Of Microbes and Planets

Microorganisms are fundamental and vital for the dynamics of our planet

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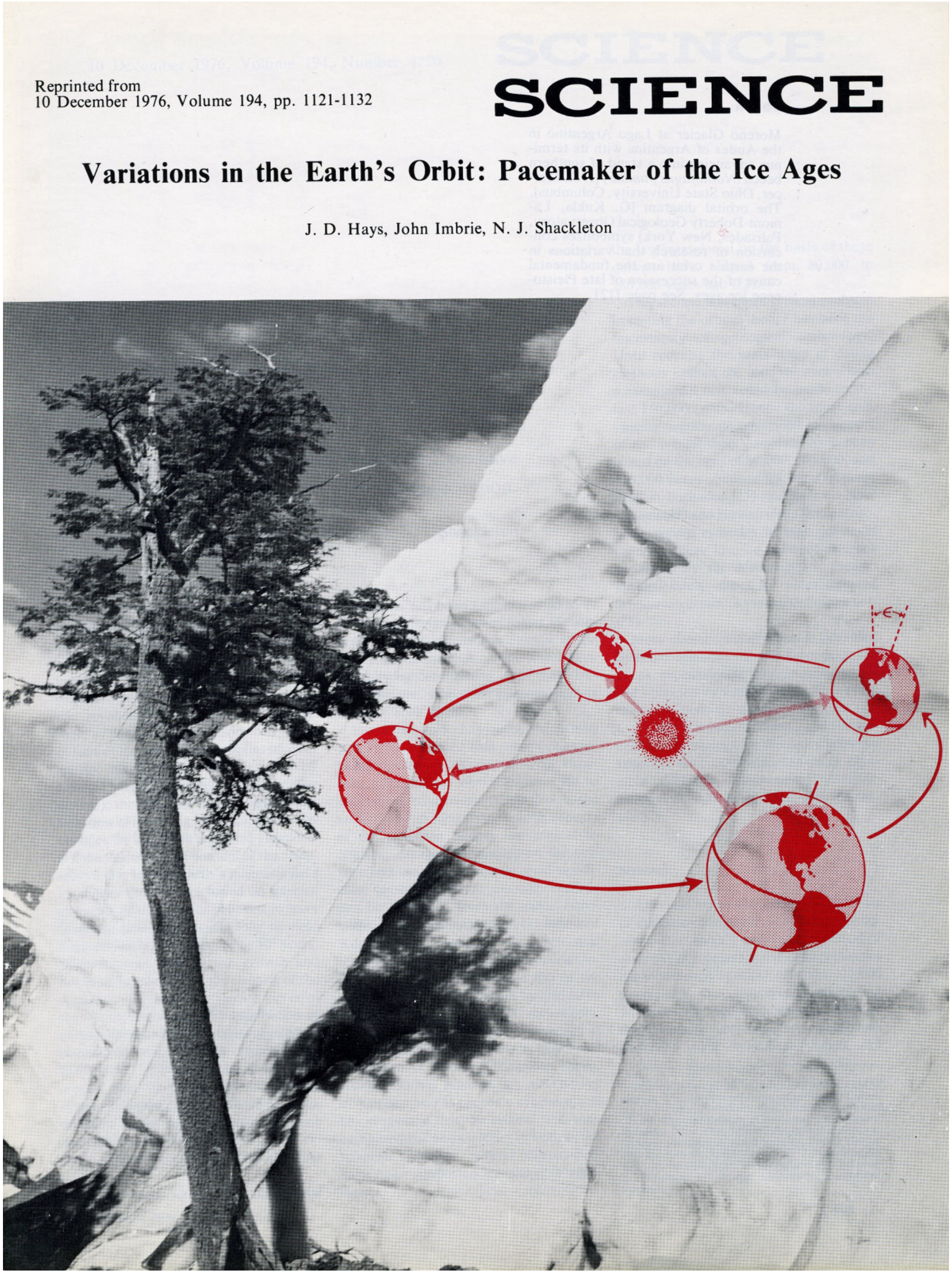


