Martin Nowak and the Origin of Life

Martin Nowak has stirred up his share of trouble in academia — most recently by disproving a popular and long-held strategy of evolution.

The debate played out in the pages of *Nature*, one of the world's premier scientific journals. Nowak and his co-authors, including eminent biologist E.O. Wilson, faced off against more than a hundred researchers who disputed Nowak's claims about a kin selection. In the realm of academic spats, it was epic.

But Nowak appeared unfazed as he recounted the event at an informal Sunday morning gathering in Cambridge. "One-hundred and thirty-seven scientists signed a petition that we were completely wrong but no one has actually explained why were are completely wrong," he said.

Nowak didn't set out to provoke these fights. Instead, an unlikely and seemingly innocuous tool has led him into them: mathematics.

Nowak is an Austrian-born mathematician and biochemist who leads the Program for Evolutionary Dynamics at Harvard, a research team he founded in 2003. The team's work, largely supported by The Jeffrey Epstein Foundation, is aimed at bringing the rigor of mathematics to the wet-lab world of biology, especially evolution.

Nowak sees the widespread application of math to biology as inevitable — "a kind of maturation process," as he told the *New Scientist* magazine last year. "Without a mathematical description, we can get a rough handle on a natural phenomenon but we can't fully understand it.... The beautiful thing about mathematics is that it can decide an argument. Some things are fiercely debated for years, but with mathematics the issues become clear."

Indeed, Nowak sees signs that his fellow researchers are coming around to his ideas about kin selection — an evolutionary strategy that favors the survival of an individual's close relatives — and to the mathematics that underlies it.

Ant debate:
E. O. Wilson is in his 80s and has studied insects, particularly ants, for a half-century. Ants are a hugely successful species, accounting for about 50 percent of the insect biomass on Earth. One of the traits that drives their success is altruism. Simply put, ants help each other out. And that hard-wired behavior gives the whole species an evolutionary edge over its competitors.

Darwin struggled to reconcile this kind of altruistic behavior with his theory of natural selection, which characterized life a "struggle for existence" that pits one individual against another and favors selfish behaviors that guarantee reproductive success. Kin selection offered a solution. Since close relatives share much of their genetics, helping one another out actually makes reproductive sense.

In the 1960s, E.O. Wilson helped popularize the idea that kin selection and a theory called inclusive fitness underlie the altruism of ants and other species. Inclusive fitness describes kin selection mathematically, which helps evolutionary biologists model the effects of kin selection.

But in the paper he wrote with Nowak and Corina Tarnita, another researcher at the Program for Evolutionary Dynamics, Wilson denounced inclusive fitness. "Our calculations struck it down," explained Nowak. "The big fight here is really about the mathematics of evolution."

Nowak modeled a form of social organization exhibited by ants (and a handful of other species) called eusociality. It's an extreme form of altruism. Ants produce offspring but their offspring don't have babies of their own. Instead, they stay with their mother, the queen of the ant colony, and help her raise their sisters. They'll complete any tasks that need to be done, for example, feeding larvae or defending the nest.

The model suggests that one mutation is all it takes to start a eusocial lifestyle. The mutation renders the queen's daughters infertile, laying the foundation for a colony that relies on their cooperation. The model also suggests that inclusive fitness is mathematically flawed and irrelevant to the ants' success. They argued instead that the standard theory of natural selection explains it best.

Life notes:
A Ping-Pong table greets visitors to the Program for Evolutionary Dynamics. It's not just for graduate students. Nowak plays, too (though he doesn't have a partner at the moment).

In the nearby offices overlooking Cambridge's Brattle Square, Nowak and the center's other theorists engage daily in a kind of intellectual sport that has them studying viral infection, cancer therapies, the evolution of language, cooperation, punishment and much more. The breadth of their interests and expertise is remarkable.

Nowak is spending much of his time these days on a project he calls "prelife," which seeks to understand no less than the origins of life. Essentially, he wants to know what ingredients constituted the proverbial soup that gave rise to life itself.

For a biochemist like him, there isn't a more fundamental question. It's not hubris then when Nowak likens the project to "inflation theory" for the origin of life, referring to the standard model in physics for the expansion of the very early Universe, moments after the Big Bang.

Few biologist think about what came before RNA and DNA — the building blocks of life — and natural selection, the force that drives evolution. Or if they do, they attribute the rise of life, and the specialized molecules and forces that support it, to chance.

Nowak has a different view. He suspects there was an organizing force — one that can be described mathematically — that got us to RNA in the first place. (RNA is thought to have arisen before DNA, making it the ancestral molecule of life. It has the ability to replicate, which is the basis for heritability, a critical characteristic of living systems.)

So he and his collaborators are examining how simple chemistry can give rise to large molecules of variable length, a process known as polymerization, some of which may have the ability to replicate. They've developed a model that hinges on the availability of monomers, the chemical subunits that combine together to form large molecules, and the presence of conditions that are conducive to polymerization. Once the model is refined, other biologists working in laboratories may be able to put it to the test.

The work raises a lot of big questions. For example, how should we put new knowledge of the molecular prelife on Earth to use? Could it be misused? And what does it mean for religion? Does is rewrite the rules?

While standing at a chalkboard in his office that Sunday morning, Nowak was quick to dismiss some of those concerns, arguing that such knowledge will boil down to detailed chemistry that few will take an interest in. He also wonders whether we could one day send probes, fertilized with the essential chemical ingredients, to create life on another planet — a kind of manmade panspermia.

As for the implications for religion, the question is not lost on Nowak, who considers himself a religious person.

"But I'm also a scientist. I don't need God to interfere with the whole thing," he said.