INDIA ABROAD PERSON OF THE YEAR 2013

P RAJENDRAN

INDIA ABROAD FACE OF THE FUTURE AWARD 2013

MANU PRAKASH

A BEAUTIFUL MIND

Such an awesome journey

Manu Prakash has been a tinkerer all his life. **P Rajendran** meets the inventor of the 50 cent microscope, the Foldscope, and the winner of the **India Abroad Face of the Future Award 2013**

COURTESY: FOLDSCOPE TEAM

Manu Prakash demonstrates a Foldscope.

When Manu Prakash comes upon a bug, he may do a variety of things. He might pick it up and study it, he may have it skate across a plate while he films how it works, find ways to get it to light up in different colors, see how much force it takes to suck up water, give it the equivalent of human sweat to quaff its thirst... Or, if curiosity overcomes caution, bite into it.

Manu is a scientist at Stanford University's Department of Bioengineering who lives, breathes and, as mentioned, eats science. He recently gained fame for his revolutionary foldscope — a 50 cent microscope that has a resolution equivalent to many in laboratory and can fit in a child's pocket.

Drawing from origami, polymer science and acoustics, besides microscopy, the unit also makes it easy for health care workers to get more accurate measures of samples under the lens. And if you see videos of Manu stomping down on it, rest assured he's only showing how durable it is.

But he is also interested in fluid motion in a plant cell, drawn to children's art, charmed by algal blooms, drawn to robotics, captivated by cartoons, fascinated by insect metamorphosis, and pulled in so many directions by so many things that one lifetime may be insufficient for him to do everything he wants to. Though, of course, he's trying....

Manu has remained a tinkerer throughout his life though he did not bend his mind to academics a little later than most.

He was born March 6, 1980, in Mawana, a small town in Uttar Pradesh that relies on the bounty of the Ganges, about eight miles away, to be home to the sixth-largest private sector sugar manufacturer in India. Manu remembers seeing a Mawana Sugars office during a trip to London.

His parents decided that the children, Anurag and Manu, needed a better education and so the family pulled roots and moved to Delhi.

Manu went to the Prabhu Dayal Public School there when his mother Sushma Rani found a faculty position in political science in the Uttar Pradesh state education system. His father Brij Pal Singh, who was in the real estate business, traveled a lot, leaving the children with their mother.

Manu was not great at school.

"I was OK. For many years, I was terrible," he says "In Delhi (*in elementary school*), I was probably pretty bad. If I was to be ranked, I'd be maybe 20th out of 50 kids. So just average... But I spent a lot of time outdoors doing stuff. Then we moved to Rampur and then I think I got better in school as well."

It was also in Rampur that Anurag and he found both the friends who thought like them, and the opportunity to do weird things.

Given their fascination with fire, they came up with a project which, he admits now, "was kind of stupid.... We went and collected every non-exploded cracker (*left over from a Diwali celebration*). We brought them home, removed the powder, and made a giant pile. We just wanted to see from a context of how ... flammable it is, without a container..." Then he went over and lighted it from up close.

He explains how things work in such cases: "The powder catches fire and shoots up like a miniature nuclear explosion." Of course, he suffered collateral damage.

"I burned my hand," he admits, adding that experience made him a little more careful around fire.

With his brother and another child, he had also built a complete Ravan before Dussehra. This, before he was in the fifth grade.

It was a 10-foot creature with a wire mesh skeleton and stuffed with crackers and explosive powder. They had to figure out a way for the whole thing not to explode in one bang, so they ran animated strings of Diwali lights through it, the only difference being that some of the lamps were broken so that when it sparked it would light the powder. It took some planning.

But by the time he was in high school, the fires became more controlled and yet more spectacular.

They built a model of the *Exxon Valdez*, a ship that ran aground on March 24, 1989, on Bligh Reef at Prince William Sound, Alaska. But adding a touch that history has not recorded, they set it alight.

"We got people scared, but it was not out of control," he says.

The experiments were not limited to setting things alight.

He and his friend Himanshu Joshi decided they ought to build a 3-D skeleton of a rabbit.

Already canny, they decided to work out the details using frogs first. They had heard that if they buried a frog for a month in salt, the flesh would go away, leaving just the bones behind.

"We didn't have the time to wait," he says now.

So, the children experimented with ways to strip a frog's flesh until they felt they had the technique right.

Once ready, they bought a rabbit from the butcher's. Most of the flesh became lunch (*"But we were careful not to destroy a single bone"*); the bones they boiled in hydrogen

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HONOR ROLL

INDIA ABROAD FACE OF THE FUTURE AWARD

MANJUL BHARGAVA (2008)
R Brandon Fradd Professor of Mathematics, Princeton University

PRIYAMVADA NATARAJAN (2009)
Professor, Department of Astronomy and Physics, Yale University

NAVEEN SELVADURAI (2010)
Co-founder, Foursquare

SHWETAK PATEL (2011)
MacArthur Fellow and Associate Professor, Computer Science and Engineering and Electrical Engineering, University of Washington,

RAJ CHETTY (2012)
MacArthur Fellow and William Henry Bloomberg Professor of Economics, Harvard University

Manu Prakash
For being a passionate inventor; for his crusading commitment to bringing new technology to global health; for being a brilliant physicist with a child-like curiosity.

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peroxide to get rid of the remaining flesh and cartilage.

"For the three days we boiled that thing, it was nasty, but then you get these perfect (*bones*)," he says.

They relied on books that only depicted the skeletons of other mammals.

"The problem that was not anticipated was that it has almost 200 or so bones — as much as humans do. So after the technique worked so well, we got all the little fingers — everything... some of them as small as a grain," he says.

It took them six months to put the entire 3-D structure together, with the positions of the 46 vertebrae being especially challenging.

They gifted it to their school, the Dayawati Modi Academy, Rampur.

They went junk-diving in the waste pile of the photocopying machine factory near their school.

"We used to scavenge things out of that," he says, admitting, "I still have a lot of scavenged parts in my lab."

He learned more from doing things than poring through a school book.

"I think it taught me something about working hard and perseverance. Projects don't work like a problem set or a chapter that you're told to read. You read (*those*) and it's done. When you're doing a project, it (*sometimes*) just doesn't work. You can do everything and it just doesn't work. And that is just so fascinating to learn," says Manu, who says that he always enjoyed bending rules.

When in the eighth grade, he and his friend came up with a project involving them going to scenic Nainital.

"Teachers said this is crazy but, in the end, we ended up at the solar observatory in Nainital," he says. "We lived in a gurdwara because we didn't have the money to stay in a hotel. We ate in the gurdwara, we slept in the gurdwara, and every day we basically hung out at the solar observatory. They have these fantastic telescopes to actually observe solar flares.... It was tremendously exciting because even though initially it was a joke to go to the mountains, it taught me the outdoors is so important to do science in."

He did not learn much from books, museums and formal places of learning.

"Even in Delhi, I don't remember visiting a museum," he says. "Many of the places we found incredible science were at common day-to-day places."

Doordarshan had this fascinating program by an astrophysicist with white hair — Yashpal... But we had TV only for a short time — only in the later periods. I don't think I had access to books that much."

He particularly remembers how his friend Nishant figured out a way to enter a cinema hall in Rampur. But for Manu the movie was not as attractive as what put it out there.

"All the optics that goes into projecting a movie and all the complications of running this film — how mechanical it was — is so beautiful. That's where real science happens. That's when you realize, wow, look at this machine. You have to change tapes... There's chemistry on the tape."

In the midst of all these experiments he also destroyed a television just so he could find out how the electron gun worked.

And then there was the crystal radio he and his friend Abhishek built from scratch.

Wherever he was, he would spend time at the radio repair shops, learning from the unsung experts who ran them and were full of words of practical wisdom.

COURTESY: SUSHMA RANI SINGH

Manu Prakash, center, wins a prize at the Dayawati Modi Academy in Rampur where he studied from the sixth grade to the 11th grade.

When he was in the 11th grade, his mother was transferred to Bareilly. While he found most formal exams boring, his brother's experience had chastened him.

"He didn't study because we were having too much fun. But (*studying is*) what we should have been doing to begin with.... He didn't get into IIT and he went to another regional college in UP. I spoke to him (*later*) and he kind of told me that he was unhappy in the choice that he made... The surroundings (*at the new college*) were really tough ... and there was a lot of other (*non*-academic) stuff happening. That kind of inspired me to kind of say, OK, I can keep doing (*stuff*), but if I really love what I do I really need to hunker down and then I did actually really study very hard. I think that's probably the hardest I've worked in my entire life." He snorts with laughter.

"I was ranked 420 — and I was very proud of it because it is *char sau bees* (*an allusion to the Indian Penal Code number dealing with cheating*)," he says. "The day the result came out, my friends, who had not even prepared for IIT but had seen me work so hard, came in the early morning and took me on their bikes and we went around and looked for newspapers. Yeah, we were very happy..."

He did well in the All-India Institute of Medical Sciences and National Defense Academy exams. In the latter, he was a shoo-in for the air force, but his father vetoed the plan, telling him he was more cut out for research.