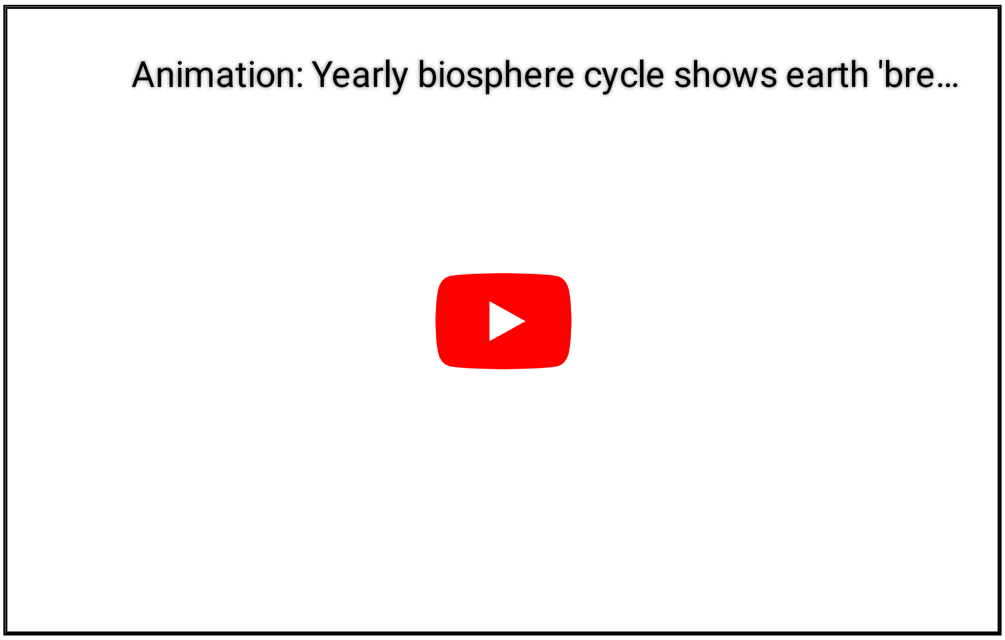
The cover of a reprint of the 1976 landmark paper by Hays, Imbrie, and Shackleton demonstrating the relation between changes in planetary orbit and glaciations. This paper was based on the microfossil record from two oceanic sediment cores.[1]

Understanding the deep history and dynamics of our planet is not an easy task: the earth escapes our attempts to visualise and characterise it. It exceeds our limited understanding and overflows the scales we are used to. Yet, people have tried to figure out our place in the universe and the functioning of the planet since time immemorial. Scientists have only recently begun to wrap their heads (and their instruments) around the planet and its complexity. The experiences of micropaleontology at sea were instrumental in this effort because they helped reveal the planetary influence of biological processes on Earth systems. In fact, the dominant model of disciplinary divisions between sciences that consolidated over the course of the 19th century had traditionally separated the geophysical and chemical *hard* sciences and their technoscientific applications from the *softer* sciences of life. The earth was treated as a backdrop on which life took place. Even though studies of microbial worlds, such as the work of Sergei Winogradsky and Vasily Dokuchaev on environmental microbiology and soils, had offered alternative visions, they remained marginal, not least due to intellectual and socio-political divisions.[2] Despite this marginalisation, research on the relation between biological and geochemical processes was profoundly influential in the successful diffusion of early systems theories in biology and beyond. Such approaches proved particularly useful for technological application and quickly led to the wartime implementation of cybernetics (famously, for instance, in the development of anti-aircraft technologies).[3] In the postwar period the interconnection between biological and earth systems gained even more traction in scientific research. The hybrid field of biogeochemistry began to bridge the traditional divide between geophysical sciences and biology, providing the foundations of ecology with an understanding of the complex relations shaping the planet.[4]

