Science is a Long Story: A Conversation with Tom McLeish

Tom McLeish FRS, physicist and Emeritus Professor of Natural Philosophy in the Department of Physics at the University of York, UK, in conversation with Dr. Samuel Loncar, Editor-in-Chief of The Marginalia Review of Books.

Introduction

As part of our Meanings of Science in the Modern World project, I had the pleasure of speaking with one of the world's leading experts in soft matter physics, academic disciplinary leader, and writer, Tom McLeish.

McLeish's publications reflect his interdisciplinary academic interests, which include science, theology, history, and theories of creativity in art and science. His most recent books include: *Soft Matter – A Very Short Introduction* (Oxford University Press 2020), *The Poetry and Music of Science* (Oxford University Press, 2019), and *Faith and Wisdom in Science* (Oxford University Press, 2014). In addition to giving public lectures in literature and science, he directs several large interdisciplinary collaborations and co-leads the *Ordered Universe* project, an interdisciplinary re-examine of 13th century science. His scientific research in soft matter and biological physics and cross-discipline collaborations have been recognized with major awards in the US and in Europe.

Our conversation was lively and illuminating, and his passion for everything from soft matter and polymers to Cappadocian theologians and the idea of resurrection was an evident delight. We begin with McLeish's journey into the scientific world, which in part was inspired by his grandmother, a botanist and lay preacher in the Church of England. This led to a rich discussion of soft matter, academic disciplines, the importance of science being in conversation with philosophy, and challenging the myth that the unexplainable was all magic until science entered the narrative.

Crossing Boundaries

SAMUEL LONCAR

You write so movingly—you made me so interested in polymers and things I know nothing about—so I'd love for you just to share a bit to begin about your own journey into the study of the natural world.

TOM MCLEISH

I honestly don't know a time when I didn't think I was a scientist. I must've been about two and a half years old. I don't know where it came from, but I remember

just loving all aspects of the natural world: the stars, the plants, the bees, and, of course, I was very influenced by NASA in the 1960s when I grew up. You couldn't really ignore the Moon Program: the sheer romantic, millennia-old dream actually realized of walking on our planet's satellite, and I was seven years old or so when Neil Armstrong stepped out onto the surface of the Moon. So that was one important strand, but of course there were others too.

My grandmother actually was an important influence on me. She had done a degree at London University in the twenties, I think, on botany, but she was broadly scientifically interested. She gave me her grandfather's field microscope when I was a child: it was a little brass microscope, which I later discovered is of the identical make with which Robert Brown made his investigations into Brownian motion. I still have this wonderful device. And I was pricking my finger and getting blood cells out and looking at them and fly's wings and things. A bit later, of course, I got a small telescope at 10 or 11 years old and found Saturn with its rings. I'll never forget the hair-on-the-back-of-the-neck-prickling discovery of seeing this wonderful, ringed planet hovering in the eyepiece under your eye.

But I should say my grandmother was also a trained lay preacher in the Church of England, which I later became myself. So it was clear in my upbringing from her that there was no conflict at all between science and religion. In fact, quite the reverse. So that was one important strand.

Of course, later I discovered that the science I really loved was called physics. I always describe physicists as the Winnie-the-Poohs of the scientific world. We're bears of little brain. Complicated things confuse us. We leave that to the biologists and chemists. We like things lovely and simple.

SAMUEL LONCAR

That's a lovely, humble view of such a rigorous field. I love Winnie-the-Pooh. The Winnie-the-Poohs of science?

TOM MCLEISH

That's what physicists are. The other strand for me is my interdisciplinary passion. Whenever I have seen the fragmentation of the academic world—I remember thinking about this at school as well as university: the entrenched polarization of

the arts and humanities, in particular of art and science—this made no sense to me, never has.

And as you may know, my own country, the UK, is one of the earliest of the G8 countries to specialize in education, something that I've been trying to inveigh against in the work I've been doing, in the educational policy work of the Royal Society more recently. We need to equip young people with both the scientific and quantitative skills but also the imaginative—the humanities and literary skills—they need to navigate the future. But I was very fortunate. My school was broad and flexible, and I was able to study French at ages 17 and 18, while I was doing my late high school science.

A French teacher (actually another Christian) was also passionately interested in Sartre, Albert Camus, and the French existentialists, so of course, I became passionate (of course you do, don't you?) for Sartre and Camus and the French existentialists. So that set me on the path. It showed me the value of the humanities and gave me an interest in the humanities discourse. I saw how important it is to keep that going alongside science because science also has its narrative and its story. So there are a few formative things.

As for polymers, I always wanted to be an astronomer. But before going to university, I took a gap year in industry. I wanted to know how science panned out in industry. I just got that bug too. And I happened to get a funded place at a company called Courtaulds that made artificial fibers, polymers. And it was a fascinating process. But they had no fundamental science whatsoever. It was all empirical. You try this: if doesn't work, you ditch it; if it works, you try it again, and see if you can sell it. That was the rule. And I remember thinking there must be a science of these extraordinary liquids—made of long-chain molecules. I knew that; I didn't know anything else.

Then at Cambridge, the Cavendish Professor, Sam Edwards, had made a career out of inventing what we now call soft-matter physics from quantum field theory, using its mathematical techniques and physical nsights, and working with this wonderful Japanese physicist and chemical engineer, named Masao Doi, to devise the first molecular physics theory of viscoelastic polymers. And when I was in Cambridge as a final-year undergraduate, I attended a lecture where Edwards announced: "Gentlemen, ladies, I do believe we have a first theory of viscoelasticity," and I remember thinking, "Oh, my word, I must be the only person here who knows that there's industry out there desperate for this. I could be in at the beginning of something really new for my PhD. Or I could be yet another astronomer." I'm not dissing astronomy, which is fantastic. And gosh, I always partly regret not being on board with the exoplanets and Hubble. However, it was lovely to be in on something new. So that's what got me into polymers and soft matter.

The Wonders of Soft Matter

SAMUEL LONCAR

That's incredible. There's so many wonderful themes there. Just to pick up on the most recent, you are one of the world's leading experts now in soft-matter physics. What is soft-matter physics? You've just explained that it's a very recent field that Edwards pioneered. Could you tell us a bit about why it's special and fascinating to you? What's enamored your mind for so long?

