Preface

Plants inhabiting high alpine and nival zones are considered as living in an extreme environment.

Extreme environments have been attractive for explorers for centuries, and nowadays they also attract tourists. Fortunately biological science is becoming increasingly aware that these remote habitats provide challenging questions that will help to understand the limits of life functions. Biota of cold, extreme environments have been brought closer to the scientific community and to the public by international activities such as the International Year of the Mountains (2002) or the International Polar Year (2007–2009).

While it is indispensable to use model plants such as *Chlorella, Physicomitrella, Hordeum* or *Arabidopsis* to follow single metabolic processes and pathways or fluxes, species from remote locations are difficult to use as model organisms: often they do not grow in culture or they change their metabolism completely under artificial growth.

Plants at the margins of life developed a broad range of adaptation and survival strategies during evolution. These are best studied with species growing in extreme environments – extreme firstly for the researcher, who tries to measure life functions in the field and to harvest samples for later studies in the home laboratory. This has been experienced by an increasing number of scientists working in the fields of geobotany, plant ecophysiology and ecology. Their work has prepared the conditions that allow different aspects in cell physiology of plants from cold environments (the same holds for high temperature biota e.g. of deserts, volcanoes) to be studied by state-of-the-art methods and the results to be interpreted in order to understand the entire organism, and not merely an isolated function.

This book is devoted to the presentation of a collection of articles on adaptation and survival strategies at the level of cell physiology. The plants have partially been investigated in the field and were partially taken directly from alpine or polar habitats for experiments under lab conditions.

The book contains 14 chapters, written by experts from different research areas. Most of the contributions are from scientists from the University of Innsbruck. This is not surprising since the “Alpenuniversität” looks back on more than 150 years of research in alpine regions in many fields, including biology, medicine, weather and climate, geology, geography and others. Surrounded by high mountains, the university still is a center of alpine research today. Several topics have been taken up by colleagues from other universities to integrate their challenging work for a better description of alpine plant cell physiology.

If physiology and cell structural research are not to lose the connection to the organism, at least partial knowledge of the environmental conditions as determinants of most life functions should be considered. Therefore, the first three chapters deal with aspects of the physical environment of alpine plants.

In Chap. 1, *M. Kuhn* explains the conditions of water input in the form of snow or rain in the High Alps. Seasonal variations, regional differences and altitudinal effects or wind exposure strongly determine water and snow situations for the plant communities. The physical characterization of snow cover will help to understand plant survival in winter. Equally important for plant life and development is solar radiation, characterized by *M. Blumthaler* in Chap. 2 for the European Alps. Radiation physics is not an easy issue for plant scientists, but it is well explained in this context. The variation in solar radiation input in the Alps comes from atmospheric factors such as aerosols, dust, clouds, ozone, and further depends on altitude, solar angle and exposure angle of a plant surface to the sun. The biologically effective UV radiation is at the center of this contribution. Chapter 3 by *W. Larcher* deals with the bioclimatic temperatures of mountain plants and connects the first two chapters with the microclimate which is closer to the plants than general weather descriptions allow. Macro- and microclimate temperatures show large differences. Less often taken into account, but of enormous influence are soil temperatures in mountain regions. Soils buffer the large diurnal temperature changes in high altitudes, thus influencing root growth. Recording actual temperatures at the plant body or in the canopy provides important data for understanding plant growth forms and the physiology of temperature adaptation.

