

Sue Nelson

Hello, and welcome to the Create the Future podcast brought to you by the Queen Elizabeth Prize for Engineering.

[Music]

Janine Benyus is a biologist and a writer. In 2009, the United Nations Environment Programme recognised her as a Champion of the Earth for Science and Technology. She's also won a Rachel Carson Environmental Ethics Award. So, no wonder she's more than happy to call herself a nature nerd. Janine works with engineers and designers to make biology a natural part of their work as co-founder of the consultancy, Biomimicry 3.8, whose clients range from Boeing and General Electric to Coca Cola and Procter and Gamble. Janine also co-founded the non-profit Biomimicry Institute in Montana in the United States, and her 1997 book 'Biomimicry: Innovation Inspired by Nature', popularised the term. So, I began by asking her to explain how biomimicry applied to engineering.

Janine Benyus

I think I'll start with a couple of examples that people experience every day and don't realise that biomimicry was part of the innovation process. One of them is, most of the phones that we use today have a chip in them, that's a noise cancelling chip. It's called the Ear Smart technology was created by a company called Audience. Lloyd Watts was the inventor. And what he did was he mimicked the human audio system, the ways in which we're able to be at a cocktail party, and focus on the person speaking to us and block everything else out.

Sue Nelson

Oh, yeah, the cocktail party effect.

Janine Benyus

Yes, exactly. And he mimicked this. And it's also why you have two inputs in the phone like, like two years. And between those, you've got this noise cancelling chip. So that's something and then the other thing that we all experience is the millimetre wave detector in airports, when you have to put your hands over your head for security. It's an acoustic camera that's based on the way the Brazilian free-tailed bat handles sensory input through its echolocation, and it's a particular millimetre that it works with that was mimicked in that camera. So, there are a lot of things, besides Velcro, which is the story of Swiss inventor coming home with burrs on his socks. And realising that seeds had figured out a good way to hitch a ride and to and to fasten easily and reversibly on something. But there's a lot of things now, biomimetic technologies in medicine, for instance, very applicable right now. There's a company called Sharklet. And they looked at how it is that the Galapagos shark does not get bacteria on its surface. Even though it's not a fast-moving shark. It's a basking shark. But he looked at the nano ridges and the structure of the denticles and found that they have a way of physically repelling bacteria. Bacteria simply don't like to land there. So he mimicked this in a contact paper that you're able to put on hospital doorknobs and railings. And what that does is it repels bacteria rather than killing it, so it doesn't breed for superbugs. And another one that's applicable right now. There's a company called Biomatrix and Nova Laboratories in the UK, and they both have mimicked a way to preserve vaccines without refrigeration. And what they did was they mimicked one of nature's best preservation techniques, which is called anhydrobiosis. And what that actually is, it happens in small organisms like the tardigrade, the water bear that can dry up almost completely into a dry state. And also brine shrimp, you know, the sea monkeys that we used to play with as kids, they can dry up almost completely. And then when you rehydrate them, they can come back. What they are actually doing is they use a sugar called trehalose that wraps their vital bits in sort of a tiny time capsule, kind of wrapping, and it keeps the cells and the organelles healthy. And so, they do the same thing and they wrap that around vaccine. And you know, solves a huge thing because most vaccines never reach their intended recipients because there's a break in the cold chain. So there are some very, I would call them paradigm shifting technologies that are coming from biomimicry right now.

Sue Nelson

You've worked with clients like NASA and Boeing and those two organisations, you really associate them with cutting edge technology and engineering. So how do you bring your viewpoint, nature, into their work?

