# Carl Zimmer

## Science columnist, The New York Times

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**Welcome to Media Masters, a series of one-to-one interviews with people at the top of the media game. Today I'm joined down the line by Carl Zimmer, the award-winning The New York Times columnist and the author of 15 groundbreaking books about science. Described as the country's most respected science journalist by New York Magazine, Carl reports from the frontiers of biology, where scientists are expanding our understanding of life. A three-time winner of the American Association for the Advancement of Science's journalism award, in 2021, Carl was a member of the team at The New York Times that won The Pulitzer Prize in public service for coverage of the COVID-19 pandemic. A Yale professor, Carl's most recent book 'Life's Edge: The Search for What It Means to Be Alive' examines perhaps the most profound scientific question of all. Carl, thank you for joining me.**

Thanks for having me.

**It's an incredible privilege to talk to you. I'm a huge fan of your writing. So this might be a little fun for you. It probably won't be good journalism on my part, but you might enjoy it. I mean, if I can ask you the first question, of course — you're the only writer I think I know after whom both a species of tapeworm and an asteroid have been named.**

Yeah, well, those are two very kind honours but from very different parts of the world, I guess. You know, I've written a lot about astrobiology and things like that, which is I think kind of how the asteroid made it my way. And then there was, I wrote a book about parasites called parasite Rex, which where I basically said that parasites were the most successful life form on earth and really deserved a lot more respect. And there was a parasitologist who in college read the book and that gave her permission to go onto grad school to become a parasitologist. And she had some tapeworms to name for new species. And she decided to name one in my honour, which is very nice, but you know, there are a lot of tapeworms out there to be named. So, there's once they finish naming all the tapeworm species, you know, they'll probably be like 40,000 of us that have names of tapeworms.

**Well, no one's named a tapeworm after me. So you went ahead. I mean, I've been compared to a tapeworm on an occasion.**

Well, there’s still plenty of time and an opportunity. That's all I'm saying is just, you know, people want to be named after a tapeworm. You still got a chance.

**That sounds good to me. I mean, congratulations, of course, on being part of The Pulitzer Prize-winning The New York Times COVID team, I mean, the virus certainly put the work of scientists sent a stage in public life, did it not?**

Yes, it really was pretty extraordinary because you know, those of us who were writing about viruses and diseases, we had been doing that at the times, quite steadily through Ebola and other diseases. But suddenly we realised in February 2020 that we were covering the biggest story of the year, maybe the biggest story of the decade, one could argue. And it's been a very intense experience ever since of bringing that science to the, in some cases, the front page.

**Well, especially, you know, given the anti-science movement at the moment. I mean, I remember president Trump famously trying to smear your account of how the virus got to America. You had the honour of him accusing you of fake news in one of his tweets. Did you consider that some kind of bizarre honour that you'd reached a certain level of impact or frankly, as I was at the time, concerned that again, the president of the United States was smearing a science journalist and putting lives at stake.**

I certainly did not expect when I got into the business of science writing that the sitting president would single out my work for an attack that was completely baseless. President Trump was trying to imply that in my article, I was saying that the virus arose in Europe when the article was quite clear that the virus arose in China and then spread to other parts of the world. But for New York City, the virus came from Europe, from people taking people who were already infected with COVID in February 2020, getting on planes, landing and spreading the disease. But, you know, he had political agenda to push and I took the opportunity to just respond to him on Twitter. Not that he would pay attention to it, but, you know, others might, and to just sort of lay out the key points of the story and why it's important for us to understand how this virus was spreading. Because the fact was that the tragic thing was really that COVID was in the United States many weeks before we really realised just how widespread it was. So there were people in New York City and some other cities just walking around, not realising they had COVID, spreading it to other people. And so then suddenly in March, you know, hospitals started filling up and it seemed to come out of the blue, but in fact, it had been simmering for weeks. And we just didn't have good tests to see that it was already here.