At IIT, he chose the mechanical engineering stream.

"There, I got top grades, which is kind of ironic because I never got good grades all my life," The grades were so good that he was given the option of changing his major if he so desired. So he did — to computer science.

"Even though I'm a tinkerer and I make stuff, my bachelor's degree is in computer science," Manu says. "It was not a mistake. It was a fun, different direction for me and it has influenced the type of science that I do."

He spent time in a robotics/mechanical engineering lab and his bachelor's thesis was about computer programs that could build machines automatically, combining the idea of computer science with mechanisms and machines.

"The fun thing about that project was that it generated mechanisms using Lego blocks, so that the mechanism you generated you could actually build," he says.

He and another friend started a socially relevant program that took them out of the campus, and helped them do something that was not all esoteric engineering.

Called BRiCS (Build Robots, Create Science), they got IIT students to run workshops where kids would make robots out of junk.

BRiCS is still running and is bigger, with 25, 30 students running the workshops, he says.

"There is this need in IITs for social engagement because IITs are about isolation," Manu argues. "IIT-Kanpur is in the middle of a village called Nankari and nobody visits the village. There is a big wall around (*the IIT*). When I was there, it wasn't (*open*)."

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Another project he was involved in was how children first learned to draw.

"The idea came about because I wanted to work with kids at that time," he says. "Clearly, I had no training in psychology. It ended up being a really interesting project because then I came up with a whole bunch of rules from these drawings. I still have the collection of those drawings ... and they are somewhere online as well (*home.iitk.ac.in/~amit/courses/768/00/manup/report.html*)."

He saw that different kids take completely different approaches to drawing a shape, before they're told how to draw. He recorded "a whole bunch of those things" and wrote a program that made drawings in a way similar to that of a child.

"(*When children draw*) there's a certain ambiguity; the path-planning is different. I was trying to capture that process in the way of writing a computer program that will draw like a kid."

Getting out of IIT made him re-evaluate his priorities. "Thing I realized when I passed out of IIT (*in 2002 is that*)... I'm a tinkerer, and it's important for me not to sit in front of a computer. So, at the graduate schools I applied to, I applied in physics departments. That's kind of weird because I didn't officially have a physics degree from IIT. I was lucky enough to find a physicist who wanted to work with me (*Neil Gershenfeld at MIT*)."

"That was a big transition for me, which I was happy about," he says, adding that he did a fellowship at Harvard in biophysics.

At Manu's current lab, among other things, he is trying to bring chemistry back into the hands of children.

"We've gone overboard — specially in the US and most developed countries, where people are so risk-averse in terms of exploration," he says, describing growing up with all types of electronics and chemical gear readily available.

"Now hands-on, physical tinkering is not that common. If I learned anything, I learned to tinker," he says.

When given the dangerous example of a curious child who tried to make nitroglycerine at home, and fortunately failed, he responds, "Those are examples that are commonly given, but there is an immense amount of chemistry you can do without blowing everything up... Frankly, I did a lot of blowing stuff up."

Early on, that gave you lesson of how to be careful. You kind of understand the power of nature. It's all the more fascinating... You have a tiny amount of something and how much energy is stored (*in it*). The energy density of oil is so high; immediately you think that, you know, all the bonds that I make, that's an immense amount of energy. That really makes you think."

He also argues for more openness in science, particularly when it comes to publishing.

"We pay thousands of dollars to get access to pieces of work paid for by tax dollars," Manu complains.

Talking about open-source journals and how that area is being infiltrated by unscrupulous publishers putting out dubious research papers, he takes the conversation to a more spiritual plane.

"It's very sad. Science is also pure. You cannot bring impurity into science..."

He also argues for the potential of the developing world.

"If you look at scientific output, many developed countries have a tremendous output. When you make that map (*of research output*), India kind of shrivels up; Africa completely shrinks out. And this is where the majority of kids are growing up." He believes that the problems affecting developing countries are quite different from that in the developed kind.

"Those problems (*of the developing world*) get zero traction," Manu argues, slumped in his chair and twisting the cord on his sweatshirt. "Nobody is really working on them. They are intellectually fascinating, they are very important for the world to survive, and they are very context-dependent," he says, adding, "If we just make the best institutes in the world and have them do science for a small group of people, we will not be able to solve problems because, frankly, most of the time we haven't even heard of those problems."

One such urgent problem is that of water quality, which Manu's lab is addressing with a punch-card based mechanical chemistry kit that a child — or a health care worker — can use.

"You put all the chemicals on the chip.... Punch in the protocol you need (*and*) you can do very complex protocols anywhere in the world," he says.

He points out how inexpensive computers have changed things for a lot of people. This is his way to make things as cheap when it comes to physical things.

The gizmo tests for nitrates, phosphates, pH, ammonia, heavy metals, pollutants like PCB (polychlorinated biphenyl).

He spoke of a mail he got the day before from an organization that supports science education for farmers. It told him that farmers walked more than 9 miles with a soil sample from their farm, depositing it somewhere, and heard from the facility — if at all it replied — after a month. By which time, a bad crop would have failed."

COURTESY: TWITTER.COM/PRAKASHLAB

Manu Prakash, standing third from left, in Nigeria. While many developed countries have tremendous scientific output, he points out that when you make that map of research output India shrivels up and Africa completely shrinks. It is a gap he wants to bridge with his frugal science.

"I think we've made it sound like science is very hard and that only people who can read all these books should do science," Manu says. "What we're trying to do in our lab is flip that around and say, to hook people to science you need to just give them the tools and get yourself out of the way. Don't make it feel like a club. Once people are hooked they will actually pick up the scientific knowledge that they need to become better."

But then, science *is* a bit of a club.

He agrees.

"Ignorance can be cured by bringing information out but we went to a point that we told the world that to do science there is only one model," he says. "That's not fair. It's perfectly OK for people to really engage in science broadly and use that as a platform to then learn more."

"Top-down science is not the only way science should be done. There ought to be a bottoms-up sense of science. Anything that's on a planet scale, it's important to engage this broad group of people.... Because we have these global indicators that are telling us that the planet is not happy. But we're going to have to go down and ask how are we going to do science at that scale?"

Manu is a big proponent of intuition — his personal fount of novel wisdom.

"Without intuition there wouldn't be anything," he says, rounding that up with the Zen-like statement: "Most of the time we're teaching things that we know; we should be teaching things we don't know."

He says the frugal science that his lab works on is meant for people around the world with the opportunity to bring up their own doubts about science.

"Not the questions that we framed, the questions that they framed for themselves," he says.

Half his lab works on biophysics, the other half on 'frugal science.'

"You can think of them as very applied — the frugal science. That's really about solving problems. And the other half is very

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curiosity-driven, big questions in biology.

And then he's on a roll.

"Things like... how do insects go through metamorphosis... 95 percent of the cells are killed and they are born from scratch. Why would something like that happen to begin with? The pupal stage is literally a sitting duck: It's food for a lot of other things. It cannot move. It just sits there. Sometimes (*metamorphosis*) takes a few days. Sometimes (*like in cicadas and other things*) it could take years."

And there's work on marine organisms — squids, cnidarians.

In squids he wants to know what controls the patterns the animal uses for camouflage — the neural control of their color cells, the chromatophores.

He says his biggest focus in biophysics is what happens when you let go of complexity in simple multi-cellular animals such as sponges or comb jellies.

"We would like to understand simple animals completely as a physicist, just like what we did with the E coli (*in biology*). We are searching for an E coli for multi-cellular animals. Many animals like *Caenorhabditis elegans* (*a kind of roundworm*) or flies are way too complex..."

"You can go from physics to life in one shot. Physics to behavior is what we think about a lot in the lab. We write down equations that could actually calculate behavior in very quantitative terms."

"The lab does not rely on just statistical probability," he says, arguing that their predictions are intended to be unambiguous.

"That's why we work on simpler animals — (*so*) that you can actually come up with a deterministic (*prediction of behavior*). It's not with the goal of saying that, OK, when you can do that you can do that for a human or something.... What we're trying to say is that it is very important to understand that complex biology in its entirety."

As a physicist he believes that there is not enough detailed information about free will and similar conundrums. He also has no time for people who use the cutting edge of science to argue their personal flavor of theological philosophy.

"There's a lot of crap," he says. "Basically, when you don't understand something, you throw (*in*) something else that you don't understand — and say, aha, these (*things are connected*)."

When Deepak Chopra is mentioned, he just sails on:

"Bullshit has no place in science. Understanding is something very deep for scientists. It's perfectly OK to say that we don't understand."

"That's exactly what we're trying to rid off in science," he says, and then segues to a discussion about jargon: "Let's not hide behind jargon; let's just do the science."

Manu complains about doctors in India who tell you to take their tablets, but will not explain what the problem is. In the US, he says, doctors communicate their science without jargon, without hiding behind that jargon. Physicist Richard Feynman has this famous quote, right? 'If you can't explain it to your grandmother you don't know it.'

He says it is harder to inform people, but it needs to be done and is not an impossible task. He admits that this is harder to communicate about work at the cutting edge of science, when people are still working hard on the topic – or in abstruse mathematics.