The following Chap. 4 by *C. Lütz* and *H.K. Seidlitz* describes effects of anthropogenic increases in UV radiation and tropospheric ozone. Sophisticated climate simulations demonstrate that alpine vegetation as well as one of the two Antarctic higher plants will probably not suffer as a result of the expected increases in UV. In contrast, ozone, which accumulates at higher levels in European mountains than in urban environments, may threaten alpine vegetation by inducing earlier senescence. In a combination of physiological and ultrastructural studies, *Lütz* et al. (Chap. 5) describe cellular adaptations in alpine and polar plants. Chloroplasts show structural adaptations, only rarely found in plants from temperate regions that allow them to use the short vegetation period in a better way. Possible control by the cytoskeleton is discussed. These observations reflect high photosynthetic activities; and development of membranes under snow in some species is documented. By contrast, the dynamic of high temperature resistance in alpine plant species is presented by *G. Neuner* and *O. Buchner* (Chap. 6). Tissue heat tolerance of a large number of alpine species is reported. Heat hardening and developmental aspects are compared. As high temperatures in the Alps normally occur under high irradiation, the authors look more closely at the thermotolerance of photosystem II. Acclimation of photosynthesis and related physiological processes in a broader view are discussed by *P. Streb* and *G. Cornic* in Chap. 7. Aspects of acclimation in alpine plant photosynthesis include C4 and CAM mechanisms and the PTOX electron shuttle. The protection of photosynthesis by energy dissipation and antioxidants is also considered.

R. Bligny and *S. Aubert* (Chap. 8) investigate metabolites and describe high amounts of ascorbic acid in some Primulaceae. By using sophisticated NMR methods they also identify methylglucopyranoside in *Geum montanum* leaves, which may play a part in methanol detoxification, and finally study metabolites in *Xanthoria* lichens during desiccation and hydration. In Chap. 9 *F. Baptist* and *I. Aranjuelo* describe metabolisms of N and C in alpine plants – often overlooked by physiologists. Plant development depends greatly on carbon fixation and a balanced N uptake by the roots. Snow cover and time of snow melt determine N uptake for the metabolism. Storage of C and N in alpine plants under the expected climate changes is described and discussed.

The high mountain flora shows that flowering and seed formation function despite the often harsh environmental conditions. In Chap. 10 *J. Wagner* et al. explain how flower formation and anthesis are regulated by species-specific timing based on the plant organ temperatures. Snow melt – again – and day length control reproductive development and seed maturity.

The next two chapters report on recent findings describing adaptation to subzero temperatures. As *S. Mayr* et al. show (Chap. 11), alpine conifers are endangered in winter by limited access to soil water, ice blockages of stored water in several organs, and frost drought in the needles. Embolism and refilling of xylem vessels are studied by biophysical methods and microscopy, resulting in a better understanding of the complex hydraulics in wooden alpine plants. Thematically related, *G. Neuner and J. Hacker* discuss freezing stress and mechanisms of ice propagation in plant tissues (Chap. 12), using alpine dwarf shrubs and herbs. Resistance to freezing stress depends greatly on plant life forms and developmental stages. The capacity of supercooling is studied in some species. By means of digital imaging they describe ice propagation in leaves and discuss the structural and thermal barriers in tissues that are developed to avoid ice propagation.

D. Remias continues with snow and ice (Chap. 13), now as a habitat, and reports on recent findings in the cell physiology of snow and ice algae from the Alps and polar regions. The extreme growth conditions require special metabolic and cell structural adaptations, such as accumulation of secondary carotenoids ("red snow") in the cytoplasm, or vacuolar polyphenols as a protection against high PAR and UV radiation (glacier ice algae). Photosynthesis is not inhibited by zero temperatures and not photoinhibited under high irradiation – comparable to many high alpine species. Even smaller in size, but best acclimated to cold temperatures are microorganisms in alpine soils, presented by *R. Margesin* in Chap. 14. These organisms serve as ideal study objects to characterize cold active enzymes, cold shock proteins and cryoprotectans. Microbial activity in alpine soils at low temperatures has an important influence on litter decomposition and nutrition availability, which connects to higher plant root activities.

After many years of studying alpine and polar plants under different aspects, it was a pleasure for me to edit this collection of research contributions; I thank all colleagues for their participation and effort in presenting their data.

I hope that this book expands the information on cell physiology of alpine/polar plants including the connection to the physical environment they are exposed to. The different contributions should encourage more scientists to incorporate plants from extreme environments in their studies in order to understand the limits of cellular adaptation and survival strategies.

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Innsbruck, spring 2011 Cornelius Lütz

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