**I'm a Brit and I, and a lot of Americans, aren't flabbergasted by this, of course as well, but just how science, the scientific method, the commitment to truth has become politicised because it's not really about politics, but when you have a frankly, a crazy president making false allegations, you have to step in, you know, should scientists get directly involved in political debates. It seems like you're being dragged into something that reluctantly, but that you have to do. I mean, look at evolution — if it's not taught in our schools, then how are our young people going to frankly, learn the truth about how we evolved as a species?**

I think I was maybe more prepared for an anti-science pushback than maybe some other journalists were just because, you know, not only am I a science journalist, but a lot of what I did early in my career was on evolution. And so I was working at a magazine where people were covering different topics and evolution was my thing, and I loved it and it was great. And it was an amazing experience. And I still write a lot about evolution, but I was the one who would get lots of emails, I'm sorry, this is before email — I would get lots of letters from creationists. And then you know, these well-funded creationist organizations we have in the United States would single me out for attack and distort what I was writing and just go after me, you know, month after month. So I knew what this experience was like, and it was disappointing to see that during COVID, that happened all over again, but it really comes with the territory, you know, part of it is that people tend not to really have a great understanding just what the scientific process is like. So then it can be easy to use cherry-picked quotes or misleading depictions of how science works to then get people to think that 'oh, these scientists have some sinister agenda', you know, and then we saw this with global warming, where climate scientists were villainized. You know, there are reasons that people want to distract the public from the threats of things like global warming, but here we are years after these attacks on climate scientists were made and we didn't have prompt action to deal with climate change. And, you know, now

London is burning. I mean, we are now living through the extreme weather and other impacts of climate change that we had been warned about decades ago. But, you know, there was a strong concerted campaign to undermine the trust in climate scientists. And it was quite successful.

**You've written several very authoritative books on evolution — is taking on, you know, the creationists in this aspect, but as you make the wider point there about climate change deniers, is it a constant battle? I mean, I'm glad you do it, but it must be tedious. I mean, I've had the privilege of knowing professor Richard Dawkins for many, many years, and I've worked with him from time to time and he taught me an excellent phrase, which is that you can't reason someone out of a position that they didn't reason themselves into. Is it futile?**

Well, I would say that the way I deal with it is that I try to just keep focused on the science and the real pleasure there is in learning about the history of life. I just find this research endlessly fascinating and I'd like to share that fascination with my readers. So I might be writing about a new fossil in an article for The New York Times, or I might be writing a book about some particular aspect of evolution, or, you know, I've also written a couple of textbooks where I try to give the whole broad overview of the evolution and, you know, there I want to present it as it is — as a very vibrant science and so that I think is, you know, ultimately an effective way to counteract all these claims that evolutionary biologists are terrible people who just want to, you know, do terrible things to our school children or whatever you hear from creationist outlets and various politicians. Because you can just see, like, look, I mean, the history of life is astonishing, it's surprising, and we can actually understand by looking at fossils and DNA and living organisms, some of that history we can put together billions of years of our history. And it's quite remarkable. And it's something that keeps changing so that even, you know, with our own species, you know, scientists in recent years have been finding some really exciting new fossils of ancient humans, ancient relatives of humans that really helped to flesh out that tree of life that gave rise to us. Creationists will then say 'ah, you see, here's some new thing' and it tells us that evolutionary biologists don't know anything, but like that gets everything completely backwards. The whole point of science is to come up with explanations that do a good job of making sense of the evidence that we have, and then look for new evidence and see, well, does that fit with what we thought or does that require us to update the way we think? And if that's true, whether you're talking about evolution or astronomy or any of the sciences.

**I watched a YouTube video a few years ago called 'Four Horsemen' and it was Sam Harris, Christopher Hitchens, Daniel Bennett, and obviously Richard. And one of the things that I can still remember from that is they compared the origin story of the Bible to that of science. And they said the Bible is an old book that not only do you have to trust it 100% but it's blessed for us to question it, whereas in compare that to us and they search for truth is that we're constantly trying to test the evidence of our theory for the origin of the universe against what we see. And that's why it emerges, evolves and changes. That's why the doctrine of inflation, for example, is being explored at the moment, because if we have a theory and it doesn't quite fit the facts as we see them, then we seek to perfect the theory. And that for me is the scientific method.**

Yes. So I mean, certainly that is a scientific method. I mean, as a journalist and as a book author, I don't get involved with disputes about religion. You know, I'm not a theologist.

