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## Arjun G. Yodh

Growing up in Maryland as the son of immigrants from Pakistan and India, Arjun Yodh was more interested in professional sports and music than science. Although his father is a high-energy physicist and he was surrounded by the concepts of scientific inquiry from an early age, Yodh never imagined he would one day become a leading biomedical physicist.



"My father definitely had an influence on me," he says. "Not that I was sure about going into science back then, but it was an influence. At one point I actually was thinking of becoming a journalist."

Both professions require passion for inquiry and a desire to understand what makes things tick. They also require the ability to consider situations from many points of view and to synthesize and analyze diverse data.

"Doing experiments is like a craft," he says. "It takes attention to detail, innovation, creativity, and an understanding of what you are trying to accomplish. If you listen to the pianist Glenn Gould play the Goldberg variations, for example, he has thought about how every single note should sound. That approach to a project appeals to me on an aesthetic level."

Yodh was an undergraduate at Cornell University in the late 1970s when he first began to realize that his father had influenced him more than he first thought. At Cornell he found himself drawn to fundamental physics research, with an emphasis on optics. The physics-optics theme continued into the 1980s during his grad-school research at Harvard, where he worked with Tom Mossberg, and during a two-year postdoctoral fellowship at AT&T Bell Laboratories, where he focused largely on traditional atomic physics as a research associate with Steven Chu and Harry Tom.

"My formative research years were really important because I got to interact with Mossberg, Nicolaas Bloembergen, Chu, and Tom," he says. "Those guys did a lot to inspire me. They taught me how to think about science, how to do science, how to go about finding new kinds of problems, and the value of working hard to achieve a goal."

In 1988, Yodh joined the University of Pennsylvania faculty as assistant professor of physics with a plan to use lasers to study molecules on surfaces. During his first days at Penn he attended a seminar given by Dave Pine, who was then at Haverford College and today is a professor at New York University. That seminar was another turning point, Yodh says, because it brought to his attention

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an emerging field of condensed-matter physics that used highly scattered light to peer into turbid matter.

"Diffuse optics is always about optically thick materials, and at the time there was a whole area of research opening up that explored how light propagates in these materials and how the properties of these materials are impressed upon propagating light," he says. "Dave and I started collaborating on this problem, and that initial research turned me on to soft condensed matter."

### Seeing both sides

Throughout his career, what has made Yodh unique is that he has been drawn into conversations and collaborations not just with other physicists but with biologists and clinicians as well. His initial research into how light propagates in optically thick media, combined with his close proximity to the medical school at Penn, ultimately led him to meet with Britton Chance, professor emeritus of biophysics, physical chemistry, and radiologic physics at Penn.

"As I became increasingly interested in this general problem of diffuse optics, I started talking to Brit and he gave me a lot of encouragement and intellectual support from the bio side. Picking up on work by Enrico Gratton (then at the University of Illinois), I realized that diffusive waves behave in a manner that is very analogous to optical waves. This led to some early refraction, diffraction, scattering, and image-reconstruction experiments in diffuse optics."

To Yodh's delight, over the last 10 years these initial "proof of concept" physics experiments have evolved into preclinical applications and devices that address real-world issues in medical care, particularly in breast, brain, muscle, and tumor tissues. One fruit of this labor has been the Network for Translational Research in Optical Imaging, which aims to apply optics in multimodal contexts to the problem of breast-tumor characterization and monitoring.

Another of Yodh's projects uses light to detect oxygenation, blood flow, and other metabolic ingredients in the brain to better monitor and treat stroke-injury patients. Similar ideas are being applied by the group toward photodynamic therapy of various cancers, and, more generally, for monitoring of tumor treatment.

"One of the tools we have brought from physics to the clinic is the use of intensity fluctuations in time as a means to measure blood flow. The combination of blood flow and blood oxygen saturation is much more valuable than either alone," Yodh says. "My colleagues John Detre and Joel Greenberg in the medical school believe that diffuse optics may be very useful in this context for the management of stroke injuries."

Today, as the James M. Skinner Professor of Science at the University of Pennsylvania, with appointments in the Department of Physics and Astronomy and the Department of Radiation Oncology in the Medical School, Yodh's interests continue to bridge both fundamental and applied research in condensed-matter physics, medical and biophysics, and the optical sciences.

"I am happy about the way we have moved from the demonstration of concepts in diffuse optics to where we are learning about physiology in the clinic," he says. "But the other thing that is gratifying is that I've had really good students and post-docs who have gone on to start great careers."

He also applies many of the lessons he's learned along the way to helping his three children figure out what they want to do with their lives.

"I tell my kids that if you want to be good at anything, you have to work really hard at it. Find out the things you like and then obsess about them," he says. "My oldest is a starting pitcher as a freshman in college, and it's all about trying to outsmart the batter. My middle son is obsessed with 'Guitar Hero,' which requires a surprising degree of attention to detail, and the youngest is quite good at tennis. I'm hoping their interests will evolve, but they have certainly figured out for themselves what they like and that is important. Once I figured out what I wanted to do, I just kept doing it. I'm lucky because this job is fun."

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