example.

A few good specimens of larch branches interspersed with some branches of arolla or Swiss pine (*Pinus cembra*), together with their fruits and cones (consisting of woody scales), seeds and kernels. The twigs of dwarf shrubs such

as bilberry (*Vaccinium myrtillus*) or cowberry (*Vaccinium vitis-idaea*) and specimens of companion forest plants like wood cranesbill (*Geranium silvaticum*) or alpine coltsfoot (*Homogyna alpina*) can also be added to the conifers. With a little luck, the pupils will be able to add to their display a few feathers of birds such as the chaffinch, tree pipit, bullfinch and, above all, the spotted nutcracker with its chocolate-brown plumage dotted with small white patches. The same box could also contain eggshells, the teeth of small mammals such as the garden dormouse, bones as evidence of feasting by birds of prey, bits of wool and fur.

► At the same stage, another example:

Still at the subalpine stage in temperate regions, yet another box might represent a humid depression (a cold gorge or an avalanche corridor) and contain leaves from the green alder, flowers of the roundleaved saxifrage and, if possible, a few specimens of large perennials (megaphorbaies) found especially on scree soils that are humid and rich in humus and minerals. The pupils take certain precautions (washing their hands) after choosing samples of and handling any type of poisonous species, such as monkshood (*Aconitum*).

5. Study the finished mosaic in detail

Group study of the mosaic is important.

► Each pupil assesses the visual interest of the composition as a whole.

Representing the mosaic of mountain vegetation by horizontal strips consisting of boxes displaying different themes means that each unit is revealed and observed singly, so that attention is drawn to details and hence to the objects that make up the units, to the similarities and differences between one object and another (a natural tendency of perception being to move from the whole to the parts). Three boxes for each stage, for example, are sufficient to convey a sense of the diversity of species and habitats and of the variability between habitats.

► Pupils are able to observe that, wherever they live in the world, diversity is a special feature of mountain ecosystems (with the exception of the snow zone, which cannot be reached and which is a largely mineral area, populated in places by lichens and spiders).

► They assess the **localization** of mountain species at predetermined altitudes and of the astonishing **diversity** of species due to the large number of habitats. The mosaic allows this fragmentation of mountain habitats to be highlighted.

6. Put concepts together

► The teacher examines the composition of each box and interprets the biotope it represents. The teacher gets the pupils to recall the sites they have visited.

The teacher explains the relationship between the species represented in the composition and the habitats to which they belong:

- living organisms are affected by their habitat in that their very existence is dependent on **resources** (water, soil quality and nutrients) and determined by **conditions** (temperature, rainfall and snow).

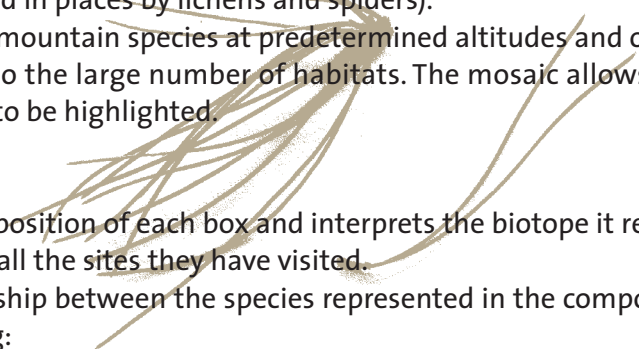
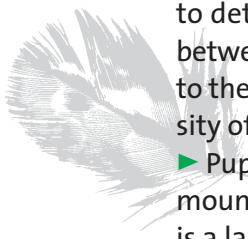
- other factors specific to the spatial character and relief of individual mountains act on the species living in them, such as the height of the mountain mass, the gradient of its slopes and their exposure to the sun (the amount of sunshine that they receive).

► The teacher continues:

- Living organisms are also affected by the other species around them, first and foremost through **food chains**. Species are directly related to one another by what they eat.

- In the mountains more than anywhere else, each species makes an impact on the environment within what is known as an **ecological niche**, inhabiting the space that it has acquired by virtue of its diet and its competitors. It is the best adapted species that occupies the natural space or biotope, which supplies it with food in accordance with the seasonal changes inherent in the mountain ecosystem.

With each season, plant-life offers different dietary resources to herbivores, as herbivores do to carnivores.





20. Erosion at montane level, Paray Dorénaz, Switzerland © UNESCO/Olivier Brestin



21. Himalayan vulture (Gyps himalayensis), Ladakh, India © UNESCO/Olivier Brestin

22. Valley floor and mountains, Aïr, Niger © Michel Le Berre

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23. Dried apricot seller, Leh, Ladakh, India © UNESCO/Olivier Brestin

24. Domesticated yak, Nubra Valley, Ladakh, India © UNESCO/Olivier Brestin

25. Hairy alpenrose (Rhododendron hirsutum), Simplon Pass, Switzerland © UNESCO/Olivier Brestin



26. Crantz (Laserpitium halleri), Mont Laitmaire region, Switzerland © UNESCO/Olivier Brestin

27. Fruit of Prinsepia utilis, Lachung, Sikkim, India © UNESCO/Olivier Brestin

28. Picea Spinulosa branch, Lachung, Sikkim, India © UNESCO/Olivier Brestin



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Example:

The chamois, which fears the sun, appreciating combs and the shaded environments of the ubac (northern slope) feeds on clover and leguminous plants in summer and falls back on pine needles, bark and mosses in winter.

A carnivore such as the eagle, which lives above the tree-line has a natural taste for marmots. When these hibernate in their burrows deep below the ground, the eagle preys, during the winter months, on partridge (ptarmigan), mountain hare, with its pure-white winter coat, or grouse.

- The remains of dead animals are eaten by detritivores (necrophages, earthworms and ants). Matter that is not eaten by detritivores is broken down by micro-organisms known as **decomposers**.

Relationships between species can also be less direct and less easily identified.

- Between species with similar needs, **competition** is the norm: it is the species best “equipped” for the struggle for existence that occupies the natural space or the one that best tolerates the constraints the space imposes.

Example:

The plant that is best adapted physiologically to find water will dominate in dry places; in dry, chalky areas, well-adapted pioneer species grow and exclude species that are less well adapted.

- Competition does not prevent certain species with additional needs from becoming established. Thus, a plant species will grow next to another species in a similar environment under the strict principle of specialized plant **association** (involving only a small number of species), varying considerably from place to place.

Example:

The bearded bellflower will happily grow next to the alpenrose or the edelweiss together with the alpine aster.

- To complete their biological cycle, many species require interaction with other species.

Example:

Gentians in bloom on a mountain ridge are pollinated by bees.

7. Bring these concepts to life by making up a story

► After the teacher explains how species relate to one another and to their habitat, the pupils focus on the mosaic and make up a story that brings together and connects the various items in the composition.

► The aim is to bring to the fore the relationships discussed by the teacher (the connection between species and resources, the food chain, competition, association and interaction) by getting the pupils to make up a story in their own words, producing a spontaneous narrative that flows smoothly and seamlessly from object to object. They move freely and quickly from element to element, then from biotope to biotope, suggesting the idea of a linkage or interactivity between the different biotopes in the functioning of the ecosystem as a single entity.

► In composing their story, the pupils can introduce an imaginary dimension (Once upon a time...), providing that their interpretation of the biotope, the ecosystem and its functioning is consistent with what they have just learned.

► The teacher then points out any inconsistencies.

An example of trophic network in a temperate mountain region

Tertiary consumers



Golden eagle
Aquila chrysaetos



Brown bear
Ursus arctos

Transformers



Collembolan



Bacterium

Detritivores

Necrophages



Griffon vulture
Gyps fulvus

Scatophages



Dor beetle
Geotrupes stercorarius

Secondary consumers



Stoat
Mustela erminea

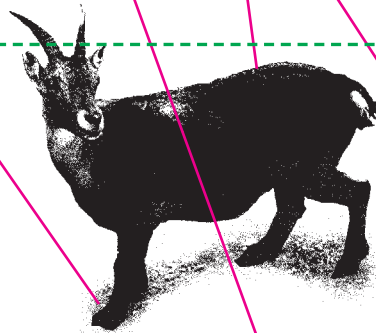


Ground beetle
Chrysoscarabus solieri

Primary consumers



Snow vole
Chionomys nivalis

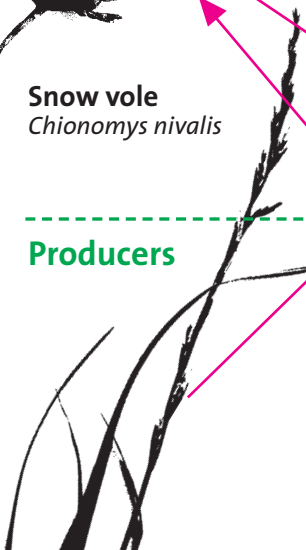


Ibex
Capra ibex



Alpine bumblebee
Bombus alpinus

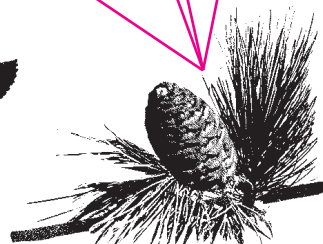
Producers



Coloured fescue
Festuca varia



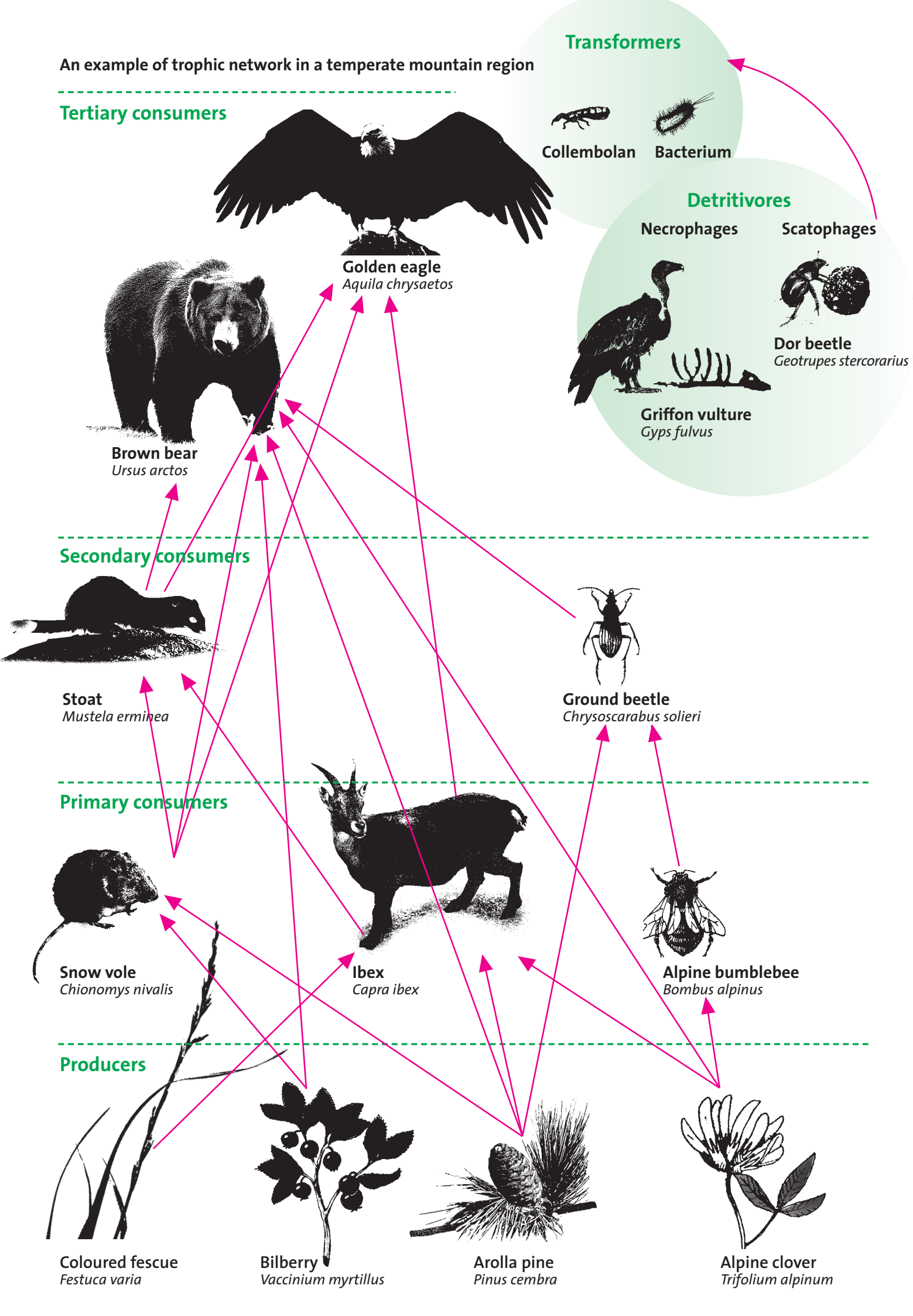
Bilberry
Vaccinium myrtillus



Arolla pine
Pinus cembra



Alpine clover
Trifolium alpinum



03 Land, rock and erosion

Level 
intermediate

Place 
outdoors

Duration 
2 sessions

Objectives

1. Discovery of the environment

Through learning about relief formations and the composition of the geological landscape with their teacher, the pupils make a connection between the nature of rocks and soil quality, and between rocks and sediments.

2. Knowledge and comprehension

After several brief reviews of the mineral landscape (tracing shapes, making sculptures), the pupils depict the phenomenon of erosion in mountain areas in a series of drawings, and begin to understand the importance of soil nutrients in the ecosystem.

Methodology

1. Identify minerals

A mountain is, by definition, a relief formation composed of rock masses produced by uplift of the earth's crust. It is therefore essentially mineral.

► The pupils with their teacher choose to focus on different high-altitude sites, where mineral elements predominate.

At several different levels on the slope, they observe:

- at low altitude, an **alluvial cone** formed by scree, where a torrent deposits its load of mud and pebbles;
- at high altitude, at the alpine stage, a field of stones or a pavement of slabs formed by rocks breaking up or flaking as a result of frost and eventually being carried down by mud;
- high up or in the distance, the jagged alpine crests revealing their sharp ridges.

2. Observe the geological dimension of the mountain relief

► The teacher then describes the geological formation of the mountain, beginning with the type of rock that can be found on the various sites to be explored.

This can be:

- **Sedimentary rock**, formed when layers of material transported by the water and wind are compacted, such as schists and sandstones, formed from the debris of ancient rocks that have been eroded;
- limestone, another sedimentary rock, which has formed in an underwater environment and is composed of plant and animal remains;
- **Igneous rocks**, formed from an eruption of magma or molten rock, which, by intrusion and cooling, gives rise to a coarse-grained rock such as granite;
- Or even **lava** which, on erupting above the earth's surface, cools rapidly into basalt, another igneous rock.

► The teacher takes advantage of the time spent studying rocks to link the study to the process that gave rise to the relief of the mountain being visited by the class.



29. Zaskar mountain range, view from Phyang Monastery, Ladakh, India
© UNESCO/Olivier Brestin

- Is this a volcano, which has the shape of a regular cone and stands alone?

Example:

Volcanoes such as Kilimanjaro in Tanzania or Etna in Sicily are mountains that stand alone.

- Or is the mountain, on the contrary, part of a group of summits of roughly similar origin and forming a chain linked to other chains in a long and complex system, such as the Rocky Mountains or the Himalayas?
- Is the formation of the relief due to thermal factors in the earth's crust, as is the case with volcanoes, which appear on the earth's crust following an upsurge of magma and/or an eruption of lava?
- Is it due to some other cause, namely **tectonic** movements created by the drift of continental plates on the surface of the globe?

Example:

A collision between the African and Eurasian plates created the Alps some 50 million years ago.

- Under the extreme pressure, buckling occurs when the plates crash into each other, the one passing over the other, and at this point the faults break.

The pupils can thus identify in the landscape signs of fold or fault-block mountains by observing the parallel folds in the relief, as in the photograph on page 29, or else huge fractures or faults which give rise to block formations, such as those in the Rocky Mountains.

- Does the mountain form part of a volcanic massif produced by the accumulation, rather than the irruption, of lava at the earth's surface, causing it to swell and eventually to become a dome mountain, formed of solidified lava, such as the Drakensberg in South Africa?
 - Is the relief a combination of these different phenomena of folding and faulting, and of magma intrusion as in the Andes? The "Cordillera" of the Andes, from the Spanish word "corde", is the longest system of landforms on earth, and although they are the result of tectonic movements, they are also crowned with high volcanoes along their entire length.
- After identifying in the landscape telltale signs of a specific geological formation, the pupils make soundings in the soil at the various points that they have observed on the slope.



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30. Arid mountains,
Atacama Desert, Chili
©UNESCO / Olivier Brestin

31. White marble, *Aïr, Niger*
© Michel Le Berre

32. Thermal erosion on rocks,
Aïr, Niger
© Michel Le Berre

33. Fairy Chimneys,
Cappadocia, Turkey
© Michel Le Berre

34. Granite (detail),
Aïr, Niger
© Michel Le Berre

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35. Fold mountains, *Hemis region, Ladakh, India*

©UNESCO/Olivier Brestin

36. Traditional building bricks, *Phyang, Ladakh, India*

©UNESCO/Olivier Brestin

37. Workers laying the foundations of a house, *Phyang, Ladakh, India*

©UNESCO/Olivier Brestin

38. Cave dwellings, *Cappadocia, Turkey*

© Michel Le Berre

39. Oasis and irrigated crops, *Middle Draa Valley, Morocco*

© Michel Le Berre

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- ▶ They discover that it is composed of **sediments** produced by the breakdown of the rock that forms the relief: stones, pebbles, sand, silt and clay.
- ▶ They compare the high altitudes characterized by landslides, bare ground, which has practically no soil except what is produced by the weathering of rocks caused by water, wind and alternate freezing and thawing, with the depressions lower down the mountain, where the soil layer thickens.
- ▶ They distinguish clearly between, on the one hand:
 - low-altitude soils, often moist and rich in **humus** (produced by the decomposition of organic plant and animal matter), while the bedrock is concurrently attacked by earth worms, abundant roots, micro-organisms and plants, all still alive, thus causing **biochemical erosion**; and, on the other hand,
 - at high altitude, raw mineral soils formed by rock erosion, no more than a thin coating on expanses of blocks or sparse plant life in the crevices of rocks (where lithophytes cling to the rocks).

3. Make the connection between soil and relief and place oneself in the landscape

- ▶ Next, at different levels on the slope, the pupils identify a point from which they can observe the relief in the distance.
- ▶ They establish an optical, visual and physical relation between the ground beneath their feet and the distant relief by engaging briefly, but in a variety of ways, with the landscape.
- ▶ They handle the minerals by creating sculptures from collections of stones or sediments (tumuli, cairns and circles); they also make patterns with their footprints.
- ▶ The teacher gets them to devise a scale (human scale, natural scale) linking their activities and the landscape:
 - a stone set on its edge or an artificial tumulus just a few dozen centimetres high can reproduce the shape of the distant relief. These creations, placed in the foreground in relation to the observer, with the relief as the backdrop, seem to take on the dimensions of the background relief itself, as well as its appearance and texture. The association is striking;
 - a straight line traced with the shoe on flat ground and aligned with a relief can, through the effect of perspective, create a link between the observer standing on the ground and the relief in the distance, between the human scale and the scale of the landscape, and between the ground and the vertical shape of the relief.

These sculptures or artificial patterns introduced into the landscape are also a sign of human activity in vast natural expanses – enabling pupils to capture two kinds of action and creation – the human and the natural – and become part of the landscape.

4. Identify signs of water erosion on the slope

- ▶ When they studied the soil at different levels on the slope, the pupils were able to observe the prominent role of water – in all its guises, including snow and ice – in soil formation. Whether it causes **avalanches**, weathers rocks, opens up **curms**, causes landslides or concentrations of runoff, leaches the soil, cuts furrows or deep rills in the mountainside or creates alluvial cones, the action of water is constantly changing the mountain slopes.
- ▶ At this point, the teacher reminds the pupils about the meaning of **erosion**: it occurs when various agents such as water, wind, ice, heat or roots, wear away and transform the earth's surface.
- ▶ At different levels on the slope, the teacher draws pupils' attention to the action of water in the form of frost and ice, snow on the ground, rain, surface **runoff** and erosion by torrents.

Example:

The effect of frost can be seen where:

- granite rock is crumbling (ice expands the water-filled crevices, causing the rock to flake);
- friable rock has been softened, causing a mudflow;

40. Catchment basin,
Château d'Oex region, Switzerland
©UNESCO/Olivier Brestin



- porous rock, vulnerable to frost, has been hollowed out into a shelter beneath a layer of more resistant rock. The effect of ice can also be seen from the impact of a glacier on the whole of the landscape, its underside often carving out a flat-bottomed, 'U'-shaped valley, the work of large boulders that it has dragged along.

5. Draw

- The pupils can enjoy identifying the most significant signs of the sculpting effect of water on the landscape.

There are often plenty of examples and, depending on where they happen to be and the particular circumstances, they can take out their sketchbooks to:

- draw the jagged summit crests, shaped by the action of frost and ice;
- capture the detail of a rock chiselled into myriad microsurfaces or microridges by the same process of **conglifraction**;
- catch the way in which frost attacks crumbly rocks such as limestone, creating isolated, cleanly delineated patches of **scree**;
- sketch the unusual profile of the relief, where stripping has produced spires and needles like Mount Cervin in Switzerland – encircled, as the result of erosion, by numerous curms – and “**fairy chimneys**”, produced by mechanical erosion, the effect of rain on friable rocks, creating slender columns topped by a stone that protects them as would an umbrella;
- draw the furrows cut by runoff – the gullies in argillaceous rocks that usually converge in the **header pool** of a stream – or the **karren** – real channels (sometimes ten metres deep), made ever deeper by water on limestone plateaux. To portray these chiselled terrains, the pupils choose contrasting tones (light/dark; bumps/holes; sun-lit slopes/shaded slopes).

6. Interpret the drawings and understand the effect of water erosion on the environment

- The teacher facilitates the interpretation of the drawings and explains how water erosion is a cause of degradation in soil, which is sometimes barren because it is constantly exposed to frost and sometimes decalcified because it is leached by percolation, which takes the mineral elements to deeper levels. The rock is scoured and stripped bare; living organisms are few and far between.



41. Nomadic shepherds,
Lake Thachung, Ladakh, India
©UNESCO/Olivier Brestin



42. Abandoned camp,
Lake Thachung, Ladakh, India
©UNESCO/Olivier Brestin



43. Nomadic shepherds' camp,
Lake Thachung, Ladakh, India
©UNESCO/Olivier Brestin

► The teacher explains the causal relationship between the lack of vegetation and the intensity of water erosion: wherever the earth is unprotected by vegetation, the soil is easily washed away by water; the barer the soil becomes, the more exposed it is to the harsh mountain climate, either subjected to severe frost or baked by intense sunlight and so subjected to desiccation.

► Lastly, the teacher returns to the contribution of human beings to the instability of mountain soils. When human activities take insufficient account of the natural context, they can prove harmful to the ecosystem and to the safety of people themselves:

Roads or mountain resorts may be built on young, clayey, silty slopes that are quite unstable; When these developments are accompanied by ill-considered land reclamation, extensive deforestation or overgrazing activities, the damage done to the protective cover of plants becomes a locus of active erosion.

The impact on the ecosystem can be very great; partial destruction of the plant cover is transformed into widespread gully erosion, with a serious risk of mudslides or avalanches, which are equally destructive to the local human population.

7. Identify an area of land that is protected from erosion

► The pupils identify an area that is less bare and less vulnerable to water erosion than the areas just combed, at the mountain vegetation stage, for instance, on which conifers stand.

- How is the area protected from runoff?

By vegetation, which allows the water to seep into the soil and fertilize it by percolating to a deep level.

- Why is the area fertile? Humus, made up of needles, decomposes slowly and helps to build up the thickness of the soil: the moistness of the top layers of soil also causes fine elements and nutrient-rich minerals to migrate deeper, so that the soil becomes thicker through a process of accumulation.


► The pupils study the soil by digging up a sample. They examine and analyse its constituents: in addition to containing particles of friable rock (sand and clay), a productive soil is composed of humus, **nutrients**, water, air, identifiable living elements or organisms such as roots, earthworms, detritivores and other organisms invisible to the naked eye such as the filaments of fungi, bacteria and other micro-organisms.



► They can then take soil samples on the different sites visited in the course of the exercise. These samples are kept in transparent containers so that the composition, texture and colour of the soils in question can be seen.

► The pupils complete the sampling operation by wetting the samples and rubbing them on either paper or cloth to fully bring out the relatively rich textures of the various soils.

04

On the tracks of wild animals

Level 
intermediate

Place  
classroom
outdoors

Duration 
3 sessions

Objectives

1. Discovery of the environment

Get close to animal species in their natural habitat by listening to sounds, following tracks and identifying other perceptible clues.

2. Knowledge and comprehension

After reviewing the characteristics of animal species in mountain areas, learn to use story-telling to highlight the relationship between an animal and its biotope and to gain a better understanding of how the same environment can mean different things to different species that use it.

Methodology

1. Make a first sighting

► The pupils go out into the surrounding countryside looking for wild animals.

Guided by their teacher and accompanied by a tracker (see below), they try a discreet approach and discover the technique of hiding out (which requires prolonged self-control, without making any noise or sudden movements) in order to catch species in their natural setting and to get as close as possible to observing their natural behaviour.

The class chooses the time of the thaw and early spring for carrying out this activity, since after the long, hard months of a severe winter, animals venture out readily into the open and so are more likely to be seen, if only from a distance and through a telescope or pair of binoculars.

Remarks:

The thaw at high altitude is also an interesting time, since, in these open environments above the tree-line, the lingering snow patches make it ideal terrain for tracks, all of them signs of hidden activity, which pupils learn to interpret.

Owing to scattered patches of snow, contrasts in microenvironments can be identified between the alpine stage, with its juxtaposition of ridges where the snow never settles, and the snow **combes** or **neves**, which are still in the grip of winter. These microenvironments offer a wide variety of living conditions within a relatively small area, constitute an equally varied range of habitats for animals and are fascinating for the pupils to explore.





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44. Herd of chamois,
Rocky Mountains, USA
© Steve Estvanik

45. Pair of ibex,
Vanoise National Park, Alps, France
© Racahout

46. Ibex in mountain pastures,
Chamonix region, France
© Floconagile



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► Pupils go in search of wild animals at different times of the day: early morning or later in the day when the spring sunshine is warming up the mountainside.

With the help of their teacher, they choose different weather conditions, such as a fine day punctuated with April showers in temperate regions or a cool but pleasant day typical of the short transitional seasons of cold, arid regions (Himalaya and Patagonia).

► They instinctively relate what they see to what they hear, and equipped, if possible, with a tape-recorder and microphone, they record the general sounds of the habitat and the noises made by the animals.

If recordings are not possible, the pupils simply listen.

Example:

They can thus listen to:

- the droning of pollen-carriers such as the alpine bumblebee, decked out in its ruffled coat;
- the agitated calls in the courtship displays of a number of birds, such as the ptarmigan or black grouse, distinguishing between their loud, raucous warning cries;
- the bleating of young ibex later in the season, whether in the Alps or the Pamirs, distinguishable by their noisy cavorting, their head-butting, in playful or in earnest, and the noisy herd movements;
- the warning cries of marmots in Asia, Europe and North America.

► After several recording sessions, once they are more familiar with recording techniques, the pupils can use more sophisticated equipment, if their school has any, to analyse the pitch of different sounds and to make micro-recordings at ground level, in trees and ideally in such places as the tree-line area, where the fauna of both the forest belt and of the alpine stage may be found.

It is a thrilling experience, if, after much concentration, one can spot a rodent scurrying past and capture the sound on tape, or a bird beating its wings or the echoing cries of birds of prey and corvids (eagle, chough and raven) that may be fighting over prey or territory.

► As they analyse their listening sessions afterwards, the pupils identify species from their calls and try to match these calls with situations.

► They observe, listen to and interpret minor events, telling moments in the behaviour of a species, such as an eagle hunting its prey or a herd of caprids (chamois, Pyrenean chamois, ibex and Rocky Mountain goats) fleeing from danger.

► Thus, they identify the eagle gliding noiselessly through the air, high above its territory, the bellows-like noise as it swoops down and, on the ground, the warning shrieks of mammals such as marmots, the scurrying for shelter and the sound of larger animals taking flight.

► They distinguish between the different noises made by caprids sensing or fleeing from danger: from the nasal whistle of the ibex – a fairly placid creature if it is not frightened – to the panicky behaviour of the chamois, that stamps and hisses, a hiss that quickly becomes a loud whistle when it breathes out, and the muffled, raucous bleating signalling the distress of the whole herd as it gallops away to safety.

Is there anything about each call that gives a clue to the species' way of life and to their territorial behaviour? How can we tell? How far does a particular animal flee and how big is its territory? What does it eat? Is it a predator?

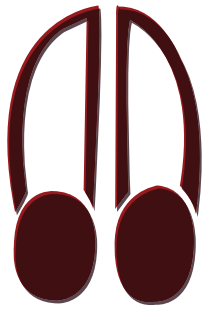
2. Identify animal tracks

► For this activity, it is strongly recommended that the teacher seek assistance from an experienced tracker who is used to identifying animal tracks in the snow or wet areas. These tracks are akin to calling cards left on the thin layer of snow, clues to activity that continues regardless of the cold at high altitude.

47. Turkey vulture (*Cathartes aura*),
Pan de Azucar National Park, Chile
©UNESCO/Olivier Brestin

48. Crested caracara (*Polyborus plancus*),
Pan de Azucar National Park, Chile
©UNESCO/Olivier Brestin





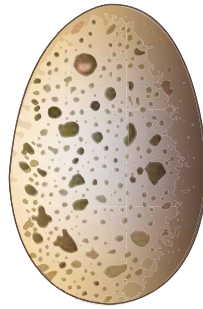
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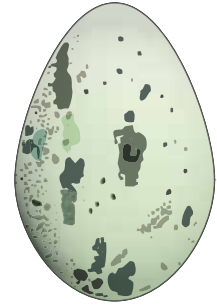
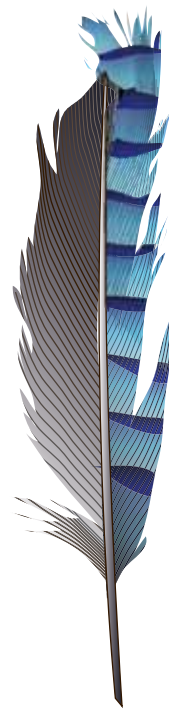
Fox



Rabbit



Black grouse



Eurasian jay

The pupils start their investigation, guided by the tracker.

► They first of all pick out fresh or frozen footprints, in the snow or near a torrent, of animals typically found at that particular altitude, sometimes **endemic species**.

Example:

With the help of the tracker, the class learns to distinguish the tracks of birds in temperate regions: those of the crossbill or nutcracker, which can withstand the extreme cold but, owing to their pine seed diet, venture down to the upper limit of the forests; the tracks of the flightless ptarmigan, which are easily recognized and detected, since it does not really leave the **moraines** or more open scree areas at high altitudes; next, and equally distinctive, the tracks of other species found at very high altitudes, among them the mountain hare with its extremely long hind legs armed with stout claws.

► The tracker teaches the pupils to identify tracks even more precisely by distinguishing, for example, between two ruminant herbivores belonging to the same family species; they could choose, say, a duiker and a guib in the African rainforest, a wild yak and a Tibetan gazelle in the Himalayas or a chamois and an ibex in the Alps.

► With the last two, for example, it is interesting to differentiate the size of the plantar cushions that make contact with the ground, the length of the foreleg hooves, whose span may or may not be constrained by interdigital webbing: the chamois uses its membrane-clad hooves like snowshoes, as its tracks are clearly visible on the snow-clad slopes and **neves**, whereas the ibex, lacking this advantage, often sinks or stumbles in the deep snow. Since it also injures itself on ice, it prefers the rocks, staying clear of **combes** and neves.

► Once they become familiar with the tracks, thanks to the expertise of the tracker, the pupils make quick sketches of them in their notebooks.

► They highlight the salient details of each footprint (the star-shaped tracks of birds, the rounded tracks of canids such as foxes, the elongated tracks of the hind-legs of hares and rabbits, and the trails of insects). They strengthen their identification skills by drawing the tracks – overall appearance, hooved or clawed – and memorize the number and pattern of each species's pads and cushions.

Example:

The badger has five pads that are close together, arranged in a perfect semicircle and ending in long claws.

► The class then goes off to find signs of animal activity from earlier in the season, which become visible as soon as the snow begins to melt.

Thus, the thick, branch-like strands of earth that are sometimes found on the ground signal the presence of a snow vole. It has been busy disposing of the earth cleared from the galleries of its burrow, moving about in the ground beneath the snow; it may also have banked up the earth to protect the entrances. All this is visible once the snow has melted. Furthermore, it is constantly tidying up, sorting out and stocking up, and in preparing its food may leave it to dry on stones, another sign of its ceaseless activity.

3. Search for other indications of species' lifestyles

► The focus next switches to the search for other signs indicating the presence of one or more species and revealing clues about their life-styles.

► The tracker and teacher together remind the pupils of the precautions that they must take and the rules that they must observe during the exercise:

– Avoid disturbing animals, destroying shelters or burrows, encroaching on their territories, destroying plants that are vital to animal diet or habitat, going too close to eggs or litters and touching young animals.

► If they look closely, pupils may find droppings, **regurgitation pellets**, feathers, possibly even evidence of fighting on the ground, bits of shell, half-eaten fruit or cones, nests, shelters, telltale smells, clues to a species' biological rhythm and signs of **migration** or movements within a territory.

► The tracker teaches the pupils what each of these objects or traces mean.

What do they reveal about the feeding habits, reproduction, territory, mobility and relation to the biotope of one or more species present in a given locality?

Example:

On the various continents, the tracker can describe the numerous species of the mustelidae family, predators of varying sizes, which also includes badgers, honey badgers, martens, sables and weasels, renowned for their emission of musky, and in some cases foul-smelling, odours (the polecat), when attacked. How long is it since the animal was in the locality being visited? Did it take over another animal's burrow? What was the species in question? Some trackers are particularly adept in this respect: do the telltale smells allow identification of the animal's sex or age?

Comment:

Sounds and noises, hoofprints, the objects and smells left behind are all evidence of a species' existence; but although they make fascinating study material – sometimes graphic, arresting and somewhat mysterious – they are facts about a species' existence that are off camera, hidden from view, that have in many cases already occurred. At this stage, it is important for the teacher to take the pupils back into the classroom, to assemble the scientific information and knowledge to be transmitted and to fit all pieces of the jigsaw together, assigning each species to its proper place within the ecosystem as a whole.

4. Sum up species information

► After some time has been spent gathering source materials from books, photographs, and possibly from the Internet (if the school has this facility), the teacher gives a description of the main species in the local ecosystem.

► For each species, the teacher makes a point of including both its general characteristics and the specific ways in which its morphology, physiology and behaviour are adapted to mountain ecosystems.



Badger
©Luxe (Fotolia)



Footprint



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49. Asiatic black bear (*Ursus thibetanus*),
Sikkim, India
© UNESCO/Olivier Brestin

50. Snow leopard (*Uncia uncia*),
Sikkim, India
© UNESCO/Olivier Brestin



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A. The general characteristics of species

► The teacher explains a number of fundamental concepts.

- What is a **species**?

There are more than one and a half million recorded species on earth, with by far the biggest number belonging to the animal kingdom.

Each species, for example the Barbary sheep (*Ammotragus lervia*), is unique. Members of a species usually mate only with other members of the same species and share a particular set of physical characteristics.

- Each species belongs to a **family**.

In scientific classifications, living organisms are ordered in groups of increasing importance that indicate how different species are related to one another. Thus, the Barbary sheep (*Ammotragus lervia*) belongs to the sub-family of caprids, which in turn belongs to the family of bovids.

- What is a **mammal**?

The family of bovids belongs to the **class** of mammals (*Mammalia*).

In spite of differing widely in shape, size and behaviour, most mammals are covered in hair and all suckle their young.

- What does a particular species eat?

Is it an herbivore, a granivore, an insectivore, an **omnivore** or a carnivore?

Example:

In mountain regions, many animals eat practically everything that is edible; thus, the marten hunts all day long and feeds as readily on mice, small hares and squirrels as on raspberries and blackberries, the badger will satisfy its hunger on earth worms and mushrooms alike and the brown bear of the Pyrenees will adapt its menu to seasonal availability, to the extent of being vegetarian in wet years and carnivorous in dry years.

Compared to other species, these omnivores are better at adapting to changes in their habitats. The hedgehog, for example which is unambiguously insectivore, is obliged to hibernate for months, when the temperature falls and its very specific food is no longer available.

- What is a **predator**?

An animal that feeds on prey.

► The teacher explains predation in the context of adaptation to the environment and the competition between species, or in other words the relentless struggle for survival.

It is a difficult way of life that often involves the idea of strategy, for prey are always on the alert and flee at the slightest hint of danger.

Many animals are predators.

Examples :

The mountains of East Africa are home to a few specimens of leopard that adapt equally to the forest and the savannah as to altitude. Hiding in the thickets, they launch surprise attacks on adversaries sometimes as formidable as the bongo antelope, which has powerful horns and does not hesitate to fight back in self-defence. In temperate regions, the ermine, which is found in mountain areas, is highly carnivorous. Extremely supple, it skilfully weaves its way through the rodents' galleries, plans its attacks and kills its victims by biting their necks, so that they bleed to death.

► The teacher moves on quite naturally to the notion of defence among animals and to the methods of self-defence that they have developed.

- Most try to flee or to cover their tracks.

Example :

In escaping from the ermine, mentioned above, the mountain hare, possessing long hind legs, can reach speeds of sixty kilometres an hour and, downhill, can make leaps of several metres.

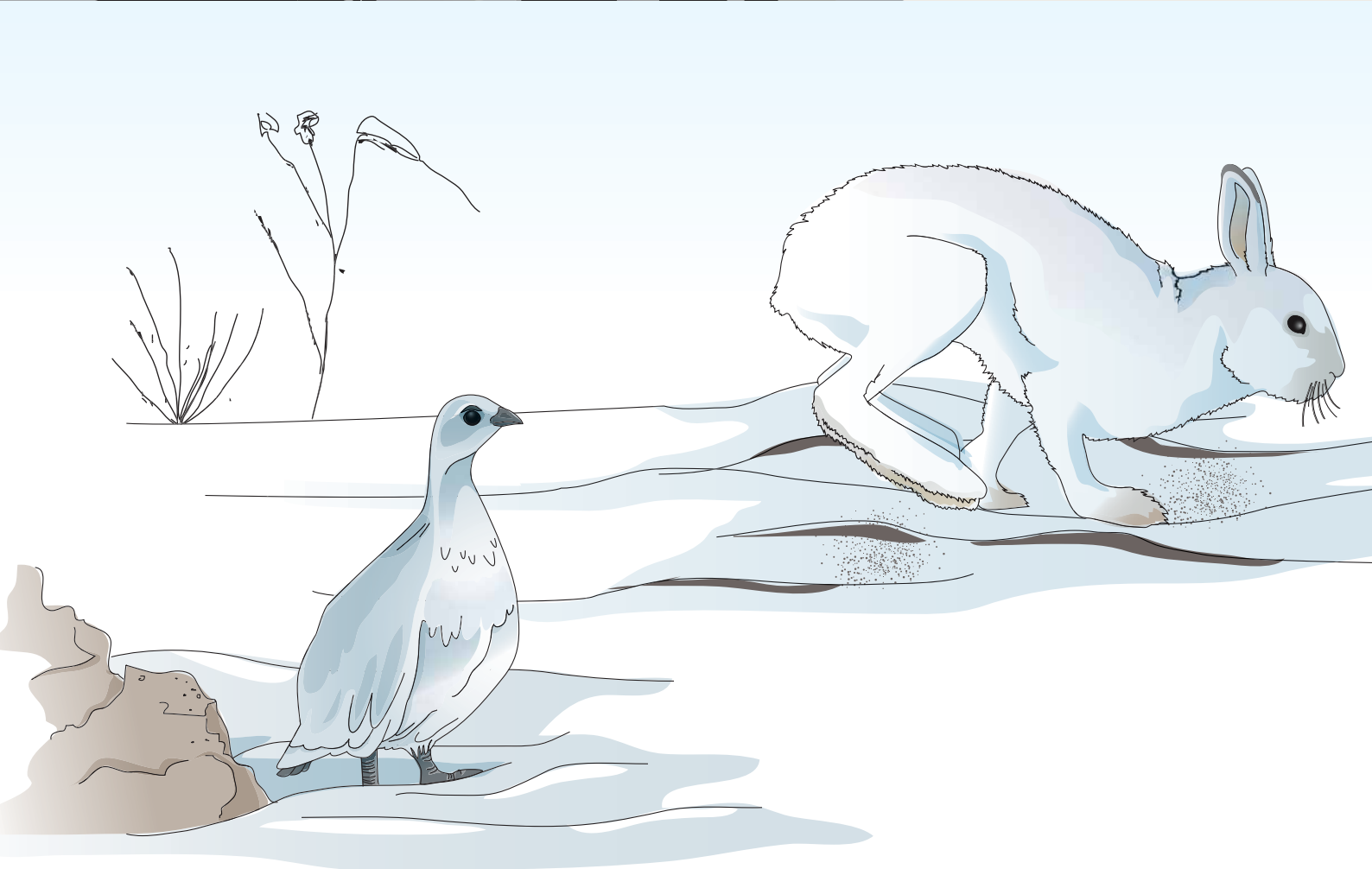
In the winter snow, when it is searching for food over long distances, it always remembers to cover up its tracks, making a thousand detours and leaving false trails, for it knows it is prey to numerous predators.

- Other species (or the same ones) adopt mimicry strategies (**mimesis**) to hide from their enemies by blending in with their surroundings.

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Coat and plumage of the mountain hare and rock ptarmigan, which change seasonally



Examples:

Like the rock ptarmigan with its changing plumage, the mountain hare moults several times a year, so that it can merge more effectively with the landscape. In spring, its coat is dark brown; it then grows a transitional coat until late November, when it acquires its pure white coat, which serves as **camouflage** in the snow. Similarly, the autumn plumage of the ptarmigan is grey, which enables it to blend in with the stones and grass, before becoming completely white when the snow falls.

► The teacher also gets the pupils to think more generally about the relationships between animals and between species.

• Some animals are said to be “social animals”. They live together in groups, herds or clans. This makes it easier for them to find food, rear their young and spot predators by helping one another and sharing tasks.

Example:

The life of a herd of chamois follows a particular pattern: after the birth of the young, the herd is composed of females, kids, and chamois born the previous year. When they are guarding their young, which are learning how to play, the mothers stay close together, presenting a united front, as it were, to ward off danger.

• Animals form a number of “functional” relationships with other animal and with plant species.

► At this point, the teacher broaches these partnerships between species in terms of **mutualism**, **commensalism** and **parasitism**.

• Mutual assistance between two species or mutualism is said to exist when the relationship is based on a form of cooperation that benefits both parties.

Example:

The wood ant has a taste for the sweetish droppings of the greenfly and thus keeps the greenfly’s habitat clean.

• Commensalism exists when a species that is host to another species supplies it with some of its food without receiving anything in return.

Example:

Flies, which swarm in eyries, feed on the bird of prey’s kills and on the eaglets’ leftovers.

• Parasitism occurs between two living organisms when the parasite exploits its host by living either inside it or on it and by feeding on it. The relationship is destructive to the host.

Example:

The flea exploits the eagle by feeding on its blood.

B. Physical and behavioural adaptations of species in a mountain ecosystem

The teacher explains that animals face several major challenges:

- withstanding the cold and lack of oxygen at high altitudes;
- tolerating gale-force winds;
- coping with the scarcity of food.

Over time, species have developed numerous tolerance or avoidance strategies in order to adapt to the hostile weather conditions, the extremely low temperatures and the frost and long snowy winters when the snow hardens and covers up the vegetation.

► The teacher begins by highlighting the **anatomical and morphological adaptations** by which species cope with the cold, the drop in atmospheric pressure and life at high altitudes.

• Most animals have very large lungs, in which blood and air can interact more easily, so that they breathe more freely in spite of the lower levels of oxygen.

Example:

Eagles, which need very large amounts of energy in order to fly in rising air currents, have exceptional circulatory and respiratory systems.

• Though bigger than their lowland counterparts, mountain animals have smaller extremities: ears, muzzles and sometimes feet, which limits heat loss.

Example:

The brown hare has much longer ears relative to its body size than the mountain hare.

- To survive on the sheer gradients of the bare rocky slopes, many animals have a good sense of balance and move among the rocks with ease, their feet having evolved for that purpose.

Examples:

Owing to thick pads on their feet, the snow panther and the ibex have a good grip on the rocky surfaces and the caprids also have protruding spurs located behind their hooves that act as brakes.

- ▶ The teacher then moves on to the **physiological adaptations** of species to reduce heat loss and withstand freezing conditions:

- Most insects living at high altitude acquire dark colourings; their bodies, very often black, enable them to absorb the heat from the sun's rays more effectively.

Example:

This is the case with weevils and ground beetles, which are black and flat and take refuge under stones that store heat.

- Mountain mammals are equipped with a coat or fur that possesses excellent insulating properties, while the plumage of birds is thicker and again provides good insulation.

Example:

The plumage of the rock ptarmigan may even cover its feet and toes, parts of a bird's body that are normally bare.

- At altitude, mammals further increase the effectiveness of the protection given by their coats by producing a subcutaneous layer of fat, which is equally effective in building up their resistance to the cold.

Example:

Marmots will eat as much as they can before hibernating, thus developing a layer of fat under their skin.