**Sensible, isn't it? It's the hairdresser's remit, isn't it — never mention religion or politics because it's just inevitably divisive and I think you're telling right. I mean, I was actually going to say, I was taught that science at school, the old way, which alienated me, you know, that physics was the most important one, and then to lesser extent chemistry, and biology was never even mentioned. It was almost like an afterthought and having read your most recent book 'Life's Edge' and learning about the more that scientists are learning about the living world, they have that finally, how to even define what life itself is and locate at the edges. It's just absolutely fascinating. I feel that I was sold a puppet school in college because actually biology is the most fascinating of all of the sciences and the study of life itself. And frankly, on the physics front, they can't even explain 96% of the universe, where's the missing mass and where's the expansion, so you will leave them to it. I mean, biology is infinitely fascinating.**

I certainly agree that biology is infinitely fascinating, but I do not try to compete with my colleagues who write about physics or chemistry or so on. I think there's plenty of fascination to go around. I do think that biology certainly up until recently, hasn't really been presented with the excitement that it deserves. I mean, certainly, in high school, I got a very lacklustre biology education, pretty forgettable and you know, I really had to kind of discover it on my own. I grew up on a small farm and I was seeing lots of life all around me and would, you know, read about it, and then really once I became a science writer, I mean, I would just become this wonderful ongoing education where I could read about scientific research and biology and then just call people up and they were really enthusiastic to talk about what they'd been up to and then I'd ask, 'well, can I come and pay you a visit at your field site or at your lab?' and they'd be 'like, yeah, come on over'. So I felt very fortunate to be making up all these years for that bad start in my biology education.

**You wrote recently that you were in awe of viruses and their ability to hijack cells. I like the use of the word "awe" really because what they do is awe-some, isn't it? And we underestimate them at our cost. We need to know our enemy. One of the things, obviously I find fascinating about viruses is the whole debate about whether they constitute life, whether they're alive or not. I mean, when you look at the Mimivirus, for example, these mega viruses, some of them are bigger than, you know, things that are quote-unquote alive, like bacterial cells and so on. No, one's better qualified than you to answer this, but like forgive the profound nature and possible banal nature of this question, and how I put it, but like, what is life?**

Amazing question. Perhaps the most important question there is in biology and it fundamentally is very difficult. Maybe impossible to answer. The problem is that we're trying to seek a definition when we ask that question when what we probably need is a theory. In other words, a broad explanation for a phenomenon that then leads to predictions and new research, and so on. When alchemists were trying to make sense of the materials that they were experimenting with, you know, if they said, 'well, what is water?' It was almost pointless for them to ask the question because they just lacked, really lacked the concepts to even begin to understand what water is. And it would be centuries before modern chemistry emerged and produced a theory about atoms and molecules that made water much less mysterious and we could talk about water in terms of H2O and so on. And then that would lead to lots of experiments to look at the behaviour of water. So life is, I think, you know, what life might turn out to be, might be a spontaneous property of matter that involves a remarkable level of organization and replication. But, you know, it's, even when I'm talking about it here, I'm sort of falling into just giving you like a shopping list, a cat, a list of characteristics. And that's not really a definition.

**I like what you're saying about the theory because I mean, we know almost everything about gravity in terms of its effects and how it works, and so on, the only thing we don't know is what it is. We think it's a distortion of space-time and the universe is a flat rub sheet and the more mass it has, that's why there's all 'blah, blah, blah'. But we still don't quite know what it is. Maybe that is the answer to this question, that it's not the question that we need to be asking. As you were answering that, I remember when I did my law degree, years ago, there was some supreme court case about pornography and the court was having to define what pornography was, and one of the supreme court justices says, 'I can't define it, but in one sense, it's like an elephant — I can't describe it, but I know it when I see it.'**

Well, I think with life, one reason that life is particularly vexing in this regard is that we're all alive. And so our brains are set up to monitor our internal states. In other words, we know what it feels like to be alive. We know that experience. So if it's obvious to us what it feels like to be alive, then we feel like, well, it shouldn't be that hard to define life, but it has to sort of include us. And in fact, we kind of make ourselves the centre of any definition of life, but, you know, that gets us into all sorts of problems because the vast majority of life is not like us. So most things on earth that we would consider alive, don't have brains to start with, you know, and the brain is very important to our definition of life. In fact, the legal definition of death is brain death. It's that the brain becomes what defines us as truly being alive.

