PROFILE GÜNTER WÄCHTERSHÄUSER

Between a Rock and a Hard Place

Günter Wächtershäuser had a radical theory of how life began, and he needed all his skills as a patent lawyer to persuade a skeptical community to take it seriously

MUNICH, GERMANY—Overturning long-cherished theories, especially ones that underpin a whole field, can be a thankless task. Few theories are as iconic as the prevailing explanation of how simple chemicals in a cozy puddle of primordial soup first assembled themselves into the precursors of the earliest forms of life some 4 billion years ago. But such an elevated status does not prevent Germany's Günter Wächtershäuser from wanting to tear down the theory and replace it with one that puts the origins of life in seemingly hostile environments such as deep under the sea, on mineral surfaces around midocean hydrothermal vents.

A practicing patent lawyer here for more than 30 years, Wächtershäuser is good at poking holes in things. "That's what I like about being a patent lawyer. To make your case, you have constantly got to turn things on their head and come up with new ways of looking at things," he says. Despite having neither a lab nor a track record in the field, Wächtershäuser has spent the past 20 years on what he calls "the mother of all problems." And slowly but surely, Wächtershäuser's argument that surfaces served as the cradle of life has found a home among biologists and biochemists.

"He really added a breath of fresh air to the field," says Norman Pace, an evolutionary biologist at the University of Colorado, Boulder. "Wächtershäuser brought surface chemistry to the attention of origin-of-life people. No one who thinks about the origins of life thinks about solution chemistry anymore." James Ferris, a chemist at Rensselaer Polytechnic Institute (RPI) in Troy, New York, agrees: "The broth was probably much too dilute to bring the chemicals together to react in the first place. A mineral surface is a good way to concentrate the compounds."

But not everyone is ready to ditch the old broth theory. "Do—or did—the proposed chemical reactions actually take place in the real world?" asks organic chemist Jeffrey Bada of the Scripps Institution of Oceanography in La Jolla, California. "[His theory is] a bold step, but there's probably nothing there, because, otherwise, people would have found it already."

In a soup

The pond, or primordial soup, theory was dreamt up by the German biologist Ernst Haeckel in the late 19th century. But it was largely ignored until 1953, when Nobel laureate Harold Urey and Stanley Miller, then at the University of Chicago, attempted to mimic the early Earth's atmosphere in a test tube. They showed that a gas mixture of hydrogen, methane, ammonia, and water vapor can produce a rich brew of organic molecules such as amino acids and nucleotide bases—if sparked by electric discharges similar to bolts of lightning. These compounds would rain down into the primordial oceans, so the theory goes, until somehow they self-assembled into multimolecular aggregates and, eventually, cell-like structures.

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Molecular meeting place. Günter Wächtershäuser believes simple compounds necessary for life formed on lumps of pyrite.

In the mid-1980s, however, geologists began to question some of the assumptions Urey and Miller had made about the gas mixture. Methane and ammonia were too ultraviolet-sensitive to be stable under the conditions of the early Earth, they realized. At the same time, planetary scientists discovered that Earth's early days were anything but tranquil. For most of its first billion years, Earth was under constant bombardment from asteroids and comets, heating the atmosphere above 1000 kelvin and triggering much volcanic activity. And when marine biologists found bacteria that were able to thrive at temperatures as high as 80°C in hot springs and around oceanic vents, says Pace, "this meant that life was possible at much higher temperatures than we previously thought."

Enter hobby chemist Günter Wächtershäuser. Although not affiliated with any research institution, Wächtershäuser is far from being a stranger to science; he earned his Ph.D. in organic chemistry in 1965 at the University of Marburg, Germany, and served as a postdoc there for more than a year. But he fled the rigid German academic system because he felt that the university environment was not giving him enough freedom to come up with original ideas. So even while working on his thesis he began to take law classes because he had decided to become a patent lawyer, "one of the few options for a chemist at the time where you can be your own boss," he says. He bid farewell to research in 1966, got married to Dorothy Gray, an American historian, opened his own law firm, and settled into a life poking holes in his clients' patent applications. "I thought I'd never go back to do science," he says.