- Most hibernating animals will therefore survive the winter by burning up their fat reserves. When the temperature drops, the brain secretes a hormone that allows the body to release energy and to extract small quantities of nutritive substances from reserve tissues.

Example:

This is true of dormice, garden dormice, hazel dormice, hamsters and marmots, which go into a state of lethargy for weeks, even months.

- Some animals, insects in particular, cope with the cold by allowing the night-time frost to harden their bodies. Their body substances include a chemical antifreeze that enables them to survive temperatures of -30°C without ice crystals forming in their bodies.

Example:

This is true of springtails, which are even found in Antarctica.

- When food becomes scarce and difficult to find, true hibernants escape the cold through a long period of rest in the shelter of a burrow beneath the snow (which also acts as a thermal blanket). In animals, the slowing down of the body's metabolism is linked to a drop in the outside temperature. The heart slows down, breathing becomes less frequent and the animal falls into a long sleep, during which it will survive on its fat reserves.

Example:

The marmot hibernates for nearly six months and breathes less in one month of hibernation than in two days of wakefulness.

This is clearly an avoidance strategy for coping with low temperatures.

- The life cycle of many high-altitude animals is spread over several years. Their growth cycle is then longer; thus, the frog's "tadpole" stage, which lasts for two to three months in the plains, can be as long as two to three years at the alpine stage. The reproduction cycle itself is longer, the egg-laying season and the season for giving birth being less frequent.

Example:

The gestation period for a salamander embryo can last between one and three years, depending on the altitude, and the larvae develop directly inside the mother's womb rather than in eggs laid.





52. Himalayan marmots (*Marmota himalayana*),
Saboo Pulu, Ladakh, India
© UNESCO/Olivier Brestin



53. Alpine marmot (*Marmota marmota*),
Cirque des Bouttières, Mézenc, France
© Michel Le Berre

► The teacher ends by explaining species' behavioural adaptations to the mountain ecosystem, particularly when they are faced with hostile weather conditions, especially strong winds, and when the opportunities for sheltering are limited or even non-existent.

- Animals with coats or thick plumage stand facing the wind, which flattens the fur or feathers against the body.

Example:

If snow is mixed in with the wind, the mountain hare allows itself to be covered and is thus naturally “protected” by the snow, which serves as a kind of igloo, ventilated at the top by the animal's breath (which creates a kind of ventilation shaft).

- Migratory birds avoid getting caught up in cold air currents, simply by flying at low altitudes.

Example:

Sparrows fly through passes and valleys in order to cross mountain chains.

- Similarly, and even more systematically, insects stay close to the ground, avoiding all movement through the air. They are thus less likely to be carried off by squalls.

Example:

Grasshoppers and crickets living at the alpine stage crawl or hop through the grass.

Behavioural adaptation may well be a factor in anatomical changes, since most of these insects, above a certain altitude, are totally wingless and therefore lose their ability to fly.

5. Study an animal in the environment and take notes

To conclude this activity, the teacher organizes a new phase of observations of local species, sending the pupils back “into the field” to study a species (domesticated or wild) in its own environment.

Each pupil chooses an animal and observes it closely for several days.

► The pupil observes and takes notes on its comings and goings, its behaviour in its environment and its reactions to events. The notes can be complemented by drawings and quick sketches, since the aim is not to show off one's drawing skills but to capture a particular body movement or posture.



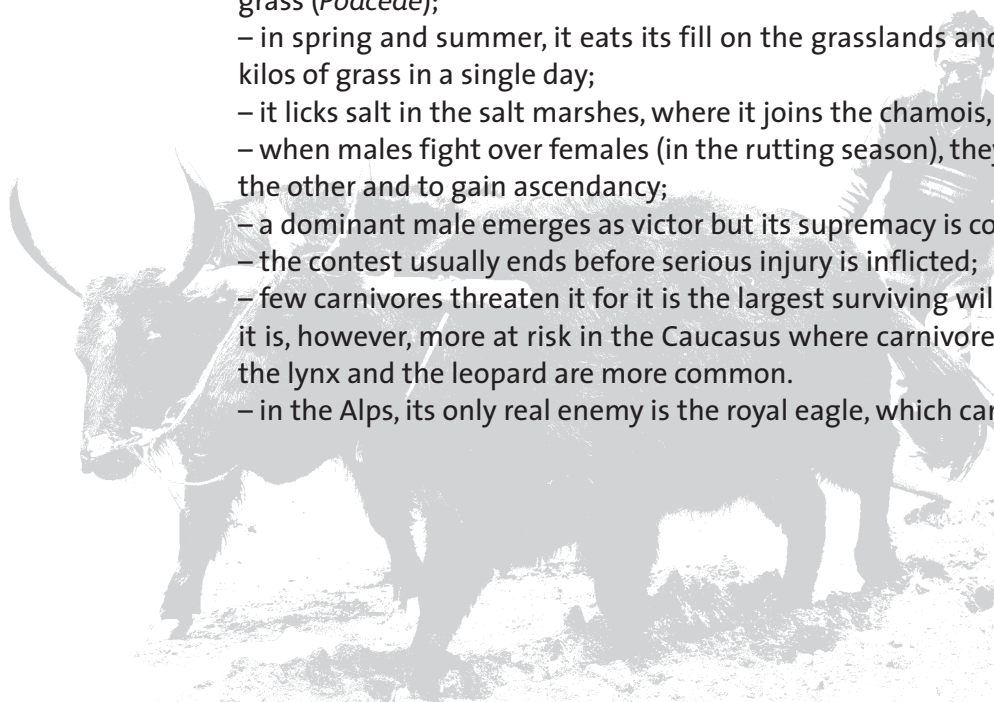
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► In any case, the notes taken will be descriptive and evidence of the pupil's powers of observation. Example: the ibex (*Capra ibex*). Depending on the regions, it could be a West Caucasian tur in Eurasia, a Nubian ibex in Africa or an Iberian ibex:

- its eyes are gold-coloured, its horns enormous;
- its movements are slow, which gives it a majestic air;
- it is rather indolent, less sprightly than the chamois, but endowed with a highly developed sense of balance and immune to vertigo;
- it lives above the tree line;
- it occasionally leaves this area, but only in the spring when, desperate for food, it seeks out young shoots;
- it prefers rocky areas, the steepest and sunniest rock faces; it likes to laze in the sun...
- the thinner the layer of snow, the more easily it can get to the low vegetation that it feeds on: lichens, clover, sainfoin, lady's mantle, wormwood, with a predilection for alpine fescue, a kind of grass (*Poaceae*);
- in spring and summer, it eats its fill on the grasslands and pastures and can devour up to 20 kilos of grass in a single day;
- it licks salt in the salt marshes, where it joins the chamois, which gives way to it;
- when males fight over females (in the rutting season), they lock horns, each seeking to topple the other and to gain ascendancy;
- a dominant male emerges as victor but its supremacy is constantly challenged during the rut;
- the contest usually ends before serious injury is inflicted;
- few carnivores threaten it for it is the largest surviving wild mammal found in alpine regions; it is, however, more at risk in the Caucasus where carnivores such as the brown bear, the wolf, the lynx and the leopard are more common.
- in the Alps, its only real enemy is the royal eagle, which carries off its young.



6. Choose a species and write a story of the animal's life.

► Back in the classroom, pupils take turns to get a species to “tell its story” through the narratives they make up themselves.

Everyone chooses a species that he or she wishes to represent and then plays the part.

Example:

“I’m a wild yak. I am the indisputable master of the high steppes of Tibet. I am much wilder and much more impressive than my cousin, the domestic yak, I can attack humans with my horns, which are curved at their points. Wrapped in my thick, hairy coat, I spend the winter in snowy fields, sometimes 6,000 metres up. When a snowstorm rages, I turn my back to the wind, so that the fur on my flanks protects my lowered head, and I wait for it to pass ...”

► This exercise helps pupils to remember what they have been taught. They absorb information better by internalizing it, feeling it and expressing it through their own voices and bodies. When they tell these stories, pupils should not merely mime situations but let their imagination take over, within the bounds of what they have been taught, and stress the relationship between an animal and its biotope.

How can the same environment be perceived and interpreted by different users?

What determines the pace of these animals’ lives in their mountain environment and what difficulties do they face?

► The stories are told one after the other and the examples mount in number, different points of view emerge from the personifications and give a good idea of the many ways in which the environment is used by different animal species.

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56. Goats' horns near a camp, Thachung Lake, Ladakh, India
© UNESCO/Olivier Brestin

57. Bongo antelope (*Tragelaphus eurycerus*)
© David Davis

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58. Goat at Sand Dunes, near Diskit, Karakorum, India
© UNESCO/Olivier Brestin

05

Mural of an ecosystem

Level

advanced



Place

classroom
and outdoors

Duration

4 sessions



Objectives

1. Discovery of the environment

Portray the ecosystem as a functional unit by making a large, colourful mural of a number of communities of plants, animals and micro-organisms interacting with the non-living environment.

2. Knowledge and comprehension

Use the mural to reveal the logic that governs the way ecosystems work, drawing on the concepts of species interdependence, trophic networks and ecological succession.

Methodology

1. Choose two areas in the environment with a high level of biological diversity

► The class scours the mountainside for two areas that represent the local ecosystem.

The teacher gives some guidance:

The towering relief imposes a vertical spatial structure on the ecosystem, traps and influences winds and precipitation according to its irregularities. The mountain ecosystem is discernible nonetheless, owing to the plants.

Plants make up the bulk of the biomass; they are distributed differently at various altitudes, form living communities that play an active role in the ecosystem and mark the changes wrought by the seasons.

► The pupils therefore choose two areas that differ in terms of plant cover; ideally, an area of natural vegetation (a natural ecosystem) and, by contrast, a cultivated area (a semi-natural ecosystem, shaped in part by human activities).

Examples:

In the temperate regions of Europe, these could be a cultivated area at altitude (barley, wheat, oats) and the transitional area, or **ecotone**, between forest and alpine grassland, located above the tree-line, with its scattered populations of dwarf shrubs or of moorland rhododendrons. In Central Asia, they might be a cultivated area of fruit-trees in the mountain oases and an area of high steppes with their vast, grassy expanses.

2. Locate these two representative areas in the wider context of the landscape

► It is important at this stage for the pupils to see the two selected areas against the broader background of the landscape as a whole.

How do two ecosystem components, characterized by the species that inhabit them, fit into a much larger one, the surrounding landscape, defined by its forms and contours?

► In this exercise, the teacher gets the pupils to “zoom out”, to find a vantage point, either a distant one on the slope opposite or one that is higher up the massif, giving a commanding view. How do the contours structure the landscape? Is the skyline shut off by foothills or rocky outcrops? How far away are they? Is the viewpoint a mountain ledge, several hundred metres above the surrounding valleys?



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59. *Rhododendron campanulatum*, near Lake Tsomgo, Sikkim, India ©UNESCO/Olivier Brestin

61. *Rhododendron hodgsonii*, near Lake Tsomgo, Sikkim, India ©UNESCO/Olivier Brestin

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60. Harvesting Tea, Happy Valley Tea Estate, Darjeeling, India ©UNESCO/Olivier Brestin

62. *Rhododendron hodgsonii* flowers, near Lake Tsomgo, Sikkim, India ©UNESCO/Olivier Brestin

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Is it, by contrast, in the hollow of a small valley, facing a V-shaped or U-shaped valley opening out ahead, or in the dip of a ridge, whose two sides form a pass where they meet?

- ▶ The pupils then make a series of sketches capturing the landscape's physical structure, consisting of linear and surface elements.
- ▶ Their drawings divide up the landscape diagonally, then with vertical lines to give heights and differences of level, and with horizontal and oblique lines to mark surface details.
- ▶ They pinpoint the location of the two areas representing the ecosystem. Are they located on a gradient? On the top of a plateau? Are they tucked away on a valley floor? Where is North? And South? On which side does the sun rise?

Is either of the chosen areas exposed to strong sunlight? Is either situated on the **adret**, the south-facing slope, which heats up and dries out very quickly in fine weather? Or on the side that gets hardly any sun, the **ubac**, which tends to remain cold and humid?

Is one area wetter than the other? How much rain does it get? Is the area located at mid-altitude (tree zone), where rainfall is highest? Is it ever shrouded in cloud? Does it get frequent mists or morning dew, caused by the condensation when humidity comes into contact with the cold plants?



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Does any water flow through the area as meltwater or a stream? A waterfall swollen by each storm?

These are all important points to note and will be useful in planning the overall structure of the mural.

3. Sketch a basic outline of the landscape

► Back in the classroom, the pupils use several large sheets of paper laid side by side. These are then fixed to the wall. The mural will therefore have a landscape format, unfolding and read from left to right.

► Using the information collected on site (sketches, photographs and general views), the class draws a basic outline of the landscape, which will serve as a kind of reference point for easy identification of the two ecosystem areas selected.

This drawing occupies the left-hand panel of the mural, providing the “introduction”, as it were. It shows the cardinal points, the main elements of the relief, the skyline and the water present in its various forms, and ensures overall consistency of the representation of the ecosystem. The latter must not be portrayed as one or more spatially separated units but as a unified whole, a complex of ecosystems that are interrelated within the landscape.

► The pupils spend time colouring in this general drawing and indicate by means of two arrows the location of the two zones being studied.

► Next to the drawing, the representations of the two selected areas are displayed in close-up and in detail respectively, like two enlargements – the ecosystem under a microscope.

Two areas (one natural, one cultivated) are chosen in order to show that although the ecosystem takes on a different form in different parts of the landscape, the same principles are still at work.

► Prior to these representations, the teacher gets the pupils to observe in detail the selected environments.

4. Examine each area in detail

► The pupils draw up a list of the species that make up the biocenosis of each area.

► They identify the **notable** species of each type of plant.



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Examples :

In the oases of the Pakistani Karakorum, apricot groves, in association with species of wild apple, often predominate, planted on alluvial cones at high altitude.

Species of pioneer trees such as the larch and the arolla pine (or Swiss stone pine) form the last, thinly scattered clusters of trees in the ‘combat area’ of the European alpine massifs. At this altitude (about 2,100 metres), they face the fury of natural elements like cold and strong gusts.

► The teacher encourages the pupils to talk to local experts (herders and foresters, in particular), who are a mine of information when it comes to the local environment.

Which **companion** plants coexist with the notable species seen earlier?

► With each other’s help and guidance from the teacher, the pupils learn to identify and recognize species in the field.

Example :

At the upper limit of the forest on European mountains, larches and arolla pines are still present in dense clusters and coexist with shrubs like the bilberry or mountain cranberry, and herbaceous species like purple colt’s foot (*Homogyna Alpina*) or wood crane’s-bill (*Geranium sylvaticum*).

Higher up, the ecotone between forest and grassland becomes a perfumed garden with the moorlands and their rhododendrons, among them the alpenrose, which secretes a toxic liquid that looks like iron oxide and grows in association with spiked plants such as lycopods (*Lycopodium alpinum*) or the woodrush with its small, brown flowers (*Luzula sylvatica*). The rhododendron “grove” may also be dotted with a few rare arolla or dwarf larch specimens.

Higher still, the ecotone between forest and alpine grassland becomes shrubby moorland populated by black crowberry (*Empetrum nigrum*) and bog bilberry (*Vaccinium uliginosum*), while forest plants give way to unambiguously alpine species.

► Herders and foresters are well acquainted with the associated species belonging to the habitats just described.

Foresters, in particular, monitor the “combat area” on a regular basis (being constantly between forest and grassland), which they work hard to replant, since it is frequently the starting point for most avalanches. In fact, the combat area is often lowered artificially by human intervention;

tourist facilities in mountain areas disturb the vegetation stages, destroy grazing land, and are responsible for the loss of large areas of woodland.²

Reforestation towards the summit with arolla pines and larches, even if these grow as creepers or are stunted, helps to stabilize the soil and retain the mantle of snow.

► Lively anecdotes by mountain experts brilliantly evoke the inhabitants of the various flora and enable pupils to learn in a very colourful way about the selected areas.

Examples:

It will be interesting, for example, to depict the combat area by means of the different species of birds that fly about in it.

Where the forest ends, forest birds with a fondness for bright undergrowth, such as the tree pipit and the dunnock, go in search of even more sunlight and open spaces, flying from one solitary larch to another.

The spotted nutcracker clearly lives in association with the arolla pine, given its liking for the large nuts contained in the cones. It stores most of the seeds in its oesophagus and under its tongue, disgorging them later and burying them in different places in anticipation of the winter. The forgotten seeds will germinate and ensure the propagation of the Swiss stone pine. This process is known as **zoochory**.

At higher altitudes, the black grouse or heathfowl, an arboreal animal, values the open terrain of the rhododendron “grove” to perform its spectacular courtship display; it likes to exhibit itself, at the same time exploiting the mosaic of shelters provided by the rhododendrons for its dramatic production.

Finally, the ptarmigan or snow partridge roams about the combat area at even higher levels, combing the heathland that is home to the black crowberry, whose berries it finds irresistible and which it helps to propagate by means of its droppings, one more example of zoochory.

► Foresters and shepherds, too, may brief the pupils about which areas are suitable habitats for particular species; they show them how to find both sheltered and humid microenvironments (this happens especially in the combat area, which is above all a mosaic of intermingling environments, a mosaic due to the contingencies of the relief). They give the pupils useful tips about finding their bearings, where to find surface water and the location of the water table.



Spotted nutcracker
(*Nucifraga
caryocatactes*)
pecking at an
arolla pine cone
(*Pinus cembra*)



67. Conifer and evergreen forest,
Lachung region, Sikkim, India
©UNESCO/Olivier Brestin



68. Pine forest, Lachung region,
Sikkim, India
©UNESCO/Olivier Brestin

► Pupils write down these valuable pointers in their notebooks and make connections between the resources and conditions of the environment and the species it shelters.

Example:

The larch is sensitive to soil conditions and aspect.

It dislikes a humid atmosphere and is found above the mist area (the most humid area of a massif). It can brave the extreme cold since it loses its needles in winter, but since it transpires a great deal in summer it needs large quantities of water. It therefore grows best at altitude, in a relatively moist soil where conditions are cold and dry, even sunny, but shaded in summer so that it does not quickly become dehydrated. As to the arolla pine, it is considerably less delicate, and can tolerate the most inhospitable conditions.

5. Put ideas together on the basis of observation in the field

Before any work is done on the mural, the teacher uses diagrams to contextualize the concepts that emerged in the earlier exploration of the terrain.

A. Interaction between living species and the non-living environment

- The teacher may draw diagrams of some situations on the board to spark pupils' interest
- The following points are illustrated:
 - each of the two selected areas supports an ecosystem as a dynamic network of one or more communities of living organisms and their non-living environment;
 - the different species affect one another in various ways and also depend on **abiotic** factors, that is, non-biological factors such as soil and climate;
 - these abiotic factors are environmental **resources**: water, light, nutrients (in the soil) and space, as well as the **conditions created** in the mountains by temperature, wind, rain and climatic variations, and the height of the mountains, the gradient of the slopes and exposure to the sun.

2. The development of winter and summer sports is partly to blame for changes in mountain ecosystems, but the tendency of the upper limit of forests to move further down the slope is a very old phenomenon, which started in Europe in the late Middle Ages, not only with felling by monks

but also by the alpine farmer in need of wood for house-building, heating and industrial purposes. In Europe, nearly all (more than 90%) of the mountain forests had disappeared by the late nineteenth century.

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69. Caterpillar nest on blackthorn (*Prunus spinosa*) and blackberry (*Rubus fruticosus*) bushes, Auvergne mountains, France
©Hélène Gille

70. Bumblebee gathering pollen
© UNESCO-MAB, R. Bill

71. Dogrose flower (*Rosa canina* L.)
©Hélène Gille



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B. Interdependence between species and trophic networks

► The teacher can draw different diagrams, including a simplified food chain. Arrows are used to show the links between living organisms that serve as food for other organisms (see the diagram on p.25). It is to be noted that the arrows indicate the direction of food transfers and not the direction of predation.

Example:

Seeds ► Vole ► Stoat

► The teacher may choose to mention the points below.

- Most species eat a variety of foods and so are a part of several food chains, which form a **trophic network**.
- The different food chains start with plants, which are the **producers**. Plants use the energy from sunlight to convert the carbon dioxide in the atmosphere into organic molecules, thus producing proteins and sugars in the form of plant matter that can be used by other organisms (see Ch.2, Act.3, p.86).
- Other species in the food chains are **consumers** (animals and humans), which develop by eating producers and other consumers.
- It is important to remember the **decomposers**, which feed on dead organic matter that they break down and partly mineralize to produce humus, a complex mixture of earth and animal and plant remains and a natural fertilizer for the soil.
- **Transformers** continue the work of decomposers; these are bacteria, fungi and animalcula in the soil, which refine partially decomposed dead matter until it returns completely to its inorganic state, thereby recycling the nutritive elements in the soil.
- “A eats B” food dependencies are not the only form of interaction.

Besides commensalism, there is zoochory, namely the dispersal of fruits and seeds by animals. There is also phoresis, the process by which an animal (acarids, insects or molluscs) is carried from one location to another by another animal organism.

C. Ecological succession

The teacher can use a timeline to show how an ecosystem evolves. This explanation, given in a lively manner and with illustrations, allows the idea of time to be introduced into the ecosystem.

► When an ecosystem is destroyed by a storm, a series of avalanches or a forest fire, the natural environment is gradually regenerated.

In a process known as **ecological succession**, it goes through different stages until a stable biocenosis is achieved.

- Where the soil is bare, wind-borne seeds fall and germinate. In the right conditions, so-called “pioneer” plants can thrive without competition from other species.

- Bigger plants then join the original plants and start to dominate them. Competition for light enables one plant to dominate another, in an upward race for a “place in the sun”.

Trees ultimately become the dominant vegetation.

- In mountain rainforest areas, at about 1,500 metres, below the permanent cloud ceiling, the same strata of tropical forest as in the plains are found. The taller trees tower above the canopy, which itself covers a shrubby layer of broad-leaved, **sciaphilic** (shade-tolerant) plants such as the tree ferns (*Cyathea arborea*) on Mount Kenya in Africa. The herbaceous stratum is always dark and cool with decaying leaves that quickly decompose.

6. Make the mural of the ecosystem

After this explanatory stage, the class sets about making the mural by first of all penciling in the broad outlines of the cultivated and natural vegetation areas on the mural background.

► The pupils use any materials available: coloured pencils, crayons, pastels, water-colours, poster paint or powder paint.

► The drawing task is parcelled out among the pupils and each pupil subsequently colours in the section they have drawn.

► The pupils use colour as a basic tool for creating the mural, since it allows them to illustrate the concepts explained earlier by the teacher. Use of colour to show the various strata of vegetation helps to clarify the broader concept of ecological succession mentioned earlier.

Plant strata
in mountain rain
forest



Example:

For the alpine grasslands, the colours of the ground stratum, consisting of rosulates, mosses and lichens, will be varied and the range of shades will be different from the colours of the aerial stratum, consisting of the stubble of different grasses and of the stems and leaves of tall herbaceous species.

- ▶ For the mountain rainforest, the class chooses different shades of green to differentiate between the very tallest trees, the canopy, the shrub stratum and the herb stratum.
- ▶ To ensure that the outlines of the plants stand out from the colours, the pupils go over them with a lead pencil or a fine paintbrush.
- ▶ They also use colour to highlight the time cycle in the ecosystem.

In mountain environments with seasonal climates, resources and conditions in the ecosystem change with the time of year.

The more marked the seasons, the greater the transformations in the vegetation and the micro-mosaics under the combined effect of the micro-relief and the climatic variations due to altitude.

- ▶ Pupils can show how the same association of plants changes with the seasons by varying the colours.

To do this, they learn how to create “windows” on the mural: they draw a separate circle, in which to portray an earlier or later situation, or an added or enlarged detail on which they wish to “zoom in”. The use of such a “window”, linked to the main drawing by a line, makes it easier to show seasonal colour changes in the same association of plants.

Example:

In the rhododendron grove of the combat zone, the alpenrose (*Rhodendron ferrugineum*) “bursts” into a mass of red flowers in early spring, whereas in autumn its dominant colour is that of its foliage, which remains green; conversely, the rowan (*Sorbus aucuparia*), which grows in association with it, is green in spring (outside the flowering season) and brilliantly coloured in the autumn, with scarlet berries and a golden brown foliage. These two situations can be compared by adding a “window” and linking it to the main drawing in the mural.

- ▶ By varying colours, the pupils can represent the temporal changes in the ecosystem in a different way. Thus the temporal succession of **synusiae**, that is, all plants in the same stratum developing simultaneously at a given time of year, can also be portrayed.

Example:

In temperate forests with seasonal climates, the trees lose their leaves in the autumn, rest during the winter period and remain bare; then they bud in the spring and regain their thick, dense foliage from late spring and throughout the summer. The climatic conditions in the undergrowth will therefore change along with the seasons from cold and bright during the winter and light and damp in early spring to warm and dark with the onset of summer. These changes obviously affect plant life. In tropical regions, there are two quite distinct seasons, owing to the amount of rainfall (the dry season, the wet season), and their impact on flowering and the loss of leaves can be represented.

- ▶ Still using colours and “windows”, the pupils illustrate the succession of different **synusiae** on the same site.

Example:

In the understorey in temperate regions, the yellow or mauve carpet of **geophytes** (daffodils, ramsons and arum) that grow together in early spring and “hasten” to flower before the trees grow their leaves, are a feast for the eyes. Then later on, in this same patch of understorey, the green carpet – dense or sparse, depending on the particular spot – of plants that require warmer conditions, such as ferns, euphorbia (mercury and wood spurge), and often perennial **rosette** plants and **epiphytes** such as mosses.

- ▶ Lastly, the whole class position the animal species on the mural. Each species is placed in its own environment.

In the case of areas with a variety of environments, like the combat area, some species are introduced by means of windows to give close-ups.



72. High mountain pasture with monk's rhubarb (*Rumex alpinus*) in foreground, Little St Bernard Pass, France
© Michel Le Berre

The pupils first of all draw the main species in the environment, which they locate by means of arrows on the mural itself.

Example :

For the combat area, the garden dormouse (*Eliomys quercinus*) at the foot of a conifer, the southern wood ant in its nest, represented on the mural by a mound, the spotted nutcracker (*Nucifraga caryocatactes*) at the top of an arolla pine, the ground beetle (*Carabus solieri*) in all its glory but nevertheless hidden among tufts of grass or under stones on the edge of the grassland stage, the snow vole, a rodent belonging to a different family from that of the garden dormouse, the muridae, and living higher up the massif.

► Next, windows are inserted to permit close-ups and put more localized species in place.

Thus a window “opened” on the trunk of a larch will reveal a few insects or larvae such as the larvae of the sirex woodwasp, the sabre wasp or the larch bud moth, a tiny moth that attacks conifers. Their predators, such as the black woodpecker, are also represented. The pupils reflect on the matter. Who eats whom? Which animals feed on a living organism such as the larch – on its trunk, to be more precise? Which of these are eaten by other living organisms? What are these other living organisms?

► These windows show that at different points in the landscape, the ecosystem functions through the species that live in it.

► At this stage, however, the pupils can be induced to make certain observations: comparing the diversity of species, they sometimes observe a clear difference between the area of natural vegetation and the cultivated area.

When the latter is an area of intensive farming, as in some fruit-growing oases on the Indus, extensive use of pesticides has killed off communities of wild herbs and the ecosystem can no longer recover naturally, or even semi-naturally, in some places. It has to be maintained artificially, as there

are no natural plants to fulfil important ecological functions such as returning nutrients to the soil or maintaining pollination. In the medium term, such intensive farming can lead to soil exhaustion and to a significant decrease in **biodiversity**.

► In the best-case scenario, however, the two areas and their biocenoses replicate each other on the wall; the impression, then, is of a mural that is inhabited, teeming with life. The idea is not so much to capture the animals in their everyday postures or movements (sketching from nature is difficult) but to evoke their existence and their place in the ecosystem by drawing them on the mural. The class reveals the hidden face of the ecosystem, as if the species could really be seen and identified.

► Windows can be used to depict the different synergies of activities that integrate animals into the ecosystems.

One could be the interdependence of species in regard to diet, another the notion of a cycle involving the pollination of flowers (birds and bees), the dispersal of seeds (birds) and the germination of plants.

The notion conveyed is that the various ecosystem components are synchronized, that network dynamics are at work, that the ecosystem is a kind of “factory” that keeps on producing and keeps on evolving.

Mauve carpet of bluebells
in mid-altitude undergrowth
in spring





Chapter 2

Maintaining plant cover



01

Steps towards understanding plants and flowers

Level 
easy

Place  
classroom
and outdoors

Duration 
2 sessions

Objectives

1. Discovery of the environment

The pupils begin with a sensory exploration of plants in their surroundings, then work with colour to study and identify angiosperms (flowering plants) in particular.

2. Knowledge and comprehension

The pupils acquire an understanding of the role of flowering plants in the reproductive cycle of species and assess their fundamental importance in maintaining plant cover.

Methodology

1. Explore the world of plants through the senses

The teacher gets the pupils to make a number of trips during the fine season, between spring and autumn in temperate regions, to explore plants through their five senses.

▶ They visit areas with different plant formations, beginning with one that is dominated by grasses (poaceae). They walk through the tall grass; in Europe, a field of hay at the montane stage, in tropical mountain areas the grasses of an acacia savannah.

▶ They brush against the high grass, observe it swaying gently in the wind and listen to the regular, soothing sound created by its movement in the air.

▶ They savour the quite different atmosphere of an underwood; they learn to distinguish between the types of conifer, feel the different types of bark and, standing beneath their crowns, note the habit of different species.

▶ In the same way, the class learns to recognize the reddish, pillar-like trunks of Norway spruces (*Picea abies*) in the **spruce forests** of Europe and the Himalayas, the bright silhouettes of larches (*Larix decidua*) with their exfoliating bark in the forests of Scandinavia or Siberia, or the gnarled arolla pine (*Pinus cembra*) with its thick, dark trunk in the Carpathians and Switzerland.

▶ The pupils experience the dark, quilted surroundings of the spruce plantations, thickly carpeted with moss, then the light, flower-bedecked undergrowth of the arolla and **larch forests**.

▶ At a lower level, they can pick out the broadleaved forests of light-seeking species such as oaks and limes, which span several vegetation strata, and forests of shade-seeking species like beech, which are often confined to a single stratum.

They can then distinguish the dry beech groves (often south-facing), with a predominance of sedge (*Carex alba*), and the colder beech groves, where broadleaved herbaceous plants such as alpine blue-sow-thistle (*Cicerbita alpina*) can be seen.

▶ Under the spruces, they breathe in the persistent odour of fungi and humus, while in other areas, where the forest thins out, it is the scent of rhododendron flowers that predominates.

▶ The pupils identify the different flower smells and take samples of very small fragments of conifer, and, holding them up to their noses, crush them to release their scent.



Examples:

In spring, the soft green shoots of fascicles of larch needles, and the same thin “foliage” in autumn, but this time orange or golden and heavily scented, the scented scales of the spruce’s **cones**, which have not yet **lignified**, the scale-like leaves of the mountain cypresses such as *Cupressus sempervirens* in the Mediterranean mountains or the fleshy berry-like cones of junipers (*Juniperus*).

- ▶ The pupils make up collections of smells, even ephemeral ones, by sealing their samples in tins or bottles. They then try to recognize these samples with their eyes closed.
- ▶ In the mountains around the Mediterranean, the pupils extend their collections with species that are typical of scrubland with their particularly strong scents, such as the strawberry tree, broom and rockrose, and aromatic plants such as thyme and rosemary.
- ▶ The same exercise, once proper precautions have been taken, can be adapted to taste and flavours by slowly savouring or simply tasting the fruit, seeds or leaves of wild plants.

A word of warning: the teacher must be able to tell the difference between edible plants and poisonous ones from the start.

1. From left to right: Mountain stream in an undergrowth (Switzerland), undergrowth plants (*India*), view of *Dana Nature Reserve* (Jordan), bamboos (*India*)

2. Meadowland in bloom, looking towards *Mont Chevreuil*, *Château d’Oex* region, Switzerland
© UNESCO/Olivier Brestin

1



2



Examples:

Whether in Europe or in the forests of Schrenk's spruce (*Picea schrenkiana*) in the Tian Shan Mountains, one can taste the leaves of the herbs mentioned above or the fruit of the faithful companions of the spruce, namely blueberries or (mountain) cranberries.

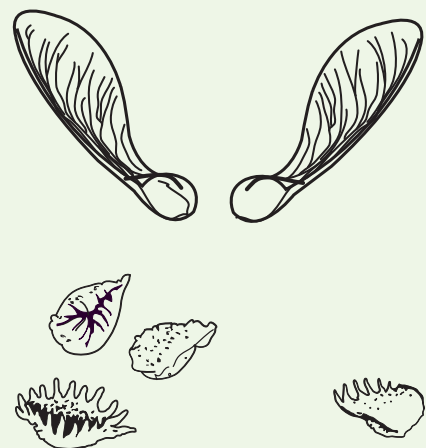
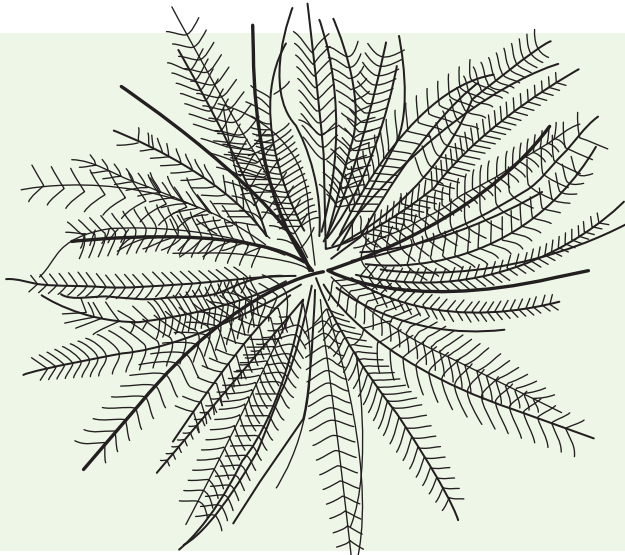
In the boreal mountain forests of Scandinavia or Siberia, pupils can vary their experiments. They come upon a large quantity of different autumnal berries in these parts, some of them found also in Europe but others that are not, among them black crowberry (*Empetrum nigrum*), bog bilberry (*Vaccinium uliginosum*), cloud-berry (*Rubus chamaemorus*) and Eurasian dwarf cornel (*Cornus suecica*).

2. Make tactile boards from collected items

- ▶ Pupils juxtapose, crisscross or superimpose samples of the leaves collected.
- ▶ They learn how to keep them together by using pine needles, which are easy to find in a mountain environment, or else by using a small blob of glue.
- ▶ Working in groups, they mount their plant compositions on some cardboard backing to keep them firmly together.
- ▶ They now use their sense of touch to identify the different material and texture of leaves:
 - there are flat leaves, thick leaves, needles, scales and ribbons;
 - leaves can be smooth, soft, tough, shiny, crassulescent (fleshy), hairy, sticky... needles can be long, pointed, flat, soft or pliable.
- ▶ Although the fertilization of plants in mountain areas is more unpredictable than elsewhere, the pupils take note of the extreme variety of seeds produced.
- ▶ There is an abundance of seeds in autumn, or sometimes late winter for the plants that take longest to mature. This is the time when the pupils go up into the massifs; they find and collect the seeds and husks of some of the most common plants: the capsules of poppies, the pods of fabaceae, the siliques of cruciferae, or, among the more unusual ones, the dried-out scapes of certain gramineae, retained by them for part of the winter thus giving them protection from the cold. The new leaves of blue sedge (*Carex firma*) are similarly protected by the tubular sheath formed by the previous year's leaves.

3. Fruits and seeds, from left to right:
Alpine French honeysuckle pods,
Downy fruit composed of achenes (dryas),
Double samara of maple (separated),
Spiky-edged fruit of the king of the Alps,

Fruit on long stems of Mont-Cenis bluegrass,
Mountain hawkbit fruit with egret,
Multiple fruit of pasqueflower.



► The pupils make tactile boards using all these elements, fruits and seeds that have been pasted on the boards. They take stock of the variety of substances, textures, sizes and colours of all the assembled elements.

Example:

The board could contain maple samaras or the winged seeds of gentians, admirably shaped for flight (yellow gentian, purple gentian), fruits with an egret that may be downy, as in the case of the mountain hawkbit (*Leontodon montanus*), or the multiple fruit of the alpine pasqueflower (*Pulsatilla alpina*), composed of numerous achenes, sainfoin pods with their dark flowers (*Hedysarum hedysaroides*) among the fabaceae, and beech-nuts and beech seeds (*Fagus sylvatica*).

In the case of the more fragile fruits, samples are collected and placed immediately between two sheets of newspaper or two pages of a book for better protection.

3. Tackle the notion of reproduction, first in fruit then in flowers

► In spring, pupils can complete their display by adding ligneous amenta such as those of the hornbeam or alder, or small cones picked from conifers.

► Using these displays of seeds, cones covered in pollen and fruits, the teacher gives a basic account of the different stages of the plant reproduction cycle.

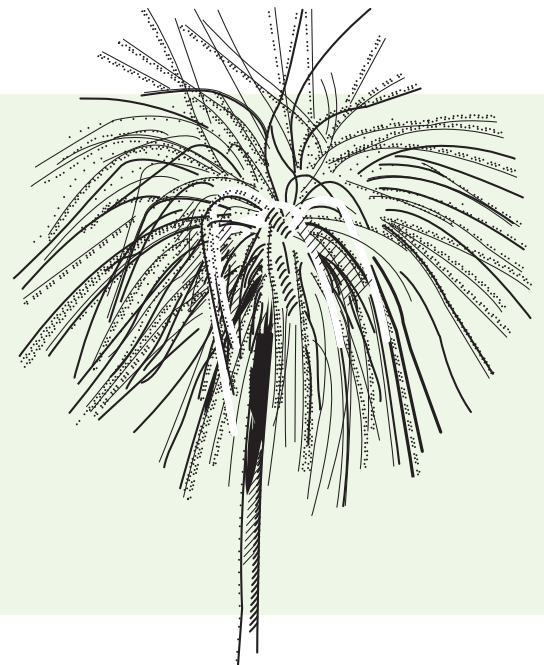
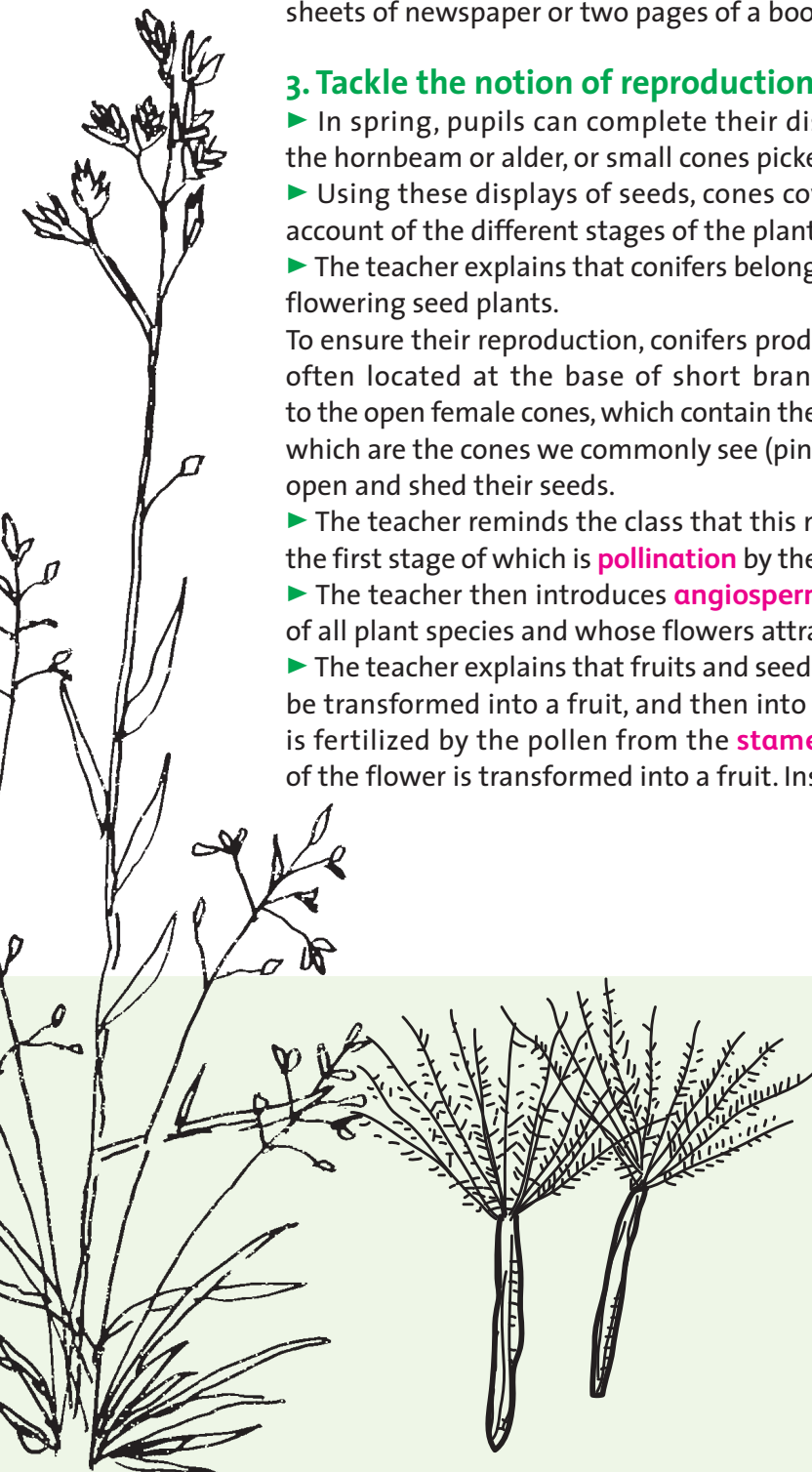
► The teacher explains that conifers belong to the **gymnosperm** group of plants, which are non-flowering seed plants.

To ensure their reproduction, conifers produce distinct male and female cones. The male cones, often located at the base of short branches produce pollen; the wind carries the pollen to the open female cones, which contain the ovules. The seeds then grow inside the female cones, which are the cones we commonly see (pine cones). Once they have ripened on the branch, they open and shed their seeds.

► The teacher reminds the class that this method of reproduction and dissemination in plants, the first stage of which is **pollination** by the wind, or **anemogamy**, is not the most common one.

► The teacher then introduces **angiosperms** or flowering plants, which account for up to 80% of all plant species and whose flowers attract and fascinate us.

► The teacher explains that fruits and seeds usually come from the flower. Before the flower can be transformed into a fruit, and then into seeds, it must first of all be pollinated. As soon as it is fertilized by the pollen from the **stamens** (male sexual organs), the **pistil** (female organ) of the flower is transformed into a fruit. Inside the fruit are the seeds.





4. Kingcup (*Caltha palustris*),
(Ranunculaceae), French Alps
© UNESCO/Olivier Brestin

5. Alpine pasqueflower (*Pulsatilla alpina*),
(Ranunculaceae), cluster in detail
© UNESCO/Olivier Brestin

6. Pasqueflower (*Pulsatilla vulgaris*),
(Ranunculaceae), Swiss Alps
© UNESCO/Olivier Brestin

7. Yellow alpine pasqueflower,
(*Pulsatilla alpina* subsp. *apilifolia*),
(Ranunculaceae)
© UNESCO/Olivier Brestin

8. Globeflower (*Trollius europaeus*),
(Ranunculaceae), Swiss Alps
© UNESCO/Olivier Brestin

- ▶ Before returning in more detail to each stage of the reproductive cycle in plants, the teacher gets the class to go off and explore flowers, concentrating their attention on specimens with a wide corolla, or at least one that is open and colourful.
- ▶ The teacher explains beforehand that flowering plants can grow as trees, bushes, climbing plants, herbaceous plants, soft grasses or stems; they have conquered every environment on the planet and have adapted to the difficult conditions of existence in mountain ecosystems (see. Ch. 2, act. 3, p.83).

4. Study flowers by focusing on their colours

- ▶ Conditions permitting, the teacher conducts this part of the exercise when the plants are in full bloom.

Depending on where one lives in the world, the flowering season will conjure up either spring-time and the “magical” appearance of vernal plants that have just burst into flower and are scattered about the landscape, or else a profusion of summer blooms with no transition from one season to another.

In either case, after a long, harsh winter in the mountains of continental Europe or the cold, arid, dry mountain masses of Asia, which are hot in summer, the season of good weather is short and bright.

- ▶ The teacher takes the class up to the higher slopes, where exposure to the sun and luminosity are greatest in fine weather.
- ▶ The pupils are instructed to take along with them a notepad for making sketches (they can make one from scrap paper stapled together between two covers of previously used coloured paper), coloured pencils, crayons, small blocks of water-based paint... or, best of all, tubes of poster paint. These materials are distributed among the small groups that have been formed.

Note:

Collecting mountain plants is strongly discouraged, since they are fragile and rare, even “threatened with **extinction**”; pupils will therefore have to learn other ways of recollecting them, by “capturing” on paper first their colours, then their shapes, sketched on the spot, from life.

- ▶ When they get to the chosen site, each pupil notes the abundance of flowers and the brilliance of the corollas, which are fully opened and brightly coloured.

Examples :

In the Alps, the immaculate white of the spring pasque flowers (*Pulsatilla vernalis*) at the beginning of the season, the deep blue of the trumpet gentians (*Gentiana kochiana*), the sulphur yellow (pale) of the yellow alpine pasqueflowers (*Subspapiifolia*) and the intense fuchsia of the wood cranesbill (*geranium sylvaticum*). Elsewhere, in the Himalayas, the same colours, associated there with anemones and gentians, the distinctive pink of primroses (*Primula denticulata* Smith), the strong mauve of *Porana grandiflora* and the golden yellow of the kingcup (*Caltha palustris*).