**It does now of course, but of course, one of the difficulties historically in defining death is we didn't know what life was. So death used to be that you weren't breathing. And now that we have the ability to prolong life or life via a ventilator, it's become brain death and now brain stem death. I mean, it's a continuum perhaps, is it not?**

The thing is that like, you know, defining death as brain death, it's not a sort of a purely objective statement. I mean, as you say, things have changed. And one of the reasons they've changed is because we have made choices about what's important to us. So these are there. These are judgments about the value of things and different kinds of experiences. So, you know, someone who is on a ventilator, but who is showing no response from their brain, and there's no chance that they're gonna recover. You know, we have come to agree largely as a society that that's not really being alive. And there's an opportunity for someone else to gain a meaningful life by receiving organs from that person. So this is all tied up with organ donation, you know, like the invention of these ventilators, and at the same time, the development of transplantation surgery created this pressure to change how we think about what it means to be alive and to be dead. And that's okay, I mean, that's all right, but we just have to make sure that we do not make mistakes about pretending that something is just somehow purely quote-unquote scientific and completely outside of our experience as human beings.

**I remember when I was at school again, my biology teacher said 'one of the things that we can be certain of in defining life was that we either eat plants or we eat the animals that ate plants, and therefore photosynthesis is the key to life.' And of course, now we know about chemosynthesis, you know, the bacteria thriving on the ocean floor using sulphur released by the thermal vents and combining that with oxygen and carbon dioxide to create sugar. I mean, even that, what I learned was the only thing that is key to life, isn't?**

We do have a habit of looking around us and deeming what we've learned about biology and saying, 'okay, that's it.' And now we can start making some absolute rules. And as you say, life has a way of surprising us and breaking those rules a lot of the time. So, you know, I think we have to, you know, it's okay to sort of think about the possible boundaries of life, but we have to have a light touch. So for example, you know, some people have said like 'well, life is a way of copying DNA.' I mean, you can make DNA central to your concept of life if you're just talking about life on earth. As far as we can tell all cellular life is based on DNA now, of course there, you know, you mentioned viruses, a lot of viruses actually use RNA for their genes of DNA, but, you know, they have to infect cells that have DNA. So, you know, maybe they're kind of an extension, but on the other hand, a lot of scientists have actually decided that probably life on earth began with RNA-based life, like cells with RNA in them. And then that gave rise to DNA-based life. And it's possible if we were to get to other planets and find life there that leaving aside what it means to define life, you know, we might find things that use other molecules to store genetic information. There's no reason to totally rule out the possibility that other elements on the periodic table could produce a gene — it would be tragic to send probes out to other planets, looking for life that could only find DNA, that could only find DNA-based life, because if we don't find it, it would be a mistake then to say like, 'ah, well, there's no life out there.' I mean, all that would tell us is that 'well, there's no DNA-based life out there,' but we could just be missing the other kind of life that's right nearby because we don't know how to look for it.

**Or we could be the aliens. I mean, space rocks have fallen to earth in the last a hundred years within the last century. So that contain the five bases, that store information in DNA and RNA, maybe there is that, you know, this emerging theory that in fact life started away from earth and we came in on an asteroid and you only have to see the fact that if you script the outer shell of the international space station, you can find life, are tardigrades there?**

Well, we bring the tardigrades there to the space station like that, it's not like they're hanging out.

