We Are Stardust—Literally

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Astrophysics and medical pathology don't, at first sight, appear to have much in common. What do sunspots have to do with liver spots? How does the big bang connect with cystic fibrosis?

Astrophysicist Karel Schrijver, a senior fellow at the Lockheed Martin Solar and Astrophysics Laboratory, and his wife, Iris Schrijver, professor of pathology at Stanford University, have joined the dots in a new book, *Living With the Stars: How the Human Body Is Connected to the Life Cycles of the Earth, the Planets, and the Stars*.

Talking from their home in Palo Alto, California, they explain how everything in us originated in cosmic explosions billions of years ago, how our bodies are in a constant state of decay and regeneration, and why singer Joni Mitchell was right.

"We are stardust," Joni Mitchell famously sang in "Woodstock." It turns out she was right, wasn't she?

Iris: Was she ever! Everything we are and everything in the universe and on Earth originated from stardust, and it continually floats through us even today. It directly connects us to the universe, rebuilding our bodies over and again over our lifetimes.

That was one of the biggest surprises for us in this book. We really didn't realize how impermanent we are, and that our bodies are made of remnants of stars and massive explosions in the galaxies. All the material in our bodies originates with that residual stardust, and it finds its way into plants, and from there into the nutrients that we need for everything we do—think, move, grow. And every few years the bulk of our bodies are newly created.

Can you give me some examples of how stardust formed us?

Karel: When the universe started, there was just hydrogen and a little helium and very little of anything else. Helium is not in our bodies. Hydrogen is, but that's not the bulk of our weight. Stars are like nuclear reactors. They take a fuel and convert it to something else. Hydrogen is formed into helium, and helium is built into carbon, nitrogen and oxygen, iron and sulfur—everything we're made of. When stars get to the end of their lives, they swell up and fall together again, throwing off their outer layers. If a star is heavy enough, it will explode in a supernova.

So most of the material that we're made of comes out of dying stars, or stars that died in explosions. And those stellar explosions continue. We have stuff in us as old as the universe, and then some stuff that landed here maybe only a hundred years ago. And all of that mixes in our bodies.

Your book yokes together two seemingly different sciences: astrophysics and human biology. Describe your individual professions and how you combined them to create this book.

Iris: I'm a physician specializing in genetics and pathology. Pathologists are the medical specialists who diagnose diseases and their causes. We also study the responses of the body to such diseases and to the treatment given. I do this at the level of the DNA, so at Stanford University I direct the diagnostic molecular pathology laboratory. I also provide patient care by diagnosing inherited diseases and also cancers, and by following therapy responses in those cancer patients based on changes that we can detect in their DNA.

Our book is based on many conversations that Karel and I had, in which we talked to each other about topics from our daily professional lives. Those areas are quite different. I look at the code of life. He's an astrophysicist who explores the secrets of the stars. But the more we followed up on our questions to each other, the more we discovered our fields have a lot more connections than we thought possible.

Karel: I'm an astrophysicist. Astrophysicists specialize in all sorts of things, from dark matter to galaxies. I picked stars because they fascinated me. But no matter how many stars you look at, you can never see any detail. They're all tiny points in the sky.

So I turned my attention to the sun, which is the only star where we can see what happens all over the universe. At some point NASA asked me to lead a summer school for beginning researchers to try to create materials to understand the things that go all the way from the sun to the Earth. I learned so many things about these connections I started to tell Iris. At some point I thought: This could be an interesting story, and it dawned on us that together we go all the way, as she said, from the smallest to the largest. And we have great fun doing this together.

We tend to think of our bodies changing only slowly once we reach adulthood. So I was fascinated to discover that, in fact, we're changing all the time and constantly rebuilding ourselves. Talk about our skin.

Iris: Most people don't even think of the skin as an organ. In fact, it's our largest one. To keep alive, our cells have to divide and grow. We're aware of that because we see children grow. But cells also age and eventually die, and the skin is a great example of this.

It's something that touches everything around us. It's also very exposed to damage and needs to constantly regenerate. It weighs around eight pounds [four kilograms] and is composed of several layers. These layers age quickly, especially the outer layer, the dermis. The cells there are replaced roughly every month or two. That means we lose approximately 30,000 cells every minute throughout our lives, and our entire external surface layer is replaced about once a year.

Very little of our physical bodies lasts for more than a few years. Of course, that's at odds with how we perceive ourselves when we look into the mirror. But we're not fixed at all. We're more like a pattern or a process. And it was the transience of the body and the flow of energy and matter needed to counter that impermanence that led us to explore our interconnectedness with the universe.