- ▶ Split into groups, the pupils gently take hold of the peduncles and examine the typical anatomy of a flower, which is based on four elements necessary for fructification: two central elements, the **pistil**, often composed of several carpels (female sexual organs) and the **stamens** (male sexual organs), and two auxiliary elements, the **calyx**, an outer circle of sepals that protects the flower when it is in bud and the **corolla**, an inner circle of petals – which are the sign of a flower in bloom – with the pistil and stamens in the centre.



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9. Alpine rose (*Rosa pendulina* L.),
flower (detail) and bush
© UNESCO/Olivier Brestin



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10. Fairy lily (*Zephyranthes carinata*),
Phodang, Sikkim, India
© UNESCO/Olivier Brestin

Examples:

Among the species that are anatomically interesting and could therefore be studied are all the anemone and pulsatilla of the ranunculaceae family, the yellow alpine poppy (*Papaver rhaeticum*) and numerous species of iridaceae and liliaceae (**geophytes**) all over the world, which are excellent subjects for observation, because their very striking floral elements make them easily recognizable. To take a few more examples at random, in Europe there is turkscap (*Lilium martagon*) – take extra care, since it is both toxic and a protected species – all of the spring crocuses, *Lilium medeoloides* in the Japanese Alps and in the High Andes of Argentina a liliacea such as the *Tristagma anemophilum*.

► The teacher returns to the vivid colours of the corollas and links their remarkable colouring to the strong light.

- The intensity of the light is greater at high altitudes because the intensity of sunlight increases when the humidity and the air become rarefied.
- Now direct light is rich in red rays, which are the most active rays in photosynthesis (see Ch.2, act. 3, p.86).
- The high intake of chlorophyll results in the overproduction of sugars for the plant, which cannot convert these sugars into starch because of the cold.
- The sugars stagnate in the plant's cells, making it more resistant to the cold and producing high levels of pigmentation in its flowers, and also in its stems and leaves in some cases (which may turn brown or red).

► At the same time, the class as a whole looks for other reasons to account for the high concentration of pigments in flowers.

- Their bright colours attract the few pollinating insects that exist at this altitude.
- Indeed, the higher one climbs, the rarer **anemophilous** plants (plants pollinated by the wind) become.
- Plants tend rather to protect themselves against the violence of the wind than to turn to it for fertilization.
- They have therefore adapted to the rare visits of the small numbers of insects living at these heights, and the intensity of their colours and scents can be explained in these terms.
- Thus, bees, bumblebees, other insects and butterflies transfer grains of pollen from the stamens to the pistil of flowers of the same species. This process is called **cross-pollination**, since the pollen a flower needs is generally brought from another flower by insects, but always from flowers of the same species: the ovule of a yellow alpine poppy can only be fertilized by a pollen grain from another yellow alpine poppy.

► On site, the pupils begin by noting the size of flowers, which makes the flower itself a convenient platform for insects to land on.

► They then note each interesting detail of the corolla. Thus, as with the trumpet gentian (*Gentiana kochiana*), which has green spots inside its bells, patterns of lines and dots can guide pollen-gathering insects towards the pollen reserves.

► Next, they focus on single colours and identify precisely the intense hue of the petals that serve as beacons for insects.

Where possible, they use actual objects or referents, whose colours have a symbolic meaning, to describe the hue in question: straw-coloured for *Pulsatilla flavescens*, golden yellow for the creeping avens and orange-yellow for mountain arnica (*Arnica montana*).

► They create colour-charts in their notebooks, experiment with colours, juxtaposing dabs of colour until they get the precise shade of the flowers that they have chosen to represent.

► Whether the materials available are coloured pencils, crayons or water paints, they use them in exactly the same way.

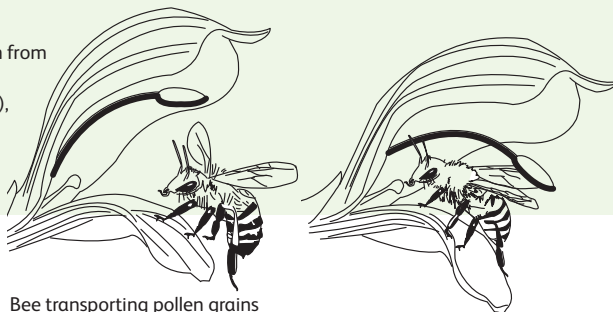
► Once they have reproduced the desired shade by superposing or mixing colours, they begin by painting in the petal outlines, then move on to painting in each area, spreading the colour in flat tints. In this way, they capture the shape and the colour of the corollas.



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11. Meadow in flower, oxeye daisies
(*Lucantheum vulgare*), Auvergne, France
©Hélène Gille

12. Bumblebee gathering pollen from
flower of bell rhododendron
(*Rhododendron campanulatum*),
Sikkim, India
© UNESCO/Olivier Brestin



Bee transporting pollen grains
from stamen



12

► After a few practice runs, they “insert” what they have drawn into larger sketches of entire species which they situate in context (on a ridge, near a spring), still observing the specimens as they do so.

5. Understand the concept of inflorescence and extend the colour exercise to the study of all flowers

► After studying plants with simple flowers that grow singly on a peduncle, the pupils now turn to flowers that grow in characteristic groups, known as “**inflorescences**”.

An inflorescence is an arrangement of flowers grouped together on the stem of a plant.

► The teacher shows the pupils how to distinguish several types.

- A **spike** is an inflorescence whose flowers are attached directly to a single stem, without a peduncle.

Example :

The purplish spikes of the alpine timothy (*Phleum alpinum*).

- A **cluster** is an inflorescence whose flowers are attached to the main stem by a peduncle.



13. Cluster of white foxglove flowers (*Digitalis purpurea alba*), Yumthang, Sikkim, India
© UNESCO/Olivier Brestin



14. Cluster of *Rhododendron cinnabarinum*, Yumthang, Sikkim, India
© UNESCO/Olivier Brestin



15. Umbel of a primrose (*Primula atrodentata*), Yumthang, Sikkim, India
© UNESCO/Olivier Brestin

Example :

The large, blue clusters of monkshoods (*Aconitum napellus*).

- A **capitulum** is an inflorescence that looks like a single flower but is actually a cluster of florets grouped together on a flat disc.

Example :

All asteraceae or composites that are found in mountain environments, such as alpine aster (*Aster alpinus*), with its highly distinctive, purplish blue to pink head and a golden yellow central disc, a common sight in Europe, Asia and North America.

► The teacher gives the explanations below:

Though appearing to consist of a heart and an annulus of petals, the flower heads of asteraceae, such as the alpine aster or the large-flowered leopard's bane (*Doronicum grandiflorum*), are not, in fact, single flowers; the heart is a group of hundreds of tubular flowers and each "petal" is a **ligulate** flower.

Some composites have completely tube-shaped heads, and their flowers are either all tubular, as in the case of the woolly thistle (*Cirsium eriophorum*), or all ligulate, as in that of the Pyrenean hawkbit (*Leontodon pyrenaicus*).

► Pupils are reminded by the diversity of inflorescences, that the strong light creates the right conditions for plants to thrive at soil level but with large, spreading flowers (nutrients being plentiful, the plant can make do with a simpler bodily apparatus, but can also allow itself the "luxury" of growing flowers with an "appetite" for chlorophyll).

In exploring the sheer variety of different inflorescences, the pupils notice that, in comparison, flowers in the underwood are small, since food is less plentiful; the plants "economize on effort", as it were.



16. Cluster of viper's bugloss flowers (*Echium vulgare*), in Verzasca Valley, Ticino, Switzerland
© UNESCO/Olivier Brestin



17. Spikes of meadow bistort (*Polygonum bistorta*) and capitula of goat's beard (*Tragopogon pratensis*), Mont Laitmaire, Switzerland
© UNESCO/Olivier Brestin



18. Simple flower of alpine pansy (*Viola calcarata*), Simplon Pass, Switzerland
© UNESCO/Olivier Brestin

- ▶ In this respect, the teacher adds that the composition of the flora at soil level is also determined by the general character of the forest, on the kinds of trees that grow, by their habit and ramification mode and how much light they let through (see. Ch. 2, act. 2, p.72).
- ▶ Once the concept of “inflorescence” has been fully explained, including umbel and corymb inflorescences, using the alpenrose (*Rhododendron ferruginum*) as an example, the pupils list the species in their notebooks, classifying them by colour.
- ▶ They identify the colours, adding new colour ranges to their notes.
- ▶ They then take out their coloured pencils or paintbrushes and set about the task of portraying the different inflorescences they have selected, starting with the colour they have identified.
- ▶ With the paintbrush method, for example, they use long strokes for the spikes and shorter ones for clusters.

For instance, for clusters of **fabaceae** – a common family in mountain areas, along with alpine clover (*Trifolium alpinum*) and mountain sainfoin (*Onobrychis Montana*) – they learn how to convey by a particular brushstroke the “papilionaceous” crown of inflorescences.

They “sketch” the erect position of the vexillum (the upper petal of each flower), the keel with its two lower petals, joined at the middle and shaped like the bottom of a boat, and the two side petals that stick out to form two symmetrical wings.

With a few, well-placed strokes of colour, and the flowers viewed from the front and from the side, the inflorescences gradually reproduce the cluster.

- ▶ After a few practice attempts on paper, the pupils, on returning to the classroom, compose displays on boards, grouping together several sketches, which they classify by colour.

The board format allows a closer study of colour: simple and compound flowers (inflorescences) are represented side by side on the same board and different shades of the same colour can be distinguished.

Water colours of poppies
and sweet peas
© Neal and Nina Cooper



Example:

On the “blue” board, for example, the flowers of the stemless trumpet gentian (*Gentiana clusii*), attached singly to their peduncles, sit next to the blue capitula of mountain cornflowers (*Centaurea montana*) and the pale-blue cyme inflorescences of wood forget-me-nots (*Myosotis sylvatica*).

- ▶ The pupils can, if they wish, colour in the stems and foliage.
- ▶ Finally, they identify the flower, and even more so the plant, by its association with a colour.
- ▶ The teacher closes the activity by summarizing the key role played by angiosperms in mountain ecosystems.

6. Register the importance of flowering plants in maintaining plant cover

- ▶ The teacher again runs through the stages of pollination, fertilization and **seed dispersal** in the context of the reproductive cycle of a species, since the primary function of flowers is to ensure that species is reproduced.
 - A seed can only be produced if pollination is followed by the fertilization of ovules.
 - The teacher explains that in flowering plants, ovules are contained within the ovary. When a grain of pollen falls onto a receptive stigma, a pollinic tube is formed that descends into the ovary to reach an ovule. The latter is fertilized and transformed into a seed.
 - The seeds are then dispersed and thus ensure the reproduction of the species.

► The teacher explains that to complete these different stages in the reproduction process at high altitudes, flowering plants have sometimes adapted by employing highly “original” methods or by relying on an exceptionally diverse range of pollinating and dispersing agents.

► The methods adopted are described below:

- **Autogamy:** pollination occurs within a single flower belonging to both sexes. The plants in question are therefore bisexual and fertilize themselves before their flowers open.

Examples :

Wheat (*poacea*) growing at altitude or mountain clarkia (*Onagraceae*) in the Sierra Nevada in California are autogamous plants.

- **Vegetative reproduction:** in addition to sexual reproduction, some plants are propagated by vegetative reproduction, involving small roots or shoots that appear on the parent plant. These subsequently turn into new, completely independent plants.

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19. Spring gentian (*Gentiana verna*),
Paray Dorénaz, Switzerland.
© UNESCO / Olivier Brestin



20. Forget-me-nots (cyme inflorescence)
© Nathalie P.

20



21. Mountain cornflower (*Centaurea montana*),
Château d'Oex region, Switzerland.
© UNESCO / Olivier Brestin



22. Stemless trumpet gentian (*Gentiana clusii*), Simplon Pass, Switzerland
© UNESCO / Olivier Brestin

21



21



22



23. Edelweiss in bloom (*Leontopodium alpinum*),
Château d'Oex region, Switzerland
© Nadine Samson

Exemples:

This is true of most gramineae or poaceae, which grow shoots along their stolons or small adventitious roots on their underground stem, like the *Trisetum distichophyllum*.

- Apomixis: this is asexual reproduction without fertilization.

Some plants appear to reproduce sexually by, for example, growing a leafy kind of bud, whereas they fall, in fact, into the vegetative reproduction category, producing bulblets among their leaves, like alpine meadowgrass, or seeds that remain unfertilized, as in the case of the alchemilla.

► As to the pollinating and dispersing agents used, the teacher gives the following explanation:

- Some flowers can be fertilized by any insect rather than being **infeodated** to a single category of visitors.

Example :

Cushion plants such as *Androsace Helvetica*, which keep the decomposed bases of their old stems, provide a home for bacteria, fungi and small animals. Insects thrive under these natural cloches, which contain their own humus, and so collembola and small spiders can fertilize the flower.

- Other flowering plants intensify their nutritional and aromatic properties to attract specific pollinating or disseminating agents.

They develop fragrant, volatile substances, located in the flower or the seeds, as in the case of the sylvan violet, whose seeds contain essential oils appreciated by some ants that will disperse them in their turn.

Others adopt complex shapes or 'compensate' for the lack of a landing pad, for instance, by releasing heady scents, absorbing large quantities of nectar or directly "offering" their reproductive organs to pollinators.

Example :

Thus the flower of the turkscape attracts moths, such as the hummingbird hawk-moth, that can pollinate it in mid-flight, without having to land on the plant.

- ▶ At this point, the teacher draws everything together in a final summary.
- The nectar and essential oils of flowers, and subsequently their fruits and seeds, are the food of a considerable number of species that perform countless ecological tasks in return, such as dispersing seeds, maintaining the fertility of the soil, selecting species, controlling populations and providing services that are essential to the functioning of the ecosystem.
- Moreover, when an ecosystem has been damaged as a result of major disturbances – avalanches, fires, mudslides or flooding, for example – angiosperms play an active part in restoring an ecological balance, owing to colonizing species that soon become established and enable plant associations to develop rapidly.
- On limestone scree, unstable rocks and avalanche corridors, the first plants to become established are flowering plants, sown by the wind or some other dispersing agent. They will trap earth, pebbles and humus, stabilizing the soil and, quite literally, preparing the ground for other plants.

Example :

Creeping avens in the Alps or the magnificent mountain avens could be mentioned.

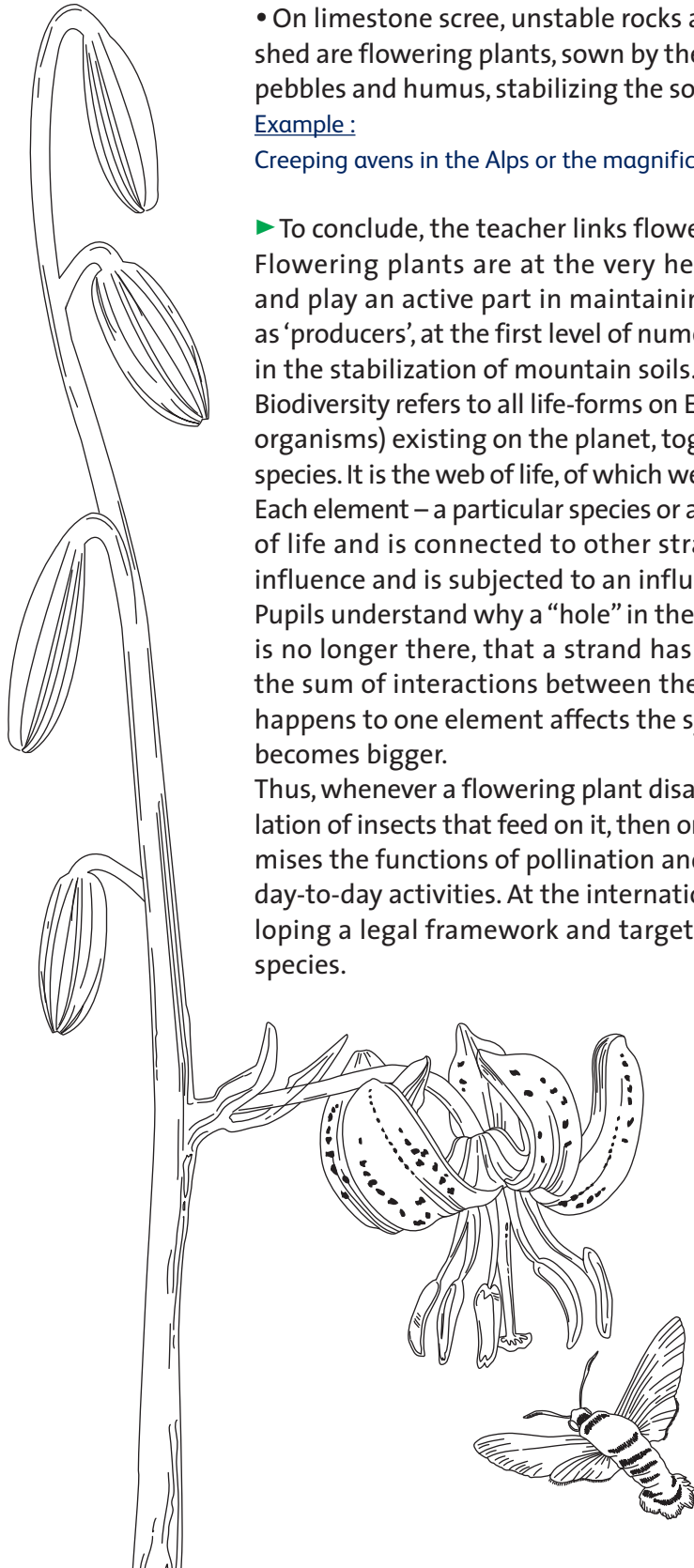
- ▶ To conclude, the teacher links flowering plants to the concept of **biodiversity**:

Flowering plants are at the very heart of biodiversity, of what is known as the web of life, and play an active part in maintaining the balance of ecosystems. They do so in several ways: as ‘producers’, at the first level of numerous trophic networks, as pioneering plants and as a factor in the stabilization of mountain soils.

Biodiversity refers to all life-forms on Earth. It denotes all living species (animals, plants and micro-organisms) existing on the planet, together with the natural characteristics of each one of these species. It is the web of life, of which we are an integral part and on which we are totally dependent. Each element – a particular species or a natural characteristic of that species – is a strand in the web of life and is connected to other strands in the web. Each element in the network exerts an influence and is subjected to an influence, acts and is acted on.

Pupils understand why a “hole” in the web of life not only means that a species has disappeared, is no longer there, that a strand has unravelled; it also means that there is a discontinuity in the sum of interactions between the different elements of biological diversity, that whatever happens to one element affects the system as a whole: the strands are ‘stretched’ and the ‘hole’ becomes bigger.

Thus, whenever a flowering plant disappears from an ecosystem, this has an impact on the population of insects that feed on it, then on the birds that feed on those insects and all of this compromises the functions of pollination and seed dispersal performed by these same animals in their day-to-day activities. At the international level, the **Convention on Biological Diversity** is developing a legal framework and targets as a practical response to the universal decline in living species.



Pollination of turkscap lily
by hummingbird hawk-moth in flight

02

Shape and design: the anatomy of trees and shrubs

Level 
easy

Place  
classroom
and outdoors

Duration 
2 sessions

Objectives

1. Discovery of the environment

The pupils are made more aware of the anatomy, the “habit” and the growth of trees and shrubs (including dwarf shrubs), by studying them from a distance, then at close quarters, alternating drawings with observation.

2. Knowledge and comprehension

By studying woody plants (their silhouette, crown and leaves or needles), the pupils discover the impact of external factors on the habit and adaptation of trees in mountain areas and understand the crucial role of broadleaved trees and conifers in mountain ecosystems.

Methodology

1. Discover the architecture and the habit of trees by observing different species

► The teacher gets the class to study woody plants in terms of their overall appearance, focusing on the trees and shrubs in their immediate environment.

► The pupils think about the following:

- What is the overall shape of the tree?
- How is it structured?
- Are the trunk and branches visible?
- Do these have a load-bearing function, like columns and lintels?

► Starting with broadleaved trees, before moving on to conifers, the pupils observe how each tree acquires a particular **habit**, grows into a particular shape, depending on the size and number of its main branches and the angle they form with its trunk.

Out of this basic structure, a network of secondary branches grows in the case of broadleaved trees and, in the case of conifers, a ramification of smaller branches.

The crown of leaves or needles is distributed over the whole structure, depending on whether the tree has leaves or needles.

► The pupils take note of the tree’s habit, based on its trunk and main branches, and draw sketches. Does each species have its own particular habit?

Example:

Birches (*Betula pendula* or *Betula pubescens*) south of the taiga in the mountains of Siberia and Scandinavia have a straight white trunk, with upright but pliant branches ramifying into secondary branches (sometimes pendulous, sometimes not), which remain flexible, the better to withstand the onslaught of storms and gales at high altitude.



24. Subalpine firs (*Abies lasiocarpa*),
Yosemite National Park, USA
© Thomas Schaaf

The tree is described as a “full sunlight” species, which thrives on the light at high levels. It therefore grows high up the mountain and often has a narrow, undeveloped crown reaching towards the light, and is therefore oval in shape, with thin foliage that allows the light to penetrate, giving light-filled underwood.

Similarly, many species of conifer in mountain areas have conical tops and look like columns, owing to their short branches that grow at an angle to the trunk and so retain a minimum amount of snow. In keeping with the principle of apical growth – upwards from the tree’s apex – the ramifications are regular and the higher branches protect the lower ones, which, in addition to being at an angle, are pliable – like those of the birch itself – all morphological factors that enable them to shed their load of snow and to bend in the wind in bad weather.

► The pupils learn to recognize the distinguishing features of each species and do a series of sketches.

► Depending on the region, they draw the silhouettes of column-shaped conifers like spruce (*Picea abies*) in the European Alps, California red firs (*Abies magnifica*) in the Sierra Nevada or *Abies lasiocarpa* and *Abies bifolia* in the Rocky Mountains.

► They capture the graceful silhouette of a tree that is a familiar sight in mountain areas, the larch (*Larix deciduas*), a conifer with deciduous needles that grows in the forests of the Alps, the Carpathians and Siberia.

According to the time of year the class sketch it in colour, edged with soft-green shoots and red cones in spring, decorated with orange or gold in autumn, or bare with bristling branches in winter.

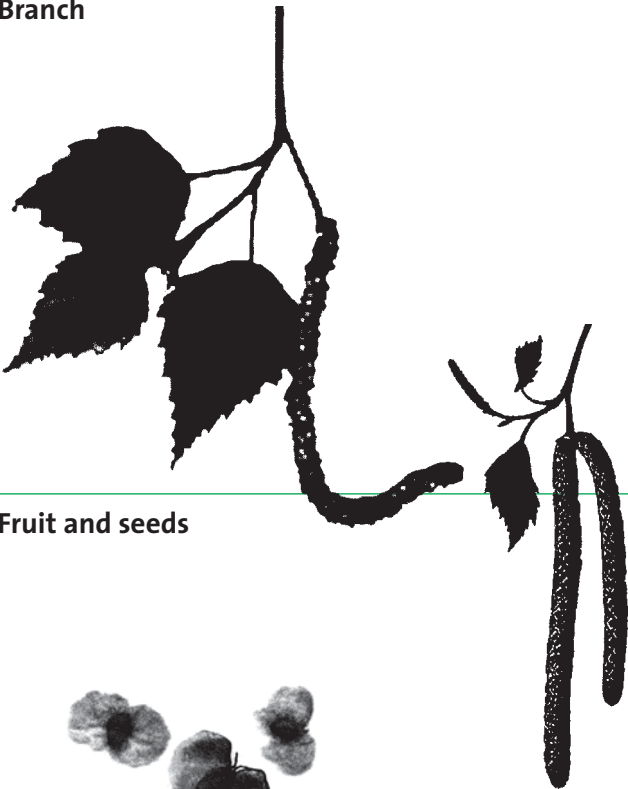
Its soft, pliable needles form an extremely light foliage. Like the birch, it is a full-sun species, with the same pliability and lightness of structure and readily adaptable, a pioneer species spreading to empty spaces higher and higher up the mountainside.

Birch

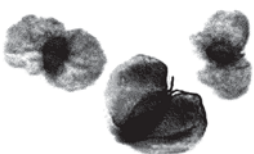
Tree



Branch



Fruit and seeds



Larch

Tree



Branch



Fruit and seeds

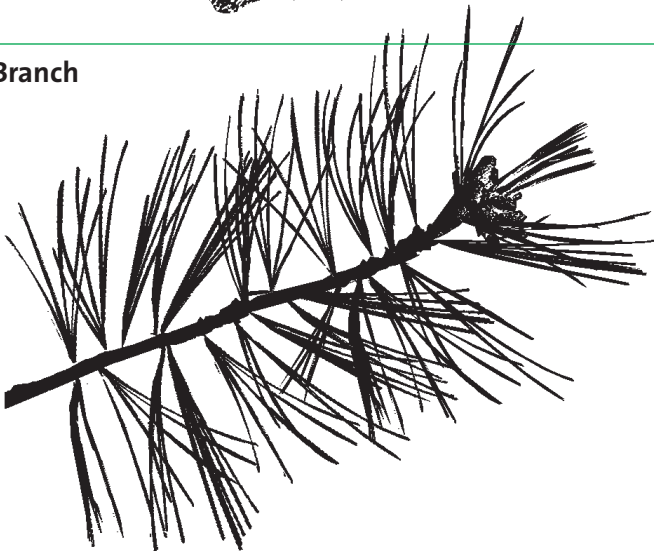


Arolla pine

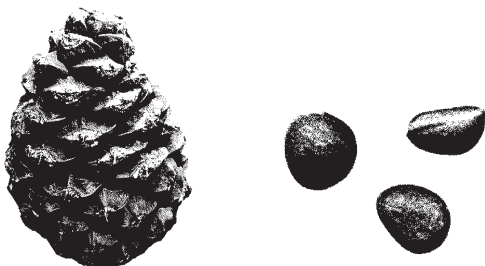
Tree



Branch



Fruit and seeds

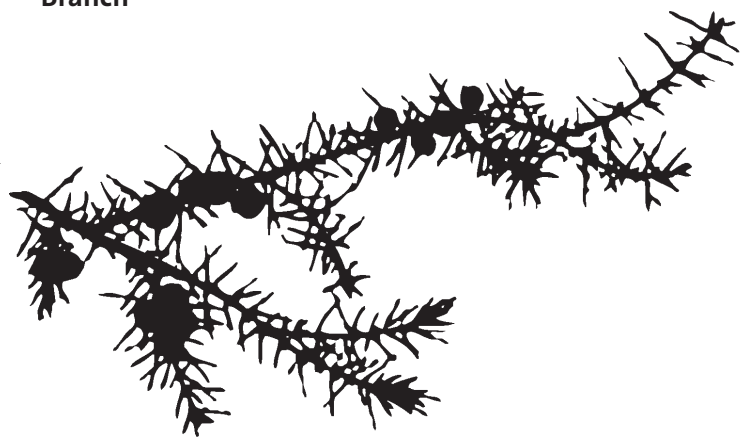


Juniper

Tree



Branch



Fruit and seeds





25. Various species of conifer, Yosemite National Park, USA
© Thomas Schaaf



26. Cultivated fields and groves of apple trees and poplars, Basgo, Ladakh, India
© UNESCO/Olivier Brestin

- ▶ The pupils produce sketch after sketch, their drawings bring lines to life: the flowing, rhythmical lines of the species they have just been studying; and the outline of the tree they have succeeded in rendering is not a boundary imposed abstractly by the mind but the result of an interplay of internal forces in the tree itself.
- ▶ They capture the elevation of the tree, which can be light and vigorous, but, equally, heavy and powerful in a species like the arolla pine (*Pinus cembra*). They then reproduce its torsion, its plasticity, by means of the thick, dark lines of its ramifications clothed in thick green foliage and purplish-brown cones.

2. Add some basic notions about plant growth

- ▶ The teacher stresses the importance of the ligneous roots of trees, which anchor the trunk firmly in the soil.
 - Most trees have two transport networks: one for water, which is known as a **xylem**, the other for food, called a **phloem**.
 - The roots draw, or “suck up”, water and minerals from the soil.
 - Water is pulled up through the tree, via its trunk, as a result of evaporation through the leaves or needles, causing a column of water to rise, as if pumped, through the entire length of the tree. The overall shape of the tree is to a large extent determined by its system of “tubes”.
- ▶ The teacher expands on earlier remarks by explaining that, in mountain areas, especially in conifer forests, the roots of certain trees such as spruce can be quite close to the surface.
 - In fact, the underwood floor is covered in a layer of poor, fibrous litter consisting of tons of decaying needles.
 - The litter releases “aggressive” organic acids, which, in combination with the percolation of water, subjects the soil to intense leaching and carries mineral particles to very deep levels.
 - As a result, the spruce’s roots are short and thus remain in the nutritious top-soil layer.
 - It therefore has to enter into a mutualistic or **symbiotic** association with the **micorrhizal** fungi that colonize its roots and supply it with vital nutrients such as nitrogen and phosphorus; the fungi use their filaments to extract these nutrients from minute porous spaces deep below the ground; in exchange, they are supplied with sugar produced by the photosynthesis process.



27. Stands of pines,
Yosemite National Park, USA
© Thomas Schaaf



28. Cultivated valley floor, between arid slopes,
Arasbaran Biosphere Reserve, Iran
© Thomas Schaaf

3. Discover how geometry works in nature through close observation

► After studying the overall shapes of trees, pupils turn their attention to the leaves and needles, and consider the relationship between the overall shape and the hierarchy of lines.

While the shape of a tree is determined by its system of “tubes”, the shape of a leaf is determined by its network of veins.

The Swiss artist, Paul Klee, made a special study of this in his 1926 pedagogical sketchbooks: “The two-dimensional shape that emerges is dependent on the hierarchy of lines. And where the line runs out of power, there the outline appears; this is the flat shape’s boundary”.

► The pupils find that conifer needles, whose surface is hard and tough, have parallel veins.
► Focusing on the morphology of a leaf, the pupils observe and draw the shape of its **lamina** and **petiole**.

They also observe the network of veins that divide the leaf into macroscopic cells, each with its own water supply.

A leaf studied through a binocular microscope, if the school has one, is a fascinating sight!

► The pupils learn to differentiate between, and to draw, two basic types of leaf:

- **Simple** leaves, like the leaves of beech trees (*Fagus sylvatica*), with their tough, shiny texture, or leaves with a variety of lobes, like those found on stands of oak trees in mountain areas.
- **Compound** leaves, like the leaves of the rowan (*Sorbus aucuparia*), which consist of several pairs of dentate **leaflets**.

► They then study how the leaves are arranged on their stem and note the order and precision of this arrangement for each species.

They distinguish, for instance:

- leaves that are arranged alternately on each side of the stem, known as alternate leaves, with a single leaf appearing at each level (node) on the stem, as in the case of the green alder (*Alnus viridis*) or of the diamond-shaped leaves of the downy birch (*Betula pubescens*);
- leaves that are arranged opposite each other; with two leaves facing each other at each level, as do those of the sycamore maple (*Acer pseudoplatanus*) or the Swedish dwarf cornel (*Cornus suecica*);

- leaves that are whorled; appearing in clusters of three, four or five at each level, as in the case of the whorled lousewort (*Pedicularis verticillata*) or the lilac sage (*Salvia verticillata*), which is found in the limestone soils of the garrigues in the mountains of the Mediterranean area.

- ▶ Next, the class closely examine the branches of conifers and again discover a variety of “leaf” shapes and different arrangements of these needles or scales on the branches: the dense, rigid structure of the long needles of the arolla pine (*Pinus cembra*), in clusters of five to withstand the cold at high altitude; the paired needles of the Scots pine (*Pinus sylvestris*), which copes well with the hot summers of the arid hillsides; the dark-green, flattish needles of firs, attached singly to their branches and sometimes seen to be two-toned when turned over, like the white underside of the silver fir’s needles (*Abies alba*); the prickly needles of the spruce, arranged all round the branch; the short needles, set in erect rosettes, of the magnificent cedars found on arid slopes – the Atlas cedar (*Cedrus atlantica*) and the Lebanon cedar (*Cedrus Libani*); and lastly, the soft, pliable needles of the larch (*Larix deciduas*), these, too, set in rosettes, but more unusual in that they turn yellow in autumn and fall to the ground in winter.

- ▶ The pupils discover, through their sketches and drawings, that the leaves on a stem and the needles on a branch are arranged in a particular order, depending on the species. This organization of plant elements, known as **phyllotaxy**, is also evident in the distribution of smaller branches on the main branches and of the main branches on the trunk.

- ▶ The teacher allows enough observation time for pupils to appreciate the ordering and the geometry (in the spacing of the various elements, for example) that govern the growth of plants.

- ▶ Lastly, the teacher asks the class to consider the factors that inhibit the natural growth of a tree or shrub or give it a stunted or distorted appearance.

- What causes a tree to lose its natural shape?

- Do some species naturally have a dwarfed or prostrate habit, because of genetic characteristics resulting from adaptation, their genetic response to environmental pressures?

- Do other species grow into twisted or deformed shapes as a result of wind, frost, snow, solifluction, sunlight or the impact of human activities?



Flag tree, deformed by the wind



29. Dead trees in salty soil,
Death Valley, California, USA
© Michel Le Berre



30. Thinly populated pine forest on boulder field,
Yosemite National Park, USA
© Michel Le Berre

4. Think about the effect of external elements on the habit of a plant

- ▶ The teacher reminds the class that a plant's shape is pre-programmed by its genetic make-up. There are, however, factors that can disrupt the expression of this programme.
- ▶ The class is taught how to differentiate between the genetic characteristics of a plant (due to adaptation) and external factors that influence the expression of its genetic make-up.

A. The effect of wind, frost and snow

To brave the fury of the wind at high altitude, plants on the high summits are short (with reduced stems) and low-lying.

Cushion plants are said to have a bunched, ripple-effect architecture; such plants, namely the Swiss rock jasmine (*Androsace helvetica*) or alpine toadflax (*Linaria alpina*), are shaped like the crown of a hat and grow flat against the rock.

Woody plants manage to survive as creeping dwarf shrubs or else assume an “espalier” shape, the ground itself providing the support.

Subalpine forest pines, such as the mountain pine (*Pinus mugo*) and *Pinus pimula* in the Far East, develop a thick mattress of low branches, which protects them from the snow in winter.

- ▶ The pupils take due note of these particular habits and try to produce a few sketches of them, while the teacher explains that the habits in question are genetically determined (they presuppose a gene pool) as distinct from being malformations due to the direct action of external elements.

Example:

The mountain pine (*Pinus mugo*) retains its prostrate, low-lying shape even when it is cultivated at low altitudes. It is an intrinsically mountain species.

- ▶ For the purposes of comparison, the teacher draws pupils' attention to other specimens of species, whose contorted, dishevelled shapes actually are attributable to the mechanical action of bad weather.

The “flag” shape of numerous trees in mountain areas, for instance, is caused directly by the wind, aided by the cold.

A tree might grow lopsided because of violent winds, which blow off the buds on the exposed side, so that all growth occurs on the other side of the tree. Under the combined effect of wind and frost, the higher branches exposed to the wind are also destroyed by icy blasts, broken off or drilled full of holes by icicles.

► Accompanied by the teacher, the pupils climb up to the high altitudes, looking for specimens that have the curious “flag” shape. They make a few sketches of this strange, almost other-worldly subject.

B. The effect of human activity

1. Overgrazing

► The teacher reminds the class that in arid mountain areas (from the high, hyper-arid mountains of Iran and Afghanistan to the dry mountain areas of the Mediterranean region), vegetation is very sparse and herbivores feed directly on the **ligneous (woody) plants**.

- In the dry season, animals plunder the evergreen – **sempervirent** – foliage and devour the little vegetal matter they provide.

- When the leaves have all gone, they turn their attention to the thorns and branches and even the young shoots, when the plant is trying to replenish its foliage. In such cases, environmentalists speak of negative impact on the plant cover and of **overgrazing**.

Example:

In the mountains of Crete, the gnarled cedars and Cretan maples (*Acer sempervirens*) are literally shorn of their leaves and “gnawed away” by goats until they look like bonsai trees (ornamental trees whose diminutive size is induced artificially, especially in Japan).

2. The collection of firewood

► Among the negative impacts caused by human beings, the teacher returns to the unsustainable exploitation of each blade of grass and each leafy twig in arid mountain areas. Although collecting these resources on a systematic basis allows cattle to be fed and produces wood for the kitchen fire, it ultimately leads to the total loss of pockets of trees that are all too sparse to begin with.

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31. Argan under pressure from herbivores, Morocco
© UNESCO-MAB

32. Solitary acacia, *Air*, Niger
© Michel Le Berre

33. *Balanites aegyptiaca*, *Air*, Niger
© Michel Le Berre

33





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34 & 35. Forest areas give way to agricultural needs, Entlebuch Biosphere Reserve, Switzerland
© Thomas Schaaf



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Example:

Such pockets are found, for example, in certain favourable humid spots in the Sahelian mountains, and the sight of the pruned trees (“slashed” might be a better word), such as *Ziziphus mauritania* or *Balanites aegyptiaca* that humans leave in their wake are evidence enough that they have been there.

► The pupils carry out their own investigations. They identify trees that have been stripped bare, had their branches broken or have suffered damage to their structure. They produce sketches, highlighting details that point to the cause of the disfigurement or destruction. For these purposes, they can insert text or arrows into their drawings.

► Next, the teacher deals with the issue of deforestation, pointing to certain human activities that not only distort or influence the natural growth of trees or shrubs but prevent it altogether, sometimes irreversibly by wholesale deforestation. Such deforestation compromises the balance of an ecosystem, by removing the benefits of the ecological functions that trees fulfil at these altitudes.

3. Deforestation by the herder in the ecotone between forest and grassland

► The teacher comes back to the transition area, or ecotone, between forest and meadowland, which sometimes merges with heathland.

► The teacher explains that the pressure on plants from large flocks of sheep is so great that those plants that are vulnerable to being trampled or crushed owing to the constant presence of cattle, simply disappear. Herders make the situation even worse by disposing of native woody plants, on the grounds that they do not make good forage.

Example:

In temperate regions, alpine herders burn dwarf junipers, sometimes routinely, claiming that it causes a build-up of acid humus in the soil.

The plain fact is that the disappearance of the juniper aggravates the poor condition of the soil, since it leads to the proliferation of mat-grass (*Nardus stricta*), a hardy species that smothers other types of forage and is a sign that the pastureland is exhausted.

4. Large-scale deforestation

- ▶ Lastly, the teacher illustrates mass deforestation in mountain areas, using materials prepared in advance.
- ▶ The teacher explains that in numerous massifs in Europe, and to a lesser extent in North America, the upper limit of forest vegetation has been lowered artificially by human beings.
 - In the past, land was cleared to accommodate the occasional farm, its chalets and granaries on the alpine slopes; lower down the slopes, new pastureland and fields for growing silage were created, encroaching on the forest.
 - Deforestation for grazing purposes or for the growing of crops is still intensively practised in some regions of the Andes and the Himalayas, sometimes to excess.
 - Overall, however, clearances that do the greatest damage to mountain ecosystems in Europe are those that remove large swathes of forest in order to develop winter sports sites at the expense of the plant cover.
 - The creation of ski-slopes and chair-lifts, and the reshaping of the landscape by bulldozers open up pathways and artificial thoroughfares; these become channels for runoff and active erosion sets in. Elsewhere, the grassland deteriorates and, on the exposed soil, gullying, too, starts to appear and becomes a permanent feature.
- ▶ The teacher makes pupils aware of the work done by foresters, who frequently reforest this area on the upper limit of the forest, since this is an area where dangerous avalanches can start. Reforesting at this altitude and extending the forest further up the slope can avoid catastrophes. The trees planted here will take time to grow, but once they are sufficiently developed, they will hold the snow cover in place.

5. Return to the essential role of trees in mountain ecosystems

- ▶ To end the session, the teacher explains that by destroying forests, human beings are contributing to the degradation of the land in mountain areas, since a whole range of functions that are generated by trees disappear, especially when the crowns of these trees possess leaves or needles.
 - The crown acts as a shield against the wind at mid-altitude and can protect crops of barley, hemp and flax in agroforestry areas, whether these are located on the slopes of the Andes, the Himalayan massifs or even the Alps.
 - Once the leaves or needles have fallen to the ground, they decompose, making the soil richer in organic matter. Plant cover consisting of woody matter constantly produces organic matter and humus, since it promotes biochemical erosion: earthworms and micro-organisms in the soil, in conjunction with the tree's **litter** and the action of its roots penetrating deep into the soil, react with the subsoil, turning it into a thick layer that produces a gentle surface relief. Trees therefore build up the soil in mountain areas and hence are effective in protecting it against mechanical erosion
 - Trees also create plant cover that is protected, since moisture builds up at the base of their trunks; this process of humidification binds the soil particles together.
 - Finally, the roots of trees play a central role in mountain areas, since they hold the soil in place and prevent it from slipping down the slope, the root divisions providing anchorage points that create a stable structure.

03

“Life at the top” or the adaptation of mountain plants

Level 
intermediate

Place  
classroom
and outdoors

Duration 
3 sessions

Objectives

1. Discovery of the environment

The pupils discover the different ways mountain plants adapt to the extreme conditions at high altitude by drawing them, as a way into exploring their morphological features in particular.

2. Knowledge and comprehension

The pupils learn to distinguish between the morphological adaptations of mountain plants and their physiological adaptations, compare these adaptations to the adaptations of other plants growing in hostile environments, such as dryland ecosystems, and acquire an understanding of the concept of convergent evolution.

Methodology

1. Identify the most typical morphological adaptation of plants by drawing them

► The teacher takes the class up to high altitude (following preparatory procedures outlined earlier) in order to study some of the more striking morphological adaptations adopted by mountain plants.

Depending on the part of the world, these summit plants have to battle against intense cold, which increases with altitude, violent desiccating winds, wide variations between day- and night-time temperatures, frost, snow, a very short growing season and, in tropical mountain areas, the constant humidity of the air and the soil, in addition to mist and wind on exposed ridges.

36. Mountain houseleek (*Sempervivum montanum*)
(*Crassulaceae*), plant and flowers (detail), *Simplon Pass*, Switzerland
© UNESCO/Olivier Brestin

37. Cushion plant, *Khardungla*,
Pass, Ladakh, India
© UNESCO/Olivier Brestin

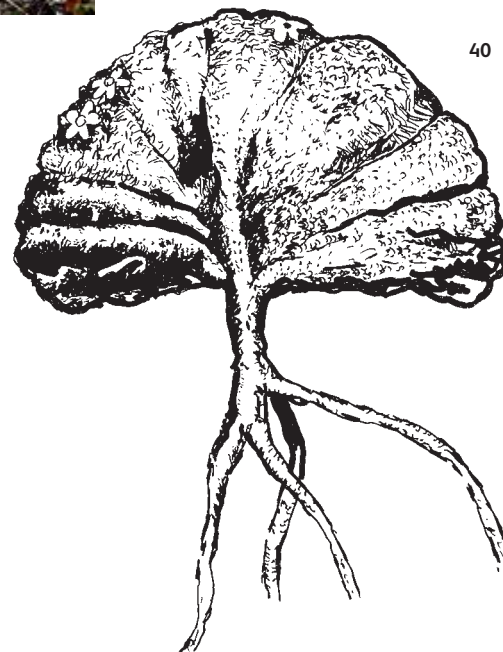
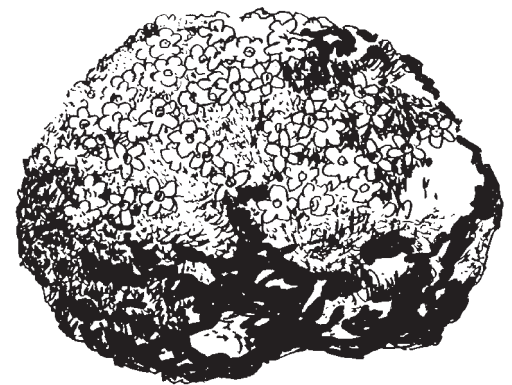


- ▶ The teacher explains that, in order to combat these hostile climatic conditions, especially the fury of the wind, high-altitude plants have short stems and form a carpet on the ground.
 - ▶ The teacher completes the explanation by referring to the climatic factors that prevent the stem from growing longer:
 - intense light at high altitude blocks the growth of stems (even though it promotes photosynthesis by leaves);
 - while growth could, then, in principle, take place at night, it is again blocked or restricted, this time by the night-time cold;
 - in addition, the wide discrepancy between day- and night-time temperatures reduces the plant's capacity for growing a longer stem.
 - ▶ The pupils observe on site that plants tend to bunch together; this is the result of the general shortening of their stems combined with a high capacity for ramification.
- The pupils identify and draw the most striking morphological types and look for potential similarities between these plant forms and everyday objects.
- ▶ They familiarize themselves with cushion plants, noting their general shape – a rounded cushion or dome – and their structure: from very short stems, they branch into densely packed forks, each branch growing identically so that together they form a hemispherical, bell-shaped plant with its terminal flowers sitting on top.

38. Cushions of alpine toadflax (*Linaria alpina*), Simplon Pass, Switzerland © UNESCO / Olivier Brestin



39. Moss campion (*Silene acaulis*), Simplon Pass, Switzerland © UNESCO / Olivier Brestin



40. Cushion plants at the alpine stage

Example:

The class climbs up to a rocky area in order to study, touch and part the tightly bunched cushions of saxicolous plants (from Latin saxum, meaning “rock”), such as Swiss rock jasmine (*Androsace helvetica*), which colonizes the limestone rock faces, or moss campion (*Silene acaulis*), which prefers siliceous ridges.

