
EXTRA TERRITORIAL
Issue No. 002
Ted Chiang
MACROCOSM IN MINIATURE
Nina Lanza
EXPERIMENTER ON MARS
Kyle Harper
MICROBIAL EMPIRES
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EXTRATERRITORIAL

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THOMAS ASHCRAFT

BUILDERS OF & TIME SPACE

THE EXTRATERRITORIAL ability to build from the fabric of space and time is a rather unique one.

The historian seems to defy the arrow of time by establishing a new and unlikely order in the past. Or as Herodotus wrote, "prevent the traces of human events from being erased by time."

The writer of science fiction conjures up new dimensions by turning the investigative tools of mathematics and science into construction kits for possible realities. And yet what they so often find, as the writer Stanislaw Lem observed, is that "We have no need of other worlds. We need mirrors."

We place mirrors into telescopes that contract the extraterrestrial light of time and space, thereby making it possible for astrobiologists to move experiments from laboratories on Earth onto the surface of Mars, upon which alternative forms of life might have deposited in slight traces evaporating histories.

In the second volume of *Extraterritorial*, I am speaking with three colleagues, all of whom have discovered ways of forming out of different materials — archives, fables, and transmissions — new configurations of worldly design, and by doing so transform phenomena from the past, the imagination, and outer space into analytically intimate experience.

After all, the whole point of breaching territory is to bring a little more world-space into the insufficient time of attention.

— David Krakauer
Editor-in-Chief, SFI Press
President & William H. Miller Professor
of Complex Systems, Santa Fe Institute

MACROCOSM IN MINIATURE

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TED CHIANG

Miller Scholar, Santa Fe Institute, Santa Fe NM

Author

Ted Chiang's fiction has won four Hugo, four Nebula, and six Locus Awards.

FURTHER READING:
Exhalation (2019);
Stories of Your Life and Others (2016)

Ted Chiang at the SFI InterPlanetary Festival
PHOTO: KATE JOYCE

DAVID KRAKAUER: So, let's imagine that you go to dinner, and on one side, you have Nabokov, and on the other side, Calvino. They ask you, "What kind of writer are you, Ted?"

TED CHIANG: Well, in that company I might say I'm no kind of writer. But in general, I identify as a science-fiction writer. I think there are a lot of people who write in a speculative vein but don't identify as science-fiction writers — I think Calvino was one of them — but I definitely came out of a science-fiction tradition. That was what I read when I was young, that was what inspired me to be a writer. One of my favorite definitions of "genre" is that a genre is not so much a specific collection of tropes as it is an ongoing conversation between authors and readers over decades. I'm a science-fiction writer because science fiction is the conversation that I want to be a participant in. I am writing in dialogue with the science fiction that's been published for the last century.

There is no writer living in the contemporary world who can ignore certain facts of life — things like cell phones and Zoom. As society becomes more obviously technological, is all writing science fiction?

I think that over time this distinction will become less important because genres evolve, in the same way that conversations can evolve and formerly distinct conversations can merge. That said, I don't think that contemporary literary fiction's acknowledgment of digital technology, by itself, makes it science fictional. If we stick with the conversation analogy, a writer who mentions digital technology while being in dialogue with, say, John Updike or Philip Roth isn't necessarily participating in the same conversation as a writer who mentions digital technology while being in dialogue with Arthur C. Clarke or William Gibson. I think literary fiction has historically been resistant to mentioning new technology for fear of dating a story, but now a story feels dated if it *doesn't* mention it. But for the genre borders to fully dissolve, we will need to see stories that are simultaneously in dialogue with Updike and in dialogue with Gibson.

At SFI, we now have two authors affiliated with us — you and Cormac McCarthy — who are interested in troubled mathematicians. Both of you are also interested in Cantor, Gödel, and von Neumann, who were each interested in how the most pristine systems of thought are founded on the most shaky foundations.

