The Lautaret Alpine Botanical Garden

Guidebook

Serge Aubert

The Lautaret Alpine Botanical Garden, as it exists today, has been shaped by the work of the botanists involved in its development for over a century. This guide presents the Garden itself (its history, work and collections), the exceptional environment of the Col du Lautaret, and provides an introduction to botany and alpine ecology. The guidebook also includes the results of research work on alpine plants and ecosystems carried out at Lautaret, notably by the Laboratory of Alpine Ecology based in Grenoble.

The Alpine Garden has a varied remit: it is open to the general public to raise their awareness of the wealth of diversity in alpine environments and how best to conserve it, it houses and develops a variety of collections (species from mountain ranges across the world, a seed bank, herbarium, arboretum, image bank & specialist library), it trains students and contributes to research in alpine biology. It is a university botanical garden which develops synergies between science and society, welcoming in 15,000 – 20,000 visitors each summer.

Prior to 2005 the Garden was not directly involved in research, but since then a partnership has been established with the Chalet-Laboratory through the Joseph Fourier Alpine Research Station, and mixed structure of the Grenoble University and of the French Scientific Recearch Centre (CNRS). These shared facilities also include the Robert Ruffier-Lanche arboretum and the glasshouses on the Grenoble campus. The Lautaret site is the only high altitude biological research station in Europe, and has been recognised by the French government's funding programme (Investissements d'avenir) as Biology and Health National Infrastructure (ANAEE-S) in the field of ecosystem science and experimentation.

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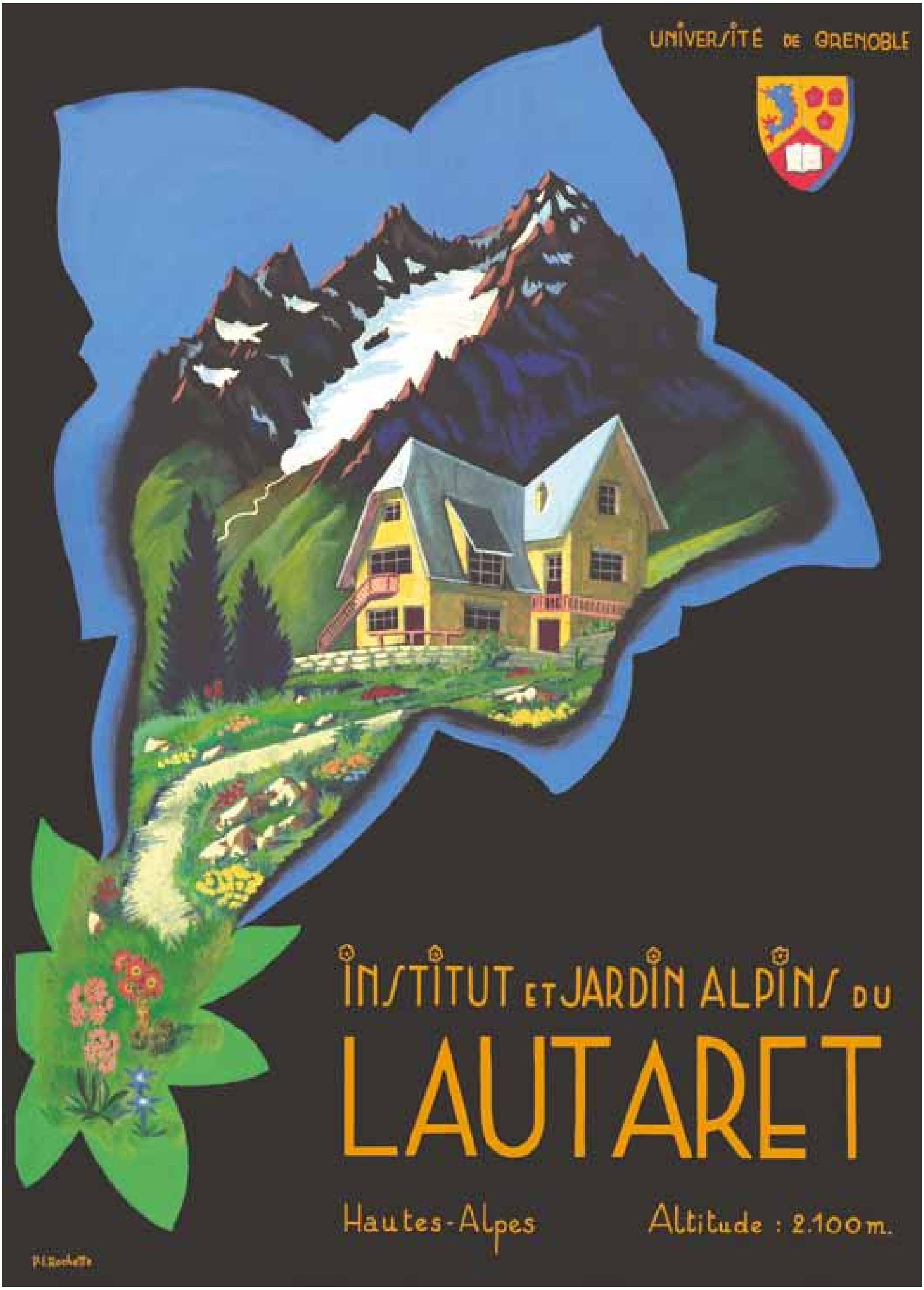
Contains over 500 pictures, diagrams, drawings and graphs



Poster showing the Lautaret Alpine Garden, inside a Gentian sketched in the 1960s by Paul Rochette (1923-1989); a teacher-researcher and botanist at the University of Grenoble.

Outline

1. A one-hundred-year-old garden 1

- Lautaret - a truly remarkable site 2
- One hundred years of history 11
- The Garden's Collections 21

2. Alpine flora 31

- What is an alpine plant? 32
- The history of alpine flora 41
- Alpine plant diversity 51

3. Botany basics 61

- The flower 62
- Relationships between species 71
- Adaptations to alpine life 81

4. A remarkable range of environments 91

- Tall-herb communities 92
- Wetlands 101
- Plants and snow 111

5. Man and the Pass 121

- The history of the Pass 122
- Living in the mounains 131
- Man & plants 141

6. Recent improvements to the Garden 151

New signs, School of Botanics, Illustrators in residence, Publications, High-Altitude Arboretum, Participation in Research, New Developments, Picture bank, A major project: the Alpine Gallery

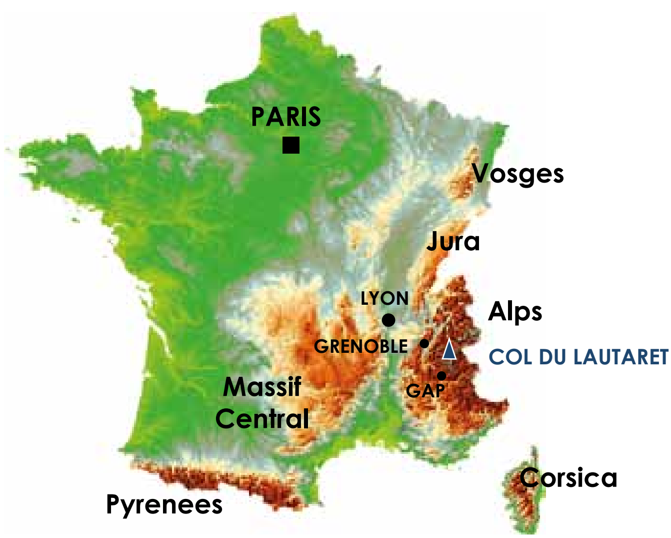
7. The Rock Gardens 161

8. Bibliography 200

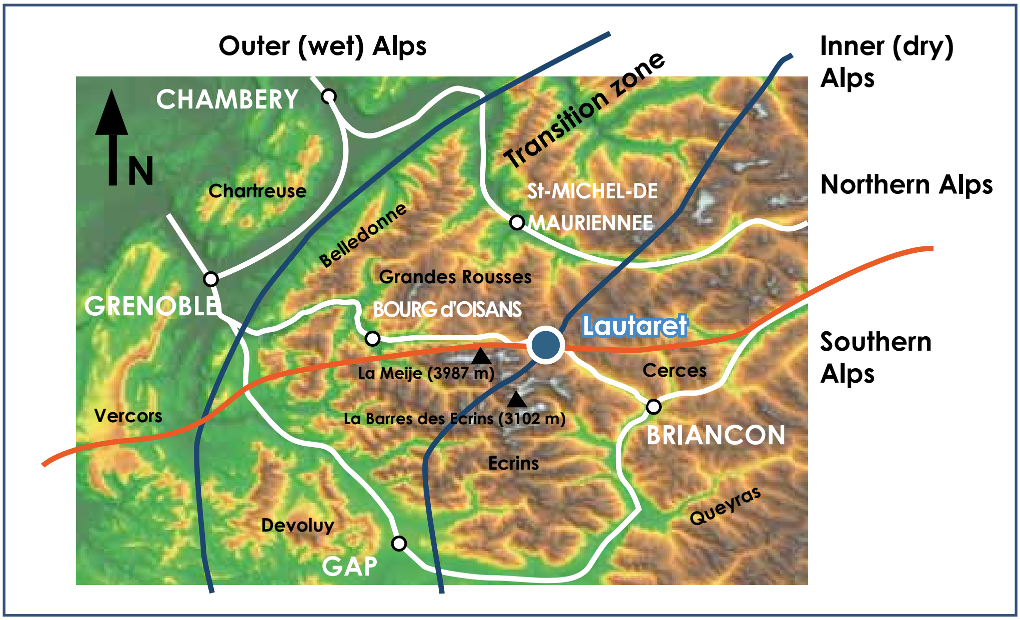
A one-hundred-year-old garden

Lautaret - a truly remarkable site

The Col du Lautaret is a truly remarkable place, a genuine geographical, climatic and geological crossroads. At the junction of the Northern and Southern Alps, and the inner and external Alps, the wide geological diversity of the landscape and its particular climate make it a hotspot of natural botanical diversity with almost 1,500 plant species: one-third of the flora of France. Dominique Villars (1745-1814), the famous doctor and botanist from Champsaur in the Hautes-Alpes (Villars 1779), first recognised its remarkable biodiversity at the end of the 18th century.



Map of France showing the main mountain ranges: Alps, Pyrenees, mountains of Corsica, Massif Central, Jura and Vosges.



The Col du Lautaret is located at the crossroads of the Northern Alps (high snow cover and cloud amount) and the Southern Alps (high levels of sunshine and mediterranean influence) on the border of the external Alps (oceanic influence causing high levels of precipitation) and the dry inner Alps (continental influence).

The Guisane valley, the Col du Lautaret and the Ecrins Massif seen from Grand Galibier (3229 m). The highest summits can be seen behind the Pic du Combeynot. The white star indicates the location of the Alpine Garden.

View from the Col du Lautaret of the Guisane valley (to the east towards Briançon), and the Cerces and Combeynot massifs.

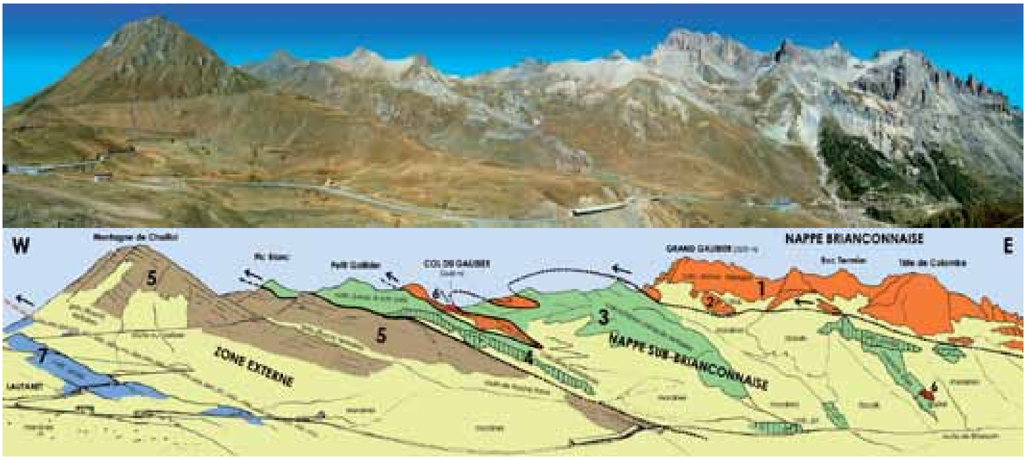
The Col du Lautaret, at 2056 metres altitude above sea level, marks the watershed divide between the river Guisane to the east, which flows into the Durance in the Hautes-Alpes, and the river Romanche to the west, which flows into the Drac and then the Isère, in the region of the same name. It is a frontier on the road from Grenoble (90 km distance) to Briançon (30 km distance), marking the transition between the Rhône-Alpes and Provence-Alpes-Côte d'Azur regions, and a tourist hub at the junctoin of the Oisans, Briançonnais (two regions in the Dauphiné) and Savoie regions.

The Col du Lautaret also marks a climatic crossroads. Not only is it located at the boundary between the wet external Alps (under oceanic influence from the west) and the dry inner Alps, but it also marks the transition between the cloudy Northern Alps and the Southern Alps, whose sunny climate derives from Mediterranean weather systems that move up the Durance valley. The diverse climatic influences around the Col du Lautaret are clearly visible in its vegetation. Very different types of forests can be found just tens of kilometres apart. Beech and spruce are commonly found to the west, particularly in the region of Bourg d'Oisans, whilst Scots pine and larch are more common in the east.

