



POPULAR SCIENCE ARTICLE

A longer day for a breathing planet: how Earth's slowing spin may have helped oxygen fill the air

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Abstract

The length of Earth's Day has changed enormously over geological time and so has the oxygen content of the atmosphere. This article asks whether the two histories are connected, that is, whether the slowing of Earth's spin could have helped oxygen-producing microbes raise oxygen levels in the air. It explains the three natural records that allow the length of ancient days to be measured, namely tidal rhythmites, climate-driven cycles in layered rocks and daily growth lines in fossil shells, which together indicate a day of about 13 hours some 3.2 billion years ago rising to 24 hours today. It then describes the two competing tidal effects that set the day's length: the Moon's gravitational brake on the ocean tides, which lengthens the day and the Sun's pull on the atmosphere's daily thermal tide, which slightly shortens it. Whether the two effects once came close to balancing each other, holding the day near 19 hours for a billion years, is still disputed. Finally, the article shows how day length can change the amount of oxygen released by microbial mats, drawing on published laboratory work with mats from a low-oxygen sinkhole in Lake Huron and on a simple reaction-diffusion model of a mat that the authors wrote themselves. It closes by setting out the measurements that could put the idea to the test.

Keywords: day length; Earth rotation; tidal friction; thermal tides; microbial mats; Precambrian

1. Introduction

A day on Earth is a compromise between the Moon and the Sun and it has not always lasted twenty-four hours. About 3.2 billion years ago a full cycle of day and night probably lasted only about 13 hours (Eulendorf and Heubeck, 2023). The day has been growing longer ever since and it is still growing: records of ancient eclipses and modern measurements show that the average day has lengthened by about 1.8 thousandths of a second per century over the past 2,700 years (Stephenson *et al.*, 2016).

Oxygen has its own long history. For roughly the first half of Earth's history the air contained almost no oxygen. Oxygen first built up during the Great Oxidation Event, which began about 2.43 billion years ago and became permanent by about 2.22 billion years ago (Poulton *et al.*, 2021). It then stayed low for more than a billion years, a quiet stretch that geologists nickname the 'boring billion'. Life was not idle, however: 1.6-billion-year-old rocks near Chitrakoot in central India contain fossils that have been interpreted as the oldest known red algae (Bengtson *et al.*, 2017). A second rise in oxygen came between about 800 and 540 million years

ago (Lyons *et al.*, 2014) and only after that did large animals appear.

Most explanations for these two steps focus on the organisms that make oxygen, on volcanoes, on drifting continents and on the supply of nutrients. In 2021, however, a team of microbiologists and ocean scientists proposed an additional and surprising factor: the length of the day itself (Klatt *et al.*, 2021). The proposal is easy to state and hard to prove. A microbial mat that needs several hours of daylight before it can begin releasing oxygen loses a larger share of its working time under a short day than under a long one, so the lengthening day should have allowed mats to deliver more oxygen to the ocean and, eventually, to the air.

If the story is correct, the habitability of our planet has been tuned in part by the orbit of its Moon. This article asks one question: did our slowing spin help decide when the air became breathable? To answer it we need to know how ancient days are measured, why the day grew longer and whether it ever paused and how day length can affect oxygen at all the subject is not remote from everyday life on the planet's surface. The same spin that sets the length of the

day also sets the rhythm of sunlight, heating and cooling and the daily cycle of photosynthesis and of nutrient uptake by plants; it drives the Coriolis effect that shapes winds, ocean currents and rainfall belts; and, through the tides, it mixes nutrients in coastal waters generation after generation. When the day was 13 hours long, those rhythms ran on a different clock. Understanding how the length of the day changed and how organisms responded, therefore speaks to questions that still matter on a working planet: how the carbon cycle balances, how oxygen is produced and consumed and how tightly life is tuned to the rotation of the world it lives on.

2. Reading ancient clocks in rock and shell

Nobody could time a day two billion years ago, but nature kept records. Three kinds of natural 'clock' are especially useful (Figure 1a).