Yet, most of the early works in ecology relied on limited experimental settings, using small, enclosed environments for research, like Evelyn Hutchinson's studies of Linsley Pond.[5] This is also why oceanography, with its 'big science' appeal and its global scale, proved to be an incredibly successful field in which to ask biogeochemical questions. In combination with postwar science and its fascination with outer space, the study of the world's oceans effectively expanded biogeochemistry to provide a tool that could encompass (and in turn shape) the planetary scale.[6] The efforts in deep sea drilling produced growing numbers of records which are accumulated in museums and other scientific collections, including the Lamont-Doherty Collection. While also contributing to mineralogical and geophysical studies and collections, these materials – most importantly – highlighted the centrality of microbial life for regulating the habitability of Planet Earth.[7] Combined with advances in microscopic media and our understanding of the molecular workings of life, these studies formed two fundamental arguments: firstly, that microorganisms should be considered to be the ancestors of all life on our planet, and secondly, that they determine and mediate the geochemical cycles on which life depends. As such, they provide an important record of the changing conditions of our planet. This offered the basis, for instance, for Hays, Imbrie, and Shakleton's milestone paper published in *Science* in 1976, demonstrating the impact of planetary dynamics on ice-age cycles by using Cycladophora as a biomarker of paleotemperatures.[8]

In the 1970s, the view of microorganisms as ancestors of all life and their metabolic role in all sorts of physico-chemical processes converged in the formulation of the controversial Gaia hypothesis by NASA scientist James Lovelock. The hypothesis proposes that living organisms interact with inorganic physicochemical planetary systems to form an integrated, self-regulating system that maintains the conditions of habitability on Earth.[9] The role of microorganisms in this system was stressed especially through Lovelock's collaboration with microbiologist Lynn Margulis, famous for her pioneering proposal of how cells evolved through endosymbiosis.[10] While some critics view Gaia as a new-age personification of the planet, Margulis pointed out how the self-regulatory character of the system is in fact better understood as an emergent property caused by the interactions between organisms on a planetary scale. Thus, the Gaia hypothesis gained much support, also thanks to its traction in popular science and the countercultural movement. Yet, more official scientific circles remained skeptical, in part also because of the unconventional character of Lovelock and Margulis and the success the hypothesis had with counter cultural movements.[11] Yet, more evidence pointing at the planetary impact of microbial life has accumulated since the 1970s. An important example is the characterisation of what is commonly known as the Great Oxygenation Event. This refers to an essential episode in the biogeochemical history of the planet, which saw a shift from an oxygen-poor to an oxygen-rich atmosphere. Without this event, life as we know it would not be possible. And while scientists still debate the details of *how* exactly this shift took place, it is clear that microorganisms – in particular cyanobacteria, also known as blue-green algae – had a key role in it, radically altering the atmospheric composition of our planet. Today, most of the oxygen in our atmosphere continues to be produced by photosynthetic microorganisms living in the ocean, such as diatoms.[12]

The history of how we slowly came to recognise the importance of microbial life for our planet and its dynamics still continues. Microbes – and their deep evolutionary histories – are entangled in the fabric of our planet, and they are crucial to making life on Earth last. Even though microbes remain often marginal to our understanding of the world, their planetary histories show how they continue to be a vital part of our lives.



An animation issued by NASA illustrating the cyclicity of primary production and the biogeochemical processes it involves. (Source: Carbon Brief/YouTube)