Add to this eclectic mix the dry, persistent wind, and you get a cold, dry climate characterised by plentiful sunshine and wide thermal variation.

Autumnal colours in the Romanche valley show up in the beech (deciduous, 1) and spruce (evergreen conifer, 2) forests. These two trees are characteristic of the wet external Alps; they are no longer found east of the Col du Lautaret, superseded by Scots Pine at low altitudes (montane zone) and by larch, Pinus uncinata *and* Pinus cembera*, at high altitudes (subalpine zone).*

The autumn colours of the Guisane valley clearly show up the locations of forests of Scots Pine (1’) at the montane zone and the larch forests (2’) at subalpine zone. Larch forests are characteristic of the inner Alps which have a dry, sunny summer climate. Note that the larch is the only conifer in France which actually loses its needles in the autumn.



The Galibier massif, culminating at 3229 metres, is composed of highly varied sedimentary rocks: Dolomitic limestone, limestone, quartzite, shale, etc. It also contains gypsum, easily recognisable due to the remarkable erosion patterns in the form of dissolution funnels visible at the Col du Galibier (photo: Francou; interpretive cross-section: J. Debelmas).

From a geological perspective, the Lautaret region is an area of great contrasts, with very different types of rocks found within short distances of each other (Debelmas et al 1999). There is notably a clear distinction between the sedimentary massifs of Galibier and Cerces, located to the north, and the crystalline massifs of Combeynot and Ecrins located to the south. This diversity of rocks creates a variety of ground surfaces which differ in terms of their acidity, porosity, water retention, etc. In addition to this, the variations in geographical relief offer plants a wide range of ecological conditions in which to develop.

View of the Meije crystalline massif at the heart of the Ecrins National Park and mountain range. It is composed of granite and related rocks. In the foreground, meadows with high biodiversity just above the Alpine Garden, on the road to the Col du Galibier. Here we can see single-flower knapweed (purple), large-leaved helianthemum (yellow), alpine aster (blue), and mountain sainfoin (pink).

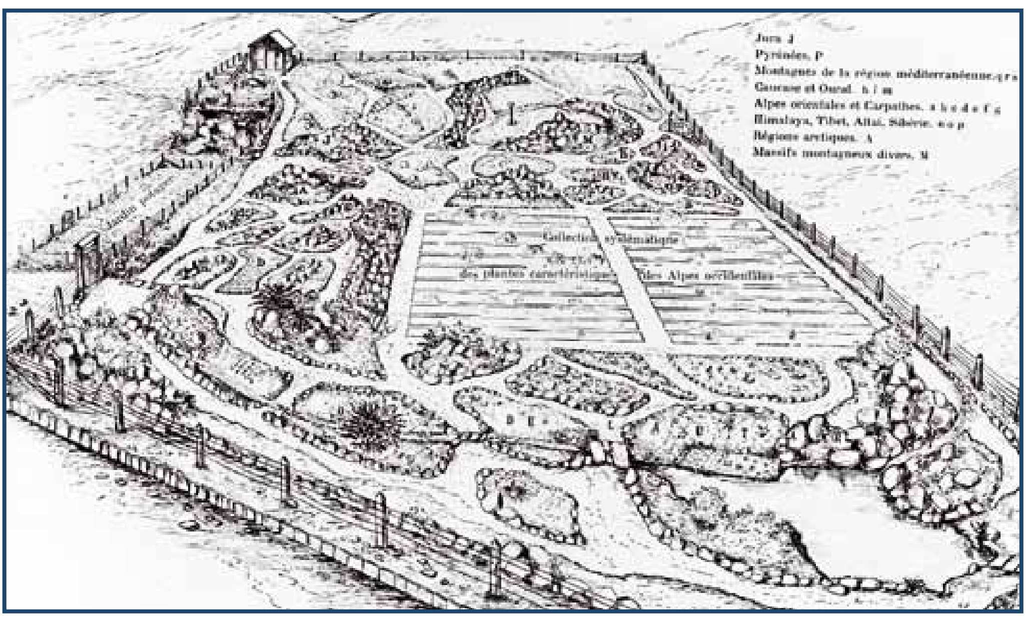
One hundred years of history

At the end of the 19th century alpine gardens were all the rage! They were initially popular for aesthetic rather than scientific reasons. In Switzerland during 1889, Henry Correvon was the first to plant an alpine garden. It was intended to be both aesthetically pleasing and a means of protecting certain plants. The need to protect the mountains was already making itself felt at this time, as forests were cut down and alpine plants pillaged by amateurs, botanists and plant merchants.

View of the Col du Lautaret, around 1935, with the Dauphin's refuge, the Napoleon refuge and the Hotel des Glaciers (at the far end), the PLM Chalet-Hotel and its garage, the Alpine Garden and its Chalet (in the foreground on the right). In the background, the Combeynot (right) and the Cerces (left) massifs. See the chapter on the history of the pass (p.122). Photo Gep, coll. Bignon.

Jean-Paul Lachmann, Professor at the University of Grenoble and creator of alpine gardens in France, first at Chamrousse then at the Col du Lautaret.

Jean-Paul Lachmann (1851-1907), Professor of botany at the University of Grenoble, gave the Alpine Garden its research remit. His conception of an alpine garden was that of a natural high altitude laboratory, in which alpine flora could be studied and protected. It would test the possibilities for the acclimatisation of edible and forage plants and teach the general public about the richness of the flora and its conservation. By 1894, he has created the first alpine garden at Chamrousse, but, despite its proximity to Grenoble, the Garden was soon abandoned as there was no access road (the ski resort did not exist at this time).



Layout of the first Lautaret alpine garden (drawing by Marcel Mirande, from a photo taken from the Hotel des Glaciers chalet).

After being moved and rebuilt at its current location, the new Alpine Garden was inaugurated on 5th August 1919. At the centre, under the entrance gate, which is still in place today, the Professor Marcel Mirande (1) and Henry Defer (2), Vice-President of the Touring Club de France. Photo H. Müller.

A chalet was built, now known as the Mirande Chalet. It provided vital impetus for boosting activity on the site. The chalet was home to the gardeners, housed a small laboratory where researchers studied biodiversity and mapped vegetation, and it included a mineral museum and an ethnography museum set up by Hippolyte Müller, founder of the Dauphinois Museum in Grenoble. This "new" Alpine Garden was inaugurated in August 1919 and became renowned, both as a tourist and scientific destination, right up until the Second World War.

These mushrooms are a species first described in the Lautaret region by Roger Heim, whilst he was an intern at the Alpine Garden in the 1920s. He benefited from a research grant allocated by the Touring Club de France (the Blonay grant). Roger Heim subsequently became the Director of the National Natural History Museum and a member of the Academy of Sciences.

An example of field research carried out by scientists using the facilities at the Col du Lautaret. Here we see researchers taking measurements from **Silene acaulis** ***(Moss campion), a high altitude cushion plant found at alpine level (p. 87). To the right, Philippe Choler, a pioneer of research into alpine ecology at the Alpine Research Station.***

The Lautaret site is the only high altitude biological research station in Europe, and has been recognised by the French government's funding programme (Investissements d'avenir) as biology and health infrastructure of national importance in the field of ecosystem science and experimentation. From 2006 to 2012, 60 scientific papers and 12 theses relating to studies carried out at the Alpine Garden were published. This was only possible thanks to the Lautaret research facility and the botanical and horticultural expertise of its teams.

The Robert Ruffier-Lanche arboretum located on the Grenoble campus is home to around 250 tree and shrub species. Set up in 1966 by the Alpine Garden head gardener and then abandoned in the 1990s, it was restored by Joëlle Leplan-Roux, Nursery Assistant at the Alpine Research Station from 2000 onwards. It is open to the public. The Manuel Forestini Planetary Path was installed in 2003.

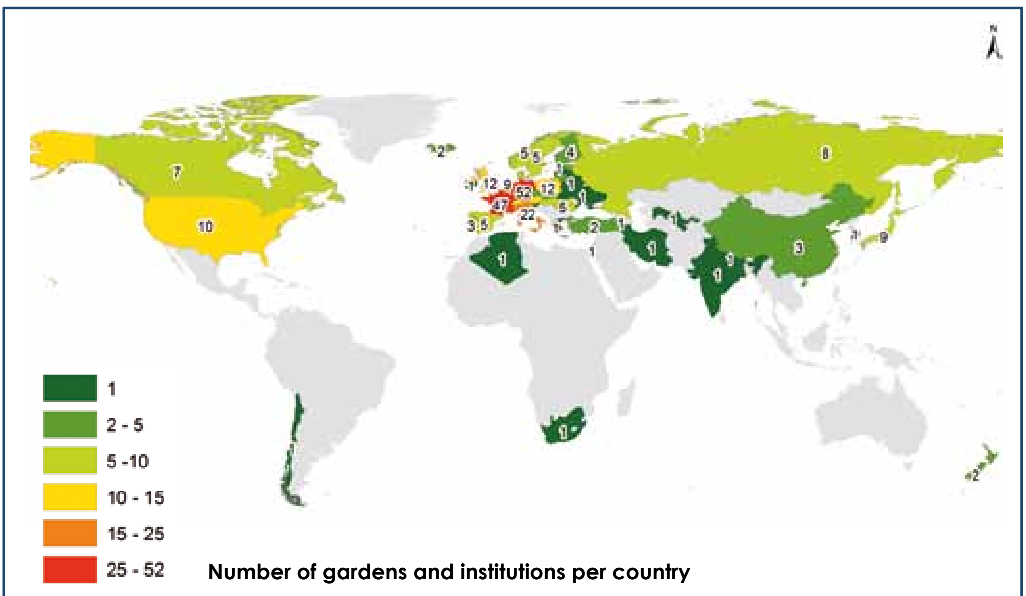
Around the garden: The Louis de Polignac foundation prize

The Prince Louis de Polignac Foundation awarded its 2007 Prize to the Lautaret Alpine Botanical Garden in recognition of its contribution to research in alpine biology. The €25,000 prize was awarded by the Academy of Sciences (Institut de France) based on submissions. It rewarded a century of passion, hard work and dedication to scientific popularisation and research. This was the joint remit originally defined by Jean-Paul Lachmann when the Garden was first started. The prize money was used to help fund several projects, in particular the installation of high quality signposting around the Alpine Garden (p. 152) and the publication of a tri-annual portfolio produced by the garden's illustrator in residence (p. 154).

The Alpine Garden has been recognised for the quality of its collections and its contribution to research. It has been awarded the labels Jardins Botaniques de France et des pays francophones (JBF), Conservatoire des Collections Végétales Spécialisées (CCVS) and Jardin remarquable.

The Garden's Collections

The Lautaret Alpine Botanical Garden contains over 2,300 plant species which represent Alpine flora from throughout the world. The Garden obtains its plants through a seed exchange network of botanical gardens and institutions across the world. Via this network, the Alpine Garden corresponds with almost 300 gardens in around 50 countries.



The various international botanical gardens and institutions with whom the Alpine Garden exchanges seeds (figures for the period 2008-2010; produced by J. Renaud).

Putting the finishing touches to the new Alpine Garden nursery in 2012, by installing shades to protect the plantlets from the adverse effects of the additional light they are subject to at high altitude. The nursery is managed by Amandine Deschamps, assistant gardener who has worked at the Alpine Research Station since 2012 (photo P. Salze).

The new nursery provides ideal conditions for introducing the species which are first sown in the plain before being transferred to the Alpine Garden. Specimens of rare species are kept here in case of damage in the Garden and experiments into propagation by cuttings are carried out. Here, Pascal Salze, head gardener since 2009, checks on an experiment involving cushion plants.

Cuttings of* Mimulus cupreus*, a Phrymacae collected in Chile in January 2003, were successfully propogated and planted in the Garden in 2004.

Expeditions are also organised in order to obtain seeds from mountain regions where there are no botanical gardens. In the summer following an expedition (or after one or two years depending on the species), the propagated plants are transplanted to the rock gardens. Out of 100 species sown in Grenoble, around 70 will germinate and 40 survive the transfer to Lautaret three years after being planted in the rock gardens.

The Alpine Garden contains around fifty rock gardens divided into the so-called "geographical" beds, displaying flora from mountains the world over, and the "ecological" beds containing regional flora from different habitats. One thematic rock garden is dedicated to regional plants used for specific purposes.

This low wall made of calcareous tufa from the garden's tufa deposit, was built between 2008 and 2011 (p. 106). Plants which grow in siliceous or limestone rocks and are notoriously hard to cultivate are introduced to the Garden here.

An example of a so-called "ecological" rock garden, in this case dedicated to screes in montane and subalpine zones. Regional plants are displayed in these rock gardens according to their natural habitat (wetlands, rocks, alpine meadows, alpine screes, etc.).

The rock gardens require considerable maintenance: weeding, planting new species, and pruning shrubs. They need to fulfill both their aesthetic purpose (the gardener's area of expertise) and faithfully imitate the plants' natural habitat (the botanist's area of expertise). During dry periods, the gardens are watered to improve species' chances of survival.