I think a lot of people are surprised that Cormac McCarthy has turned to this subject matter. I don't think his interest in these subjects was evident in his earlier work. And I think his association with SFI was similarly unexpected — he was not an obvious choice.

It was probably around college that I really began reading about Gödel's work and the historical context for it, like David Hilbert's aspirations to put mathematics on a really solid foundation. That is fascinating stuff and arguably underappreciated by people who don't work in the sciences. If you have any interest in math at all, I think, you can sympathize with what Hilbert was trying to do and understand just how significant a blow Gödel dealt to that. It has profound philosophical implications that I believe a lot of people would find worthwhile thinking about, so I think it fair to say that Gödel's work is not as widely known as it ought to be.

You delight in certain mathematical minimal frameworks, which feels connected to your preference for writing in the short story format.

That's an interesting suggestion. There was an argument made in science fiction some decades ago that the novella was the ideal length for science fiction. The argument was that a short story doesn't give you enough room if you are interested in exploring an idea, but a novel can't be sustained by a single idea; a novel needs things like subplots and will generally require you to go outside the scope of a single idea. So, if you're interested in exploring a single idea — the argument went — the novella was the ideal length. Of course, not everyone buys this argument, but I personally find myself very sympathetic to it. A longer piece of short fiction is my sweet spot because the things that I am interested in are harder to get at in a really short piece of fiction. However, I feel like the closest literary analog to mathematical equations would be poetry, because poetry is all about maximizing compression, and I am absolutely not a poet.

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if you are interested in exploring an idea,
but a novel can't be sustained on a single idea.

Ellipsis and compression in poetry maximize ambiguity whereas you are not ambiguous at all. There's a clarity and lucidity in your compression.

That's a good point. I completely agree that ambiguity is often an important aspect of poetry, and I try to avoid ambiguity in my work. It's very interesting — very flattering — to hear you talk about my work this way. I've often felt that the lack of ambiguity in my work was a deficit, or was commonly perceived as a deficit and would be held against me.

In your short story "The Evolution of Human Science," you describe a world where humans become critics of artificial intelligence and not authors of intelligent theories.

You once made the comparison that AI was or ought to be something like an electron microscope — this tool that enables scientists to see things that they couldn't otherwise see. I like that analogy, and I hope that's the role that AI plays in scientific research. By contrast, some people have suggested that in the future AI will be conducting scientific research without humans participating at all. That's similar to the situation in my story, where superintelligent beings are conducting scientific research that is completely beyond the ability of humans to comprehend. It's an interesting thing to think about, but I don't know how likely it is.

It's one thing for AI or superintelligent beings to be able to answer questions that we can't answer ourselves. It's another for superintelligent beings to conduct research where we could not even understand the questions being investigated, no matter how much education we received. Cosmologists have questions which we can't answer, but at least we know what it would mean to have an answer. Is it meaningful to say that a question is subject to scientific investigation if we cannot in principle understand the question? At that point you may have reached the limits of the scientific enterprise.

How did you manage to balance the demands of being a technical writer while being a writer of fiction?

I wasn't able to balance the two when I was a full-time employee. I was trying to write in the evenings and weekends, and I could not make that work. I had to quit my full-time position and become a freelancer so that I could take time off from technical writing and write fiction in the interval.

The writer Gene Wolfe had a full-time day job for much of his fiction-writing career; he was an engineer and he edited an engineering magazine, and he wrote *Book of the New Sun* on evenings and weekends. He once said in an essay that if you only have an hour a week in which to write fiction, you will write even if you are in the back of an open pickup truck speeding down the freeway. He said a real writer can't stop themselves from writing.

I took this to mean that I was not a real writer, because it was so difficult for me to write. I struggled with this for most of my adult life until, eventually, I came to the realization that Gene Wolfe was actually incorrect on this point. There are a lot of different ways to be a real writer.

If you had to pick an object or idea to send into space on a new Voyager mission, what would it be?

