Biomedical Engineer

Interview by Melissa Hartman

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Warren Grayson was an undergraduate majoring in chemical engineering at The University of the West Indies in Trinidad when a soccer injury—and subsequent visits to an orthopedic surgeon—made him consider combining his training in chemical engineering with a career in medicine. After earning his doctorate in biomedical engineering at Florida State University, he completed his postdoctoral training at Columbia University. Dr. Grayson joined the Johns Hopkins faculty in 2009.

Did you go to college with the goal of becoming an engineer?
Yes. In high school, the subjects that resonated most with me were physics, chemistry, and mathematics, and thinking about what I might do with those interests led me to engineering. I decided early on that chemical engineering was the one that I would pursue, and my bachelor's degree is in chemical engineering.

But you went to graduate school in biomedical engineering. Did you have to take much coursework to make up for the biology part of biomedical engineering?
I did. When I started graduate school, I had pretty much no biology background. My last biology course was in high school when I was about 16. So for about the first year and a half of graduate school, I was taking both graduate engineering classes and undergraduate cell biology, molecular biology, anatomy, and physiology classes. It was pretty intense. The school even offered to let me switch to a Ph.D. in chemical engineering, but I knew that I definitely wanted to study biomedical engineering.

Please tell me about the kind of tissue engineering your lab at Hopkins focuses on.
We are working on growing bone from adult stem cells derived from bone marrow and fat. We place these cells into three-dimensional scaffolds made from naturally occurring biomaterials—not in petri dishes, because cells in the body do not grow on flat surfaces. We incubate these cells in bioreactors that provide an environment that can guide these cells to form functional tissue. The bioreactor is essentially a small incubator that controls temperature and pH, adds growth factors, and can give physiological signals by controlling all the mechanical and biophysical forces to help guide cell development. We try to mimic what happens in the body that will result in tissue growth.

The idea is to grow these cells on their scaffolds for several weeks outside the body to give rise to functional tissue. Once this new tissue is implanted in the body, the hope is that it will integrate with the host tissue.

Why did you decide to work on bones in the head and face specifically?
We wanted to address some specific challenges. The first challenge was to engineer larger bones. Bones—and almost all tissues within the body—have a blood supply for the cells to receive oxygen. Outside the body, if you put cells in a scaffold and the scaffold is above a certain size, the cells on the inside tend to die from lack of oxygen. So it has been challenging to make larger pieces of bone. We also wanted to make a bone with an irregular shape and that can withstand forces. These criteria led us to focus on bones around the region of the jaw.

For bones in the head and facial areas, there are currently no good clinical options. Titanium and hard plastic don't interact with the body very well, and bone grafts from other parts of the body can't be shaped precisely enough. If our work is successful, it could have an immediate impact on people's lives. That is a huge motivator.

How long do you think it could be before your work can be applied to humans?
That's always a tricky question. Our admittedly optimistic goal is to get to clinical trials within four to five years. We still have to do large animal studies, which we are getting started, and we are doing those not just as proof of principle, but also to figure out what aspects of our approach we will need to improve.

We are working on several elements simultaneously. One is vascularization: Can we build or create vascular networks that are sufficient to provide

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nutrients to these cells within that graft we're making, and do they connect quickly enough with the blood vessels within the body? We're experimenting to see if we can improve the design of the scaffolds: Can we improve their structure to facilitate better blood vessel growth and bone formation, or to send better signaling cues to the cells? We're also working on developing computer models to better predict what will happen once we transplant scaffolds into the body.

It sounds like this work requires a wide range of expertise.
There are a lot of people playing many different roles, from clinicians, materials scientists, and stem cell biologists to people who do different types of medical imaging, to computational people. Another thing that's important to understand going forward is immune responses, so immunologists will be important as well.

What does a typical day entail for you?
Although my work is all about experimental research, I do not conduct the actual experiments. Students and post-docs do all of the experiments, and I have meetings with them to discuss experimental design and the data they've collected. If we know there's a technique or certain elements that we need that we can't do ourselves, I sometimes meet with other scientists who can help. But most of my time is spent writing grants, trying to raise money to pay the students and post-docs and get supplies for the research.

It is not a 9:00 to 5:00 job. Because I do a lot of work on the computer, I'm not limited by location. I don't have to be at the office to work unless I'm meeting with someone. This means that work tends to happen all the time. I work early mornings, at night, sometimes throughout the night. My work happens around the rest of my life.

Your dedication suggests that you find it rewarding.
Most certainly. Coming up with new things and testing them is completely rewarding. And we're always doing something new; we have lots of different projects within our lab, and people with many different backgrounds. Even trying to understand different elements of the project—trying to understand how cells work, how the body works, how materials work—means there's always something new to explore.

The intellectual and creative element is one of the most rewarding aspects of my job, but I also really enjoy interacting with people. I get to work with really nice, smart people, whether they're students or collaborators.

What do you find most challenging?
The most challenging practical thing is finding funding. The scientific problems themselves are also challenging. This means that despite having worked on this for a long time, we still don't have a good enough replacement bone to implant into patients. It's not just that *we* haven't solved it, but no one has solved it. It's a challenging problem, but that challenge is also part of the reward.

What advice would you offer to aspiring scientists reading this interview?
Try to get as much exposure as possible to science and different scientific approaches, whether within high school classes or through independent study. High schoolers might also find opportunities to work within a university or commercial lab, and I would recommend that. Exploring different fields to see what they really entail is the only way to find what resonates most with you. ■

What biomedical engineers do
Working at the intersection of biology and engineering, biomedical engineers solve some of the most challenging problems in health and medicine. They might design prosthetic limbs or surgical devices, develop new imaging techniques or drug delivery methods, or invent new materials that can be implanted in the body. Creating everything from artificial organs to visual simulations of biological systems, biomedical engineers' work is incredibly diverse—and always interdisciplinary.

Where they work
Biomedical engineers work in a wide range of settings, including universities, hospitals, government and industry labs, manufacturing companies, and regulatory agencies.

Education Required
Biomedical engineers need at least a bachelor's degree in biomedical engineering or bioengineering. A graduate degree is typically required to lead a research team.

Salary Range
According to the Bureau of Labor Statistics, the median annual wage for biomedical engineers was $86,220 in May 2015. For those conducting research and development in the physical, engineering, and life sciences, the median wage was $97,100.

For more information

BLS Occupational Outlook Handbook
www.bls.gov/ooh/architecture-and-engineering/biomedical-engineers.htm

Designing a Career in Biomedical Engineering
embs.org/docs/careerguide.pdf

Dr. Grayson's TEDxBaltimore Talk
youtube.com/watch?v=PIEb50m7v_k