TOM MCLEISH

One of the special and fascinating things is that it is exactly what it says on the tin, and very often it is in the tin: jellies, soups, sticky liquids. It is the physics of softness, and of course softness is very subtle. Some of your readers and viewers today might have seen the demonstration of the rose, the softest of all petals, being dipped in liquid nitrogen, so that it's frozen. And then you lift the flower out—no chemical change, nothing; it's made of exactly the same stuff it was before—and tap it with a hammer, and the thing shatters like glass. So softness is not purely a function of material and structure. It's also a function, it turns out, of dynamics. That is what heat is. Temperature is the motion or lack of motion at the smallest length scale of the molecule.

So, it's the emergence of properties like softness, stickiness, foaminess, bubbliness. We have plastics, we have foams, we have biological tissue. The fact that their molecules can be, for example, long chains or networks, and entirely new properties emerge. That this is physics, not just chemistry, although, of course, it's inherently interdisciplinary, is itself very interesting. And it was Sam Edwards who realized that a super large molecule made of thousands and thousands of chemical units, at some length scale its properties just emerged from the fact that it is a string.

The tiny little beads on the string which possess the chemistry are good for local things. But the overall properties like its rubberiness—elasticity, just the stretching out of rubber—doesn't come from stretching chemical bonds; it comes purely from stretching out individual thermally excited strings that would like to be randomly sampling all possible paths, but as you stretch them, they are constrained to sample fewer and fewer of them. Let me just grab a little cable to illustrate this. So here's a long chain polymer, and it's just dancing around forming all sorts of conformations, but when I stretch it out, it's partly confined to just a few. And that's the statistical pressure that rubber and elasticity works on. The mathematics for this come straight out of quantum field theory: Feynman path integrals and all that, as Sam realized. So soft-matter physics is really born from the quantum field theory of the post-war years in terms of its method. [It also comes from] the chemistry of

increasing kinds of materials, humanmade materials available to industry in the postwar years, too, and it's another example of how industry and academic science reciprocate in terms of knowledge exchange.

It's not that ideas come in universities, and we apply them in industry. It's much more nonlinear and complex than that. My own research later in soft matter, for example—my first big bite of a new puzzle—had to do with what happens if you take these long-chain molecules and branch them into tree-like or cone-like structures. After all, we've learned that part of their key physics is that two strings can't cross each other in three dimensions. That was a fundamental interaction, what we'd call a topological interaction. So it became obvious to ask, what happens when one changes the topology of the molecules themselves? And the answer is whole new emergent properties leap out, and that was fun to explore for quite a few years, in collaboration with chemists and engineers and computer scientists and industrial scientists, too. So that gives you an idea of soft matter, and the latest thing that's happening is, of course, that we are made, life is made, of soft materials. So you'll now find myself and other soft-matter physicists engaging more and more with biologists and together exploring how the physics of biological cells and biological matter works.

SAMUEL LONCAR

It's an extraordinarily exciting field then. You mentioned it comes out of quantum-field theory, so in one sense, it is itself a fruit of the latest science. Was there a previous interest in the problems, or was the conceptualization necessary for the issues that now make up soft-matter physics something that couldn't emerge until quantum-field theory and twentieth-century physics?

TOM MCLEISH

The interest goes back a long way. In the nineteenth century, we have the emergence of rubbers. Actually, rubber technology has been around since the Incas; it's been around a long, long time. And the science of rubber and the industry of how you turn latex— a viscoelastic slimy resin—into crosslinked rubber with vulcanization and so on—is technology more than a century old.

Fascinatingly, one really important property, which later became a real key to its physical physics, is that when you stretch rubber, it gets warm. And if you take a stretched rubber at room temperature and you relax it, it cools. So there's strange thermodynamics going on. It's called the Gough effect, after a man named John Gough who lived in the Lake District. And, very interestingly, he was blind from birth, so he had to develop his other senses, his non-sighted senses, in his exploration of the science that he loved, and I think it's really a wonderful thing that he discovered an effect that other people completely missed because it's a very

subtle change of temperature. Anyone can detect it. Just stretch a rubber band on your lower lip, which is sensitive to temperature. This is what he would do. So the Gough effect goes back to the nineteenth century.

I should say that the notion that there were giant molecules was still being contested in the 1920s, and the German chemist who first promoted the idea that there were macromolecules was Hermann Staudinger. He was reviled by his colleagues because giant molecules, of course, have an indeterminate molecular weight. How many units are you polymerizing, 10,000 or 10,002? Molecular chemistry is supposed to be an exact science.

This is one of the Kuhnian socially constructed barriers to new understanding that had to be overcome in the early days. There's prior history of chemistry and material science. Maxwell was interested in viscoelasticity. The Maxwell model actually comes from the simplest possible mathematical model of a material which is a solid if you observe it at short times and a liquid at long times. So, it has a nineteenth-century history as well. But you're right that it needed both the chemistry and physics—the postwar mathematical methods—to reinvigorate interest.

There's one other historical aspect of the science here. You get the wonderful chemical physics that scientists like van der Waals were doing at the end of the nineteenth century. There were statistical methods behind the colloidal part of soft matter— in distinction to the long stringy polymers, there are also tiny round things, and they're the colloids. But all of that went on hold – the physics thereof at least, when quantum mechanics stepped onto the scene, because everyone had to do electrons, and everyone had to do Heisenberg and Schrödinger stuff. And all that quantum-mechanical stuff had to calm down for a few decades before people went back in the sixties to say, "Well, now we know a bit more mathematics than this. What was this fascinating program on complex fluids that that was going on before we all got excited about quantum mechanics?" That's slightly tongue in cheek, but only a bit. That's the potted history.

Natural Philosophy, Science, and the Extraordinary

SAMUEL LONCAR

As a philosophical issue, it's fascinating that the very field that you're in reflects the evolution and purification of what in retrospect was a very significant error in early modern philosophy. Softness would be what the early modern philosophers would have called a secondary property, right? Not a core property of intrinsic reality. And yet, it seems that what is so interesting is that this quality—a quality that is inherently, we would say, qualitative—in fact seems to be embedded in some

of the most profound, fundamental, mathematically complex structures that we can now study. It's a very interesting evolution from the early modern mechanistic view to this now very dynamic view, which is statistical, although still highly, highly fundamental in its profundity of engagement with the structures of reality.

TOM MCLEISH

Yeah, absolutely. It's statistical; it's also emergent.

SAMUEL LONCAR

Could you say more about emergence? It's an exciting quality.

TOM MCLEISH

Having a chair of Natural Philosophy, I try to do some philosophy or just to engage with philosophers, as well as doing the science. Ever since I was at Durham, before my current appointment, I have become very interested in the philosophy of this thing, or these multiple ideas, called emergence.