Do you remember this publication called *Mathematics Magazine*, which ran this feature called "Proof Without Words?" I think it might have run on the inside of the back cover. In each issue they would have a mathematical identity or proof which was demonstrated in purely visual form. There was something about that which I very much liked, this visual or geometric argument being made so that you just look at it and you go, oh yeah, I see, this does equal that. Given how much I am interested in clear explanation, I might pick some artifact that performs explanation visually rather than linguistically. I've often said that a good explanation isn't just useful, it can be beautiful too. Isn't that, in a way, what science is looking for?

EXPERIMENTER
ON MARS

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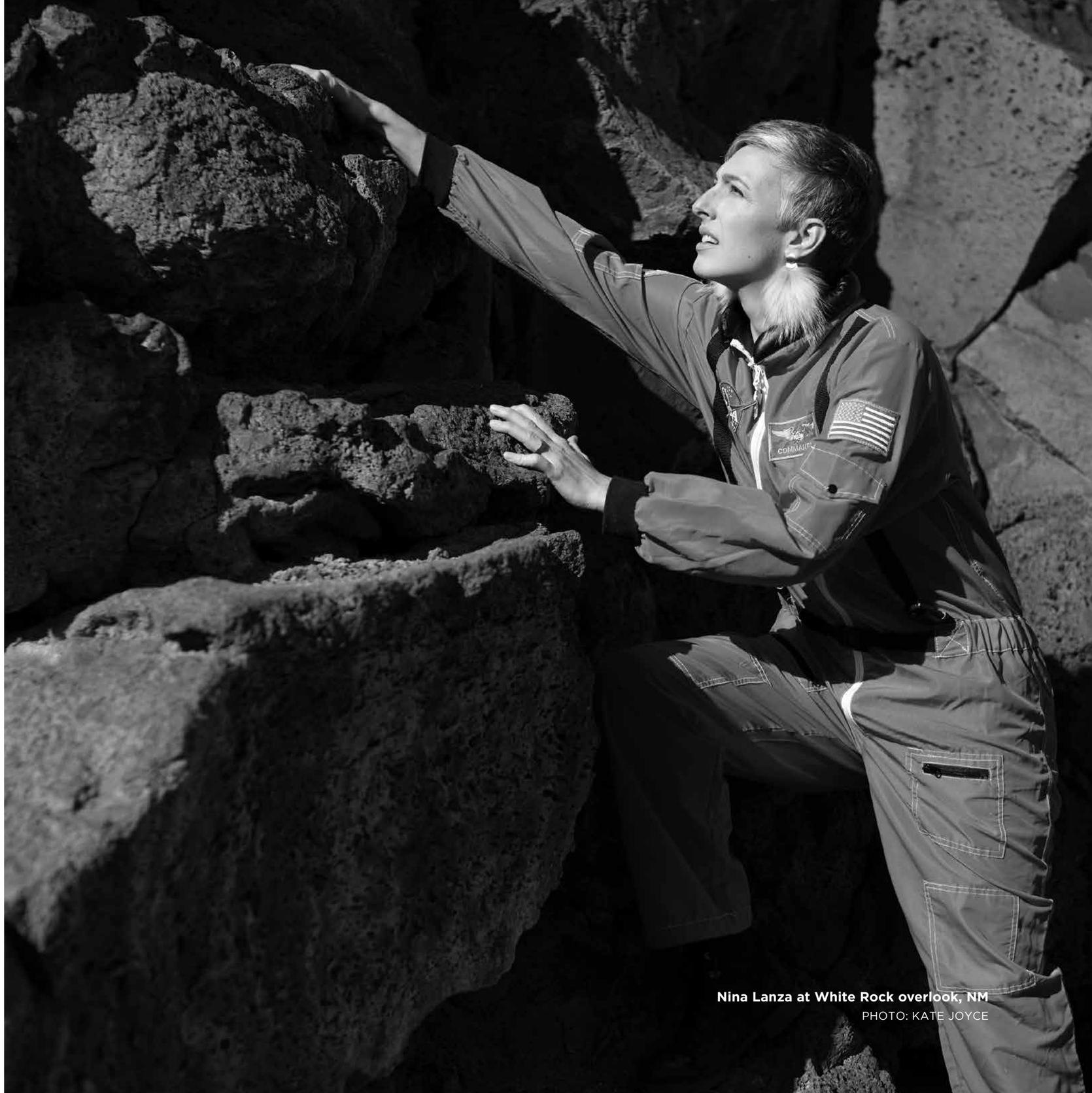
NINA LANZA

