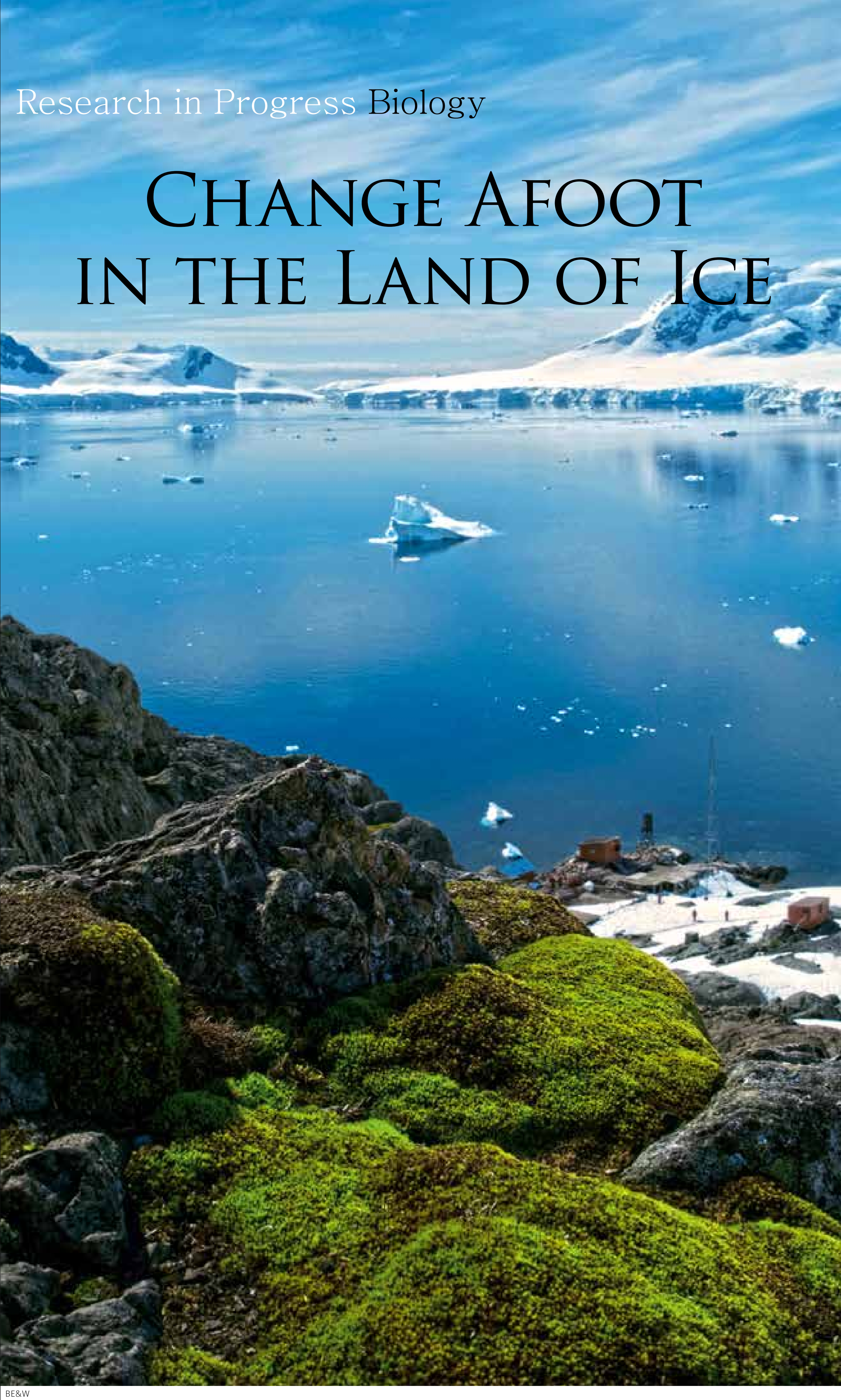
Change Afoot in the Land of Ice



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It's difficult to imagine a more curious continent: Antarctica, once very austere and inhospitable, is now becoming greener as a result of climate change.