And it's a challenge to one of these optional interpretive schemes of modern science, which is reductionism, the idea that there's a level of linked scale at which all the causal variables seem to operate with the fundamental variables. Yes, of course there are large, coherent bodies of structure in motion, like breaking waves, or like sheep, or like trees, that can be talked of and conceived of and analyzed in terms of themselves. But at the end, it all comes down to the atoms. Oh, actually, when I say atoms, it's not the atoms, but the protons and neutrons. Well, actually, no, not the protons and neutrons. It's the quarks. Maybe. We think.

You see the problem here. How many layers of this onion do you peel off before things become emergent? I like to tease my quantum-field-theory friends by asking them to show me the Standard Model Hamiltonian, which has 23 or 19 (I'm not quite sure how many) arbitrary parameters, and I show them the Edwards Hamiltonian of the physicist polymer, which has two parameters, from which all properties of polymers emerge. We don't need the quarks, thank you very much. Which of these is more fundamental? We can at least argue about it.

And after all, does it not seem rather strange that all irreducible causal agents might occupy the same energy or length scale? That's a rather arbitrary thing. There may be universes in which that is the case. We'd better go and look empirically at ours, hadn't we? Because perhaps there are irreducible agents at a range of length scales. I think the empirical observational data of our own universe point very clearly to the latter case.

So there are cases within quantum mechanics, there are highly demonstrable cases within statistical mechanics as well, of irreducible causal powers. That's maybe a little bit controversial to some people. It's not controversial to me. But there's an exciting literature on this. Certainly in practice, all science works as if a strong emergence were true. That's how we actually do things. When my biological colleagues work on membrane proteins, they don't talk about the electrons or the quarks or the field theory or the gluons in there. They talk about the membranes and the properties of the membranes and the properties of the proteins and Brownian motion of the subunits. And those are all you need to know to understand this extraordinary world of the soft matter of the cell, for example.

SAMUEL LONCAR

What you're saying is very significant. We've separated science and philosophy. I know you recognize the value of the philosophy of science to the practice of science, but you can see why some physicists or others wouldn't, until you start to get into these issues where there are empirically salient, highly relevant things in science that speak to deeply philosophical issues. And so about the reductionist program, you tell the famous anecdote of Laplace in your book, *Faith and Wisdom in Science* published by Oxford.

The Laplacian dream was of a scientific program that came out of Newtonian mechanics in which, by understanding the very simple fundamental structures of reality, you could if you had all of the information, all of the initial parameters, get a complete, deterministic picture of everything. And yet the picture that's actually emerged in science—particularly since the twentieth century, and in your own work and in your own field—tells us a much more dynamic, complicated, and interesting story. Is that a fair high-level summary of what's at stake here? There are different worldviews that have animated science, and soft-matter physics is partly a philosophical change in outlook about what the fundamental structure of the philosophy of physics might be.

Investigating the Stories Science Tells

TOM MCLEISH

Yes, I think that's true. It certainly informs the philosophy. And we see the observed reemergence of what I used to call (I might be swayed to call it something else) strongly emergent, as an irreducibly emergent, agent at high length scales. Now, of course, this whole program comes from the philosophy of mind. And this is where I think the physicists might make a helpful suggestion—we have made a suggestion or two, which I hope have been helpful to the philosophers of mind. You see, the motivation behind a non-reductionist philosophy of mind is, of course, that we don't experience our minds as being reducible. We don't experience our minds as

being mere epiphenomena of matter. This is, by the way, an old discussion; this is not a new discussion driven by artificial intelligence.

My favorite debate as to how one tells whether mind is reducible to its matter or components in terms of thoughts—call it soul, if you wish—goes back to Gregory of Nyssa, one of the great Cappadocian theologians, and his elder sister, Macrina, who's also one of the great Cappadocian theologians, in her deathbed discussion, which is often translated *On the Soul and the Resurrection*. It should really be *On the Mind and the Resurrection*. And they go hammer and tongs about this. Interestingly, Gregory takes the view that everything is reducible to atoms, material properties—just for fun. He doesn't believe that, but he takes that view for the sake of debate. And Macrina takes the view that the mind is a causal agent: we make real decisions, we have freewill, and so forth. And she ends up by pointing out that we know this is true because mind has the ability effectively to do science, to reconstruct nature. So when we see the phases of the moon, we conceive not of a little penny that grows from a sliver into a round and back to a sliver again during the month, but of a sphere, illuminated by the sun in fully three dimensions. In other words, we do not merely record perceptions; we recreate the entire universe in model form.

So much for mind. But my suggestion from the physics is, look, if mind is a big problem, then what's more ethereal than quarks? Mind is a long way out there. If the universe has irreducible strongly emergent structures, then we might be well advised to look for them at length scales in between the atoms and mind. Simpler emergent structures—let's establish those with the physics that we understand. We don't understand the physics and chemistry and neurochemistry of mind yet. Let's do that.

So that's where I think I've experienced a very happy and integrated meeting of physicists and philosophers. In fact, this Durham Emergence Project, which the Templeton Foundation funded, brought physicists and philosophers together, not just for one conference, which is the standard way of doing it, but for weekly meetings over three years, interspersed by interchanges and sabbaticals, interspersed by major conferences and writing books and papers together. That kind of engagement across disciplines was interesting. Some of the philosophers of science said they'd never experienced anything like it. They never experienced scientists as tenaciously interested in talking to them for long periods of time. Well, hooray, I'm proud of that. I could say the same thing: thank you to them for talking with us with serious investments of time.

And out came a philosophy based not on nineteenth-century science or at best quantum mechanics, but right up-to-date stuff, buying into some of the emergent soft matter and emergent quantum field theory in condensed matter these days. So

we had lots of very fruitful engagement, working towards a renewed natural philosophy, I think.

SAMUEL LONCAR

That's very exciting. And I love the anecdote you give of Macrina, which you have in the book. So maybe we could use that as a way into some of the issues that you're raising in physics and philosophy and the philosophy of mind. You give an example of people doing something like science 1600 years ago. That might surprise some people because of our image of science today. But your whole work and life has always challenged this idea. You were raised in a household in which the very idea of a conflict between religion and science would have seemed ridiculous because of the shared singular source of inspiration you had from your grandmother. So where do you see our image of science today? And how does your own work in this case challenge it? I mean, how old is science? How long have we been interested in science as humans?