SFI InterPlanetary Fellow,
Santa Fe NM

Planetary scientist; Team Lead for Space & Planetary Exploration in Space & Remote Sensing, Los Alamos National Laboratory; Principal Investigator, ChemCam instrument, Mars Science Laboratory Curiosity rover

Fellow of The Explorers Club (2021); Selected as a Department of Energy Woman@Energy (2020)

FURTHER READING: "Why Premature Claims of Life on Mars Hurt Science," *Scientific American* (Jan 14, 2020)



Nina Lanza at White Rock overlook, NM
PHOTO: KATE JOYCE

Here we are, these tiny creatures on this tiny rock in this tiny solar system.

Whatever problem I have here on Earth is **not as big as what's out there.**

DAVID KRAKAUER: Your work focuses on the far reaches of space. What is your emotional response to the solar system?

NINA LANZA: Incredible awe and fascination. I was never afraid of space. A lot of people imagine their tininess in the universe and they feel horrible and they never want to feel that way again. But I love that feeling of smallness. I think it puts every problem that I have into a perspective that's manageable. Here we are, these tiny creatures on this tiny rock in this tiny solar system. Whatever problem I have here on Earth is not as big as what's out there. The universe is a strange, huge, and amazing place. As a child, I wanted to know more. I remember just staring at the sky trying to see more and more just with my naked eye. Could I resolve these stars that I knew to be two instead of one? Could I see more features on the moon?

Do you like that sensation of being lost in something vast?

Yes. I mean, I think it's both, right? I spent a season in Antarctica and that's a place on Earth that wants to kill you at every given moment. You are so small and nothing that you do has any effect on the landscape. The universe, also, doesn't concern itself with you at all. And it's terrifying, but also relieving to me. It's an incredibly emotional experience. I don't know if I would describe it as love, but it's like it's a pull that has never gone away from me.

That's the way that Mars is.

You always see something that's new and, sometimes, you have to act on that really rapidly.

So, I want to ask about really routine things. What does it mean to work in a team on a project that is so uncertain and so far away and where your decisions involve such latencies?

Sometimes we talk about the latency on Mars as if it's large, which it is because we can't communicate instantaneously. Depending on where we are in or our orbits, we're either about seven minutes or 20 minutes latency. But we also have a lot of data streams coming in from Mars. We have many spacecraft there — on the ground, in orbit. It's not as if we were going to Pluto where it takes a long time for that signal to get back. When New Horizons was passing and taking its data, they didn't have the ability to make decisions in real-time. They had it pre-programmed so that they could get those data and they knew what they wanted. So for Mars, we're actually quite close in that way.

Of course, we don't try to drive our rovers in real-time, but we do have set times when we get data back. On any given day, we're seeing new things, and sometimes it can be incredibly exciting. We have to rapidly assess those data to make decisions on this tactical timeframe. There are very few times where you ever go back to something you saw on Mars, so you need to get all those data immediately. There are times where I have dropped everything to say, okay, I'm gonna do this assessment, I'm gonna present it to the team, I'm gonna get their feedback, I'm gonna reiterate through this and do it again and try to figure out what's happening here before we have to drive away. That's the way that Mars is. You always see something that's new and sometimes, you have to act on that really rapidly.

What have you learned about yourself and about what it takes to run a team designing for a machine operating on another planet?

