help to avert exposure to an environmental danger. However, food aversion can be harmful if the allergy no longer exists or when it interferes with oral immunotherapy — a way of treating a food allergy by the reintroduction of increasing amounts of allergy-triggering foods[9].

Humans have a greater capacity for learning than do mice, and thus food avoidance probably involves more-complex learning in humans than the simple behavioural conditioning seen in rodents. Unlike humans with food allergies, mice with an experimentally induced food allergy do not completely avoid the allergen. Instead, the animals studied by the authors ingested low volumes of allergen-embedded drinking water, probably triggering a minor response. Furthermore, it is interesting to speculate that underlying immune-mediated mechanisms might contribute to food choices even in individuals who show no overt signs of allergy.

These findings might prompt further testing of potential treatments because drugs are available that precisely target identified allergy mediators. Omalizumab, an antibody that blocks IgE, is approved for the treatment of conditions such as asthma and, on the basis of early clinical studies, shows promise for treating food allergy[10]. Dupilumab is a clinically approved antibody that blocks IL-4 signalling. Furthermore, the types of leukotriene identified by Plum *et al.* and Florsheim *et al.* are readily blocked by clinically available drugs that interfere with the molecules' synthesis or with receptor-mediated signalling. In addition, a mast-cell-depleting antibody is in early clinical development[11]. Beyond anti-allergy therapeutic strategies, GDF15-based drugs are being tested in preclinical animal models[12].

Memory is a feature shared by the brain and the immune system, although the mechanisms involved differ vastly. The latest findings identify the importance of immunological memory, mediated by a classic allergic response, in acting as a primer for food aversion. Whether direct memory in the brain is also involved remains to be determined.

The mechanism of food aversion uncovered by the two studies is a notable leap forward in our understanding of the molecular and cellular bases of the neuroimmune connections involved in behavioural conditioning. Plum *et al.* and Florsheim *et al.* thereby provide a new meaning to picky eating.

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1. Pawankar, R., Canonica, G. W., Holgate, S. T. & Lockey, R. F. (eds) in *The WAO White Book on Allergy* 12 (World Allergy Org., 2011).
2. Plum, T. *et al. Nature* **620**, 634–642 (2023).
3. Florsheim, E. B. *et al. Nature* **620**, 643–650 (2023).
4. Hadamitzky, M., Lückemann, L., Pacheco-López, G. & Schedlowski, M. *Physiol. Rev.* **100**, 357–405 (2020).
5. MacQueen, G., Marshall, J., Perdue, M., Siegel, S. & Bienenstock, J. *Science* **243**, 83–85 (1989).
6. Valent, P. *et al. Theranostics* **10**, 10743–10768 (2020).
7. Lockhart, S. M., Saudek, V. & O'Rahilly, S. *Endocr. Rev.* **41**, bnaa007 (2020).
8. Bernstein, I. L. *Nutrition* **15**, 229–234 (1999).
9. Sabouraud, M. *et al. Arch. Pediatr.* **28**, 319–324 (2021).
10. Dantzer, J. A., Kim, E. H., Chinthrajah, R. S. & Wood, R. A. *J. Allergy Clin. Immunol.* **151**, 1–14 (2023).
11. Terhorst-Molawi, D. *et al. Allergy* **78**, 1269–1279 (2023).
12. Xiao, Q.-A., He, Q., Zeng, J. & Xia, X. *Biomed. Pharmacother.* **146**, 112582 (2022).

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Climate-change ecology

The great melt will shape unprotected ecosystems

Nicolas Lecomte

Glaciers should be prioritized in conservation agendas — and soon. Analysis suggests that glaciers could lose around half their area by the century's end, with uncertain consequences for postglacial ecosystems. **See p.562**

Glacier shrinkage is driving one of the most rapid ecosystem shifts on Earth: as anthropogenic climate change causes glaciers to recede, the future of species that have adapted to glacial conditions remains unclear. A comprehensive spatial analysis that quantifies and anticipates this transformation has so far been lacking. But on page 562, Bosson *et al.*[1] project that glaciers outside the Antarctic and Greenland ice sheets could lose as much as half of their area by 2100. Their estimation that around half of these glacier areas are currently unprotected underscores the urgent need for enhanced climate-change mitigation and conservation measures.

