Pol III and protein synthesis, but Maf1 loss in worms had the opposite effect and actually extended lifespan¹². This raises doubt as to whether ageing mechanisms are really so similar in different animals. But we should not expect them to be; the complex relationship between cellular metabolism, physiology and mortality clearly varies from species to species, and will need to be understood differently in each.

Looking beyond Pol III, one study¹⁴ has shown that both synthesis of ribosomal RNAs and the size of a nuclear structure called the nucleolus, in which ribosomes are assembled, diminish as flies age, and another¹⁵ reported a correlation between small nucleoli and longevity. Furthermore, suppression of ribosomal-RNA processing and nucleolar function can extend lifespan in worms and flies^{14,15}. This suggests that various interventions that reduce ribosome production or function might help to stave off age-related pathologies. Given the complexity of the protein-synthesis machinery, there should be scores, if not hundreds, of molecules that might be targeted to suppress protein synthesis and extend lifespan. But a bonanza of promising molecular targets does not mean that translation to the pharmacy will be fast. As evidenced by various trials involving mTOR inhibitors, understanding which cells to suppress to combat a given condition, and how to hit them precisely and sufficiently without stopping them dead, remains a major challenge. ■

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PALAEOGLACIOLOGY

Antarctic ice dynamics in warm climates

A geological record reveals that the Aurora sector of the Antarctic Ice Sheet showed contrasting responses to past periods of atmospheric warmth. The findings might help to predict the ice sheet's response to modern warming. SEE LETTER P.225

SARAH GREENWOOD

Some numerical models suggest^{1,2} that melting of the Antarctic Ice Sheet will cause global sea level to rise by 3 metres or more by 2300. But such models differ in the exact magnitude of the rise, as well as in which parts of the ice sheet are likely to contribute and the mechanisms involved. One way of assessing how well models perform is to see whether they correctly 'hindcast' the ice sheet's response to past changes — which requires independent geological evidence of what actually happened. On page 225, Gulick *et al.*³ present a record of sedimentation on the periphery of the Antarctic, beyond the Aurora sector that drains ice from the east of the continent. The record spans the whole period from ice-sheet inception to the present day, and reveals how the ice sheet has responded — or not — to warm climate periods in the past.

Since the inception of ice on Antarctica about 34 million years ago, there has been a general trend of global cooling. But superimposed on this trend have been periods of relative warmth⁴, during which temperatures and atmospheric carbon dioxide concentrations were comparable to those expected under future climate-warming scenarios. Geological records show that sea levels were relatively high during these periods, which means that ice equivalent to several metres of sea-level rise must have melted from Antarctica^{2,5}.

Antarctic surface melting today had been thought to be negligible, but recent work⁶ shows that surface drainage is widespread around the periphery (Fig. 1). The fate of increased meltwater in a warming climate and its effect on ice flow are unclear. Meltwater could speed up ice flow by enhancing the slipperiness of the ground over which the ice flows, or cause water-filled crevasses to propagate through floating ice and drive its collapse. A higher meltwater volume could also increase the efficiency of meltwater export, avoiding either of those developments.

On the other hand, it is widely feared that ocean warming will destabilize marine margins of the ice sheet^{1,2}, particularly where the ground deepens inward of the ice margin. This effect promises future sea-level rise, with deep basins in the interior of the ice sheet, such as

the Aurora Subglacial Basin in East Antarctica, being especially vulnerable.

Continental shelves are repositories for sediments that have eroded from the continental interior and been brought to the margin. Gulick *et al.* used a technique called seismic reflection profiling across the Aurora continental shelf to reveal the subsurface stratigraphy of sediments approximately 1,300 metres deep, which encompass the whole history of the Antarctic Ice sheet in this sector. The authors identify three sediment groups (packages) of distinctly different character. The lowermost package is non-glacial, but, towards the top, isolated pebbles indicate the first arrival of icebergs loaded with glacial debris, drifting across the site.

The second and third packages reveal two contrasting glacial regimes. In the lower of these packages, 11 stacked sediment layers have rough surfaces, produced by erosion from an ice sheet that had expanded onto the continental shelf. The surfaces are dramatically incised by channels, indicating that liquid water flowed in large volumes along the bed of the ice sheet. These periods of abundant meltwater are interspersed with long periods of marine sedimentation (which occurred when the ice margin retreated hundreds of kilometres into the continental interior, before advancing again). By contrast, the uppermost package lacks channels or any substantial marine sedimentation. This indicates a marked switch to an ice-sheet mode characterized by the polar conditions of more-recent, large ice sheets, which retreat only briefly between glacial expansions.