The rock garden dedicated to the flora of wetlands in Siberia and the Caucasus at the start of the season (mid-May 2003). The Garden, littered with dead stalks and leaves, is certainly not at its best. However, in just a few weeks it will undergo an incredible transformation (compare to page 99), thanks to the gardeners' hard work and the rapid growth of the plants, which have a very short growth cycle.

Weeding the "Carophyllaceae" rock garden in July 2012. Around twenty students from horticultural and landscaping colleges take turns throughout the season to do this painstaking work, supervised by two permanent gardeners. Since the start of the 2000s, students recruited from the University of Grenoble conduct guided tours three times a day.

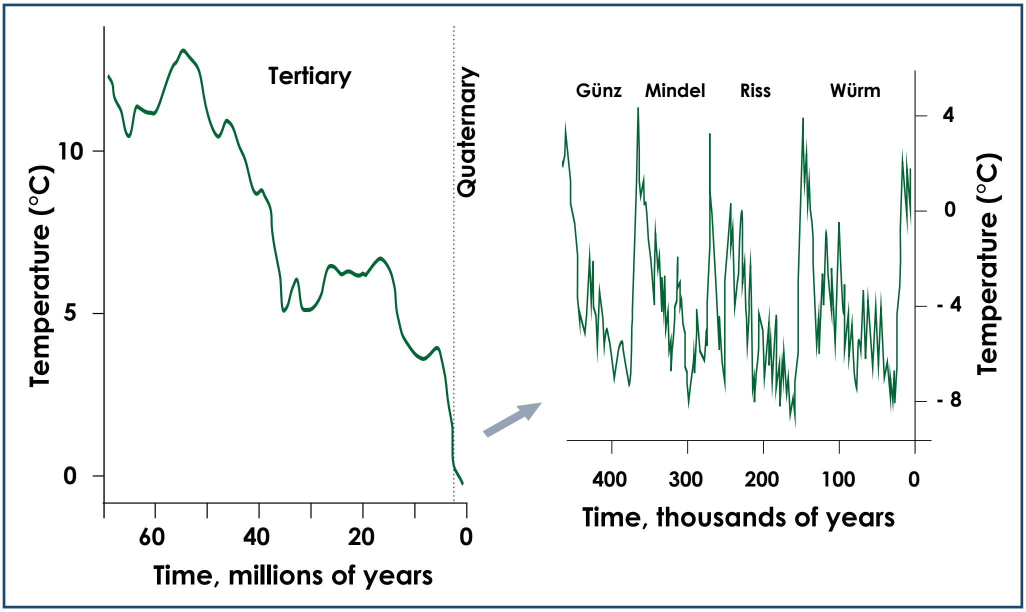
Primroses (above Primula bulleyana *and* Primula secundiflora*) originate from Central Asia. Both species can be found in the Garden in the "Central Asia" rock garden.*

The genus Campanula *(here* Campanula alpestris*, in calcareous scree in the alpine zone) is an example of a plant originating from the Mediterannean region.*

At the end of the Tertiary Era the world's climate cooled by several degrees. The subtropical vegetation suited to hot, wet climates which covered Europe at this time completely disappeared, leaving just a few relict species which today constitute isolated anomalies within the alpine flora. These species testify to the climatic fluctuations that the European continent has experienced. Examples include *Berardia subacaulis* and *Juniperus thurifera* in the Alps, and the Pyrenean violet in the Pyrenees.

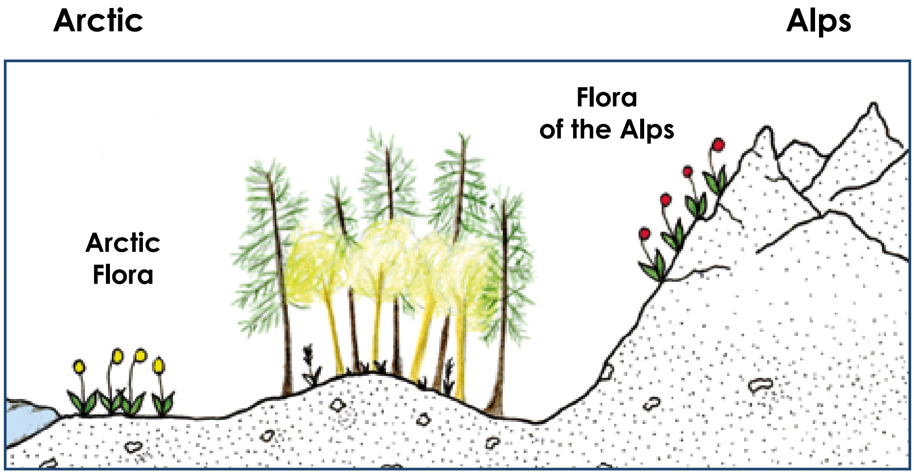
During the Quaternary Period, Europe went through several major glacial cycles. The alpine valleys were covered with several hundreds of metres of ice. The general cold climate left high altitude plants with little chance of survival in mountain regions. During the glacial maxima the flora of the Alps and the arctic flora, both pushed back by the advancing glaciers, ended up co-existing in the plains of central Europe. This repeated contact encouraged exchanges between the arctic and alpine flora. These floristic shifts during glacial periods may explain the disjointed or arctic-alpine distributions of several species present in both the Alps and the Arctic.

The Pyrenean violet (**Ramonda pyrenaica*****) is a Gesneriaceae endemic to the mountains of the Pyrenees. The plants of this family mainly grow in the tropics. The violet is a relic testifying to the tropical climate which existed in the south of Europe during the Tertiary era. The species successfully adapted to the cooling in the Quaternary era.***

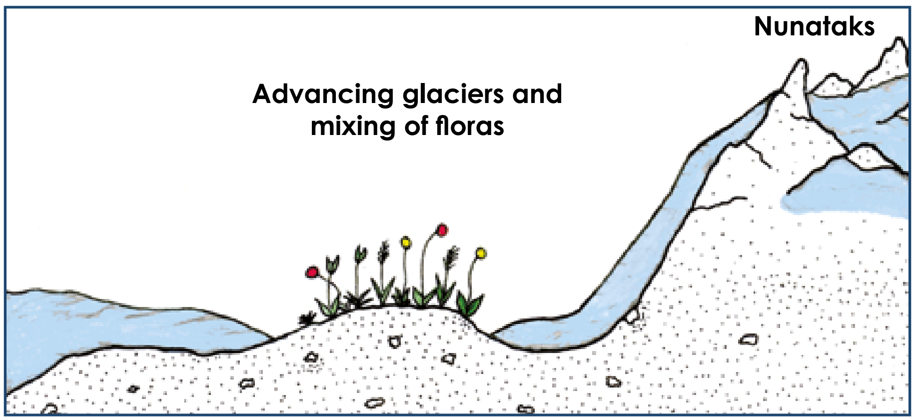


Temperature variations over the last 70 million years. The right-hand side details the last 500,000 years and shows the four major glacial periods: Günz, Mindel, Riss et Würm. The most recent glacial cycle ended just 10,000 years ago. This is a simplified version of the graph from Graham 1999 Am. J. Bot 86: 36; Petit et al. 1999 Nature 39: 429.

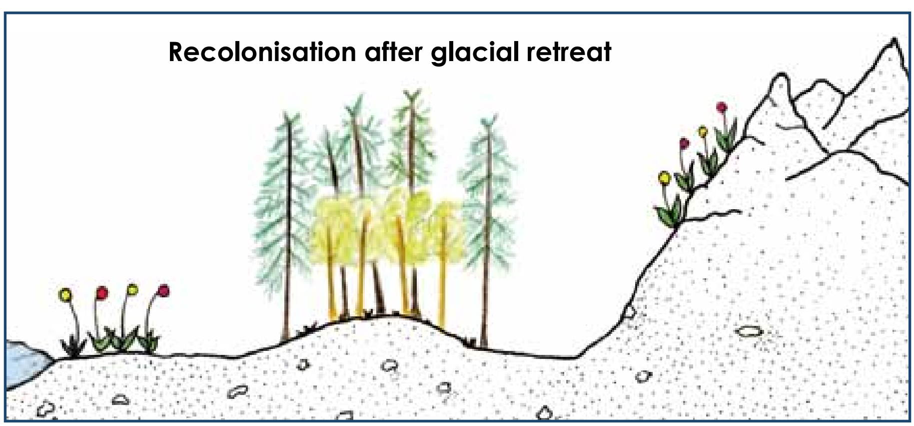
Berardia subacaulis *(Asteraceae), an example of a relic from the Tertiary era which colonises the calcareous scree of the alpine zone in the Southern Alps, here at the Col de l'Izoard at around 2600 m. This plant is protected in France and can be seen in the Alpine Garden in the "Alpine calcareous scree" rock garden (photo T. Syre).*



Prior to glaciation

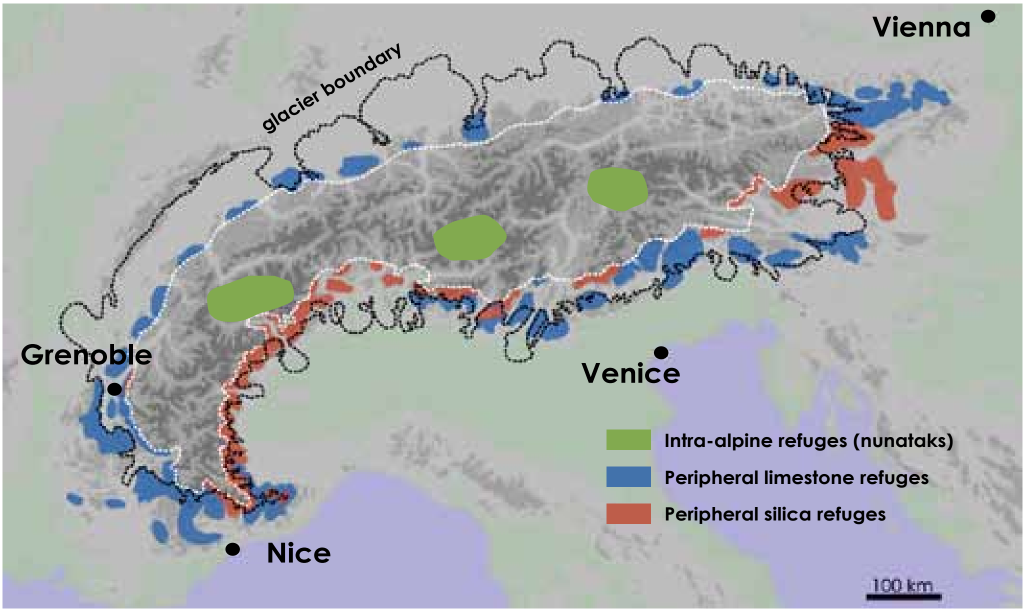


Glacial period



Post-glacial period

This series of diagrams explains the scenario by which plants from the Alps and the arctic regions may have come into contact and mixed during the glacial maxima (drawings Ch. Perrier).



Representation of the peripheral and intra-alpine refuges of several alpine plants during the last glacial period (20,000 years) based on genetic diversity studies (adapted from Schonswetter et al 2005* Molecular Ecology *14: 3547-3555).

Two hypotheses have been put forward to explain the recolonisation of Arctic regions and the Alps after the last glacial period. The "tabla rasa" hypothesis assumes that all plants disappeared entirely from the Alps and the Arctic during the glacial period and then colonised from distant ice-free regions. The "nunatak" hypothesis suggests that there were refuge areas within the glaciated regions from which local recolonisations originated. Modern genetic techniques suggest that both mechanisms may have played a part in the recolonisation of the alpine mountain ranges after the last glacial maximum.

Examples of ice-free areas (small nunataks) amongst the glaciers which cover part of the Svalbard islands (Spitzbergen, Norway, 79 °N).

Arctic-alpine species of the Lautaret region

*Mountain avens (*Dryas octopetala* Rosaceae) is a species found on rocky slopes experiencing a long duration of snow cover in the subalpine and alpine zones.*

*Purple mountain saxifrage (*Saxifraga oppositifolia, Saxifragaceae*) is a low-growing, creeping cushion plant abundant in alpine zones, shown here growing on the Galibier ridges at 2700 m.*

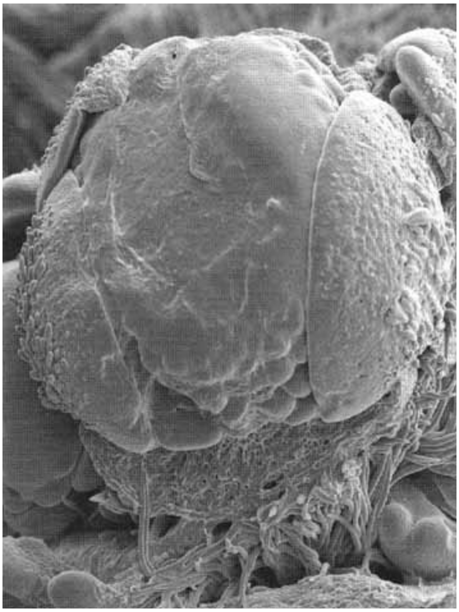
*Mountain sorrel (*Oxyria digyna, Polygonaceae*), a species characteristic of acidic scree, shown here growing in the Combeynot nature reserve at 2400 m.*

It is often said that flowers which grow at altitude have brighter colours than those found in plains in order to attract pollinators more effectively. Whilst it is true that many well-known alpine species are very brightly coloured, studies carried out in the mountains of Norway have found no case for generalisation. There was no significant increase in colour, size, or any other characteristic associated with attracting insects such as a zygomorphic shape (p. 64) or the size of spurs, with increasing altitude (Totland et al 2005 *in* Aubert et al 2006). However, research carried out in the Andes has shown that plants at altitude have longer flowering periods and durations, allowing them to compensate for the small number of insects.