► The pupils then pick out the characteristic rosette shape into which some plants grow in order to promote leaf growth. Here, too, the same stem-shortening principle is at work: the nodes on the main stem are extremely close together and, as a result, leaf growth is bunched at the base of the plant.

The rosette is the result of a circular arrangement of leaves that spread out and radiate from the hypocotyl between radicle and the stem. The pupils may associate this shape with the shape of a star that has numerous points or a flower with a fully opened crown.

► They enjoy detecting, bringing to light and drawing the rosettes of the tumbling waters Pyrenean saxifrage (*Saxifraga longifolia*) or the common houseleek (*Sempervivum tectorum*), from which a floriferous stem sometimes emerges that will die off after flowering.

► They raise the layers of leaves and part the ramifications in order to produce cross-sectional drawings, as well as side views and top views of the rosettes and the cushions.

► Touching and feeling the plant’s substance, the pupils gauge the leaf thickness of fleshy, succulent plants covered by a waxy cuticle, such as the houseleek, which store their water reserves in their leaves.

► With the teacher, they compare the ways in which mountain plants and desert plants adapt.

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41. Mountain sainfoin and bird’s foot trefoil (Fabaceae) clinging to rocks, Mont Laitmaire, Switzerland
© UNESCO/Olivier Brestin

42. Common houseleek (*Sempervivum tectorum*)
©Hélène Gille

43. Rosette foliage of common houseleek with floriferous axis



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2. Use drawing as a basis for comparing mountain plants and plants in dryland areas

► As a first step, the teacher goes over certain general traits of plants and their role in the biosphere:

- without plants, there would be hardly any life at all on Earth;
- they release into the atmosphere the oxygen that we breathe;
- plants breathe and transpire, just like ourselves;
- when plants transpire, this generates humidity. **Transpiration** cools the air by several degrees in dryland areas and causes condensation in mountain areas, upon contact with cold air masses.

Note:

At a certain height on the slopes of tropical mountains, the forests, still dense, are engulfed in a mass of cloud, since they are in the front line, where the mountains cause masses of air to rise and then condense. The trees fuel cloud formation by releasing water vapour through their stomata during the transpiration process. The concentration of water vapour is such that the humidity is constant and, in combination with high altitude winds, prevents plants from growing at this height. Any trees that do grow are small in stature, stunted, gnarled and covered in mosses and epiphytes.

Example:

Forests in the Luquillo Mountains of Puerto Rico that grow at this height are known poetically as the “elf forests”.

- In addition to the process of transpiration, plants also generate the process of **photosynthesis** in order to synthesize substances necessary to their growth.
 - Most plants are rooted in the soil and take up water and vital nutrients through their roots, as well as carbon dioxide through the stomata in their leaves.
 - Owing to the presence of **chlorophyll**, a green pigment contained in their leaves or their stems, plants then harness solar energy and use it to convert the water and carbon dioxide into simple sugars that constitute their food. This chemical reaction is called photosynthesis.
 - In absorbing their food, plants then produce vegetal matter that will sustain other living organisms (herbivores).
 - As this is happening, the plant discharges oxygen into the atmosphere as a by-product.

44. *Rhododendron campanulatum*, near Lake Tsomgo, Sikkim, India
© UNESCO/Olivier Brestin



45. Harvesting tea, Happy Valley Tea Estate, Darjeeling, India
© UNESCO/Olivier Brestin





46. Tropical montane cloud forests,
Hawaii, USA
© Thomas Schaaf

- ▶ The teacher then revisits the principal characteristics of “xerophilous” plants (plants that like dry conditions).
- ▶ The teacher refers to one type of adaptation developed by **succulent** plants to cope with the lack of water in dry ecosystems. They accumulate and store water in specific organs, namely leaves, stems, trunks or even roots, and this accounts for their shape and volume.
- ▶ The pupils apply this information to the plants they have just been studying, to the houseleek, for instance, and its thickened leaves.
- ▶ The teacher explains the following points.
Mountain winds, like desert winds, are desiccating and increase transpiration. Arguably, the violence of dry winds at high altitudes, combined with the biting cold, sometimes poses a greater threat of dehydration than the dryness of the air in desert latitudes.
- ▶ The class then clearly appreciates the connection between the shape of the tough, thick, even swollen, foliage found at high altitudes and the fight against desiccation.
- ▶ The pupils also associate the shape of cushion plants with their capacity for retaining moisture: the new shoots grow under the old leaves, which dry out inside the cushion, and accumulate humus and a high proportion of water. The habitat remains moist during periods of drought.
- ▶ The same thing happens in the case of rosette plants: the upper parts of their foliage die off but remain in place, protecting the new shoots from desiccation.

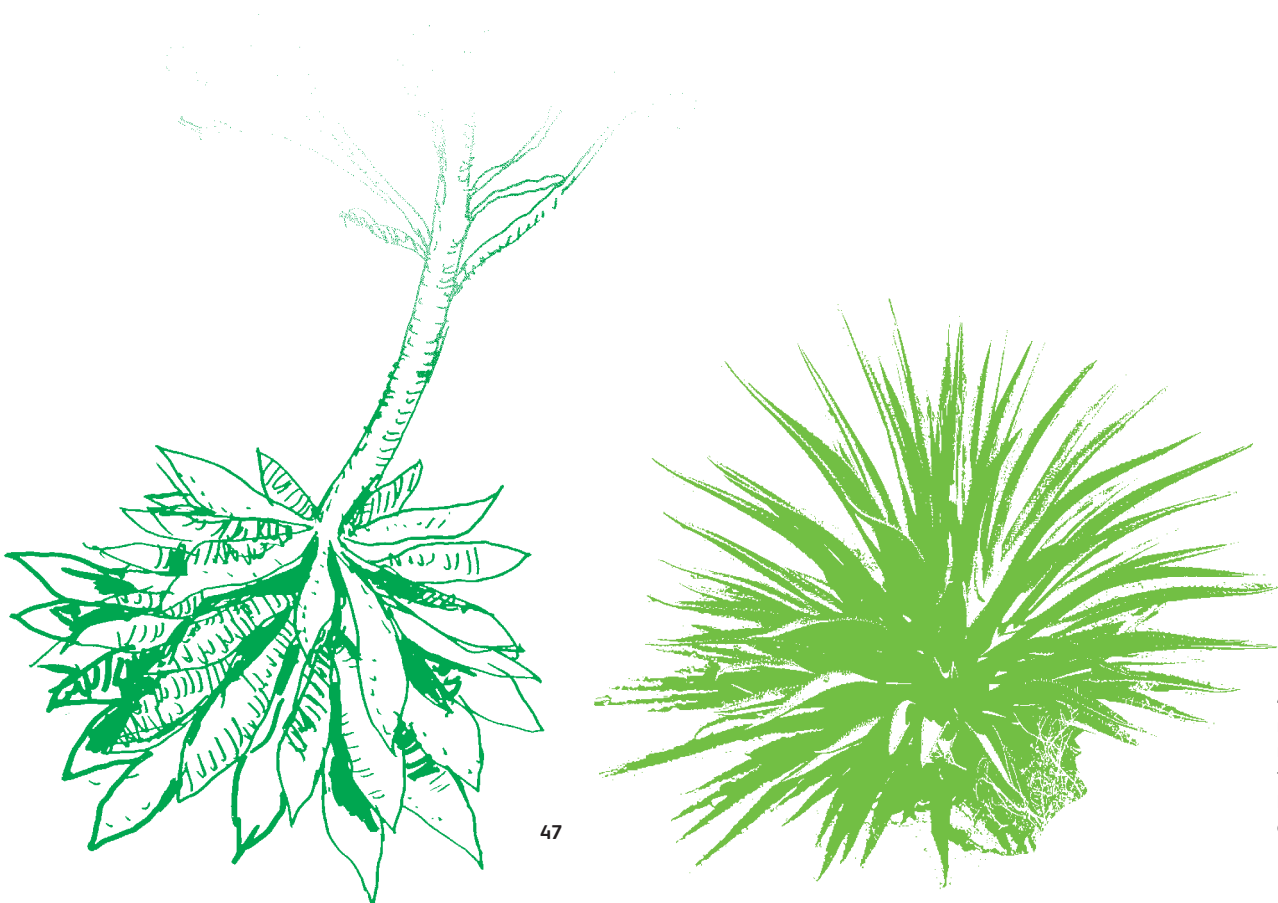
- ▶ Pupils then start on a series of fun drawings comparing the rosettes of mountain plants and the agaves and aloes in dryland areas, and the cushion plants at high altitude and the dome-shaped cushions of desert cacti.
- ▶ They also capture through their sketching and certain effects of texture obtained with pencil, the virtually identical appearance of **tomentose** plants, whether they be dryland or mountain plants.
- ▶ The drawings deliberately exaggerate the short hairs on the leaves of the edelweiss (*Leotopodium alpinum*), whose many functions include moisture retention. Also, a parallel is drawn between the warm, whitish “coat” of wormwood and the down of *Espeletia schultzei* in Venezuela, which, in the context of tropical high altitudes, is as much a screen against excessive solar radiation during the day as a protection against frost at night.
- ▶ By making comparisons and using material compiled earlier in the classroom, the pupils identify a few hairy surfaces among the dryland plants and make a variety of comparative drawings.

3. Clarify the concept of convergent evolution

- ▶ The teacher explains that the particular characteristics of mountain plants cannot be attributed purely to the impact of the environment, in terms of a simple cause and effect relationship.
 - Adaptation is not a matter of fitting in with or adjusting to a context; high-altitude plants are not lowland plants reshaped by altitude, they are species in their own right, endowed with a specific gene pool. Adaptation presupposes genetic inheritance. Only over time and by means of genetic encoding can environment be said to influence plants and to impose on them a particular form of existence.

High-altitude plants are “born” with, or germinate with, their particularities.

- Moreover, when plant species evolve in similar ways to resist extreme conditions (of intense heat or severe freezing, both of which lead to desiccation) despite growing in different geographical locations that are sometimes far apart and having no common ancestor (belong to different families), the phenomenon is known as **convergent evolution**.



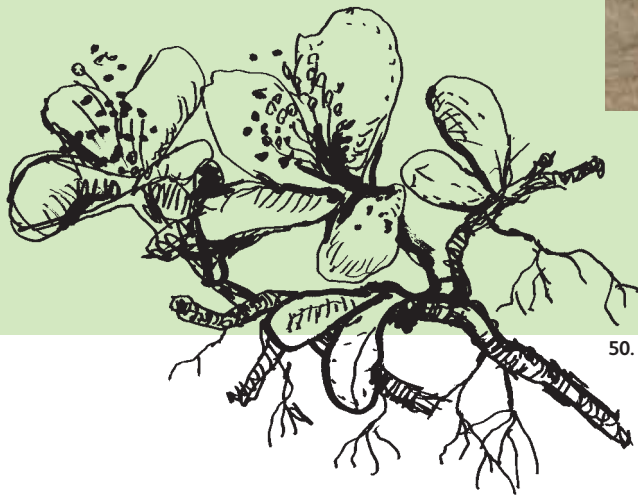
47. Drawings comparing mountain and desert rosette plants, tumbling waters Pyrenean saxifrage (left) and agave (right)



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50. Retuse leaved willow (*Salix retusa*)

48. Creeping Norway spruce,
Simplon Pass, Switzerland
© UNESCO/Olivier Brestin

49. Dwarf pines,
Uzice region, Serbia
© Natasha Lazic

Example :

There is a remarkable convergence between certain mountain and desert plants, which develop a similar cushion- or rosette-shaped habit and even a layer of down or thorns (these particular traits can be seen as an added form of protection, against the teeth of cattle, since mountains, like dryland areas, are rangelands). These kinds of plant adaptation act as a defence against dehydration.

► The teacher explains that another form of convergence is found in the way roots have developed in mountain and dryland areas.

In both cases, the root system of plants is often huge and grows along two different lines:

- a system of horizontal roots, rather shallow, allowing the plant to absorb water over a larger area (and in the mountains, of course, allowing it to become firmly anchored, to withstand the winds, to strengthen its hold by moulding itself to the ground in the way that woody creepers extend their network);
- a vertical system, exemplified by the large pivoting root of cushion plants, which anchors the whole plant in the soil and also allows it to reach deep into the subsoil from which it takes heat, nutrients and, invariably, water.

By way of comparison, pupils can picture the pivoting roots of acacias in the wadis, which, in other parts of the world, plunge vertically into the soil to a depth of up to thirty metres in order to reach the **water table**.

4. Distinguish certain types of physiological adaptation in mountain plants

- ▶ At this stage in the exercise, the teacher may choose to show certain types of physiological adaptation in high-altitude plants by opting for on-site observation of plants at key moments in their growth cycle.
- ▶ Ideally, the teacher chooses the thaw or early spring to enable the class to observe how the pace of life in plants has slowed down under snowy conditions, though the plant still remains active, or to observe the explosion of flowers with the arrival of the first fine days.
- ▶ The teacher explains that the most interesting types of physiological adaptation concern the reaction of plants to a shorter growing season. This term refers to the time cycle plants need in order to perform their vital functions of germination, foliation, flowering and fructification.
- ▶ The teacher points out that the growing season becomes perceptibly shorter with altitude. Beyond 2,500 metres in temperate regions, it lasts no more than about a month and a half.
- ▶ The notion of a “growing season” helps pupils to understand what they have already observed, namely that there are no more trees above a certain altitude. In fact, these life forms need a long summer to complete their cycle of growth, and while the beech requires more than five months of warmth, even a larch or a birch requires three...

What strategies, then, have high-altitude plants developed in reaction to a growing season of merely a few weeks?

- ▶ The teacher first of all lists the small number of **annual species** that complete their cycle from seed to seed in a single growing season. These plants manage to speed up the stages and have adapted so as to complete the entire cycle of germinating, growing, flowering, becoming fertilized, fructifying and dying within the few weeks of the summer season... not without having first ensured the conservation of the species by dispersing fertile seeds. Quite an achievement! Such plants are, however, few and far between, since the environment of the mountain summits does not suit to them.

Examples:

They are plants of very small stature and with thin stems, such as euphrasias and snow gentians (*Gentiana nivalis*).

- ▶ The teacher then describes the various kinds of adaptation of perennial species, which live for several years, the stock surviving from year to year.
 - The very short growing season, is followed by a period during which these plants live life at a slower pace. In fact, they use a number of means to prolong the growing season.
 - Thus, some plants have persistent foliage, which enables them to absorb energy all year round, even in snowy conditions, as soon as a ray of sunlight penetrates the blanket of snow. They are thus protected and pursue their physiological activity, sprouting new leaves and flower buds very early on.

Examples:

This is true of the trumpet gentian (*Gentiana kochiana*), houseleeks, saxifrages and numerous ericaceae.

- ▶ Where the teacher is familiar with the area, the class can have fun clearing away a small area of snow to get a glimpse of buds and leaves that have already formed.
- ▶ The teacher explains that high-altitude perennial plants grow slowly, may go for years without producing any seeds and are usually propagated by **vegetative reproduction**.
 - Other plants cannot assimilate food directly through the snow, and their buds are not located at ground level, sheltered by the rosettes of their leaves, but actually in the ground, which provides the shelter.
 - The teacher explains that this is yet another way of surviving in a dormant state and of prolonging the growth cycle.

These plants also benefit from the mantle of snow, which is an excellent insulator. Taking full advantage of the fact that the ground temperature is stable and often positive, and of the permanent humidity, many bulb plants (**geophytes**), even after the seeds have ripened and the plant



51. Alpine clover (*Trifolium alpinum*) and golden cinquefoil (*Potentilla aurea*) on alpine grassland
© UNESCO/Olivier Brestin



52. Alpine toadflax (*Linaria alpina*) and oxeye daisy (*Leucanthemum vulgare*) on rocks
© UNESCO/Olivier Brestin



53. Alpine pansy (*Viola calcarata*) and golden cinquefoil (*Potentilla aurea*) on alpine grassland
© UNESCO/Olivier Brestin

has matured below the ground, may wait for months, or even years (during excessively cold periods) before properly germinating, budding and sending out young shoots.

Examples :

Noteworthy species include the spring meadow saffron (*Bulbocodium vernum*), the magnificent Didier's tulip (*Tulipa gesneriana*) and the numerous crocuses (*iridaceae*), which literally burst into flower as soon as the snow melts, dotting the grasslands with their generally light-coloured crowns.

These plants, without exception, influence the duration of their growth cycle, either by anticipating the various stages of growth or by resisting the extreme climatic conditions through economy of effort (a slower pace of life), while waiting for more clement conditions in order to perform their vital functions.

► The pupils are encouraged to make colour drawings of this springtime vegetation, of bulbs but also of flowering snowbells and anemones, which transform the upper slopes into the first of two coloured mosaics (the second one occurring in late spring). Even the rocks are decked with flowers!

► The class can produce two sets of drawings, a “before” and “after”, that contrast the blanket of pure white snow with a plant cover dotted with soft, fresh colours.

► The teacher gives a final example of physiological adaptation in the form of plants that ripen their seeds by retaining their flower scapes throughout the winter.

This is another means by which plants lengthen the ripening period for their seeds, which they carefully store “wrapped up” in the sheathes of their old leaves, in lichen or in their dried-out scapes, depending on the species.

Examples :

These are often tall plants that stand out clearly above the mantle of snow in winter, such as the blue sedge (*Carex firma*) or the yellow gentian (*Gentiana lutea*).

► The teacher explains that these plants ripen their seeds in the atmosphere, at a later stage, and that damp, cold conditions in winter, and even frost, are factors that activate rather than inhibit the ripening and germination of seeds.

Once the seeds are ripe, they are carried long distances by the wind and begin the first stage of the growth cycle.

► The pupils can produce a second series of comparative drawings, this time with the bright colours of late-flowering plants (appreciative of the long winter), such as certain poppies, aconites and, again, yellow gentians (*Gentiana lutea*).

5. Bring the activity to a close with the principle of plant associations

▶ To conclude the activity, the teacher revisits the principle of “plant groups” or “plant associations”.
 ▶ Firstly, the notion of vegetation is related to plant groups in the form of forests, scrubland, savannahs and grasslands.

▶ The teacher further explains that two comparable areas of vegetation consisting of the same basic vegetation – the grasses of a dry savannah or of an area of steppe, for example – might not have a single species in common.

▶ In fact, even when they grow in similar climates, plants are subjected to a whole range of factors, such as rainfall, wind, evaporation, light, average temperatures, temperature ranges, the chemical, mineral and physical make-up of the soil, and the other species present on the site.

Each of these factors, as well as their combined effects, acts on the vegetation and the plants it comprises. Vegetation, then, is a complete reflection of the resources and conditions present in a given environment.

▶ The teacher relates this notion to the mountain grassland level.

The same principle of plant association obtains, but this time it applies to a population consisting of a particular group of species.

▶ The teacher explains that these species no longer reflect the conditions of an environment but, more specifically, of a microenvironment and a microclimate.

- They have been subjected to the principle of natural selection, since the difficult conditions prevailing at high altitude, especially the extremes of temperature, have eliminated the less hardy species.

- Furthermore, only those species that can withstand competition from their neighbours are found in plant associations at these altitudes. Again, the other species have been eliminated.

▶ The teacher sums up by explaining that a plant association at high altitude therefore brings together species with particular requirements and displaying ecological affinities that link them to a specific microenvironment. These requirements are shared by the species, but may not be exactly the same for all the species. These requirements need only differ in one respect for peaceful coexistence to be possible between two otherwise competitive species.

Example:

To illustrate animal rather than plant associations, coexistence between ibexes and chamois, which differ only slightly in their food preferences, could be mentioned.

▶ The teacher ends by explaining that the grassland stage in mountain areas has highly diversified microenvironments, with great contrasts between one locality and another: a windy ridge gives way to an arid limestone slab, which, in turn, gives way to a peat bog, and beyond this appears a rocky area, followed by a hollow where the snow still lingers.

- These microenvironments harbour very specific communities of species, the balance between them being preserved by the total adaptation of a species to specific natural constraints and by the complexity of the relations that link each individual member to the others.

- Plant associations in high mountain areas are therefore very specialized and the higher the altitude, the simpler communities become, as they come under the pressure of accumulating constraints.

Associations, at this level, consist of few species and a small number of individuals.

Every species living high up chooses who to live with!

Association really is a matter of election.

Example:

Bellflowers thrive in association with purple gentians and alpenroses. At higher levels, edelweiss coexist almost exclusively with alpine asters and fleabanes.

04

An inventory of useful plants

Level 
intermediate

Place  
classroom
and outdoors

Duration 
5 sessions

Objectives

1. Discovery of the environment

Using an inventory compiled from drawings, oral and written descriptions, tasting and highlighting the differing qualities of those plants that meet certain needs in the local population, the pupils gain a full understanding of the direct usefulness of plants in the various spheres of the life of the community.

2. Aptitudes

Under the guidance of the teacher, the class learn to gather information and to think about the ways in which plants are harvested and consumed and, by extension, about how natural resources are managed. After talking to the local experts, pupils will initiate a debate on the management of resources with environmental professionals.

Notes and suggestions

For this laboratory workshop on the role of plants in their everyday lives, the pupils and teacher can use either a separate room or the back of the classroom.

They attach three large sheets of paper to the wall, for listing the plants, and reserve space nearby for displaying specimens; the whole area serves as a reception area, where plants can be tasted and mini-experiments conducted (plants in pots, dyes).

The teacher leading the activity takes a holistic view of the relationship between human beings and their environment, regarding the local population as an integral part of the ecosystem. Human activities, whether they be agricultural, industrial or commercial, have a great impact on ecosystems. We constantly receive products from ecosystems and derive numerous other advantages from them. These ensure our well-being and, more generally, our quality of life.

In this respect, the ecosystem will be perceived primarily as a source of crops and other useful products, a garden¹ in the wider sense, whose fruits are picked by the community and which the community, in return, must “garden” sensibly, combining economic development with the sustainable management of natural resources.

The teacher might consider grouping the plants around three themes illustrated by the three panels:

A. The Nourishing Garden;

B. The Healing Garden;

C. The Protecting Garden.

1. This neologism is modelled on the term used by Gilles Clément in his work accompanying the exhibition: *Le Jardin Planétaire [The Global Garden]*, Albin Michel, Paris, 1999.

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54. Spike of barley, steppe at high altitude, Ukraine
© Olivier Brestin

55. House made of bamboo, Singtam, Sikkim, India
© UNESCO/Olivier Brestin

56. Bamboo stalks, Sikkim, India
© UNESCO/Olivier Brestin



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Methodology

► The teacher divides the class into three groups of pupils, each group being in charge of one of the three panels providing an inventory of plants that are useful to the community. Each group thinks about how its panel should be organized.

► The pupils begin ordering the plants according to their use:

- food;
- personal care, medicines and rituals (bodily health and spiritual well-being);
- raw materials for building houses (shelter and protection for the family) and for making clothes (protection for the individual).

Some plants are used for different purposes and so will feature on more than one panel.

► With guidance from the teacher, the pupils in each group then draw the subdivisions in each panel.

A. The Nourishing Garden

1. Classify

► The pupils in this group make a preliminary classification of edible plants in the local area, according to the following categories:

- **edible bulbs**, e.g. garlic, onions;
- **edible stalks**, e.g. bamboo shoots (*Phyllostachys edulis*) – considered a delicacy if picked when they are still very young and their outer leaves are removed, celery stalks, lovage or Italian lovage (*Levisticum officinale*) and the underground stalks (tubers) of the potato;
- **edible roots**, e.g. carrots and cassavas (*Manihot esculenta*), from which fufufou, an edible paste, is made in the rainforest mountains of Africa;
- **edible leaves**, e.g. watercress (*Nasturtium officinale*), dandelion (*Taraxacum officinale*);

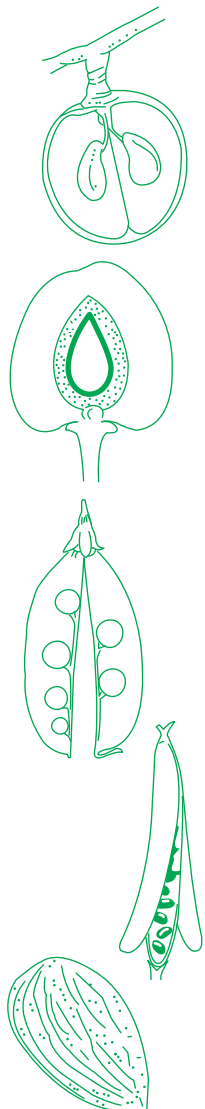
- **Pulpy fruits:**

- **berries or seeded fruits**, e.g. the abundant fruits of the forest, cranberries (*Vaccinium oxycoccos*) in the mountains of Scandinavia and Russia, sweet granadillas (*Passiflora ligularis*), a type of granadilla that grows at altitude in tropical regions, strawberry guavas (*Psidium cattleianum*) in the West Indies;
- **drupes, or single-seeded fruits**, e.g. olives in mountains in Mediterranean areas, apricots that are grown throughout the forests and oases in the mountains of central Asia.

- **Dry fruits:**

- on the one hand, **dehiscent fruits** (which can be opened), such as:
 - the **pods** of the various species of peas and beans (of the family *Fabaceae*), including the common bean (*Phaseolus vulgaris*) and the lima bean (*Phaseolus lunatus*) of the Andes, the broad bean (*Vicia faba*) in Russia and the cowpea (*Vigna unguiculata*) grown extensively in tropical Africa.
 - **siliquas**, including Indian mustard (*Brassica juncea*), which can be found at altitude in Siberia and Mongolia and is used for its seeds, which serve as condiments, and its leaves, with their spicy flavour, as a vegetable;
- on the other hand, **indehiscent fruits** (which cannot be opened), such as:
 - the **caryopses** of the family *Poaceae*, including wheat and maize, grown more or less throughout the world;
 - **achenes or single-seeded dry fruits**, e.g. the acorns from kermes oaks in the mountains of the Mediterranean region.

This gives pupils a first glimpse of the **natural resources** available, whether they be cultivated or wild.





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57. Apricot grove, Achinathang, Ladakh, India
© UNESCO/Olivier Brestin

58. Apricot blossom, Phyang, Ladakh, India
© UNESCO/Olivier Brestin



59. Apricots ripening, Dah Hanu, Ladakh, India
© UNESCO/Olivier Brestin

60. Dried apricot sellers, Leh, Ladakh, India
© UNESCO/Olivier Brestin



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62. Women checking drying barley, *Bitchu*, Sikkim, India
© UNESCO/Olivier Brestin



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63. Woman baking traditional bread, *Tiger* Village, Karakorum, India
© UNESCO/Olivier Brestin

64. Traditional bread, *Tiger* Village, Karakorum, India
© UNESCO/Olivier Brestin



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2. Draw on the panel

- ▶ Then, the pupils in the edible plant group take it in turn to enter into the relevant category on the panel one of the local plants that have been selected.
- ▶ They note the name of the plant in the appropriate box and do a coloured drawing of it in the same box.

3. Taste

- ▶ As soon as pupils have listed and recorded the details of local edible plants, they can move on to the next stage, which is to taste and at the same time to represent them on the panel.
- ▶ For this exercise, they bring from home samples of specimens or of dishes based on some of the selected plants.
- ▶ Depending on the region, they offer soups, fruit drinks, porridge, cakes, types of pasta, uncooked leaves or fruit under the watchful eye of the teacher. They naturally provide known edible species only. They test one another's ability to recognize flavours by blindfolding candidates for the taste test, who have to identify the plant.
- ▶ The same plant can be tasted twice, if variations are introduced through different family recipes.

Example:

In the mountains of Japan, the adzuki bean can be offered in the form of a porridge sample with sugar; it can then be offered again in a thinner version containing lotus seeds, when it is known as "adzuki soup". In the Andes, particularly in Bolivia, pupils can bring a sample of quinoa pancake or offer it in a creamier form, mixed with milk... it retains its typically "woody", rather strong taste, which the pupils recognize.

- ▶ This mini tasting workshop enables the teacher to create as many opportunities as possible for tasting and identifying the different flavours of known local plants (those readily available and others less so); in the case of wild plants, this might mean searching for increasingly rare specimens.

Example :

In the mountains of temperate regions, pupils can discover the taste of oregano (*Origanum vulgare*), either as a condiment or as a substitute for tea; they can savour an ancient soup, still known but no longer eaten, despite being palatable, namely nettle soup with its *Urtica dioica* base, which grows in the Alps in association with Geneva bugleweed (*Ajuga genevensis*); they can even rediscover elderberry (*Sambucus nigra*) jam, made from its fruit (black berries), or elderflower wine, with its base of macerated flowers. However, caution is necessary here: only the cooked berries are edible, and the berries of the elder must not be confused with the poisonous berries of the dwarf elder (*Sambucus ebulus*), which is an herbaceous species.

4. Seek and integrate information

► The pupils return to the panel and, after some preliminary research, add notes to their drawings on the use of edible plants:

- Is it a cultivated plant or a wild plant?
- If it is cultivated, is it grown from seed or is it planted?
- Is it eaten cooked or raw?
- What adjectives could be used to describe the taste of the plant?
- Is it a common or rare species?
- Is it a plant found in its natural state, has it become rarer locally over time?
- Is any information available on the **population growth** of this wild species?
- Is it an endangered and/or protected species?
- Does the plant contribute anything to food resources (by covering certain nutritional needs)?
- Does it contribute to a varied diet?

Observation

It is important for these notes to be visually incorporated into the panel, either being arranged around the drawings and “wedding” their contours, or forming separate but uniform blocks on the panel as a whole. They can be linked together by graphic symbols to indicate, for example, that a plant is rare or threatened with **extinction**.



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65. Fruit stall, Chowk Bazar, Darjeeling, India

© UNESCO/Olivier Brestin

66. Vegetable stall (variety of leaf and stalk) Bhutia, Darjeeling, India

© UNESCO/Olivier Brestin

67. Peas and herbs in the market, Bhutia, Darjeeling, India

© UNESCO/Olivier Brestin

5. Discuss local plants and food production with resource people

► At this point in the exercise, the teacher encourages contact or interaction with at least two local persons who are authorities on the local environment:

- someone elderly (a respected member of the community), who is well acquainted with the biodiversity of the locality as a source of extra food and income;
- a farmer/stock raiser who understands the importance of cultivated plants in food production and the role of **indigenous plants** in the preservation of the local ecosystem.

► The teacher gets the class to talk to these local actors.

- Is there evidence that uncultivated plants in mountain areas are becoming increasingly rare?
- Are certain harmful farming practices entailing
 - high rates of deforestation (because of the need for firewood or land for grazing),
 - soil exhaustion (through **monoculture**, using carefully selected modern species, or through overgrazing),

in combination with natural erosion, a permanent problem on mountain slopes, not a threat to the **conservation** of local plants that grow in the wild and are often a source of income in mountain areas?

Examples:

The inhabitants of the mountains of Sikkim and Bhutan earn a good price for giant cardamom plants, which they select from among the wild species growing on their slopes; other Himalayan farmers exploit wild species of lemon, orange and mango trees commercially, selling them in the markets; in Ethiopia, wild sorghum seeds are isolated, selected and sold for mixing with cultivated species of sorghum and for promoting mutual fertilization.

- In what ways are local biodiversity and natural plants essential to farming (and therefore to food production) in terms of their role in the ecosystem?

Examples:

Certain local or wild plants of the fabaceae family, such as lucerne, clover, vetch and alfalfa, can take nitrogen from the atmosphere and fix it in the soil, making it available to other plants. These plants are a particular asset, therefore, when it comes to establishing growing methods that aim at self-sufficiency without the large-scale use of fertilizers.

In the tropical mountains of Burundi, farmers and agriculturalists have tested the association of a leguminous plant grown as a hedge between rows of coffee trees. Studies have measured the benefits to coffee trees of the biological fixation of nitrogen.

In many of the mountains in the Andes and in Asia, crop rotation is practised, with alternate sowings of leguminous and non-leguminous species. When cereals replace lucerne or clover on a plot, they can take up a ready supply of fixed nitrogen.

68. True cardamom crops,
Singhik, Sikkim, India
© UNESCO/Olivier Brestin





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69. *Andrographis paniculata*, medicinal plant, Sikkim, India
© UNESCO/Olivier Brestin

70. Woman harvesting edible wild plants, Maenam Wildlife Sanctuary, Sikkim, India
© UNESCO/Olivier Brestin



B. The Healing Garden

1. Record and draw the medicinal plants on the panel

- ▶ Another group of pupils is created to deal with those local plants that possess medicinal or other beneficial properties and are used in **herbal medicine** and **cosmetology**.
- ▶ Following the same procedure as the earlier group, they record and draw the plant species and **medicinal plants** on the second panel.
- ▶ The teacher encourages contact between the class and the traditional healer or herb doctor, who is the local expert in this field.

The class ask him to take part in composing the panel.

He could, for example, contribute plant samples or the pupils could accompany him when he goes off to collect his samples, if he agrees to this.

- ▶ Following the valuable advice of the expert, the pupils sort the plants according to their properties. They are recorded in different sections, depending on whether they are known for their tonic, antifebrile, expectorant, anti-inflammatory or digestive properties.
- ▶ The teacher can avoid this vocabulary by simply referring to the ailments that the plants cure.

Examples :

In the Chinese provinces of Yunnan and Sichuan, but also in Mongolia, the dried roots of milk-vetch (*Astragalus membranaceus*) have been used as a tonic for centuries. The plant is recognized, in particular, as a stimulant of the immune system.

In the mountains of Chile, boldo is famous for its hepatic properties (properties connected with the proper functioning of the liver); its leaves are cholagogic (they stimulate the secretion of bile) and the plant is a traditional ingredient in herbal teas that aid digestion.

On Mount Kerinci, on the island of Sumatra in Indonesia, a local species of cinnamon-tree (*Cinnamomum burmanii*) is grown for the essential oil of cinnamon that is extracted from its bark. It is a recognized antiseptic (effective against the typhoid bacillus, for instance) and has antifungal properties (it reduces the spread of fungi, hence of yeasts and moulds, in the body). It can be used diluted with a plant (-based) oil for use in massages, as an inhalant, and a few drops can be used in cooking.

Among the local plants that grow in the mountains of Europe, mountain arnica (*Arnica Montana*) is known for its anti-inflammatory properties and is used for treating contusions (lesions resulting from blows that do not tear the skin) and muscle problems (sprains, strains and inflammation). As output still consists largely of plants picked in the wild, it has become vitally important to protect it as demand grows; it is regarded as an endangered species in both Germany and Switzerland.

Another plant that could be mentioned is coltsfoot (*Tussilago farfara*), whose dried capitula are the basic ingredient of some herbal teas and of syrups used to treat colds, coughs and bronchitis. The plant is both an expectorant (enables secretions from the respiratory tract to be expelled) and an antitussive (soothes irritated coughs), depending on one's needs.

► As for the edible plants, pupils do coloured drawings of the medicinal plants selected, classifying them on the panel. They take care to reproduce the colours of the capitula, the magnificent orange-yellow of the arnica and the strong yellow of the coltsfoot.

2. Identify how healing and rituals are connected through plants

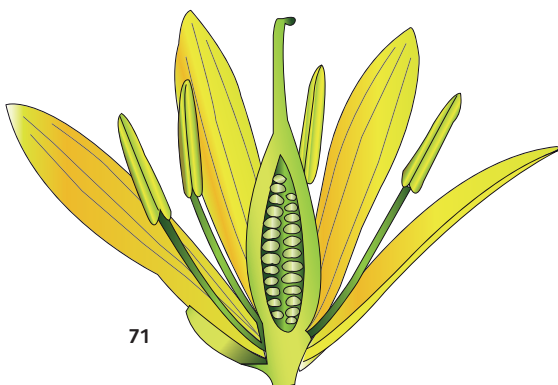
- The teacher broaches the subject of fragrances.
- The teacher explains that a number of local plants in mountain areas are used for their exceptional aromatic qualities in the manufacture of expensive products, preparations, elixirs and liqueurs, and in the production of **essential oils**.
- The teacher also explains that the intensification of aromatic properties is another indication of the plants' adaptation to mountain environments and to the need to be identified by the occasional pollinating agent that braves the wind and cold.
- Guided by the herb doctor, the pupils observe that in conjunction with their high concentration of pigments, the majority of flowers are laden with nectar and give off very strong scents.
- In the classroom, the teacher revisits some examples.

Examples :

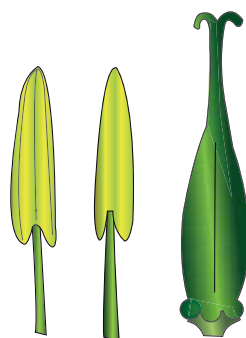
The capitula of alpine wormwood (*Artemisia mutellina*), and the plants' hidden parts, such as the rhizome and the roots of the (great) yellow gentian (*Gentiana lutea*), are used to make highly rated liqueurs.

The natural aromas are extracted by distillation as in the production of essential oil, which is obtained from the aromatic volatile constituents of the plant.

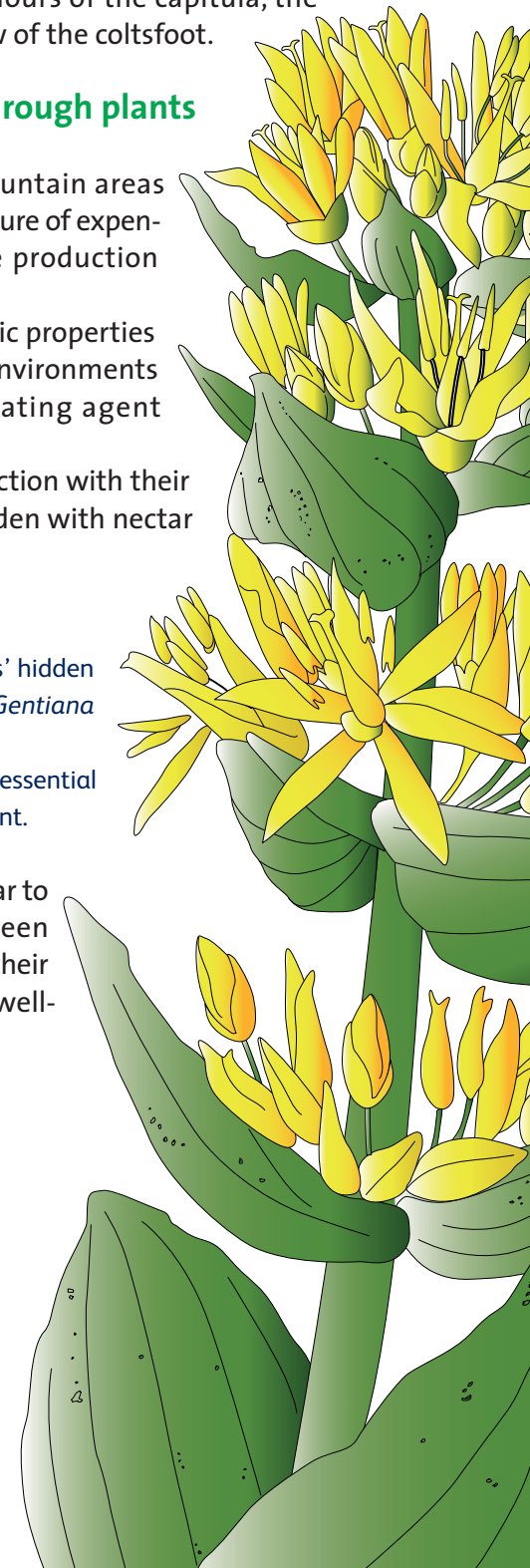
- The teacher returns to the use of **aromatic plants**, in particular to the personal care oils in cosmetology – fine oils that have been produced for beauty care on every continent for centuries – and their use in the practice of rituals related to worship or to spiritual well-being.



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Examples :

Myrrh and incense are traditionally associated with funeral ceremonies in many mountain cultures of the countries around the Mediterranean; juniper essential oil, especially cade juniper (*Juniperus oxycedrus*) – long used for washing the dead and during rituals connected with embalming – is still used today to promote physical and spiritual harmony. Tibetans also use the berries of a neighbouring species (*Juniperus recurva*), which is also **dioecious**, for making the “incense” that they burn during purification rites.

► The teacher explains the sacred dimension of certain plants.

– They are sacred because they are associated with the practice of a religion/religious worship and with various rituals, whether these are funerary rites, initiation rites or healing rituals.

– They are regarded as sacred because they grow on land that is itself seen as sacred by the community. Such land consists of remote, protected areas, often situated “higher up” the mountain, and in a sense “closer” to a form of divine presence worshipped as part of the local animistic tradition or else reserved for ancestor worship.

Example :

High up in the Andes, situated on the very edge of the human world, is the paramo, an area regarded as sacred and demanding a certain code of behaviour requiring the population to respect and maintain the site. The same is true of the sacred forests of the sherpas in Tibet.

► The teacher explains that the few trees that do exist in these remote spots are often considered to be the habitats or the manifestations of the divinity that is worshipped.

Example :

The sherpas of north west Nepal venerate specimens of juniper belonging to the same species as the rhododendron, willow and birch, and located at symbolic points in the landscape. Small altars reserved for prayer are often built at the foot of these trees.

► The use of local plants during rituals, their veneration as objects of worship, their sacred dimension and their use in cosmetology are all mentioned on the panel dedicated to medicinal plants in a subdivision headed “beneficial plants” (the well-being of bodily health and spiritual well-being).

► The pupils specify these uses and include precise information, as they ensure a complete match between text and drawing in arranging this subdivision of the second panel.

3. Explore the relationship between plants, cultural traditions and conservation

► To complete the exercise, the class reflects on the local population’s consumption of the beneficial and medicinal plants found in the local ecosystem.

- What non-destructive methods can be used for harvesting these precious, usually wild, plants?
- Have there been cases of species extinction?

71. Stamens and pistils of the great yellow gentian flower (*Gentiana lutea*)

72. Inflorescence of great yellow gentian (*Gentiana lutea*)

73. By-product (sweets) with yellow gentian base





74. Planted willow trees,
Phyang, Ladakh, India
© UNESCO/Olivier Brestin



75. Barked willow branches,
Phyang, Ladakh, India
© UNESCO/Olivier Brestin



76. Barking willow branches,
Phyang, Ladakh, India
© UNESCO/Olivier Brestin



- Have there been any attempts to balance the size of the harvest against the population size of particular species?
- Has any attempt been made to limit or to manage the harvesting of wild plants?
- What are the consequences for cultural traditions if a species becomes extinct?
- Is not the vast knowledge of the herb doctor or the traditional healer a living record of the relationship between the local ecosystem and the practice of herbal medicine, which is often vital in mountain areas where access can be a real problem?
- Can rehabilitating this kind of local knowledge contribute to the preservation of the ecosystem?
- Can this local knowledge be improved by a better understanding of the recommended doses of particular plants, of their counter-effects (toxicity of species) or side-effects, which can be harmful in the long term?
- Does the knowledge of the herbal doctor and the healer not complement the theoretical and scientific knowledge that children acquire at school?
- How can the transfer of knowledge between generations be promoted?
- Finally, has the population protected the areas where these plants grow owing to the importance attached to certain plants in the practice of religions generally?
- Are they **sacred natural sites**? Can something be learnt from these sites in order to preserve the environment?

C. The Protecting Garden

In addition to providing food, medicines and the ingredients for our rituals, plants are also a source of materials for building houses.

- ▶ A third group of pupils focuses on those plants that make up every form of housing devised by human beings in mountain areas to protect themselves from the harshness of the climate and the weather.
- ▶ The pupils also include species that produce fibres and barks that are useful in the manufacture of furniture and clothes, another form of physical protection in the environment.

1. Do some preliminary research

- ▶ The teacher gets the pupils to research the various types of **vernacular** housing in the area.
- ▶ The class interview well-informed members of the community with recognized experience of herding, forestry, crafts and light industry.

Can several types of dwelling be distinguished, between which the villagers move, with each change of season and altitude, on account of their work? Do grazing patterns, for example, force them to alternate between temporary quarters and a permanent home?



77. Willows pruned and topped, Phyang, Ladakh, India
© UNESCO/Olivier Brestin



78. Stored willow branches, Phyang, Ladakh, India
© UNESCO/Olivier Brestin



79. Traditional ceiling made from poplar and willow, Phyang, Ladakh, India
© UNESCO/Olivier Brestin

2. Make an inventory of plants that are useful for house building and fittings

► The pupils think about the type of housing selected.

Types of nomadic dwellings:

- A yurt, or ger, is a common type of dwelling in Central Asia, widely used by nomads in Mongolia. What is it made of?

Its frame is covered with layers of felt, which keep the cold out. Is the frame made of willow or larch?

The frame consists of a woody trellis held together by rope. Is the rope made of horsehair or of plant material?

The central dome is formed by poles. What material is used to make these poles?

The Kyrgyz yurt, which does not have a sheet over the felt coverings and soon dries out, can be dismantled. Can the ger be similarly dismantled?

- The huts used by hunters in the mountains of northern Russia are traditionally protected by a covering of birch bark? Is this still the case?
- Goths” are mobile shelters designed by herders in the Annapurna region of Nepal. Apart from bamboo and rhododendron, what else is used for their construction?

Types of sedentary dwellings:

- The houses of Nordic peoples, such as the Russian and Siberian isba or the Finnish kota, have walls built from perfectly straight trunks placed horizontally one on top of the other (a technique called “horizontal stacking” (see photograph 86, p.106).

Are these spruce, larch or fir trunks?

Their roofs are covered with small squares of bark? Which species are preferred for these tiles?

► The class turns its attention to other types of sedentary dwellings:

- In the mountains of Western Europe (Prealps, Pyrenees) and the Mediterranean region, where two thirds of the original forest have been destroyed, stone has frequently been used for building at high altitude. Most buildings in the mountains are made of stone at the lower levels, and a wooden frame.