Asked if that wasn't very difficult to do at the realms of science where the physical laws people are used to fall away, he says, "True, but that just means we've not built intuition completely... Frankly, there is a lot of stuff that the people who truly understand can formulate it in ways (*that can be easily understood*)."

Clearly, you can't ask somebody to cram this concept (*and give it*) to me in less than 10 seconds, which is what science has become now. You have to have the passion for it. You have to dedicate time."

Asked about dealing with failure, he laughs: "I fail every day."

Addressing a deeper meaning of failure, he says, "The whole idea of working in the space of global health is that it's such a big challenge... Look at the number of people who, at this very moment, need the types of breakthroughs. At this very moment, it could be a difference between life and death. You have to live with this thing every day."

"As a pure scientist, you sometimes try to ignore that and just say, hey, keep building and at some point this will make an impact in people's lives. And you think, why can't I do it now..."

"The reason I started working in this space (*of global health*) is that intellectually it's very exciting. But it's really driven by this giant gap we've created ourselves, and that in itself is a failure. Why have we not been able to excite scientists and scientific thinking in such an important aspect of people's life all around the world? Why is that other physicists are not thinking about global health?"

Manu at work. He calls the Prakash Lab a 'cabinet of curiosity.'

P RAJENDRAN

Physicists are known to make tools. But I go to these meetings and I only meet epidemiologists who've done a fantastic job of documenting how problems arise. There are very few people who are actually changing fields and going out and trying to implement things in the space. There is a kind of urgency in what we do but we have to take baby steps. Science always moves in baby steps. It's all just slog and baby steps."

"I don't like big failures. What I end up doing is that I fail small very, very quickly. At the lab, there are 20 or so projects going in different directions. Are all of them going to succeed? Maybe not. Some of them will have different types of impacts."

He quotes Nobel Prize-winning chemist Linus Pauling: 'The best way to have a good idea is to have lots of ideas.'

"I think I definitely follow something like that," he says. "The cost of trying things is low now ... Especially while you're working on frugal things you just try things."

Getting away from the philosophy of science, Manu discusses the Foldscope, the creation that brought him fame.

He says it can change the teaching of biology if all children in the world have microscopes in their pockets.

The first set of lenses in the microscopes are just glass beads. The next set will be aspherical to both increase magnification and reduce fringe color. The larger magnification also ensures that malarial parasites — which can be just 600 nanometers wide — are also visible.

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He has always wanted to know 'Why?'

Anurag Prakash, on his brother and fellow science adventurer Manu Prakash

Manu Prakash, second from right, and his brother Anurag, second from left, enjoy a game of soccer with friends from Dayawati Modi Academy. Both brothers played on the school team.

COURTESY: SUSHMA RANI SINGH

It began with a simple question: If a grasshopper can jump up to many times its size, why can't we? That's one of the questions my brother had asked. Unable to get an answer, he would start his experiments.

We studied together at the Dayawati Modi Academy in Rampur (*Manu from grade 6 to 11 and Anurag from grade 7 to 12*) and did a few projects together, from making the skeleton of a rabbit to simulating oil spills.

He has always been a very hard worker and always wanted to know 'Why?' He has always been curious about how things worked and why they were the way they were, and he has always been passionate about what he believes in.

I remember a trip to a trade fair in Delhi where he was really amused by how a missile fuse system worked. The next day he was ready with his own mechanical fuse system made of match sticks, and that must have been around the time when we were in fifth grade.

The first real challenge he had was his IIT exams. When he was preparing for his IIT entrance exams, he would work on problems in mathematics and physics throughout the night.

Instead of gaining theoretical understanding he always tried to gain an understanding by solving problems, not just reading about them. That would require him to sometimes spend double the time, but he was driven. It's his passion and focus that drives him.

During his undergraduate course at IIT-Kanpur, he picked up some projects like BRiCS (Build Robots Create Science) where he developed a handheld printer to help craftsmen develop their own designs on a computer and get them printed on clothes instead of paying fortunes (for small craftsmen) in the making of dyes.

It was not only developing things of that nature, but he would even go and attend the NGO sessions for craftsmen and showcase to them various uses of such instruments.

Bringing the capabilities he learnt to use for making different things is probably why he did not join a career in Computer Sciences, which was his chosen stream of study.

The choices in his earlier life were mostly driven by family and simply by our society. My brother and I always wanted to go into the science stream and we chose the same (*Anurag Prakash is a now a principal engineer in the optical communications division of Ciena India Pvt Ltd*). However, once he went into undergraduate studies his interests lay far ahead of merely getting a high-salary job — which, as a computer science under grad from IIT-Kanpur, was easy for him. He chose to do research.

I believe it's in this phase that he started making his own choices and deciding to do what he wanted.

MIT gave him a great platform to build upon his interests in physical sciences and the capability to implement natural laws with simple tools. That was probably a turning point in his career where he could launch himself towards his interests. But all that came with great effort, judging by the amount of time he used to spend in the lab there. A couple of times when I visited him, he would come back early in the morning.

The best thing about all my interactions with him is he never complains, ever!

Manu has always been focused and never been bothered about how others perceive him. What mattered to him was what his efforts could achieve.

Currently, he is driven by the fact that he missed a lot of opportunities in his school/undergrad years due to lack of resources in the Indian education system. He wants to make a difference there be it education or health. And he has already begun the process by showing that creativity has no boundaries (geographical or virtual); it's limited only by the barriers you build around you. ■

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A drop of UV acrylate, a plastic, is placed in an aperture and an acoustic field — a set of sounds — causes the drop to vibrate and shift from a spherical shape.

"If you care about every kid having an instrument, should they have it in their hand or should they have access to it only for 10, 15 minutes in the lab," he asks.

The children can build their own instruments, some of which have light-emitting diodes, along with condensers and diffusers.

The kind made for health-care workers include a Vernier callipers to make calibration easier.

Usually making aspherical lenses is not easy. It takes machining, grinding and so forth. In Manu's model, it is just sound that jiggles the lens into the right shape, with the UV setting it.

"Science education is one aspect of it; global health is the other. In science education, we want the microscopes to be everywhere, immediately available; with the health care side, we need to be very careful and take small steps, make sure we do all the validation studies in the field, peer review and publish those."

Because we don't want anybody randomly just getting a hand on a microscope and pretending they know how to diagnose diseases — you need to also understand what you're seeing — even though the instruments look very similar, the health-care instruments will be available only to health-care professionals. There is a training program. On the science (*education*) side, it's microscopy for everyone.

"We have a vision where we want this to go. And that vision is as important as the technology. There's sometimes a scenario where the technology is preserved and the vision is not. That's what we're trying to deal with: it's very important for us to essentially direct it in the right place at the right price point at the right audience. Right? ■

INDIA ABROAD PERSON OF THE YEAR 2013

'His mind, his imagination, his passion took him there'

Manu Prakash's parents Dr Sushma Rani and Brij Pal Singh tell **Monali Sarkar** about their son's incredible journey from small town India to being one of America's most inspirational young scientists

COURTESY: SUSHMA RANI SINGH

Manu Prakash with his parents Dr Sushma Rani and Brij Pal Singh on a vacation in London.

The Prakash Lab at Stanford University is a fascinating place to be in. Ideas — unfeasible, wild, weird, inspiring — reign supreme under Dr Manu Prakash. It is a 'cabinet of curiosity' that holds the Foldscope, the $5 chemistry set, and other wonders. And while it is true that it is the United States that allowed Manu's ideas to soar, the root of those ideas is firmly planted in a house in Bareilly, Uttar Pradesh — home to his parents Dr Sushma Rani and Brij Pal Singh.

Manu, a curious and creative child, had the good fortune of being born to parents who put their two children's education before everything else; every life choice they made after the birth of their sons was dictated by that ultimate goal.

At the time of Manu's birth the family lived in Shamli, UP — though his birth place is Meerut, also in UP — and his parents were unhappy with the choice of schools there.

"Our only aim in life was to give our sons a good education," his mother, a professor of political science, tells *India Abroad* over piping hot cups of Chai, proudly placed on Stanford University coasters. "We were worried that it would not be possible in a small town like Shamli. So we decided to move to Delhi."

His father, a retired businessman, says, "There were no good schools there. Coming to Delhi cost a lot. Spending Rs 4 lakh to Rs 5 lakh (*Rs 400,000 to Rs 500,000*) on our kids in those days (*1983*) was a huge deal, but I wanted to give them a good education."

He relocated his business to Delhi and the family moved there. But the years there were difficult. In addition to the cost of relocation and schooling, Manu's father met with an accident that led to losses in the business. His mother, who had finished her PhD by then, stepped in so that the children's education could continue in the manner they had dreamed of.

The job, which she got in 1987, was at a college in Baraut, about two hours away from Delhi, which meant about four hours on the road every day for the next three years. "But it never occurred to me to pull them out of the school in Delhi (*and move to Baraut*)," she says. "I wanted a strong foundation for my sons. Had I moved my children to Baraut, they might not have been where they are today."

"The education in Delhi," Manu's father adds, "gave them an academic foundation that has held them in good stead all their lives."