Janine Benyus

Well, we are biologists at the design table, essentially. So what biomimicry is, it's inventions inspired by nature. And yet many inventors, engineers, chemists, material scientists, architects, designers, do not have a not biology background. So, what we do is we go into a company, and we work with, you know, we've worked with over 250, Fortune 500 companies, a lot of people are using this technology, we go in and we ask what is the function that you're trying to solve for? And then we say, what in the natural world has already solved your problem. So, we were for instance, working with a large consumer products company that does industrial laundry, they said that blood on sheets is one of the most energy inefficient processes that they do because it's very difficult to get a blood stain off of sheets. So, we went and we studied in the literature, all the organisms that take a blood meal. And how do they break apart haemoglobin, so we looked at things like leeches and mosquitoes and hookworms and each of them have a particular kind of chemistry that actually is very, very efficient, because it's important to break that haemoglobin apart. The haem is the pigment that stains and it's also very reactive. So, they have ways of crystallising that and doing different technologies. That's how I think of it in order to solve that problem. So that resulted in four different kinds of patents for those folks. And even though they had 1000, PhDs on staff, so very large company. None of them had looked to the natural world yet, for solutions. It's a patent database, 3.8 billion years of R&D. And more and more people are realising that, and realising that if you take function, as we do in our consultancy, we break it down to function. That's sort of the Rosetta Stone between engineering and biology, is that concept of function. And you can look into the natural world, you know, for instance, the function might be light weighting. So there's an engineering firm called Altair Engineering. And Jeff Brennan was a bone researcher. And he came one day and gave a seminar about how bones remodel throughout your life. They respond to stress in a way that they demineralise one part of the bone and add minerals to the other part of the bone where it's needed. And that's essentially a light weighting process or an optimization process. They took that and they put that into software called OptiStruct, which is now when an engineer sits down with a CAD programme and wants to do topological optimization it's called, they, you know, put in a block beam or whatever and then run a programme to lightweight it in response to stress. They're using a bone inspired algorithm. And that's, that's in many, many software programmes now. It's an amazing thing for biologists to be able to take what they know about the adaptations in the natural world, the natural technologies and offer them to companies. Very often what you do is you're offering something that has been optimised for energy efficiency. Or to, you know, it shaves material costs for the company, because life has had to be so parsimonious with its materials and sip rather than guzzle energy.

Sue Nelson

Ah yes, I saw one of your talks where you'd mentioned about and I hadn't known this were a whale's, are they flippers, the shape of the whale's flippers were, you discovered, actually, it was applied to wind turbines.

Janine Benyus

Yeah, it's something called tubercle technology and tubercles are these scalloped edges, think of a big blue whale, or any sort of whale really has these, these scalloped edges on the leading edge of their flipper. And what that does is it reduces drag by 32%. Frank Fish, no pun intended, is the person who actually discovered this phenomenon in the natural world. And then he put those on, you know, the leading edge of an aeroplane wing, put that in a wind tunnel test found that it was a reduction of 32% in drag, because of the way that plays with the flow. And the reason that whales will use it, some whales do what's called bubble feeding, where they actually need to turn like a giant ballerina, you know, in a very tight spiral, and they're blowing

bubbles the whole time. And that creates a column of bubbles that traps the fish or krill. And then they all go and do their bubble feeding, they go down, and they go through this column with their mouths open. But the need to be able to go at those angles without stalling and to do that very efficiently over millions of years that has led to the to these tubercles. People have seen that for years and years and years. And just now we're starting to get to the point where biologists are asking, "what might that tell us about our engineering, our wind turbines?", for instance.

Sue Nelson

It's amazing, isn't it? The advances that can be made by looking at biology. And I should imagine considering, you know, engineers, by nature are very flexible, they're looking for solutions. They're very creative. I'm assuming you find them really responsive to your approach. Or maybe they don't.

Janine Benyus

You know, what we have found, and we've been doing this for about 20 years now is that the engineers at a company, at first are understandably sceptical. And so, they tend to be the ones sort of in the back of the room at an initial discovery workshop, and they've got their arms crossed, they're going, yeah this is so good, why haven't we done this? Once they sit down, and I have many examples of this, once they sit down and solve a problem, to go through the biomimicry process, we show them some biological models that answer the function they're looking at. They become the biggest advocates, you know, and then I find out that they're doing brown bag lunches at the company, and what they've realised is "wow", this is just it's like, all of a sudden, finding a library you never knew was there. There's, you know, 10 to 30 million species, all of them full of adaptations, especially when we're trying to find more sustainability. So, the engineers, actually, I guess you would say that, once they try it, and it they get the "aha", then you just can't, you know, you can't stop them.

Sue Nelson

I can see why though, I can totally see why. Because it's a bit like being an artist with a paint palette of 10 colours, and somebody suddenly coming in with 50, new ones that you didn't know existed. No wonder people are converts.