Horizontal beams, or wood-ties, were incorporated into the stone walls to strengthen them. What species of trees were used for these wood ties?

The roofs were tiled in thackstone (large schistose slabs). Which species were used to support such heavy loads? Sometimes, whole trunks of spruce or larch.

- In some mountain areas of Europe, where the forests are still diversified, some traditions of wood-tiled roofs have survived; these tiles are made of high-quality timber, to resist moisture.

Examples :

Chestnut is used for wood tiles (‘essendoles’) in the Alps, and the heartwood of the best spruces for tiles (‘ancelles’) in the Jura; in the Tyrol, arolla pine is used.

- ▶ After a close study of a small number of selected houses, the pupils record on the panel the plant species from which they were made.
- ▶ They divide the upper part of the panel into smaller sections, each of which will feature a particular type of dwelling, and they group together the plants that relate to it.
- ▶ As with the previous panels, on each occasion, the pupils draw a specimen of the plant used.

3. Depict a typical dwelling on the panel

- ▶ The group of pupils make the necessary preparations and execute a large-scale drawing of a typical dwelling in the lower part of the panel. They choose to sketch it either from the outside or from the inside, or both.
- ▶ Using arrows and notes, they indicate clearly the plants that have been used to make the house.
- ▶ They highlight details of its construction and fittings, produce close-ups of the roofwork, construction of the walls, furniture, anchor points and plants used for tying the various components together.

Example :

In the mountains of tropical regions, in Tamil Nadu in southern India, the traditional toda dwelling features a roof structure made of acacia or eucalyptus wood (a hardwood) or of individual bamboos tied together with rattin (*Calamus pseudotenius*) and covered with grass that has been carefully cut and made into bundles (*Andropogon polypticus*).

4. Make the connection between environmentally friendly dwellings and natural resources

- ▶ The teacher explains how the mountain population has learned to make the most of each plant's qualities by gradually developing specific, highly specialized uses for plants in building and fitting their houses.

- In the mountains of the Mediterranean region, Canada and Japan, the qualities of cedar wood are put to the best use.

Although the wood is rather brittle, which restricts its use for structural purposes, a variety of other uses have been found for it, capitalizing on its resistance to rot: in ship-building, as cladding for external walls of houses and for roofs.

Its fragrance has made it a favourite among makers of high-quality furniture and coffins.

- In the mountain areas of Japan, both traditional and modern-day houses still reflect the abundance of species rich in resin and plant essences.

These dwellings evidence a certain amount of planning and sustainable management with regard to natural resources, by combining species and selecting them for specific purposes in the detail of the house.

Example :

The wickerwork screens used in summer to divide rooms are made from ancient cypresses and their tracery or trelliswork of strips of wood allow the air to circulate freely and create a pleasant smell at the same time.

- ▶ The class might, however, think about the following.

Although people living in mountains can take full advantage of the qualities of local plants, does this necessarily mean that they produce housing that is adapted to the environment and to climatic conditions?

Thus, while Japanese houses, being lightweight structures that seem to have been placed gently on the ground, enable the consumption of forest species to be held at moderate levels, does this necessarily mean that they are adapted to repeated seismic quakes caused by volcanic activity? In addition to appropriate use of forest resources, other criteria come into play in planning sustainable building in mountain areas.

- ▶ The teacher gives the pupils some guidance in thinking about these issues. These criteria involve a consideration of contour lines, orientation and relief.



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80. Low-relief work on magnolia wood, Darjeeling, India
© UNESCO/Olivier Brestin



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81. Low-relief on magnolia wood, Darjeeling, India
© UNESCO/Olivier Brestin

82. Bushel-maker's workshop (fir and willow), Château d'Oex, Switzerland
© UNESCO/Olivier Brestin



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83. Tools and gauges in the workshop, Château d'Oex, Switzerland
© UNESCO/Olivier Brestin

84. Cowshed roof made of shingles, Mont Chevreuil, Château d'Oex, Switzerland
© UNESCO/Olivier Brestin

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85. Shingles (detail), Château d'Oex, Switzerland
© UNESCO/Olivier Brestin

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Thus, a well-sited dwelling will often be situated on the slope facing the sun (adret), on a rocky outcrop rather than beneath one, will be of a piece with the slope in the sense of fitting snugly into it, moulding itself at first-floor level to the slope behind. If it is part of a village, the houses will be grouped more loosely, will be more spaced out if they are at right angles to the wind, and more tightly packed, closer together, if they are exposed to the wind.

5. Draw conclusions about the use of forest resources for house construction

► The teacher gets the whole class to think about local methods of harvesting and consuming natural plant resources, especially trees.

- Is this method of harvesting and consuming sustainable?
- Does it involve woody species collected for building and fitting out houses?
- Is the pattern of collection the same for building work and construction, the craft industry and heating purposes?
- Are the natural wood reserves sufficient to meet such a demand?

► The teacher explains that when pressure on resources grows consistently because of the steady increase in population, if these resources are not renewed, deforestation poses a major threat to the region.

► The teacher requests the pupils to assess the local situation thoroughly and to compare it with situations elsewhere in the world, by reusing the examples of selected housing types and the kind of wood consumption entailed.

In which regions of the world is excessive tree-felling threatening the delicate balance between the population and nature?

86. Method of horizontal stacking in the construction of a Russian isba, *Ilmen Nature Reserve*, Russia
© Michel Le Berre

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87. A scattering of chalets on the mountainside, *Château d'Oex*, Switzerland
© UNESCO/Olivier Brestin

88. Chalet built along the contour line, *Château d'Oex*, Switzerland
© UNESCO/Olivier Brestin



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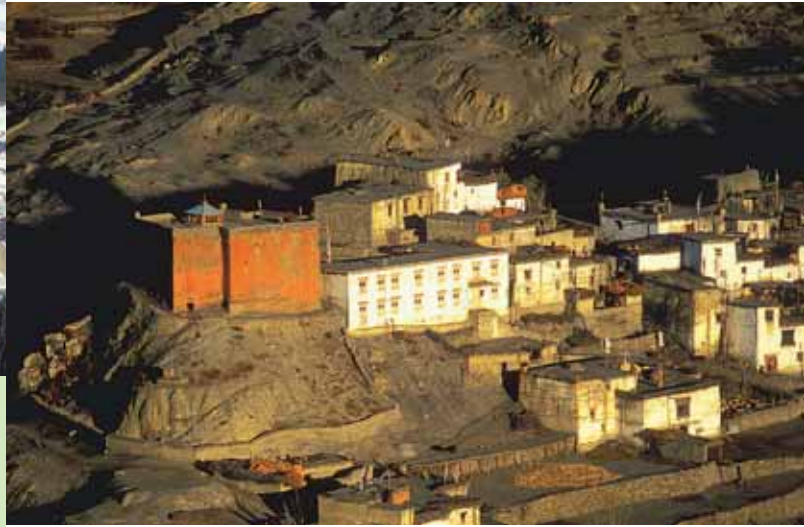
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89. Les Arcs 1800 ski resort,
Savoie, France
© Yann Arthus-Bertrand
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90. Jomson Village, Mustang
region, Nepal
© Yann Arthus-Bertrand
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Exemple :

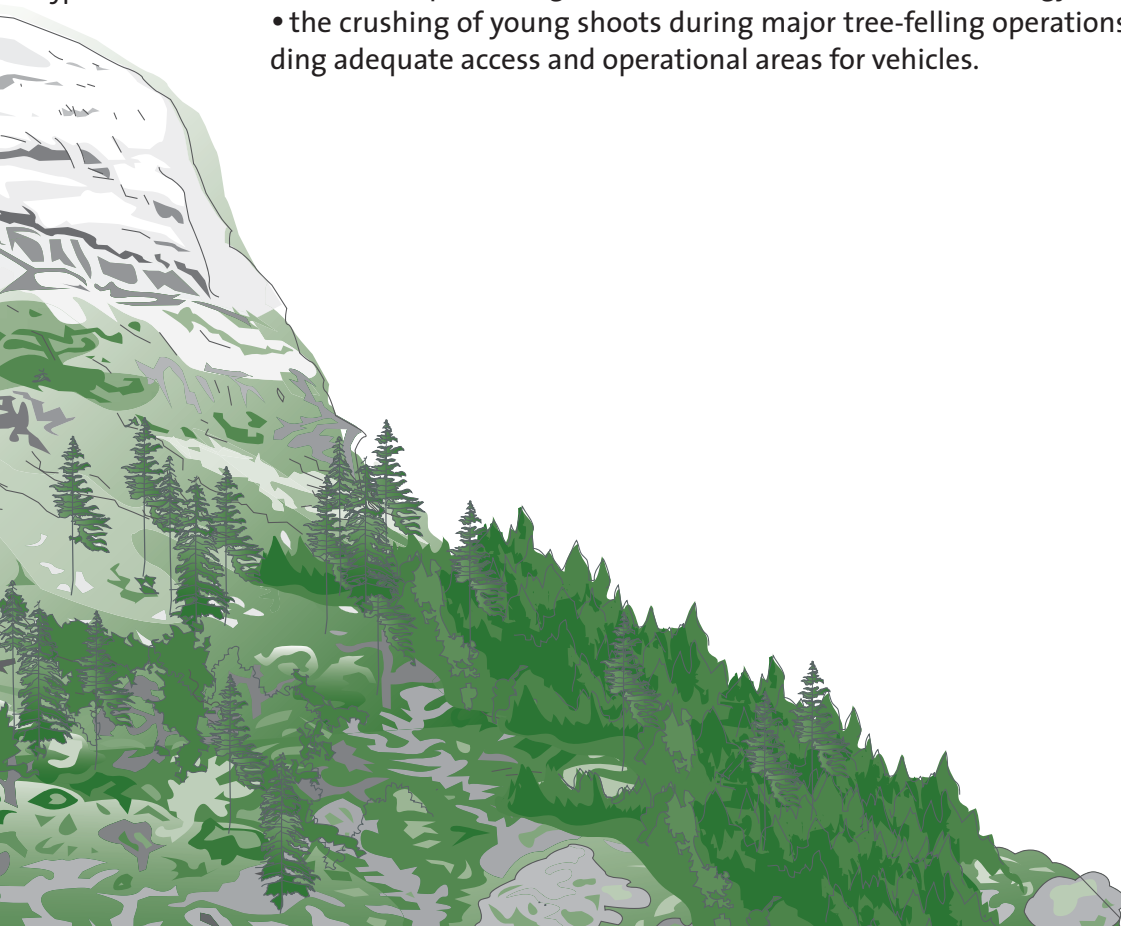
In southern and central Asia, in the Hindu-Kush, the Pamir, the Himalayas and Northern India, owing to constant demographic pressure, sparse forests are being felled at an unrelenting rate to provide **firewood** and wood for building purposes, and especially to bring new land into agricultural use.

In these regions, tree cover is becoming woefully inadequate: it no longer retains water in the soil level, regardless of whether the water in question is the seasonal, but very heavy, rains of monsoon areas such as India or the water from melting snow, which, in mountain areas, transforms small streams into raging torrents of muddy, foaming water. In either case, the result is catastrophic: **deforestation** results in floods and mudslides, and the leached soils are eroded and dessicated, reducing productivity even more.

- ▶ The teacher encourages the class to analyse and discuss the situation.
 - What should be done in vulnerable areas to compensate for the need to use trees as an immediate source of income, felling them at a rate that makes their replacement impossible?
 - Should livelihoods be diversified through a combination of agriculture, cattle farming, **agroforestry**, mountain aquaculture, produce from hunting and fishing, and perhaps the collection of wild plants, whenever resource management allows?
 - Should infrastructure for transport and industry be developed in order to exploit and process the various forestry resources at local level.
 - Should the practice of drawing on plant and forest resources for the walls and roofs of houses be abandoned and replaced by building in stone, with mineral coverings and binders, thus minimizing the use of wood?
- ▶ At this point, pupils look again at the examples of housing studied earlier:
 - Is the technique of horizontal stacking, used for building in the mountains in the north and requiring large quantities of wood, characteristic of densely wooded mountain regions?
 - Even though the boreal forest, stretching from the Canadian to the Siberian mountains, is immense, are ever larger areas being logged, as these forests supply more than half of the world's timber that is felled for industrial use?
 - Is the consumption of wood for stacking, in addition to the number of trees felled for commercial use, for exploiting the subsoil or laying **pipelines**, incompatible with the long-term exploitation of the forest?
- ▶ The teacher also provides explanations in connection with the questions below.

- Does intensive exploitation of forests entail reliance on the rapid growth of one or two selected species of conifer, while others could also be felled?
 - Are varieties of species (notably the broadleaf species) cleared in order to plant a single, fast-growing species such as spruce?
 - ▶ The class ends its question session by evaluating a housing-related example mentioned above.
 - Is too heavy a burden being placed on the mountains of Europe in supplying cladding wood for the manufacture of wooden tiles, for instance?
 - Are the most recent cladding materials used in mountain areas, such as aluminium plates, less costly? Do they use up fewer natural resources? Do they not result in structurally lighter buildings, which require less structural timber?
- ▶ To finish, the teacher gets the pupils to think about the sustainable management of forest resources. How can forests be exploited without disturbing the natural balance?
- Firstly, we must continue to maintain them by:
- facilitating the growth of young saplings by regular weeding, in other words, by removing invasive shrubs and bushes;
 - felling trees that are very old, decaying or attacked by insects;
 - replanting, ensuring that the diversity of tree species is given priority; for the diversity of species and the possibility of substituting one species for another often allow local resources to cater for a number of the population's specific needs;
- Furthermore, cutting methods should be monitored:
- for specific needs, selective cuts should be chosen, which involves singling out trees that have been earmarked in advance, or using traditional cutting methods, such as the controlled pruning of larger trees and the selective **pruning** of smaller ones;
 - for industrial and commercial needs, trees should be logged in strips, by felling and leaving trees standing in alternate sections of forest;
 - the felling of immature trees and young saplings should be avoided; they must be protected from grazing animals and from collecting by monitoring grazing areas, installing protective barriers and promoting the use of alternative sources of energy such as solar power.
 - the crushing of young shoots during major tree-felling operations must be avoided, by providing adequate access and operational areas for vehicles.

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91. Plant levels in the Alps: from montane (at the bottom) to subalpine, alpine and lastly nival

Right-hand page:
92. Jacques Cartier River, forests and mountains, Canada
© Yann Arthus-Bertrand
La Terre vue du Ciel, UNESCO

93. Felled area in forest, Mézenc, France
© Michel Le Berre





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05 The experimental garden

Level ★ ★ ★
advanced

Place 
outdoors

Duration ● ● ●
Over several seasons
as the plant grow, patience
is a virtue...

Objectives

1. Discovery of the environment

Pupils develop for the whole school, over several years, an experimental garden that will be a testing ground for good practice in gardening, cultivation and forest management, good practice that will prove useful for protecting the environment, particularly the soil, and for combating natural erosion in mountain areas.

2. Aptitudes

Pupils acquire practical and technical skills in the maintenance of cultivated plants and in agro-forestry and can validate their experience when in contact with environmental professionals.

Notes and suggestions:

For this activity, it would be a good idea to get together a team of several teachers, perhaps from more than one school. Starting with an introduction to the basics of environmental protection and conservation, the teachers develop a practical approach to learning based on the garden. They ensure that the concept of “**sustainable development**”, with reference to the **Decade of Education for Sustainable Development**, is central to the project by educating pupils to act with the long term in mind, not only for their own benefit but for the benefit of future pupils and generations. The experimental garden is developed as a natural extension of pilot projects and individual initiatives concerning environmental protection set up on the different sites chosen by local stakeholders. The schoolchildren will therefore divide their time between “laboratory conditions” in the experimental garden and “real life” conditions in areas cultivated by professionals, where they can, if practicable, test their knowledge and experiments a second time.

94. Forest warden's house and garden, *Ilmen Nature Reserve*, Russia
© Michel Le Berre

95. Garden in apricot grove, *Dah Hanu, Ladakh*, India
© UNESCO/Olivier Brestin

96. Himalayan strawberries (*Fragaria nubicola*), *Sikkim*, India
© UNESCO/Olivier Brestin

97. Fruit trees in blossom, *Comtat Venaissin, Vaucluse*, France
©Hélène Gille

98. Fruit of *Prinsepia utilis*, *Lachung, Sikkim*, India
© UNESCO/Olivier Brestin



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Methodology

1. Understand and take on board local environmental protection initiatives

- ▶ The teachers consult environment professionals: stakeholders or decision-makers, farmers, stock raisers, foresters, knowledgeable or influential individuals, engineers, researchers, students and other teachers.
- ▶ The team of teachers gathers information about environment protection initiatives launched locally, whether by individuals or as pilot projects. These initiatives mainly involve the protection, maintenance and enrichment of soil quality.
- ▶ The teachers are fully briefed about mountain ecosystems, which are characterized by poor soils that often contain little clay at the higher levels, where they are of even poorer quality.

Reminder:

- These ecosystems are shaped by the nature of the terrain, the frost and the cold, the amount of exposure to solar radiation and total rainfall: some of them experience violent downpours, while others receive very little rain but are covered by snow for long periods and then subjected to the impact of heavy snowmelt, as happens in cold, arid regions.
- Soil formation is therefore slowed down by the freezing temperatures and the slow growth cycle of plants, their vegetation period and growth being a long drawn-out affair.
- The topsoil layer, normally a source of nourishment, contains little humus, therefore, and is often thin and slow in forming, while the slopes are prone to erosion.

- ▶ The teachers take on board the importance of knowing how to protect and enrich the arable layer of the soil, which is the best part.
- ▶ A variety of initiatives exist in this area and teachers take each one of them into account. They include:

1. making a number of diagnoses of flora using indicator plants, in order to assess soil quality at high altitude;
2. knowing how to make and use **compost** in order to revitalize poor soil or maintain a soil's fertility;
3. spreading green manure on fallow land, thus containing erosion and **surface-sealing** (compacting) of the soil, while improving its structure and ensuring that the next season's crops will have a supply of organic matter and nutrients;
4. prioritizing crop rotation, alternating plants typically found at altitude – roots, tubers, cereals – with **leguminous** plants, which have the special property of transferring nitrogen from the atmosphere to the soil and making it available for other plants;
5. cultivating the same association of typical and leguminous plants simultaneously on the slopes, using **intercropping** or alley cropping methods;
6. regenerating alpine grassland that has been damaged by **overgrazing**, by using methods suited to the impoverished soil: clearing by hand, (in certain cases) spreading manure, spreading green slurry, using decomposable mulch on very badly damaged soil;
7. introducing **agroforestry** by planting woody species to restore the fertility of the soil, for example around areas where vegetation has been slashed and burnt (in the tropical mountain areas of central Asia, which are vulnerable because of deforestation);
8. more generally, maintaining the forests on a regular basis and gaining a fuller knowledge of the existing species of trees and their distribution;
9. maintaining forest resources by monitoring the diversity of tree species and, where necessary, replanting selected, nursery-grown species;
10. knowing how to set up a **nursery** and produce plants from seed;
11. developing the commercial value of existing mountain forestry products, such as products that are extracted and harvested, and the cultivation of companion plants;
12. establishing growing areas under tree cover;



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99. Various terrace crops,
Chemdry, Ladakh, India
© UNESCO/Olivier Brestin

100. Rice fields,
Tashiding, Sikkim, India
© UNESCO/Olivier Brestin

101. Rice fields,
Dikchu, Sikkim, India
© UNESCO/Olivier Brestin

13. maintaining the presence of trees in the mosaics of vegetation and the traditional farming areas (of dryland or Mediterranean mountain ecosystems), where they play a major ecological role in stabilizing the soil, making the local climate milder and providing shade for crops.

► The teachers receive training from environmental professionals. They learn to identify the wild flora locally, make compost and liquid fertilizer (green slurry), choose seeds, sow crops, grow seedlings, bed them out, set up a school nursery, maintain a small area of forest and manage an orchard of fruit-trees.

Example:

Within the framework of the activity undertaken by the Tunisian branch of the **SUMAMAD** project in the mountains in the south west of the country (the Jeffara region), an action research project initiated by **UNESCO's MAB** Programme, to facilitate close collaboration between the local authorities, farmers and cattle-breeders, and research-workers at the **IRA** (Arid Regions Institute), it is likely that the local actors will be willing to pass on some practical knowledge to the teaching team.

Facilitators often act as links at the local level between research workers and farmers; they are often the parents of pupils and are involved in deforestation work or grazing-land improvement schemes. They can take on a coordinating role for the various partners in the group, explain the rationale of the experimental garden and introduce the teachers to different methods of producing maps of the local plants and soils, and to the planting of fodder crops, either in the form of local shrubby plants or woody species brought in from elsewhere.

► Once the teaching team has been trained, it meets to determine the educational scope of the garden project.

► Next, there is a meeting with the pupils to inform them about the local situation and the initiatives undertaken by the population to protect and conserve the ecosystems.



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102. Man bedding out young plants,
Phyang, Ladakh, India
© UNESCO/Olivier Brestin

103. Sown fields,
Phyang, Ladakh, India
© UNESCO/Olivier Brestin



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► In this context, pupils are told about the various themes of the educational activities planned around the garden, and how they too will have their chance to learn certain techniques and eventually transfer their experiments to real-life settings and draw on the methods and advice of professionals.

2. Decide on the location of the garden and find a provisional site

► All classes, teachers and environmental professionals associated with the project decide together on the site for the experimental garden.

► It should be located not far from the school but ideally at altitude and, depending on the part of the world in question, should reflect the climatic and ecological conditions of the massif itself.

Example:

In temperate regions, the ecotone area or upper limit of the forest is recommended, since it is typical of mountain environments with a seasonal climate (provided it is within reasonable distance of the school). This area is characterized by micro-mosaics of vegetation that accurately reflect the varied climate, the harsh temperatures of high altitudes, the temperature range, the strong sunlight, the high rainfall levels and the presence of the mountain relief, which at this height deflects winds and disrupts the distribution of rainfall, creating dramatic contrasts between different areas.

► The stakeholders in the project then work out in more detail the desired site conditions.

- The site should be some waste ground that had previously served a human purpose but not in the last few months or even years; it has therefore been reclaimed by nature, in the form of weeds and **self-propagating plants**, with **ruderal plants** growing along the roadside, if there is a road, and colonizing banks, mounds, alluvial deposits and the rubble of old buildings.

- The area should also be of adequate size and provide contrasting environments. There should be at least two: an open environment (such as an old south-facing terrace, subalpine grassland

that is bare and rocky, meadowland that is rich in species and tall grasses, a chablis or clearing that has been opened up in the canopy (tropical mountain) or a high-altitude steppe area) and a contrasting, enclosed environment (dense understorey, a forest area partly overgrown with brush but where a variety of local woody species coexist or a snow combe).

- It will be an advantage if there is a water source that is not too far away (a stream, a spring, a steppe lake, a mountain river or a bog).
- Lastly, the area might include a piece of land that is in a particularly bad state, such as an area of grassland that has been impoverished by overgrazing, where the plant cover has, in parts, disappeared and where gullying is very much in evidence; or else a steppe area covered in sagebrush, where the **perennial** grasses have been plundered and thistle and couch grass have taken their place.

► Once these conditions have all been taken into account and the contending sites scrutinized, all of the project stakeholders decide on the location of the experimental garden and agree the precise surface area.

► Under the guidance of the teacher, the pupils carry out a preliminary exploration of the site and record the species of wild plants present.

3. Carry out diagnoses of certain flora in order to assess soil quality

► After this preliminary exploration, the pupils seek the advice of those local residents who have expert knowledge of the area's wild plants that are indicative of soil quality.

► Briefed by the teachers – who have been through an induction – on the relationship between plant populations and environmental conditions, the pupils seek to build on this knowledge.

► They visit farmers on the higher slopes, who can very often name, classify and describe indicator plants.

Although plant indications are only valid if there is a sufficient number of subjects, it is equally true that plant populations will often reflect the soil's mineral components (whether it is predominantly calcareous or siliceous) as well as its nutrient content (an excess or a shortage of organic matter, and the nutrients present, such as nitrogen and phosphorus).

► Depending on where they live, pupils learn, for example, to identify plants that indicate an excess of organic matter.

Examples:

When there has been too much manure on a piece of grazing land because cattle regularly graze on it, the surplus nitrogen is indicated by the presence of populations of monkshood or of very thorny plume thistles.

Elsewhere, in a meadow at a lower altitude, a very dense and invasive population of dandelions will equally indicate the level of saturation by organic matter, just as the saturation of the soil by iron, at the foot of a slope or close to rubble, will be signalled by a dense population of nettles.

► The pupils also familiarize themselves with the role of wild plants that grow next to, and often among, crops, except in areas of intensive farming, where they are systematically destroyed and threatened with extinction, owing to the wholesale use of herbicides and pesticides.

Example:

Farmers in the Venezuelan Andes, who grow their wheat in two-yearly cycles, constantly use these plants in order to find out whether the earth has become “thin” between two crops or whether it is still rich in nutrients, in other words, “well nourished”. Thus, if a poacea such as rat-tail fescue (*Vulpia myurus*) is seen to be thriving, the farmer will be persuaded to leave the plot fallow for the land to rest, whereas the presence of a fabacea, usually lupins or chocho (*Lupinus paniculatus*), will indicate a good, even distribution of nitrogen in the soil and hence a sufficiently fertile soil.

► Guided by their teacher and drawing on the farmers' knowledge, the pupils become more aware of the value of local wild flora and self-propagating plants, often described as “weeds”.

They prevent erosion, for instance, and help to structure the soil:

In fact, some wild plants take to clayey soils, sometimes where the soil is very thin, with closely packed particles that leave little room for air; they help to aerate these soils through their strong root system, which they use to pull up water and trace elements and create the right conditions for new plants to become established.

Examples:

Orange mullim, lovage and common sorrel, with their long, pivotal root, which starts to grow again as soon as it is broken off, thus play an ecological role by stabilizing banks and helping to prevent erosion on slopes.

► The pupils understand the importance of **messicole plants**, which are associated with cultivated crops.

- These wild plants have adapted to crops over time. They appeared with the advent of farming and evolved and diversified as farming practices changed.
- They travelled in sacks of grain, spread, then adapted to conditions in numerous regions of the world and very quickly modified the composition of local flora.
- It is estimated that about “one third of all flowering plants in Central Europe are connected with the various types of traditional agriculture”².
- Self-propagating plants, such as the poppy in temperate regions, are on the decline, because they have been eradicated from farmland (their original habitat) by intensive farming.
- However such plants are treasure houses of biodiversity; for one thing, they form a unique store of genes, and a mere handful of species (about forty in temperate regions) are home to several hundred species of insects: arthropods, diptera which include syrphid flies that are natural predators of aphids (greenfly), and also ladybirds and lacewings.

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104. Examples of Alpine Fabaceae: bird's foot trefoil and alpine clover
© UNESCO/Olivier Brestin

106. Common poppy (*Papaver rhoeas*), arable plant
©Hélène Gille

105. Oxeye daisy, arable plant
©Hélène Gille



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2. According to Georg Grabherr in his book *Ecosystems of the world*, Ulmer, 1999.



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107. Working in the fields,
Bagmati region, Nepal
© Yann Arthus-Bertrand
La Terre vue du Ciel, UNESCO

108. Working in the fields,
Gandaki region, Nepal
© Yann Arthus-Bertrand
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► The teacher gets the pupils to think about the questions below:

- In sheltering the natural predators of pests in this way, are these plants not a natural way of protecting crops and of limiting the use of artificial **inputs** in agriculture, whose effect on the health of human beings has not yet been fully evaluated?
- Can these plants not be preserved without affecting crop yields, if plants are sorted into types at the harvesting stage?

► The teacher guides a class discussion of ways and means of preserving messicole plants: around the edges of fields, on small plots, in grassy strips adjacent to crops or, under carefully controlled conditions, among the crops themselves. This does happen in the traditional farming systems still used in mountain areas in a number of developing countries, where the plants are not automatically cleared.

► The teachers remind the pupils that the garden will also have an aesthetic dimension in addition to its scientific and experimental roles.

The flowering of messicole plants is a feast for the eyes; the flowers can be densely packed, the multicoloured mass of flowers being more like a flowerbed or, alternatively, they can be more scattered, splashes of colour among patches of grasses that gently sway in the wind.

► They provide an opportunity for photography (depending on the school's facilities), coloured drawings, paintings, research into the symbolism of weeds and wild flowers historically in many cultures.

Examples:

In temperate regions, the cornflower of France, the thistle, which is the national emblem of Scotland, and the edelweiss, the Swiss national symbol.



109. Man opening furrows using a plough,
Phyang, Ladakh, India
© UNESCO/Olivier Brestin



110. Women raking the ground,
Phyang, Ladakh, India
© UNESCO/Olivier Brestin



► Once this stage of making the pupils more aware of wild flora has been completed, the class moves on to diagnosing the flora on the garden site.

Which areas are in a particularly poor condition? Which plants indicate this?

Example:

A concentration of matgrass (*Nardus stricta*) with some early mountain arnica (*Arnica montana*) on a thin carpet of alpine grassland indicates that the soil has become acidic, in some cases highly acidic.

Erosion may have removed the minerals, thus decalcifying the surface soil.

- Can this be remedied and, if so, how? By fertilizing the soil? (see below).
- The pupils select those plant specimens, located at strategic points in the garden, that perform an ecological function. They decide to keep them.
- In other parts of the garden, on the other hand, they carefully weed by hand those areas reserved for new plants and prepare the soil.
- With due regard for existing flora, they decide where to plant the herbaceous borders that will accommodate the complementary sowing of messicole or **melliferous** plants.
- Finally, as a group, they undertake the task of clearing the wooded area.

4. Carry out soil improvement work in preparation for the new plants

► Depending on the diagnoses of the soil quality and the expert advice of the specialists, the class may decide to spread **green manure** on the land set aside for new plants.

What does green manure consist of?

- The first task is to plant, on a temporary basis, a fast-growing species, chosen to suit the condition of the soil, in order to increase its potential yield.
- Thus in eroded soil that has been compacted but is nevertheless deep, a deep-rooted plant is sown that reaches down into the soil, and aerates and structures it.
- Next, depending on how rich the soil is in nutrients, a plant is chosen that retains excesses of nutrients, for example rye, which absorbs surplus **nitrogen** or, in contrast, a plant that enriches the soil with nutritional elements, such as a leguminous plant of the luzerne or red clover type, which transfers nitrogen from the air to the soil by means of its powerful root system, the roots then distributing it in the earth, taking it back up to the surface and making it available to the other plants. What actually happens is that bacteria (*Rhizobium*) invade the deep roots of these plants, including beans and peas, and form nitrogen-fixing nodules on them. The nitrogen is then incorporated into the proteins of the plant, which distributes it through its roots. The pupils are introduced to sowing techniques by the farmers and, depending on the region, broadcast their green manure.

Examples:

Millet can be used in eastern Africa, India and Nepal on poor, sandy soils, and rye on the poor, cold soils and acidic soils of Central Asia.



111. Couple ploughing and sowing,
Korzok, Ladakh, India
© UNESCO/Olivier Brestin



112. Broadcast sowing of barley,
Korzok, Ladakh, India
© UNESCO/Olivier Brestin

► Once the plant has gone to seed, the pupils set about working it into the soil, seeking some mechanical assistance from the local farmers. Green manure certainly must be worked well into the soil; doing this adds a surface layer of organic matter to the soil and produces humus, which is good for its structure.

Example:

If the green manure chosen is mustard (*Sinapis alba*), used in the mountains of the Near East, it must be ploughed in before the seeds appear, otherwise these will be scattered... and the plant will spread like a weed.

► As a group, the class runs through all the factors that favour the use of green manure and incorporates them into the project notes:

- It covers the soil between two growing periods, which would otherwise be exposed to erosion by the elements and to leaching by rain; the leaching out of nutrients causes loss of fertility, the leaching out of nitrates into water sources causes serious pollution.
- Green manure also keeps the soil loose, prevents it from becoming compact as a result of exposure to recurrent frosts, sun and the hooves of cattle.
- Lastly, it means that there are no empty spaces into which self-propagating plants or “weeds” would spread, since they quickly take over in mountain areas owing to the humidity.
- But the biggest virtue of green manure is that it keeps a proper balance of nutrients in the soil, very often ensuring a supply of nutritional elements for the next crop.

► In this respect, the class might also want to use **compost** to fertilize areas that are to be planted or sown.

To that end, the pupils will have already learnt the technique of composting some weeks earlier.

- They dig a big hole not far from the school or the garden site.
- They throw into it plant remains from the garden and vegetable remains from the kitchen: mounds of dead leaves, fruit and vegetable peelings, “weeds” (except for tough plants like couch-grass), grasses that have run to seed and species that are unambiguously poisonous, and so dangerous, but common in the mountains, such as monkshood, astragalus, hemlock, veratrum and digitalis).
- They add goat and sheep droppings and cowpats. They can complete the cocktail by adding straw left over from the harvesting. They cover everything with a layer of earth and leave it to stand for several weeks.

► The teachers show the pupils how to turn the heap over and to water it regularly, so that everything is broken down.

They ultimately obtain some excellent compost!

- Just before they begin to sow, the pupils spread the compost over the area to be sown. They first turn over the surface layer of soil, which airs it, and mix it evenly with the compost that they have prepared.

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113. Mountain village, Cauca Province, Colombia
© UNESCO / Pierre A. Pittet

114. Stone terracing, Pisac, Peru
© UNESCO / Georges Malempré



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115. Growing agaves, Valles region, Jalisco, Mexico
© UNESCO / Carlos Tomas



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116. Woman threshing barley, high plateau region, Bolivia
© UNESCO / Pierre A. Pittet



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► The class should avoid being too liberal with manure on land which, quite possibly, is being regenerated or enriched in other ways, at least in the initial stages.

Spreading farmyard manure has a radical effect on a soil's composition and it is as well to know in advance whether or not the soil has a high-nitrogen content, in case it becomes overloaded. If pupils are required to maintain and improve an area of grassland where they judge the deterioration to be average or which they have previously scythed, they could decide to use cattle that they will take out to graze; though not before carrying out very precise tests on the state of the soil, and they should not use cattle too often.

► Another way of improving grassland that has deteriorated completely is to spread slurry at the very beginning of the growing season, usually in spring in the northern hemisphere.

► In temperate regions, the pupils could use a plant like comfrey (*Symphytum officinale*), which is rich in potassium, the plant matter coming from crops grown previously. Comfrey roots reach deep into the soil, where they absorb valuable mineral elements (not only potassium itself but also calcium and trace elements) that are inaccessible to other plants, which it then stores in its mass of thick, hairy leaves.

► The pupils allow one kilogramme of plant matter to ten litres of water; they let it macerate for a certain length of time determined by outside temperatures (a few days only, if it is very hot), they stir it to promote maceration and stop the process before putrefaction sets in (the signs of which are unmistakable). They then filter the mixture to remove most of the solid matter, retrieve a very thick liquid and then spread it as slurry.

► Depending on the region, the pupils use the most appropriate local plants.

Example:

At the sub-Andean stage or the high pastureland stage (always green) of the Paramo, the pupils harvest a plant that will provide plenty of matter, the sap in its leaves producing a similar effect.

5. Get the plants established and introduce an association with leguminous plants

► Once the land set aside for growing the plants has been loosened and enriched, the pupils proceed to sow or plant the crops.

Again, nothing must be left to chance.

► Listening to and following the advice of the professionals, the pupils take account of the local climate and learn all about the best “orientations” for planting their crops.

The cold at high altitude, for example, can slow down the growth cycle and impose a two-year cycle, as in the central Andes, where wheat is grown at about 3,000 metres, or sometimes at 3,500 metres.

► The class takes advantage of the unique experience of growers like the Andean farmers, who understand the finer points of ecological **gradients** and the micro-climates relating to the layering of the slopes, and who are experts in diversifying crops on their layered terraces.

Examples:

At high altitude in the mountains of Peru and Bolivia, quinoa can be grown twice a year. As a plant that has a short growth cycle and can tolerate dry winters and moderate frosts, it can be sown in autumn and sometimes a second time in the same year, if rainfall has been abundant.

In the Andes, amaranth (*Amaranthus palmerii* or *Amaranthus caudatus*), a plant grown as food, whose leaves are eaten like spinach, is best sown in March, after the rainy season. Well adapted to the mountain microclimate and sown in shallow furrows, it is an easy plant to grow manually and an ideal one for the young gardeners and their experimental garden. It also produces spectacular results, large leaves and long ears that can be used in various ways: the seeds can be roasted and the leaves can either be eaten raw in salads or cooked in tortillas!

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117. Terraced rice fields,
Ambohimanga, Madagascar
© Michel Le Berre

118. Growing roses and fruit
under cover, Baños, Ecuador
© UNESCO/Alison Clayton



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119. Mountain pastureland in dryland region, Iran
© Thomas Schaaf

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120. Flock of sheep, Achinathang, Ladakh, India
© UNESCO/Olivier Brestin



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121. Stripped wooded slopes, Kyrgyzstan
© Thomas Schaaf

122. Bedouins outside their tent, Dana Biosphere Reserve, Jordan
© Thomas Schaaf



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- ▶ The pupils derive pleasure from maintaining a degree of biodiversity in the mountain plants that they grow, especially in tending hardy species like teosinte, amaranth, lupin, quinoa or, in other places, the castor plant, spelt and cardamom.
- ▶ For some of the time, they can go outside the perimeter of the garden and make it “nomadic” by moving between levels on the slope to learn about different crops.
- ▶ In addition to sowing, they also learn how to bed out... tomato plants, for instance, spacing out the plants and their stakes according to the size of the species.
- ▶ In due course, they will add a few plants to the garden, choosing seedlings and plants on the basis of the garden’s altitude.
- ▶ If, in spite of the soil having been prepared, the plants do not become established, the teacher gets the pupils to use particular techniques to strengthen them.
- ▶ They therefore learn how to combine cereal crops (wheat, barley and maize) with leguminous crops (luzerne, red clover and lupin in Latin America), so that the cereals can benefit from a permanent supply of nitrogen from the legumes.
- ▶ The plants are laid out in alternate strips on the same plot. This is a spatial form of **intercropping**, as distinct from the temporal form that was used with green manure.

During the planting process, the pupils take every care to keep the rows completely separate and distinct, while alternating them. The deeper roots of the legumes will pull up moisture and minerals from the subsoil and distribute the nitrogen, making it available to the shorter roots of the cereals, which are close to the surface. Another method of associating the plants is for

the class to plant them in corridors (“alley cropping”). The same alleys of annual cereals are planted, but this time interspersed with hedges of shrubby legumes, species such as powderpuff (*Calliandra calothyrsus*), African locust bean (*Parkia biglobosa*) or pigeonpea (*Cajanus cajan*).

► The shrubs partition off the alley crops and the pupils prune them regularly to fertilize these same crops from above ground, by carpeting the surface soil.

The cereals are nourished from two sources: the nutrients in the soil, which enter their roots, and minerals released when the leaves of the legumes decompose on the surface.

► The advantage for the class in using shrubby legumes rather than herbaceous ones is that they are perennials and so will not have to be replaced.

Each year, the pupils rotate the crops growing in association with leguminous plants: one year the crop will be a cereal, the following year it will be a root crop (sugar beet) and the year after that a crop of tubers (potato).

► Exploiting the same idea of protecting crops under a cover of dead and decaying plant matter, the pupils can use the technique of **mulching**.

► In arid mountain areas, in particular, where erosion is rife, children learn to spread decomposable mulch on or between rows of crops.

Made up largely of straw, post-harvest residue, the haulm of grasses, like *Aristida* sp in steppe regions, and other dead vegetation such as pine needles, dead leaves and wood or bark shavings, this decomposable blanket enriches the layer of humus and, above all, keeps the soil moist for a long time, providing plant germs with the necessary moisture and reducing the immediate need for watering.

6. Maintain and enhance the tree area

► For the last part of their work, the pupils focus on the tree area of the experimental garden. They study it closely.

Is the area one that has been abandoned? Has it deteriorated? Does the situation suggest that the forest has been overexploited locally? Does it suggest a lack of management of the forest’s potential resources?

123. Researcher in front of a row of *Atriplex Halimus* dividing a barley crop, Khanasser Valley, Syria
© Thomas Schaaf



124. Intercropping, Khanasser Valley, Syria
© Hélène Gille





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125. Visitor centre,
Dana Biosphere Reserve,
Jordan
© Thomas Schaaf

126. Mediterranean
plants, *Cuenca Alta del
Rio Manzanares
Biosphere Reserve*, Spain
© Thomas Schaaf

127. Rosemary and
thyme in flower,
Luberon massif,
Provence, France
© Hélène Gille



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- The teacher initiates a debate with the professionals on these issues.

Example:

The pressures exerted by the population on the fruit trees of Central Asia (Kyrgyzstan and Kazakhstan) are often too great for these forests to recover naturally.

They were originally overexploited to provide firewood and building materials, although they cover too small an area to meet these countries' needs. Even when supplies of construction timber were brought from elsewhere, the forests continued to be burnt, cleared and turned into agricultural land to meet the immediate needs of a growing population. Today, these forests are being overgrazed. Flocks of sheep and cattle are brought to graze in the underwood and much of the forest pasture is cut for hay. In addition, with no real agreed forest management policy, fruit resources (nuts in particular) are picked down to the very last ones, without the trees being given time to recover.

- In all those mountain areas where the forests are being burnt to create pastureland or farmland, the pupils are encouraged to reflect on the viability of this practice.

Although shifting cultivation through slash and burn methods is considered sustainable in tropical mountain areas, in the high-altitude forests of Africa, because of the speed with which the vegetation recovers, these practices must still be pondered.

When the trees have been felled and the soil exposed to the rain, does not the earth reveal its fragility by becoming barren soon afterwards? When human beings encroach on the forest, do the areas cleared not converge with other cleared areas, creating fringes of cultivation that then become ribbons of deforestation that lead to the fragmentation of the massifs?

- Under the guidance of experts from the forestry services, the class catalogue the main species of trees in the forest.

Species that constitute a source of income for the population, that allow the forest to be exploited economically, are given pride of place.

Examples:

Mention can be made of the numerous fruit-bearing species of the mountains of Central Asia, ranging from walnut trees, the dominant species, to wild apple trees; the cork oak or the kermes oak of the Mediterranean garrigues, the sugar maple of the mountains of Canada, the argan of the Atlas Mountains, the birch of the taiga and the cow tree (*Brosimum galactodendron*) of the Venezuelan Andes.

- The pupils make a thorough study of these species' habitats.

Which slope do they occupy? Which direction do they face? What are the companion plants? Which species of shrubs make up the understorey? What are the herbaceous species at soil level? What wildlife do they shelter?

- Back in the garden, the pupils find some of the same species and take measures to protect and maintain the tree section.

After the weeding operation has been completed by the whole group, the class see more clearly the amount of space in which individual trees can grow. How well are the specimens of the main species growing? Have they fully benefited from the advantages of the environment? Have they managed to grow in good numbers and to a good height?

- By tidying up the soil, the pupils show to good advantage the companion species, the shrubs that grow in the understorey alongside the main species.

Examples:

In the birch groves of the mountainous regions of the taiga, these are often alders and willows. Under the majestic walnut trees of the mountains of Central Asia (*Juglans regia*), there are several varieties of maple (*Acer turkestanikum*, *Acer semenovii*), plum trees, almond trees and pistachio trees.

- After a thorough study of the species on the site and their **ecological range**, the class, under the guidance of the experts, choose to make additions to the plot, but without compromising the quality or the diversity of the species of trees.

For this purpose, the pupils select and transplant plants that have been grown in a school nursery.

- In terms of timing, the teacher knows that sowing the seeds in the nursery is done months before the plants are **transplanted**.

128. Farmer holding a young *Atriplex Halimus* plant, Khanasser Valley, Syria
©Thomas Schaaf



129. Growing seedlings in plastic bags in the nursery, Khanasser Valley, Syria
©Hélène Gille



- ▶ The seeds have first of all been harvested: in the case of trees bearing fruit with stones, like cherry or plum trees of the family Rosaceae the stones have been kept; in the case of walnut trees, the shells of the seeds have been removed to maximize their chances of germinating, and they are sown while they are still fresh, before they have dried out.
- ▶ Next, the pupils plant the seeds directly in pots or polythene bags. The pots, made of terracotta, will be about ten centimetres in diameter; the bags about 40 centimetres in length and cheaper, but they can also be a source of pollution.
- ▶ The pupils have prepared in advance the fertile mix for the pots, formed of sand and garden mould that is as light as possible. The mould consists of particles of eroded rock: clay, silt and sand, mixed with humus (decomposed organic matter). The pupils can enrich the mould content themselves by adding compost (see above).
- ▶ They place the pots on level ground, shielded from strong sunlight and wind.
- ▶ When the first shoots appear, they are thinned out: only the sturdiest shoot in each pot is kept and any “weeds” are removed. If they are to reach a height of 30 to 40 centimetres and develop a healthy root system, the young plants must be watered regularly by the pupils in turns.
- ▶ As soon as any decision is made to plant a tree or shrub in a particular spot, the pupils clear the area concerned and dig a fairly big hole (up to 50 centimetres deep for a shrub and 80 centimetres for a tree). They leave the hole exposed to the fresh air for a few days to aerate the soil to this depth.
- ▶ Assisted by the teachers, they then enrich the earth that has been taken from the hole. They remove any pebbles and other debris, and mix the soil in equal proportions with the compost that they have prepared. On the day of the planting, they throw a small amount of this earth into the hole to form a dome.