Indeed, there are very few insects at high altitudes and this limits the possibilities for pollination. Many of the species which dominate alpine meadows are in fact wind pollinated, Poaeceae and Cyperaceae for example.

Several alpine plants, including glacier crowfoot and numerous Saxifrages, can pre-form their flower buds, sometimes one or two years in advance allowing them to bloom rapidly as soon as the conditions are favourable.

Furthermore, many alpine species reproduce by means of vegetative reproduction, which, due to its greater reliability, provides a contingency against the risks associated with sexual reproduction (p. 85).



On the left, glacier crowfoot (*Ranunculus glacialis, *Ranunculaceae) is a species which only grows in alpine zones in the European Alps, between 2300 m and 4250 m, and is amongst the plant species growing at the highest recorded altitudes. It favours wet scree, in particular shale, as found here on the ridges of the Col du Galibier. On the right, a flower bud seen using scanning electron microscopy: the bud is pre-formed a year in advance, allowing the plant to take full advantage of the short growing season (In Körner 2003).

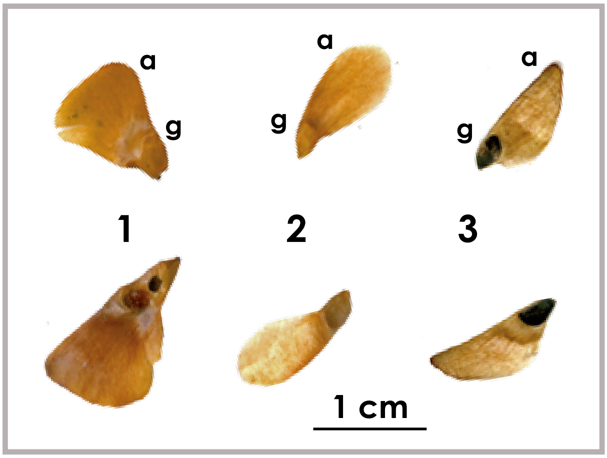
Plants and the wind

The wind is a constraint for plants which causes mechanical damage and drying. However, as plants are sessile organisms which cannot move, the wind can also be an asset used for transportation. Many plants therefore utilise the wind as a pollen vector or for seed dispersal. In both cases large quantities of pollen or seeds are produced to compensate for the uncertain nature of this form of transport. Other adaptations to increase the efficiency of wind transport include a small size of seed and pollen or the development of specialised structures to increase seed surface area.

*The bay willow (*Salix pentandra*) a native species found in the Alpine Garden, produces small downy seeds which are dispersed by the wind in September. Other such examples are commonly found in epilobium or poplars. In the latter, the masses of downy seeds produced in the spring are often mistaken for pollen. The cottongrasses commonly found in boggy environments are known as *Eriophorum*, which etymologically means "which wears wool" and refers to the downy seeds, which in the past were used to fill cushions.*

Pine pollen grains, here from Scots pine, have two lateral bladders full of air which lower the seed's density and allow it to be easily carried in the wind. Photographed here using scanning electron microscopy, http://www.psmicrogra- phs.co.uk/.

In the Poaceae (grasses) the X-shaped stamens (E) grow along a long filament (f) and are moved by the wind freeing the pollen, which is then subsequently trapped by the long downy stigma (S).



The seeds (g) of various conifers, here spruce (1), larch (2) and Scot's pine (3), have a wing (a) which helps them to "fly" and facilitates their dispersal. One notable exception is Pinus cembra*. Its large wing-less seeds are dispersed instead by the spotted nutcracker bird.*

Around the garden: The globeflower, the paradox of the closed flower

*The globeflower (*Trollius europaeus*, Rannunculacea) is abundant in the alpine meadows surrounding the Col du Lautaret, here shown growing alongside poet's daffodil, (*Narcissus poeticus*, Amaryllidaceae). This plant has the unusual characteristic of never opening. In fact, the tiny openings between its petals allow the small* Chiastocheta *fly to enter the flower. This fly is a very special kind of pollinator: It uses the flower as a shelter to lay its eggs in the ovules, and its larvae parasitise the flower by feeding on some of its seeds. This cost is offset by the benefit the plant derives from pollination (research carried out by Laurence Després' team at the Laboratory of Alpine Ecology in Grenoble, see Ibanez and Després 2009).*

Relationships between species

Plants are immobile living organisms. Fixed to the ground (or onto other plants) they extract the elements they need to live from the surrounding environment: water and nutrients from the soil, CO_2 from the air, and light to provide the energy required for photosynthesis. However, plants rarely grow in isolation and the presence of neighbouring plants can significantly improve or hamper an individual's performance.

When an environment contains a large number of species with similar ecological requirements, some resources can begin to become limiting. For example, if some plants grow to a significant height, light may become a limiting factor for shorter shaded individuals. However, tall plants can also protect smaller neighbouring plants from the harmful effects of excessive light.

The fescue meadow (*Festuca paniculata*, Poaceae family) is a remarkable environment found in the Lautaret region. It is mainly found on gentle, south-facing slopes up to 2400 m altitude. The biodiversity found in this environment is quite simply exceptional as it contains over sixty species including leopard's bane (*Arnica montana*, Asteraceae, yellow), bearded bellflower (*Campanula barbata*, Campanulaceae, blue) and the pink globe orchid (*Traunsteinera globosa*, Orchidaceae, pink).

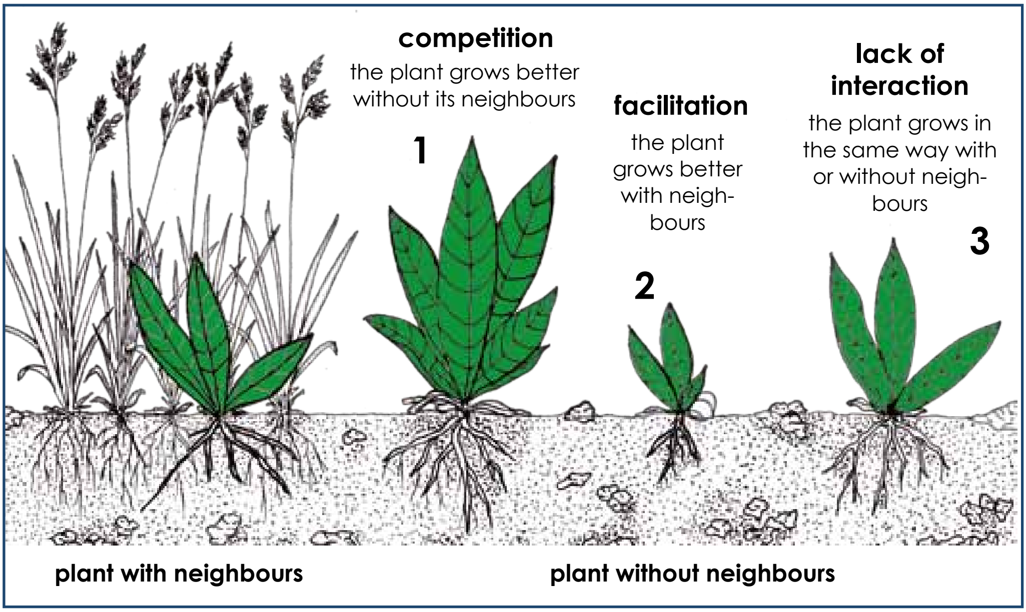


Diagram showing the three types of interactions between plant species: when a plant's neighbours are removed experimentally, it either grows better (1), less well (2) or identically (3). This reveals the type of relationships existing between the plant and its neighbours.

Competition implies a "struggle" between species for the use of a resource vital to their growth, such as light, water or mineral nutrients from the soil. This phenomenon is most commonly observed in rich environments where there is an abundance of available resources. In these conditions, some dominant species (such as *Festuca paniculata*) often prove capable of capturing the majority of the available resources. They generate intense competition with other species whose growth is consequently limited.

Conversely, in more hostile habitats, such as on steep slopes, poor soils or in very cold environments, colonisation is simply impossible for many species. However, the growth of one species well adapted to the conditions can prepare the way and act as a refuge for other, more fragile species.

This is the phenomenon known as facilitation, which refers to the positive relationships between plants. A study carried out by several laboratories (including the Laboratory of Alpine Ecology in Grenoble) in several mountain ranges across the world (including in the Alps in the Lautaret area) has shown that in alpine zones, where constraints are at their highest, more facilitation is observed than competition, whilst the opposite is true in the less stressful conditions of the subalpine zone (Callaway et al 2002).

*Violet fescue (*Festuca violacea*) is a Poaceae with a highly developed root system which enables it to grow on steep slopes creating a landscape of mini-terraces (here on shale screes at the Col Agnel in the Queyras massif). Numerous so-called facilitated species then take advantage of the ground which has been stabilised by this structuring species (see close-up below).*

*Close up of a mini-terrace (above, in the Galibier area) where the growth of violet fescue (*Festuca violacea*) allows numerous other species less suited to these unstable slopes to establish. Here we can see* Senecio incanus *(Asteraceae, yellow),* Cerastium arvense *ssp.* strictum *(Caryophyllaceae, white), and* Campanula scheuchzeri *(Campanulaceae, blue).*

Around the garden: Examples of cushion plants

*Some examples of cushion plants in the alpine zone of the Col du Lautaret region. Above, mossy cyphel (*Minuartia sedoides*, Caryophyllaceae, green) and Pyrenean whitlow grass (*Petrocallis pyrenaica*, Brassicaceae, pink), two species from shale grasslands. Below, mossy saxifrage (*Saxifraga bryoides*, Saxifragaceae, white) and Herald of Heaven or king of the Alps (*Eritrichium nanum*, Boraginaceae, blue), two species commonly found growing on siliceous rocks.*

A remarkable range of environments

Tall-herb communities

The Col du Lautaret, being situated in a transitional zone, is home to a wide variety of habitats. One habitat found in the area, the tall-herb community, is a good example of the luxuriant and diverse vegetation that can be seen in the subalpine zone. Tall-herb communities are composed of both tall herbs and plants with large leaves. The leaves form a canopy under which a humid and shady microclimate develops. The vegetation is dense and offers optimal conditions for plant development, with soils rich in water and nitrogen, and high levels of humidity, even in the summer.

On the Sentier des Crevasses footpath, at an altitude of 2000 m in the Ecrins National Park. The leaves of Adenostyles alliariae (Asteraceae) are unexpectedly large at this altitude, a fact explained by the water and nitrogen-rich soil.

Etymology

The French word "mégaphorbaie" used for tall-herb communities originates from the Greek *méga* (big) and *phorbè* (pasture).

In the Lautaret region, tall-herb communities mainly occur in cool and humid areas on north-facing slopes. They are particularly common in disturbed areas, regularly rejuvenated by avalanches. They are often found alongside woods of green alder (known locally as "vernes") which play a key role by enriching the soil with nitrogen (see below). As conditions become less disturbed, larch forests can begin to succeed.

Tall-herb communities boast a wide variety of flowering plants. These include alpen rose (*Rosa pendulina*, a thornless Rosaceae), wood cranesbill (*Geranium sylvaticum*, Geraniaceae), great masterwort (*Astrantia major*, Apiaceae), martagon lily (*Lilium martagon*, Liliaceae), wolfsbane (*Aconitum lycoctonum* subsp. vulparia, a toxic Rannunculacea).

The complex inflorescence of* Adenostyles alliariae. *Like all Asteraceae (daisy, dandelion, etc.), its flowers are actually capitula of small flowers. Here the inflorescence is made up of numerous small capitula, each composed of 3 – 6 flowers.