The first is tidal rhythmites, layered sediments laid down by tides. Each tide leaves a thin layer and the layers grow thicker and thinner with the monthly cycle of strong and weak tides. Counting the layers in one cycle tells geologists how many days there were in a month and therefore how fast Earth was spinning. Tidal layers in 3.22-billion-year-old rocks of the Moodies Group in South Africa suggest a day of about 13 hours and a Moon only about 70 per cent as far away as it is today (Eulendorf and Heubeck, 2023). Similar layers in South Australia, laid down roughly 620 to 635 million years ago, record about 400 days per year, or a day of about 21.9 hours (Williams, 2000).

The second clock uses slow climate rhythms. Earth's orbit and tilt wobble over tens of thousands of years and these wobbles leave repeating patterns in layered rocks. The timing of some of these wobbles depends on how far away the Moon is, so the patterns can be used to calculate the length of the day. With this method, researchers estimated a day of 16.9 hours at 2.46 billion years ago from iron-rich rocks in Western Australia (Lantink *et al.*, 2022) and 18.7 hours at 1.4 billion years ago from the Xiamaling Formation in Hebei, North China (Meyers and Malinverno, 2018).

The third clock is the daily growth lines in fossils. In 1963 the American geologist John Wells counted about 400 daily growth lines per year in corals roughly 390 million years old (Wells, 1963). More recently, chemical analysis of a 70-million-year-old shell of a rudist, an extinct type of clam, found 372 daily cycles per year, equivalent to a day of about 23.5 hours (de Winter *et al.*, 2020).

Together these clocks tell a clear story: the day

has lengthened from about 13 to 24 hours. What they cannot yet tell us is exactly how it lengthened between 2 and 1 billion years ago, because reliable measurements from that interval are rare.

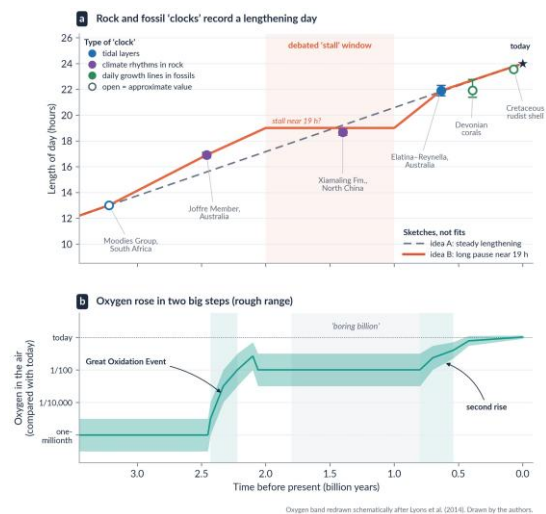


Fig. 1. Earth's lengthening day and the rise of oxygen. (a) Day length from tidal layers, rock-layer climate rhythms and fossil growth lines; dashed lines sketch the "steady lengthening" and "stall" ideas. (b) Rough atmospheric oxygen range relative to today.

3. A tidal tug-of-war and a stalled clock?

Why does the day grow longer? The Moon's gravity raises two bulges of water in the oceans, the tides. Because Earth spins faster than the Moon travels around it, friction carries the bulges slightly ahead of the Moon. The Moon's gravity then pulls back on the leading bulge and acts like a brake on Earth's spin (Figure 2a). The spin that Earth loses is not destroyed but handed to the Moon, which slowly drifts away. Laser pulses bounced off mirrors left on the Moon show that it is moving away by about 3.8 centimetres per year (Williams and Boggs, 2016). India's Chandrayaan-3 lander, Vikram, carries a small NASA-built mirror of this kind and in December 2023 a laser on a NASA orbiter bounced a signal off it (NASA, 2024).

A second, much weaker tide pushes the other way. Sunlight warms the air every day, creating a pressure wave with two peaks per day, at about 10 a.m. and 10 p.m. local time. The Sun's gravity pulls on this 'air bulge' and because the bulge sits slightly before noon, the pull speeds Earth up instead of slowing it down. Today this push is only about 6 per cent as strong as the Moon's brake (Farhat *et al.*, 2024).