I think a lot about leadership and I try to pay attention to leadership all around me. I have a lot of control over people's careers and I have to be careful with that. To me, leadership is a service and a responsibility. It is not about being able to wield power. My responsibility is to make sure that my team is functional, happy, productive, and can work together effectively. I have to be able to smooth out the inevitable disagreements that happen with passionate people.

So, some of the things that I've learned: I think people can forgive you for making a wrong decision as long as they feel like they were heard and that you acknowledge when you're wrong. A big part of leadership is saying: Hey, I want to get

your input. I may not do what you've asked, but I want you to have been heard. Spending time with people and building relationships is really critical. In places where maybe there's no right answer, but you have to make a decision, you choose the one that you think has the least amount of harm and you accept that people will be upset with you for that. And you take the fire away from others because you are the decider. Being the focal point for anger is actually part of the job.

Like every other costly activity, we as scientists are asked to justify our work. Given that people are starving to death on this planet, what are we doing on Mars?

There are things of value that have no dollar amount that can be attached to them. Art is a really good example. Why do we need art? People should not be starving. I would never advocate for taking money from somebody who's starving. But we need all of these things to be whole — we need more than just food in our bellies, shoes on our feet, a roof over us. We all deserve and need those things, but we have the resources to do that. We just don't allocate them. The universe belongs to everyone and no one. It's accessible to anyone who can look outside.

Everyone talks about the importance of taking risks to make significant progress. How do you conceptualize the concept of risk when you are working on projects that have a very significant failure probability?

You can think about risk in two ways: *risk* in a technological sense — how likely is this to work, break, et cetera — but also *risk*, as in, are these ideas worth pursuing? We want to decrease the risk of hardware failure because if it fails it doesn't get fixed. We don't go back. We don't just change the tire and keep going. Being careful and very risk-averse with hardware is actually very important.

So, getting good enough data: there's something to be said for getting something that's safe and low risk. I'm a little crazier. I'm like, we went all the way to this other planet and I think we can explore some ideas. In two missions alone, Curiosity told us so much about Mars. We had no idea. You could not have predicted it, ever. And if we had not spent time exploring those things because they were weird and not sure if there was value, then we wouldn't know those things.

The universe belongs to everyone and no one.
It's accessible to anyone who can look outside.

Curiosity told us so much about Mars. **We had no idea.** You could not have predicted it, ever.

Talking about risks, what are your thoughts on the possibility of an impact with a giant asteroid and our early efforts to prevent this?

I think you're referring to the recent DART test, which is amazing. The rocks that we're trying to prevent from hitting us are actually quite fascinating. The problem is way weirder than we thought it would be. Asteroids are not solid rocks. These are like little dust balls of very, very poorly held-together, unsorted materials. So, you hit them and it's not like they move as a group. They just spray out everywhere. So, the problem is actually way harder. What if one of these giant dust balls is coming toward us? How do we redirect? I love that this is a conversation that we're having. It's actually really important. We know for a fact that one of these impacts could destroy most of life on Earth. We've seen that in the geologic record.

What would be the implications of finding as good as unequivocal evidence of life having been on the surface of Mars?

Nothing, and everything, would change. Our day-to-day lives are not affected by that knowledge or lack of knowledge. But everything changes because our place in the universe has completely shifted. And, of course, knowing that life existed elsewhere is only the first part of the answer. Is it like us? Is it different? That is the scientific pursuit. But it's also really important philosophically. Is life everywhere just like this, or is life everywhere totally weird and wacky and different, and why? We have no examples of life except on Earth, and all of life on Earth is very closely related. Is that because this is the best way to foster life in the most likely way? Or is it because these were the pieces of material that happened to be here and that life can actually use a lot of different things and a lot of different frameworks?

