The history of ice on Earth

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Primitive humans, clad in animal skins, trekking across vast expanses of ice in a desperate search to find food. That's the image that comes to mind when most of us think about an ice age.

But in fact there have been many ice ages, most of them long before humans made their first appearance. And the familiar picture of an ice age is of a comparatively mild one: others were so severe that the entire Earth froze over, for tens or even hundreds of millions of years.

In fact, the planet seems to have three main settings: "greenhouse", when tropical temperatures extend to the poles and there are no ice sheets at all; "icehouse", when there is some permanent ice, although its extent varies greatly; and "snowball", in which the planet's entire surface is frozen over.

Why the ice periodically advances – and why it retreats again – is a mystery that glaciologists have only just started to unravel. Here's our recap of all the back and forth they're trying to explain.

Snowball Earth

2.4 to 2.1 billion years ago

The Huronian glaciation is the oldest ice age we know about. The Earth was just over 2 billion years old, and home only to unicellular life-forms.

The early stages of the Huronian, from 2.4 to 2.3 billion years ago, seem to have been particularly severe, with the entire planet frozen over in the first "snowball Earth". This may have been triggered by a 250-million-year lull in volcanic activity, which would have meant less carbon dioxide being pumped into the atmosphere, and a reduced greenhouse effect.

Deep freeze

850 to 630 million years ago

During the 200 million years of the Cryogenian period, the Earth was plunged into some of the deepest cold it has ever experienced – and the emergence of complex life may have caused it.

One theory is that the glaciation was triggered by the evolution of large cells, and possibly also multicellular organisms, that sank to the seabed after dying. This would have sucked CO_2 out of the atmosphere, weakening the greenhouse effect and thus lowering global temperatures.

There seem to have been two distinct Cryogenian ice ages: the so-called Sturtian glaciation between 750 and 700 million years ago, followed by the Varanger (or Marinoan) glaciation, 660 to 635 million years ago. There's some evidence that Earth became a snowball at times during the big freezes, but researchers are still trying to work out exactly what happened.

Mass extinction

460 to 430 million years ago

Straddling the late Ordovician period and the early Silurian period, the Andean-Saharan ice age was marked by a mass extinction, the second most severe in Earth's history.

The die-off was surpassed only by the gargantuan Permian extinction 250 million years ago. But as the ecosystem recovered after the freeze, it expanded, with land plants becoming common over the course of the Silurian period. And those plants may have caused the next great ice age.

Plants invade the land

360 to 260 million years ago

Like the Cryogenian glaciation, the Karoo ice age featured two peaks in ice cover that may well have been distinct ice ages. They took place in the Mississipian period, 359 to 318 million years ago, and again in the Pennsylvanian 318 to 299 million years ago.

These ice ages may have been the result of the expansion of land plants that followed the Cryogenian. As plants spread over the planet, they absorbed CO_2 from the atmosphere and released oxygen (PDF). As a result CO_2 levels fell and the greenhouse effect weakened, triggering an ice age.

There is some evidence that the ice came and went in regular cycles, driven by changes in Earth's orbit. If true, this would mean that the Karoo ice age operated in much the same way as the current one.

Antarctica freezes over

14 million years ago

Antarctica wasn't always a frozen wasteland. It wasn't until around 34 million years ago that the first small glaciers formed on the tops of Antarctica's mountains. And it was 20 million years later, when world-wide temperatures dropped by 8 °C, that the glaciers' ice froze onto the rock, and the southern ice sheet was born.

This temperature drop was triggered by the rise of the Himalayas. As they grew higher they were exposed to increased weathering, which sucked CO_2 out of the atmosphere and reduced the greenhouse effect.

The northern hemisphere remained relatively ice-free for longer, with Greenland and the Arctic becoming heavily glaciated only around 3.2 million years ago.

Latest advance of the ice

2.58 million years ago

The Quaternary glaciation started just a few million years ago – and is still going on. So its history is relatively recent, in geological terms, and can be studied in far more detail than the others'. It's evident that the ice sheets have gone through multiple stages of growth and retreat over the course of the Quaternary.

During "glacial" stages, the temperature was low and ice extended far away from the poles. During "interglacials", the temperature was somewhat warmer and the ice retreated. Brief, inconclusive periods of advancing ice – typically lasting less than 10,000 years – are called "stadials"; conversely, periods when the ice retreated, but only briefly, are called "interstadials".

The main trigger for the Quaternary glaciation was the continuing fall in the level of CO_2 in the atmosphere due to the weathering of the Himalayas. However, the timing of the glacials and interglacials was driven by periodic changes in Earth's orbit that change the amount of sunshine reaching various parts of the planet. The effect of these small orbital changes was amplified by positive feedbacks, such as changes in greenhouse gas levels.

During the first two-thirds of the Quaternary, the ice advanced and retreated roughly every 41,000 years – the same tempo as the changes in the tilt of Earth's axis. About a million years ago, the ice switched to a 100,000-year cycle for reasons that were until recently a mystery. Now more detailed information about the timing of the ice's movements may have helped glaciologists find an answer.

To make matters more complicated still, the ice didn't advance and retreat simultaneously all around the world. Often it would begin advancing on one continent, with the others only being covered thousands of years later, and then linger on a few continents several millennia after it had disappeared from the others.

So there were actually many overlapping glaciations within the Quaternary, each separately named: the Bavelian and Cromerian complexes of glacials and interglacials; the Elsterian glacial; the Holsteinian interglacial and the Saalian glaciation, among others.

Between 130,000 and 114,000 years ago, the ice retreated during the Eemian interglacial – and then advanced again to create the glacial that most people know as "the ice age".

Our ice age

110,000 to 12,000 years ago

The cool temperatures of the Quaternary may have allowed our brains to become much larger than those of our of hominid ancestors. While that's still open to debate, it's plausible that the most recent glacial period left its mark on our species.

Neanderthals, with whom we shared the planet until just before the last glacial maximum, 20,000 years ago, may have struggled to survive as the rising and falling ice ate away at their habitat – although many other explanations for their extinction have been suggested. What is beyond doubt is that *Homo sapiens* survived and turned to farming soon after the ice retreated, setting the stage for the rise of modern civilisation.

As the glacial period drew to a close and temperatures began to rise, there were two final cold snaps. First, the chilly "Older Dryas" of 14,700 to 13,400 years ago transformed most of Europe from forest to tundra, like modern-day Siberia. After a brief respite, the Younger Dryas, between 12,800 to 11,500 years ago, froze Europe solid within a matter of months –

probably as a result of meltwater from retreating glaciers shutting down the Atlantic Ocean's "conveyor-belt" current, although a cometary impact has also been blamed.

Twelve thousand years ago, the great ice sheets retreated at the beginning of the latest interglacial – the Flandrian – allowing humans to return to northern latitudes. This period has been relatively warm, and the climate relatively stable, although it has been slightly colder than the last interglacial, the Eemian, and sea levels are currently at least 3 metres lower – differences that are being closely scrutinised by researchers keen to understand how our climate will develop.

But this respite from the ice is likely to prove short-lived, at least in geological terms. Human effects on the climate notwithstanding, the cycle will continue to turn, the interglacial will some day come to an end – and the ice sheets will descend again.