By 1990, his mother had cleared the Public Service Commission inteviews and been selected to teach at a college in Rampur, UP. But the parents were not about to make the move without confirming one crucial thing — the availability of good schools there. They found the Dayawati Modi Academy a good fit for both sons.

And they did something that was fairly unheard of in India of that time. Manu's mother moved to Rampur in 1990 alone with the two children. Manu was in grade 6, his brother Anurag in grade 7.

It then fell to her to single-handedly parent the boys.

"I lived with the kids in Rampur for six years. He (*Manu's father*) used to live in Shamli then," she says. "I made sure there was discipline in their lives. I was particular about who they hung out with. I would closely monitor them for they were at a tender age where they could easily be influenced. Had they gotten spoilt then, there wouldn't have been much I could have done to change the situation."

She recounts how close a watch she kept on them: "I would give them an hour for football (*soccer, both sons enjoyed the sport*). If they would be delayed even by 10 minutes I would drop anything I was doing, even washing utensils or sweeping the floors, and go out to fetch them. I was very particular about punctuality, be it play time, party time or time to study."

She makes her responsibilities in those years sound matter of fact, but it couldn't possibly have been. Though both boys performed well academically they were also extraordinarily curious and innovative and always up to something.

When 9-year old Manu heard of the *Exxon Valdez* oil tanker accident of 1989 he decided to demonstrate the need for a better way to control oil spills. He built a model tanker filled with oil and blew it up in a pool, a fact he hadn't shared with his parents.

"All the teachers at DMA used to call him a 'problem creator,' his mother recalls. "His Hindi teacher didn't understand or like him. She told me that he would always keep asking questions and embarrass her. Either she didn't have the answers to his queries or she couldn't handle his curiosity."

"But his chemistry teacher used to tell him that he would one day be written about in newspapers."

While the school months were filled with working on projects under an encouraging school principal, Manu's vacations at his maternal grandparents' home in Mawana, Meerut, were inspiring too. They were days spent exploring with cousins and being influenced by bright minds around him.

His mother, who is the oldest of six sisters and a brother, says, "All my sisters are professors. My brother is a professor, my father too. My mother gave a lot of importance to education. It was inspiring because whenever he visited there Manu would feel that the quest for knowledge was a great thing."

It is clear by now that Manu takes after his mother in much more than the way he looks.

His father promptly agrees to the role she played in the children's upbringing when he wasn't around: "After Delhi, I got to spend very little time with my children. We never sent them for tuitions outside school other than for maths from ninth grade to 12th grade (*for the crucial 10th and 12th grades of the Indian education system*). She monitored them. She set them onto the path of a disciplined study routine."

But she is taken aback at the suggestion that she inspired Manu.

"I don't think I was an inspiration," she says. "It was he who wanted to invent, to do something new. In fact, he tells me that you were a professor and you had us educated, but you could have done so much more than that. He keeps telling me that. When he sees me doing a lot of extra work at col-

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'His mind, his imagination, his passion took him there'

lege, attending conferences, reading papers, he likes that and encourages that."

She is unconvinced that she could be his biggest inspiration and insists Manu's achievements are inspired entirely by his own self: "Right from the start he has said he wanted to achieve something. And after the ninth and 10th grades I never needed to urge him to study. He would be studying 17 to 18 hours a day, what more could I do?"

Both parents also credit Anurag's presence.

"Manu was very close to his brother," his mother says. "They are just two years apart. That was another reason I never had to say much. The two of them would work on science models together."

Plus, his father adds, Anurag was even better than Manu at academics.

Manu, however, was extraordinarily hard working, they say, pulling out memories — like the time in 10th grade when Manu worked through some 100 pages of maths sums in a night.

By the time Manu finished 11th grade, his mother was transferred again. This time, to Bareilly. Anurag had finished the graduating 12th grade by then and made it to the Kamla Nehru Institute of Technology, Sultanpur, UP, but Manu had to move to Bareilly and he hated the idea of a switch in a crucial year.

Despite Manu insisting he remain in Rampur, the school's principal offering to act as his guardian and the school offering a scholarship for the year, as the parents recall, there was no question of leaving their son behind and alone. They wanted to be there as a support system, and his father says, "take care of his health" while he prepared for his 12th grade.

They moved him to the Army Public School, Bareilly Cantonment, where he finished his 12th grade as the topper in the area, setting a record for the school then.

Interestingly at this time Manu had dabbled with the idea of being an Air Force pilot.

"He was selected for the Services Selection Board (*for the Indian armed forces*)," his father recalls. "Usually entire teams get washed out in the SSB, but three people, including Manu, were selected from the team he led. He wanted to go into it. He was drawn by the adventure. But I told him to keep studying till he could. This was just after the 12th. His education might have stopped if he had pursued that path. I told him you have not seen anything of life yet. There is much more to the world and that he should keep studying till he could."

It was advice that Manu took to heart, also probably knowing by then that while the adventure of flying planes was tempting, science was even more adventurous for him.

And it was an adventure he lived to the hilt at IIT-Kanpur, shifting streams from mechanical engineering to computer science engineering, practically living in the labs, but brushing away attractive job offers.

His mother says, "He has always been stubborn about his aims. Once he decides what he wants, he is not bothered about what we say or others say."

COURTESY: SUSHMA RANI SINGH

Manu Prakash, second from left, with his cousins. The vacations he spent with his cousins at his maternal grandparents' home were inspirational for him.

She cites how in his third year at IIT, Manu received a job offer with a hefty pay packet and rejected it because he knew by then that he wanted to study at MIT and do research.

"I was worried that he would be studying for another 10 years. But he told me not to be like other mothers and ask him to chase money. He said we just needed enough money to sustain ourselves and that I could ask him to think about money the day I saw that changing."

She looks around the room and adds with pride, "All of this is a result of our hard work."

His father says, "We have never expected anything for ourselves from them. We only wanted to give them a good education and let them fly."

"To be honest," his mother adds, "we had never imagined that our child would become a professor at Stanford University. We had only dreamed that he would go to a good college and get a good job. But his dreams, his goals were different. It was his mind, his imagination, his passion that took him there. We only supported him in whatever way we could."

Much of that support during Manu's time at IIT would have to be monetary for his experiments.

"Manu's father would chide me for sending so much money for his experiments, for not sending as much money to our older son," she said. "But I told him not to stop Manu from doing his experiments. He always loved tinkering with things, exploring them. I still have so many of his projects, wires, batteries etc. He is still like that."

"Money," his father says, "is not a consideration to him at all."

Money or other aspects of living have always found very little space in Manu's mind, which is almost always focused on work, exploring, and creating.

"When he was at IIT and we would go to visit him, sometimes he would promise to have dinner with us," his mother says. "We would look forward to those 15, 20 minutes with him because in those four years he didn't come home for a single vacation; he would take off for advanced courses during every vacation. This one time I kept waiting for him. His father had gone off to sleep after a while, but I was worried and stayed up all night waiting."

"Finally, around 6 am, I went to his friend to ask where Manu could possibly be. His friend asked me to look in the lab. When I reached the lab Manu was just shutting down. He is still like that. Even now when we visit him we keep waiting. He returns at odd hours of the night and leaves early in the morning. Since we are asleep then we don't even know when he comes and goes."

"Let me tell you about one more incident," she adds. "Once I had to go to college for an exam from 3 pm. It was after 2 by then and very hot, so I asked Manu, who was studying, to drive me to the college on our scooter. It would have taken him only a few minutes, but he refused to stop studying. He told me, 'Those few minutes will interrupt my tempo for the entire day.' He refused to budge. His father often tells me I encouraged his stubbornness, but I didn't. His stubbornness is what makes him who he is."

It was that stubbornness that brough Manu to the US for the first time, changing the course of his life. In his third year at IIT, he received an offer to work on a project at Montana University for three months. But just before he was to leave he came down with very high fever. Both parents pleaded with him not to go, but he refused.

"His father was so angry he refused to go see him off or give his blessings to the trip," his mother recalls. "Manu told me, 'Please see me off; I just need your support. I don't even need papa's support.' What could I do? I gathered my courage and gave him my approval to leave even though he was ill. I went to see him off. I still remember those three months of worrying, but sometimes a mother just has to be strong. That trip opened his path to MIT and kick-started his career. He tells me had I stopped him then, he would not be where he is today."