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Antarctica separated from South America when the supercontinent of Gondwana broke up about 41 million years ago, opening up the Drake Passage. Antarctica's spatial isolation was then further deepened by the emergence of the Antarctic Circumpolar Current, an ocean current that flows around Antarctica between the latitudes of 40°S and 56°S and curbs the exchange of heat between the continent and the rest of the world, significantly contributing to the cooling of the region.

Nonetheless, what influences the climate of Antarctica most of all is its geographic location: the further south one goes, the steeper the angle at which the Sun's rays strike Earth's surface. Covered with ice and snow, practically the whole of the continent has a high **albedo**, so it absorbs very little of solar radiation, with a substantial portion of the energy that reaches the surface being used in the process of melting.

A place cold and impoverished…

The Antarctic ice sheet, which averages 2 km in thickness, makes Antarctica the highest continent on Earth. The shape of the terrain causes the air to move from more elevated parts of the ice sheet towards lower coastal areas. In the lower-lying parts of the ice sheet, these katabatic winds become stronger as a result of a tunnel effect and may reach very high speeds, even more than 40 m/s. As a result of the **Coriolis force**, these winds change direction, forming a polar front. In combination with the Antarctic Circumpolar Current, this front practically blocks the atmospheric exchange of heat between Antarctica and the rest of the world. All this makes Antarctica the coldest region on Earth. Average summer temperatures range from −30°C inland to −4°C in the regions closer to sea, with winter temperatures ranging from −70°C to −25°C, respectively.

In addition, Antarctica is a very dry continent, with average annual precipitation of around 166 mm – the highest values being observed over the Antarctic Peninsula (600–700 mm), the lowest inland (less than 50 mm). Essentially everywhere on the continent, water comes into the ecosystem in the form of snow. As temperatures are very low and very little water evaporates, the humidity of the air is very low. Therefore, what poses an insurmountable barrier for many living organisms is not so much Antarctica's physical separation from the rest of the world as its ecological isolation, caused by the extreme conditions on land. Nevertheless, life forms have evolved even in such unfavorable conditions, although they are limited to very small ice-free areas that comprise a mere 0.34% (<50,000 km^2) of the whole Antarctic surface. The fauna and flora of the Antarctic region are mainly concentrated in narrow coastal strips located as far as hundreds of kilometers away from one another, as a result of consecutive glaciations that have occurred over the past 1 million years; this unique geography makes the Antarctic ecosystems insular in nature.

Poorly developed soils with low organic and nutrient content are yet another factor that limits the presence of land organisms. The region is dominated by cryogenic soils affected by permafrost, with some occurrence of ornithogenic soils particular to Antarctica, found in the areas of penguin rookeries. Antarctic soils are often exposed to cycles of freezing and thawing (cryoturbation). In combination with permafrost, this makes Antarctic soils very unstable. This, in turn, impacts significantly on the ability of life forms to live and survive.

The terrestrial ecosystems of Antarctica largely rely on the supply of organic matter, biogenic substances, and mineral salts from the sea. Their main source is the guano of the marine birds that nest on land, in particular penguins but also pinnipeds, which also move on land, and macroalgal thalli that are washed ashore. Nevertheless, the distribution of biogenic substances on land is very uneven, with richly organic

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GLOSSARY

Albedo
(Latin for "whiteness") – a coefficient that describes the reflecting power of a surface

Coriolis force
– an inertial force caused by the Earth's rotation from west to east and the difference between the linear speeds of points located at different latitudes

areas being often located in close proximity to extremely poor areas.

Over the past 30 million years, many organisms have died out during consecutive glaciation periods in Antarctica. As a result of the oceanic and atmospheric circulation around the continent, the organisms that have survived also evolved in isolation. The result is that the local flora and fauna is characterized by a paucity of species despite the simultaneous presence of a high number of endemic species.

