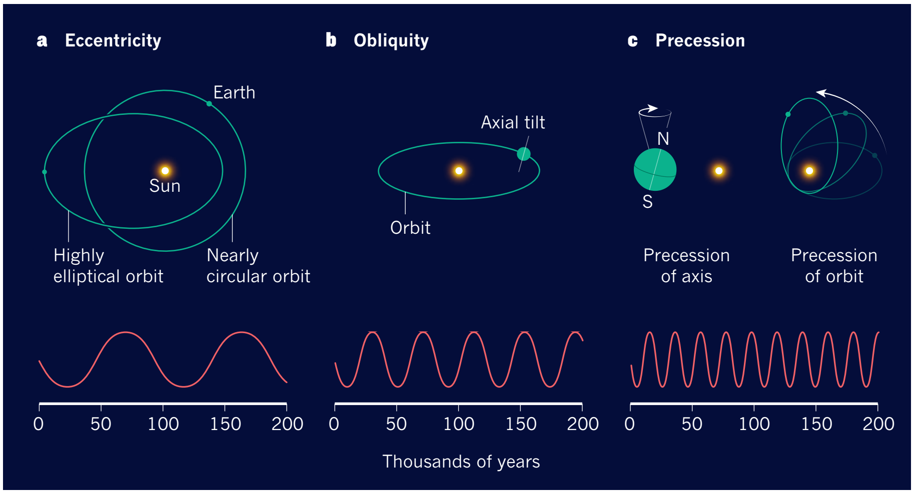

Figure 1 | Milankovitch cycles. In 1976, Hays, Imbrie and Shackleton[1] provided the first clear evidence that variations in Earth's orbit around the Sun dramatically change our planet's climate, a concept known as the Milankovitch theory[2]. There are three types of variation: eccentricity, obliquity and precession[1,2]. **a**, Eccentricity describes the shape of Earth's orbit around the Sun, and varies from being almost a circle to an ellipse, with a period of about 96,000 years[6]. **b**, Obliquity is the tilt of Earth's axis of rotation with respect to the plane of its orbit, and it oscillates with a period of about 41,000 years[6,8]. **c**, Both Earth's rotational axis and its orbital path precess (rotate) over time — the combined effects of these two components and the eccentricity produce an approximately 21,000-year cycle[6,7].

By demonstrating the clear link between orbital forcing and Earth's past climate, Hays, Imbrie and Shackleton legitimized what was to become one of the most powerful tools in stratigraphy. For example, reliable age models have been constructed for climate records covering at least the past 5 million years by tuning the orbital parameters to the ice-age cycles[3]. Such age models can be applied to any long-term palaeoclimate record, allowing marine and land records to be compared.

In addition, the various effects of the three orbital parameters have been used to study orbital forcing at different latitudes. Obliquity has a strong influence at high latitudes, whereas precession has a significant impact on seasonality in the tropics — precession has been linked to the rise and fall of the African rift-valley lakes, and even to our own evolution[4]. Evidence for the orbital forcing of climate has now been found as far back as 1.4 billion years ago, in the Proterozoic eon[5].

Hays, Imbrie and Shackleton clearly set out the limitations of their study and presented the scientific community with a range of challenges, many of which remain today. In particular, the authors recognized that variations in the orbital parameters did not cause the ice-age cycles, but rather paced them. Any given combination of parameters can be associated with many different climates — for example, Earth's orbital configuration today is similar to to that of 18,000 years ago, when a 3-kilometre-thick ice sheet covered North America. Feedback mechanisms take the small changes in insolation that are driven by the orbital parameters and push Earth into or out of an ice age. Therefore, the next step was to understand the relative importance of the feedbacks involving the ice sheets, oceans and atmosphere; this led to the discovery that greenhouse gases had a pivotal role in controlling past climate.

The authors' work also recognized what is known as the 100,000-year problem. Before 1 million years ago, ice ages occurred roughly every 41,000 years owing to variations in Earth's obliquity[6]. This makes climatological sense, because Earth's axial tilt directly controls how warm or cold the summers are in the Northern Hemisphere. But the past 8 ice-age cycles had a longer period of 100,000 years[7], which is similar to the period associated with eccentricity. In terms of forcing, eccentricity is by far the weakest of the three orbital parameters. Therefore, if eccentricity were responsible for such 100,000-year cycles, there would need to be a complicated 'nonlinear' amplification effect by Earth's climate system.

However, the similarity between the two periods turned out to be an artefact of spectral analysis[6] — although the previous 8 ice-age cycles lasted for about 100,000 years on average, they ranged in length from 80,000 to 120,000 years. With the realization that eccentricity is not the major driving force, a debate has emerged as to whether precession or obliquity controlled the timing of the most recent ice-age cycles. Some researchers argue that the deglaciations occurred every four or five precessional cycles[6,7], others that it was every second or third obliquity cycle[8], and some argue that it was a combination of the two[9]. The debate started 40 years ago and still rages today.

The authors' work also provided a tool with which to investigate the future of Milankovitch cycles. It has been suggested

50 Years Ago

At the neuromuscular junction[1], as well as at neuronal synapses[2], calcium plays an essential and direct part in the process whereby depolarization of the presynaptic nerve terminal leads to release of the transmitter substance. It is also known that a nerve impulse releases the transmitter in quantal form, that is, in discrete multimolecular amounts of a fairly standard size … The question is raised whether other ions can replace calcium in this process and if so is the transmitter still released in quantal form? … Fig. 1 shows sample records from one experiment where calcium and strontium were applied simultaneously to different synaptic spots on the same end-plate … These experiments show that strontium can replace calcium in the process of transmitter release by a nerve impulse and that the transmitter is still released in quantal fashion.
From *Nature* 10 December 1966

100 Years Ago

Prof. J. W. Gregory, in his presidential address to the Geological Society of Glasgow, gave an account of the chief sources of the world's supply of phosphates, in the course of which he pointed out that an instructive lesson in the conservation of mineral resources was to be learnt from this subject. He showed that Britain has but limited supplies of natural phosphates, and these were being left unworked owing to the introduction of cheaper and richer products from foreign deposits. Prof. Gregory has done valuable service in again directing attention to our supply of phosphates, and it is clear that, from the point of view both of the natural and the artificial phosphate supply, the question is one of vital importance to our great agricultural interests.
From *Nature* 14 December 1916