"He has always been like that," she says. "His work is his passion. He has just wanted to do research and he brings all his passion and dedication to it. He is not distract-

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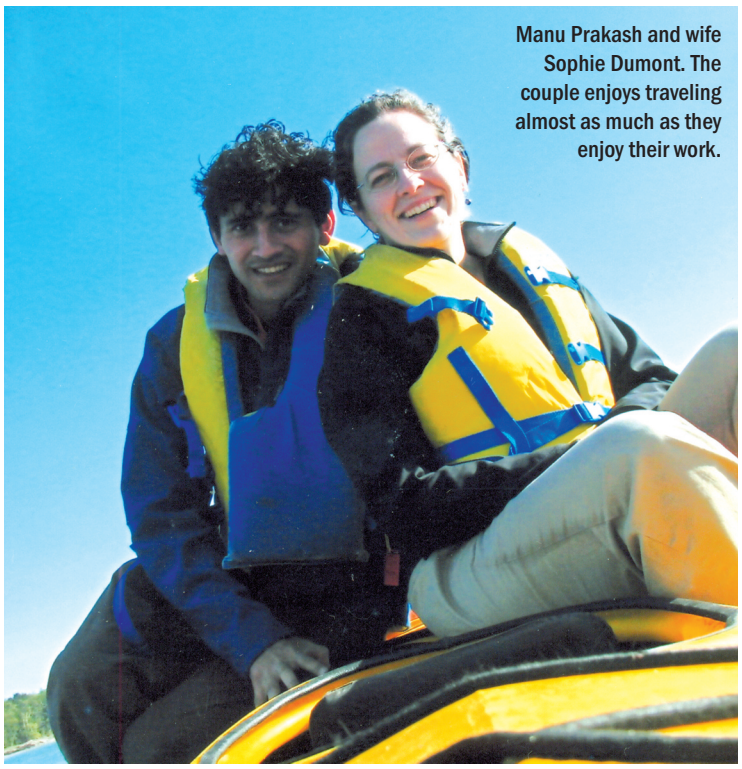
'Manu can talk about science anyplace, anytime'

Sophie Dumont introduces **P Rajendran** to her brilliant and forgetful husband



Manu Prakash and wife Sophie Dumont. The couple enjoys traveling almost as much as they enjoy their work.

COURTESY: SUSHMA RANI SINGH

Manu Prakash is willing to tear away at the unknown for hours, ripping through it with a bewildering array of creative mental tools. But remembering where he parked a bike can overwhelm him.

Which is why he now does not have one, explains Sophie Dumont, his wife and an assistant professor at the University of California, San Francisco.

Like most people around Manu, she is interested in really getting into the real nitty-gritty of how things work.

In her case, it is the details of how a cell avoids errors when separating its chromosomes during division. But she worked on condensed matter at Oxford before she decided her interests lay in biology, and then transferred to UC, Berkeley, to study the mechanics of simple molecules.

Manu impressed Dumont when she met him first at Harvard.

"I thought he was a very smart guy and very creative," she says, adding that, more importantly, he was "a very good, humble, simple person."

Though she's very curious, too, she admits she was bewildered by the variety of topics he ranged over. "I could not quite comprehend that. I guess I hadn't met scientists like that before. He has *such* a wide range," she says, laughing quietly.

The scale she addresses in her research falls between that of Zev Bryant (Manu's colleague who Dumont knew at Berkeley and who works on tinier mechanisms) and Manu, who looks at things at the tissue and organismal level.

"Manu also has an interest in things at the smaller scale — because he's interested in everything," she says, laughing.

"Manu has published papers in physics to fluid mechanics to organismal biology... That's what's very rare. What's interesting about Manu is not (*just*) that he has a wide range, but that he does actually very serious work — academic work – in a broad range of disciplines."

What about the beetle that he got interested in?

"Is this the click beetle — the headlight beetle?"

No, the beetle he saw running over water in Massachusetts.

"Oh yeah, yes, the other beetle. He actually saw that beetle on a pond in Massachusetts. He brought it back to my house and he first filmed this beetle (*on a dinner plate filled with water*) with a high-speed camera on my dining table."

That led him to discover that it uses its wings to generate power to move, and hooks to hold the water as it moved.

Then there's the story of the click beetle he found in Costa Rica. "He basically fell in love with that beetle while on a family vacation," Dumont says. "He was extremely excited about this bug, which can emit enough light to basically read a book in the forest. He brought back the beetle — not to the US — but to the house we were staying in."

She says Manu enjoyed a kind of vacation study program while making movies of it.

"So while my brothers were in the pool, Manu was making movies of this beetle," she says, laughing.

Manu discovered that that beetle could emit light in two colors and found out which stimuli got the beetle to light up in each. He also found the control system the beetle used while controlling the intensity of light.

"People would go to sleep at night — and Manu would go into the forest to find his beetles and bring them back," Dumont says. "He has a high-speed camera. He had a microscope."

It was harder for them to find faculty positions in the same area, because they were working in such specialized areas. When the offers came, Stanford and San Francisco were close enough for them to decide to move there.

"We're both scientists and neither of us is particularly domestic. Life at home is pretty minimal for us. He spends all his time in (*his*) lab. I spend all my time in (*my*) lab. And then on the weekends we spend time together," Dumont says.

"We talk about science," she says. "Manu can talk about science — anything, anyplace, anytime. If we go to a restaurant and there's some kind of swirls in the coffee he will go into some explanation about why the coffee is swirling. We talk about our research groups, labs, family, travel..."

Manu and Dumont met in 2009, and decided to get married in summer 2011. In August they were engaged, and married in March 2012.

The marriage was to happen in New Delhi, which had the kind of hotel that could address the needs of Dumont's ailing mother.

Manu realized that he was far behind on a grant proposal — and given that their funds were already tight — told her to go off alone. And so Dumont landed up in Delhi, all ready to be married, while 7,700 miles away the groom-to-be dreamed up novel ways he could loosen a research committee's purse strings.

From her family, 25 people went to Delhi for the wedding, which lasted two days.

There were the *haldi, mehndi* and *sangeet* ceremonies on the first day, the marriage itself on the second.

"It was great. My family loved it. Manu's family also loved it," Dumont says.

Then another grant-related situation and the cautiousness of the Iranian consulate also shortened their honeymoon. But, among other places, they got to visit Tehran, Shiraz and Persepolis, and enjoyed the company of the local Iranians, who she described as "superfriendly."

Travel, which they both love, is particularly easy because neither of them are picky about food.

"We love eating out so we try out restaurants from all kinds of countries," Dumont says, adding that Manu probably prefers Indian food the most.

While very comfortable with the complex and the arcane, Manu has a problem with everyday challenges — like paying income tax, checking if there is food in the house or mold in the bathroom or booking an air ticket.

"Manu, on a routine basis, buys plane tickets for the wrong day, or for the wrong location. Most recently, he managed both at once," she says, with a laugh she tries to suppress without much success. "The wrong date *and* the wrong location."

His child-like approach to things used to exasperate her a bit at one time, but — she laughs — "I just kind of gave up."

She gives the example of how, when she went for a conference in Europe, he decided to do the family laundry but forgot to take the clothes out of the washer. When she returned, she found them covered in mold in a variety of brilliant colors.

"Well, I just washed them again," she laughs yet again.

She also speaks about how Manu nearly couldn't graduate without first negotiating a large library fine. Though they were not a couple at the time, he came to her for help. But given the enormous sum involved, she didn't have enough either. Finally, they borrowed it from her brother Charles.

"He loves books — and reads massively," she says of Manu. Of course, in this case the cost was rather high.

Manu never has a dollar in his wallet, Dumont says, and adds that her husband is more absent-minded than most people.

"He gets no-parking fines. He'll forget the car somewhere. He'd forget a bike somewhere and they'd get stolen. So now he doesn't have a bike any more," she says, explaining that while he's very creative and absorbed in science, other things don't matter. He is very fond of children, though.

"He's amazing with kids," Dumont says. "At family parties, all the kids gravitate to him even if, at times, they don't share the language (*as in her family*)," she says. "Even at a Christmas party, Manu can be found somewhere in a bathroom, the lights down, showing a kid on a microscope something... He's a kid magnet." ■

INDIA ABROAD PERSON OF THE YEAR 2013

‘He would move the system to meet his goals’

Professor **Amitabha Mukerjee** recalls Manu Prakash as one of the most creative students he has encountered

HITESH HARISINGHANI

Professor Amitabha Mukerjee shares a video of Manu Prakash demonstrating a tank tread climber during his IIT-Kanpur years.

We get two kinds of students who clear JEE *(Joint Entrance Examination)*. One is the *ghiso pito* kind, who have slugged it out through all kinds of coaching, and the other is students who manage to clear the JEE with a little less intensive coaching.

Manu Prakash was definitely in the second group. These students are actually some of the brightest and most creative students in IIT, and Manu was definitely one of the most creative people I have encountered.

Manu took a couple of courses from me; one was in artificial intelligence. Among his peers we had an active robotics group and we wanted to do something societal and change things a bit. We wanted to use robotics in schools to enable kids to build something with their hands. The program was called BRiCS, Build Robots Create Science.

We did workshops in probably 500 schools (while elite schools would pay for the workshops, the team would use that money to offset costs of taking the workshop to underprivileged schools in the area) around the country where we got kids enthused on the theme of robotics; we used to use Lego kits.

Manu was very involved in this. There was a group of four or five core people and Manu was definitely one of the leaders.

A majority of our kids come from upper-class backgrounds. When we were doing these workshops we met a lot of poor people. If you take a kid from the slums and say, ‘Build something,’ he is going to say, ‘I’ll do whatever you tell me.’ You have to work with them. You have to tease the idea out. And say, ‘The things we are saying are not important. What you are saying is important.’