Janine Benyus

Absolutely. And there's a biomimic named Julian Vincent, who did a study. And what he did was he looked at the patent database, the human patent database, and basically said, you know, what are the problems that we're trying to solve? We're trying to make it strong, but lightweight. And then he looked into the natural world, he's a zoologists. And he said, how has nature solved it, or the rest of nature solved it? And how have we solved it? And he thought that those would overlap. You know that we probably would have come up with the same things. What he found was 88% of the time, the biological solution was novel. New to us. So that's the other thing I think that engineers realised very, very quickly, is that evolution is an optimization programme. And it's a very quick way for us as humans to move over to that solution that has been optimised. Now, human creativity then gets going, because mimicking these things, it can be simple, or it can be very, very difficult depending on you know, whether you're trying to create a material or trying to, you know, try to mimic photosynthesis. Or it can be just rearranging things that we've already got off the shelf technologies in new ways. Like, for instance, John Dabiri, he had his students when he was at Caltech, now he's at Stanford, his labs at Stanford, they were working with vertical axis wind turbines, very tall, and he had them study fish, and how fish, they do this thing it's called Kármán street is the term for the for the phenomenon. But when a fish moves in the water, it has a sinuous movement. And what it does as it's moving is it creates vortices in the water. And then, when the next fish comes up behind it, it kind of curves its body, like a hydrodynamics sail, and it gets flung upstream by that vortice. Now, if you have many of those happening, that's why fish are able to move upstream. And so well, you know, in a group. So, what they did, what John Dabiri had his students do is take the

vertical axis wind turbines were already developed, they put them close together. In this case, the turbulence was seen as a positive. And he put them in the same formation so that they would start to do this thing that they would start to turn before the wind even hit them in a sense. And he found a five times increase in power output. That's why engineers I think, get excited.

Sue Nelson

And it's funny, you talking about shoals of fish effectively, it sort of reminded me of how much engineering and robotics is often looking at, say, the social behaviour of ants and swarms of bees. And I know that companies years ago, were making robotic fish and, you know, just looking at all the different ways of travelling underwater it's a rich seam effectively, of ideas. When did you realise you know that for you "Wow, this is what I want to make my career about" because it is an unusual one.

Janine Benyus

Absolutely. Well, I am a science writer and I had written, you know, 'Biomimicry' was my sixth book. But the books I had written before were natural history books. They were ecological guides to habitat through the eyes of why are certain species in certain habitats. And so, my books, I was tracking these technologies, these adaptations, not realising that. And one day I just basically said, designers must sit with biologists. And there must be a field in which we're learning from the natural world. You know, this is back in 1990. What I found was that it was a very faint signal in the scientific literature. There were a few people doing this, but they were doing it in very disparate ways. You know, it was biomimetics was mostly about materials. There were a lot of people in space, in ESA, for instance, that were working on sensing and, you know, how organism sense. It was disparate, you know, there were there were people in agriculture working on trying to mimic perennial polycultures of prairies. None of them knew each other. That's what was really interesting. And they didn't have a common name to call this field. So, after I was collecting, I was working on another book. And one day I walked by my file cabinet, and I had to name the folder, you know, the first folder. I named it bio-mimicry, you know, for the Greek bio and bios and, and mimesis and put it together in biomimicry, and I named the folder that and then I walked by a file cabinet and there were four drawers full of these scientific papers I was finding and I said "this is crazy, this is a field without a name". And I wrote this book. And then it was amazing, everything, my life really changed because then companies started to call me. And, you know, it was everybody from GE, to Nike, to Boeing. It was many, many industries. It coincided with a time when companies were trying to reduce their energy costs, and toxicity and just have, you know, fewer materials and just a smarter, more sustainable product line. And I realised very quickly that there was a new field that needed to happen. So we, my partner, Dayna Baumeister, and I started to train people to do this. Now we have a, we have a two-year Master's science course at Arizona State University. So, people are becoming certified biomimicry professionals. And now it's very much, you know, jumped into industry.

Sue Nelson

That's great. And I can see the progression of how it's all sort of come together for you as well, because your degree was English and Natural Resource Management.

Janine Benyus

That's right.

Sue Nelson

You use the word sustainable, a lot of the time and saving energy. So, it's all applied perfectly in terms of your knowledge, your ability to communicate the science and the biology aspect of it, and then apply it and show engineers how to apply it. It's all the right pieces in the right place at the right time.

Janine Benyus

I feel very lucky. You know, I couldn't have created a more exciting, more fulfilling combination. Obviously, I was very enamoured with the natural world, and fascinated since childhood. So, to be able to share that fascination and to have that, hopefully, through the brilliance of the designers and innovators we work with, have that turned into something that, in turn is going to protect both people on planet. It's good work.

Sue Nelson

Where you see areas in the future, where nature and engineering can perhaps solve some really big potential issues, or are there no boundaries here?

