Earth's weather and climate are influenced by variations in its orbit as well as by oscillations in its internal systems.

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CLIMATE SCIENCE

A delicate balance

Earth's climate and biosphere have always shaped one another. **James F. Kasting** approves of an attempt to reveal the planet's future by reading its past.

Earth has warmed rapidly before. About 55 million years ago, the temperature of the planet rose by as much as 8 °C over 20,000 years and remained elevated for roughly 100,000 years. The cause is unknown, but it may have been a result of cage-like methane clathrate molecules in the sea floor destabilizing and releasing into the atmosphere huge amounts of greenhouse gas. This Palaeocene–Eocene Thermal Maximum is of great interest to climatologists: the estimated temperature increase is similar to the future warming predicted owing to human activities, although we are perturbing the climate system much faster.

Such events show that if you want to understand the climate's future, you need to learn about its past. *The Goldilocks Planet* — named after the concept that Earth, unlike its planetary neighbours, is just right for life, neither too hot nor too cold — describes that past, from its fiery beginnings to a warmed world. The book is stronger on geologically recent history than on the deep past, but it shows that the story of past climate change is a powerful way to convey the realities and risks of human-induced global warming.

Jan Zalasiewicz and Mark Williams are both experts in Quaternary micropalaeontology: they study the microbial fossil record from just under 2.6 million years ago to the present. They are also well versed in isotopic biogeochemistry, deciphering the planet's history from the chemical traces of life.

The Goldilocks Planet: The 4 Billion Year Story of Earth's Climate
JAN ZALASIEWICZ AND MARK WILLIAMS
Oxford University Press: 2012. 272 pp. £16.99, $29.95

The climate of the Quaternary period has been defined by a cycle of successive ice ages and interglacial periods. The authors discuss in depth what drives this, describing Milankovitch cycles — climate excursions caused by variations in Earth's orbit — and the less well-known Dansgaard–Oeschger and Heinrich events, both climate variations on shorter time scales, thought to result from oscillations within Earth's system. These sections form a good introduction to the topic for non-specialists.

There are some amusing stories here. The authors tell of a journey through the Drake Passage, which runs between South America and Antarctica, in the UK Royal Navy's icebreaker *HMS Endurance*: a flat-bottomed vessel that "rolls like a pig" in high seas. We learn about the geologist Nicholas Shackleton's love for clarinets, and what boron isotopes reveal about the acidity of ancient oceans.

There is a fascinating account of the closing of the Isthmus of Panama, some 3 million years ago. This allowed land animals such as armadillos — introduced in the book as Texan roadkill — to migrate between North and South America, and increased the salinity gradient between the Atlantic and Pacific oceans, helping to establish the modern pattern of thermohaline ocean circulation. The authors are true experts in this field.

Zalasiewicz and Williams are also knowledgeable about the climatic history of the Phanerozoic eon, the time from 542 million years ago to the present in which there is a good fossil record of multicellular plants and animals. From tales of traipsing around ▶

England's rocky shorelines, I learned how graptolites — microscopic colonial animals that lived in sediments during the early Palaeozoic era, about 450 million years ago — vanished from the fossil record when the climate cooled, because the cold, oxygen-rich water that penetrated the deep sea let predators invade the sediments and eat them.

But the book's coverage of climate evolution during the earliest nine-tenths of Earth's history — the Precambrian era, 542 million years ago and earlier — is neither so detailed nor so scientifically balanced. One chapter describes most of this time interval, and another focuses on the Late Proterozoic Snowball Earth glaciations, when ice repeatedly covered nearly all Earth's surface, around 635 million years ago.

Zalasiewicz and Williams give scant attention to the carbonate–silicate cycle that many Earth scientists believe is the key to Earth's Goldilocks status. The basic idea is that volcanoes add carbon to the atmosphere and the sea, and the weathering of silicate minerals on the continents and the deposition of carbonate sediments in the oceans take it out. Weathering slows as the climate cools, so carbon dioxide builds up, warming the climate and creating negative feedback. This feedback is mentioned as causing the Snowball Earth to melt, but its importance in regulating climate in general is not really discussed.

Neither are the authors the best guides to Snowball Earth events. They give too much weight to discarded ideas such as the high-obliquity hypothesis, which argues that the glaciations resulted from the tilt of the Earth's axis, and they omit to mention the latest thinking and evidence.

The last chapter of *The Goldilocks Planet* deals with the Anthropocene epoch — a term popularized by Nobel-prizewinning atmospheric chemist Paul Crutzen to describe the geological epoch in which humans have significantly modified the Earth's climate. This is well-trodden ground, but the discussion is on the mark, and the preceding review of climate history gives it credibility. If Earth's climate is as sensitive as it seems to be, then how could it not respond to the massive greenhouse forcing that humans would create by burning a significant fraction of the available fossil fuels?

Pennsylvania State University teaches a general-education Earth science course that approaches global warming in the same way: reviewing climate history to give a context for the anticipated future. It works well for us, and it works for *The Goldilocks Planet*, too. ■

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Ferdinand de Saussure was hugely influential in the social sciences, despite publishing little.

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LINGUISTICS

Sound sculptor

John A. Goldsmith is intrigued by the life of a linguistics giant who felt himself to be a failure.

"Any life when viewed from the inside is simply a series of defeats," wrote George Orwell. Each serious study of a great scientist's life is bound to leave us reflecting on that truth, and linguist John E. Joseph's monumental *Saussure* is no exception.

Ferdinand de Saussure (1857–1913) was one of the great nineteenth-century linguists, and Joseph's book, the first comprehensive biography, sheds brilliant light on his life and work. This rich account — sympathetic, respectful and sensitive to political and intellectual context — reveals how Saussure, a dazzling and driven scholar from a bourgeois Swiss family, blazed trails to new vistas of social science that opened out in the century after his death.

Saussure emerges as a complex individual. As Joseph shows us, his virtuosity was counterbalanced by a series of unfortunate failures to get projects finished. That Orwellian 'inside story' hums away in the background of the book.

Saussure
JOHN E. JOSEPH
Oxford University Press: 2012. 800 pp. £30.00, $55.00

Two works of genius bookended Saussure's life. The first was a revolutionary monograph on Proto-Indo-European — the 'raw material' of modern languages from English to Sanskrit — self-published when he was just 21. Saussure's contribution was to deduce that ancient Indo-European must have contained certain sounds that had disappeared from more modern languages and so were undetectable in linguistic history. The prediction was confirmed much later in an analysis of Hittite documents from the thirteenth century BC.