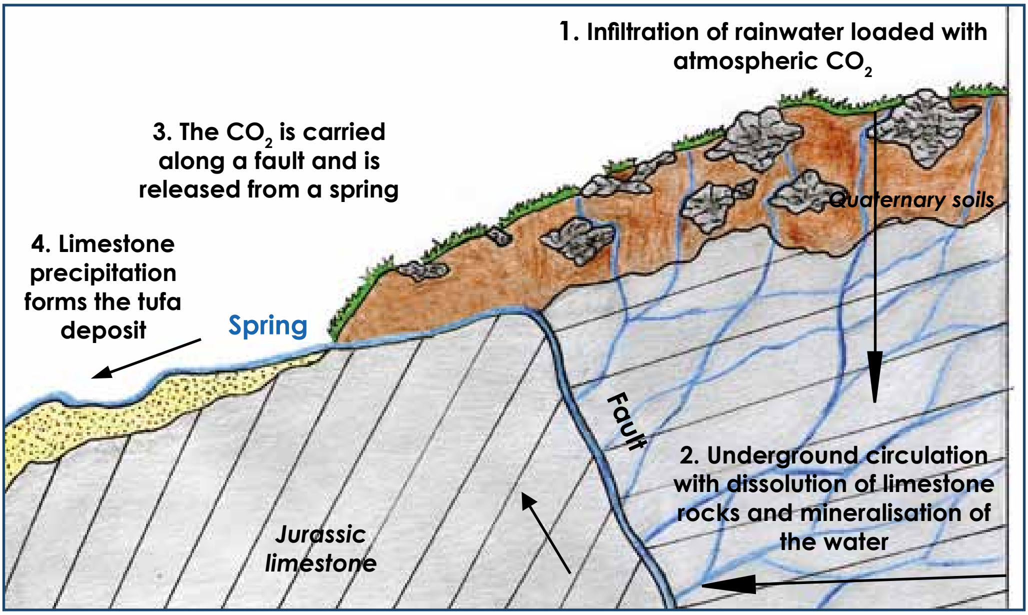
*Two tall-herb species: to the left, wolfsbane (*Aconitum lycoctonum *subsp.* vulparia*) is a highly toxic Rannunculacea. It contains lethal alkaloids (in particular aconitine). To the right, great masterwort (*Astrantia major*) is an attractive Apiaceae, several varieties of which are grown in gardens in plain areas (in moist, rich soils which imitate its natural habitat).*

*The tall-herb community near Combeynot (Ecrins National Park) is home to many magnificent species such as the alpine leek (*Allium victoriale*, Amaryllidaceae, white) and the martagon lily (*Lilium martagon*, Liliaceae, pink). It is strictly forbidden to remove any plant or animal species from the Ecrins National Park. Elsewhere in the Hautes-Alpes, the collection of martagon lilies is strictly regulated, limited to one handful per person with the removal of roots forbidden (p. 103).*

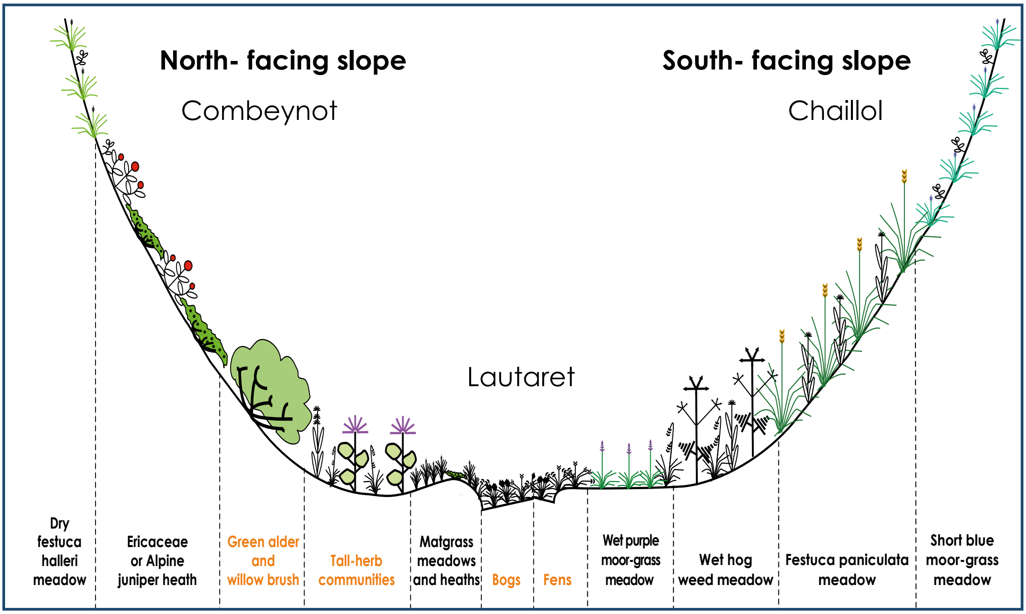
Tufa deposits, one of which is located close to the gazebo in the Alpine Garden, are formed when water passing through surrounding calcareous rocks, becomes loaded with bicarbonates which subsequently precipitate in the form of limestone, forming a petrified spring. A sloping fen then develops, containing a rich flora. The travertine (or calcareous tufa) which accumulates over several thousands of years, captures and fossilises the neighbouring plants. Studying these deposits makes it possible to reconstitute past environments (Latil et al 2012, p. 109). This habitat is now protected under the European Natura 2000 programme.

Alpine dactylorhiza (**Dactylorhiza alpestris*****, Orchidaceae) in the tufa deposit located in the upper section of the Alpine Garden.***

The active tufa deposit in the Alpine Garden. Iron deposits colour the limestone which has precipitated at the petrified spring, red.



Rainwater acidified by atmospheric carbon dioxide (CO_2) dissolves limestone rock (calcium carbonate: $CaCO_3$) it passes through during its underground journey. The water becomes mineralised, loaded with dissolved ions (calcium Ca^{2+} and hydrogencarbonate HCO_3^-). When it reaches the spring, the water contains more CO_2 than the air and this excess carbon gas is degassed or absorbed by algae and photosynthetic bacteria. The calcium ions precipitate in the form of calcium carbonate ($CaCO_3$) which encrusts plants and fossilises them. Sketch Ch. Perrier.



Transect showing the distribution of plant groups in subalpine zones in the Col du Lautaret area, on the south and north-facing slopes. In orange, the environments described in this section (from Molinier and Pons 1955, Bull. Soc. Scient. du Dauphiné 69:2-19, details in Aubert et al 2011).

*Two superb Gentianaceae from the Alpine Garden tufa deposit: willow gentian (*Gentiana asclepiadea*, left) and felwort (*Swertia perennis*, right). Willow gentian grows in the mountains of central and eastern Europe, especially in moist forests. Felwort is a species found in the Northern hemisphere (Eurasia and North America), typically in fens, which is very sensitive to habitat destruction.*

Studying fossils in the tufa deposits in the Alpine Garden has provided us with a good historical overview of the plant life and some of the fauna in the area studied. In particular, the presence of forests of Pinus uncinata *(above) and deciduous trees (below) dating back 10,000 years raises questions regarding the expansion of forests and movement of glaciers at this time, at the end of the glacial cycle (Latil et al 2012).*

Plants and snow

One of the main constraints in alpine zones is the cold, and one of the consequences of low temperatures is snowfall. Snow causes serious damage in the winter, especially to trees and shrubs. It is also one of the factors which determine how plant communities are structured by altitude.

Snow is destructive, but it can also be protective. Indeed, it is a very poor heat conductor. The temperature under very thick snow cover does not drop below zero even in the depths of winter. This is because the snow cover traps lots of air which has insulating properties.

Summer visitors to the Alpine Garden may find it hard to believe that it is covered in snow for over half the year. Note that the Mountain pines* Pinus mugo *disappear under the snow (p. 164, 180, 186).

*An example of opposite facing slopes on the Chaillol mountain (which dominates the Garden to the north). The south-facing slope thaws several weeks before the north-facing slope. The growing season is longer but plants have to adapt to increases in frost and excess light. The types of vegetation commonly found on the upper parts of the south-facing and north-facing slopes are respectively, blue moor grass (*Sesleria caerulea*, Poaceae, picture bottom left) and Ericaceae heaths, including alpenrose (*Rhododendron ferrugineum*) and the bilberry (*Vaccinium myrtillus*, picture bottom right). In the autumn, the blueberry leaves colour the north-facing slopes of the mountains red.*

Snow beds: Advantages and disadvantages

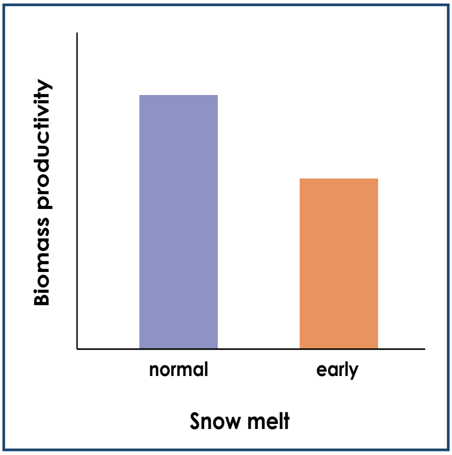
Plants in snow beds are protected throughout the winter by snow cover. However, in years with high levels of snow cover, the growing season is almost non-existent as the snow doesn't have time to melt over the summer. Under these conditions, plants can survive for one, sometimes two, years under the snow. The following year they will make another attempt to grow and flower.

Snowbeds are particularly fascinating environments. These are troughs in the ground where particularly thick snow cover of several metres accumulates and where extremely tiny plants are found. This is as should be expected since the time required for the snow to thaw means the growing season is very short, allowing plants just 2 to 3 months to grow and reproduce, in a good year. The only way to really get to know these species is down on all fours with your nose to the ground!

Recent research at the Laboratory of Alpine Ecology in Grenoble (by Ph. Choler, R. Geremia and shown here, J.-C. Clément and S. Ibanez) looks at the dynamics and functioning of microbial communities in mountain soils. Bacteria and fungi remain active under the snow (see picture above taking winter samples from a snow bed) with different species found during snowmelt and during the summer. These micro-organisms play a key role in carbon and nitrogen cycles (photo Ph. Choler).

When the snow melts, young alpine foxtail plants (*Alopecurus alpinus*, Poaceae, white circle) develop a root network which grows at the interface between the snow and the soil (arrows). They probably facilitate the assimilation of the nitrogen present in the snow cover, as demonstrated in a snow bed plant in the Caucasus.

Unlike snow beds, ridges are exposed to the wind and the plants are only covered in snow for a few weeks each winter. They have a long growing season but have to cope with more intense stresses: extreme cold, drought, excess solar radiation, poor soils. These plants have adapted both morphologically (tussock and cushion plants which conserve heat, for example) and physiologically (frost resistance, recycling of mineral elements from dead leaves, etc.).



Experiments with early snow melt in snow beds have been carried out at the Alpine Station with the aim of imitating global warming. The plants which emerge from the snow cover earliest have the lowest productivity (production of biomass in relation to the number of days without snow) even though they have a longer growing season. It would appear that they have a low resistance to frost at the start of the season when they are unprotected by snow cover. Paradoxically climate warming will actually leave these plants more exposed to the cold (research work coordinated by Ph. Choler at the Laboratory of Alpine Ecology in Grenoble; Baptist et al 2010).

The first plants to grow in the garden after the thaw

*The white marsh marigold (*Caltha leptospala*, Ranunculaceae) is found in humid environments in the west of North America. It grows from Alaska down to New Mexico in subalpine and alpine zones.*

On the left, Primula rosea *(Primulaceae), a splendid species found in humid areas at altitude in the Himalayas. On the right,* Erythronium grandiflorum*, a bulbous Liliaceae found in the subalpine forests of the west of Canada and the United States of America.*

Adonis pyrenaica ***(Ranunculaceae) is rare plant protected nationally (Appendix I). It grows in rocks and scree in the French and Spanish Pyrenees, as well as very locally in the Alpes-Maritimes.***

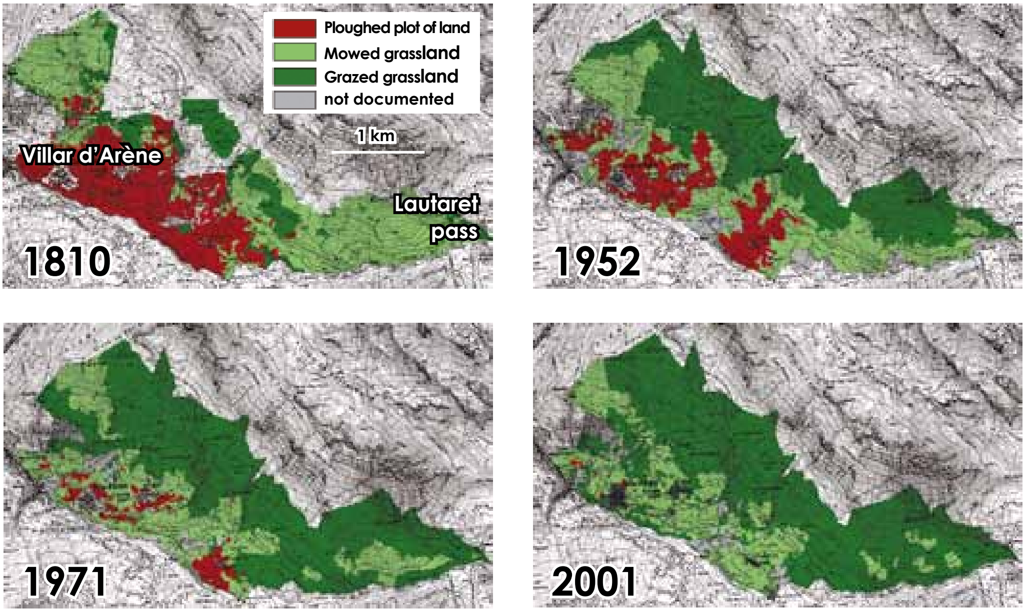
Left, Michael's flower (**Fritillaria michailovskyi,** ***Liliaceae), a bulbous plant from the mountains of the North-East of Turkey. Right,*** **Tulipa turkestaniska** ***(Liliaceae), is a tulip from the mountains of Turkestan and the North-West of China***

Living in the mountains

Man's settlement of the Lautaret region is etched into the landscape, particularly on the sunny south-facing slopes which were deforested and terraced for ploughing and crop-growing. Crops were grown up to an altitude of 1800 - 2000 m. The highest meadows (sometimes up to 2400 m) were mown and used for pasture (up to 2600 m). The shaded north-facing slopes provided wood for construction and heating. Cattle were pastured in the light larch forests and in mown meadows over 2200 m.