He was wrong. In 1972 he came across a paper on the origins of life by Hans Kuhn, one of his erstwhile university teachers. Although the paper "got me thinking about the subject," recalls Wächtershäuser, it wasn't until a decade later, after being dragged by his wife to a talk about scientific progress by the late philosopher Karl Popper, that Wächtershäuser was hooked. The two men became friends, and Popper encouraged Wächtershäuser to expand his efforts beyond a few sheets of hand-scribbled notes.

Another chance encounter sealed his fate. A distant relative of Wächtershäuser's was working as a graduate student at the University of Illinois, Urbana-Champaign, under microbiologist Carl Woese, who had a long-standing interest in finding the last common ancestor of all living organisms on Earth and working out the evolutionary tree of microbial life. "Carl, you've got to meet this guy," Woese recalls the student telling him. "He's got some interesting ideas about the origins of life." Woese assured Wächtershäuser that the topic was worth pursuing,

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pointing to several inconsistencies in the broth theory.

One flaw was what Wächtershäuser calls the entropy problem. The dilution of the organic compounds in the early Earth's vast oceans makes any chemical reaction between two molecules unlikely and a meaningful encounter improbable. "As far as I'm concerned, the soup theory is more of a myth than a theory, because it doesn't explain anything," he says. Once he realized that molecules needed some place to meet, it took him only one night to sketch out a first draft of his theory. The meeting place is provided by the surfaces of iron-sulfur minerals such as pyrite, which abound around underwater hydrothermal vents. The formation of pyrite, he speculated, could even serve as a chemical power plant, adding the chemical energy needed to react volcanic gases.

His new friends urged him on. "I was lucky," he says about his relationships with Popper and Woese. "I met the right people at the right time. Without their support, this would have gone nowhere." In 1988 Popper submitted Wächtershäuser's first paper on the subject to the *Proceedings of the National Academy of Sciences*. "It was my first scientific publication in 22 years," he says.

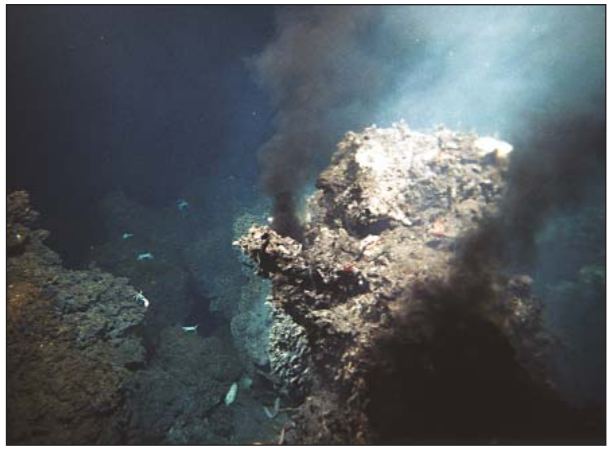
A series of purely theoretical papers followed, sketching out Wächtershäuser's "iron-sulfur world" in Earth's early days, a complex network of chemical reactions that the 64-year-old patent lawyer is happy to scribble down on scrap paper as he explains his theory. His theory-laden approach, with little observational evidence in sight, is pure Popper. In Popper's view, says Woese, true scientific progress is possible only by building a theory and then trying as best as one can to prove it false. "[Wächtershäuser's] opponents constantly objected to his 'paper chemistry,' saying it was nothing but theory. Well, I'd say that's about the only thing a lawyer without a lab can do," says Woese, who refers to Wächtershäuser as "the last disciple of Karl Popper."