**Sorry, my question wasn't properly built, but it can survive in space, it’s that I suppose what we say, maybe we are the aliens?**

Right, I mean, in a way, this is actually not all that new of an idea. In the 19th century, people were speculating about whether life could spread from planet to planet. You know, this was around the time that microbiologists were discovering bacteria and also discovering the bacteria could form these incredibly tough spores that seemed to withstand virtually everything. So the question now is could life have begun to stay on Mars, which is a smaller planet, with less gravity, and so it might be easy relatively speaking for, you know, an asteroid to smash into Mars and loft up some rocks with bacteria inside them, which then float around for a while and then land on earth and then seed our planet. Things that happen 4/4.5 billion years ago are really hard to pin down, obviously. I don't think that we can rule that out, but you know, there's still no strong evidence yet that that actually is what happened. And there are plenty of compelling scenarios that scientists are developing for how life started on earth. So we'll see but yeah, it's something that certainly can't be ruled out and it does make you wonder is life on earth floating out there in space just wandering around?

**Talking of the creation of life, I read Mary Shelley's ‘Frankenstein’ recently, of course, Victor very firmly created life with his monster. And then the book I read after that was ‘Life's Edge’, your own book, where you yourself followed Victor in trying your own hand, evolving life in a test tube, and with frankly unnerving results. I mean, could you share with our listeners that journey, that was just absolutely, that was genuinely blown away.**

I didn't actually make life from scratch, I should point out, but it was a lot of fun to actually carry out an experiment to watch evolution happen basically in front of my eyes, I had the opportunity to work with a couple of scientists where they just kind of watched over me and made sure I didn't screw things up. And so what I was doing was taking bacteria and very common bacteria that grow on the surfaces of the plants and things like that, and I had it in a test tube growing on these little beads. And what I would do is I would transfer the bacteria on those beads to a new test tube each day, which also had beads on it. And they would try the bacteria would jump on those beads and replicate and so on. And the thing was, what I was doing was I was actually carrying out natural selection, I was playing that part because, you know, the bacteria that were able to grab onto these beads and grow successfully on them, they were the ones that were most likely for me to, to reach in with my tweezers and move them onto the next test tube. At the end of the process, we were able to, you know, take those beads and like take the bacteria and spread them out on Petri dishes and watch them grow, and then compare them to the bacteria on Petri dishes from the start of the experiment. And this was just really just over the matter of about a week. And it was kind of amazing that like these were different bacteria. Like they grew in colonies that were different shapes. It was very strange and it really just shows you that evolution is such a powerful ever-present force and even an idiot who's just learning about how to run a microbiology experiment can make it happen and make it just visible to the naked eye. So yeah, so that was a huge fun and I should point out this was actually developed at the University of Pittsburgh as a high school science class experiment.

**It’s absolutely fab.**

I really wish that my high school biology class had been like that. I did not have a high school biology class that had that kind of stuff. So I'm a little jealous of kids who these days have biology teachers who take advantage of all the stuff that's out there. There are so many opportunities to appreciate how biology works in a deep way, even if you're a high school kid.

**As I said to you before we started this podcast, I feel I was let down, by the way, I was taught science at college and at school, because I've since discovered it’s learning about how the world works and, to my shame, it took me to sort of my thirties to realise, to discover the joy of science. I was actually reading your book — she has her mother's laugh. And one of the**

**quotes that came to mind then is you were talking about biology classes is that you, one of the quotes I remember is you saying "research is overturning the things that you were taught in biology classes" and absolutely fascinating study that book into genetics, heritability acquired traits. Is that your beat then? Do you consider life and the definition of life to be your beat?**

Yeah, I mean the broadly defined I feel very fortunate that it's a huge universe of research to explore. And yet, there are these connections between them all so that, you know, I might be writing about COVID one day, and then writing about the possibility of life on other planets the next day. But I can see connections there that there are the same kind of underlying questions and underlying concepts that apply to them both. So the fundamental questions about life itself, they matter to us in a very deep and practical way, like medicine is applied biology and so if we want to take good care of our own lives, it helps to get a deeper understanding of life across the board.