The atmosphere, however, has a natural 'ringing' period, like a bell. When a regular push matches that period, even a small push can build up a large swing, just as well-timed pushes make a playground swing go higher. This is called

resonance. Scientists proposed decades ago that when the day was about 20 to 21 hours long, the Sun's twice-daily push matched the atmosphere's ringing period of roughly 10 hours at that time. The solar push might then have become strong enough to cancel the Moon's brake, so that the length of the day 'stalled' (Zahnle and Walker, 1987). The possibility matters for our question: a stalled day would have held the mat microbes at the same day length for a very long time. Recently, one climate-model study concluded that the day stayed near 19.5 hours from about 2.2 to 0.6 billion years ago and that without this stall today's day would be more than 60 hours long (Wu *et al.*, 2023). A review of geological data likewise suggested a stall near 19 hours between about 2 and 1 billion years ago (Mitchell and Kirschner, 2023).

The idea remains controversial. A team that modelled the atmosphere in more detail found that the resonance was probably too weak to hold the day in place (Farhat *et al.*, 2024). A later review pointed out that the case for a stall relies partly on older, uncertain measurements from stromatolites, the layered mounds built by microbes; using only the more reliable data, a stall is not required (Laskar *et al.*, 2024). As Figure 1a shows, the few trustworthy data points, including the value from China, fit either a smooth curve or a curve with a flat step. More measurements from rocks between 2 and 1 billion years old are needed to decide.

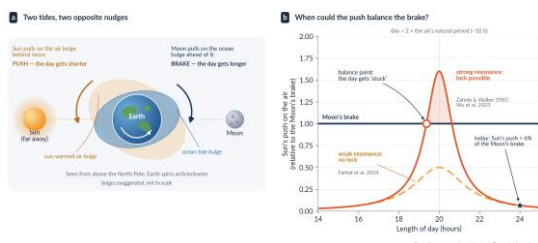


Fig. 2. The tidal tug-of-war that sets day length. (a) The Moon's ocean bulge slows Earth's spin; the Sun's air bulge speeds it up slightly. (b) Illustrative strength of the two effects: a strong solar peak could stall the day, a weak one could not

4. How a longer day could mean more oxygen

How could the length of the day change the amount of oxygen in the air? The answer comes from microbial mats: thin, layered carpets of microbes that covered shallow seafloors for billions of years. Similar mats still grow today in the Middle Island Sinkhole in Lake Huron, USA, where low-oxygen, sulfur-rich groundwater seeps into the lake bed (Biddanda *et al.*, 2006; Snider *et al.*, 2017). There, purple cyanobacteria, which photosynthesise like plants, share the mat with white bacteria that feed on sulfur (Klatt *et*

al., 2021).

The mat follows a daily routine. At night and in the morning the white bacteria lie on top and shade the cyanobacteria. When light arrives, the cyanobacteria first photosynthesise using hydrogen sulfide instead of water, which releases no oxygen. Only after the nearby sulfide is used up and after the white bacteria move away, do they switch to making oxygen. Even then, oxygen must accumulate inside the mat before any of it escapes into the water. Klatt and colleagues observed that this morning delay can last several hours (Klatt *et al.*, 2021).

The key point is that this 'start-up cost' takes roughly the same number of hours whether the day is short or long. Think of a shop that needs two hours every morning to set up before it can sell anything. If it opens for six hours, a third of its time is lost; if it opens for twelve hours, only a sixth is lost. In the same way, a mat under a longer day spends a smaller share of its daylight paying the start-up cost, so more of its oxygen escapes, even when the sunlight per hour is the same.

To make this idea concrete we wrote a simple reaction-diffusion model of a mat (Figure 3a, b). It is not the model used by Klatt and colleagues, but it has the same basic ingredients: sunlight; oxygen and sulfide spreading through a mat 4 millimetres thick; a fixed delay of 2.5 hours before oxygen production starts; and the same sunlight per hour for every day length. In our model a 12-hour day releases only about 38 per cent as much oxygen per hour as a 24-hour day, while a 16-hour day releases about 69 per cent and a 19-hour day about 84 per cent. A real mat measured in the laboratory showed an even stronger effect (Figure 3c): under a 12-hour day it released essentially no oxygen, a 16-hour day released about a third as much as a 24-hour day and a 21-hour day about two-thirds as much (Klatt *et al.*, 2021).

Why should this matter for the whole planet? When more oxygen escapes from a mat, less of the organic matter it has made is later broken down again, so more carbon can be buried in mud. Buried carbon leaves its oxygen behind and this is one of the main ways oxygen has built up on Earth. Using a global biogeochemical model, Klatt and colleagues argued that the lengthening day could have contributed to both big rises in oxygen and they noted that a stall in day length would coincide with the boring billion, with renewed lengthening afterwards coinciding with the second rise (Klatt *et al.*, 2021).