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130. Cherry trees in blossom and watering method, *Vaucluse*, France
©Edmond Boyeldieu



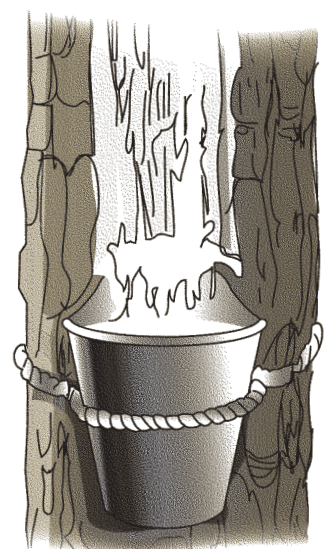
131. Pruning cherry orchards, *Vaucluse*, France
©Edmond Boyeldieu



132. Birch forest with ground stratum of bracken, *Raskuikha*, Urals, Russia
© Michel Le Berre

- ▶ They remove the seedling from the pot by tapping all round the outside, moisten the ball, disentangle the roots and position the plant in the middle of the hole, perfectly upright, spreading the roots on the surrounding soil.
The teacher must check that the highest part of the tree's or the shrub's roots are about ten centimetres below the surface.
- ▶ The pupils then fill in the hole and tamp down the soil, using their hands or their feet, but without compacting it too much. To complete the job, a small hollow is made at the base of the tree and generously watered (about ten litres).
- ▶ It will, however, be several years before the first fruit can be harvested in the orchard... before the almonds, pistachios, cherries, plums and walnuts can be tasted.
- ▶ Similarly, the class will have to wait until their trees are fully grown before they can draw off the rich sap of the maple and extract the sugar, or until they can tap a birch tree to obtain a beverage that is sweet and acidic.
- ▶ In the meantime, therefore, before they get any benefit from the garden's fruits, the class must devise proper management methods.
 - The plot must be tended and fertilized regularly to aid the growth of the young plants;
 - Any part of the garden that can be quickly exploited for its woody species of fodder crops, whose foliage is pruned, is cordoned off;
 - The orchard's forest cover and shaded environment must be left undisturbed, since they are indispensable for sexual reproduction during the first flowerings;

Harvesting conifer resin



- When the first fruits appear or the trees are ready for substances to be extracted for the first time, the harvesting of young plants is kept to a minimum.
- There are periods when nothing at all is picked, the orchard enjoying a total form of conservation; this gives the plants time to rest during their natural growth.

► The class has the time to learn from the professionals practical skills and techniques that are indispensable for running the garden.

How is a tree tapped without it being damaged?

How is sugar extracted from sap?

How is the outer layer of bark stripped from trees, essentially the **bark stripping** of cork oaks (*Quercus suber*)?

How are tannins extracted from wine?

How is the resin of conifers harvested (for the manufacture of essential oils)?

How is the fruit picked from a tree without damaging those parts of the plant that are vital to its future growth? How is the ground stratum of a birch grove maintained while a population of fruit-bearing shrubs (of the bilberry type) is preserved or enriched at the same time?

How can a population of aromatic plants rich in essential oils be preserved at the base of newly planted kermes oaks (*Quercus coccifera*)?

How can a dense carpet of herbaceous companion plants be transformed into fully fledged crops? Of baneberries or white trillium under maples, for example, or Canada horsebalm or “heal-all” under oaks in the Appalachian mountains?

► The pupils will thus learn about the commercial exploitation of non-woody forest plants.

► They will learn some techniques for extracting and producing small quantities of gums, resins, fibres, oils, honey or cork, as the case may be. If they cannot follow up with the manufacturing process, they outsource production to their partners.

► In any case, once certain results have been achieved, the class invites its project partners, the farmers and researchers, to taste and test the end products.

► After years of exchanges, advice and the transmission of practical knowledge, the garden attests to the school’s ability to manage land in a way that is both effective and ecologically sound.

► The question of strategic development can then be tackled.

If, for example, different areas are reserved for specific purposes – for example, a grazing area may be kept separate from an area where forest resources are being developed – this can be of real benefit to the community and can demonstrate the value of diversifying production.

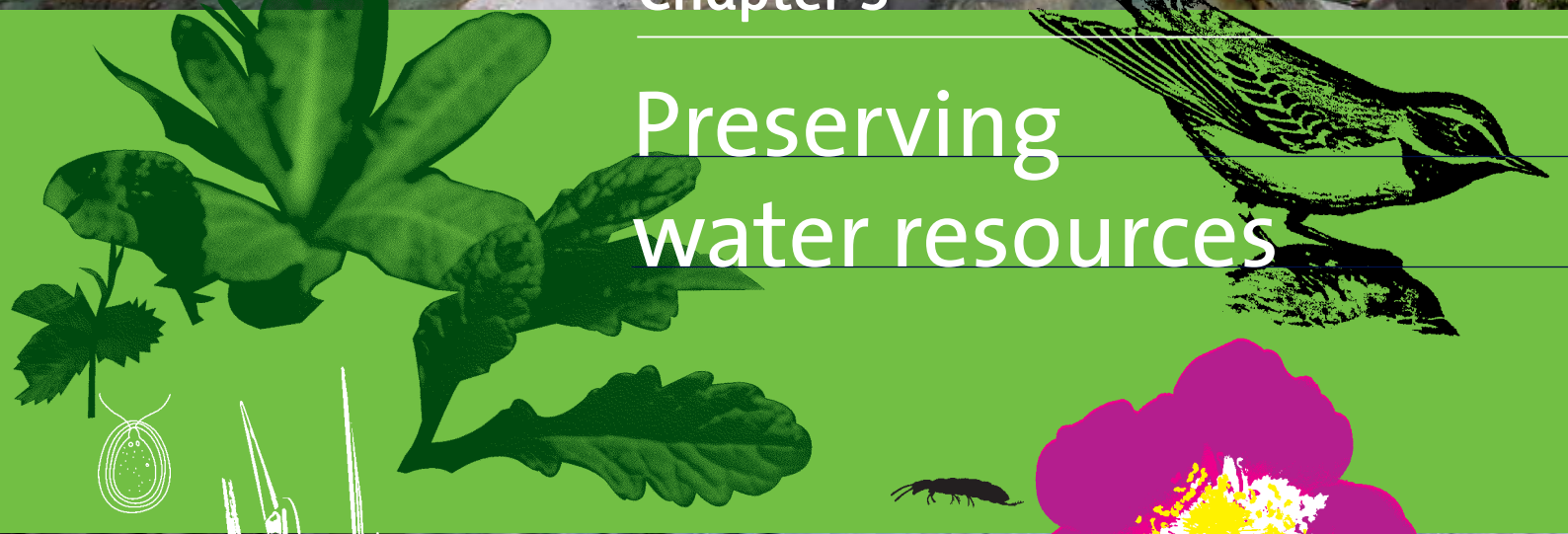
133. Scots pine forest,
Raskuikha, Urals, Russia
©Michel Le Berre





Chapter 3

Preserving water resources



01

Force, flow and transparency: water in mountain areas

Level 
easy

Place  
classroom
and outdoors

Duration 
3 sessions

Objectives

1. Discovery of the environment

By using and handling watercolours, pupils test and highlight the physical qualities of water, such as its ability to flow and to run off surfaces and its transparency.

Use these exercises to interpret the erosive action and the colour of water in the environment.

2. Knowledge and comprehension

By studying water in the landscape, the pupils are introduced to natural resources – surface water and groundwater – in the context of the water cycle, both in time and in space.

Methodology

1. Use paint to highlight the physical qualities of water

Water is the element that awakens or “wakes up” our senses.

► In class, the pupils talk about experiencing the sensory qualities of water in the mountains. They think of special occasions when they have come into contact with water, in either its solid or its liquid state – snow, ice, frost, torrent, stream – and describe the sensation.

Examples:

- Listening to feet crunching through the snow and tamping it down;
- Running one’s fingers over the light, downy crystals of a fresh fall of snow;
- Observing from close up the decorative patterns of frost on a cold surface (window panes, a mirror);
- Experiencing the mineral taste and transparency of water from a swirling torrent gushing from beneath a glacier;
- Admiring the beauty and fertility of a torrent at altitude, which cascades down into a wide basin, a fountain, a “giant’s cauldron”, encircled with moss-covered stones, teeming with insects and carpeted with riparian vegetation, its bed populated with minute crustaceans or gastropods.
- Watching the clouds lifted by rising air currents;
- Feeling the damp air of a bog area when evening falls;
- Listening to the sound of a stream as it flows past, gushing down the slope, weaving its way round obstacles and tumbling down in cascades;
- Listening to the roar of a torrent of snowmelt washing down debris and large boulders;
- Listening to the crash of a wall of water, on approaching a (hydroelectric) dam or converging falls.

► The pupils study the ambivalent relationship that exists between those who live in the mountains and water.

It is an extraordinary resource, pure, clear and full of oxygen. The mountain massifs are giant water towers, amassing vast reserves of water, much of which is distributed down their slopes to the inhabitants of the villages.

Water is also a formidable force that must be harnessed and in a sense “tamed” by people, for it can be hugely destructive and constitutes a real danger to the population



1



3



2

1. *Verzasca River* (whirlpool),
Verzasca Valley, Ticino, Switzerland
© UNESCO/Olivier Brestin

2. *Torrent at altitude* (cascade),
Simplon Pass, Switzerland
© UNESCO/Olivier Brestin

3. *Verzasca River* (source area),
Verzasca Valley, Ticino, Switzerland
© UNESCO/Olivier Brestin

Example:

To the east and south of the Himalayan ranges, on the rain-drenched slopes of the Annapurna massif, the villages located near the alluvial cones are directly at risk from the dominant torrents, since their beds are raised a little higher with each outbreak of rain, owing to the accumulation of debris brought down by the flow of water.

► The teacher gets the pupils to use watercolours to reveal the physical qualities of water, such as its liquidity, its ability to flow and its transparency.

► They paint with a range of instruments – a brush or similar object, a sponge, a stick – or a finger or a hand. They paint on various materials, such as card, thin paper, recycled paper or fabric stretched over a frame.

► By using particular painting techniques such as running, dragging, sprinkling and dripping, and observing the effect of each of them on the instrument and on the paint (which will sometimes be thick, sometimes diluted), the pupils reproduce the dynamic processes of water and the traces left by water in its natural setting.

► They test as rigorously as possible the liquidity and fluidity of their material and, in doing so, reveal effects that are characteristic of water – its ability to absorb, to cover, to flow and to dissolve – and of its chemical action in the ecosystem, when it breaks down the ingredients in the soil into a paste-like lava, a mixture of water and earth flowing down the slopes, or when rainwater then leaches the soil, dissolving the unabsorbed phosphates and nitrates and carrying them down to the rivers and the sea.

► Working in groups, the pupils begin by creating flat washes, surfaces painted in one colour, using several coats of paint.

They repeat the process, adding more water each time – the same colour, diluted more and more.

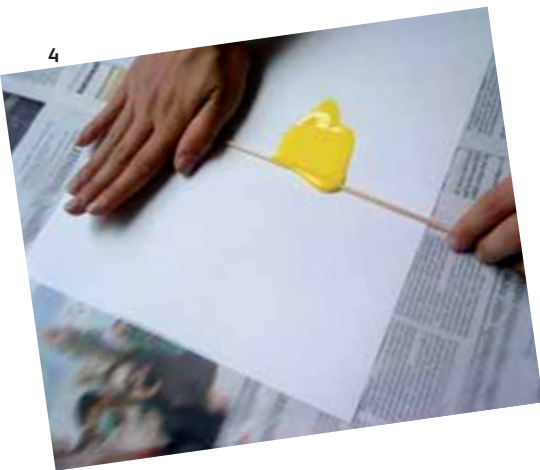
► They can then add to this uniform, thickly coated surface, using a brush that has been dipped in water, a streak effect or the kind of pattern, full of curves and scrolls, that is produced with a flourish of the brush.

They observe the results: the water that causes the paint to run, gives it a lighter colour, displaces it, the sense of fluidity and dynamism it conveys, and sometimes the freedom and beauty of the brushstroke.

► Still under the teacher's guidance, they add several more colours, first of all as flat washes that they paint side by side without waiting for them to dry, then as patterns produced by different brushstrokes, using several colours and several brushes simultaneously. They study the patterns made where the paint has run, and the smudging and blending effects obtained.

► Then they experiment with sprinkling, flicking and the more controlled dripping effects. The water and paint are absorbed by the paper. When the paint is highly diluted, it soaks and transforms the paper.

4



4. & 5. Experiments to express the fluidity of water visually
© Nina Cooper

5





6

6. Woman stocking up with water from the river, *Batopilas*, Mexico
© UNESCO/Olivier Brestin

7. Woman stocking up with water at a water access point, isolated village in the Andes, Ecuador
© UNESCO/Jean Cassagne



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► As a follow-up, the teacher conducts a further exercise.

A pupil lets a diluted blob of paint fall onto a sheet of paper and then moves the paper about, to make a pattern determined solely by the movement of the paper until all the liquid is absorbed.

Other pupils observe the effect produced by the absorption and the merging of different coloured drops and use the same method to produce their own paintings.

Once they are dry, the resulting paintings can be touched up with a pen or a brush and figurative elements or contrasts in materials can be introduced.

► Finally, the class studies the relationship between water and oil by using a “developing bath” to reveal the patterns formed by dripping oil-based paint onto water.

- A large container is needed for this – either a bowl or a pan – that is filled with water.

- A group of pupils drips a small amount of oil paint of different colours onto the surface of the water. Only a small quantity is used, to avoid polluting the environment later.

- Other pupils stir this floating mixture, using a stick, or some other piece of wood –and shapes begin to appear.

- As soon as a shape looks interesting, the pupils “capture” it by placing a sheet of paper on the surface of the water.

- They carefully remove the sheet, on which the floating shape and colours have been imprinted by absorption.

The exercise can be varied by masking part of the sheet (with sticky tape, for instance).

The covered part protects a drawn motif from the colours in the water. Once the shapes are “captured”, they serve as the background for the motif when the tape is removed. They could, for example, represent the ocean, a river or waves.

A comb could also be used to make different shapes on the surface of the water.

► Having grasped the whole range of expressive techniques derived from paint and its liquid, watery characteristics, pupils display their paintings together on the wall. They illustrate an approach to water that is both sensory and sensitive; its elusive liquidity, its ability to intermingle, to infiltrate, to overflow, to cover up, to dissolve and to corrode.

2. Learn to read signs of water erosion in the landscape

- ▶ The teacher takes the pupils outside and, drawing on lessons learned from these earlier exercises, they are better placed to identify and interpret the traces left by water and its action on the landscape and the environment.
- ▶ The teacher could also re-use, and elaborate, the instructions given in paragraphs 4 and 5 of Activity 3 in Chapter One “*Earth, stone and erosion*”.
- ▶ The class will therefore focus specifically on the signs of **runoff**, evidence of the movement of water down slopes and hillsides.
- ▶ For this exercise, the pupils climb high enough to locate the first signs of the chemical action of water: after the frost, it steadily dissolves the softest, most soluble rocks like gypsum and attacks the mineral aggregates in the hardest rocks.
- ▶ The pupils locate, as far upstream as possible, the first signs of rivulets in sludgy residues or of sheet erosion.

▶ The teacher may also encourage the pupils to list nouns associated with the adjectives “liquid” “solid” and “gaseous”.

In most parts of the world, one learns to draw mountain torrents, which cut channels in the slope, reshaping it from top to bottom.

- ▶ Further upstream, pupils sketch the enormous funnel-shaped **header pool**, carved in the rock by the accumulation of runoff water;
- ▶ Lower down, they capture in their drawings the corridors that converge towards the pool outlet, where the funnel suddenly narrows into a “bottleneck”. The water rushes into it, forcing its way through, sometimes carrying along large boulders.

Still further down, the pupils represent the fan-shaped slopes of the **alluvial cones**, where the torrent deposits its cargo of debris mixed with mud and pebbles.

Each pupil strives to show the power with which water carves its mark on the landscape showing the striae gouged out of the slope, stripping it bare of any vegetation, the deep ravines with their sharp ridges and pointed crests, in which mountain matter is moved around, reshaping the slope.

- ▶ The teacher stimulates the imagination of the pupils by quoting texts in which the power of water, among the other elements, is described.

Example:

What is more fluid,	To withstand it.
More yielding than water?	So it is that the strong are
Yet back it comes again	Overcome by the weak,
Wearing down the rigid	The haughty by the humble.
Strength which cannot yield	This we know, but never learn.

Lao-Tseu, Chinese philosopher, 570 B.C./ tr. Witter Bynner

- ▶ On the plateaux, the class also detects signs of **infiltration** through the fissures in the soil and in rocks.

When the rock is limestone, for instance, the water breaks up the terrain into **karren**. To begin with, these are natural fissures in the ground; they are made deeper by the water, which sometimes filters down to the **water table**.

3. Link the erosive action of water to the possibility of water pollution

- ▶ The teacher explains the pollution risk:

When a large quantity of water penetrates the soil as a result of the infiltration of rainwater or snowmelt, an external pollutant, such as an excess of nitrates, can migrate downwards with the percolating water, reaching the groundwater network and entering drinking water.

- ▶ Studying traces of erosion and working with watercolours have provided ways of highlighting the power of water in displacing objects and its ability to dissolve, absorb and mix with other substances.



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8. Drainage basins of several torrents, *Château d'Oex* region, Switzerland
© UNESCO/Olivier Brestin

10. Convergence of flow corridors, *Château d'Oex* region, Switzerland
© UNESCO/Olivier Brestin

9. Flow channel cut by torrent, *Simplon Pass*, Switzerland
© UNESCO/Olivier Brestin



9



10



11. Dejection cone of torrent, *Kalsey, Ladakh, India*
© UNESCO/Olivier Brestin

12. Mountain torrent at foot of slope, *Achinathang, Ladakh, India*
© UNESCO/Olivier Brestin



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12

- ▶ The teacher stresses the importance of protecting mountain areas from all external sources of pollution, whether in the form of pesticides, agricultural fertilizers, industrial waste or decomposed matter from the carcasses of abandoned animals. If any of these elements are absorbed, leached by runoff and carried down through the soil by infiltration, they can contaminate rivers or pollute groundwater.
- ▶ The teacher uses the drawings to emphasize the danger: between the point of infiltration, located high up in the mountains (on the heights of the limestone plateau, for example) and the point of retrieval (the springs from which the villagers draw their water) located down below, the water, in its journey below ground, must be kept clean and free of pollution, which could poison the populations on the lower slopes.

4. Focus on the colour of surface water

- ▶ Another characteristic of water highlighted by the use of paint is its transparency, plus the fact that it can be tinted or coloured.

Is mountain water always transparent?

Does all water have the limpidity of spring-water at its source or in its downhill course?

- ▶ The pupils visit locations where water is a feature of the landscape and, using notes and sketches, try to determine the colour of the water on the site.

Examples:

Depending on the region where they live in temperate zones, they can walk up to the terminal lakes at the foot of glacial valleys, if they are unable to reach the more inaccessible cirque lakes at higher elevations.

They can compare them with the dams or artificial lakes lower down.

In the Himalayas, they can visit the banks of mountain rivers like the Amou-Daria, which flows as far as the Tien-Chan massif.

They can observe the turbulence of a melt water torrent. Does it change colour at different points on the slope?

Depending on its rate of flow or on its immediate environment? Does it take on a different colour and appearance when it meanders through the plain before joining a river?

- ▶ The teacher explains the following.

The colour of the water differs, depending on the points or stretches where it is found.

Its colour depends on a number of factors:

- in its pure, natural state, water is translucent and colourless; under a blue sky, water reflects the colour of the sky and looks blue when it is pure and has depth;

13. Retainment lake,
Tchimgan region, Uzbekistan
© Michel Le Berre



14. Storage canals for surface water,
Tiger Village, Karakorum, India
© UNESCO/Olivier Brestin



15. *Thachung Lake*, partly iced over,
Ladakh, India
© UNESCO/Olivier Brestin



- the dominant colours in the surrounding landscape visually influence its colour;
- the colouring of deposits on the ground beneath modify its colour;
- the dissolved or suspended organic matter or minerals in the water itself alter its composition and colour.

Examples :

A green colour is created by the presence of organic substances like algae; a deep green indicating the possibility of an abundance of phytoplankton. However, at high altitude, the calcium carbonate in limestone springs can also give to water a subtle emerald-green hue. Some decomposed mineral substances like iron make the water appear yellow, while a high level of humic substances (produced by the decomposition of plant matter like pine needles) can give water a wide range of hues, from black to brown to yellow.

► Confronted with several stretches of still water – a white, limpid glacial lake, fed directly by the snowfields or a high-altitude bog area in the “bugris” of central Asia – the pupils become aware that water “carries” with it the colour of the environment below and above its surface, and reflects and influences that colour when it comes to a standstill.

► Confronted with several sources of running water – a milky waterfall created directly by the melt water of a glacier or a stream swirling between the limestone concretions and the mossy stones – the pupils also become aware that water “carries” with it the colour of the environments through which it has passed.

The colour of water therefore tells a story, about the past and the present.

► Its colour may thus depend on the rocks over which it has passed and which it has washed during its underground journey between the point, at altitude, where it infiltrates the soil and the point, lower down the slope, where it re-surfaces (resurgence water from mountain springs, which emerges at the point where the **aquiferous** layer meets the surface of the slope); its colour may also be determined by the sediment that it carries (a torrent of snowmelt water) or by the vegetation it has dragged down or decomposed (a taiga river, full of tannin and humic substances).

► However, the teacher adds certain qualifications, as a warning to the class.

Using several samples taken from different water sources, the teacher demonstrates that water that appears to be slightly coloured or to contain particles may be more transparent than it looks.

► The teacher explains that in a natural, pollution-free environment, pure water is not necessarily colourless to the eye.

► The teacher adds, however, that once water has been drawn, it must be clear or else purified, filtered and made safe before it is drunk or used in paper-making, textile-manufacturing or food production.

16. Verzasca River (its bed widened),
Verzasca Valley, Ticino, Switzerland
© UNESCO/Olivier Brestin



17. Drinking from the Sacred Lake,
Ambohimanga, Madagascar
© Michel Le Berre



18. Tignes retention lake,
Vanoise massif (in the background), France
© Michel Le Berre





19. Hot spring, *Puja Valley, Ladakh, India*
© UNESCO/Olivier Brestin

21. Domesticated yak, *Tso Kar Lake, Ladakh, India*
© UNESCO/Olivier Brestin



20. *Thachung Lake, partly frozen, Ladakh, India*
© UNESCO/Olivier Brestin



► Conversely, water that is only slightly tinted (or even transparent) can be very polluted, since water can dissolve, dilute and absorb soluble chemical elements that are dangerous, just as certain pollution sources that are bacteriological in origin (the causative agents of dysentery or cholera, for example) are invisible to the naked eye

► The teacher adds by way of qualification that most residuary traces that cause water pollution are insoluble and float on the surface, making them easy to identify; they also change the colour of the water in some places. This is true of many waste products generated directly by the chemical industry or those that are created when non-degradable products are scrapped or when fertilizers and pesticides are used in farming.

► To end, the teacher advises pupils always to seek information about the state of a water source that they do not know well and to examine it thoroughly before they bathe in it or drink its water.

► The pupils make sketches of different bodies of water in different weather conditions and at different times of day.

At the same spot, changes in the intensity of the light cause changes in the colour of the water.

► They also produce sketches from different angles – looking down, close up and from a distance. This, too, causes the colour of the water to vary.

► From close up, they capture the detail of the expanse of water, which is not all the same colour, and, using coloured pencils, try to capture the interplay of reflections and their coloured shadows on the surface.

5. Incorporate this understanding of water into the notion of cycle

► To conclude the activity and to reinforce the idea that water has a history and that its passage is also a matter of time, the class visits a variety of points of access to drinking water – the fountain in the village square, a pump that supplies clean water for the crops on the slope, a natural spring finding an outlet and gushing forth.

► The pupils taste several samples of drinking water.

Although it is often odourless, it does have a taste and this taste likewise reflects the characteristics of the environments through which it has passed.



22. Natural drainage and irrigation on limestone alpine grassland, Little Saint-Bernard Pass, Italy
© Michel Le Berre



23. Alpine lake surrounded by bogs, Little Saint-Bernard Pass, Italy
© Michel Le Berre

Formation of a lapiaz through rainwater runoff on limestone soil

► Since it is not always easy to describe this taste, the teacher asks the village water-diviner to help. A water-diviner can often locate the presence of an aquifer, if it is not far below the surface, by studying the shape of the relief and the height of the massif.

► He traces the precise path taken by the water from the moment it runs off the high slopes, then filters through the natural fissures in the rocks and finally slowly migrates through the soil.

► The water-diviner, often a “water taster” and well acquainted with the geology of the area, can help the pupils to describe the taste of the water sampled. Depending on the particular soils, rocks and vegetation they have passed through, these samples may taste of sulphur, iron, iodine or limestone, or may sometimes have a plant-like aftertaste.

It takes training to be able to recognize the more subtle differences, you have to be trained, but water tasters talk of camphor, cucumber, onion and others.

► Continuing the study of drinking water and its travels, the teacher establishes the relationship between the water that we drink and the groundwater drawn at the pump. The very best water for drinking is water that has been filtered naturally as it passes through the soil and through rock, whether it is drawn from the water table by sinking a well or whether it feeds a spring that comes straight out of the ground.

► The teacher also points out another connection between drinking water taken from underground and surface water that seeps down into the ground. In both cases, it is the same water: it starts as surface water from precipitation and then becomes groundwater through infiltration, some of it returning to the surface by various means.

– The aquifer meets the surface at some point, which is the principle behind the formation of mountain streams. Owing to the action of the climate on a constantly changing relief, cracks cause water to ooze out of the ground, forming streams.

– Wells are sunk directly into the water table by the local people to meet their constant need of water for drinking and irrigation purposes.

The teacher also points out that water can return to the surface by the process of evapotranspiration (see. Chapter. 2, Activity. 3, p.86).

– Plants absorb water through their roots and transpire through their leaves.

This last point leads on naturally to the water cycle, which is the theme of the next activity.

02

The water cycle

Level 
intermediate

Place 
classroom

Duration 
3 sessions

Objectives

1. Discovery of the environment

The pupils concentrate on the different states of water as a substance – solid, liquid and gaseous – and set about relating these transient states to the various stages of the water cycle.

2. Knowledge and comprehension

Through a series of “soundscapes” and scenes from nature, which they are taught to enact using mime and sound effects, the pupils learn about the water cycle and its impact on the environment.

Methodology

1. Explore the various states of water as a substance and the origins of water in mountain regions

► The teacher gets the class to distinguish the three states of water: liquid, solid and gaseous. The teacher can conduct a few simple experiments on the subject.

► The pupils heat some water and observe its **evaporation**; the steam marks its transition from a liquid to a gaseous state (while still containing droplets of water, which make the process visible to the naked eye).

To observe the transformation of water from liquid to solid and the process in reverse, a refrigerator, which is not always available in rural mountain areas, is required. If there is one, the class makes some ice, then puts a large cube in the sun to melt.

► To observe the transition from gas to liquid, a cold pane of glass is placed above a container of boiling water and the steam condenses immediately.

► The teacher may also encourage the pupils to list nouns associated with the adjectives “liquid” “solid” and “gaseous”.

Examples:

Associated with liquid states: rain, storm, melt water, torrent, cascade, fall, stream, river, lake, pond and bog.
Gaseous states: steam, fog, mist (which is not completely true, since fog and the condensation on “misted-up” windows are really liquid forms of water, produced when water vapour condenses, vapour actually being invisible to the naked eye).

Solid states: frost, hail, ice, snowflake, snow, glacier and ice floe.

► Each pupil individually sums up in a few lines what each state of water, in its various forms, is considered to be.

What does snow evoke for a child who lives high up in the mountains?

Storms? Gales? Cold? A snowy mantle? Isolation? A long wait? Games? Avalanches? A winter diet?

What does the thaw conjure up?



24. Vanoise massif, seen from
Little Saint-Bernard Pass, France
© Michel Le Berre

A huge reserve of water? The return of spring? A season of rapid change? An explosion of plant growth? More games?

Helping with farm work again at the start of a new season?

Examples :

In the mountains of Nepal, hoeing the small plots of land, sowing the buckwheat, planting potatoes...

Helping to maintain the slopes?

Using **gabions** to build weirs? Keeping drystone walls in a good state of repair? Or the bridges?

Helping to restore the terraces?

► The teacher uses pictures in documentation already available or researched in advance, to illustrate, describe and comment on the different states in which water can be found.

► The teacher provides some facts that are prerequisites for a proper understanding of the series of transitions that water goes through in the course of the water cycle:

- fresh water is a rare commodity;
 - 70% of the Earth's surface is covered in water, 97.5% of which is salt water (the seas and oceans);
 - less than 3% of the water is fresh water and most of this is inaccessible, locked in glaciers (more than 98% of all fresh water) or in very deep **groundwater** reservoirs; a total of barely 1% of the earth's fresh water is accessible from springs that break the surface, streams, rivers, lakes, ponds, artificial lakes and **reservoirs** (where it is treated) and groundwater that is tapped by digging wells or by installing pumps.
 - these resources are limited, even though they are often replenished because water is constantly on the move, circulating through ocean, atmosphere and land in a complex cycle driven by the sun.
- The teacher reminds the class of the importance of glaciers (see the paragraph below for their formation), which, storing 98% of the planet's fresh water, are a considerable and precious resource.

The teacher points out that there are several types of mountain glacier:

- the icecaps, perched on summits that show few irregularities, that are virtually flat, like bonnets made of a dome-shaped layer of ice;
- cirque glaciers (or hanging glaciers), confined to high-altitude cirques, where feeder basins develop, to which they are confined;
- valley glaciers, which, in contrast, have a downhill orientation and move towards the lower slopes; they start from a feeder basin, consisting of several arms that meet at the foot of the dominant peaks, and are extended by an impressive river of ice that is both wide and long.

► In explaining the principle of snow melt, the teacher points out that the melt water from a glacier feeds a sub-glacial torrent that flows through the face of the glacier.

The glacier can build up such a reserve of water downstream because gravity causes it to move continuously through the river network and over the groundwater. Indeed, unlike water courses that have a different origin, the discharge of sub-glacial torrents increases in summer as a result of snow melt.

Examples:

The amount of water that the mountains in Switzerland contribute to the flow of the Rhine is considerable and the effects are felt well beyond the Alps and as far away as the Netherlands; up to 50 % in summer, when farmers with land not too far from its banks need water most.

In inhabited highland areas, water for consumption comes directly from glacier snow melt. Whether it runs off the surface or infiltrates the soil and becomes groundwater, the water is directly collected in artificial lakes or reservoirs, where it is treated for human consumption. This is what happens in the cities of *La Paz* and *El Alto* in Bolivia, which draw virtually all of the water that they require from the surrounding glaciers.

► At this point in the lesson, the teacher explains that this precious supply of glacial water is actually under threat.

Although mountains provide most of the water that finds its way into lowland areas, glaciers have been retreating and disappearing since 1850; according to expert opinion, this retreat is directly attributable to increases in **greenhouse gases** and to **global warming**, as a result of human activity.

Example:

In this process of glacier retreat, mountain glaciers are melting more quickly than glaciers in polar regions; thus the sea of ice at the top of Mont Blanc, in France, has retreated by 9 kilometres since 1850; over the same period, the number of glaciers in the Rocky Mountains has fallen from 150 to fewer than 50.

► Before examining the different stages of the water cycle in detail, the teacher explains that the impact of global warming on the mountain cycle is twofold:

- on the one hand, warmer soils create more condensation, which leads to more precipitation and so more snow.
- on the other hand, the general rise in temperatures triggers snow melt.

Consequently, the net result of the warming process is an intensification of the water cycle, which both generates and “treats” more snow and more snow melt.

Now, the intensification of the water cycle in mountain areas brings with it certain disadvantages (see. para. below).

2. Break down the stages of the water cycle for easier comprehension

► At this stage the teacher draws or copies a diagram of the water cycle on the blackboard.

Then the teacher explains the main stages of the cycle.

- Driven by the energy of the sun, water in the sea and oceans evaporates into the atmosphere in the form of water vapour.

The same process takes place at the surface of lakes, glaciers and land (evaporation), as well as on the leaves of plants (transpiration). The entire phenomenon is known as a “**evapotranspiration**”.

- In the atmosphere, this invisible vapour condenses into tiny water droplets to form clouds.



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25. *Grand Paradis Glacier*
Aosta Valley, Italy
© Michel Le Berre

26. *Aletsch Glacier*,
Switzerland
© András Szöllösi-Nagy

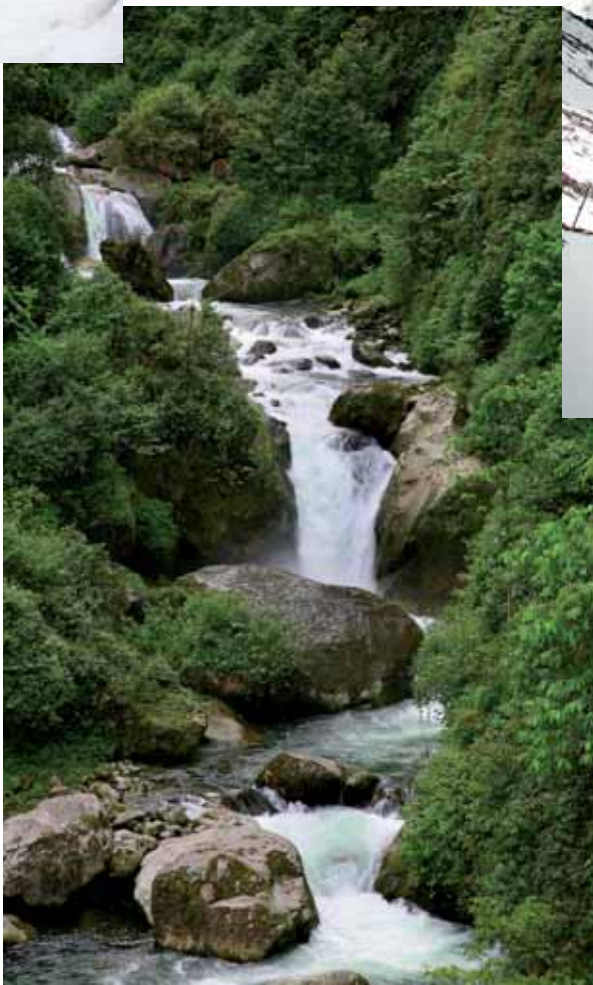
27. *Thaw*,
Khardongla Pass,
Ladakh, India
© UNESCO/Olivier Brestin

28. *Khardongla Pass*
under snow
© UNESCO/Olivier Brestin

29. *Mountain torrent*,
Burtuk, Sikkim, India
© UNESCO/Olivier Brestin

30. *Rows of gabions*
reinforcing the banks
of the torrent at *Valnontey*,
Aosta Valley, Italy
© Michel Le Berre

29



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These are blown by the wind from the sea towards the land.

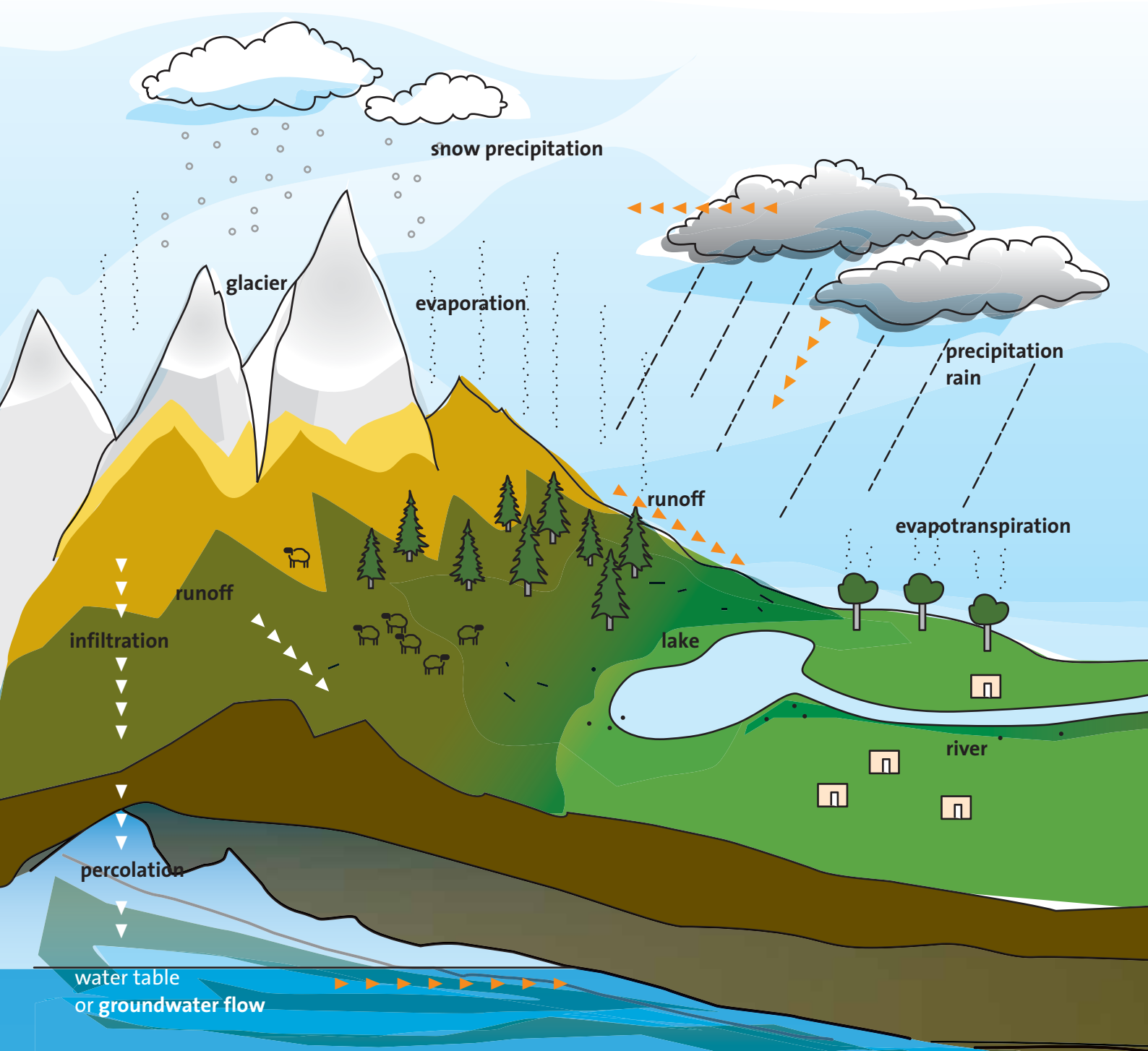
As they rise to the mountain summits, the tiny water droplets cool and in so doing collide and coalesce to form bigger drops that are heavy enough to fall as rain.

- High mountains are a particular obstacle for air masses. They block warm fronts and force them upwards until they meet freezing temperatures, creating the right conditions for continual condensation.

In addition, when the temperature inside a cloud is below freezing, the water droplets, which vaporize, instantly freeze and turn into ice crystals.

When these combine and coalesce into flakes, rain becomes snow. At very high altitudes, moisture only ever falls as snow.

The water cycle



- Whether in the form of rain, sometimes violent such as monsoon rains, torrential rain being a sign of increased precipitation levels (as in the Maghreb) or as snow showers, which are both heavy and frequent in the mountains, the water vapour in clouds returns to the planet's surface as **precipitation**.

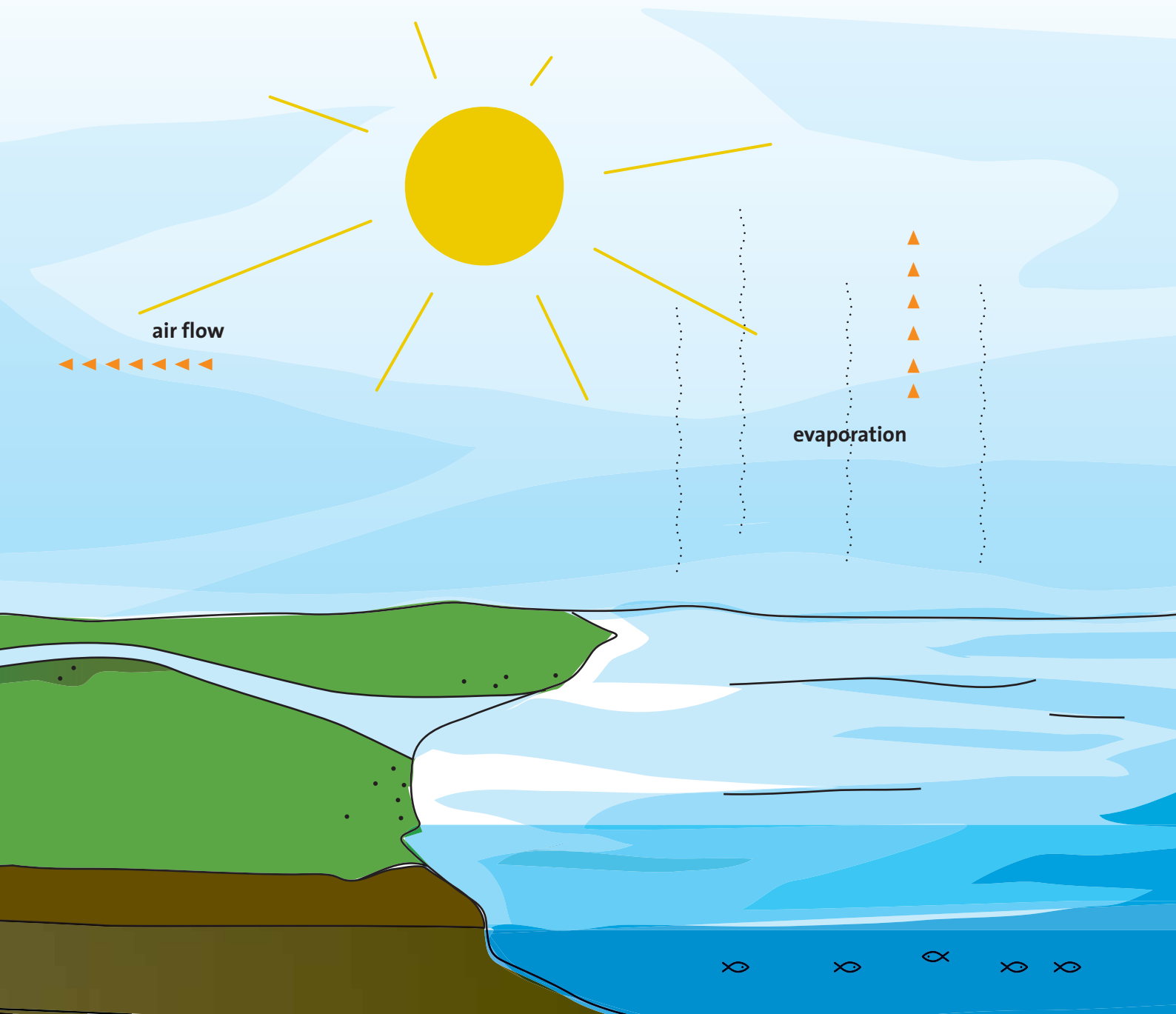
Seven ninths of rainwater falls into the sea and two ninths on land. Out of one hundred drops of seawater that evaporate, ninety-seven fall back on to the sea.

The water that returns directly to the sea then evaporates again, continuing its endless cycle.

- Of the water that falls on land, a small percentage is retained in mountain glaciers. These are formed precisely when more snow falls in winter than is lost through snow melt or evaporation. An ice mass is created by the compaction of overlying layers of snow, which, owing to the presence of melt water in the mantle, will successively melt and then refreeze at night, until the snow has expelled the air that it contains (transition from **neve** to glacier).

The snow mantle then fuses together into a mass of compact ice dragged down the slope by its own weight (gravity flow, which is imperceptible to the naked eye).

- These rivers of ice are very precious, since they allow precipitation to be expelled gradually, spreading the process over a period of time. They inch their way down to fairly low altitudes, melting gradually and re-entering the water cycle process again (which they feed on a continuous basis).



At the same time, they provide human populations, which only drink and use fresh water, with a unique reserve of salt-free water, a reserve that is regular and constant, providing it does not run dry as a result of climate change.

- The melt water that flows down slopes or the water that falls on the land as the result of precipitation either runs off the surface or infiltrates the ground, replenishing the groundwater. In either case, humankind has learnt to harness high-altitude water through drainage and canalization systems in the case of underground water (such as the **foggaras** in Algeria) by constructing artificial lakes, retention lakes or **reservoirs**, to stem a river network whose flow is controlled by gravity.

In some parts of the world, water from high altitudes is the only available source of fresh water.

Example:

In arid or semi-arid regions, only the mountains and highlands receive enough rain to constitute a resource, which, if it is harnessed, accounts for 90 % of the entire fresh water supply in the **drainage basin**.

Not all of the harnessed mountain water finds its way to the lowlands, where it also meets a growing demand for water for irrigation purposes (for an ever-growing population); stored in the retention dams in the mountains, it is also a source of hydroelectric power.

Example:

Seventy-five per cent of the energy used by the cities of *La Paz* and *El Alto*, the cities referred to earlier, comes from an hydroelectric power-station located at altitude on the eastern slope of the Andes.

- It could also be pointed out that of the water that comes into contact with the land, only a small fraction is used by living organisms, regardless of whether it runs off the surface, infiltrates the soil or is taken up into the ambient air as vapour.