**Like what's in happening for the medium term for you. I mean, coronavirus still hasn't gone away. What are the sort of big-ticket stories that you are working on at the moment? I imagine given you're such a prolific author, you must have some books along the way, and others planned.**

I kind of jumped on the COVID team at The New York Times at, I guess, the end of February 2020. There was a good, I don't know, over two years where pretty much was only writing about COVID, day in and day out. And, you know, sometimes writing a couple of stories a day because maybe there was a new variant that had popped up and maybe there were new results from a vaccine trial. There was just, it was basically, taking science and turning it into sort of a breaking news story. And, you know, there were so many vaccines that eventually I decided that we had to run a tracker to just keep track of every single vaccine in clinical trials and we've got, I don't know, 120, 130 of them now that we're trying to keep track of. So it was very different from any experience I had after that, and you know, unfortunately, the pandemic is not over, no matter what people might want to say, but I think, a lot of the basic science of the pandemic is now fairly well worked out, we know this virus quite well compared to other viruses. And so, you know, I'm still writing about COVID but at a slower pace, so now I'm kind of trying to pick aspects of COVID that I can kind of dig into and write, you know, longer pieces and thinking about kind of where things are and where things are going. I do wanna work on a book about COVID and I've got an idea for a book, but it's not, I don't wanna say too much about it now, but suffice to say that I'm interested in how this experience of COVID has fit into some broader, scientific questions that we've been dealing with for a longer time but in the meantime, you know, I'm turning back to a number of the things that I was writing about in the before times. And it's really, it feels good to get back to them, you know, one of the questions I've always been fascinated by is how our ancestors came on land. And I wrote my first book about that. It's called 'At the Water's Edge.' So, you know, that's a book that came out 22 years ago, but, or no, 24 years ago, sorry, 24 years ago. And I went back and interviewed one of the key people in that book, because he's got a new fossil that, you know, tells us something new about, you know, that transition that we did not know about before. So that's been quite refreshing after a couple of years of being in the COVID trenches.

**Yeah, absolutely. It changes good as the rest. What are the hot topics in biology at the moment, other than the usual suspects that we've just discovered now? I mean, you talk to a quantum physicist and they'll talk about dark energy and dark matter. You know, I remember reading debates between Stephen Jay Gould and Richard Dawkins about the mechanisms of evolution, all of these kind of things. What are the controversies at the moment, what are the hot topics within the biology sphere?**

I think that there are just so many because there are just so many different fields of biology that are moving forward in interesting ways. And I guess also like maybe the way we approach them is changing in interesting ways because we get new tools. So one tool that I've written about a lot is CRISPR, which is this technology for editing DNA. And so people tend to just, if they've heard of CRISPR, they think, "oh, that's the designer baby thing" and, you know, it is true that you can edit the DNA of embryos with CRISPR. That's true. But really like if you look across biology, that's not where the action with CRISPR is.

**I'm excited by CRISPR because I want the body beautiful without having to resort to frankly, diet and exercise.**

Yeah. Don't hold your breath on that. Yeah. No, in the meantime…

**Oh.**

Sorry. Yeah, and really like, you know, for biologists who wanna understand life better, I mean, CRISPR's an amazing tool because you can precisely shut down different genes or you can dial down how much protein an individual gene makes or increase it, and then you can start to ask questions like, okay, well, you know, without this gene what happens or, all right, let's, swap this set of genes for different ones and see how that changes, how this cell behaves. And so, you can come up with, you know, like a catalogue of all essential genes in a cell. Like you can do that now. And you know, of course, then the question is like, okay, well, why are they all essential? And how do they work together? CRISPR then lets you address those questions. To me it seems like, you know, there are big, there are some questions that are so big and wide open that it's not even like there's, I wouldn't characterise them as like, you know, the hot debate because people are just trying to get their bearings. We're at the point where scientists are starting to like piece together entire networks of how thousands of genes inside of cell, and the switches that turn them on and off, how they all interact. So that's just, it's a huge challenge, but it was an unthinkable one before and now with things like CRISPR, it becomes possible. So it's fascinating to watch that biology sort of rose to this new level of complexity.

**It's truly mind-blowing, isn't it, to think that we have, in a sense, a code in all of our cells that then proteins read that code and then make me, and I was, my mind was blown even further a couple of years ago when I realised that I'm not even me, like the majority of my biomass that presents in my pants and shirt right now is actually bacteria. That isn't me, that's in my gut and, and all over the microbiome. I mean, it actually is more than I am. Am I their parasite rather than the other way round?**

I wouldn't say that it's the majority of your biomass because it's, you know, if you took all the bacteria and other stuff, that's, you know, living on you and in, you would come to a few pounds. So just pound for pound…

**But they outnumber me, don't they?**

Yes. Well, if you count up the cells you probably have, it's probably roughly a tie between the human cells and the cells of bacteria.