TOM MCLEISH

When I was growing up, so as a very young scientist and then as an early career scientist, I had the coffee-table books or school histories of science that said that there wasn't much going on before the seventeenth century. Before that we were in the middle of the Dark Ages, and it was all magic and superstition, and then suddenly Copernicus, Galileo, Kepler, and Newton appeared. "Nature and Nature's laws lay hid in night / God said, Let Newton be! and all was light," as Alexander Pope famously wrote.

I never believed this, and I didn't believe it because I just don't think things change that quickly. Rarely. So something's been missed out. It smelt artificial to me from a very early age, but you have to do a bit of digging to discover that, yes, it absolutely is artificial, totally artificial. Of course, there have been changes in the scale, the depth, the style, in which we do science. No more, no less, there have been huge changes in the scale and style and depth and capacity with which we write, play, and sing music. But that doesn't mean that there wasn't any music before William Byrd or Monteverdi. Pick your favorite early modern composer.

In fact, we know from drilled bone flutes, that my colleagues in archaeology here in York know a great deal about, that tens of thousands of years ago, human beings were playing notes from our current harmonic scale on hollowed out bone and it's very likely, therefore, that they had also discovered that strings have the same capacity. So what we now call science, by other names in the past, is as old as any other human cultural endeavor: music, art, telling stories, narrative, singing, painting, the works.

TOM MCLEISH

If you want to change the metaphor: the great flowing Amazon River that we now call science has tributaries, traceable tributaries, that go right back to highlands in prehistoric times; certainly, there are two big ones: one Greek, the other (less-recognized one) Hebrew.

And even the story as I was told had a slight flaw to it, in that we were introduced, of course, to the great ancient Greek scientists: the great Eudoxus, the wonderful Aristarchus, Hipparchus, the great astronomers like Ptolemy. And then we get this painful and ghastly, dreadful, ignorant narrative that even great public communicators like Carl Sagan bought into, tragically. Neil deGrasse Tyson, in our own time, is someone else who trots out this garbage about the Dark Ages. The only dark thing about them is our own willful ignorance of the subtlety and progress that were made by just a few people in small populations but were being made throughout the first thousand years of the Christian era. We also have the development of Aristotelian science in the Islamic and Arab milieu and its translation into Europe and the Latin West.

Great Carolingians like Alcuin, who worked just down the road from me in York, was one of the greatest natural philosophers of the ninth century, Charlemagne's great natural philosopher. Mary Garrison, my colleague here in history at York, and I have been discovering and writing about Alcuin's late-eighth-century correspondence with Charlemagne on the retrograde motion of Mars. In a most subtle and intricate way it is the longest early medieval discussion of the retrograde motion of the planets. It all fits into a long story that was always embedded in the cultural and belief systems of the time. Science is a long story.

SAMUEL LONCAR

"Science is a long story." This is a total challenge to the dominant view, right? This narrative comes out of the Enlightenment, which creates this historiographical image of the Renaissance and the Dark Ages.

This is linked, as I see it in your work, to a very unusually comprehensive and developed anthropology of science. So, basically, it seems like you would agree with Aristotle: that science is as deeply human as anything can possibly be.

Aristotle starts the *Metaphysics* by saying, "All humans by nature desire to understand." And you see in that desire to understand both a deeply human thing and also something that's linked to even the possible healing of much of the pain that humans suffer. It's a very beautiful but a very unusual view in the

contemporary landscape, and that's partly why I wanted to stress it and ask you more about it.

This view that science is very recent is linked to the view that science is in some sort of deathly conflict with religion, which, of course, we know is absolutely false for anyone who cares to just read the scholarship. On the one hand, we think we need a greater public understanding of science; we want people to engage more with science. On the other hand, we ignore what we know about science is based on the broader science of what you call the cultural history of science.

So in your view, why is it that we are so committed to a type of ignorance about this practice? Why do we think about science the way we do given that as you show—and you draw on so many other scholars—science is as old as our species? But why are we hung up on this story?

Why Are We Committed to A Type of Ignorance?

TOM MCLEISH

I think we're hung up on it because it's played into too many people's interests and too many power games' interests to push this Enlightenment view of science, a Kantian view of science, however untenable that is. We think of fake news being a symptom of our own times. It's really been around for a very, very long time. I think there are several aspects to this.

One is, of course, that there was in the Latin West and we still are in the Latin West (nobody speaks it anymore, but we are)—there was a regrettable pretense of a clean cut in the seventeenth century. This is Francis Bacon and others, although doing wonderful things in terms of putting experimental science on a firm foundation, which itself is a vital tale to tell. I mean, the very existence of experimental science is demonstratively arrived at through an imaginative metaphysical leap, fueled by the Christian doctrine of grace. Now, there are readers who are going to shake their heads and say, "He's gone off his rocker saying that," but that's not a niche opinion.

But, nonetheless, the great medieval strides made in astronomy, medicine, materials-theory, and color were metaphorically a palimpsest. They were wiped clean by the early moderns in some sort of pretense that they were starting all over. Aristotle was bad and wrong, and we were starting all over again. Medieval scholastics were wrong.

Now that played into their power game, but at the same time they are using everything that went before: philosophy, theology, and science. And then, of course, in the Europe of the eighteenth and nineteenth centuries, you have an educational system dominated by classical humanities, disciplines in which the

sciences were elbowing for room and finding it hard to get. People like Huxley had to become very combative in their language to establish science education as

normalized between the ancient universities of England, for example. So it became unnecessarily uncollegial.

Another ingredient, possibly the saddest of all, comes within the post-Reformation broken, and. fragmented church. You have a Reformation and a Counter Reformation, and a nineteenth century of extreme Protestant-Catholic tensions that were eventually fought out, as Peter Harrison's colleague, James Ungureanu, has shown recently with his co-author, my colleague, David Hutchings, in their book *Of Popes & Unicorns*. The conflict narrative reaches its final articulation in Andrew Dickson White and John William Draper—the Draper-White thesis. Most people who read this won't have heard of Draper and White, yet their books with titles like *A History of the Warfare of Science with Theology in Christendom* were reprinted and translated into dozens of languages; they sold tens of thousands of copies in the latter half of the nineteenth century. They were the texts that got the discipline of the history of science going, but it was founded not on historical academic methods, but on anti-Catholic Protestant polemic. It's a tragedy: the idea that one could tar Catholicism with a brush of being anti-science if one invented a bit of history and read the Galileo affair in a particular non-historical way and told lies about how the medieval church taught that the earth was flat. No, they didn't. No one (apart from one or two ideosyncratic individuals in late antiquity) ever thought the earth was flat. It's only in our own time that people think that, ironically and distressingly. The medievals knew exactly that the earth was round, how we know it was round, how big it was, how anyone could tell why it was round—north, south, east, and west—and it's in all the thirteenth-century books, by the way. Very impressive. Oh, and why God wants you to know this and work it out yourself.