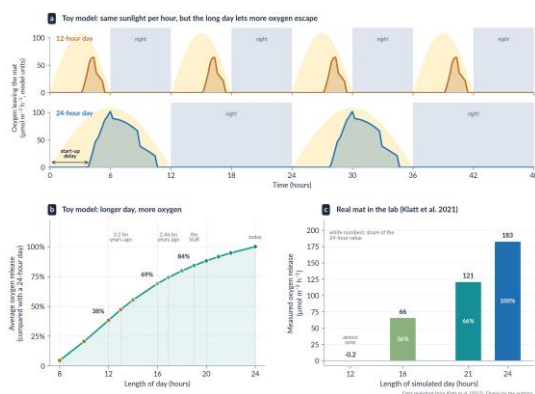


Fig. 3. Longer days let a microbial mat release more oxygen. (a) Modelled oxygen release under 12-hour and 24-hour days. (b) Average release versus day length. (c) Measured release from a Lake Huron mat under 12–24-hour days

5. Weighing the evidence

The idea is attractive, but there are three reasons for caution.

First, a match in timing is not proof of cause. Oxygen levels were also shaped by drifting continents, by the supply of the nutrient phosphorus from weathered rocks and by volcanic gases that consume oxygen. Klatt and colleagues themselves present their mechanism as working alongside these factors, not replacing them (Klatt *et al.*, 2021). Our own model shares the wider limitation of all such work: the properties of a mat three billion years ago, including its thickness, its sulfide supply and the microbes living in it, are unknown.

Second, the stall itself is uncertain. If the day lengthened smoothly, longer days would still slowly raise the oxygen output of mats (Klatt *et al.*, 2021), but they would no longer explain why the boring billion was so stable. The two histories would then be parallel rather than linked.

Third, the laboratory evidence comes from one modern mat measured under a limited set of conditions and computer models depend on assumptions about ancient microbes, sunlight and seawater. Ancient mats may have behaved differently (Klatt *et al.*, 2021).

These doubts point to clear tests. New day-length estimates from rocks laid down between 2 and 1 billion years ago, for example in North China, which gave us the Xiamaling record, or in India's Vindhyan and Cuddapah basins, could confirm or reject the stall. Experiments on more kinds of mat under different day lengths and measurements of how much carbon modern mats bury, could show how general the effect is.

6. Conclusions

The length of Earth's Day is not fixed. Driven

mainly by the Moon's tidal brake, it has grown from about 13 hours to 24 hours over the past three billion years, possibly with a pause near 19 hours. Laboratory work on living microbial mats suggests that longer days let mats release more oxygen, because a fixed morning delay becomes a smaller share of a longer day. This makes a day-length contribution to the rise of oxygen plausible, though not yet proven: the mechanism has been demonstrated for one mat under one set of conditions and the proposed pause in the day's lengthening rests on data that are still debated. The idea is worth pursuing because it connects two histories that are usually told separately. It is also a reminder that a habitable planet depends on connections across the whole Earth system: the orbit of the Moon, the ringing of the atmosphere and the daily routine of microbes may all have helped to make the air we breathe.

That wider lesson has a practical edge. The productivity of soils, waters and crops today rests on the same daily and seasonal rhythms of light, temperature and nutrient supply that the lengthening day once reset and the same balance between carbon burial and decay. Studying how a single planetary parameter, the rate of rotation, propagated through the ancient Earth system is therefore good training for the questions that face us now: how the carbon cycle responds to change and how far the living and non-living parts of the planet can be treated as one system. The most direct way forward is geological. Day-length estimates from rocks between 2 and 1 billion years old, including the Proterozoic basins of Peninsular India, would test the proposed stall and laboratory work on modern mats and their carbon burial would show how general the oxygen effect is. Both kinds of work are within reach of existing laboratories and both would turn a promising idea into a testable one.

Conflict of Interest

The authors declare no competing or conflict of interest.

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Statement on the use of AI tools

During the preparation of this manuscript, the authors used an AI assistant (Claude, Anthropic) to help with literature searching, drafting text and writing plotting code. The authors checked all facts, data and references against the original sources, revised the text and take full

responsibility for the content of the article.

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