Thanks to erosion of the sea floor in the most recent phase(s) of glaciation, parts of each of these three sediment packages can be found close to the sea floor. This allowed Gulick and co-authors to analyse marine microfossils and terrestrial pollen in sediment cores to determine the ages of the three sediment packages. They found that the first arrival of debris-carrying icebergs to the continental shelf occurred earlier than the climate transition 34 million years ago. The change from channel-rich, dynamic ice sheets to the current polar conditions occurred a minimum of 8.6 million to 4.78 million years ago. Importantly, this work provides a regional framework of ice-sheet events with

Figure 1 | Antarctic meltwater. Gulick *et al.*³ find evidence for ancient, high meltwater fluxes from the Aurora sector of the Antarctic Ice Sheet. They interpret this to mean that there were high rates of surface melting of the ice sheet during some, but not all, warm climates.

some preliminary age constraints for a little-understood sector of the Antarctic Ice Sheet.

There are several unknowns in this picture. It is not possible to infer the distances to which grounded ice withdrew during any retreat episode, nor the rates at which it did so. Instead, the authors make an assumption based on different erosion patterns beneath the present-day ice sheet⁷. Reconstructing ice extents smaller than current ones is a considerable challenge for all scientists in this field — any surviving evidence is now buried.

The report of large channels is exciting. The authors link them to the production of surface meltwater by warm air temperatures — which is reasonable, because the channel (water) volumes are large and unlikely to be produced by melting due to pressure or friction at the bed, and because well-developed subglacial river networks are commonly fed by surface meltwater that infiltrates the ice body⁸. The drainage of subglacial lakes could also have formed the channels. But such lakes are active beneath the present-day ice sheet⁹, and the offshore sediment stratigraphy of recent glaciations³ is distinctly different from that of the earlier, water-rich glaciations discovered by Gulick and colleagues. A lake origin would therefore demand a different storage, routing and refilling regime from that observed today.

The authors' discovery of a relatively stable Aurora sector for roughly the past 5 million to 8 million years is at odds with findings from the neighbouring Wilkes sector, in which ice underwent episodes of major retreat¹⁰ and advance¹¹ about 5.3 million to 3.3 million years ago, during a warm period known as the Pliocene epoch. This disparity is not necessarily cause for concern. Alternative behaviours or rates of change in different ice-sheet sectors are well known from contemporary observations¹² and from the most recent deglaciation¹³, and model

simulations of the Pliocene echo the contrasting responses of the Wilkes and Aurora basins recorded by geological evidence⁵.

Recent experiments¹⁴ show that different Antarctic sectors are probably influenced by different climate properties, and that the Aurora sector is indeed most sensitive to air-temperature changes, whereas others are vulnerable to ocean warming. Gulick and colleagues' findings may constrain those results, by showing that an early period of warmth

produced abundant meltwater and drove major changes in the size of the Aurora sector, but that this part of the ice sheet was basically unresponsive to the subsequent Pliocene. Ice-sheet sectors that dance to different tunes may be the norm, but that means that there is an urgent need for geological data that can constrain the magnitudes and scales of that variability if we are to better understand the different vulnerabilities of different sectors. ■

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INFECTION

Viruses hijack a long non-coding RNA

Manipulation of host-cell metabolism is an essential aspect of viral replication cycles. Viral co-option of a cellular long non-protein-coding RNA has now been found to be a key step in this process.

NICHOLAS S. HEATON & BRYAN R. CULLEN

Viruses are totally reliant on the metabolic products of the cells they infect. Indeed, there have been numerous reports of viruses actively modulating cellular metabolism to establish an optimal environment for replication¹. Most such studies have found that these metabolic alterations are accomplished by viral targeting of protein–protein interactions, or targeting of host messenger RNAs by virally derived, non-protein-coding microRNAs. Could a class of host RNA known as long non-coding RNAs (lncRNAs) also be targeted to achieve a similar goal? Analysis of the roles

of cellular and viral lncRNAs in infection has previously focused mainly on modulation of innate immune responses². Now, writing in *Science*, Wang *et al.*³ reveal a different mechanism by which the virus appropriates host-derived lncRNA: activation of a host-cell metabolic pathway required for viral replication.

Long non-coding RNAs (non-coding RNAs more than 200 nucleotides long) have roles in many aspects of cell biology^{4,5}. In the nucleus, they are involved in transcriptional regulation and remodelling of chromosomes, and in the cytoplasm, they regulate microRNA function as well as the translation of mRNAs to generate proteins. But there are scores of lncRNAs whose