Y. BERLINER/RIA NOVOSTI

Aleksandr Oparin (seated) posited that life emerged from compounds in the atmosphere of early Earth.

# IN RETROSPECT

# The Origin of Life

**Clifford P. Brangwynne** and **Anthony A. Hyman** celebrate the first book to plausibly suggest how life began.

"No religious or philosophical system, no outstanding thinker ever failed to give this question serious consideration." So wrote Aleksandr Oparin more than 75 years ago, about the quintessential conundrum of how life self-assembled from inanimate components. The Soviet biochemist's answer is his book *The Origin of Life* (1936). Roughly based on a pamphlet he published in 1924, this book is an enormous contribution to our understanding of life's improbable beginnings. In it, Oparin argues that conditions on early Earth nurtured the synthesis of amino acids and their assembly into protocells.

Although he trained as a biochemist, Oparin studied the chemical make-up of Earth's crust, as well as other planets in the Solar System and the Sun. He realized that Earth's early atmosphere was a strongly reducing environment, rich in methane, water and ammonia. He posited that, with time and a supply of energy such as lightning or geothermal activity, these simple components would form the complex building blocks of life. And after an English translation was published in 1938, Oparin's ideas became well known in the West.

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For more on the Miller–Urey experiment, see:
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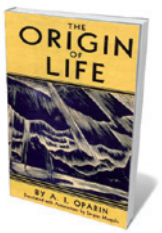


**The Origin of Life**
A. I. OPARIN; TRANSL. SERGIUS MORGULIS
*Macmillan: 1938.*

Nearly 20 years after the book's publication — and 60 years ago this year — Stanley Miller and Harold Urey tested Oparin's hypothesis in a lab at the University of Chicago in Illinois. They sent a continuous electric current through a glass vial containing water, hydrogen, methane and ammonia. Within a week, a substantial amount of the carbon had been converted into complex macromolecules, including many amino acids. This 'Miller–Urey' experiment confirmed the significance of Oparin's ideas, and Miller duly referenced *The Origin of Life*.

Oparin's work thus played a seminal part in the formulation of our modern ideas of life's conception. His ideas on the organization of cells and first stirrings of life continued to attract an important audience. In 1957, a large international meeting (attended by Miller) was held in Moscow to discuss the origin of life, the proceedings of which make it clear that Oparin's book had had a profound influence. And yet, despite his towering achievement, Oparin is today largely forgotten by the broader science community, particularly in the United States. Why?

## SOCIAL STRUGGLE

There are two reasons. The first is that after the Second World War, biology in the West moved away from thinking of the cell in physicochemical terms, towards a reductionist molecular-biology approach, with a DNA-centric viewpoint.

The second lies in the cold-war collision between science and politics. Oparin graduated from Moscow State University in 1917, the year of Russia's October Revolution, and his ideas were forged within that radical context. He explains, for instance, that the question of life's origin "was always the focal point of a sharp philosophical struggle which reflected the underlying struggle of social classes". As a prominent Soviet scientist with the full backing of the state, Oparin's thinking was rooted and framed in the Marxist philosophy that the origin of life is "merely one step in the course of its historical development".

Not surprisingly, cold-war divisions led many US scientists to dismiss Oparin. The Nobel laureate Hermann Muller, who thought that life originated as a gene, criticized the poor status of DNA within Oparin's picture of early life. (Oparin apparently stated: "DNA is the end product of metabolism and the nucleus is the dustbin of the cell.") The proceedings of the 1957 conference point to a growing split between US and Soviet perspectives. With less scientific interchange, the ideas in *The Origin of Life* became marginalized in the West.

After Stalin's death in 1953 — the year the Miller–Urey experiment was published — Oparin faced criticism within the Soviet Union. He was later forced to resign from the secretaryship of the academy of science because he, along with the rest of the country's scientific establishment, had supported the discredited agricultural pseudoscientist Trofim Lysenko. Oparin was later forgiven and, in 1979, shortly before his death, received the Lomonosov Gold Medal from the Soviet science academy for outstanding achievement in the natural sciences. His book retained a small but dedicated following.

Today, the primary legacy of *The Origin of Life* is the Miller–Urey experiment, but the synthesis of amino acids took up just part of the book. Oparin went on to describe a mechanism by which macromolecules would self-assemble into large liquid-like structures

that he called "complex coacervates" — what today might be called colloidal assemblies. He suggested that these protocells were a key step in the origin of life. However, given the uncertainty at that time about the nature of biological macromolecules, it was unclear exactly how these colloids might form.

This hypothesis of colloidal assembly has largely been displaced by other concepts of life's origins. For example, some hold that membranes must have come first, arguing that the prebiotic soup contained molecules with water-attracting and water-repelling ends capable of self-assembling into cell-like structures (liposomes). Interestingly, later in life, Oparin himself expressed regret at having focused on colloids instead of liposomes.