Manu really felt this and said this was a very serious problem. He really liked working with children.

One thing that was very openly discussed when Manu was at IIT was the sad status of our education system and how the competitive pressures, the quota culture, and the coaching culture really destroys childhood.

The most brilliant people in India are doing things they have no interest in due to which India as a country is not able to meet its human potential. We had been discussing this for a long time and Manu was a key change agent in this process.

Unfortunately, he has gone to the US. If he were in India he could do a lot more of this kind of thing because he has a lot of capacity to get people involved and build teams.

We really need to do something where children discover themselves and not textbooks. This is what we were trying to do.

One of the big ideas we had was these toys (*used initially in the BRiCS program*) were very Western oriented and we needed to relate it to the children and their stories and lives. In this context we ran a contest in 2002 called Robot Ramayan where people built all kinds of things, from the origins of the universe to Draupadi’s *swayamvar*.

We also had something called Programmable BRiCS, the idea is that you are programming these robots by writing a program on a computer using a visible metaphor, which kids can use and download to a machine. This was originally Manu’s idea. Manu also has good artistic sense and had even collaborated with another artist and brought out a lot of cartoons of how to make toys.

In fact, we had a patent filed in 2002 and granted in 2010 for programmable assembly for puppets. It is related to Digital Kathputli (*puppet*).

These kind of programs were things Manu was very actively involved in when he was at IIT. I am very happy that I was able to work with Manu in that period.

The thing about Manu is that he is very passionate. One tenet of creativity is that you do not stop if something is impossible, you do not totally reject it straight away. Manu had this in very high measure. He would perceive all kinds of weird things that were not obviously feasible. But sometimes some things would turn out to be feasible.

That is the real power of creativity that Manu has, which lot of students in IIT don’t have because they come through this pipeline (*coaching*). What happens now is we pressure kids so much that we don’t get kids like Manu coming very often.

Manu was that kind of a kid who if he wanted to do something would pursue it even if it seemed very obvious that it wasn’t working. So, out of 10, 15 ideas maybe two would work, but that’s OK. That is enough.

He didn’t have anything that you would consider a successful student — he didn’t have publications, he didn’t have CPI *(Cumulative Performance Index)* — but he had these ideas.

He was an inventor. He was interested in getting the invention out. He would bend systems. If he needed to get something built and there was a machine shop that he needed to work with he would badger them. Ultimately he would get the thing done. He would work, influencing the system rather than work beyond or within.

You cannot work outside the system so he would move the system to meet his goals and this is true of many creative people. These kind of people are change agents. We really need people like Manu to do these things.

(*Usually*) you have no idea where these kids can go. The most creative guy may suddenly go and join the IAS (*Indian Administrative Services*). But Manu, I thought, would be going to academics. But I wasn’t too sure that academics would be able to manage with him. I am glad he has been doing well.

There are many other things Manu has done before the Foldscope that I have followed to some extent. If you look at the Foldscope idea it is not completely a new idea. But to make it and package it this way is Manu’s particular thing.

But invention is not the only solution. We need people to adopt it. The Foldscope can penetrate, but it needs somebody to take over who is an entrepreneur not an inventor...

Manu is good at many of these things himself — he is one of the most creative guys who have come out of IIT in recent years — but to get this thing to penetrate the market we need more than creativity. We also need a lot of social penetration. If these things happen, the Foldscope will really do well, because the idea is brilliant.

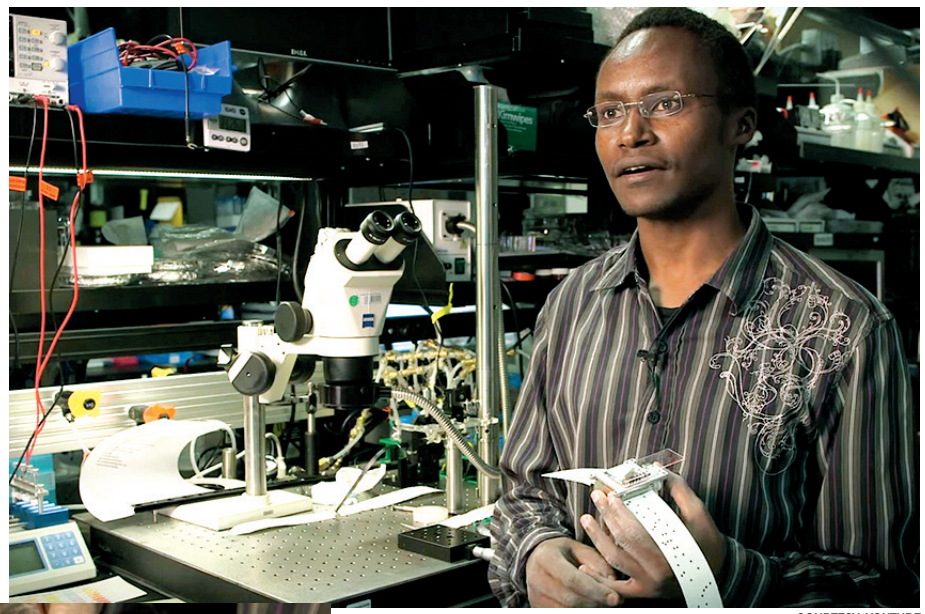
I would really like to see Manu get more involved in reaching these inventions to the masses. ■

Dr Amitabha Mukerjee is a professor at the Department of Computer Science and Engineering at IIT-Kanpur. He spoke to Monali Sarkar.

INDIA ABROAD PERSON OF THE YEAR 2013

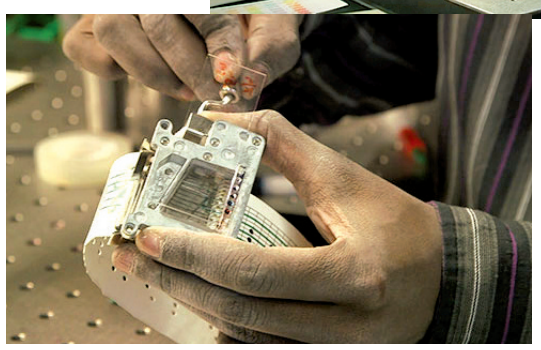
‘He’s the most curious person I’ve ever met’

‘He’s extremely open to all sorts of ideas — and extremely encouraging to pursuing different things,’ Grad Student George Korir tells **P Rajendran**.



COURTESY: YOUTUBE

George Korir demonstrates one of the newest creations coming out of Prakash Lab, a $5 chemistry set. Inspired by a music box, it won the top prize at the SPARK competition.



If George Korir ever thinks of a particularly crazy idea, he knows which professor to go to.

His mentor Manu Prakash will always run over an outlandish-sounding idea thoroughly before deeming it unviable.

“He’ll be open to it and be able to engage in a very excited way,” says Korir, who remembers how Manu turned what he had deemed a liability in a mechanism into an asset.

“Once I went to him with a problem because my device was not working the way it should. Just from his curiosity about the way it was working, we ended up using (*the changed behavior*) as a feature — and it turns out to be the best feature we have in that device,” Korir says.

Like his lab mates, Korir has an impressive resume. Son of subsistence farmers in Kenya, he was sponsored for an education at the Harvey Mudd College, where he earned an engineering degree. After studying the properties of dyes there, he worked for his sponsors on a Defense Advanced Research Projects Agency prosthetics program.

He then went on to do a feasibility study on ways to use light to see if a patient’s lung had collapsed, and then to find ways to gauge if cancer treatment was indeed working.

He had been deciding whether he ought to begin a career immediately or do a stint in graduate school. His positive experiences with research made him opt for a PhD. He came up with a choice between an MIT-Harvard medical engineering program, and the Stanford one.

After meeting and interacting with Manu, he thought that his lab would be a very good fit for his interests.

He recalls Manu telling him then, ‘As you evaluate your options, think also about the person you want to work with. I think it matters.’

“We have a lot of commonalities. I really enjoy being here,” says Korir, who is also getting two years of medical school training on the side.

“I could see he was interested a lot in what I’d done,” he said, describing Manu as asking about his experiences in Kenya and the field work the lab does.

“That was very attractive to me because I always wanted to implement (*ideas*),” says Korir.

Though he was not on recent field trips

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‘Analytically brilliant and extremely creative’

The first line he said was, “Do science like you're an eight year old.” I think that's what drives everything in this lab,’ Grad Student Haripriya Mukundarajan tells **P Rajendran**

When Haripriya Mukundarajan first joined Manu Prakash’s lab, she wondered why on earth would she need to check the volume and contents of bug spit.

The kind of work that each student does in the lab also gives observers an insight into their mentor’s long-term vision.

Before she came to the lab, moving over from a product design program at Stanford, the IIT grad had helped put together a few inventions in India — a satellite called Pratham, that is still to be launched; a $100 incubator for newborns made from local material, and a cold water jacket for milk cans.

In the bug spit case, Mukundarajan concluded that it was far better to have mosquitoes leave their disease-bearing load in sterile samples than in human volunteers.

She takes the example of dengue.