This picture from the beginning of the 20th century shows the two sides of the Haute Romanche valley – the south-facing slope of Villar d'Arène on the left (note the terraces) and the north-facing slope on the right (larch forest). In the background, the Col du Lautaret, and the Combeynot massif. Old postcard, photograph Oddoux.

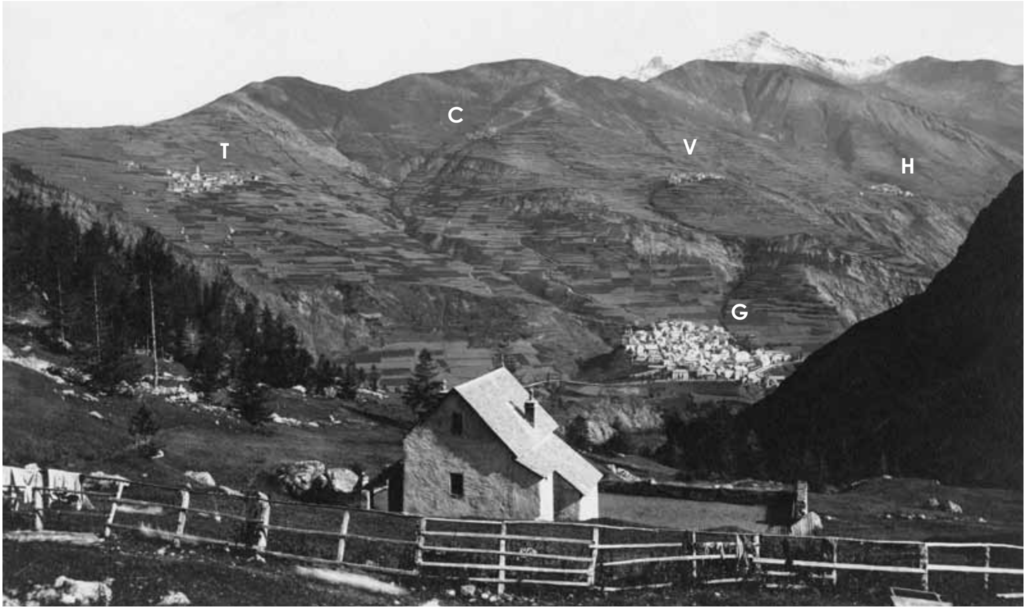
Harvesting with the Faure and Clot families, September 1953, in the hamlet Les Cours (Villar d'Arène) The person sitting on the plough, Edouard Clot, is using a rake to straighten up flattened crops so that the mechanical blade can cut them more easily. The horse is being led by Pierre Faure and three people behind him are binding the sheaves. Fonds Marcel Maget, MuCEM.



Evolution of land use on the south-facing slope of Villar d'Arène. There is a notable retreat of ploughed land (in red) between 1810, 1952, 1971 and 2001 (interpretation by the Napoleonic cadastre, or survey, after Mallen, 2002, In Girel et al 2010, work funded by the Ecrins National Park under the Natura 2000 programme, interpretation of aerial photos by J. Girel). Base map SCAN 25 ® - © IGN / PFAR CRIGE 2000 (produced by P. Lamarque).

Haymaking in the 1950s, in the mown meadows of Aiguillon (belonging to the Villar d'Arène municipality). Here we can see a combination of ancient techniques (cart and rope used to create bags) and new practices (use of the first slope mowers). Fonds Marcel Maget, MuCEM.

Image of high altitude agriculture on land belonging to the municipality of La Grave, with the glaciers and the Grand Pic de la Meije in the background (3987 m). The slope of the south-facing meadows is well suited to mechanical mowing. Once the swathes have been gathered, the hay is pressed into round bales.



La Grave (G) and its hamlets of Ventelon (V), Les Terrasses (T), Les Hières (H) and Les Clots (C, only inhabited during the summers) in the 1860s. This picture, taken from the Chalvachère Chalet, shows the optimal use of the arable land during period of highest population density in the middle of the 19th century. In light grey, is the land used for cereal crops. In the background, on the right, is the Aiguille du Goléon (3427 m). Photograph Michaud ; © Institut de Géographie Alpine/UJF - photograph Musée dauphinois.

Settlement in the region was typically in villages of closely grouped houses, which left more land available for agricultural purposes, and made it easier to get about during the long snowy winters. Stone was the preferred construction material because wood was scarce. Inside the houses, the rooms used by people, for their animals and for storing grain were close together in order to benefit from the warmth of the animals. The balconies were used to store and to dry grain and dung. Many houses in Haute Romanche had independent buildings used for storing provisions, a "grenier" made of wood, or a "chambre" made of stone (p. 134). Below ground level there was a root cellar for keeping winter vegetables and potatoes. On the ground floor linen and sheets were stored, hams and sausages were dried hung from the ceiling, and chests (called "arches") were filled with salt, flour and seeds. Grain was also stored in large containers made of rye straw called "barnores". Above this, the "grenier" or attic contained screens for drying boiled bread. These "chambres" contained the family's most precious belongings which were protected by beautiful doors, surrounded by cut stone and closed with large locks. The rest of the house was only locked on very rare occasions (Mallé 1999).

Since 2003, Sandra Lavorel's team (Laboratory of Alpine Ecology in Grenoble) has been leading European and national projects which use the south-facing slopes of Villar d'Arène as a reference site for research into agro-pastoral farming in mountains. This incorporates the agricultural history of the land, current practices and an understanding of how the ecosystem works, in order to understand meadow development in light of different possible scenarios regarding the socio-economic context in which farming takes place. This multidisciplinary research makes it possible to measure the various different benefits of agro-ecosystems at altitude. They combine field work, semi-controlled experiments, laboratory tests, as well as social science approaches to understand the perspectives of the inhabitants (including farmers and elected representatives), land managers (Ecrins National Park) and tourists.

The experimental zone in the Alpine Garden allows experiments to be carried out under semi-controlled conditions Here, the pots contain "simplified meadows" with a selection of species for studying the interactions between plants, interactions between plants and micro-organisms in the ground, and the interactions between plants and insects (grasshoppers are trapped beneath the white netting).

Villar d'Arène: Freemen for centuries...

From the 14th century and up until 1789, Villar d'Arène held a charter which meant it was a free community, or a rural "enfranchised" community. Its inhabitants, known as Faranchins, bought the right to own land, to have a communal oven and mill in exchange for a share of their taxes. They elected a consul and held regular assemblies together to organise the life of the community. Although the Col du Lautaret is an obvious geographic boundary, it is not the administrative frontier between the departments of Isère and the Hautes-Alpes. After the French revolution, the inhabitants of the La Grave canton asked to belong to the Hautes-Alpes region, hoping for access to the forests of Briançon. The promise was not kept, and, later, they were not able to join Isère like the other Oisans cantons.

Man & plants

Plants have always been used by man as food (wild plants and cultivated plants), medicines, for making tools, and for their aesthetic, supernatural or magic properties. Rye was the most important cereal in the diet because it allowed people to make their bread for the year. Bread was made once a year every November in the villages, when everybody gathered around the communal oven and batches were baked day and night. This festive tradition persisted in Villar d'Arène with the peculiarity that the bread was made only with rye flour and hot water, without yeast. It was this "Pô buli", or boiled bread that inspired a remarkable study by the ethnologist Marcel Maget (1989).

Left, making black rye bread (called "tourtes") and adding the owners' marks, here by Jean-Baptiste Faure and Louis Bois (source Marcel Maget, MuCEM). Right, a marker for the family bread A. Clot (coll. Clot).

Potatoes, shown here in Villar d'Arène, flourish in the mountains. Introduced from the South American Andes, the potato established itself as a common food in the 18th century. It was Antoine-Augustin Parmentier (1737-1813), an army chemist, who made growing potatoes popular after having convinced King Louis XVI of their potential to relieve food shortages.

These large cast iron dishes were used for making potato pie and for cabbage pie, the traditional dish of Villar d'Arène consisting mainly of cabbage, salted belly of pork, sour cream and chestnuts. Note the repairs to the lid of the dish which suggest how important the object must have been (coll. Amieux).

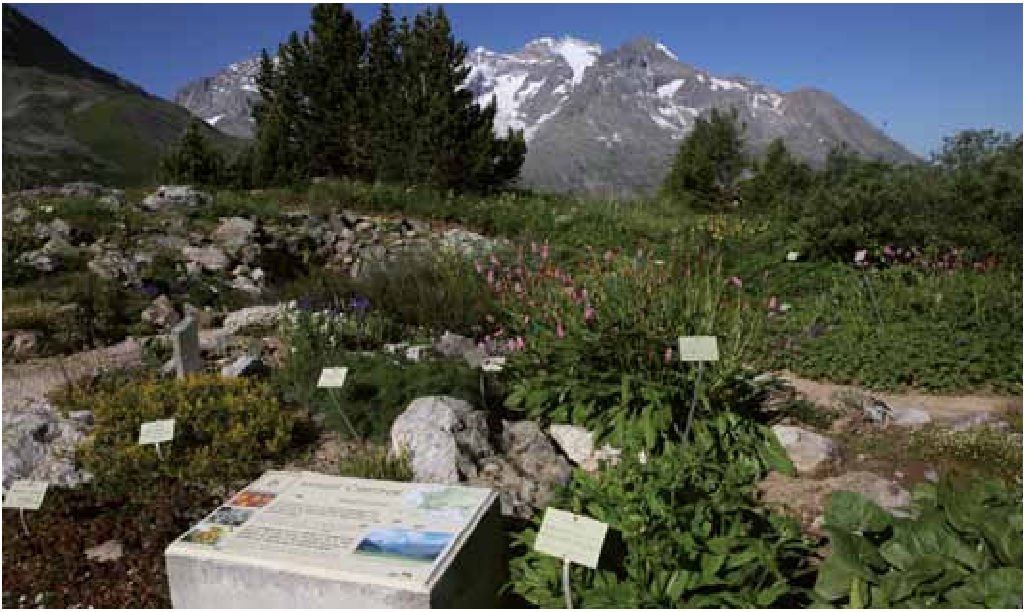
Recent improvements to the Garden

New Signs

Between 2008 and 2013, around sixty enamelled sandstone information boards were produced for the Garden. They present the different rock gardens in the Alpine Garden and describe the world's mountain ranges, alpine ecological habitats, and present the new School of Botanics (p. 153). The same style of boards have been placed at various intervals throughout the Garden, providing visitors with information to aid their discovery of the Garden. The same content is also available on the Joseph Fourier Alpine Research Station's website. Geological panoramas of the Col du Lautaret and the tufa deposit in the Garden are also presented on three larger information boards.

Illustrated labels have been created to identify the wild plants that grow in the meadows of the Alpine Garden (p. 30), as well as plants from the Lautaret region that are used for specific purposes.

This project was funded by the Provence - Alpes - Côte d'Azur and Rhone-Alpes regions and by the Garden itself using the prize money from the *Grand Prix de la Fondation Prince Louis de Polignac* (p. 20).



An enamelled sandstone information board presenting the rock garden devoted to flora from the Pyrenees. The board displays a map, a photograph taken of the mountains* in situ*, a short description and three photos of representative plants.

The school of Botanics

The Alpine Garden's university connections and its special relationship with the research sector make it the perfect setting for projects which aim to spread scientific knowledge. The innovative idea behind this 'school' is to assemble groups of alpine plants under key biological themes. This educational approach presents plants already established in the Alpine Garden according to their natural environment ("ecological rock gardens"), their geographical location ("geographical rock gardens"), or their properties ("plant for special purposes").

Six themes are explored: plant organisation, alpine plants, interspecific relationships, plant distribution, plant reproduction and plant classification. Each theme is displayed in a raised bed. The project was funded as part of a wider project to update the Alpine Garden's signposting and information boards.

Each theme, (plant classification shown here), is displayed in a raised beds which houses the relevant plants and two information boards.

Illustrators in residence

Philippe Danton, botanist and illustrator, started a residency programme for botanical illustrators at the Lautaret Alpine Botanical Garden in 2006. The programme is linked to a public collection of drawings dedicated to Dominique Villars (1745 - 1814), a botanist and doctor born in the Dauphiné, who was the first person to recognise the remarkable biodiversity in the Col du Lautaret region.

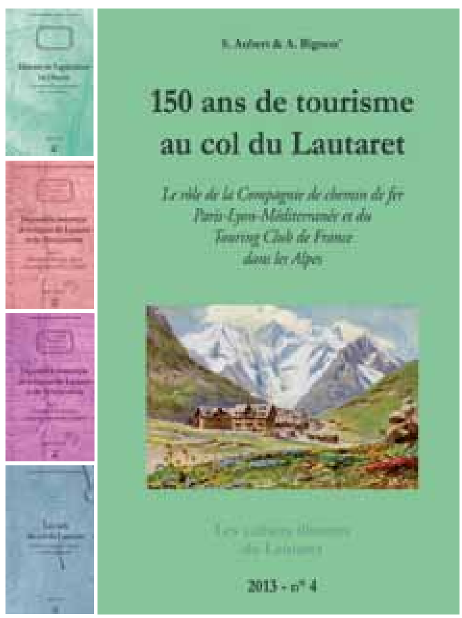
Every year, two illustrators are selected by a committee and invited to the Col du Lautaret for a week to produce drawings of the plants at the Alpine Garden. In exchange for this period of residence, each illustrator contributes two drawings to the Dominique Villars Collection. This programme reflects the importance of documentary botanical drawings, in bringing art and science together. It has also taken on an international dimension with the participation of illustrators from Argentina (Darwinian Botanical Institute, Buenos Aires), Italy, Spain (Royal Botanical Garden of Madrid) Tibet (Men Tsee Khang, Tibetan Medical and Astrological Institute), Austria, Japan and Brazil.