**Fallen into the trap of a non-scientist asking as someone who actually knows what they're talking about and getting the question phrased wrongly.**

No, no, no, but you may have, look, science changes. It was just a few years ago that, you know, the general estimate for how many, you know, microbes are in the human body. It was like, you know, they outnumbered human cells 10 to 1. That was the estimate. And then people just did a more careful survey and made more careful estimates. They're like, no, I think it's about even so maybe about 30 trillion microbial cells, about 30 trillion human cells in your body. But you think about it like those microbes, those bacteria, those fungi, those viruses, those part zones that are living in your body, they come in thousands and thousands of species and each of those species has its own distinctive set of genes. So if you were to make a catalogue of the genes in your body, there would be about 20,000 or so protein-coding genes considered human and maybe another 10,000 or 20,000 that encode RNA molecules, we don't really know yet. So let's just say 40,000, you know, there'd probably be hundreds of thousands of genes in your body that are not human. So genetically speaking, you're not human. And some of those genes are actually really important to your survival because those genes can encode things like synthesising vitamins or breaking down certain substances that you can then turn into food or breaking down other substances that would otherwise be toxic to detoxify poisons and so on. So basically there's a huge amount of sort of genetic wherewithal and the microbiome that you depend on for your own wellbeing.

**I mean, the importance of the microbiome has really come to the fore recently. I have an American friend that blames, what he considers his increased propensity to illness, on the fact that he was born cesarean — he doesn't blame his mother, obviously, but he blames the American medical system. He says that, you know, midwives and doctors get more money if they perform a cesarean and it's just human nature. And he regrets the fact that he didn't get to travel down his mother's birth canal because the exposure to all to her microbiome, you know, obviously he would say has would've stood him in good stead to battle disease. And I mean, I just find that's absolutely fascinating as well that they're not an inconvenience either there, as you've said, they're absolutely crucial to the success of our lives.**

I don't think that you can, you know, as an individual, you know, the real medical issues you may be dealing with, you know, in adulthood on whether you did or did not get a C-section when you were born you know, these things are complex and there are studies that show that there are some differences in the microbiomes of kids who are born C-section versus kids who are born vaginally. And it is true that, you know, a mother's birth canal is coded in bacteria. And those bacteria take on some interesting changes right before birth. So, you know, it is possible that that is an adaptation that, you know, that the mother is seeding the baby, and that might be important for development of the immune system and digestion and so on but you know, our microbiomes are so complicated, you know, they're different from one person to the next and each of us, they change over time. So that it's really hard to, to translate, you know, differences that might be seen in a small survey to, you know, really sort of practical sort of medical guidance. And so, you know, I find the microbiome really fascinating, but when I'm reporting on it, I really I've learned to use a light touch because if you see a pattern there in the data one day, you know, once scientists go out and sequence a bunch more microbes the next day, the pattern may change. So it's really kind of we're still really very much in the early days of discovery now, you know, because we've only had the tools to really identify microbes individually based on their genes for, you know, maybe 10 or 20 years — before then, it was really hard to know what was really in us because you know, most of the things that grow inside your body they're not happy on a Petri dish, they don't wanna be there. It's in fact, it can be, you know, just sitting there exposed to the air that can be lethal to them, but you can, if you can fish out the DNA from stuff on your skin or in your stool or so on, like all of a sudden, a whole world opens up.

