From super-pills to second skin: meet the Willy Wonka revolutionising medicine

Robert Langer's trailblazing research in nanotechnology, which ranges from haircare to cancer treatments, has already improved the lives of at least 2 billion people

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Treatments for diseases such as polio, TB and malaria are being developed by Langer, which will benefit billions of children across the developing world.

Robert Langer seems incredibly well adjusted for a man with transatlantic jetlag. And, for that matter, for someone who struggled for years to get his pioneering work in drug delivery accepted by the scientific establishment. As a young professor, his first nine research grant applications were turned down. Once, at a formal dinner in the early 80s, a senior colleague blew smoke in his eyes and told him to find another job.

And yet here he is, a good-natured nanotechnology trailblazer, swooping into the UK for duties associated with having won the £1m Queen Elizabeth prize for engineering. His work has improved the lives of 2 billion people and counting. He has collected awards from two US presidents, as well as the Queen. He has more than 1,000 patents on the go, and 30 companies have spun out from his vast lab at Massachusetts Institute of Technology (the largest biomedical lab in the world). At 68, he is still the future.

It's hard not to see Langer as a medical Willy Wonka, with armies of students and post docs, beavering away on the huge range of his research interests. There's contraceptive microchip implants; a gel to repair damaged vocal cords; spinal cord repair tissue; an invisible "second skin" for conditions such as eczema (with the cosmetic side effect of rendering skin smooth and elastic); cutting-edge anti-frizz haircare; and what Langer calls "super-long-acting capsules or pills, that would last a week, a month, or even a year". If anyone could figure out how to make everlasting gobstoppers, it would be Langer.

Commonly, when pharmaceuticals enter the body, they are coated in synthetic substances called polymers. These allow effective amounts of the drug to reach the body, slowly enough so as not to cause toxicity. Until Langer came along, this controlled method only worked for simpler, small-molecule drugs. Sophisticated large-molecule drugs, that can target diseases such as cancer, diabetes and mental illness, were too big to pass through polymers. "People wouldn't think you could walk through a wall either," he says. "But we built all these tortuous channels in what was the equivalent of the wall so somebody could get through, but they get through very slowly, like driving through London in rush hour."

Langer also designed biologically tolerable polymer pellets – nanopellets, he calls them – that enable drugs to be implanted directly into cancer tumours. This enabled Langer and the cancer researcher Judah Folkman to isolate the first vascular inhibitors, which stop new blood vessels feeding tumours. "We thought it could be a new way of treating cancer," Langer says, "and it's become that. Drugs such as Avastin [bevacizumab] and Eylea[aflibercept] are based, in part, on our early research." He also created new polymers that could dissolve like a bar of soap and release drugs in a very controlled way over months to years. And he and neurosurgeon Henry Brem developed implants (called gliadel wafers) that could be implanted in the brain to treat brain cancer. Trials in 1996 saw a 63% survival rate against just 19% in the control group.

More than 20 million patients around the world have been treated with vascular-inhibiting substances and other medicines derived from Langer's engineered polymers. He also invented drug-coated cardiovascular stents, which have benefited more than a million. There are, however, plenty more medical conundrums to be solved. "We're doing a lot with the Gates Foundation," he says. The chief aim of the super-long-acting pill is to tackle low patient compliance rates in the developing world, in treatments for malaria and TB. "You have a much greater chance of solving the problem or eradicating the disease if you could do that," he says. But there would clear benefits, too, for conditions such as Alzheimer's or schizophrenia.

Langer picks up a pencil and draws a star with stick arms, like a snowflake, and describes his solution in beautifully simple terms. To avoid excretion, the pill must be too big to pass from the stomach into the gastrointestinal tract, but small enough so that it doesn't cause a blockage. "Let's say you had a capsule, made out of something that dissolves in acid in your stomach. And then you make a material that's super elastic, or has shape memory." The super-elastic star is squished into the capsule, and unfurls in the stomach after the capsule dissolves. Finally, he says, "you want to tune the degradability, so that it can last whatever amount of time you want. That's what we're trying to do."

The microchip birth control is another Gates Foundation project. "It could also be useful for osteoporosis," he says, where there's a high drop-out rate among women needing frequent injections of the parathyroid hormone. "We might be able to give them a little implant and just deliver the drug every night."

"Another question the Gates Foundation has asked us is: can we come up with ways to make it easier for people to get iron and zinc and vitamins?" The solution: the healthiest seasoning ever. "We're coming up with a salt you can boil for up to two hours and nothing happens, but then, when you eat it, within an hour, 11 different nutrients come out. They are in polymers that are edible."

Also on the boil, he says, "are better vaccines for polio and other things." These usually require booster shots, but many people don't come back for the second injection. "So we're designing some systems where you can give a single injection of nanospheres, and they'll just pop at different times. One might deliver the drug at time zero, another at six months, another at a year." This would have the added benefit of fewer injections, so less risk of infection, and save time and money by only requiring one medical appointment. "We're calling it pulsatile," he says, always with an eye on broader uses. "Why not apply that to other diseases, such as HIV?"

Because of the wide use of treatments based on his work, Langer has met many of the people whose lives he has affected. "I almost feel bad," he says. "You want people to have healthy lives, so it's better if they haven't benefited from [the treatments]. But, yeah, it's a lot of people." Too many people to feel emotional about? "Well, you always do, though. If somebody has benefited and feels grateful, I think you feel glad, but I always hope they don't need what we do – other than the hair and skin products, perhaps."