All these strands come together. And then, of course, in that milieu in come new ways of reading the Bible, which are really old ways of reading the Bible, as you know. I've been reading Robert Grosseteste, one of the greatest thirteenth-century polymaths. He invents a big-bang theory of the medieval cosmos and reads scripture in a much more authoritative way, but not a scientific way. He knows that if we are to describe the physics of the formation of the early cosmos, then that's what we do with God's gift of natural philosophy to us. We don't read it off the page of Scripture. It's only in the twentieth century that we began to think that, and this comes from a sort of eugenics twisting of Darwin.

So it's a perfect storm in the mid-nineteenth century of social, ecclesiastical, as well as academic and educational tensions, in which different factional parties found it for a while convenient to peddle a myth of the conflict, the historical conflict, between science and religion, and we're still trying to unpack this now. And it's vital that we do, because I don't want to meet another young person, who is

someone of faith and loves science and is taught at their university about the glorious richness and structures of life involving evolution and all this, and then when they go to church on Sundays hear "this evolution is evil" stuff. No wonder it leads to poor mental health. That is just one flag that we've got to stop this

nonsense, and people from evangelical preachers right the way through to Jerry Coyne, who is an evangelical preacher at the other end of the spectrum (if I may say so)—all this fundamentalist thinking is very much to blame. That's my sermon.

SAMUEL LONCAR

It's wonderful, and I want more of the sermon. One of the great ironies that comes out of the work that you're summarizing is that the history of science wasn't scientific; the history of science was, ironically, itself a fruit of inter-Christian religious conflict.

And one of the great dangers of our so-called secular culture is that whatever people's personal beliefs are, we've got to know the history of our context if we're going to understand why we're framing these things. It's significant to realize that we are only very recently coming to have a historical understanding of what we call science.

There are deep concerns you mentioned [in Part 1] about eugenics, the twisting of Darwinism, that get into really hard issues in science. At the time, for example, eugenics was presented as science, and what we call social Darwinism wasn't called social Darwinism. It was just Darwinism, and it was presented as the truth of biology from many leading authorities in the scientific community.

In America, as I am sure you know, progressive religious leaders were some of the main architects at places like Harvard and Yale, for example, of pushing eugenics. So eugenics was advocated as a scientific doctrine. It was given a great deal of energy by the elite religious establishment and partly under this guise. So that, I think, raises this difficulty: fundamentalists are often thrown under the bus for understandable intellectual reasons. But if we historicize the context of their concerns, it was conservative religious people that we would now view as anti-scientific who were in general hostile to eugenics.

I want to ask about the deeper theological concerns underlying this, about the fact that science has under that name, even in the past one hundred years, presented itself as the justification for a program which led, for example, to the forced sterilization of people in America, which the Nazis then imitated.

Much of their policy on eugenics, as I'm sure you may know, came out of an imitation and study of the American progressive eugenics movement. So I do think

the issue of science's embeddedness in culture and its embeddedness in theology is difficult.

How do you think we should think about the fact that science has not only gotten science wrong, as you mentioned, but that Science isn't science because it's always right?

You say maybe it's a more productive way to think about a history of error (*pace* Karl Popper), but science has also presented itself in a way that has almost justifiably generated a counter reaction. We could say, well, the reaction is no longer justified, but how would you speak to people who are in those communities now? Can you help people think about that?

What Is Science For?

TOM MCLEISH

I'm not an expert on that aspect of science history, though I do know about it, and it gives even more force to the urgency of giving science a healthy social and cultural embedding. So, of course, science is going to be wrong. It has repeatedly been wrong in the past. But as for any really difficult, edgy thing—you end up making mistakes. We know you're going to do that, whatever you're trying to do.

You're trying to build a car, you get it wrong ten times; you put things together the wrong way. It's through the mistakes that you learn the path ahead. You're navigating your way through a complex mountain landscape; you might have a map, but if you don't have a map, you're definitely going to get it wrong: you're exploring new territory—which science is. So understanding that means that checks and balances are all important, and understanding what science is anthropologically or even theologically (I know we're going to go there, and I think now is the time to go there) is therefore vital, because you need to be able to blow the whistle. We can't do nothing. We know that we've got to explore with this amazing gift. We know we've got to understand new territory. We know that is going to be difficult; we're going to make mistakes, but there are ways in which we can make fewer mistakes and see the wrong turnings earlier.

But we can't do that—or we risk not spotting when things are going wrong—when science is put in a big shiny box on the shelf marked "For experts only." They know what they're talking about. You don't. They're clever. You're not. They possess erudite methods and wear white coats and carry clipboards. But that's not the point because they know how to do science. That is where we currently are in science.

That's why, by the way, I'm working with my friend and colleague—Dame Ottoline Leyser, who's currently Chief Executive Officer of the UK Research Innovation (she's really important now in the UK) in the Royal Society—on a

project called "Reimagining Science." And post-COVID it has become all the more important that, as she puts, we take science out of its "shiny box" and that people engage with science in a similar way that they might—I don't know—follow a football club. In other words, think about football and music—or whatever your national sport is. It's not saying that there aren't people we need who are really, really good at this and much better than we are, people who play for the professional teams or who lead the violins in the orchestra we go and listen to or play in the rock

band that we pay unbelievable amounts of money to get our ears blown out at—whatever your taste. However, the point is, we go and watch, and we watch critically, and we might play for an amateur team or play for an amateur orchestra or sing in an amateur choir. There's this continuous ladder of engagement that constructively criticizes and supports something all the way through. And with science, it's as if we've knocked out the middle rungs of that ladder, and we have those of us who watch the programs ("Oh, we now know this about the galaxy"), but we don't think critically about it, and that's very dangerous. It's very important to think critically about it.

And one of the organizations best placed to think ethically, critically, and discursively about science is the Church. Now, I know this is true because David Wilkinson—the Revd. Dr. Wilkinson, a former astronomer, now principal of the theological college at Durham—and I have run this project for seven years called "Equipping Christian Leadership in an Age of Science," where we get Christian leaders and churches engaged in science, give them resources to do this, and find that the two fit hand in glove. During the COVID pandemic, for example, it's through the churches that we've been able to counter anti-vaccine false narratives. In so many ways, a science-embedded church is rediscovering itself, just as in that lovely conversation we were referring to a moment ago [in Part 1] between Gregory of Nyssa and Macrina, talking in the fourth century about experiments to do with water and air and astronomy and observing the moon—a common human experience. And in one way, they were also doing this in a lovely local interpersonal experience. I forgot to mention that she was on her deathbed, and this discussion is her generous giving as a dying woman to her distraught brother to help him through his grieving process, which has already started.