“(*When*) a person gets bitten by a mosquito, we have no idea how many bites it takes to make somebody fall sick, and how many virus particles come out in each bite, and what is the minimum load of virions that make them fall sick (*the number is called the infectious dose*). You have no idea what is going in with the saliva.”

Since 70 percent of the infected show no symptoms, and those who do exhibit them after a week, assessing spread by counting the patients at a hospital would not be very effective.

The Manu Prakash lab solution to getting more information with little danger to humans, involved making mosquitoes bite into bubbles of distilled water given the odor and warmth of human sweat so that they left behind saliva that could be measured for pathogens. The samples are on cards that are directly mailable through the postal system after the mosquitoes have done their business in these little spittoons.

“I think I’ve started liking to tell my friends that my adviser is the guy who licked a slug on a bet,” Mukundarajan says, and laughs.

“I always feel like I would like to be like Manu, except for this one thing,” she says, adding, with emphasis: “I... would never... want... to lick a slug.”

Mukundarajan, a vegetarian who hopes to be vegan, had some reservations about Manu’s diet.

“We used to have these crazy insect things that used to be handed around and people used to eat. And he used to keep saying that insects are super tasty.”

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'Analytically brilliant and extremely creative'

So Mukundarajan decided to help out.

"I bought him a lollipop with a scorpion inside because I thought he might like it. But then he didn't eat it. But he did eat one with a larva inside."

Despite seeing that, and watching him take a meal at lab get-togethers, she says, "I'm not sure Manu eats very often. It's a running lab joke that he absorbs nutrition intradermally from the air. Because he gets these sandwiches and they sit on his desk. He's so super busy all the time and we don't see them get eaten. He still has ridiculously high energy levels. We think that's partially because he drinks a lot of coffee that is less coffee and more coffee-flavored sugar. But on a daily basis, yeah, it's like a joke that the boss lives on air."

She really likes the lab trips he organizes.

"It's like the most atypical lab trips ever. Other labs maybe go to an amusement park or something like that, but our lab goes tide-pooling. We went and looked at anemones and starfish and crabs and stuff.

"We go to Monterey from time to time, which is super fun because our lab trips — or retreats — become more like marine life foraging with a lot of fun and food."

And when going kayaking, she describes how Manu is torn between enjoying the experience in the single-seater and recording it on video for future generations.

"He kept getting left behind because he couldn't row and record," Mukundarajan says, describing how everyone else had to wait for him to catch up.

Having Manu as an adviser, she says, is particularly inspiring for personal reasons.

"It kind of gives me hope that even people who get easily distracted, and who are kind of all over the place, and who are really interested in everything, and don't want to focus on any one particular thing, still have the potential to become super-successful."

And then there's art.

"Manu is a really good cartoonist," Mukundarajan says.

P RAJENDRAN

Haripriya Mukundarajan with a cartoon sketched by Manu Prakash.

"That's why, for me, it's like I ended up in the perfect place because I, too, want to be a part-time science cartoonist. Manu is the perfect person who will encourage stuff like that."

The lab once gifted him a mug with a picture of something he sketched on it.

Mukundarajan still has a book of his sketches.

"He keeps saying he should take this back from me, but he keeps forgetting." Since she and the book are located less than 20 feet from his office, perhaps she just forgets to return it.

"I think it's the best lab ever because this is a place I never ever thought I could find. In a place like this, I can work on bugs, and I can work on useful things like infectious disease transmission, and I can work on cool stuff like how algae make very pretty pictures, how insects can water-ski, and how bubbles freeze into really beautiful patterns. I really like the range of both fun stuff and serious stuff that I can do."

She describes a class she took under Manu.

"The first line he said was, 'Do science like you're an eight-year-old.' I think that's what drives everything in this lab. I'd like to be like Manu in a lot of things, except there are a couple of really outrageous things he does that I could never ever want to do. I don't think I ever want to be a kind of person who licks a slug, but that doesn't stop me from thinking it's extremely cool."

"One thing I really like about Manu's work is the diversity of it. He's not afraid to jump into any field or tackle a problem, no matter how strange it might be or whether he has a background in it or not. I think that's really awesome and admirable. Because it's really the question that matters to him, and not whether he has the tools in his toolbox to produce an answer."

"The culture in the lab has also been that: it's the problem that is really important, and the tools are something you learn on the way. I think most of us in the lab admire how much Manu has learned over the years — and I'm always thinking, my God, I'm three years into my PhD and I don't feel one-fourth of the way to where he is right now."

"That way, I think he's an absolutely fantastic example of how you can be analytically brilliant and extremely creative, and do both really good theoretical work and be extremely hands-on. I think this all-round excellence is what sets Manu apart."

In his lab, Mukundarjan says, "It's OK to be really, really stupid — as long as you're not really, really stupid for very long, you're willing to do something about it." ■

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'His mind, his imagination, his passion took him there'

ed by what people say, he is not distracted by normal things like working hours, clothes, or even food when he is working on something."

"Yes," his father says, "we are a little worried about the fact that he has no interest in money."

"He doesn't shave, doesn't cut his hair, wears shabby or torn clothes," his mother adds. "If I ask him to shave, he tells me, 'Is that even a thing to bring up? Ask me to do something constructive, ask me to find or create something new'."

"Like Arjun," she adds, "he can only see the eye of the fish (*a reference to a challenge in the Mahabharata where Arjun had to shoot a fish through its eye by looking into its reflection in water*). He doesn't care about what his parents, friends or others say. He doesn't worry about failing — he knows he will fail too — but he wants to keep trying."

"He keeps telling me that we should leave something valuable behind for the world. He is not worried about his life, his health, but he is very worried about global health."

Manu has traveled through almost 25 countries in 10 years, many of them in Africa, taking stock of the health of children in those countries. Whenever he visits India, the last time was in August 2013, he makes the time to meet underprivileged children, take stock of their health, find out which diseases afflict them, what can be done to improve their health.

"He feels very sad about the conditions here," his father adds. "He gets upset over the fact that though India has so much as a country, there is so little improvement."

"He wants his inventions — a Foldscope, a chemistry set or the smartphone that detects cancer — in everyone's pockets," his mother says,

"He wants to give the patent to somebody for commercial production," his father adds, "but he wants to ensure that it will be cheap and widely accessible. He is not interested in making too much money out of it."

When it comes to work, Manu is single minded, but that has in no way precluded him from having other interests, other adventures. Those who know him best say he is always up for a new experience.

"He loves traveling," his mother says. "Whenever he gets a few days he likes to travel to a new country, a new city and explore its culture, its people, its politics. Even when he Skypes with us he wants to know about the political situation here, about the Aam Aadmi Party, about Arvind Kejriwal (*the AAP leader*). He insisted I show him my inked finger after voting (*this year*)."

"He has a restless soul," his father says.

The other constants in his life have been soccer and family. And he remains close to both.

"Whenever he comes here," his mother says, "he gets in touch with all his aunts and uncles. He makes sure the family comes together like we did when he was a child. He is especially interested in all the kids in the family. While all the adults keep hoping to speak to him, he will be caught up with the kids, finding out who is doing what, what their aspirations are." ■

Fellow scientist Zev Bryant, who is constantly amazed at Manu Prakash's child-like curiosity, shares with **P Rajendran** the curious tale of When Manu Licked A Slug

'A #labselfie' in Monterey Bay by Manu Prakash. His colleague Zev Bryant says he picks up ideas and looks at them in the same way that he picks up bugs on the street and examines them.

COURTESY: TWITTER.COM/PRAKASHLAB

'Manu behaves like a child'

"Manu is interested in many different things — and he refuses to choose between them, right?"

Zev Bryant, an assistant professor of bioengineering and structural biology at Stanford, laughs as he asks the rhetorical question while describing his colleague Manu Prakash.

"He refuses to choose between the basic physics of biology and applications. He refuses to choose between the laboratory and the field. Naturally, when you are keeping so many things going, there's going to be some amount of chaos," he says.

Bryant does some fun work himself — such as on DNA gyrase, which is involved in DNA coiling, and the behavior of myosins, which along with actin, plays a starring role in all the sinews that the muscle-bound exhibit.

While Bryant works at the molecular scale, Manu works at a larger one — involving physical biology at the organism level.

"Having Manu here has been an exciting opportunity for us to think about interfaces between those scales, and we talk often on long train rides home to the city (*San Francisco, where they both live*) about the ways we can combine the different engineering technologies."

For the first time, he says, they also have a student, Toly Rinberg, working between our groups.

Manu and Zev have not worked together yet on a research project.

"One thing we've designed together is the shared space in the new bioengineering building," says Bryant. "It's been great already for my students to have exposure to the way people in his group work and vice versa."

Bryant agrees that the way Manu's group works is interactive and chaotic.

"(*Manu*) behaves like a child," he says with a laugh. "I mean it in the nicest way possible. If you go for walk with Manu in the woods or in the park or even on the street, you'll see he's constantly doing things that many of us stopped doing when we were eight years old." (*Laughs.*)

"He's constantly picking up bugs and slugs and worms and figuring out how things work — stopping at spider webs and trying to figure out where all the bunch of little spiders are. He brings that kind of child-like curiosity to everything he does. You can see the way he picks up ideas and looks at them and turns them over in the same way that he'll pick up bugs on the street and look at them and turn them over."