You have a fascinating discussion about age. Describe how different parts of the human body age at different speeds.

Iris: Every tissue recreates itself, but they all do it at a different rate. We know through carbon dating that cells in the adult human body have an average age of seven to ten years. That's far less than the age of the average human, but there are remarkable differences in these ages. Some cells literally exist for a few days. Those are the ones that touch the surface. The skin is a great example, but also the surfaces of our lungs and the digestive tract. The muscle cells of the heart, an organ we consider to be very permanent, typically continue to function for more than a decade. But if you look at a person who's 50, about half of their heart cells will have been replaced.

Our bodies are never static. We're dynamic beings, and we have to be dynamic to remain alive. This is not just true for us humans. It's true for all living things.

View Images

Stars are being born and stars are dying in this infrared snapshot of the heavens. You and I—we come from stardust.

Photograph by NASA, JPL-Caltech, University of Wisconsin

A figure that jumped out at me is that 40,000 tons of cosmic dust fall on Earth every year. Where does it all come from? How does it affect us?

Karel: When the solar system formed, it started to freeze gas into ice and dust particles. They would grow and grow by colliding. Eventually gravity pulled them together to form planets. The planets are like big vacuum cleaners, sucking in everything around them. But they didn't complete the job. There's still an awful lot of dust floating around.

When we say that as an astronomer, we can mean anything from objects weighing micrograms, which you wouldn't even see unless you had a microscope, to things that weigh many tons, like comets. All that stuff is still there, being pulled around by the gravity of the planets and the sun. The Earth can't avoid running into this debris, so that dust falls onto the Earth all the time and has from the very beginning. It's why the planet was made in the first place. Nowadays, you don't even notice it. But eventually all that stuff, which contains oxygen and carbon, iron, nickel, and all the other elements, finds its way into our bodies.

When a really big piece of dust, like a giant comet or asteroid, falls onto the Earth, you get a massive explosion, which is one of the reasons we believe the dinosaurs became extinct some 70 million years ago. That fortunately doesn't happen very often. But things fall out of the sky all the time. [Laughs]

Many everyday commodities we use also began their existence in outer space. Tell us about salt.

Karel: Whatever you mention, its history began in outer space. Take salt. What we usually mean by salt is kitchen salt. It has two chemicals, sodium and chloride. Where did they come from? They were formed inside stars that exploded billions of years ago and at some point found their way onto the Earth. Stellar explosions are still going on today in the galaxy, so some of the chlorine we're eating in salt was made only recently.

You study pathology, Iris. Is physical malfunction part of the cosmic order?

Iris: Absolutely. There are healthy processes, such as growth, for which we need cell division. Then there are processes when things go wrong. We age because we lose the balance between cell deaths and regeneration. That's what we see in the mirror when we age over time. That's also what we see when diseases develop, such as cancers. Cancer is basically a mistake in the DNA, and because of that the whole system can be derailed. Aging and cancer are actually very similar processes. They both originate in the fact that there's a loss of balance between regeneration and cell loss.

Cystic fibrosis is an inherited genetic disease. You inherit an error in the DNA. Because of that, certain tissues do not have the capability to provide their normal function to the body. My work is focused on finding changes in DNA in different populations so we can understand better what kinds of mutations are the basis of that disease. Based on that, we can provide prognosis. There are now drugs that target specific mutations, as well as transplants, so these patients can have a much better life span than was possible 10 or 20 years ago.

How has writing this book changed your view of life—and your view of each other?

Karel: There are two things that struck me, one that I had no idea about. The first is what Iris described earlier—the impermanence of our bodies. As a physicist, I thought the body was built early on, that it would grow and be stable. Iris showed me, over a long series of dinner discussions, that that's not the way it works. Cells die and rebuild all the time. We're literally not what were a few years ago, and not just because of the way we think. Everything around us does this. Nature is not outside us. We are nature.

As far as our relationship is concerned, I always had a great deal of respect for Iris, and physicians in general. They have to know things that I couldn't possibly remember. And that's only grown with time.

Iris: Physics was not my favorite topic in high school. [Laughs] Through Karel and our conversations, I feel that the universe and the world around us has become much more accessible. That was our goal with the book as well. We wanted it to be accessible and understandable for anyone with a high school education. It was a challenge to write it that way, to explain things to each other in lay terms. But it has certainly changed my view of life. It's increased my sense of wonder and appreciation of life.

In terms of Karel's profession and our relationship, it has inevitably deepened. We understand much better what the other person is doing in the sandboxes we respectively play in. [Laughs]

Simon Worrall curates Book Talk. Follow him on Twitter or at simonworrallauthor.com.