Last year, the United Nations issued a resolution declaring 2025 as the International Year of Glaciers' Preservation, and emphasizing the importance of conserving these pristine ecosystems (see go.nature.com/3kfxmkx). Bosson and colleagues have responded to this call for immediate action by using the most precise model for glacier change[2] to quantify the impact of warming under different scenarios of greenhouse-gas emissions[3]. If emissions are cut to net zero by 2050, the authors predict that around 80% of the glaciated area they studied would remain in 2100. This fraction drops to half in a high-emissions scenario brought on by a tripling of emissions by 2075.

The implications of these predictions are far-reaching. But it is not yet clear how glaciers can be adequately safeguarded[4] — and it is perhaps even less obvious how best to protect the existence, function and benefits of glacial ecosystems[5], as well as those that will emerge in postglacial areas[6–8]. Bosson and colleagues' study opens up promising avenues for investigating the upcoming ecological changes.

Postglacial ecosystems hold tremendous potential for carbon sequestration, and research into these systems — although still in its infancy — is crucial for identifying their role as future carbon sinks. However, the development of functional postglacial ecosystems can be extremely slow and complex: slow, because it can take millennia[9], much longer than the agenda of any conservation plans; and complex, because species can respond to change positively, negatively or not at all (see, for example, ref. 10). Indeed, an understanding of the ecological processes involved is only now beginning to emerge, but their inherent complexity is already clear, and evident in the fact that several trajectories for recolonizing postglacial areas exist, even on the scale of individual glaciers[11].

Yet Bosson *et al.* estimate that, not only will deglaciation be rapid, but future deglaciated areas will also span a diverse range of biomes — from the size of Nepal to Finland — encompassing terrestrial, freshwater and even marine habitats. Such vast emergence on a relatively short timescale will add to the complexity of glacial dynamics and will increase the challenge of glacier conservation (see, for example, ref. 12).

There are several benefits associated with these predictions. First, newly deglaciated areas can already harbour plant life. For example, a remarkable discovery revealed a population of bryophytes (mosses) and associated microorganisms that had been buried under ice for 400 years[13].

Second, deglaciated areas could offer refuge for species seeking new homes, and habitats adjacent to glaciers could support such recolonization.

LOUIS H. PEDERSEN/GLACIER PHOTOGRAPH COLLECTION/NSIDC/WDCG

BRUCE F. MOLINA/GLACIER PHOTOGRAPH COLLECTION/NSIDC/WDCG

Figure 1 | Ecosystems emerge as glaciers recede. These images show the way the landscape of the Pedersen Glacier in Alaska changed between 1917 (top) and 2005 (bottom). The glacier has receded even more since then[19]. The ecosystems on, under and around the glacier must adapt to these fast-changing conditions.

Third, Bosson and co-workers' predictions suggest that areas emerging through glacier loss could promote local diversity and enhance primary productivity (the rate at which energy is converted to organic substances; Fig. 1). However, not all species will respond equally to deglaciation — it could lead to increased numbers of non-native species and those that can thrive under certain conditions[6,12].

Fourth, these newly deglaciated areas could also be viewed as potential refuges for cold-adapted species that are currently at risk. This possibility arises in a low-emission scenario, in which deglaciated areas remain hospitable for these organisms. Indeed, many studies across various taxa support this idea, which has potential implications for mitigating the effects of climate change (see, for example, ref. 14). However, predicting the successful establishment and trajectory of species in these areas remains a challenge[15]. Moreover, these areas are currently afforded limited protection, so strategies for delaying the extinction of cold-adapted species must therefore be devised in the interim.

Bosson and colleagues' study offers a rare reminder of how fast and global deglaciation will be in this century. And the study's limitations serve only to strengthen its message. For example, the analysis excludes the ice sheets of Greenland and Antarctica and their associated glaciers mainly because the behaviour of these sheets differs markedly from that of other glacial terrain, and because their current and future changes are yet to be modelled adequately. The sheer size of the Antarctic and Greenland ice areas — roughly half the size of Africa — will probably amplify the impacts reported by Bosson and colleagues.