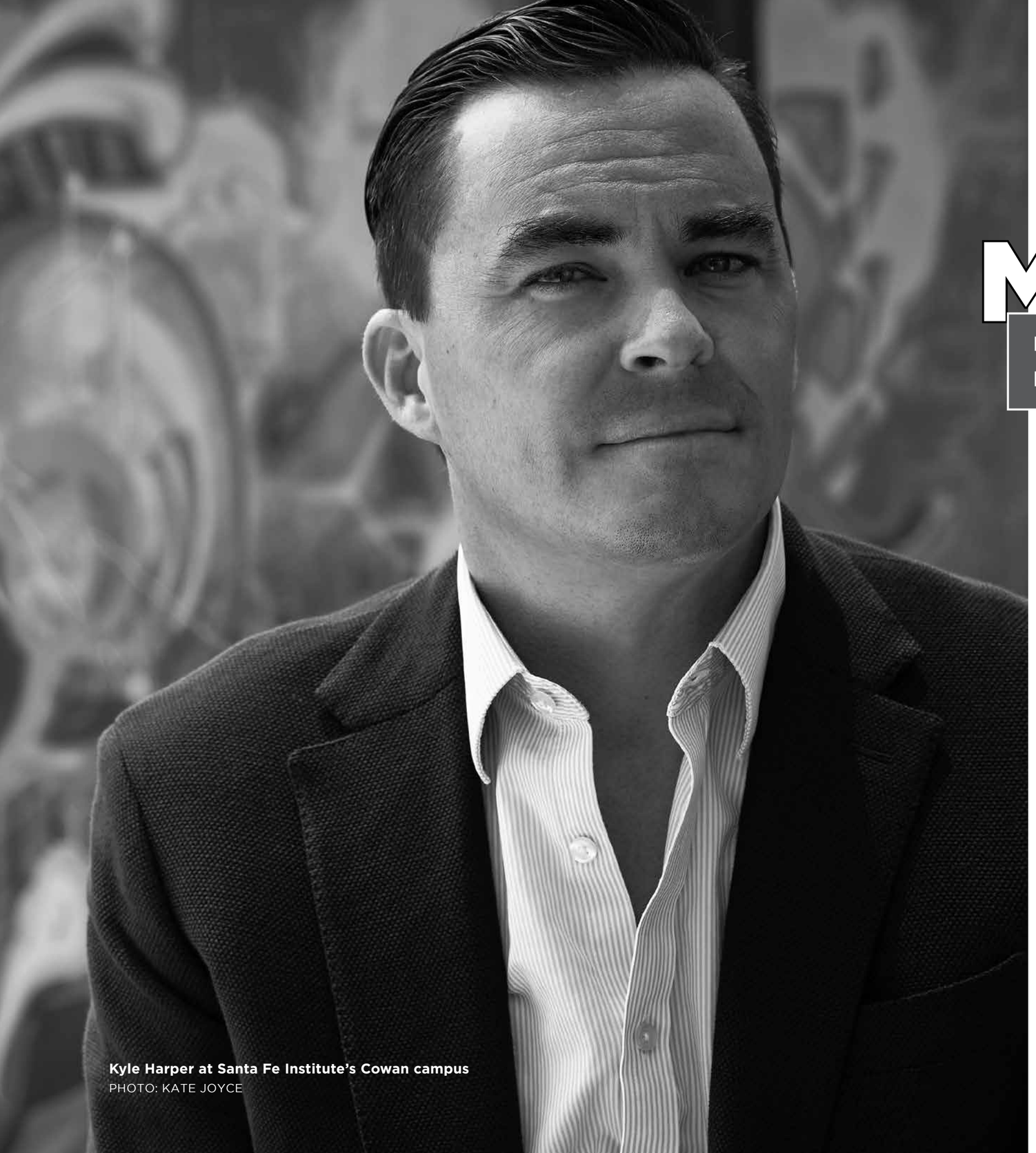
What is your take on all the gullible talk about aliens visiting the Earth, and why do you think people abandon evidence in favor of conspiracy?