Francisco Rojas, botanical illustrator from the Darwinian Botanical Institute, Buenos Aires, during his residency in 2010.

Publications

Every three years the Joseph Fourier Alpine Research Station publishes a catalogue (an A3, 24-page bilingual portfolio in French and English) which contains reproductions of the drawings produced and a short biography of the illustrators participating in the residence programme established in 2006 (Danton and Aubert 2009, Aubert 2012).

In 2010, a collection of publications entitled *Cahiers illustrés du Lautaret*, (the illustrated notebooks of Lautaret) was launched. This series of Lautaret Alpine Botanical Garden publications is a collection designed to make the work carried out at the Joseph Fourier Alpine Research Station accessible to the general public. The first publications examine the history of agriculture in Haut-Oisans (Girel et al 2010); the flora and vegetation of the Lautaret-Briançon areas (Aubert et al 2011), tufa in the Lauteret region (Latil et al 2012), and the history of tourism and the PLM company in the Lautaret region (Aubert et Bignon 2013). Future publications will cover edible plants found in the region, cushion plants, the story of Scott's equipment trials at Lautaret, grasshoppers and butterflies of the region, the region's geology, and tropical alpine mountain vegetation, amongst others.



Left,* Incarvillea zhongdanensis *(Bignoniaceae) in the Alpine Garden, drawn by Francisco Rojas in 2010. Right, the covers of the first issues of the Cahiers illustrés du Lautaret.

The High-Altitude Arboretum

This arboretum is one of the highest in France and is located above the Alpine Garden. The arboretum was planted in 1974 by the National Institute of Research in Science and Technologies for Environment and Agriculture (the Irstea formerly known as Cemegref) and the National Forests Office, to examine the performance of conifers growing at their upper altitudinal limit. Abandoned for about a decade, it is now being restored for scientific and educational purposes. According to certain models, global warming could mean that the upper altitude limit for trees may increase by several hundred metres within the next century.

One project aims to plant new forest varieties from various continents, in order to measure the trees' growth parameters and set up a marked botanical discovery trail with information panels that will extend educational visits to the Alpine Garden into the arboretum.

View of the Lautaret High-Altitude Arboretum which includes around 450 individual examples of 19 different species according to the 2008 inventory.

Participation in Research

Thanks to its botanical expertise and its horticultural facilities, the Alpine Garden is now involved in several research programmes which aim to better understand how plants have evolved according to changes in climate and agricultural practices. Other multidisciplinary projects combine botanical expertise and cutting-edge techniques in genetics, for instance the Phyloalp project, sponsored by the Laboratory of Alpine Ecology in Grenoble. This project is systematically sampling all species comprising the alpine flora (c. 4500 species) with the aim of retracing their evolutionary history. The botanical expertise of the Alpine Garden has a key role to play, with its links to the Ecrins, Vanoise, and Mercantour national parks and the Conservatoire Botanique National Alpin in Gap-Charance and the Conservatoire Botanique National Méditerranéen in Porquerolles.

The Alpine Garden also supplies samples (seeds, leaves, parts of herbs or plants) for many research projects in France and abroad.

Sampling for the Phyloalp research programme. From left to right: S. Lavergne, C. Quétel, W. Thuiller (Laboratory of Alpine Ecology in Grenoble), R. Douzet (botanist at the Alpine Garden).

New Developments

Between 2005 and 2013 there have been many developments at the Alpine Garden. It became apparent that the nursery, which was previously located next to the Mirande chalet, had become too small and also dangerous as there was a risk that the supporting wall might collapse. As a result, a new nursery was created behind the chalet, near to the experimental area, which has now also been expanded to include additional research projects (p. 8). In the area where the nursery used to be, three large raised beds have been constructed to grow more difficult plants that require excellent drainage, special watering and protection in winter.
An excavation site was created to supply the blocks of tufa used to construct a wall for growing rock plants (p. 26), and this led to research being carried out on the tufa deposit in the Alpine Garden (p.106). Finally, stone raised beds were set up for the School of Botanics (p. 153) and a path was built for people with reduced mobility.

The raised beds are used to display plants which are more difficult to grow, in particular cushion plants. On the left, the path for people with reduced mobility and the Mirande Chalet.

Picture bank

An online picture bank was created in 2000 and has been developing ever since, (www.flickr.com/photos/stationalpinejosephfourier/). It already contains more than 25,000 images. They notably illustrate the Alpine Garden's plant collections, the indigenous flora and vegetation of the Lautaret region and the flora of sites visited on botanical excursions organised for the university by researchers at the Alpine Research Station. A significant number of photos show flora from different mountain ranges across the world, with a particular focus on the flora of the Andes and Patagonia. Several botanical expeditions have been organised to these regions with the aim of developing the garden's collections and furthering its research projects. A large number of these trips have looked at the tropical alpine flora of Venezuela (from the Paramos) in relation with a research project examining how the extremely diverse and original flora in this region came into being (French-Venezuelan collaboration).

Screen shots from the picture bank showing flora from the alpine zone in the Lautaret region (left) and tropical alpine flora from the Tuñame páramo in Venezuelan Andes (right).

A major project: the Alpine Gallery

For over a century, the Lautaret Alpine Botanical Garden has forged a solid reputation in the domain of alpine biology by developing synergies between science and tourism. The Alpine Garden is now a site of research excellence, notably supported by the CNRS, as well as a major tourist destination in the Hautes-Alpes (20,000 visitors per season). However it has outgrown its infrastructure, which is now unable to cope with both the research requirements and the influx of visitors. The construction of a new building, the Alpine Gallery, has been planned. It will be built near the two existing chalets and will contain exhibition spaces, a conference room, a teaching room and laboratory facilities. The project will be funded by the university, the CNRS, the Provence-Alpes-Côte d'Azur region, the Hautes-Alpes department and the Briançon community of municipalities.

The layout of the Alpine Research Station at the Col du Lauteret has hardly changed in one hundred years. The ruin of the PLM hotel (bottom right) is a stone's throw from the existing chalets.

The Rock Gardens

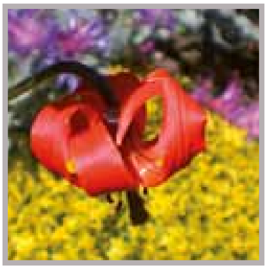
The Southern Alps

This region includes the French and Italian Maritime Alps as far as the Trentino region in Italy. It has a high species diversity and many of these species are endemic, which is connected to its geographical isolation, the presence of significant limestone areas and the overlap between the Alpine and Mediterranean regions.

European or common peony (*Paonia officinalis*) and mountain pine (*Pinus mugo*)

Allium insubricum

Rhaponticum heleniifolium



Lilium pomponium

Paederota lutea

Linaria alpina

Saxifraga retusa ssp. *augustana*

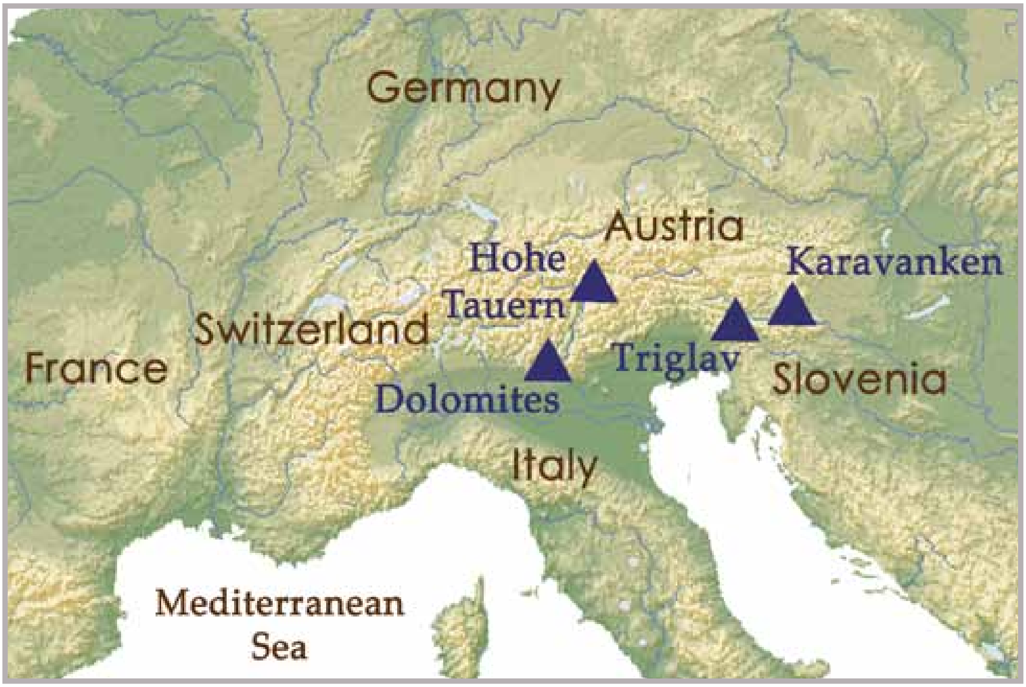
Bupleurum longifolium

Fritilaria meleagris

Leontopodium alpinum

Sempervivum grandiflorum

The Eastern Alps



At the time of post-glacial re-colonisation, this part of the Alps benefited from botanical influences from the Balkans and the Carpathian Mountains. Massifs that are renowned for the diversity of their flora include the Dolomites (3343 m), Triglav (2864 m), the Karawanken (2237 m) and the Hohe Tauern (3798 m).

Primula clusiana in front of Mountain Pine and the peaks of Combeynot


Campanula thyrsoides ssp. *carniolica*


Cirsium carniolicum


Gentiana pannonica


Hesperis matronalis ssp. *nivea*


Lilium martagon var. *cataniae*


Dianthus alpinus


Hacquetia epipactis


Scorzonera rosea


Senecio abrotanifolius


Rhododendron hirsutum

The Apennine Mountain Range

These mountains run the length of Italy for over 1,000 km. The central Apennines are made up of high massifs, such as the Abruzzo. Alpine flora has developed above the beech forest and pines. It includes species adapted to life on cliffs or on the white sandstone scree which dominates the landscapes.

Linaria purpurea and *Cerastium tomentosum*

Phyteuma scheuchzeri ssp. collumnae

Achillea oxyloba

Erysimum majellense

Linaria purpurea var. *montana*

Cymbalaria pallida

Centaurea parlatoris

Geranium argenteum

Cynoglossum majellense

Armeria majellensis

The new scree in the Apennine Rock Garden (see p. 29)

Balkan Peninsula

This peninsula in South East Europe includes the following mountain ranges: Stara Planina, Rila, Pirin and Rhodope (Bulgaria), the Pindus (Greece, Albania) and the Dinaric Alps (the former Yugoslavia). These mountains are subject to a strong Mediterranean influence that includes plants adapted to dry summers.

Visit of the biology department of Grenoble university in 2003, under the direction of J-G Valay

Anthemis cretica

Asperula nitida

Iris pallida

Degenia velebitica

Geranium macrorhizum

Geum bulgaricum

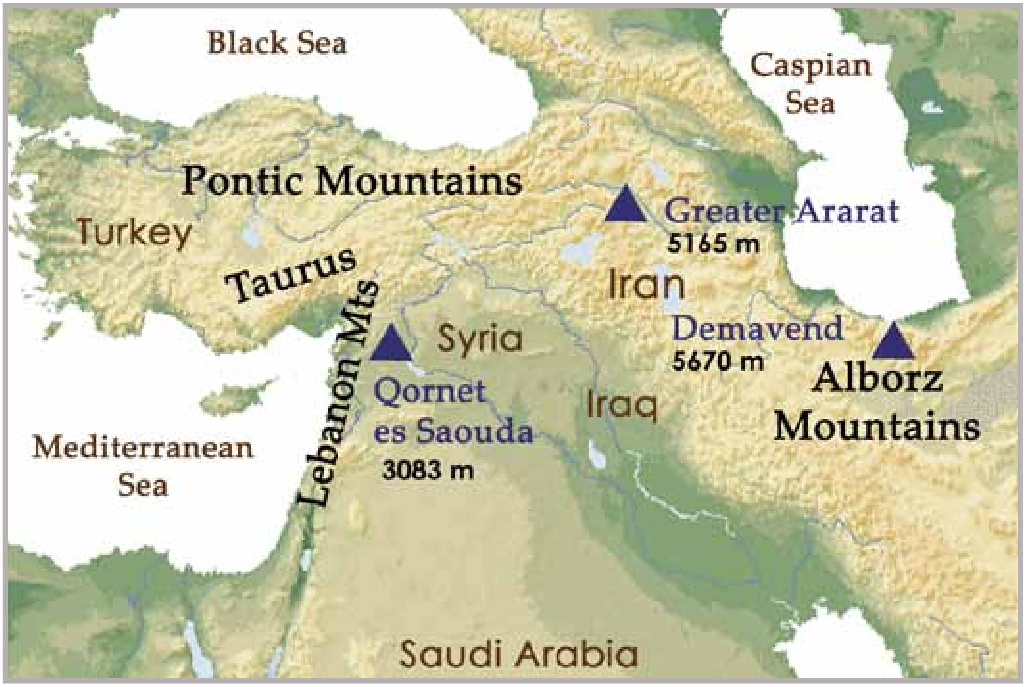
Knautia macedonica

Lilium carniolicun

Wulfenia carinthiaca

Thymus doerfleri and *Geum coccineum* at their peak flowering at the beginning of July

Mountains of the Middle-East



In the north, there are the Turkish Pontic mountains, the Taurus in Iran, and the Alborz mountain range. The Zagros range is in the south, which is far more arid. The Lebanon Mountains separate Lebanon from Syria. Most of these mountains have a cold dry climate, where thorny cushions are abundant.