The Antarctic tundra, found in the ice-free regions of the maritime Antarctic, is home to few species, almost exclusively cryptogams: lichens, algae, mosses, and liverworts. There are only two species of flowering plants: the Antarctic hair grass (*Deschampsia antarctica Desv.*) of the family *Poaceae*, and the Antarctic pearlwort (*Colobanthus quitensis Bartl.*), a representative of the family *Caryophyllaceae*. The land fauna of this region is likewise sparse and consists of two species of the order Diptera (*Chironomidae*): *Parochlus steinenii,* whose range reaches south to 62°37'S, and *Belgica antarctica*, ranging southward up to 68°17'S. Neither of those species has managed to go beyond 69°S.

Three elements are of fundamental importance for the Antarctic land organisms: temperature, the availability of water that is not in the form of ice, and solar radiation. Even small variations in any of these factors may entail great biological consequences.

…but change is already happening

The western part of the Antarctic Peninsula is one of the fastest-warming regions on Earth. Although a substantial slowdown in these changes has been recently observed, they have nonetheless made their imprint on the ecosystems of Antarctica. The consequences include an increasing number of days in the year when temperatures rise above zero degrees. This means that the spring thaw starts earlier and the fall freeze is delayed, thus leading to the prolonging of the summer period in the physiological activity of many organisms. In addition, the glaciers and ice cover melt faster, thus increasing the availability of free water in the ecosystem. The effects include increasing precipitation, frequently in the form of rain, which can be immediately absorbed by living organisms. At the same time, snow fields and glaciers melt faster, which also speeds up glacier recession to a substantial degree. Consequently, water resources in terrestrial ecosystems may run out faster, thus causing local droughts, especially at the end of the summer season. Higher temperatures in winter, in turn, may lead to periodical thaws and then to the formation of ice on the surface of the soil, which has a very negative effect on vegetation and many organisms in the soil.

Another problem is posed by the emergence of the ozone hole during the Antarctic spring, which causes increased UV radiation. The most intense radiation appears at the beginning of the Antarctic summer, when land organisms have yet to resume their full physiological activity and therefore cannot activate defense mechanisms sufficiently quickly. The potential impact of increased UV-B radiation is modulated by many factors such as cloud cover, albedo, or the angle of the Sun's rays, and on a microscale even by the thickness of the ice sheet. The most extensively studied factor was the impact of UV radiation on flowering plants. Evidence was found that increased radiation of this type damaged the DNA of those plants as well as their photosynthetic apparatus, in addition to influencing qualitative and quantitative pigment composition, thus leading to morphological and anatomical changes, among other things.

The best example of the effects of climate change in the maritime Antarctic can be found in the increasing population of the flowering plants *Deschampsia antarctica* and *Colobanthus quitensis* and a shift in their range. Higher temperatures speed up the release of nitrogen through faster organic matter decomposition in the soil. Nitrogen stimulates the intensiveness of photosynthesis in plants, thus leading to increased biomass production. As a result of these transformations, Antarctic plants change their reproduction strategies: they produce more seeds, which give rise to seedlings characterized by better survivability. This also means a significant rise in the number of dormant seeds, which form the so-called soil seed bank. Such species are not only spreading rapidly across the whole of the maritime Antarctic but also moving into new habitats. Similar changes can be observed with respect to many moss species.

Such a rapid growth in the population of selected species leads to irreversible changes in the biodiversity in entire communities and the emergence of new communities, especially in the vast areas of the barren terrain left behind by retreating glaciers. They are very quickly colonized and gradually populated by pioneer organisms, which is followed by the emergence of more complex communities and their subsequent development and evolution.

The most serious consequence of global warming in West Antarctica is the appearance of alien species that may quickly adapt to changing conditions by starting to colonize the continent. They may interact with indigenous species, which have long evolved in isolation to adapt to specific climate conditions and are unable to adjust to rapid variations in climate or competition on the part of the aggressive newcomers.

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Further reading:

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