Oh, I think it's absolutely expressing the need to connect with something larger. Back maybe 5,000 years ago that was the gods. Now we have to dress up our spiritual beliefs in a scientific framework to give it validity. That's what aliens are. It is providing for people's unexplained spiritual experiences. People want to understand their experiences, and we have some very strange experiences sometimes. Sometimes things just don't seem like they could be coincidences, and we try to come up with reasons because we like to understand why things happen.

Final question that we all now need to address: how do you balance the ever-present technological aspect in your life?

Humans have always used technology. But are you allowing it to drive your life or are you using it to build the life that you want? My son is five now and we have to go outside every day. It doesn't matter if it's snowing or if it's raining because there's no bad weather. There's just bad equipment.

I sing in a classical music group, and we do a lot of music that is a cappella. So that is very, very low-tech. It's ephemeral because the music only exists as long as we are making these sounds, and it's incredibly communal. And, it's essentially free. It's something that you can do without a lot of resources. That is a great way to use my brain in a different way.



Kyle Harper at Santa Fe Institute's Cowan campus
PHOTO: KATE JOYCE

MICROBIAL EMPIRES

— 0005

KYLE HARPER

Fractal Faculty, Santa Fe Institute, Santa Fe NM

Author, historian; Professor of Classics and Letters, University of Oklahoma

Guggenheim Fellow (2013); winner of the Wenjin Book Award (2020) and the James Henry Breasted Prize (2012)

FURTHER READING:
Plagues Upon the Earth: Disease and the Course of Human History (2021); *The Fate of Rome: Climate, Disease, and the End of the Empire* (2017)

I think you can still take completely seriously his argument that the Roman Empire was in a sense undone by what he called **its own "immoderate greatness"**. . .

DAVID KRAKAUER: You're a historian of Rome, so we need to start with the elephant in the room — the work of Edward Gibbon.

KYLE HARPER: Anybody who studies the later Roman Empire is working in the shadow of Edward Gibbon's *The History of the Decline and Fall of the Roman Empire.* And there are very good reasons for this — his history is monumental. In every way it's formative. There's no getting around it and not just because of its enduring fame. Very few have read through all the volumes, but everybody at least knows it's a landmark and brilliant history. He was a critical mind who was bringing the ideas and the preoccupations of the Enlightenment to the study of the past in a new way. He was concerned with how reason works in a human society or in a political order.

And he was drawing from the newest and best ideas in circulation in the late 18th century to look at the past in a new way. I think you can still take completely seriously his argument that the Roman Empire was in a sense undone by what he called its own "immoderate greatness," meaning that there was an endogenous (internal) dynamic, that the Roman Empire had to fall, because it's the nature of these kinds of orders that they grow too big.

Your approach to history pays more attention to external forces, including disease.

When we think about the Roman Empire — the big cycles of Roman history, like the creation of the empire, and the dissolution of the empire — it's common to start more or less where Gibbon started, which is what he called the happiest

The Roman Empire seems to have created **very suitable conditions for the rat**, which is very susceptible to plague and which lives in very close proximity to humans.

era of the human past. We would probably not agree with that totally, but he was onto something. In the first and second centuries of the Common Era, the Roman Empire reaches its maximum extent, its maximum of population, it's maximum of economic output, and in many ways its maximum of intellectual achievement.

In the middle of the second century, just when the Roman Empire is at this peak of territory, the empire is struck by an infectious disease, and we call this event the Antonine Plague. I would argue that it was probably the most severe large-scale mortality event in recorded history up to that time.

Where did the Antonine Plague come from?

There's a lot of trade across the Sahara. There's a lot of trade down the Red Sea into the Indian Ocean with East Africa. There's a lot of trade with Southern Asia and ultimately across the Silk Roads and through Southern Asia with China. When the Antonine Plague arrives in the Roman Empire it is the first time that Chinese sources record contact with Romans. Somehow — we don't exactly know how, probably a Roman trading party — made it all the way to China.