He laughs again.

"It's become a cliché to talk about scientists having a child-like curiosity, but I can't think of anyone for whom that would be a more apt description than it is for Manu."

He then describes the famous lab story: When Manu Licked A Slug.

"That came about because Nicholas Kristof (*the New York Times columnist*) had written this article ... deploring the fact that American kids these days no longer know what happens when you lick the bottom of a banana slug. Conceptually, he's deploring the idea that we've lost this visceral connection with nature..."

"As scientists, all of us are fascinated and inspired by the complexity we see in nature and that is, after all, what we're trying to explain, the thing that's driving us. But many of us can lose that visceral connection with nature as well."

"We were talking about that column when we were out walking in Santa Cruz ... There was a banana slug there that Manu picked up and was playing with for quite a while and, of course, he wanted to check if Kristof had said was true (*that*) it is supposed to make your tongue numb."

"His version of the experiment was that he licked the slug. He immediately had to (*leave to*) get on a flight to India that day. Nothing happened very fast" — Bryant laughs — "but halfway through the flight his face got quite swollen and his tongue was quite numb indeed. He now definitively knows the answer to that question about what happens when you lick the bottom of a (*banana*) slug..."

"Not as a kid — no. As a 30-year-old adult."

Bryant and Manu are working together on a proposal for a new project.

"We come to the same problem from opposite ends. We realize that while I've come from this very narrow focus on molecular mechanisms, and how molecular entities can do their work, Manu has come from the perspective of saying, well, I see this overall large process inside a cell or inside an organism. And I don't understand how that works. You look inside a plant and you see streaming; you look inside a cytoplasm and you see... streaming motion. It's a sort of macroscopic thing...'

"Manu starts there ... and he starts to dissect it in terms of the fluid. But fundamentally in these complex biological contexts you have these phenomena that arise from molecular processes. So I start from the molecules and I'm thinking of that, and we talk to each other and we realize we've been thinking of the same problem but from opposite ends."

He has observed the obsessed way in which Manu and his group do things.

"I have watched the way his team works on these global health projects and the development of this paper microscope, which, as an outside observer, it's been fascinating watching develop," he said, laughing as he describes the prototypes of those constantly littered all over the floor.

Bryant says his daughter, Navia, 7, was one of the early testers of the paper microscope.

According to him, "At home, as at work, (*Manu*) is a constant fountain of ideas. Both me and my family tremendously enjoy our time with Manu."

He remembers a short visit to Manu's flat in a basement of a place on the edge of a lake, when Manu was still in Boston.

"It was a kind of home perfectly suited for Manu," Bryant says with a laugh.

"Those 30 minutes (*or a little longer*) were like hours — not just because we had great conversation and (*because*) Manu cooked for us. We managed to find some worms and a fishing line and go fishing in the lake. So my daughter learned about fishing, I think, for the first time there. She learned about fluids from Manu. We had this amazing 30 minutes of peace before going back to whatever function we were going to next."

Bryant's daughter, like most other children, really go for Manu.

"Manu is constantly showing her bugs and other pieces of nature. He's always giving her toys that explain how fluids work," Bryant says. "Navia would rather hang out with Manu than with me."

He does not seem to mind all that much. ■

‘He’s in the game all the time’

‘He is into all kinds of unrelated things that somehow he synthesizes together in a brilliant way,’ Stanford Professor Paul Yock tells
P Rajendran

“What’s distinctive about his inventions is this: They pull from areas that wouldn’t normally connect,” Professor Paul Yock says about Manu Prakash.

“He has a very unusual creative process,” says Professor Yock. “It is very lateral. He pulls ideas from far outside his own areas. So I think he is — even for an academician — very thirsty for knowledge outside his area. He really likes to learn about things and he sets his focus very wide.”

Dr Yock, the Martha Meier Weiland Professor of Medicine and Director of Biodesign at Stanford, is a bit of a tinkerer himself.

“Inventing is a kind of hobby of mine,” he says. “I pay attention to it. I pay attention to inventors and the way they think. What’s fun about his inventing process is that his leaps forward are drawing from areas that are way out of his zone.”

He takes the example of the Foldscope, Manu’s answer to the need to get microscopy for anybody who cared.

“The concept of an inexpensive ‘scope has been around forever. ... And he just went completely lateral and had this origami concept somehow floating around in his head, and pulled in a completely different manufacturing technique for lenses — blowing little bubbles for the lenses in very high volume very, very inexpensively. (*It’s*) not a technique, he should know about, right?” Professor Yock asks as he snorts in amusement. “Why in the world would this guy know of this methodology?”

Then he answers his own question: “It goes back, I think... He did some work on birds that create little droplets. I think that may have been connected in his mind. These wild connections, you know!”

Professor Yock explains that the connection is that the birds spit out little droplets that harden up into spheres.

P RAJENDRAN

Manu Prakash at Stanford University. What’s fun about his inventing process, his colleagues say, is that he draws from areas that are way out of his zone.

Manu used a similar idea to make lenses.

“Then the idea of origami was something floating around in his head — and he put all those things together,” he says and then goes on.

“Another example — a project I really love of his — (*involves*) a mosquito vector. (*It’s*) a little postcard that has a jillion little bubbles that have a mosquito attractant. The mosquito comes and stings the bubble because it has an attractant. That captures both the DNA of the mosquito itself, so you can characterize the mosquito — and whatever (*pathogen*) that it’s carrying: Malaria, dengue... The reason for the postcard is, you want to be able to track epidemics — West Nile for example... It’s again really brilliant.”

“Now, the way people do it is they send volunteers to be (*bitten*) and the volunteers catch the mosquito. The new technique allows one to put cards outside for a week, then mail them in. What you have is a very early warning system. Like if West Nile is spreading into the Bay Area, you would know about it. We’ve never been able to do that.”

While interesting scientifically, Professor Yock says it is much more interesting from a public health standpoint.

“This is a little bit like chip manufacturing,” he says. Somehow he pulled that idea and married it with the idea of vector screening for mosquitoes.”

Professor Yock directs programs that evaluate projects for funding where Manu brings up questions.

“I do interact with him in the bioengineering department, where we deal with issues about teaching and hiring and so on,” he says. “There, too, I would say what characterizes his approach is (*that*) he really has a very lively intelligence... You just have this feeling that his headlights are always on the topic that you’re talking about. He is very likely to have an interesting insight or challenge what somebody’s saying. He’s in the game all the time.”

But Manu’s persistent questioning raises no hackles, says Professor Yock.

“No, he’s a pretty sweet guy, actually. (*Henry*) Kissinger had this line that people in universities are so nasty because the stakes are so low, meaning they fight over little things. Manu is a gentle creature. He is not as blatantly ambitious or aggressive as a lot of people with his talent.”

“I think part of the reason he’s a fit for global health type things is that he has a genuinely — this sounds a little sappy — but he has a really caring personality. He’s a really decent guy.”

And then there is Manu’s team.

“His students are extremely fond of him. He’s a character. In the way he talks and conducts himself he’s easy, he’s loose, he’s a little bit ... whatever the opposite of buttoned-down is,” Professor Yock says.

He remembers meeting Manu at the airport when he came in for his first interview for the Stanford job.

He expected the conversation would last half an hour, but it went on for one-and-a-half hours.

“It was the most interesting, wide-ranging (*conversation*). We didn’t talk about the job, but I wound up learning” — he speaks through laughter — “a whole lot of wild things, from nature to technology to politics. He’s got a lively intellect. He’s into all kinds of unrelated things that somehow he synthesizes together in a brilliant way.” ■

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‘He’s the most curious person I’ve ever met’

to Nigeria and Uganda to test ways to collect mosquito saliva, Korir says, “I want to work on medical technologies for developing countries because ultimately I want to go back home.”

One of Korir’s projects is a chemistry kit that relies on a microfluidic chip that uses no external power source. Usage does not call for much training — and the first model was fashioned from music box parts. Useful in a variety of health-care situations, it is also a good educational tool for children.

Describing Manu, Korir says, “He’s the most curious person I’ve ever met. He’s just curious about everything. I remember, once he was pushing a cart and it was making a noise he did not understand. He just stopped and started asking all these questions about that cart, and why it was making those noises.”

He admits that sometimes, that can come in the way of work.

“I think the concept of time for him is very fluid. Initially, I was very exasperated. Now I’m learning to manage it and just be flexible as well. Because when he’s present with someone, he’s totally present; he loses track of time.” Korir laughs. “So if you’re next in line, that could be a challenge.”

He sees Manu as being very engaged — and helpful to a lot of people.

Korir speaks of a visitor from Kenya who Manu went out of his way to introduce to many people in the Bay Area. “(*The visitor*) went back with suitcases full of gifts and equipment. It showed me a side of Manu — as (*someone*) very kind to others. Just being open to helping others,” he says.

“He’s extremely open to all sorts of ideas – and extremely encouraging to pursuing different things,” he adds. “As a graduate student, I find that very useful, very helpful.” ■