Janine Benyus

Biomimicry is going to play a big role in our efforts to reverse climate change for instance. There are six pathways in the natural world to take CO₂, carbon dioxide, and make it into chemistry. That's very much looked at right now, you know, the carbon capture movement is now looking for ways to utilise carbon as a building block for plastics for instance, or concrete. So, there are companies doing that, that is by mimicking the corals recipe, because coral reefs are essentially concrete made out of dissolved CO₂ and other materials. The other thing is, for engineers, particularly, we're working with Jacobs Engineering right now, as an integrated service provider, actually, that we go to clients with, and this is biomimicry at the system's level. And what we're doing is we're working in built world environments. And we're going in, and say you've got a building and a site, you know, corporate campus, say. We're going in, and we're saying, "Okay, if this is to be a biomimetic development, then it should be as high performing as the wild land next door". And so, we find a reference habitat. And we measure that to find out how those landscape attributes of that place are producing ecosystem services, like how much water are they cleaning a year? How much carbon are they sequestering? How much air are they filtering? What kinds of habitat support do they have? How much erosion are they stopping? And then we take those measurements and those are ecological performance standards, we call them because they're performance standards then for the building project. And then the building project per acre, per hectare has to meet those goals, those ecological performance goals. And it really changes design. And so the engineers at Jacobs are very excited about a whole new field for them, which is designing for ecosystem services. So, for instance, if you want to store a certain amount of water on site, how do you do that? You can do that with green roofs and cisterns, of course, but you can also do that with permeable pavement instead of the parking lot that you normally have, and retaining ponds. And so, you, you're basically using both the infrastructure, the building itself and the landscaping to meet these goals. And it's very exciting for engineers to think of, especially with as we're building so much infrastructure now in this country, hopefully, to say, how can I, you know, how can our roadways for instance, be more than carrying cars? How, what about the easements along there? How many ecosystem services can we have happening with that infrastructure project? You're either meeting those ecosystem services or not. And the engineers are just loving it. And I think that's if I was a young engineer, that's what I would go into.

Sue Nelson

Yes. And you've got speaking of young engineers, you've also got a website, asknature.org, which is a joy to just look through in terms of seeing all the different examples and the species and read about them, but it's also quite practical as well, isn't it? Because it's got quite a bit of free information for engineers.

Janine Benyus

Absolutely. What we do for those Fortune 500 companies, we wanted to democratise that and make that biological information available to any inventor anywhere in the world. It's a kind of a Google-esque thing where we're trying to organise biological information. These adaptations by function. So you can type in the engineering function 'filtration', you know, and up comes mangroves and salt glands of seabirds. And you see

how those work and you have your own “Aha”. We also do at the institute, our non-profit we also do a design contest. And the design contest this year, we have \$100,000 Prize. It's called a Ray of Hope Prize. And we got over 300 applications from small companies. So, this is you know, the start-up world in biomimicry is also very big. And you know, last year's winners were amazing. There was a company called Spotless that has mimicked the very slippery inner surface of the pitcher plant, which is a carnivorous plant, bugs can go down but they can't come back up. They did that on the inside of pipes to keep those from clogging. There's another group called Helicoid Industries where they are making very strong composites for things like wind turbine blades. It's a helical, carbon fibre arrangement that is based on the mantis shrimp, a little shrimp that that opens shells with its club, and the club has this helicoid arrangement. There's a company called Cypris that is doing spray on structural colour. So instead of painting, you spray on a substance that sets up to refract and amplify certain wavelengths of colour, in the same way as the structures on a butterfly's wing do that. You see the colour blue, from the morpho blue because all the other colours are being refracted and this one's being amplified. So, these were all in our design challenge. So, you know, we've got investors now very interested in biomimicry as an investment category, organised by innovation process rather than by type of innovation. It's kind of interesting.

Sue Nelson

And if you could apply any aspect of a biological creature, a function, be it wings or waterproofing, you know, any ability that happens naturally in biology, and that could be engineered, for your body. What do you think you'd want? You know, having seen all these amazing adaptations in a sort of sci-fi world, what would your adaptation be?

Janine Benyus

What a great question! That's such an awesome question. I, oh my god, you know what first came to mind. Flying squirrels. I love flying squirrels. We have a cabin on a lake here in Montana, there are flying squirrels there and they are so much fun to watch. And I have envy. They just open their arms and glide to wherever they want to go, I think that would be it, and I'd have webbed arms.

Sue Nelson

I'm assuming you've got a head for heights and as well?

Janine Benyus

Yeah, they make it look fun. So, yeah, I think it would help to have the gliding ability. I'd like that. And even if I get up on a ladder, I'd love to have that.

Sue Nelson

Excellent. Well, I've now got this image of you in my mind doing that, which is quite appropriate, considering what you do. But thank you so much, Janine Benyus for joining me on the Create the Future podcast.

Janine Benyus

Thanks for having me.