Biomedical Engineering (BME) is the newest department in the College of Engineering (CIT) and Materials Science and Engineering (MSE) is one of the oldest. As such, their academic and research programs follow distinct evolutionary paths. Students in both departments have access to top faculty and curricula; however, compared to materials science, biomedical engineering is a young, evolving discipline and the boundaries between engineering, basic sciences, and medicine often blur.

BME as a discipline and graduate program has had a presence at Carnegie Mellon University (CMU) for four decades, but officially the department is less than 10 years old and is still building up its identity and reputation. Ironically, MSE, which has a long history of collaborating with companies, is undergoing a character transformation as well. MSE’s impact on the steel and data storage industries is well established, but most people are unaware of the wide range of research underway in the department. In particular, materials science and engineering is at the heart of some of the most innovative energy research conducted at the university.

Through education and research, BME and MSE are addressing today’s problems and gathering scientific knowledge that primes the way for future innovations. In the following pages we will examine how these departments are forging their identities as they expand their research portfolios.
Walk into three different biomedical engineering departments and you will find that they’re all different,” begins Yu-Li Wang, the head of Biomedical Engineering. “This field is not like mechanical or electrical engineering, which has been around for many decades with expectations of what components a department should have. With respects to biomedical engineering, different places have different emphases.” And this is where Wang’s challenge lies. His charge is to determine exactly “where the College of Engineering can make the strongest impact in biomedical engineering.”

Biomedical engineering, a relatively young discipline, is broad with latitude to veer into many directions. At Carnegie Mellon, the BME department itself is small while BME-relevant research spreads across the campus. How best to leverage the department’s strengths — to avoid spreading itself too thin while taking full advantage of the existing research — represents the key consideration in building up the department.

One aspect of Carnegie Mellon that bodes particularly well for BME is the collaborative culture. “It is very easy for a department head to break barriers and collaborate with different departments and colleges here at the university. This is crucial for biomedical engineering, a field that merges all kinds of science and engineering disciplines for the benefit of human health,” says Wang. CIT researchers working on cardiovascular devices have ready access to teams working on biocompatible materials, tissue engineering, biomedical imaging or computational modeling. In many other universities, these interactions are uncommon or require higher activation energy. “At other institutions, there is a lack of cohesion,” says Wang. This is not the case in CIT, where full-time and courtesy faculty play major roles in BME’s success while 50/50 joint faculty appointments flourish. Through “synergistic actions,” multidisciplinary teams of three or four faculty members are formed easily. Small, expert teams, unfettered by bureaucratic barriers, dynamically and spontaneously assemble into successful research forces for complex problems. “At Carnegie Mellon, a central role of the BME department is to enforce a campus-wide network that connects faculty and provides opportunities for them to explore new territories,” says Wang.

Which Roads Do We Take?

With a collaborative culture and access to brilliant faculty, how does Wang decide which research areas are the most lucrative? “We don’t have a large infusion of funds coming from private foundations. Taking that into consideration, we have chosen fields that already have a strong foundation and don’t require a huge investment such as complex animal or patient facilities.” Securing more industry partners could expand research funding, yet Wang wants “to avoid putting the cart in front of the horse. We want to build our unique character first. I cannot let outside financial opportunities distort our view of the true strengths and change our priorities. But once we define our character and make it appealing to the outside world, the right partners will surface. You could say this is a risky approach and not as pragmatic as some would like. But to me this is how we can do our best.” Wang has scrutinized BME’s research portfolio to determine how current activities can “be woven into a tight network and combined with emerging research areas” to allow the department to exercise its strengths. Any future development must be tightly integrated with this network.

CIT’s Biomedical Engineering department is young, but already it is globally recognized for its development and use of computational tools, especially in biomedical imaging. Multidisciplinary research in signal processing, optics, molecular biology, machine learning and other fields enable faculty in the Center for Bioimage Informatics (CBI) to automate the processing and interpretation of biomedical images. This work in turn finds applications in cell and tissue engineering as well as drug discovery and testing. It also
increases our understanding of genetic and developmental syndromes, which lays the foundation for cures. CBI research is helping medical professionals obtain more information from MRIs and pathological samples. “In our department, all faculty leverage the powers of computation. This is an important component in our toolbox,” says Wang.

Since the department’s inception, “there has been high visibility in cardiovascular devices,” states Wang. In this area, there is much collaboration between Carnegie Mellon, the University of Pittsburgh Medical Center (UPMC) and the Allegheny General Hospital (AGH), which has helped establish Western Pennsylvania as a hub for cardiovascular research and engineering. Another thrust that highlights the synergistic relationship between CIT and other local institutions is tissue engineering. “We provide tissue engineers with fundamental knowledge and tools that lead to clinical therapies. Research in this department is widely impacting the concept of how to promote tissue growth and how to guide stem cells toward the right destination” says Wang.

“We need to understand our bodies better in order to engineer,” he continues, and that’s why BME collaborates extensively with Chemical Engineering, Mechanical Engineering, the Mellon College of Science and others to ramp up efforts in cellular mechanics. The goal is to understand how cells respond to mechanical signals and convert those signals into biochemical processes that drive cell growth, migration and differentiation. “This is a very important but often overlooked component in health issues,” states Wang, an internationally recognized researcher in this area. In addition to medical diagnostics, cellular mechanics impacts fields including tissue engineering and genomics, or the study of an organism’s genes and their function.

BME is also flexing its muscles in robotics, but not in the manner that many would envision. “We are not focused on external life-assisting devices,” says Wang, explaining that there are others at Carnegie Mellon who make devices like smart wheelchairs to improve the quality of life for the disabled and the elderly. “We are more interested in devices that directly work on or connect with the body,” he says. Illustrating his point, Wang refers to the connection between robotics and the signal processing work that is underway in his department. Byron Yu, a recently recruited faculty member in BME and Electrical and Computer Engineering, is developing computational algorithms that process signals from sensors implanted in a patient’s brain, to decipher neural signals generated when the patient intends to move a limb. Ultimately this work will lead to smart prosthetic limbs that paralyzed patients will be able to operate with their minds.

Yu’s signal processing work also connects tightly with sensor technology. “The techniques used to make electronic microchips have also been used to make microscopic devices for detecting biological signaling or microscopic motors. Mechanical Engineering faculty assist here,” says Wang. The microelectromechanical systems (MEMS) and biosensor research in BME is expanding and that is facilitating collaboration between BME and Carnegie Mellon’s Institute for Complex Engineered Systems (ICES), especially in the area of implantable medical devices. New materials will be needed in the production of

“BME is a small department with a giant footprint. We see ourselves as a manager for promoting collaborative research campuswide.”