So science as a therapeutic, contemplative good that can heal at the micro level is symbolic and indicative of its process when properly and healthily maintained to heal something at the larger social and political level.

I'm very fond of quoting the literary scholar George Steiner, who wrote a wonderful book about what he thought of as the diseased in art and humanities in the postmodern world. He has a rather rosy-tinted view of sciences, by the way—or had. He died a couple of years ago. And I remember reading this sentence about art; he says, "Only art can go some way towards making accessible, towards waking into some measure of communicability, the sheer inhuman otherness of matter."

This sentence bowled me over because it told me two things. It told me what I could have read, of course, in the *Phenomenology*—or in Aristotle and Cicero, for that matter. But one aspect of the human condition is that we're fish out of water; we don't understand. We're frightened by—and we have, at best, a dislocated experience of—the material world around us—unlike all the other creatures that seem perfectly at ease in their environment. So there's a broken relationship that needs healing.

And then, of course, Steiner goes on to say, well, this is what art is for, to talk about purpose, to talk teleologically about a human activity. Likewise, he has a Jewish background, but he's no believer: he's a post-Holocaust, Jewish atheist. But oh, by the way, he finds himself calling on the Christian story—the Friday, Saturday, Sunday story of despair and death, waiting and resurrection—as the emblematic metaphor for human existence. That's interesting, too. But then I'm thinking reading this: "Professor Steiner, yes, art; but what else is science for than to render into some measure of communicability the sheer inhuman otherness of matter?" That is what we do.

Now, let me follow this path. Understanding and instantiating a properly supported social understanding of our responsibility to steer and critically support science in a framework in which it is understood to be a toolkit for healing our relationship with nature and those that have to do with nature is a profoundly important realization, one whose absence in future might well set science down the wrong road. That is what I have to say about that. It doesn't excuse anything that's gone before. Far from it. But it points out the urgency of understanding what science humanly is for, now and in the future.

SAMUEL LONCAR

It's a profound vision; it's also a summary of what you do in the book, *Faith and Wisdom in Science*. You challenge the presentation of science and theology by doing both in the book. You give the reader a way of understanding, just as you've been doing in this conversation, and then you argue that part of how we need to heal what's gone wrong in science is by having a much better scientific culture that embraces all of us as humans, that doesn't have this contemptuous negative image of the scientific priesthood as the experts who know everything.

Instead, we need to engage science, and you're doing this fascinating and valuable work in the UK with churches. How would you respond to someone who says: *Why do we need a theology of science?* If a person, for example, isn't religious, and they say, *Well, why do we need a theology of science?*

How do you think about building buy-in or creating a culture of understanding?

In the UK—even though I know the statistics about Europe and the UK generally being much more secular in one sense—I think that by having the church as part of the culture, by having bishops in the House of Lords, there's still a degree of integration where what you're doing makes sense, which I think is so valuable.

It's an important thing, the idea that we can use churches and organizations as places to encourage science, but for people who aren't there yet, or it's just so foreign to them culturally, how do you help us understand? Do we really need a

theology of science? Obviously, you have the facts on your side. But why do we need this beautiful vision? You could say it's beautiful and maybe that's good enough. How do we think about this in a really divided context?

A Theology of Science in A Divided World

TOM MCLEISH

We're the nation with the established church where it's perfectly possible to elect an atheist Member of Parliament, and you're the absolute secular state, where it's impossible to elect to the Senate anyone who declares themselves an atheist. And in America you have "In God We Trust" on your banknotes. I can't help you there. I'm sorry, I'm mystified.

But what I say to my secular colleagues is that, like it or not—whether the idea of purpose and teleology is academically kosher or not—we all feel it; we all know it. That's what drives us. And the academic discipline that has maintained the critical tools to discuss teleology and purpose is theology. So it's useful. Even if you run a secular university, I would advise you, Mr. President, to have a theology department for that reason, if none other. Religious Studies is a good idea to have in any case, but for purpose. So that's why I like to mine theology, because I always want to know: what is science for?

In fact, the reason that I eventually wrote *Faith and Wisdom in Science* is that for years, I was asked the question: "How do you reconcile your science—your physics—and your Christian belief? How do you do that?" And, for years, I thought that that was a question. But as we've discussed, that's not the question. That's a non-question. That's like asking, "Have you stopped beating your wife yet?" What do I say, no or yes? That question buys into a world that—fortunately for my wife's case and mine—is not the world we live in, empirically.

So I realized that all our apologetics have been on the backfoot for years by buying into the belief that "How do you reconcile science and religion?" is an meaningful question. It buys into a past which, as we've already discussed, is a polemical past, not a historical past, and a philosophy which is at best a partial philosophy, not a

balanced, evidence-based one. So instead, you ask a new question. I want to know what I'm doing this for. I want to know what this is for. Is it just some personal delight? Am I just intellectually gratifying myself with understanding another molecular fact? I want it to be more than that. I want it to be a gift for others. And that was where Steiner's deeply theological insight actually came to my aid, because there's a job of healing to do.

I've always been impressed by the way St. Paul can capture this new post-resurrection, Christian, creative world of the early church in a soundbite, and I love when he writes to the Colossians (this is like the Steiner quote, something else that

hits me). St. Paul says, Christ was in the world reconciling the world to himself. Actually, the Greek is *kosmos*: reconciling the *kosmos* to himself. And so we have the ministry of reconciliation. That's his little soundbite. I think he was giving a media interview. He was asked: "Paul, are you zealots? Are you terrorists? Are you weird philosophers? Are you a part of Judaism? What is this Christian thing? What do they call you? The Way?" And he says, "I'll tell you. We're just simply in the business of healing broken relationships. That's what we do." He could say that without even drawing on Abraham or Moses or the Hebrew Bible or even on Jesus of Nazareth, who wouldn't have been broadly known across the ancient world at that point. He can say we're in the business of healing. And we all know what that is. We all need that.

And then the other—the third—ingredient, which I'm going to have to mention (no one escapes this conversation until we've visited briefly): the book of Job. So I remember again—as a young scientist, a fairly recent Christian—doing my read through the Old Testament and coming across the book of Job. And again, for the third time—we've had Paul, we've had Steiner, and now we have Job—falling off my chair in absolute delight. Why aren't people singing about this book from the rooftops? Why wasn't I taught this as a kid?