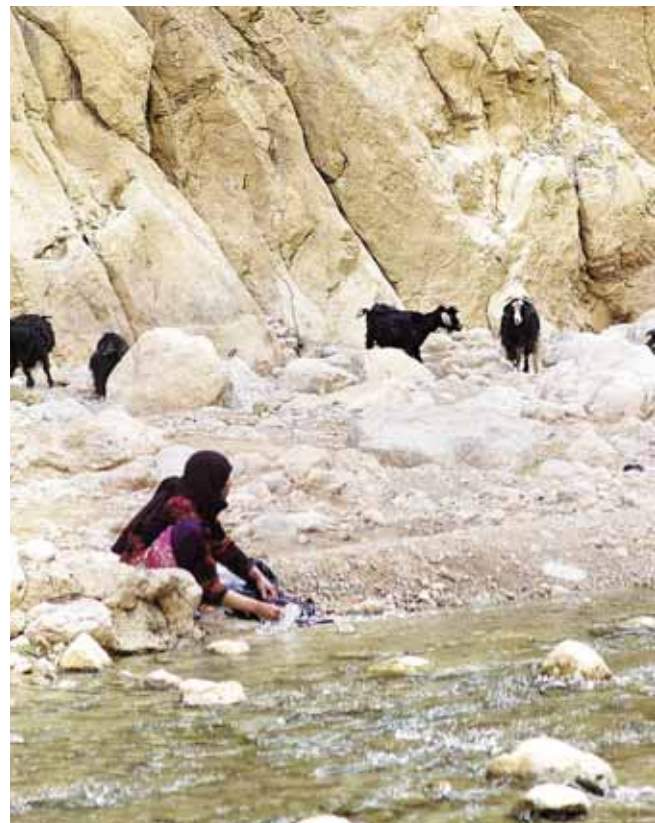
It is used in several ways:

- water that infiltrates the soil is absorbed by the roots of plants;
- water that has been harvested or made safe for drinking is consumed by human beings and animal species;

31. Gorge and river,
Errachidia region, Morocco
©Alexander Otte



32. Herder washing
in the river, Morocco
©Alexander Otte



33. Hills overlooking *Shallaleh Saghireh*, Khanasser Valley, Syria
©Hélène Gille

35. Vertical shaft leading to a *qanat*, *Shallaleh Saghireh*, Syria
©Thomas Schaaf



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34. Child playing in the *Blue Spring* in Meski, Errachidia region, Morocco
©Alexander Otte



34



35

– water that rises into the atmosphere is absorbed directly when it comes into contact with leaves, stems or epidermises.

This last phenomenon applies to all living organisms.

By thus including living species, notably ourselves, in its cycle, water plays a part in the functioning of cells, organisms and ecosystems.

In this respect, the teacher reminds the class that more than 80% of the body mass of individual plants and animals is water.

- Finally, during the water cycle, most of the water that falls on land areas returns to the sea and does so relatively quickly. This water does not infiltrate or percolate through the soil, neither is it absorbed or harnessed; it quickly drains towards the river basin and its many parts, from torrents to streams, from rivers to lakes and bigger rivers, and re-enters the sea.

► After illustrating each one of the water-cycle stages, the teacher draws pupils' attention to a number of points.

The teacher revisits the intensification of the cycle in mountain areas, which is thought to be due to global warming (see. end of para. 1 above) and explains that:

- the more slowly the water circulates, the more it interacts physically and chemically with the environment, it humidifies the soil that it fertilizes on a more permanent basis, it replenishes reserves more regularly and it enables aquiferous layers to be completely replaced over time, thus ensuring their purity;

- with the intensification of evaporation and precipitation, and the retreat of glaciers at a significant rate, so that they no longer retain as much water, we are witnessing an increase in both the amount and the frequency of runoff on the slopes.

Since the slopes are steep, the rain frequently heavy and the soil very prone to erosion, excessive runoff causes serious erosion, landslides and pollution of surface water owing to the amount of sediment washed down.

Example:

On the northern slopes of Mount Kenya, the increase in surface runoff, made worse by the recent removal of plant cover, has led to devastating flash floods and severe pollution of surface water in the region.

In mountain areas, general changes in the water cycle, associated with **deforestation** and the replacement of natural forest with other types of plant cover (forest plantations and cultivated land) are increasing the risk of water pollution.

While rates of erosion are on the increase, silting is threatening the quality of resources and the fertilizers, pesticides and herbicides used upstream are leached by runoff, frequently polluting the water further downstream.

3. Understand and interpret the water cycle through a series of “soundscapes”

► At this stage in the presentation of the water cycle, the teacher introduces role-play to associate the various stages of the cycle with sounds imitating those made by water in its various transient states. This series of “soundscapes” helps the pupils to recognize the stages of the water cycle and fit them into a clear pattern.

► The teacher begins by asking the pupils – in groups – to write down their version of the sounds water can make in its various states, or in different climatic or atmospheric conditions.

Examples:

- The deafening crash of the storm;
- The oppressive atmosphere, the clammy heat and the rumble of thunder;
- Heavy rain pounding the roof of the house;
- Hail lashing the window panes;

36. Reservoir supplying Madrid with water,
Biosphere Reserve of Cuenca Alta del Rio
Manzanares, Spain
©Thomas Schaaf



37. Small lake, *Ilmen Reserve*
Chelyabinsk Oblast, Urals, Russia
©Michel Le Berre





38. Large lake, *Ilmen Reserve*,
Chelyabinsk Oblast, Urals, Russia
© Michel Le Berre

- Icy blasts during a snowstorm;
- The creaking of blocks of ice during the thaw;
- The steady drip of a melting icicle;
- The powerful and relentless surge of a mountain torrent and the thundering cascades that echo it;
- The splash of a stream as it swirls and gushes over pebbles;
- The glug-glug of the water when a stone jar is emptied.

► The pupils then try to recreate in wordless mime – physically, using their bodies – the noises, signals and behaviour of living organisms under certain water-related climatic and weather conditions.

Examples :

The spring thaw: the sun's rays are brighter, the birds are chirping again, the insects have returned, the thaw is gaining momentum, there is the echo of flowing water, the torrents are racing down the slopes, their muddy, foaming water thunders along, the ice cracks and breaks, sending out more echoes, the flowers are bursting into bloom, the locals greet each other and go about their business.

Or the opposite picture of the stillness of a snowbound world in the depths of winter: the house is silent, silence also reigns outdoors, the cold is piercing, there is the muffled sound of footsteps as they sink into the snow, shoes are kicked together to knock off the snow, doors are hastily closed, the noises outside are muted, hot tea is poured out, the family pets doze.

► After preparing and perfecting a number of such playlets, the pupils together “act out” the different stages of the water cycle.

► They make noises and imitate expressions using gesture, movement and all kinds of props and sound effects.

► They use various musical instruments, wooden or plastic objects that make cracking or creaking noises, iron objects that can be struck or made to ring, stones and gravel shaken in various containers and, of course, water (in moderation) that can be manipulated, sprinkled, poured gently or made to drip.

► The teacher suggests breaking down the stages of the cycle into several “soundscapes”, assigned to different groups. So there might be, first, the snowstorm and the freezing over of stretches of water, the thaw and the melt water; and in other latitudes, the heavy atmosphere before a storm, the downpour itself, the runoff and rushing water, **infiltration** and absorption, **percolation** and the return to the sea.





39



40



41



42



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39. Tuareg pouring tea, *Tassili N'Ajjer*, Algeria
© Olivier Brestin

40. Quality control of tea, *Happy Valley Tea Estate*, *Darjeeling*, India
© UNESCO/Olivier Brestin

41. Tea plant and dried leaves, *Happy Valley Tea Estate*, *Darjeeling*, India
© UNESCO/Olivier Brestin

42. Kettle and basin for washing hands, Morocco
© Alexander Otte

43. Tuareg pouring tea, *Tassili N'Ajjer*, Algeria
© Olivier Brestin

► Each group combines sound effects with interpretation as they stage their play.

Examples:

For the thaw scene, the insects that appear in the first sunshine of early spring could be represented by throat noises and furtive movements; the ice that breaks by the sound of something being broken or of plastic being split and water runoff down the slopes by several quantities of gravel that are poured out gently, evenly and simultaneously in a continuous stream. Various funnels could be used, which would allow the flow rate to be limited and varied.

A long, heavy downpour may be simulated by rapid dripping into several buckets or tubs, sustained drumming on the stretched skin of an instrument or by turning gravel, then sand, over in different bowls.

In contrast, percolation could be simulated by a very slow drip and an extremely faint sound of water on the surface of a bucket.

► Once the groups have learned their routines and the way in which the different playlets fit together (different arrangements are possible), the “show” could – and really should – be performed in front of the whole community. The show could be called “Listening to the water cycle”, for example.

03

A panelled mural on mountain water management systems

Level

advanced



Place

classroom
and outdoors

Duration

6 sessions



Objectives

1. Discovery of the environment

The class considers the impact of water erosion and irrigated agriculture on soil exhaustion and on the depletion of resources in mountain areas and learns about traditional methods of harvesting, harnessing and transporting surface water, by going on discovery trails, then making sketches, which allows them to appreciate the elegance and ingenuity of these methods.

2. Knowledge and comprehension

By producing a series of large-scale drawings for the mural, the pupils highlight the ecological importance of traditional water-management methods, with their supplementary irrigation systems, required in order to make use of the slopes, and related anti-erosive structures designed to prevent natural disasters.

Methodology

1. Survey the landscape for stone constructions designed to catch runoff water and humidity

► Briefed by their teacher, the pupils go into the surrounding area to look for examples of stone structures that are scattered about the countryside. These might take the form of dry-stone walls, retaining walls, piles of stones arranged in mounds or **tumuli**, cisterns covered with a heap of limestone rocks, weirs or diguettes built across gullies on the slopes, stone cordons and others.

Examples:

Tumuli or circular stone houses (specchie) that are found on the dry mountain pastures in countries around the Mediterranean; **gabions**, which are stone diguettes held together by a metal frame, a technique introduced from Europe to combat erosion and now in common use in the mountains of many tropical countries, where they are used for terracing or for damming mountain torrents; cistern-jars derive from an ancient method of constructing a water store from an enormous stoneware jar buried in the ground and covered with a pile of limestone rocks that capture atmospheric humidity. They are very common around the Red Sea.

► The pupils wander about the area where these stone structures have been built, some of them very old, which have become an integral part of the landscape as little nooks here and there, hidden spaces, micro-environments full of surprises, following a hilly itinerary that provides plenty of healthy exercise.

► The teacher explains the following.

These stone structures play a dual water management role.

- They make it easier for runoff water to be controlled and harvested by slowing down its flow rate, holding back its **alluvium** and increasing infiltration.



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45. Landscape with low stone walls, Honaine region, Algeria
©Olivier Brestin



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46. Retention dam, El Tomadero, Anaga Rural Park, Tenerife, Canary Islands
©Michel Le Berre

- They also enable water to be extracted from the atmosphere by concentrating and condensing its moisture.
- ▶ Stopping next to a line of stones, the teacher continues to give explanations: Low walls serve several purposes in areas where water flows over sloping land.
- ▶ The teacher shows how:
 - walls act as a brake on the flow of water from the summit;
 - such walls spread out the sediment that the stream deposits on the slope;
 - the current is slowed down so that the water seeps into the soil;
 - the water, flowing more slowly, reaches the bottom of the slope instead of being lost as runoff. Where this method is not used, wadis often disappear into the ground too quickly, because of the force of the current. They also dry up in intense heat.
- ▶ The class learns how to study the micro-environment created by the wall. Local plants grow along the line of stones because humus is concentrated in these areas.
- ▶ The wall also retains the moisture that is in the atmosphere, directing it towards the ground, and provides some welcome shelter from the wind and the heat.
- ▶ The pupils discover and draw these plants, which are sometimes rare, a hidden treasure, that grow here and nowhere else, thanks to this ancient and ingenious system of harvesting water.

Example:

Stone cordons are often found at the bottom of the dolomitic limestone massifs of southern Tunisia. At the foot of these, pupils can find and draw herbaceous or shrubby plants, like *Hamada scoparia* (*Chenopodiaceae*), growing among various species of the poaceae family, such as *Stipa capensis* or *Stipagrostis pungens*, and shrubs like Mount Atlas pistache (*Pistacia atlantica*).

- ▶ They produce detailed sketches of the surroundings and then technical drawings of the wall itself, paying close attention to the stonework and whether it is made of schist slabs, round lumps of limestone, quarried stone, coarse lumps of granite or irregularly shaped stones with sharp edges.
- ▶ The teacher enhances the relevance of the exercise by focusing attention on the stones used to build a tumulus or a shelter (this can be a specchie or a mountain shelter), or else the kind of drywall shack used as a cold store for preserving fresh milk and cheese at high altitudes.
- ▶ The teacher explains that these porous stones yield water day and night.
 - During the daytime, in arid mountain areas, the wind carries smaller quantities of water vapour; this finds its way through the gaps in the stonework. Condensation occurs inside the structure owing to the sudden change in temperature, the stones being colder on the inside than on the outside. The vapour condenses into droplets which, on falling, are either absorbed by the soil or accumulate in cavities.
 - At night, condensation takes place on the outer surface of the stones, which is colder than the air; the dewdrops that accumulate seep down through the gaps into the structure, where they are harvested.



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47. Low dry stone wall, Auvergne mountains, France ©Hélène Gille

48. Plants growing on a low wall, Luberon massif, France ©Hélène Gille

49. Low wall of sedimentary stones, Luberon massif, France ©Hélène Gille

50. Borie, the Comtat Venaissin, Vaucluse, France ©Hélène Gille



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51. Hot spring (in foreground),
Chumathang, Ladakh, India
© UNESCO/Olivier Brestin

52. Bridge built of stone and wood,
Chumathang, Ladakh, India
© UNESCO/Olivier Brestin

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2. Focus on the anti-erosive structures and draw them on the first panel

- ▶ The pupils then examine the whole set of measures taken by the local population to counter the impact of water erosion and its effect on the slopes.
- ▶ They start with the stone structures or sediment dams, which are located either in the fields on the slope or directly on the stream bed.
- ▶ There and then, the teacher asks a series of questions.
 - Are the dams effective in containing the load of mud and stones?
 - Are they maintained and repaired regularly in order to remain operational?
 - Do they incorporate drystone walling techniques?
 - Are they made of gabions?
 - In the wealthiest mountain regions, the dams are made of reinforced concrete.
 - In what way do they affect the width of the flow channel of a torrent, when they artificially reduce its gradient?
 - Has this method of adjusting the gradient of slopes been fully thought through, with stone boundaries being built at intermediate points to keep the stream within its bed?
 - Is there any evidence further upstream of similar corrective action, of stone boundaries being used to contain water in gullies?
- ▶ Next, the class considers other anti-erosive measures that have been taken on unstable and bare land, such as horizontal **wattling** incorporating interwoven willow cuttings or berms of expanded metal mesh.
- ▶ The teacher adds a few more explanations:
 - Positioned at the most vulnerable points on the slopes, these structures not only trap the debris brought down by surface runoff but also hold the soil in place, so that it is not washed away by the force of the water.
 - The same fencing, netting and racks (vertical strips driven into the ground) structures are

to be found in other mountainous regions in which snowfall is heavy, such as the Rockies, the Himalayas or the Alps; they help to prevent mudflows, landslides and avalanches. Eroded soil that is subjected to strong pressure by water will, depending on climatic factors, cause various kinds of natural disasters involving water and snow.

▶ Depending on where they live in the world, pupils set about composing the first panel of the mural by making a large-scale drawing of the active defensive methods used to combat water erosion and the attendant environmental disturbances.

▶ The teacher prompts the class to include protective structures specifically designed for or adapted to very steep terrain, such as stone **snowbreaks**, those small areas of reserved land packed with large boulders and planted with trees, designed to protect farms and houses on their mountain side from any snow slippage or mudslides.

▶ Stone banks around the edges of fields are made of stones discarded during cultivation. They form effective barriers against wind and rain and also reduce crop evapotranspiration, which is more intense at high altitude, since solar radiation heats the ground to high temperatures. Here, too, water loss is carefully managed by harvesting moisture from the atmosphere.

3. Study the use of terraces in the landscape and identify them as a method of surface water management

▶ The teacher explains the following:

- Soil fertility in mountain areas is implicitly bound up with the management of water conservation. However, only some agricultural systems can guarantee a regular supply for cultivated plots.
- These include terraces and their variants, which constitute a farming method that is eminently suited to sloping land, while providing a method of harvesting the runoff water on the slopes that is so crucial in sustaining agricultural production.

▶ If the school is in a suitable location, the pupils visit sites to see at first-hand how the slopes have been converted into terraces.

They climb from bottom to top, and walk from one end of these giants to the other, discovering the micro-environments and related crops at each level, exploring every nook and cranny as they move between the different levels.

▶ They find a good vantage point and set about sketching in colour the geometry, and sometimes the wealth of colour, of the terraces viewed from above.

They thus draw:

- the contour lines, highlighted;
- the sinuous lines of each terrace level, which sometimes stretch for long distances from terrace to terrace;
- the perimeter of the plots along the contour line, each one a different shape;
- the patchwork of crops that create a mosaic of colours and shades.

▶ The teacher introduces the notion of a **contour line**, which is the line that joins up all points at the same altitude. All contour lines together allow relief to be depicted on a map.

▶ The teacher explains to the pupils that terraces are built along contour lines, where drystone walls are built as retaining walls for the flattened area of earth above.

▶ The teacher then explains that terraces make it easier to manage surface water properly, since they help to distribute the moisture evenly through the soil and, at the same time and even more importantly, to combat erosion.

▶ The pupils can see for themselves, on site, that the low wall forming the edge of a terrace leans very slightly towards the slope, enabling runoff water to flow gradually without causing erosion. Terraces thus reduce the erosion caused by torrential rain.

▶ The teacher explains that some terraces are designed even more sophisticatedly as water catchment and management systems, since they are raised.

53. Hydroelectric power station, on *Spokane River*, Washington State, USA
© Alexander Otte

54. Ancient rockslide in larch wood, *Aosta Valley*, Italy
© Michel Le Berre

55. Current upstream from *Spokane* power station, Washington State, USA
© Michel Le Berre



56. Cascade in *Le Valnontey*, *Aosta Valley*, Italy
© Michel Le Berre

57. Hydroelectric dam, *Singtam*, *Sikkim*, India
© UNESCO/Olivier Brestin



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► They consist of several different strata: on top is a layer of fertile soil, while the bottom layer consists of large stones; sandwiched between them is a layer of smaller stones which act as a drain for irrigation water.

Here, too, the effect is to promote seepage and to avoid surface erosion, two features that must be combined if surface water is to be managed properly.

► The teacher then describes other slope preparation methods that incorporate a particular adaptation of the terracing method. One such method is **benching** or Mediterranean terracing. “Benches” are terraces that consist of a subvertical riser reinforced with stones or plants and a terrace with a slight reverse slope.

Example:

They are found in the mountains around the Mediterranean and also in the Peruvian Andes, Bali, Indonesia and China, in areas where gradients are very steep and flat surfaces non-existent.

These terraces, also known as “radical” terraces, allow flat areas to be created where none existed previously and also prevent sheet erosion (surface erosion).

► The teacher explains the following.

Although benches create opportunities for irrigation and drainage down the reverse slopes, owing to the water that runs off the risers, they also increase the risk of landslip (sections of the slope breaking off), since they encourage infiltration close to the rock face.

► The teacher concludes that this method is therefore not recommended for land that is friable or porous, land composed of schist, for example.

► The teacher ends the session by broaching techniques that are specific to certain climatic conditions, like **tabias** in arid mountainous regions.

These generally comprise two to five cultivated plots, located two thirds of the way down the slope. The plots are wide, U-shaped strips and, if there are several, are arranged one above the other like terraces. They are closed off downstream by a prominent earth bund strengthened with

58. Paddy fields near Jin,
Janakpur region, Nepal
© Yann Arthus-Bertrand
La Terre vue du Ciel, UNESCO

59. Work in the fields,
Bagmati region, Nepal
© Yann Arthus-Bertrand
La Terre vue du Ciel, UNESCO



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a stone wall and fitted on the sides with stone-lined spillways, through which the water circulates to the lower plots. The central field or **jessour** is usually vast and well watered, and its crops thrive on the succession of silt deposits.

Example:

The tabias in southern Tunisia, where annual crops of barley and lentils, for example, grow in association with fruit trees such as fig, pomegranate and almond.

4. Create the second panel of the mural and include details of a surface water management system

- ▶ Back in the classroom, the pupils start work on the second panel of the mural.
- ▶ They make a large-scale drawing of a landscape featuring terrace agriculture with its stone walls, different terrace levels and means of access (often small staircases built into the walls).
- ▶ In parallel sketches, they summarize (in two comparative sketches) the way in which these components are built:
 - the construction of the walls from their foundations, which rest on large stones, while pebbles are used to plug the gaps;
 - the levelling of the terraces and the ingenious result in the form of plots of land, now flat, and ready for ploughing and the planting of crops, land wrested from a once barren hillside, yet created from nothing more than the earth on that same hillside.
- ▶ In one corner of the panel, the class tell the story in writing of the various stages in the development of these unique landscapes, a testimony to the complementary relationship between human beings and nature.

The pupils try to convey:

 - how human beings patiently labour away to reshape the arid slopes, while respecting their natural contours;

- how they locate depressions, fill the faults with gravel to prevent landslides, build stone walls and raise the ground level layer by layer, thus creating more areas for cultivation;
- how, in this way, human beings can claim to be creators of landscape, true landscape artists.

Example:

They could mention the magnificent achievement represented by the terraces of Ethiopia, northern Cameroon, the Andes or the reliefs in certain Arabic countries, especially Yemen, where the contour lines are fleshed out by stone dams that intercept the runoff water and redistribute it among the farmed plots.

- ▶ As the centrepiece of the panel, the pupils use colour to show how crops and vegetation alternate between levels and the association of different species within the same level.

Example:

In the Andes, as many as fifteen different ecosystem levels have been identified by scientists and, depending on the stage, farmers grow combinations of plant species in association, the most common being maize, beans, sweet potato, barley and quinoa.

- ▶ Various materials and the technique of collage can be used to represent crops more concretely in the drawing.
- ▶ On the central drawing, the pupils also show the different water management processes entailed in terrace farming.
 - They use arrows to show how rainwater is collected at the different levels, despite being staggered, and redistributed by natural means along the slope.
 - They also show how runoff water is slowed down by building terraces with walls leaning towards the slope.
 - If the terrace is raised, they show how surface water infiltrates the ground and migrates through the soil.
 - On “radical” terraces with their reverse slope, they clearly mark the reverse direction of the drainage of the water.

Some terraces are equipped with a rainwater catchment and transport network; this type of network can be found where there is no terrace agriculture.

- ▶ The pupils then portray the surface water management system in their village, if it has one, with or without terracing.
- ▶ The pupils determine the location of any rainwater reservoirs and its network of transport and irrigation channels.
- ▶ If the network is located on terracing, the pupils seek answers to the questions below.
 - Is the water stored high up on the slopes, in reservoirs upstream from the irrigation channels?
 - Does the water come from snow melt, streams or torrents?
 - How does surface water reach the reservoirs?
 - Is the water distributed from terrace to terrace by stone channels?
 - Is it distributed through pipes of different sizes, so that the volume of water can be controlled depending on the size of the plot?
 - Are the pipes made of bamboo, wood or stone?
 - Is the water distributed through irrigation channels that are shared, for example, by the inhabitants of the same village located on the hillside?
- ▶ Once they have clarified these different points, the pupils can produce an evocative picture of the whole water management system on the mural.
- ▶ If the network is not located on terracing, the pupils identify the water catchment reservoirs in the area, usually at the bottom of hills or in runoff areas.
 - Are they simple hand-dug reservoirs in the ground, like the johads in India?
 - Do they take the form of one or more dams that hold back the runoff water of a wadi?
 - Or are they cisterns, or “boulis”, dug straight out of the ground at the bottom of a slope



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60. Terraced vineyards,
Sierre, Switzerland
© UNESCO/Olivier Brestin

61. Terraced vineyards,
Aigle, Switzerland
© UNESCO/Olivier Brestin



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and storing only runoff water, for use in irrigating small gardens and for watering livestock?
– Is there, based on these reservoirs, a network of portable tanks that can be carried by humans or animals to the irrigation points of orchards and crops?

► Here, too, once the answers are forthcoming, the pupils portray the village's surface-water management system on the mural in a lively and colourful manner.

5. Show on the third panel the synergy achieved between erosion prevention, reforestation and good water management

► The teacher accompanies the pupils back on site, this time to areas badly eroded by rainwater.
► On site, they can see for themselves how gullies have been cut into the slopes and identify the methods used locally to curb the effects of gulying.

These often include the filter dykes mentioned earlier, which are made of stone to limit the force of the current and encourage infiltration.

In places where anti-erosion dykes are insufficient, the pupils observe the positive role played by new vegetation or a newly planted area of woodland upstream from the heavily eroded areas.

► By visiting a number of affected areas, the pupils acquire a broad understanding of the importance of reforestation in the village's water management system.

► The teacher offers further clarification:

- If there are no terraces, then reforestation is vital in action to combat erosion and preserve water resources.
- If there is no vegetation on hillsides and other runoff areas, erosion silts up reservoirs and makes it difficult for water to percolate down to the water table. Water can infiltrate more easily through the base of trunks or stems and takes advantage of the penetration of roots into the soil to infiltrate deeper.

► The teacher stresses the points below:

- The harvesting of water, reforestation and erosion control are all pieces of the same jigsaw in any serious attempt to preserve mountain ecosystems; in particular, the restoration of vegetation cover to the soil is an essential feature of the maintenance and preservation of a drainage basin.
- The grasslands at the higher levels and areas with little vegetation can be “grassed over” and planted with poaceae.
- The toughest and most rustic plants could be used to begin the first stage of plant cover on the highest crests that are the worst affected by gullying. In temperate mountainous regions, restharrow is planted at the alpine stage for much the same reason.
- Elsewhere, shrubs could be planted, using willow cuttings or sallow thorn seedlings but the ultimate stage of the restoration of plant cover on a mountain slope is, of course, the reforestation, which is also the best way of sustainably managing the surface water resources of that slope.

Example:

Some forests in the Sierra Nevada in the United States of America are particularly well controlled. They are composed of alternating plantations of conifers and evergreens. The former trap the snow in their branches and, retaining it for longer, spread the snow melt over time, whereas the areas planted with evergreens tend to store maximum quantities of snow at the foot of the tree, which guarantees basic reserves of melt water. The judicious association of broadleaved and resinous trees in the forest means that flowering plants grown down below, on the Californian plains, are irrigated on a regular and sustainable basis.

62. Hot spring channels for bathing and washing clothes, Panamik, Karakorum, India
© UNESCO/Olivier Brestin



63. Drip irrigation of terrace crops, Praia, Santiago Island, Cape Verde
© Michel Le Berre



64. Surface water storage channels, Tiger Village, Karakorum, India
© UNESCO/Olivier Brestin





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65. Watering a garden by hand,
Tiger Village, Karakorum, India
© UNESCO/Olivier Brestin

66. Woman carrying water,
Vilcanota Cordillera, Peru
© UNESCO–MAB

- ▶ The pupils end their session by focusing on those methods of growing plants that have a built-in irrigation mechanism.
- ▶ On the third panel of the mural, they make a series of drawings, showing, in successive stages, how crescent-shaped pits, or “half moons”, are dug at the base of trees planted on hillsides. This is a method of collecting runoff water over a small area.

Example:

In numerous countries around the Mediterranean, Syria and Tunisia for example, these shallow depressions, often reinforced by a lining of stones, collect enough water for an olive tree to grow and help to retain water in the soil.

Digging half-moons two to six metres in diameter allows surface water over an area of ten to twenty square metres to be harvested. Grain can be grown in them, in addition to the trees.

- ▶ Along the same lines, the pupils portray a closely related method, used on very steep gradients, of arranging stones in a half-moon shape in front of each planting hole and staggering the rows.

Example:

In Africa, manure is placed in the hole and a few millet seeds are then sown. The water retained by the half-moons makes a major contribution to the growth of the plants and to the overall success of the operation.

- ▶ In the same spirit, the pupils portray on the panel the **zai** method, which refines the planting hole with a water chamber hollowed out of the ground and enriched with fertilizer.

Using drawings that compare the different techniques, they show the increased diameter of the hole with the **zai** method and the depth of the hole, which is regularly watered and enriched with fertilizer in arid mountain areas during the dry season.

The combined action of water and fertilizer enables the crop – millet or sorghum – to survive for long periods without rain.

Glossary

Underlined terms refer to another entry in the glossary.

A

Abiotic: Non-living, referring to an element of an ecosystem. It may be an element such as water, its quality, quantity and distribution in the ecosystem or an element such as soil, its structure and humus content. Ecologists talk of “abiotic factors”, which represent the physical and chemical factors of an ecosystem.

Adret: The side of the mountain that receives the most sunshine, which, in the northern hemisphere, is the south-facing slope.

Agroforestry: Method of production combining the cultivation of trees and shrubs with the cultivation of herbaceous species. Agroforestry is recommended to increase the biodiversity of agricultural ecosystems and to improve productivity while reducing land degradation.

Alluvial cone: An accumulation of sediment washed down by a mountain torrent and deposited where the valley opens out or at the bottom of a slope. The mound is triangular in shape.

Alluvium: Deposits of sediment washed down by rivers, rainwater or any other form of running water. They are made up of sand, clay, gravel, silt and pebbles and may collect on riverbeds or, in the case of mountain areas, at those points where the slope levels out.

Alpine grassland: Over and above the adjective “alpine”, the term refers to a land biome: the biome of “alpine grasslands” or “mountain scrub and meadowland”, which is found at altitude, above the upper forest line, in many of the world’s mountainous regions. It consists of grassland and scrubland, with the dominant herbaceous stratum composed mainly of Poaceae and Cyperaceae (sedges), which vary from region to region.

Examples: alpine-stage meadowland in temperate regions, tundra in polar regions and páramo in Latin America.

Alpine stage: The stage that occurs between 2,300 and 3,000 metres in the mountain massifs of temperate regions.

No trees grow at this level, either broad-leaved or coniferous, only alpine grassland and the occasional shrub.

Anemogamy: Anemogamy, or anemophily, refers to the distribution of pollen by wind. Anemogamous plants are thus plants that are pollinated through wind action.

Angiosperm: From the Greek *aggeion*: “vase or capsule” and *sperma*: “seed”.

Angiosperm means a seed in a container, as opposed to gymnosperm (naked seed). Angiosperms are flowering plants, i.e. plants that bear seed-containing fruits. They represent 80% of plant species and more than 200,000 species are known at present. Angiosperms were preceded by gymnosperms in the evolution process.

Annual species: An annual plant is one whose life cycle (from germination to death) lasts one year. It therefore has to be re-sown on a regular basis.

Aquifer: An aquifer is a layer of ground or rock that is sufficiently porous (capable of storing water) and permeable (in which water moves freely) to contain an underground water table. The term groundwater is used to describe this type of naturally occurring fresh-water reservoir, which can be harvested to provide drinking water accessed via wells or boreholes.

Aromatic plant: Aromatic plants are plants that are used in cooking and in alternative medicine for the aromas they give off and the essential oils that can be extracted from them.

Examples: black juniper (*Artemisia genipi*), lovage (*Levisticum officinale*) and winter savory (*Satureja montana*).

Avalanche: A massive and sudden slide of snow and ice down a mountainside bringing with it earth, rock and other debris. Avalanches are caused by changes in the surface layer of the snow.

B

Bark stripping: A cork oak is stripped of its first layer of bark (the virgin or “male” cork) to ensure the healthy growth of subsequent layers.

Benching (or bench terracing): One method of managing water in mountain areas is provided by horizontal “steps” or radical terraces which mechanically reduce a slope’s incline by excavation in order to create flat terraces on relatively steep hillsides.

Biocenosis: From the Greek *bios*: “life” and *koinos*: “common”, “community”. A community of living organisms (animal, vegetable and micro-organisms) that co-exist in a defined space (biotope).

Biochemical erosion: One of several kinds of erosion that refers to the corrosive action of organisms and micro-organisms (through root exudates and decomposition) on continents and in oceans.

Biodiversity: Variability among living organisms from all sources (plants, animals and micro-organisms) on the earth, variability within the same species and variability among the ecological complexes of which they are a part. Biodiversity therefore comprises diversity within species and between species and the diversity of ecosystems.

Biotope: From the Greek *bios*: “life” and *topos*: “place”. A defined natural area characterized by specific geological, soil and climate conditions, of variable size, usually small, that supports animal and plant species adapted to these conditions. Examples: ponds, humid grassland, pine forests.

C

Calyx: All the sepals of a flower that form the outer floral envelope. The calyx protects the developing flower bud.

Camouflage: An instinctive method or system used by an animal to become less visible or to take on an appearance that can deceive another living being.

Capitulum: Type of inflorescence composed of a set of small sessile flowers (with no tendril, petiole or peduncle) that share the same base, such as members of the daisy family.

Chlorophyll: Chlorophyll is the main assimilating pigment in plants. In photosynthesis, it traps the energy of sunlight, the first stage in the conversion of this energy into chemical energy, which is vital for the production of organic carbonaceous matter during photosynthesis.

Class: In biology, class is the third level of the traditional classification of living species. The order of carnivores (*Carnivora*), which contains eight families of species (the cat family being one of them), belongs to the class of mammals (*Mammalia*).

Cluster: Type of inflorescence comprising a stem with pedunculated flowers growing at different levels.

Combe: A valley hollowed out by erosion. It is often narrow in shape, is located at the top of a fold (relief) and runs at right angles to the arch shape formed by the fold.

Commensalism: From the Latin *cum*: “with” and *mensa*: “table”, table companion. Commensalism is a relationship between two living beings in which the host provides the ‘commensal’ with some of its food without receiving anything in return. The relationship does not benefit both parties, although the host can still survive and evolve in the presence of the other organism. Certain beetles cohabit with ants in this way.

Compost: Natural fertilizer made from organic plant waste, used to fertilize crops.

Compound leaf: Leaf composed of several laminae known as leaflets. Example: walnut.

Conditions: The abiotic factors of an ecosystem are divided into two categories: resources and conditions. Conditions, in abiotic terms, include temperature, climate, the consequences of

global warming and the concept of ‘disturbance’ linked to fires, severe storms, avalanches, volcanic eruptions, mudslides and other such manifestations.

Cone: Refers to the fruit of conifers, pine or fir.

Congelifraction (or frost wedging): The fracturing of stones and rocks as a result of alternate freezing and thawing, since any water that has settled in cracks increases in volume when it freezes.

Conservation: The protection of ecosystems, species and natural resources from degradation and destruction so that future generations might benefit from them. Their protection may result in the planned management of their use by humankind.

Consumer: Within the trophic network, consumers are found at several trophic levels. Primary consumers or herbivorous animals, which feed on producers. Secondary consumers or primary carnivores and parasites, which feed on herbivorous animals; Tertiary consumers, which feed on primary carnivores.

Contour line: A contour line joins together all points with the same altitude in a particular landscape. A set of contour lines on a map represents the relief. The closer together the contour lines, the steeper the slope. In mountain areas, terraces are built on contour lines, along which stone walls are constructed in order to retain the plots of land.

Convention on Biological Diversity: The Convention on Biological Diversity (CBD) is one of the two conventions signed at the Earth Summit in Rio de Janeiro (Brazil) in 1992; the other was the United Nations Framework Convention on Climate Change. To date, 192 countries have ratified the Convention on Biological Diversity, which represents a historic commitment: it is the first global treaty to address all aspects of biological diversity, i.e. not only the protection of species, but also that of ecosystems and the genetic heritage, as well as the sustainable use of natural resources. Finally, the Convention is also the first to recognize that the conservation of biological diversity is “a common concern of human-

kind” and an integral part of sustainable socio-economic development.

Convergent evolution: When animal or plant species evolve in a similar way because of similar environmental conditions, despite a lack of geographical proximity and common ancestry (i.e. they belong to different families), the process is known as “convergent evolution”.

Corolla: The petals of a flower that together form the inner floral envelope. When the corolla is spread out, the flower is said to be “in bloom”.

Cosmetology: The study of anything related to products and treatments (health or beauty) for the body and their effect on the organism.

Curm: A curm, found only at high altitude, is a semi-circular depression bordered by walls of rock. This depression forms, or used to form, the feeder basin of a glacier.

Cuticle: The cuticle is a thin layer of cutin, often waxy, like a waterproof varnish, covering the leaves and stems of plants at high altitude or in arid regions. Cutin is a lipid substance designed to prevent water loss and is found on the outside of the aerial epidermal cells of plants.

D

Decade of Education for Sustainable Development: In December 2002, the United Nations General Assembly adopted a resolution proclaiming a Decade of Education for Sustainable Development (DESD) from 2005 to 2014. UNESCO was asked to lead the Decade and to develop the conceptual content of Education for Sustainable Development (ESD). In practical terms, this means reviewing and modifying education programmes in order to better integrate the concept of sustainability, interlinking economic, social and environmental objectives as well as respect for cultural diversity and the fight against poverty.

Decomposer: Term indicating the group of living organisms, including fungi and micro-organisms that live in soil and aquatic biotopes, which break down dead organic matter into mineral compounds.

Deforestation: All the processes by which humankind is transforming forest ecosystems and causing them to disappear: overuse of wood, forest fires, farming of wooded areas.

Detritivore: Category of decomposers that includes numerous insects that feed on plant and animal remains and on animal waste, which they decompose and partially convert into minerals, making humus in the process.

Dioecious: From the Greek *dis*: “twice” and *oikos*: “house”.

This term describes a plant species where the male and female organs are on separate plants: male flowers (with stamens) on one plant, female flowers (with pistils) on another. Fructification only takes place if the plants are close enough together. The savin juniper and Spanish juniper are dioecious species in mountain areas.

Drainage basin (or catchment): an area of land, its borders formed by crest lines (watershed), from which both surface and underground water flow into a single collection point (river, stream, lake).

E

Ecological niche: A concept used in ecology to refer, on the one hand, to the place a species occupies within an ecosystem and, on the other, the environmental conditions and factors that allow this species to live, to survive even, feed itself, reproduce and ensure the continued existence of that species in that same environment.

In other words, the concept has to do with the space occupied by the species, and focuses as much on physical space as on the functional role the species plays (its behaviour, its role in trophic terms) within the environment.

Ecological range: The ability of a species to reproduce in different ecological conditions.

Ecological succession: In ecology, ecological succession represents the development of an ecosystem over time. The process consists of a series of consecutive stages that occur in the appropriate order, such as the clearly distinct stages of pioneer herbaceous vegetation, which rapidly becomes shrubby and then bushy. The transformation of plant and animal communities, and of the soil and microclimate that characterize a succession is particularly marked following a major disturbance, such as tree felling or a severe storm.

Ecosystem: An interacting complex formed by a community of living organisms and its physical, chemical and geographical environment.

Thus, air, land, water and living organisms, including human beings, interact to form an ecosystem.

Ecotone: A transitional zone, ecologically, between two ecosystems. An example in mountain areas would be the change from forest to alpine grassland.

Endemic: A species is endemic if it grows in a specific geographical region: it is found in a particular area, the size of which may vary, and its geographical distribution is limited to that area. It is not found anywhere else.

Epiphyte: A plant that grows by attaching its roots to the surface of other plants, not as a parasite but simply using them as a support.

Erosion: The wearing away and transformation of the earth’s surface by water (rain, river, sea), ice or atmospheric agents (wind, heat, precipitation). Thus one refers to water erosion, eolian (wind) erosion and thermic (heat) erosion. This phenomenon is often aggravated by humankind (deforestation, agriculture, roadbuilding)

and results in the transformation of the relief and soil loss.

Essential oils: Concentrated liquid, obtained by the distillation or chemical extraction of the volatile aroma compounds from a plant, contained in the plant's cells.

Evaporation: Evaporation is the gradual transformation of a liquid into a gas. In the water cycle, it is the process through which liquid water escapes into the atmosphere in the form of water vapour without being absorbed by living beings.

Evapotranspiration: Evapotranspiration refers to the accumulation and, more specifically, the total quantity of water transferred from the soil to the atmosphere through evaporation at ground level and plant transpiration.

Extinction: The total disappearance of a species from the Earth.

F

Fabaceae: Plant belonging to the family Fabaceae, from the Latin *faba*: “bean”. It is a very large family with 18,000 species of herbaceous plants, shrubs, trees and creepers, including the groundnut, broom, bean, lupin, pea, acacia and carob. These plants are all able to absorb nitrogen from the air and fix it in the soil, thanks to nitrogen-fixing bacteria contained in nodules on their roots. In agriculture and economics, the term specifically refers to species that are grown for the purpose of providing food for humans and animals. In this context, a distinction is made between fodder legumes (clover, alfalfa, sainfoin) and legumes grown for their seeds (beans, peas).

Fairy chimney: A naturally occurring column of soft, crumbly, often sedimentary rocks, whose topmost part is a rock that is more erosion-resistant.

Family: In biology, the family is the set of genera (or groups of similar species) that share the most similarities. It is the fifth level of the traditional classification of living species: kingdom, phylum, class, order, family, genus, species.

For example, the genus *Canis*, which contains eight species, including the golden jackal, belongs to the dog family (*Canidae*), which comprises 35 species in all.

Firewood: Wood that is used by the population as the main source of domestic energy: for cooking and for light.

Foggara: *Foggaras* (an Algerian term) are long underground tunnels that carry water to some oases from plateaux or rocky massifs. These tunnels intersect the water table, from which they take deep-laying water and transport it to the surface near land that needs irrigation. They slope slightly, since the whole system relies on the force of gravity. Vertical wells in the foggaras allow them to be ventilated and cleaned. They were first used in Iran, where they are called “quanat”, but are also used in Morocco, where they are known as “khetaras”.

Food chain: A series of living organisms in which each eats the one below it in the chain.

Since in an ecosystem the links between species are often food-related, these relationships can be represented by sequences in which each individual eats the one below it and is eaten by the one above it. Each link in the chain is a trophic level.

G

Gabions: From the Italian *gabbione*: “large cage”. This term refers to a sort of rectangular container made of strong wire mesh and filled with stones. They are used, among other things, to build retaining walls. Gabions are widely used nowadays in Africa and Latin America to counter the effects of erosion. In order to combat erosion from rivers or mountain

torrents, they are placed at an angle or parallel to the bank. They are also used to stabilize crumbling slopes and to reduce the impact of runoff.

Geophyte: A geophytic plant is a type of perennial plant whose organs enable it to spend the season that is unsuitable for its growth (such as winter in high-altitude regions) buried in the ground. The organ in question may be a bulb (onion, lily), a rhizome (Jerusalem artichoke) or one or more tubers (potato).

Global warming: It is now an accepted fact that the average temperature of the oceans and the atmosphere has risen worldwide in recent years. Recent observations and measurements of average temperatures, the shrinking of the Arctic icefields and glacier retreat have removed all doubt over the reality of global warming. The projections of the Intergovernmental Panel on Climate Change (IPCC) predict a rise of between 1.1° and 6.4° in the temperature of the earth's surface in the course of the twenty-first century.

Gradient: Rate of change of a magnitude or datum between two points. Several types of gradient define mountain environments by the change in ecological conditions relative to altitude: a fall in temperature, an increase in precipitation, an increase in solar radiation.

Greenhouse gases: Greenhouse gases are gases in the atmosphere that absorb the infra-red rays reflected by the earth's surface when the sun's rays reach the ground. In absorbing these rays, the greenhouse gases trap the thermic energy close to the earth's surface, where it warms the earth's atmosphere. The increased concentration of greenhouse gases in the atmosphere is one of the causes of global warming.

Green manure: A fast-growing, temporary crop that enables plant cover to be maintained between two growing periods. In this way the bare ground can be protected from atmospheric conditions and the soil's natural richness preserved between these periods.

Groundwater (or water table): Subterranean water reserves, either the result of infiltration of rainwater (renewable) or “fossil” if it is very old and has been trapped underground since the geological formation of the site (non-renewable). It may be buried more or less deeply in the ground, depending on its origin.

Gullying: Gullying is the formation of gullies or ravines, the deep furrows or linear incisions created by the concentrated runoff of water on a slope. In mountainous regions, gullying may be exacerbated by the bareness of the slopes, an absence of vegetation and the impermeability of some soils that experience rainfall that is often brief but intense.

Gymnosperm: From the Greek *gymnos*: “naked” and *sperma*: “seed”. Gymnosperms are plants in which the ovules are naked (not enclosed in an ovary, in contrast to angiosperms). The plant carries its seeds in an open fruit such as cones. All conifers are gymnosperms. There are around 700 species of gymnosperm.

H

Habit: In botany, the habit of a plant is its general shape. The dense, slender shape of the cypress is different from that of the light and airy larch or the weeping cedar with its drooping branches.

Habitat: A place that is home to a particular plant or animal species, and which provides all that the species requires in order to live.

Header pool: The area of a mountain-side where runoff collects and which forms the highest part of a torrent.

Herbal medicine: The use of plants to treat illness and disease.

Humus: A complex mixture of organic substances generated by the breakdown of plant (dead leaves) and animal debris by micro-organisms (invertebrates, bac-

teria, fungi) living in the soil. Humus is a dark, earthy substance that is present in topsoil; it contributes to soil fertility by releasing nitrogen and other nutritive elements vital for plant growth.

Igneous rock: Igneous or magmatic rocks are formed from magma, molten matter deep within the Earth. When magma slowly cools and solidifies at depths, it produces coarse-grained rocks such as granite, a plutonic magmatic rock. When it is ejected at the surface, magma cools quickly, becoming basalt or other kinds of volcanic magmatic rocks.

Indigenous or native plant (or local plant): A plant that grows naturally in a given location that is part of the entire area over which the species is distributed and whose genetic material has adapted to that location. Where a plant exists only in a single location or region in the world, it is known as an endemic plant (more restrictive).

Infeodated: A species is infeodated to a particular environment insofar as it is dependent on the particular physical and chemical conditions of that environment and on a series of other living species to which it is linked. It may be closely infeodated to a given environment if the latter is very limited in space and time and has very specific conditions.

Infiltration: In hydrology, infiltration means the penetration of surface water into the subsoil through the natural cracks in soil and rocks. It is facilitated by the presence of plants and the flow that takes place at their base. Surface water feeds the groundwater reserves through infiltration and percolation in the soil.