The full-scale impact of deglaciation is only starting to be unveiled, and global models of glaciers and ice-sheet inventories are much needed. These tools offer a means of predicting the complex dynamics between glaciers, climate change and ecosystem responses, which introduce uncertainties into projections of the timing and locations of glacial losses — however certain the losses might be. Bosson and colleagues' study is vulnerable to these uncertainties, but it nonetheless provides a crucial estimate of future ecological conditions in soon-to-be deglaciated areas.

In light of the authors' predictions, and those of other researchers[16], focused management efforts are warranted on a global scale[17]. Understanding the changing ecosystems is key to the success of these efforts and will inform further research on how species respond to swift and profound shifts. Now is the time to determine the ecological consequences of worldwide glacier declines[18]. But to do so, many problems need to be solved, including what to do about the imminent loss of species that inhabit glaciers, and how to best use deglaciated areas for species that have lost their habitat elsewhere.

Previous studies of recolonization can be leveraged to help with these challenges[8]. Climate and biotic interactions are likely to be the main drivers of change in plant communities[10] and mammal recolonization will probably be driven by the body size and mobility of the species[8]. Certainly, quantitative ecological approaches for reconstructing past and present changes will be useful for better understanding these factors. To go even further, glaciologists, climatologists and ecologists need to come together to implement rigorous standardized protocols similar to those devised during the International Polar Year, which took place between March 2007 and March 2009 (www.ipy.org/about-ipy), an initiative designed to promote understanding and awareness of the polar regions.

Bosson and colleagues' analysis is the first step towards a full understanding of the ecosystem shift associated with global deglaciation. The next step will be to anticipate the even larger issues linked to changes in the Greenland and Antarctic ice sheets, which surpass the combined footprint of all other glaciers. Given the limitations of models for predicting changes in such a giant glacial footprint, the authors' pioneering global-scale analysis provides a strong cornerstone for future endeavours in tackling this formidable challenge.

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1. Bosson, J. B. *et al. Nature* **620**, 562–569 (2023).
2. Huss, M. & Hock, R. *Front. Earth Sci.* **3**, 54 (2015).
3. IPCC. *Climate Change 2021: The Physical Science Basis* (Cambridge Univ. Press, 2021).
4. Immerzeel, W. W. *et al. Nature* **577**, 364–369 (2020).
5. Stibal, M., Sabacká, M. & Zárský, J. *Nature Geosci.* **5**, 771–774 (2012).
6. Cauvy-Fraunié, S. & Dangles, O. *Nature Ecol. Evol.* **3**, 1675–1685 (2019).
7. Stibal, M. *et al. Nature Ecol. Evol.* **4**, 686–687 (2020).
8. Sytsma, M. L. T., Lewis, T., Bakker, J. D. & Prugh, L. R. *J. Anim. Ecol.* **92**, 723–737 (2023).
9. Alsos, I. G. *et al. Sci. Adv.* **8**, eabo7434 (2022).
10. García Criado, M. *et al.* Preprint at EcoEvoRxiv https://doi.org/10.32942/X2MS4N (2023).
11. Brožová, V., Bolstad, J. S., Seregin, A. P. & Eidesen, P. B. *Ecol. Evol.* **13**, e9892 (2023).
12. Lee, J. R. *et al. Glob. Change Biol.* **28**, 5865–5880 (2022).
13. La Farge, C., Williams, K. H. & England, J. H. *Proc. Natl Acad. Sci. USA* **110**, 9839–9844 (2013).
14. Dullinger, S. *et al. Nature Clim. Change* **2**, 619–622 (2012).
15. Stewart, J. R., Lister, A. M., Barnes, I. & Dalén, L. *Proc. R. Soc. B.* **277**, 661–671 (2010).
16. McKay, D. I. A. *et al. Science* **377**, eabn7950 (2022).
17. Convention on Biological Diversity. *COP15: Nations Adopt Four Goals, 23 Targets for 2030 in Landmark UN Biodiversity Agreement* (2022).
18. Cauvy-Fraunié, S. & Dangles, O. *Nature Ecol. Evol.* **4**, 688–689 (2020).
19. Black, T. & Kurtz, D. *J. Glaciol.* **69**, 251–265 (2023).

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