This beautiful poetry of anguish against the world, the chaotic, harmful, frightening world of floods and earthquakes and lightning and storms and the harm they do, and the suffering of the flesh of this poor man, and his friends' simplistic theology—the fact that simplistic theologies are criticized, as such, in the heart of the Bible ought to be more widely known. And then when God finally speaks, when he finally answers Job out of the very whirlwind that Job critiques as being the out-of-control cosmos, comes this poem. The UC Berkeley Hebrew scholar Robert Alter tells us it is the highest poetry in any ancient Hebrew literature. Job itself is the highest poetry, and the best of Job is the Lord's answer: Job chapters 38 to 40. It is a poem about the natural world in which every stanza is a question, and there I am, as a young scientist, encouraging people to realize that science is about openness and imagination.

And one way you can articulate that is to say—and many have—that science is more about questions than answers, and that the critical imaginative move in science is to conceive of the creative question, not to parrot the next answer. I know the answers are what get you to be a scientist because that's what you do in school and college. But we should train kids to ask questions more, because that's what science consists of. Do you know the storehouses of the snow? Do you know where hail comes from? Do you know where the Pleiades are clustered together? Where Orion's stars are cast apart? These are all real questions. And I'm amazed. The Bible's central passage concerning the broken human relationship with the physical world is this poem, where God the Creator invites Job to gaze upon the world as God the Creator gazes, in love and the willingness to make it fruitful and to heal it.

Now, by the way, the secondary literature on Job is largely a disaster area in my view on this one. I know it sounds appalling. How can a scientist say this? I mean, it's an appalling thing to say. But I've learned this in interdisciplinary work: when I work with humanities scholars on medieval science, often they have the best, freshest scientific insights. So it's all free and fair game here. Listen, no Hebrew ever used a question as a put-down. Yet in the critical tradition of the Christian Latin West, we've come to think that the Lord's answer to Job is some sort of put-down, but I'm sorry, it's not persuasive, and we've got to stop reading it that way. It's invitational, it's engaging, it's reconciliatory. It's healing, it's decentralizing. It's full of love for creation, and it's full of the openness of the question.

So take Job, on the one hand, in the Old Testament, and Colossians, on the other—or Romans—and out comes a theology of participating in a deeply holy work: insofar as God makes our world and loves us and heals it, what might the image of God do theologically but to make an image of the world? Well, that's what we do. That's the best description of what science is. It's the image of God, the image of the creator, creating an image of the world. It doesn't get more theological than that. But it doesn't get more faithful to scientific practice and praxis and the felt experience of everyday of a scientist's life. So when theology starts to mirror back in terms that no other discipline can—can match the felt daily, real earthy experience of science—I think we should listen to theology, and why not in partnership with philosophy?

What characterizes a relationship gone sour? Well, the first thing is ignorance. We don't know each other. That's why we don't help each other. Secondly, fear. I'm worried what you're going to do to me next, and you're worried what I'm going to do to you. And out of ignorance and fear can come only harm.

Now, look, if you want a better analysis of our current relationship state with our own planet, I don't think there is one. We've been ignorant of what causes climate change and our effects on it, but we're learning as fast as we can. And we've got to learn quickly. Bushfires wipe out cities: is Los Angeles going to be next? Great

floods on the coastal flood plains, as the sea level rises. It's terrifying and harmful. There's nature harming us. But we now know that we can harm nature, too, in our own century. So what do you do with a classic broken relationship, whether it's between two people, or between the whole human race and their planet? You replace ignorance with knowledge; that's the first scientific step. That's why Paul talks about the ministry of reconciliation having to do with knowledge and understanding. Then you replace fear with wisdom; that's the next step. That's why I called the book *Faith and Wisdom in Science,* because wisdom is how you use knowledge to be fruitful. That's the third stage: you replace mutual harm with mutual flourishing. Now, I can't think of anything more urgent than that. And if you don't like the fact that it's a theologically conceived social or political embedding in science, well, too bad. It's a good one. Whoever you are, I hope you recognize that. So just take it as a gift. You don't have to look at where it comes

from, although I would invite you to look at where it comes from. So that's, I think, why this is so important, and why a theology of science, not the battle between theology and science, is so critical for our time. It's not just about making science more democratic than it is. It's not just about helping science avoid those dreadful eugenic—and worse—experiments in the past that have been committed through its cult of expertise and hegemony. It's about saving the world. How about that?

Science and the Healing of the World

SAMUEL LONCAR

It's beautiful. And so the one last word to bring into that—which you discussed and mentioned. If people don't like the word "theology," then let's just call it philosophy.

Philosophy is the love of wisdom, and love is at the heart of this. You say in the book, in the beautiful passage near the end: "we don't think of scientific practice and love as being very connected." But in reality, as a leading natural philosopher, as a leading physicist, you're saying that they are connected, that this is *why* we do what we do.

They're doing what they do because they love things. They love their theories, so they nurture them. Even when they're young and immature, they're devoted to them—maybe superrationally or, to their opponents, irrationally. And so you make this compelling argument in the book that love is essential to the practice of the most rigorous domain we have in our culture to represent our love of wisdom and knowledge.

And you're saying that that this love is ultimately a love that's ordered towards the healing of the world. You point out every tradition has resources to bring this out. So if they don't like it, that's okay. You're saying: just take it as a gift.

But what you just did is so powerful, because the environmental narratives—and you get into this at the end of the book—they don't work. We have this incredibly bureaucratic, fear-based language. And what you're saying is we need to replace ignorance with knowledge. That's what we're trying to do in science. But we need wisdom about how to use that knowledge. So how do we cultivate a culture of love in science when we are afraid?

How do we cultivate a culture of love when people are terrified of climate change and so the narratives have been very fear based?

How would you encourage people? How do we create a culture of love for the natural world, and even a recognition that this love is what is binding us to even the most rigorous, maybe secular or atheistic-seeming practices?

We're all lovers. How do we build that into the understanding?

TOM MCLEISH

Of course, I'd love to be able to give you a full answer that, and if I could, I think we might be further down the track than we are. But I may tell you a few things.

So one is that we can just open up an understanding of the world. A problem understood is definitely a problem shared; it's a problem halved. So I think one of the problems with climate change is that people just don't understand. They just look at two sides arguing with each other. And as in the football analogy, it's possible to understand. I couldn't run down the field and take a pass and then cross it to the box and score to save my life, but I can see that's a clever move. There's a way of getting into what you love, even if you're not an expert. And I think that understanding how it is that we know what we know and what the uncertainties are—we as scientists are often frightened that if we admit the uncertainty in science, the science deniers will go the whole hog and just take the whole bite, and so when a bit uncertain, then we can just forget it.