Inflorescence: An inflorescence is the arrangement of the flowers on the stem of a flowering plant (angiosperm). There

are several kinds of inflorescence, with flowers arranged in different ways: in capitula, clusters, spikes, etc.

Inputs: An input in economic terms is a factor of production. In an agricultural context, inputs are the products necessary for a farm to run smoothly. In everyday terms, inputs are the different products used for maintaining or improving the land and crops, ranging from fertilizers to pesticides (and herbicides). Managing inputs (their use relative to their effectiveness, for example) has become a key economic issue for farmers.

Intercropping: Intercropping means that different crops are grown in the same space. Under this system, annual crops and perennial crops are grown together on the same piece of land, as long as they are mutually beneficial and not competitive. This is a way of producing a higher overall yield.

IRA (Arid Regions Institute): The Arid Regions Institute is a teaching and research institute specializing in the study of arid and desert regions (ecosystems, economy and rural communities), notably in southern Tunisia. It is located in Médine and is the Tunisian site of the SUMAMAD project.

J

Jessour: Area behind the tabias or earth dams that shore up certain types of terracing in North Africa and where loose material, silt and sand accumulate. These enriched and relatively flat plots allow crops to be grown that need a great deal of water: pomegranate trees, almond trees and annual crops.

K

Karren: The term “karren” denotes a geological formation of the ground in limestone areas, giving the rocks a jagged appearance, scored by channels, cracks and crevices, which are the result of rainwater runoff. Surface erosion often leads to perforations in the rock and the formation of caves and other cavities.

Kingdom: The kingdom is the highest level of scientists’ classification of living organisms. Excluding viruses, living organisms are divided into five kingdoms: animals, plants, fungi, protists (unicellular eukaryotic organisms) and prokaryotes (such as bacteria).

L

Lamina: Broad, flat part of a leaf through which the veins pass. Petals and sepals also have laminae.

Larch forest: In late autumn, larches shed their leaves, giving rise to a highly distinctive kind of undergrowth that is characteristically orange in colour. Larch forests are rich, fragile environments that create the right conditions for other conifers, providing a habitat for shade-loving species such as pine, spruce and beech. However, once these species become established, they eventually ‘supplant’ the larch.

Lava: Molten rock from the earth’s crust, of a fairly fluid or paste-like consistency, emitted by the crater of an erupting volcano.

Leaflet: A part of a compound leaf.

Legume: Synonym for *Fabaceae*. See Fabaceae.

Ligneous (or woody) plant: From the Latin *lignosus*, *lignum*: ‘wood’. A ligneous plant is made of wood. A plant may have

a ligneous stem as distinct from an herbaceous one. The term refers to trees, bushes and shrubs, as opposed to herbaceous plants.

Ligulate: This term describes tongue-shaped florets (small flowers) that form, for example, the corolla of members of the daisy family (*Asteraceae*).

Litter: In pedology (soil science), litter is the plant residue (pollen, leaves, fruit, seeds, branches, twigs) that falls to the ground when trees or shrubs shed their leaves (at the start of the dry season in arid regions). It litters the surface soil in forest and bushy areas. Through the activity of micro-fauna (acarids, iules, ants), fungi and bacteria, the litter gradually turns into humus.

M

MAB: UNESCO’s Man and the Biosphere Programme (MAB) is an interdisciplinary project based on research and capacity-building and aimed at improving the relationship of populations with their environment. Launched in the early 1970s, its main mission is to reduce biodiversity loss through ecological, social and economic approaches. It uses its World Network of Biosphere Reserves, comprising 564 sites (in 2010) across the world, as a tool for knowledge-sharing, research and monitoring, education and training, and encouraging participatory management.

Magma: Molten rock that contains dissolved gases and which is formed by the melting under high pressure of the earth’s crust. The magma is automatically forced upwards. Once it reaches the surface and gushes out during a volcanic eruption, it is called lava.

Mammal: From the Latin *mamma*: “breast”. Mammals are warm-blooded animals that originally lived on land, though some became adapted to life in the water (whale, sea-lion). Despite the fact that their shapes, sizes and lifestyles

vary considerably, most animals in this class are covered in hair and they all suckle their young. No other group of animals share these characteristics. Various examples of mountain-dwelling mammals are: ibex, wolves, gorillas, macaques (Japan), guanacos (Andes), the flying squirrels of North America and the Himalayan snow leopard.

Medicinal plant: A plant used by humans for therapeutic purposes.

Melliferous: Melliferous plants produce or provide substances that can be harvested by pollen-gathering insects for turning into honey. These substances are basically nectar and honeydew, pollen being an ingredient of royal jelly. A plant is considered melliferous if it can be harvested by domesticated bees.

Messicole plant: Messicole plants are annual plants that grow among crops. They are host plants in agrarian environments that have been modified by humans, where they have become established naturally. They have always been associated with crops, which derive considerable benefits from them ecologically, even though they are regarded as weeds and are often eradicated.

Migration: Migration is the movement of various species over long distances in order to reproduce or escape cold or dry conditions. They migrate periodically, returning regularly to their original region. The most spectacular land migrations involve huge numbers of mammals, such as gnus. A typical migration in mountain areas is that of the dipper (*Cinclus cinclus*), a bird that migrates from the high slopes to the plain in the cold season.

Mimesis (or mimicry): The ability of some living organisms to resemble parts of their environment or other living organisms morphologically. The aim of this imitation strategy is to enable the subject to camouflage itself, and thus avoid being seen by predators, to catch prey and to facilitate relations with fellow creatures.

Monoculture: A form of agriculture consisting of planting a single species over vast areas. Monoculture is a cause of serious ecological imbalances, since it

can result in soil erosion and encourages the proliferation of pests and diseases.

Moraine: Build-up of mineral debris brought down by a glacier or a sheet of ice, and thick enough to form a relief. Moraines can be observed trapped in the ice or deposited on top of the soil where they have accumulated.

Mutualism: Mutualism is a relationship between two or more living species that benefits both the “mutualist” and the host. The two species concerned adapt to the relationship and if one changes its behaviour, the survival of the other may be jeopardized.

For example, the ratel, an African badger, can live in symbiosis with the indicator bird, which guides the ratel to a bees’ nest with its song. The ratel opens the nest in order to eat the honey and leaves the wax and larvae for the bird. Synonym for symbiosis.

Mycorrhizal: Related to mycorrhiza, a symbiotic relationship between fungi and plant roots. A mycorrhizal fungus, therefore, is one that is associated through symbiosis with the root of a plant. Through this process of symbiosis, the hyphae of the fungus help the plant to take up, in particular, minerals from the soil.

N

Natural resources: Mineral or biological elements for which mankind has found a use. The very concept of a resource implies use. These resources fall into two categories:

Non-renewable resources, consisting of mineral raw materials, such as metals; *Renewable resources*, which can be used without being exhausted, insofar as their rate of removal does not outstrip their rate of renewal, such as forests.

Today, there is a persistent and growing trend towards exhaustion of the world’s natural resources.

Neve: A build-up of snow that, because of its particular location (orientation and relief) either does not melt at all or melts very slowly; for this reason, it remains, even in summer, below the permanent snow line. It can give rise to the formation of a glacier.

Nitrogen: A chemical element essential to the atomic makeup of biological life and constituting one of the planet’s major biogeochemical cycles.

Nursery: In agriculture, forestry, arboriculture or horticulture, a nursery is a field or plot of land reserved for the reproduction of ligneous plants in particular (trees, shrubs) and other perennial plants, and for rearing them until they are ready to be transplanted.

Nutrient: A nutritive substance (chemical elements or compounds), either mineral or organic, that is vital to the functioning of all living organisms.

The nutrients that are absorbed by plants for growth are phosphates, nitrates, mineral salts and potassium.

O

Omnivore: Living organism that feeds on animals or plants.

Overgrazing: Practice of allowing too many cattle to graze for too long a period on land that is unable to regenerate and replenish its vegetation cover. The term can also refer to the practice of allowing ruminants to graze on land that is unsuitable as pasture because of physical features such as its gradient. Overgrazing leads to soil erosion and the destruction of vegetation cover that is already fragile or sparse.

P

Parasitism: Parasitism is a relationship between two living organisms from which the parasite benefits at the expense of the host by living either inside or outside it. The parasite is a special kind of predator whose aim is not to kill the host, but to feed off it. However, it is harmful to the host.

For example, the horsehair worm (*Gordius aquaticus*), a cylindrical worm that lives in water, infects certain orthoptera (insects) that live in mountain areas and drink from mountain streams.

Percolation: In hydrology, percolation is the phenomenon in which water penetrates and passes through the pores of a soil or rock and slowly moves through the ground. Infiltration and percolation are two consecutive processes that are indispensable for the replenishment of underground water tables by surface water.

Perennial species: A perennial plant is one that lives for at least two years (as opposed to annual or biennial plants), and often much longer. Ligneous plants (trees, bushes, shrubs) and wild grasses are, by definition, perennial plants. They may keep their foliage during the winter or rainy season (broadleaved or sempervirent forest species), but usually they shed it and survive thanks to their roots or an underground storage organ (bulb) or reproduce by means of vegetative reproduction.

Petiole: The stalk by which a leaf is attached to the rest of the plant.

Phloem: In the structure of a tree, the phloem is the tissue that transports the sap. The sap moves in both directions in the phloem, whereas in the xylem cells the nutritious solution (water and dead cells) moves continuously upwards from the soil.

Photosynthesis: Bioenergetic process that enables plants to synthesize their organic matter, i.e. to make organic compounds from the carbon dioxide in the atmosphere and from water and mineral salts in the soil, using solar energy. By absorbing the sugars produced during

photosynthesis, plants produce their vegetable matter, which then serves as food for other living organisms (herbivores).

Phyllotaxy: Phyllotaxy is the order in which the leaves or branches are attached to the stem of a plant or, by extension, the positioning of the parts of a fruit, flower, bud or capitulum. Phyllotaxy is also the name of the science that studies these arrangements, which are a function of the number of leaves per node and the arrangement of these leaves along the stem. They are called ‘alternate’ if the leaves are positioned alternately on each side of the stem, ‘opposite’ if the leaves are at the same level on each side, and ‘whorled’ if there are three or more leaves at each level.

Pipeline: Pipes used to move gases, liquids or solid matter from one place to another. These pipes, which are often buried below ground, are expensive to lay and are a cause of major disturbance to the environments through which they pass.

Pistil: A flower’s female organs, comprising one or more ovaries, the style(s) and the stigma(s).

Plant cover: A collective term for the vegetation covering the ground.

Pollination: Process in which a pollen grain from a flowering plant is transported from the stamens (male reproductive organs) to the pistil (female organs) of the same species, making fertilization possible. Some flowers are pollinated by bees or insects, some by birds or certain mammals, and others by the wind. The process of pollination, followed by fertilization, is the main method of reproduction for flowering plants (angiosperms).

Population growth: An increase in the number of individuals belonging to the same species measured over time. The assessment is often conducted in a single biotope.

Precipitation: There are different types of precipitation: ranging from water droplets to ice crystals, from liquid (drizzle, rain) to solid (small hail/ graupel, hail,

snow). Precipitation forms inside clouds, as a result of condensation; the droplets collide, become too heavy to remain in suspension and fall to earth.

Predator: Organism that captures its prey alive in order to feed itself or its young. Predators deploy a number of strategies in performing this task. They directly affect the populations of their prey and help to maintain the biological equilibrium of ecosystems. Super-predators or absolute predators are predators that are not the prey of other predators.

Producer: In a trophic network containing the food chains of an ecosystem, energy passes from food producers to consumers (animals) in a series of stages known as trophic levels, traditionally represented by the successive levels of a pyramid that varies in size. Producers are plant species that produce proteins and sugars from the energy of sunlight, converting it into forms that can be used by other organisms.

Pruning: In forestry, an operation that involves cutting the lateral branches of a tree and sometimes its trunk in order to create new shoots from which the wood can then be used.

R

Regurgitation pellets: balls containing hard, undigested matter, which birds, including birds of prey, swallow when they ingest their prey whole, and which are rejected after digestion.

Reservoir: An artificial lake formed by the accumulation of the runoff discharging into a water course, after a dam has been built across it. The purpose of such a structure is usually to control the water’s natural rate of flow. The reservoir allows the volume of water that flows downstream to be regulated; it also allows a hydroelectric power station to be built.

Resources: The abiotic factors of an ecosystem are divided into two categories: resources and conditions.

Resources, in abiotic terms, include water, carbon dioxide, light, soil nutrients and space.

Rosette: A rosette in botany is the circular arrangement of a plant’s leaves around the annulus, the transitional area between its root and its stem. In harsh climates, rosettes result from the plant’s adoption of a short stem, close to the ground, and often point to the presence of young shoots protected beneath thick layers of foliage.

Ruderal plant: Ruderal plants, from the Latin *rudus*: “rubble”, grow on slopes, amongst rubble, in places where sediment has accumulated, on wasteland or at the roadside. They are often an indication that nitrogen is present and they provide shelter for a variety of wildlife. A factor in some processes of ecological succession, they are also colonizing plants that replace other plant species.

Runoff: In hydrology, runoff is the flow of water on the ground’s surface, in contrast to infiltration. Rainwater flows down slopes in the landscape and is one of the causes of erosion. The water erodes the land over which it flows by carrying away soil particles, their size depending on the quantity of water and the steepness of the slope.

S

Sacred natural site: Traditional societies all over the world have given a particular status to certain natural sites that they consider sacred: these sites show the diversity of traditional belief systems, which exist in various forms. Whether sacred forests, mountains, springs, rivers, lakes or caves, or the many other kinds of venerated sites and places, their spiritual dimension endows them all with a sense of meaning and importance. In essence, these were the world’s first protected sites.

Sciaphilic (or shade tolerant): Used of plant species that adapt well to or grow better in the shade, often in very shady environments.

Scree: Mountain terrain that is covered by a vast pile of stones, usually created by the retreat of a glacier, and where lichen grows.

Sediment: Materials produced mainly by rock erosion (soil, sand, clay, gravel and larger stones), transported by various agents such as water, wind, ice or gravity, which, after settling, are compacted and form rocks. They can also be produced by organic matter (accumulation of shells, coral debris).

Sedimentary rock: Sedimentary rocks are the result of the consolidation of layers of wind- or water-borne materials, consisting of mineral debris where other rocks have deteriorated or of organic debris in the case of plant or animal remains. They can also result from the mechanisms of chemical precipitation.

Seed dispersal: It is by means of seed dispersal that plants are scattered through their environment. Seeds may be dispersed by the wind, water or animals (birds, insects, etc.). This phenomenon is very useful from an ecological point of view for several reasons: it enables seeds to reach habitats suitable for the growth of future plants. More generally, it reduces competition between individual plants, by spreading them across a wider area; it facilitates exchanges of individuals between populations and genetic exchanges and it helps to create new populations.

Self-propagating: In agronomy, the term is applied to plant species that grow in places where they are not wanted, such as new growth from a previous crop or perennial species. The term is synonymous with “weed”.

Sempervirent (or evergreen): From the Latin *semper*: “always” and *virens*: “green”. In botany, the term refers to a plant that keeps its leaves all year round, in contrast to deciduous trees. In mountainous regions, some broadleaved trees keep their leaves; the ilex (*Quercus ilex*),

for example, on the southern slopes of the inland Alps in the South, or the numerous laurel species found in the mountains of China. Most evergreen species, however, are conifers, typical examples being the giant sequoias of the Sierra Nevada and the Californian redwood (*Abies magnifica*).

Silt: All the mineral and organic particles that rivers carry and deposit on their beds or banks, forming a fine deposit of granular particles, often referred to as silty soil.

Simple: Leaf whose lamina is a single piece, not compound. Example: the leaves of the common beech or the ginkgo.

Snowbreak: Wall or protruding mound of large stones built on a slope as a means of protection against avalanches.

Species: Group of interfertile populations, isolated from other such groups from a reproductive point of view and defined by a unique combination of characteristics.

Spike: A type of inflorescence in which the flowers or spikelets (grasses) are attached to a main stem without a peduncle.

Spruce forest: The spruce is a common conifer of the pine family (*Pinaceae*).

Stamens: Male sexual organs of a flower, the bulging end parts of which (anthers) contain the pollen (pollen sacs).

Subalpine stage: The stage occurring between 1,700 and 2,500 metres in the mountain massifs of temperate regions. Only very hardy species such as larch and birch grow at this level, above the more common conifers of the montane stage.

Succulent: Succulent plants are fleshy plants that have adapted to arid environments. They are able to accumulate and store water in their leaves, stems and trunks, which accounts for their bulky shape.

SUMAMAD (Sustainable Management of Marginal Drylands): SUMAMAD is a project of UNESCO's Man and the

Biosphere Programme (MAB), which aims to strengthen the sustainable management of marginal drylands in northern Africa and Asia. The project proposes management methods that promote economic sustainability and the conservation of resources, particularly soils and water reserves, and which foster the rehabilitation of degraded lands using an approach based on the participation of local communities. Training, capacity-building and interaction with landowners, farmers and other stakeholders are a key aspect of the project, which combines sustainable traditional management practices with scientific expertise.

Surface-sealing (or compacting): A term used in pedology to refer to soil that has become less porous, a crust tending to form on its surface as a result of the action of rain. This is one sign of soil degradation.

Sustainable development: In 1987, sustainable development was defined by the World Commission on Environment and Development as “meeting the needs of the present without compromising the ability of future generations to meet their own needs”. The definition has been refined over the years and sustainable development can be described as a form of development that respects the environment and makes wise use – through rational, moderate exploitation – of nature and its resources, thus ensuring the indefinite maintenance of biological productivity in the biosphere. *Agenda 21*, a global action plan adopted by 173 countries at the 1992 Earth Summit in Rio de Janeiro, set out a whole series of principles designed to help governments and authorities to implement policies based on sustainable development. Today, *Agenda 21* remains the benchmark for the implementation of sustainable development in a given territory.

Symbiosis: Symbiosis is a relationship between two or more living species that benefits both the mutualist and the host. The two species concerned adapt to the relationship and if one changes its behaviour, the survival of the other may be jeopardized.

For example, the ratel, an African badger, can live in symbiosis with the indicator bird, which guides the ratel to a bees' nest with its song. The ratel opens the nest in order to eat the honey and leaves the wax and larvae for the bird. Synonym for mutualism.

Synusia: Used of a range of living organisms (usually from the same environmental stratum) that are sufficiently similar in terms of their habitat, ecological behaviour and growth rhythms to share the same environment during a particular season or part of the year.

T

Tabia: Dam made of earth and stones, and sometimes very thick, that is built at the front of agricultural plots arranged in terraces on the more gentle slopes in North Africa. Tabias retain the flat part of the plots, called a jessour, on which the crops are grown.

Tectonic: Relating to the study of geological structures such as mountain ranges and cordilleras and the forces that produce them, namely the phenomena of convergence, collision or divergence of the plates that form the earth's crust.

Tomentose: Used of plants that have a hairy appearance. The purpose of this downy coating is frequently to trap dew or to prevent the plant from drying out too quickly at high altitudes.

Transformer: Denotes a category of decomposers in a trophic network: those that complete the work of detritivores by breaking down what has already been converted into inorganic matter, i.e. the dead matter of chemical compounds. Examples: bacteria and soil fungi.

Transpiration: There is a difference between animal perspiration and plant transpiration. Animal perspiration is the elimination of sweat through the skin pores of humans and mammals; it helps to regulate body temperature. Plant tran-

spiration is the elimination of excess water vapour from plants. It is a continuous process, which involves both the evaporation of water through the leaves and the simultaneous absorption of water by the roots in the soil. Transpiration takes place through the stomata and stimulates the movement of sap.

Transplant: To dig up a herbaceous plant or tree (generally a seedling) and plant it elsewhere.

Trophic network: This refers to all the food chains linked together within an ecosystem. These food chains link the various ecological categories of living organisms that make up the biocenosis, namely:

– producers, which are green plants that constitute the first trophic level;

– primary consumers, which are herbivorous animals and represent the second trophic level;

– secondary consumers, which are mainly carnivores and parasites and constitute the third trophic level;

– tertiary consumers, or super-predators which feed on carnivores and represent the fourth trophic level.

We should not forget decomposers, which break up and mineralize dead organic matter. (Cf. diagram on p.21)

Tubular (or tubulous): Refers to tube-shaped florets (small flowers) that form the heart of the flowers of the daisy family.

Tumuli: Plural of 'tumulus'. A tumulus is an artificial mound, sometimes circular, covering a burial place. Earth tumuli are rare these days, although stone tumuli (or cairns) are fairly well preserved. Civilizations in pre-Columbian America and Ancient Egypt built tumuli.

U

Ubac: The side of the mountain that receives the least sunshine, which, in the northern hemisphere, is the north-facing slope.

UNESCO (United Nations Educational, Scientific and Cultural Organization): UNESCO's ecology-related scientific programmes place ecological and earth sciences at the service of sustainable development. Among other things, these programmes contribute to the fight against desertification and erosion in mountain areas. The Man and the Biosphere Programme (MAB) is responsible for most of the activities relating to biodiversity. The International Hydrological Programme (IHP) deals with the key issue of water resources and ecosystems by trying to reduce threats to water systems. Most of the research in the fields of geology and geophysics is conducted under the auspices of the International Geoscience Programme (IGCP).

V

Vegetative reproduction: Vegetative reproduction is a type of asexual reproduction. Unlike seeds, which produce new specimens (with a new genetic endowment), vegetative reproduction produces clones (individuals genetically identical to the mother plants). It takes place spontaneously or can be provoked, without the involvement of the seed, by means of cuttings (propagation), grafts or stolons. Vegetative reproduction is therefore distinct from generative or sexual reproduction, which requires a seed.

Vernacular: Related to a specific region, to a country or its population.

W

Water Table: See “Groundwater”.

Wattling: Latticing made of stakes and branches in a wire-mesh pattern designed to hold soil in place and prevent slips.

Woody plant: Synonym for ligneous plant.

Zoochory: Zoochory is the process through which plant seeds are dispersed by animals. The seeds may be dispersed in animal faeces (endozoochory) or externally, via hooks or thorns on the fruit, which attach themselves to the animal’s fur (epizoochory).

X

Xylem: In the structure of a tree, xylem is tissue that can transport large quantities of water from the nutritious soil to the leaves, which carry out photosynthesis. It therefore transports a solution containing water and mineral salts to the top of the tree and to the leaves, which act as pumps.

Z

Zai: In Africa, zai is a traditional soil preparation technique that involves making holes in the ground to catch a small amount of runoff and then sowing millet or sorghum seeds in the holes. The resulting seedlings will then be less vulnerable in the case of irregular rainfall. The technique is more effective if the ground is prepared very early, well before the rain arrives: organic waste is placed in the holes and is eaten by termites that have tunnelled through, thus increasing water infiltration; the seeds can then be sown and manure added.

Aknowledgements

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A Creative Approach to Environmental Education

This teacher's manual forms part of the teaching resource kit entitled: *A creative Approach to Environmental Education/A Teaching Resource Kit for Mountain Countries*, published by UNESCO.

The kit is available in three languages (English, French and Spanish) and comprises two documents:

- A teacher's manual, the main component of the kit, divided into three chapters
- A class notebook for pupils

www.unesco.org/publishing



Natural
Sciences
Sector

School _____

Country/town _____

Class _____

Teacher's name _____

The class notebook

A Creative Approach
to Environmental Education

A Teaching Resource Kit for
Mountain Countries



United Nations
Educational, Scientific and
Cultural Organization

UNESCO
Publishing



Man and the Biosphere
Programme



UNESCO
Associated
Schools



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Officer-in-charge:

Thomas Schaaf, UNESCO

Editor and project designer:

Hélène Gille

Scientific advisers:

Michel Le Berre, Thomas Schaaf

Graphic design:

Mecano, Laurent Batard
assisted by M. Malpeyrat et de C. Sayous

Translation:

Paul Reed

Coordination and iconography:

Hélène Gille

With the collaboration of:

Greg Thaler

Administrative assistance:

Natasha Lazic,
Rosanna Karam

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Programme (MAB), UNESCO
1, rue Miollis
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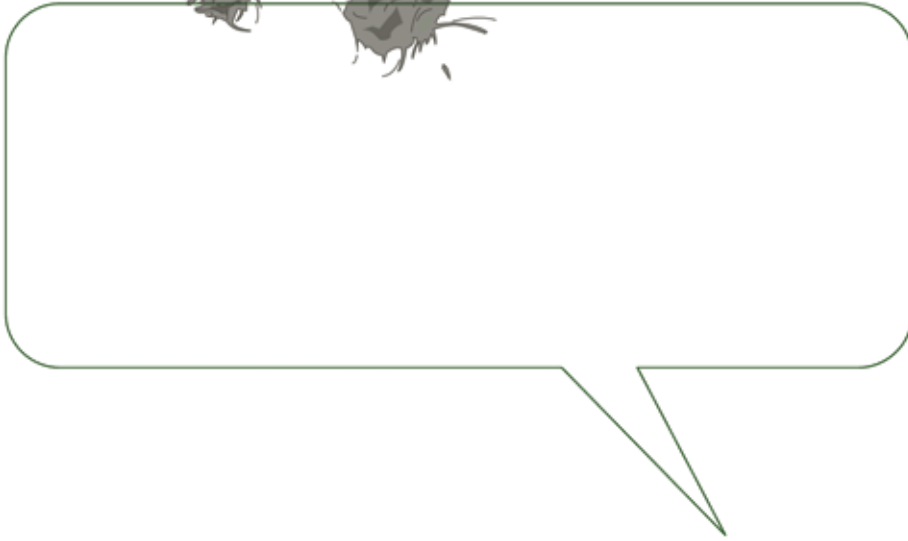
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Now it's your turn...



Talk about the activity





Why the class notebook?

You have just completed one of the kit's activities, so... get your pencils ready!
Here is a notebook especially for you, which will follow the teacher's manual.

Inside the notebook you will find the double page that corresponds to the activity you have just completed. Now it's up to you to fill it in...

With help from your teacher, get together in groups and, as you carry out the activities, each group takes it in turns to fill in the corresponding double page.

Try to remember the exercise you did, get back into the mood...

What were the different stages of the activity? What were the objectives?

Which images, which scene stick in your memory?

Is there one step in the activity that you particularly enjoyed?

Describe this... in your own words and with the terms you have learnt.

Answer the questions, and don't forget to draw and add colour.

While you were carrying out the activity together, which object, element or detail made the biggest impression on you?

How can you represent it?

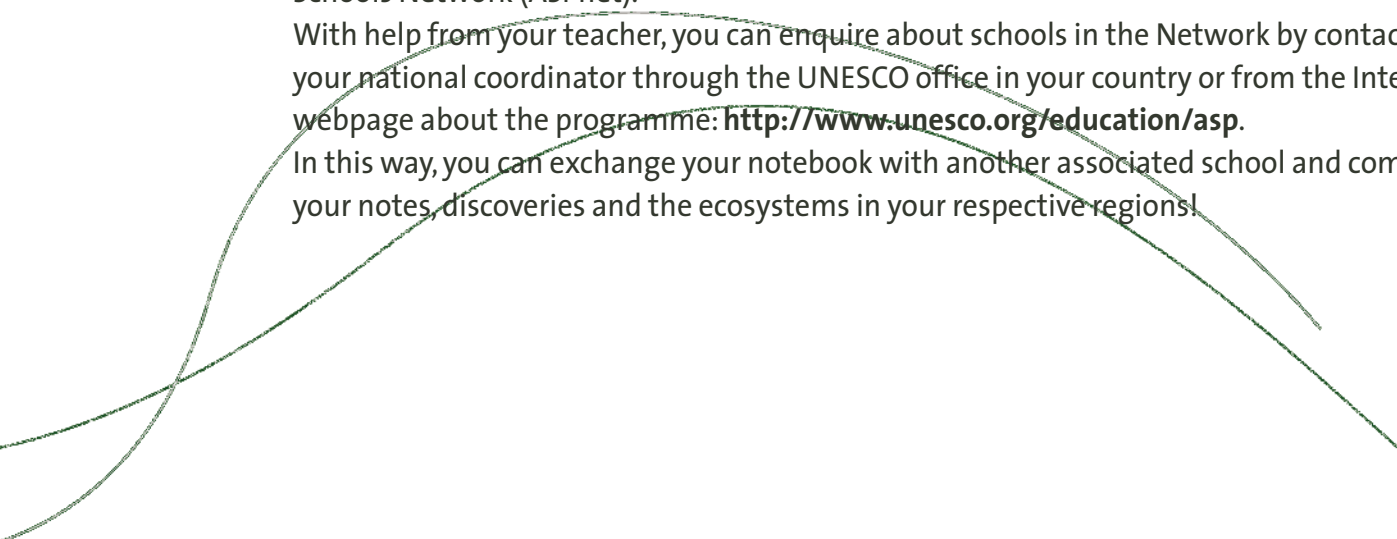
Practice and try to sketch it. The important thing is to keep a record.

If you find you need more space, you can use the last pages in the notebook, reserved for extra notes and drawings (see pages 30 to 32).

Once the notebook is full, ask your teacher to make a photocopy and, if the whole class agrees, you can send a copy of the notebook to a partner school in UNESCO's Associated Schools Network (ASPnet).

With help from your teacher, you can enquire about schools in the Network by contacting your national coordinator through the UNESCO office in your country or from the Internet webpage about the programme: <http://www.unesco.org/education/asp>.

In this way, you can exchange your notebook with another associated school and compare your notes, discoveries and the ecosystems in your respective regions!



Get your pencils ready!

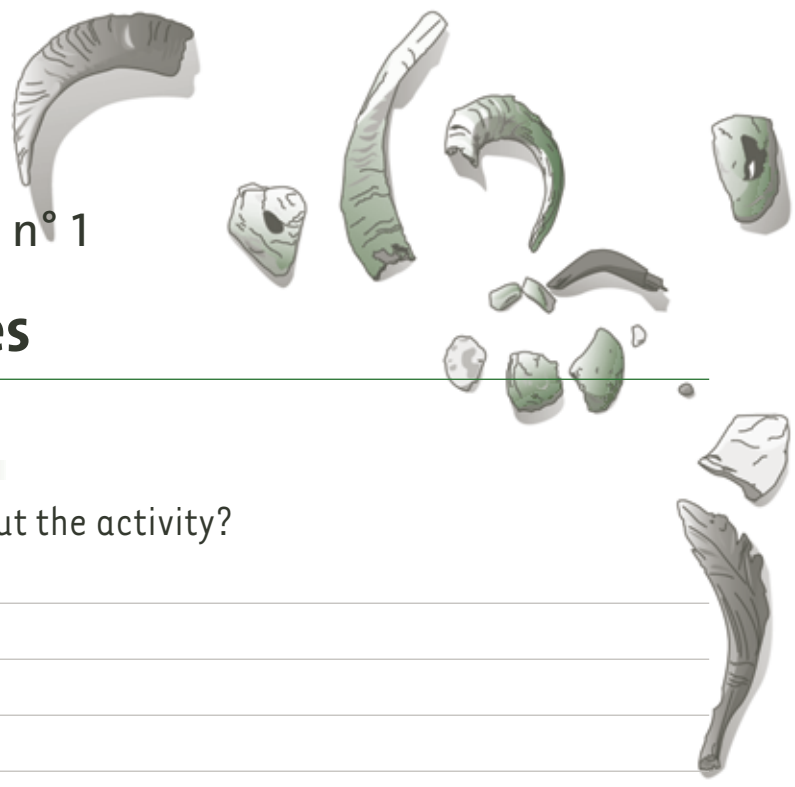
Chapter n°1 | Activity n° 1

Collecting treasures

Where and when did you carry out the activity?

How did you go about it?

Explain in more detail:



Get your pencils ready!

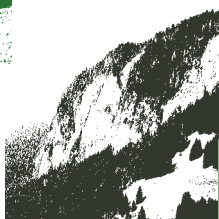
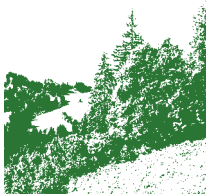
Chapter n°1 | Activity n°2

Plant cover or the mountain as a mosaic

Where and when did you carry out the activity?

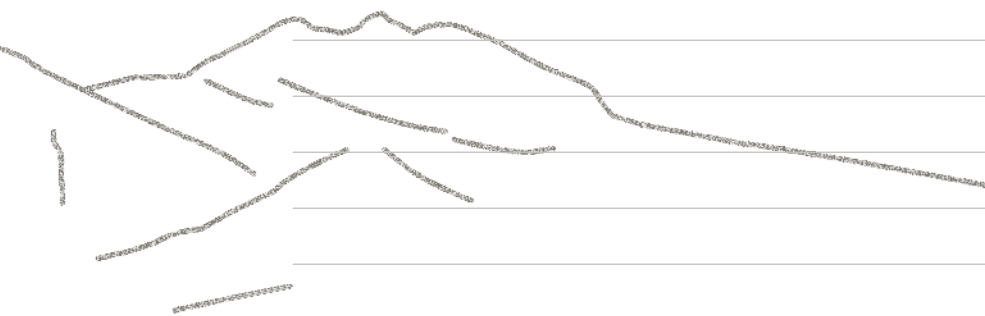
How did you go about it?

Explain in more detail:

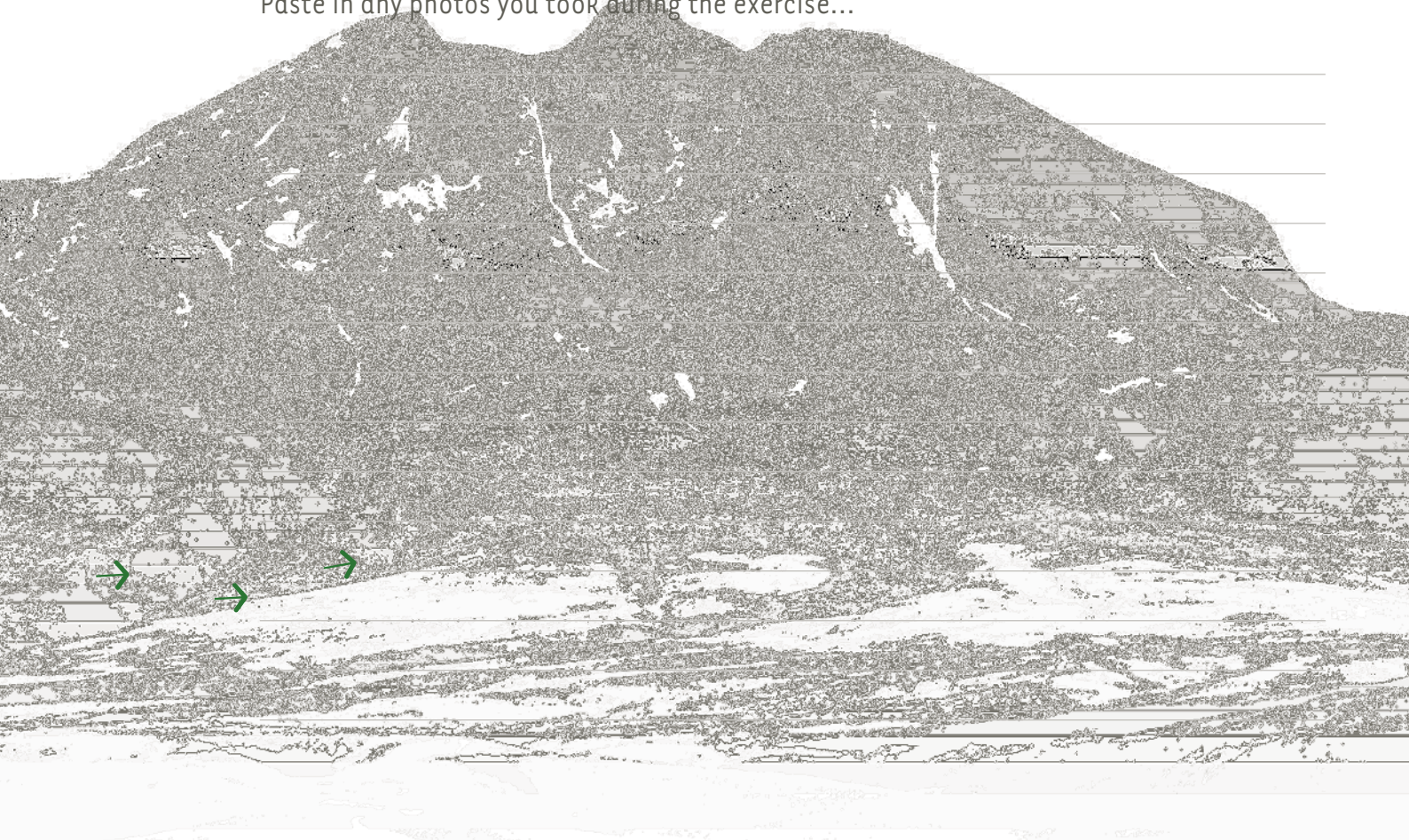




What is erosion? Describe the action of water on the relief and on slopes.



While you were carrying out the activity, which element (or object) made the biggest impression on you? Can you describe it? draw it? paint it? Paste in any photos you took during the exercise...



Get your pencils ready!

Chapter n°1 | Activity n°4

On the tracks of wild animals

Where and when did you carry out the activity?

How did you go about it?

Explain in more detail:



Name the producers, consumers and decomposers that make up a food chain you have studied in order to understand the local ecosystem.

What role does each one play within the ecosystem?

(see diagram of the trophic network p. 25 of the teacher’s manual)

Horizontal lines for writing answers to the first question.

While you were carrying out the activity, which element (or object) made the biggest impression on you? Can you describe it? draw it? paint it?

Paste in any photos you took during the exercise...

Horizontal lines for drawing or pasting photos.



Get your pencils ready!

Chapter n°2 | Activity n°2

Shape and design: the anatomy of trees and shrubs

Where and when did you carry out the activity?

How did you go about it?

Explain in more detail:



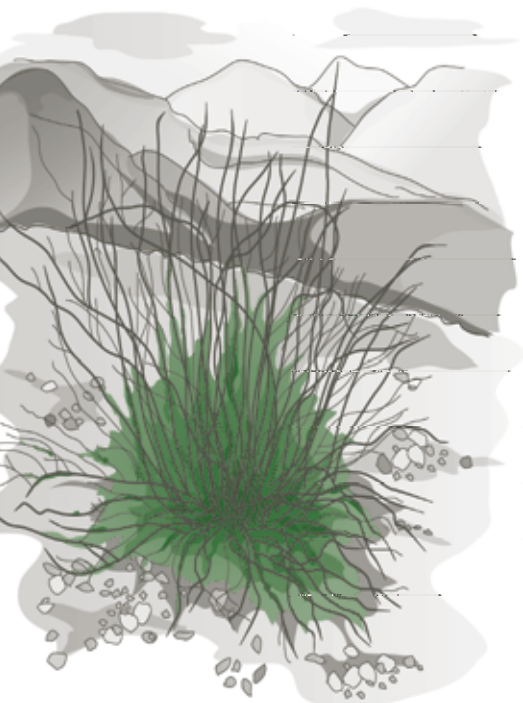
What external factors in mountain areas can make a tree look abnormal and prevent it from growing naturally?

While you were carrying out the activity, which element (or object) made the biggest impression on you? Can you describe it? draw it? paint it? Paste in any photos you took during the exercise...



What are the main evolutionary convergences between mountain and dryland plants (morphological adaptations)?

While you were carrying out the activity, which element (or object) made the biggest impression on you? Can you describe it? draw it? paint it? Paste in any photos you took during the exercise...



Get your pencils ready!

Chapter n°2 | Activity n°4

An inventory of useful plants



Where and when did you carry out the activity?

Four horizontal lines for writing the answer to the first question.

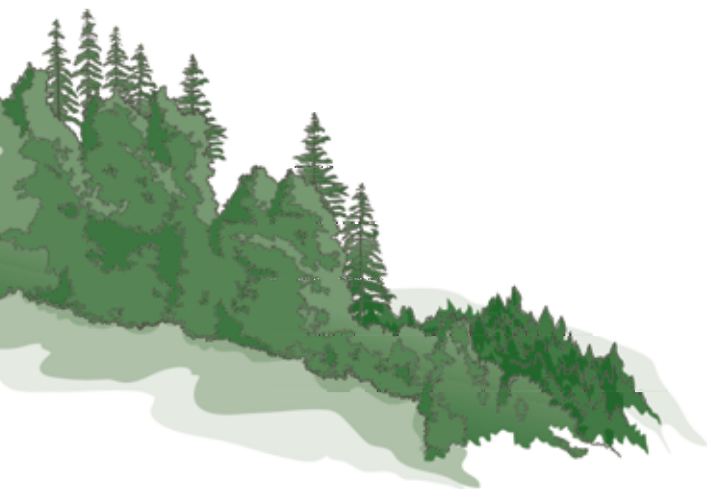
How did you go about it?

Four horizontal lines for writing the answer to the second question.

Explain in more detail:

Eight horizontal lines for writing a detailed explanation.

Eight horizontal lines for additional notes or observations.



Get your pencils ready!

Chapter n°2 | Activity n°5

The experimental garden

Where and when did you carry out the activity?

How did you go about it?

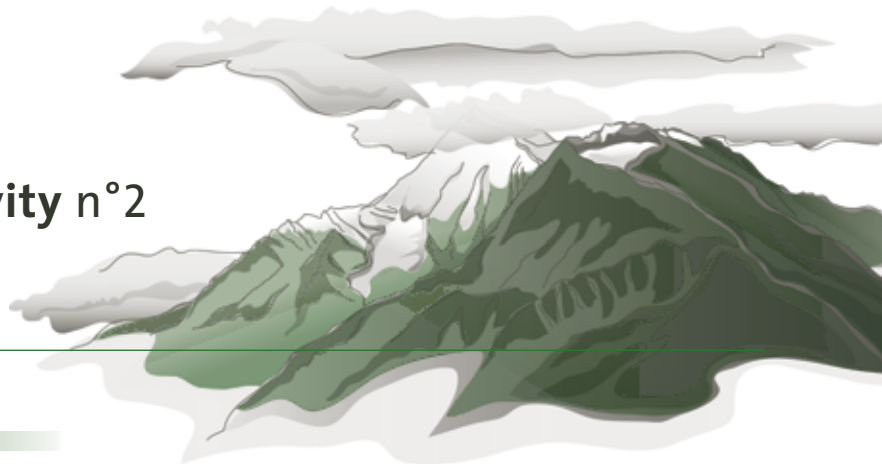
Explain in more detail:



Get your pencils ready!

Chapter n°3 | Activity n°2

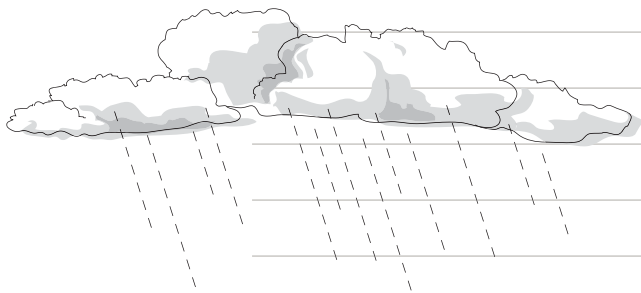
The water cycle



Where and when did you carry out the activity?

How did you go about it?

Explain in more detail:



Get your pencils ready!

Chapter n°3 | Activity n°3

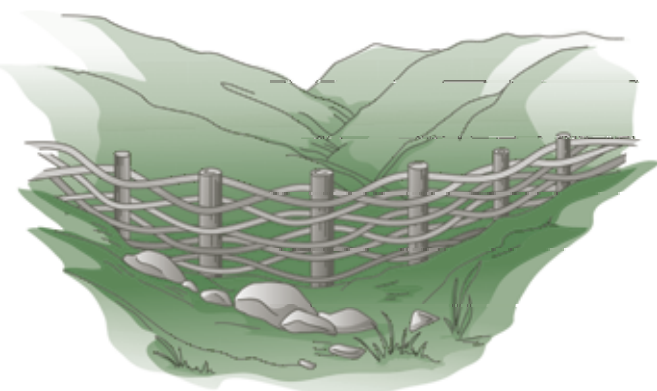
A panelled mural on mountain water management systems



Where and when did you carry out the activity?

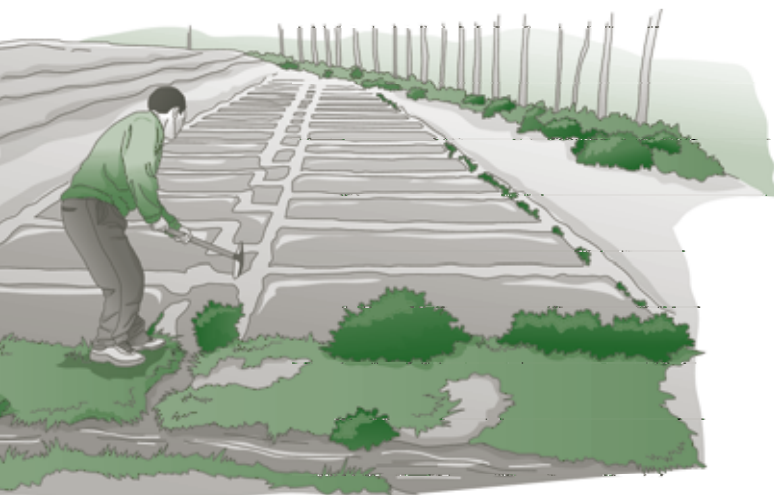
How did you go about it?

Explain in more detail:



In what ways are terraces particularly well suited to land that slopes (erosion, farming, water management)?

While you were carrying out the activity, which element (or object) made the biggest impression on you? Can you describe it? draw it? paint it? Paste in any photos you took during the exercise...



Names of the class pupils



United Nations
Educational, Scientific and
Cultural Organization

.....
**Natural
Sciences
Sector**
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