Woese suspects that some of the early attacks on the theory were fueled by the fact that Wächtershäuser "was not a card-carrying member of the origins-of-life community." But where others might have recoiled from attacks by scientific heavyweights, Wächtershäuser leapt at the chance to battle them at conferences around the world. Microbiologist Karl Stetter of the University of Regensburg, Germany, recalls a squabble between Wächtershäuser and Nobel laureate Christian de Duve in which de Duve eventually backed down, saying "Dr. Wächtershäuser, we're no patent lawyers here." Notes Stetter, "He is sort of the pugnacious type."

Wächtershäuser has his own take on the adversity he had to face: "A lot of people cling to their theories because they depend on them being true to attract research grants, students, and so forth. So they defend them fiercely."

Proving it

But Wächtershäuser knew he needed more than words to put his theory on a solid footing; he needed to test it in a lab. Joining forces with Stetter, they published a paper in *Nature* in 1994, showing that pyrite formation could indeed be the driving force in the creation of amide bonds, which form the backbones of all proteins. But the bonds between the two men soon unraveled, causing an estrangement that continues to this day. "At first it was a very exciting collaboration; I was all for it," says Stetter. "But then one day out of the blue I got a letter from [Wächtershäuser] telling me that our collaboration was over. I suspect he was afraid I'd steal the show from him."



Cradle of life. Could the heat and minerals around midocean hydrothermal vents have forged basic organic compounds?

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Wächtershäuser then turned to Claudia Huber, a chemist at the Technical University in Munich, and in 1997 the pair reproduced a key reaction: joining two carbon atoms to form activated acetic acid, a chemical at the core of many cellular metabolic pathways. A year later the team linked amino acids into short peptides, the precursors of proteins.

In August 2000, a group led by George Cody of the Carnegie Institution of Washington in Washington, D.C., reported creating pyruvate, a crucial component of all living cells consisting of three carbon atoms, with a mineral catalyst under conditions similar to the ones Huber and Wächtershäuser use. Wächtershäuser believes that the pyruvate finding could be the missing link in a so-called autocatalytic cycle, a circular series of chemical reactions that can sustain itself and produce more and more of the same chemicals. "Autocatalysis is the chemical expression for reproduction, one of the key features and, hence, maybe the first form of life," he says.

Early last year, an international team led by geologist Simon Wilde of Curtin University of Technology in Perth, Australia, presented evidence that continental crust and primordial oceans already existed on Earth 4.4 billion years ago. This suggests that as far ago as then, just the right conditions of heat and subsea volcanic activity may have been nudging organic molecules toward the earliest life forms.

The experimental results mean that "people can't just wipe [the theory] away as paper chemistry," Wächtershäuser says. And recognition was not long in coming. Wächtershäuser was awarded an honorary professorship by the University of Regensburg and has received four research grants, amounting to $500,000, from Germany's DFG funding agency. Wächtershäuser still maintains his patent practice, leaving him to ponder the secrets of early life in his leisure time. He uses the grant money to fund Huber's lab work—as well as her salary. In 1998, Huber's university contract ran out, so Wächtershäuser stepped in and now employs her through his law firm, although she still uses lab space at the university.

Even with this mounting evidence, some scientists believe that Wächtershäuser's theory is too simplistic. "Life is not just chemistry. Life as we know it is based on the passage of genetic information from one generation to the next," says Scripps's Bada. And even scientists who agree with the theme of Wächtershäuser's iron-sulfur world say that he skates over the finer chemical details. "The energetics [of Wächtershäuser's reactions] are plain wrong," says geochemist Mike Russell of the Scottish Universities Research and Reactor Centre in Glasgow. "Pyrite, for instance, plays no role at all. I don't consider any of his stuff significant except his [synthesis of activated acetic acid] in 1997." Acetic acid and pyruvate, adds RPI's Ferris, "are still pretty simple compounds. The real question is how do you build more complex biomolecules."

Woese isn't troubled by the questions that remain unanswered. "They haven't achieved the point they want to be at, but they're well on their way," he says. Along the way, in his pursuit of freedom of thought, Wächtershäuser has regained his love for science—and done it on his own terms.

–MICHAEL HAGMANN

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