Footnotes

1. See James D. Hays, John Imbrie, and Nicholas J. Shackleton. “Variations in the Earth’s Orbit: Pacemaker of the Ice Ages”. *Science* 194 (1976): 1121-1132. https://doi.org/10.1126/science.194.4270.1121.↩
2. While in their lifetime the work of these scientists remained marginal – also due to linguistic, intellectual, and later even ideological barriers – their impact on later developments of the technosciences is beginning to be recognised. See, for the case of Winogradsky: Frederick Attenborough. “The Monad and the Nomad: Medical Microbiology and the Politics and Possibilities of the Mobile Microbe”. *Cultural Geographies* 18, no. 1 (2011): 91-114; and for the case of Dokuchaev: Filippo Bertoni. “Soiling Mars: ‘To Boldly Grow Where No Plant Has Grown Before’?” In *Thinking with Soils: Material Politics and Social Theory*, Juan Francisco Salazar et al (eds.). London: Bloomsbury Publishing (2020): 107.↩
3. To learn more on the impact of cybernetics, see Andrew Pickering. *The Cybernetic Brain*. Chicago: University of Chicago Press, 2010; or watch “Sketches of Another Future: An Interview with Andrew Pickering”. *Sistemas Sociales*, YouTube, 24.03.2014. https://www.youtube.com/watch?v=juGIXi6Lyek (03.01.2022).↩
4. To learn more about the history of biogeochemistry, see T.S. Bianchi. “The Evolution of Biogeochemistry: Revisited”. *Biogeochemistry* 154, (2021): 141-181. https://doi.org/10.1007/s10533-020-00708-0↩
5. George Evelyn Hutchinson, considered one of the founders of ecology, famously carried out some important experiments using a small lake called “Linsley Pond”. To learn more about him, see Carl Zimmer. “The Human Lake”. *National Geographic Online*, 31.03.2011. https://www.nationalgeographic.com/science/article/the-human-lake (03.01.2022); and Laura J. Martin. “G. Evelyn Hutchinson’s Exultation in Natural History.” *American Scientist*, 2016. https://www.americanscientist.org/article/g-evelyn-hutchinsons-exultation-in-natural-history (03.01.2022).↩
6. On the deep relations between outer space and the global ocean still influencing current technosciences, see Stefan Helmreich. *Alien Ocean*. Oakland: University of California Press, 2009.↩
7. Some of these important collections, for instance, are part of the mineralogical collection at the Museum für Naturkunde Berlin and are studied in its geochemical and microanalytical labs, see “Geochemical and Microanalytical Laboratories”. *Museum für Naturkunde Berlin*, no date. https://www.museumfuernaturkunde.berlin/en/science/geochemical-and-microanalytical-laboratories (03.01.2022); and “Rock and Ore Collection”. *Museum für Naturkunde Berlin*, no date. https://www.museumfuernaturkunde.berlin/en/science/rock-and-ore-collection (03.01.2022).↩
8. For more on the history of this milestone article and its authors, see Mark Maslin. “Tying celestial mechanics to Earth’s Ice Ages”. *Physics Today* 73, no. 5, 48 (2020). https://physicstoday.scitation.org/doi/10.1063/PT.3.4474 (03.01.2022); and Stacy Morford. “John Imbrie: A Pioneer of Paleoceanography”. *State of the Planet*, Columbia Climate School, 19.05.2016, https://news.climate.columbia.edu/2016/05/19/john-imbrie-a-pioneer-of-paleoceanography/ (03.01.2022).↩
9. To learn more about the Gaia hypothesis, see Tim Radford. “James Lovelock at 100: The Gaia Saga Continues”. *Nature* 570 (25.06.2019): 441-442. https://www.nature.com/articles/d41586-019-01969-y (03.01.2022); or watch “Gaia Hypothesis – James Lovelock”. *Naked Science*, YouTube, 21.05.2014. https://www.youtube.com/watch?v=GIFRg2skuDI (03.01.2022).↩
10. To learn more about Lynn Margulis, see J. Lake. “Lynn Margulis (1938-2011).” *Nature* 480 (2011): 458. https://doi.org/10.1038/480458a. Fore more on Margulis’ view of Gaia, see “Gaia is a Though Bitch”. *Edge*, 05.01.1996. https://www.edge.org/conversation/lynn_margulis-chapter-7-gaia-is-a-tough-bitch. (03.01.2022).↩
11. To get a better sense of these dynamics, see Elizabeth Royte. “Attack of the Microbiologists”. *New York Times Magazine*, 14.01.1996. https://www.nytimes.com/1996/01/14/magazine/attack-of-the-microbiologists.html (03.01.2022).↩
12. Diatoms are also featured in the video about the Lamont-Doherty Collection.↩