**Your writing has inspired so many people, but you in your journey have inspired countless more, including me. What advice would you give to a young person inspired by science journalism, listening to what you've done that wants to embark upon a career in science journalism? What are the tips and tricks to succeed? What are the lessons that you could impart to someone so that they succeed?**

Well, usually the most successful pieces of science writing are involved telling a story, and that means figuring out what the story is. And that can be hard when you're staring down at a whole bunch of pretty obscure papers and trying scratching your head over what's going on. But what I find is that, actually when I talk to scientists, they very quickly will sort of bring things into focus and tell me a story you know, about say like, “well, what is all this?” and “why did you start doing this?” and “where do things stand?” They tell me a story. That's how we communicate. And so it's important to remember that when you then sit down to write something or do a podcast or so is to try to tell a story, stories have people in them, people doing things — when I'm teaching writing I'm tediously insistent about working hard to use the active voice instead of the passive voice. You know, people are doing things and things are not just done and then to use as much as possible the kind of language that you and I have been using, we have not been bogged down in jargon. Jargon is very useful in certain settings, but you lose your audience. The more jargon you use. And so it can take work to find good alternatives to jargon, but that work pays off.

**When you said that, I was reminded of Stephen Hawking in his book, 'A Brief History of Time', his agent said to him, "for every equation that you put in this book, you'll have the sales", so he asked his agent and he said, "can I just use one then?" and he said "E=mc2" and they could explain it, but I thought that was fascinating. I mean, just to carry on the discussion about sort of young people sales in their career, you were appointed professor adjunct in the department of molecular biophysics and biochemistry at Yale. Are you inspired by the work being done by the students there?**

Oh yeah. I mean, it's great to work with students there. You know, some of them are people who are thinking about journalism as a career. Some of them are going off to, you know, medical school, but they wanna be doctors who can actually communicate with their patients. And some of them have been, you know, influenced by what we've seen with COVID to say, like, I wanna be somebody who can actually speak to my community about how to stay healthy. And then there are scientists, graduate students in science that I've also worked with in workshops who, you know, they're working on agroforestry in Ethiopia or studying ocean circulation and they think that their field is really exciting and important, and they wanna be able to share that, but there's sort struggling because they're, you know, they've learned how to talk like a scientist, which is good for their career, but not so good to reach a broad audience, so yeah, so their enthusiasm is very infectious and, you know, they kind of hold me to account because, you know, I've been learning for myself how to write all these years and I'm still learning and I've come up with some principles and practices that I think are good, but, you know, they hold me to account by saying, well, why is that something good? Why don't you like my draft? I mean, you need to like, explain that to me and they're totally right. And so that kind of forces me to articulate, I think, makes for good writing and, and how to get there.

**I know the phrase "mind-blowing" is a bit cliche these days, but when was the last time your mind was truly blown by either insight or development? I mean, clearly, you're in the business of reporting and learning new things, but when was the last sort of new thing that you learned — I'm thinking of Donald Rumsfeld when he said "the unknown unknowns"?**

The nice thing about science writing is that there can be these little mind-blowing experiences and big ones just, you know, every week really. You know, it's quite common for me to come across a new study in a given week where I'm like, “wait a minute, is that really? No, that can't be right”, you know, that's crazy and actually I mentioned this transition to land I was talking about, and I have to admit, I had my mind blown when the scientist, Neil Sheehan got in touch with me, you know, he had before, like he had done this amazing work finding fossils of these fish with legs and sort of almost getting towards having feet and with toes and sort of setting up the anatomy that would allow ancestors to go on land, you know, this amazing transition that, you know, life would never be the same. So then he let me know that he and his colleagues had actually found a fossil from the same period about 370 million years ago, where you had something that had basically reverted back to being swimming around like a fish, like it couldn't walk around anymore. Its limbs sort of evolved back into fins as it were. And you know, this has happened in the history of life, you know, whales, for example about 50, 40 million years ago, they went from being kind of, you know, cow leg or hippo, like mammals on land to swimming around in the ocean. But this kind of return to the water, like literally happened, like at the very beginning, at the very beginning. And, you know, like when we have this sort of March of Progress, kind of mindset about how evolution works, evolution comes up and says like, "no, I don't need to follow your rules”. So yeah. So this particular fossil, I just was just stunned by.

**Carl. That was a hugely interesting conversation. I've been looking forward to speaking with you for so long. I'm very honoured that you took the time to do this. I've read about four or five of your books, and this has just been an incredible privilege and it was exactly what I thought it would be. Thank you ever so much for your time.**

Thanks so much for having me

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