However, current cell and molecular biology provides a new perspective on the feasibility of life beginning from liquid-like macromolecular assemblies, suggesting that Oparin might have been more correct than he thought. Many macromolecules have weak multivalent interactions with other macromolecules, which means they have several sites at which interaction can occur. RNA itself is a flexible, extended, dynamic molecular chain; the interactions between it and other molecules are typically numerous and weak. These properties are sufficient for macromolecules to self-assemble into liquid-phase droplets, like Oparin's coacervates. Recent work on RNA compartmentalization and catalysis in liquid droplets provides additional support for Oparin's concept of primitive protocells in a primordial 'RNA world'.

Oparin belongs in the pantheon of the twentieth century's greatest scientists for providing a foundation for understanding early molecular evolution. He believed that natural selection had "completely wiped off the face of the Earth all the intermediate forms of organization of primary colloidal systems and of the simplest living things". Three-quarters of a century before Oparin, Charles Darwin noted that such primitive life forms would be a poor match for contemporary, highly evolved ones. But Darwin also wrote that relatively less-evolved species — "anomalous forms … living fossils" — often come down through the ages, against all the odds.

Like the ancient mitochondrial organisms found in each of our cells, intracellular RNA droplets could reflect a still more ancient lineage in the assembly of complex cellular structure. Oparin's coacervates may still be alive and well, safe within our cells, like flies in life's evolving amber. ■

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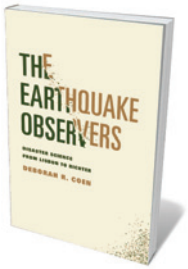
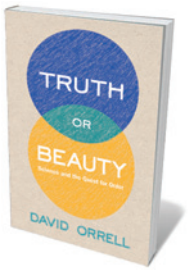
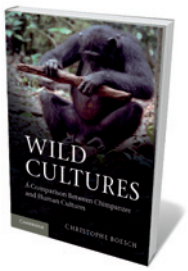
# Books in brief



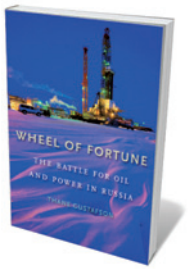

**The Earthquake Observers: Disaster Science from Lisbon to Richter**
*Deborah R. Coen* UNIV. CHICAGO PRESS *360 pp. $35 (2012)*
Crowd-sourced science has rarely been so thrilling. As Deborah R. Coen reveals, the rumbustious history of seismology began with roving scientists gathering locals' accounts of shocks, shudders and thumps. Luminaries from Charles Darwin to Alexander von Humboldt reported, too; Charles Dickens likened a quake to a great beast "shaking itself and trying to rise". Coen argues for a hybridized 'disaster science', factoring in such responses from "human seismographs" with geology and instrumental data.




**Truth or Beauty: Science and the Quest for Order**
*David Orrell* YALE UNIV. PRESS *356 pp. $30 (2012)*
The philosopher Bertrand Russell averred that mathematics has a beauty "sublimely pure, and capable of a stern perfection". But is science inextricably allied to aesthetic beauty? In applied mathematician David Orrell's exploration of the Pythagorean quest to realise the cosmos mathematically, the cracks in that paradigm show. Orrell swings from the ancient preoccupation with musical harmony and numerical ratios to Renaissance nature studies, the mechanistic approach and the physical sciences of today. Imperfect as it is, 'messy' science, he argues, has a novel beauty of its own.




**Wild Cultures: A Comparison between Chimpanzee and Human Cultures**
*Christophe Boesch* CAMBRIDGE UNIV. PRESS *288 pp. £60 (2012)*
For a third of a century, primatologist Christophe Boesch has hiked in the wilds of Côte d'Ivoire and Gabon in Africa to probe the 'culture question' in chimpanzees. Boesch presents systematic evidence for material, social and symbolic culture in wild chimpanzees, drawing too on studies of humans and captive chimps. Comparing the species, he focuses on the teaching and acquisition of cultural traits, and the link between cognition and culture. What makes us human? This book could force a rethink.




**Wheel of Fortune: The Battle for Oil and Power in Russia**
*Thane Gustafson* HARVARD UNIV. PRESS *672 pp. $39.95 (2012)*
Russian oil has had a bumpy ride. The world leader in the 1980s, the industry went into steep decline with the Soviet Union's dismantling in 1991. When the Iron Curtain rose, the state's oilmen — mostly geologists and engineers — were shocked by a global industry rife with lawyers and traders. Now oil and roubles shunt through the pipelines of new Russia, but the relationship between state and industry is often explosive. Energy-policy analyst Thane Gustafson reveals Vladimir Putin's pivotal role, the effects of the 2008 crash, and the complex currents and uncertain future of regional oil.


**Serengeti Story: Life and Science in the World's Greatest Wildlife Region**
*Anthony R. E. Sinclair* OXFORD UNIV. PRESS *288 pp. £18.99 (2012)*
Like some stupendous open-air stage, East Africa's Serengeti ecosystem hosts some of the world's great faunal dramas. Zoologist Anthony Sinclair has been observing them for nearly 50 years. This is a rich interweaving of natural and human history, covering everything from the rinderpest pandemic and ivory exploitation to today's looming threats. Glinting throughout are stories from the field, such as his wife's inadvertent sleep-in with a leopard.