climate conditions. With this approach, Radić and Hock circumvent the problem that measured mass balances are not necessarily representative for entire mountain ranges[7].

Given the shortcomings in the available data and the required simplifications in their modelling approach, the study is unlikely to be the final word. In their regionally resolved calculations, according to Radić and Hock, the largest contributions to sea-level rise originate in Arctic Canada, Alaska and the Antarctic Peninsula — where the gaps in glacier data are most severe and the differences between the various climate models are largest. Uncertainties in the extrapolated glacier response for these regions are therefore high. Furthermore, several processes that were not considered, including ice loss by iceberg calving, the replacement of ice below sea level by ocean water or the delay in runoff from ice and firn that is entirely or partly cold, are particularly prominent in these regions.

To assess these factors more accurately, glacier inventory data that include topographic information such as the minimum and maxium altitude are urgently needed[1–3,7]. Automated classification of freely available satellite data and application of geoinformatic techniques for rapid data processing and analyses[8] can help to accomplish a large part of this work within the next few years. Moreover, currently pending problems such as the separation of Greenland's local glaciers and ice caps from its ice sheet (Fig. 1) — important to avoid double counting their sea-level rise contribution — can hopefully be solved once these inventory data are available.

Radić and Hock also report a volume loss of 75 ± 15% for glaciers in the Alps by the end of the twenty-first century, in line with earlier work[9]. This highlights the importance of modelling the future development of these comparably small glaciers. Although their influence on sea-level rise is limited, these Alpine glaciers constitute an important water resource on local to regional scales.

The quantitative estimates presented by Radić and Hock[4] will need to be updated as more and better glacier data and climate models become available. But in the light of their analysis, and considering potential positive feedbacks, there is little doubt that the fate of glaciers and ice caps looks gloomy on the century timescale, even in the more strongly glacierized regions of the world.

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EVOLUTION

Old genes

During the Great Oxidation Event about 2.4 billion years ago, the surface of the Earth tipped irrevocably into an oxygenated state, as free molecular oxygen began to accumulate in the oceans and atmosphere. But the first whiffs of oxygen began to appear at least 300 million years earlier, as organisms capable of producing the gas through photosynthesis evolved. As the Earth's chemistry changed, so too must have the microbes that lived on its surface. But the rock record leaves only hints of the ecosystem, primarily in the form of isotopic fractionation of the elements — including iron and sulphur — that presumably fuelled the bacteria.

To assess the evolution of these metabolisms, Lawrence David and Eric Alm of the Massachusetts Institute of Technology looked to the genetics of extant organisms. They re-examined existing gene families using a technique that accounts for both the evolution of new genes, and the transfer of genes between different species (*Nature* **469,** 93–96; 2011). They identified a narrow window of genetic expansion between about 3.3 and 2.8 billion years ago, which they call the Archaean expansion.

During this period, almost 27% of the largest modern gene families arose. Perhaps unsurprisingly, given the geochemical upset at the time, most of the genes that evolved are associated with metabolism. Gene groups involved in the binding of iron, sulphur and oxygen were particularly expanded, as were others that used metabolites produced by respiration.

The earliest metabolic genes identified within the Archaean expansion were probably used in anaerobic respiration, and also in oxygen- and non-oxygen-producing photosynthesis. David and Alm suggest that these genes may have later contributed to aerobic respiration pathways, as well.

Intriguingly, the expansion of genes associated with molybdenum and copper utilization coincides with the increasing availability of these elements in the oceans, as predicted by geochemical models and observations. It seems that microbes were adaptable, and quickly able to evolve pathways to use these elements as they became available.

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