And it looks like the wheels came off for five to 10 years. The Roman Empire seems to have really been shaken by this kind of biological shock. To me as a historian, that's something fascinating and it's also significant, and it doesn't mean we ever have to throw out all of the human social dynamics. That would make utterly no sense. We need all of these Gibbonian dynamics that are internal to the empire: populations are growing, elites are competing, the emperor is trying to raise taxes and mobilize the army. Germans are figuring things out across the frontier. This is still an important traditional part of the story.

In your book *The Fate of Rome,* you wrote, "a bomb went off in the sixth century." What did you mean?

In sixth-century Rome, Augustin is reconquering lost territories very successfully. What we know happens next is that the world is struck by a massive outbreak of bubonic plague on a scale completely unparalleled by anything in the written record of all of humanity.

And plague doesn't require an animal reservoir. Plague is different. First of all, it never becomes a human disease. It's a rodent disease that can infect a lot of mammals, that infects humans, and can to some extent be transmitted between humans. And it certainly doesn't transmit between humans on a long-term basis. It's not like tuberculosis or malaria or smallpox or measles that become human diseases and then can spread in human populations. It's always an animal disease that gets into humans. A second feature of the plague bacterium is that it's a vector-borne disease.

A certain number of infectious diseases rely on vectors to get them from one host to the next. They're often capable of being nasty diseases. Vectors are very handy. They'll take you directly into the sterile tissue of the next host. Comparatively speaking, there aren't as many major infectious diseases that are caused by vector-borne parasites, but plague is one of them. It is transmitted very efficiently by vector intermediaries — largely, fleas — and the plague bacteria are extremely well adapted to use the flea. In effect, they form a kind of superorganism in which they build a biofilm in the digestive

The reason why we have so many infectious diseases is *us*. We are the architects of this system of which parasites become a part and it's highly unpredictable.

canal of the flea. And rat fleas can go everywhere. The Roman Empire is this interconnected urbanized world with massive systems of grain storage and transport provisioning cities and armies. The Roman Empire seems to have created very suitable conditions for the rat, which is very susceptible to plague and which lives in very close proximity to humans.

So, when I say it was like a bomb went off, it's a natural event where all of these factors seem to have aligned to create the conditions for this extraordinary biological shock.

One way to read your work is as a deliberate effort to combine internal systems with external systems of evolution and ecology. You are pursuing a rather transcendent form of history.

I think one of the arguments that I'm trying to make is that, in a sense, infectious diseases are an endogenous factor. If we think of the system, we should think of it as a system in which human beings are animals — technological animals. But what we do with technology is meaningfully describable in ecological terms as controlling the flow of energy. And parasites are part of that system. In economic history, there's a strong tendency to treat infectious diseases as an exogenous factor. Plagues are just these acts of God. They are this thing outside the box, outside the system. But I don't think that's the real story. The reason why we have so many infectious diseases is *us*. We are the architects of this system of which parasites become a part and it's highly unpredictable. The real story is one in which, if we think of economics more broadly as being a story about energy, then our parasites need to be there in the story with us.

Tell us a little about what you call "the paradox of progress."

We are populous, we're highly interconnected, and we live in very dense environments. What we think of as technological progress, which is the cumulative increase in the human ability to control the flow of energy, is also of great advantage to parasites that can somehow hack into, or take advantage of, us as sources of energy. There's technological innovation that helps humans do things better or more efficiently. But we don't intuitively think that there are downsides too. But if there are more of us more interconnected and living more densely, it's going to stimulate — or at least create the opportunity for — microbial evolution to figure out how to take advantage of us.

If we think of the system as a whole, it is a system in which human beings are technological animals. But what we do with technology is meaningfully describable in ecological terms as controlling the flow of energy, and parasites are part of that system.

PHOTO: THOMAS ASHCRAFT

The reason why we have so many infectious diseases is *us.* We are the architects of this system of which parasites become a part and it's highly unpredictable.

KYLE HARPER

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TED CHIANG

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