A "wild garden" (meadow left) and man-made garden for plants from very dry zones

Coluteocarpus vesicaria

Erodium absinthoides

Aethionema saxatile ssp. *oreophilum*

Silene caryophylloides

Helichrysum compactum

Hordeum violaceum

Muscari armenum

Stachys byzantina

Verbascum phoeniceum

Verbascum olympicum (yellow) and *Geranium ibericum* ssp. *jubatum* (purple)

The Carpathian Mountains

The Carpathians form a mountain range in the centre of Eastern Europe (Romania, Slovakia, Poland, Czech Republic, Hungary, Ukraine and Serbia). The flora of this range has strong affinities with that of the Eastern Alps and, to a lesser extent, with that of the Himalayas.

The rock garden at day break, dominated by *Alchemilla mollis* and *Pinus mugo*.

Alyssum repens

Arabis ferdinandi-coburgii

Delphinium oxysepalum

Dianthus capitatus ssp. andrzevitschianus

Jurinea glycacantha

Saxifraga marginata

Dianthus spiculifolius

Gentiana phlogifolia

Silene hayekiana

Pulsatilla halleri

The Caucasus

This range is made up of the Lesser Caucasus (in the south) and the Greater Caucasus (to the north, the higher of the two ranges). The western part of the range is listed as a UNESCO World Heritage Site due to its biodiversity which, as yet, has been largely unaffected by man. The range is home to over 5,000 species.

Papaver lateritium (orange), *Anthemis biebersteiniana* (yellow), *Nepeta grandiflora* (blue)

Androsace lehmaniana

Chrysanthemum coccineum

Arabis flaviflora

Campanula bibersteiniana

Centaurea macrocephala

Paeonia wittmanniana

Inula glandulosa

Daphne caucasica

Lilium monadelphum

View of the Mirande Chalet and the Cerces Massif

The Himalayas & Tibet

The Himalayas are the highest mountain range in the world (14 summits over 8,000 m high, 2,400 km long). The high altitude Tibetan plateaus extend to the north. The southern slopes, subject to monsoons, are more humid than the northern slopes. The Alpine zone, above the tree line, starts at around 4,000 m.

Primula rosea around a small artificial lake at the very beginning of the flowering season

Allium macranthum

Androsace sempervivoides

Aquilegia fragans

Primula vialii

Cremanthodium ellisi

Delphinium cachmirianum

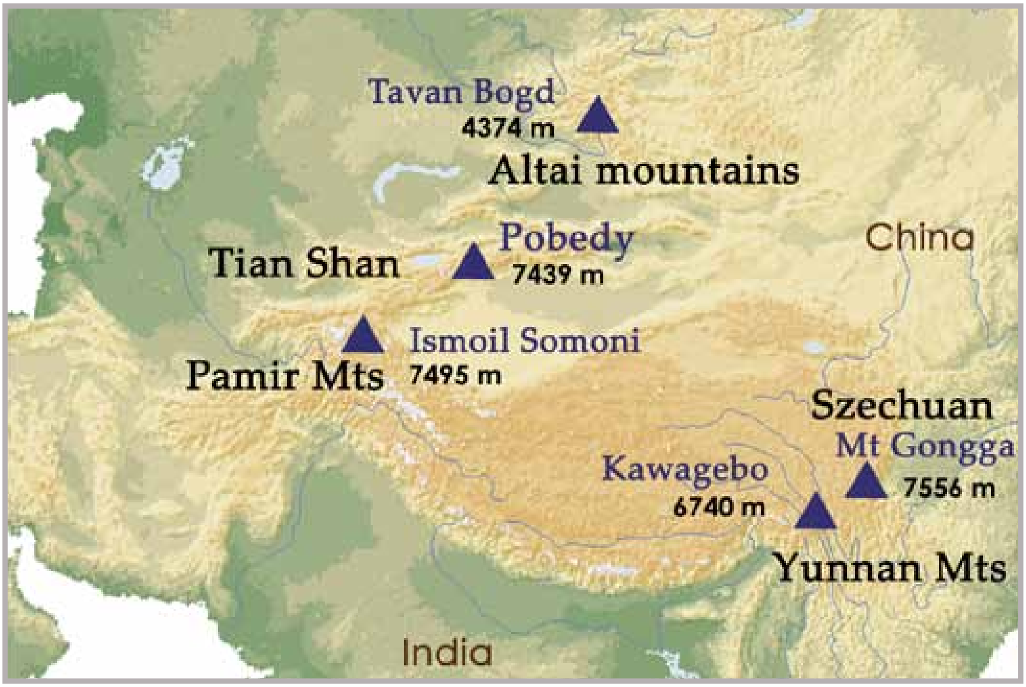
Nardostachys jatamansi

Potentilla atrosanguinea

Codonopsis clematidea

Meconopsis grandis

Central Asia & China



Central Asia is home to several mountain ranges, including the Altai, Pamir and Tian Shan mountains. The flora of Szechuan and Yunnan should also be included. The centre for the diversification of several European alpine genera such as Gentians, Primroses and Rhododendrons is located in these mountains.

View of the Mirande Chalet at sunset

Corydalis nobilis

Paeonia delavayi

Incarvillea mairei
var. *grandiflora*

Iris albertii

Iris forestii

Ligularia przewalskii

Lonicera tatarica

Erigeron aurantiacus

Rheum wittrockii

Trollius sibiricus

Arctic regions

The Arctic regions are located north of the Arctic Circle at the North Pole. Arctic flora is found at low altitude due to proximity to the North Pole and is homogeneous across all arctic regions. Cold is the main constraint, and the soil is permanently frozen at depth throughout the year (permafrost).

Rays of sunlight catch *Geum rivale* ssp. *islandica* after snow on the 10 July 2007

Castilleja miniata

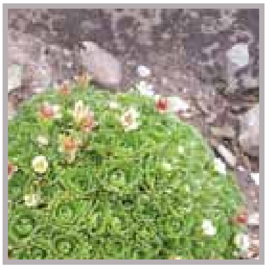
Dodecatheon pulchellum
ssp. *pauciflorum*

Lupinus arcticus

Thymus praecox
ssp. *arcticus*

Potentilla
hyparctica

Rubus arcticus



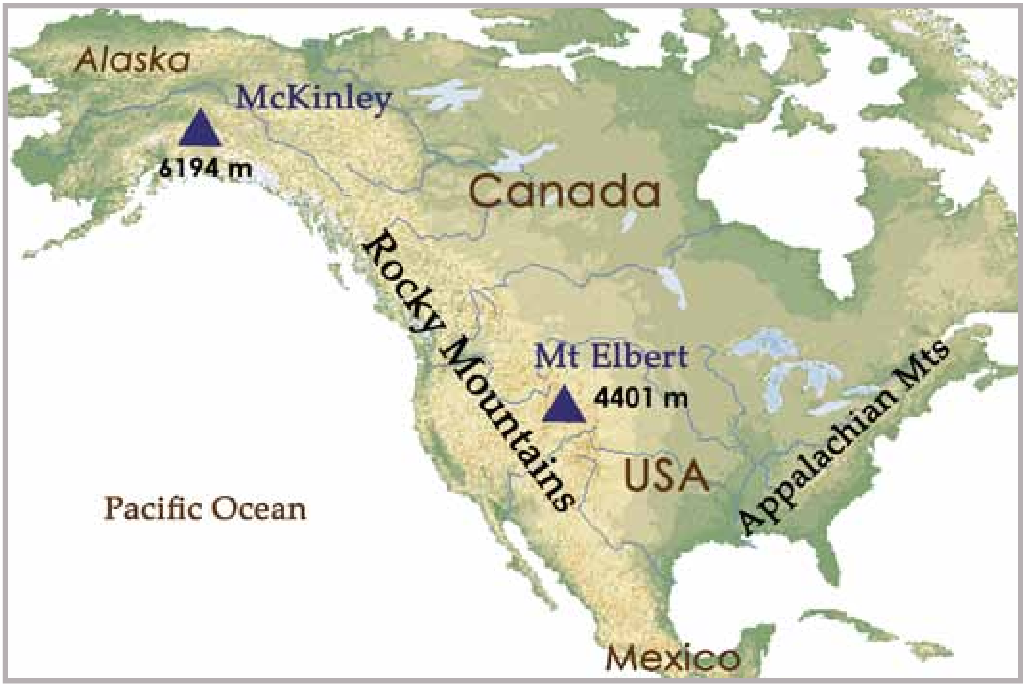
Saxifraga cespitosa

Saxifraga hieracifolia

Campanula rotundifolia
var. *alaskana*

Papaver lapponicum

North America



The Rocky Mountains stretch from Alaska to New Mexico across over 4,500 km. To the east the Appalachian Mountains are ancient, eroded mountains at a lower altitude. Amongst the purely American genera grown at Lautaret you can find *Eriogonum, Castilleja, Penstemon* and *Phlox*.

The North-American Rock garden in August

Clematis hirsutissima

Dodecatheon redolens

Dryas drummondii

Eriogonum ovalifolium
var. *depressum*

Towsendia rothrockii

Heuchera rubescens
var. *glandlosa*

Dicentra oregana

Tradescantia
ohioensis

Penstemon
whipleanus

Aquilegia elegantula

Andes & Patagonia

The Andes extend over more than 10,000 km. Patagonia and Tierra del Fuego are found to the south of this mountain range (Chile and Argentina), as well as the cold Patagonian Steppe (South Argentina). There is a great diversity of climates along the Andes, hence the rich and brightly coloured flora, rarely seen in Europe.

A guided tour run by ecology students from Grenoble University

Deschampsia antarctica

Calceolaria corymbosa

Calandrinia caespitosa

Oxalis adenophylla

Thlaspi magellanicum

Tropaelolum polyphyllum

Mimulus cupreus

Hordeum comosum

Mimulus depressus

The rock garden has been created using volcanic rock from the Massif Central

Crassula milfordiae

Craspedia maxgrayi

Delosperma congestum

Geranium sessiliflorum

Celmisia coriacea

Kniphofia caulescens

Raoulia hookeri

Cotula potentillima

Felicia natalensis

Helychrisum milfordiae whose flowers close every night

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- http://ecologie-alpine.ujf-grenoble.fr, a website where all the cartography is assessable for vegetation and alpine ecology published between 1963 and 1984 by Professor Ozenda's Plant Biology Laboratory

Outside front cover: Photos of the plant *Dryas octopetala* and the butterfly *Agrodiaetus sp*, and a sketch of *Dodecatheon pulchellum* drawn by Christophe Perrier, the 3rd illustrator in residence at the Lautaret Alpine Garden, in 2008.

Inside front cover: The Caucasus rock garden, the Mirande chalet and Grand Galibier in the month of July.

Serge Aubert was awarded the University Joseph Fourier Medal in 2009 for his involvement in developing the Joseph Fourier Alpine Station and obtaining the Grand Prix de la Fondation Prince Louis de Polignac for the Lautaret Alpine Botanical Garden.

Back cover : The Lautaret Alpine Botanical Garden and the Meije massif (3987 m), with a reflection of the rock gardens in the small lake located near the entrance.

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Serge Aubert is a Professor of plant biology at the Joseph Fourier University (Grenoble 1), a member of the Laboratory of Alpine Ecology and Director of the Joseph Fourier Alpine Station, the structure created in 2005 by the University of Grenoble 1 and CNRS. This Mixed Service Unit includes the Alpine Botanical Garden and the Chalet-Laboratory at the Col du Lautaret and the Robert Ruffier-Lanche Arboretum and glasshouses on the Grenoble campus.

The photo was taken in August 2012 in the tropical Andes (páramo El Angel, Ecuador).

The first edition of this guide was published in 2000 based on the work of Patrice Fernandez who carried out his national service at the Lautaret Alpine Research Station, supervised by the team which led the site's scientific revival through the 2000s: Serge Aubert, Philippe Choler, Rolland Douzet and Richard Bligny (Director from 2000 to 2004). When the second edition was written in 2005 (a total of 5000 copies were sold, requiring several reprints), Serge Aubert worked with Alain Bignon (1944-2012) to include a chapter on local history. This latest edition has been largely rewritten, corrected and extended to twice the original length.

Unless otherwise indicated, most of the illustrations come from the author's collection of images. Most of the older images come from the Alpine Garden's archives and the Bignon and Aubert collections. Some documents are from the collections housed at the Dauhpinois Museum and the MuCEM (the Museum of European and Mediterranean civilisations) to whom we would like to extend our thanks.

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