But I think most people understand that life is like that. We're not sure which company to invest in, but we've got to invest in something. We're not sure whether to try to have another child or not. It might turn out well, it might not. We've got to make decisions. We can't make non-decisions. And we have to move forward. Everyone understands this, and we make evidence-based decisions all the time, partly on a hunch and partly on partial evidence. We nearly called the Royal Society project "Everyone's a scientist," but some people thought that was a bit of an over-claim. But what we meant was not that everyone should be a scientist, or everyone does science, but actually, people can be caught out doing little scientific things more than they realize they are. That's one thing.

And just to follow climate science with vaccine science: the love and the dedication with which the virologists knew back in early January 2020 that there would have to be a vaccine – the one I know about is the Oxford AstraZeneca one. They actually had the vaccine by the end of February or early March of that year, and then—it was just brilliant—they had to make decisions about which technology to use and what the vector was going to be, and to pull all this together and then how they're going to parallelize all the testing. I mean, it's beautiful, and people who are worried about it would be less worried about it if they heard the scientists explain just more of the story. Jim Al-Khalili's wonderful BBC Radio 4 broadcast '*The Life Scientific*,' where he just talks to scientists, is a lovely one on exactly this topic. Science is full of just one long, lovely human story. We can tell our stories now. That's something we could do.

The other thing we can do is to take some action. Now, one known way of getting over a fear barrier is to start doing something. One known problem about climate

change is that people freeze; the reason that people freeze is this narrative: "Well, I can't do anything by myself. Nothing that I do will ever make a difference." Although if everybody said, "I'm going to do a little something," there would be a huge difference, so actually, even the premise isn't true. Everyone does make a bit of difference. But nonetheless, we know that local projects, in which several people come together to make a local climate difference—it could be decarbonizing the building or street or just sharing a common practice or working on how to save money by together as a community investing in renewable energy or working on carshare or whatever it is. And local organizations that have been extremely effective at doing this—churches, too, for all the reasons I gave—they can be fueled by the theology.

My favorite project started off life in California with some friends of mine. We formed a partnership with them through the ECLAS Project I mentioned before between York and Durham. And they've been offering to churches a theological underpinning of environmental care, together with resources and support for practical projects. It's been extremely effective, not only at making really positive local change, but also taking out the sting of this fear that comes from the feeling "I can't do anything, and I don't know what to do; I don't know what to make of it." Learn the theology and learn the science and learn the practice and enjoy doing it together. This is a model for how this huge project of healing that we talked about as biblically defined by Paul can be cashed out in small local ways, which is exactly what he would have encouraged his local churches to have done in the first century and what little local churches can do now.

Of course, we can also act politically as well. But that's also more powerful when it comes from small groups. And here's something else that the church can do, something that has really paralyzed our debates on climate change in our political action is the tense, reactionary, and adversarial nature of the debates, the

deployment of a lack of respect, of fear tactics, and of course, of lies. So the political and media debates are characterized by these things. Now, take the value of a church community. What would you say were high up on the list of values in the way we should practice our interpersonal discussions, whatever their goals are? Well, pretty high on the list might be respect. Truth. Oh, and we don't let fear through the door. It's an all-too-common preacher's point—and I've used it many times—but what's the most commonly repeated commandment in Holy Scripture? It's not one of the ten; it's "do not be afraid." Almost every epiphany has it. Don't be afraid. Jesus to his disciples, the Lord to Moses, and so forth. A church doesn't have to take a side on an issue in order to support a public conversation, which holds truth high, holds mutual respect high, and replaces fear with wisdom, as we discussed before. And I've seen this happen.

We actually held an earth-science workshop for bishops as part of this project, and we brought the earth scientists into our practical discussion. It was around fracking technology. It turned out that some of these senior clergy had previously worked in

the oil industry and were quite pro-fracking. Others were community leaders for strongly anti-fracking movements. This is back in the day when a bit less was known about it. It doesn't matter what the end of the discussion was. What matters was that I witnessed the most respectful, the most loving, the most deeply pursuant-of-science, and therefore the most productive debate on this issue, even though we had people of opposite convictions and strong feelings in the same room at the same time. Now, if that's not the gift the church can give to public life, the gift of scientifically and technologically linked urgent questions, I don't know what a better one is. So there are a few ways—practical ways, I hope—in which we can move on.

SAMUEL LONCAR

That's extremely helpful. I just want to mention to our readers, since we didn't even get to it, you have a recent book that just came out in paperback called *The Poetry and Music of Science*, comparing creativity in science and art, and I hope we can talk about that. What are some of the other books that you're reading now? Or just things you're reading that you're excited about or that you're working on?

TOM MCLEISH

I'm always reading far too many books at the same time. I like to have something theological on the go. Something poetic on the go. Something science-y on the go. And so I'm actually reading Stephon Alexander. He's a jazz-playing theoretical physicist, and he wrote a book called *The Jazz of Physics*. I'm reading that at the moment because I've gotten interested in aesthetics again, and the tortured question of the relationship between truth and beauty in science. I've also been reading Sabine Hossenfelder's book *Lost in Math*. So those two make an interesting pair

actually. Does the beauty of the equations lead us to truth? And the answer is maybe. That's a current reading project of mine.

On the history of science right now I'm reading anything I can lay my hands on about the eighteenth century astronomers William and Caroline Herschel, because in a month, less than a month's time now, I'm being asked to give a lecture on William Herschel and the discovery of the planet Uranus—a musician and astronomer under George the Third. He, like George the Third, have both an English and Hanoverian descent. And he brought music and astronomy together in the most extraordinary way. The more I go on, the more fascinated I am with the deep, deep-line connections between music and science.

There's a chapter on that in the book you just mentioned, which we will have to talk about another time because that's about another divorce, which is part of the problem. Actually, we could have drawn that as another string to our bow today: the loss of discussion of imagination within science as an essential path to knowledge and the appropriation of imagination by the arts and perhaps the humanities, and rationality by the sciences. That's another divorce, another conflict,

which is artificial and wrong, and we need to bring that back together as well. But that's all for another time.

SAMUEL LONCAR

Thank you so much, Tom McLeish, for your time and for sharing your incredible expertise and the beautiful integration that you bring to everything that you do—and the beauty that you show is just part of the life of a scientist and a natural philosopher. It's a real privilege and a delight. I thank you for it.

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