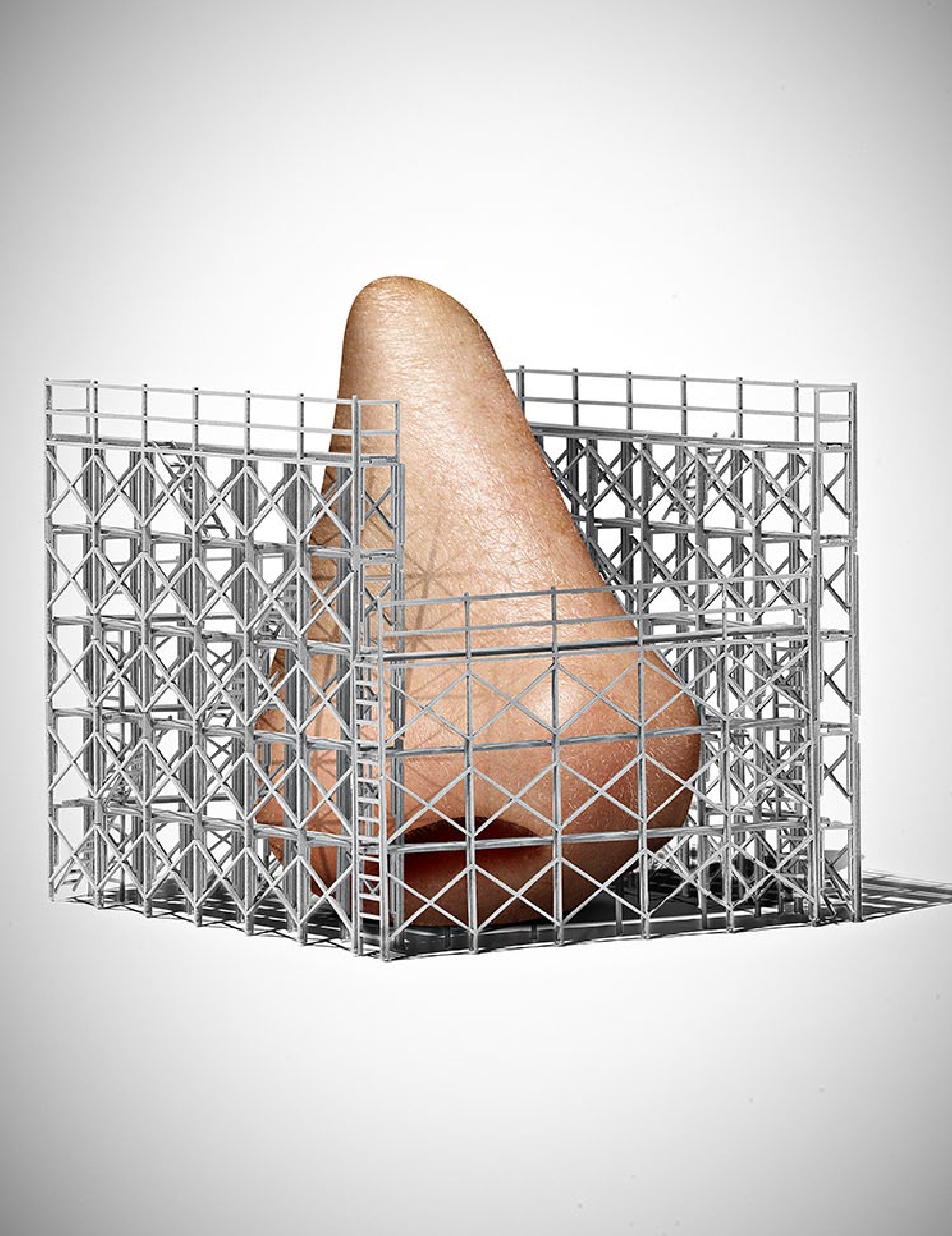

ENGINEERING MEDICINE

A JOINT DEPARTMENT BETWEEN THE MEDICAL SCHOOL AND COLLEGE OF ENGINEERING — THE FIRST OF ITS KIND AT MICHIGAN — PROMISES TO ACCELERATE THE PACE OF BIOMEDICAL ENGINEERING INNOVATION.

BY SALLY POBOJEWSKI

Sean Edwards, M.D., fixes broken faces. He knows what car accidents, guns and cancer surgery can do to the delicate structure of the human face. Edwards's job is to repair the damage and give his patients as normal an appearance as possible. Sometimes this means building them a new face.

To do this, Edwards — a professor of surgery and chief of the Pediatric Oral and Maxillofacial Surgery Service at the U-M C.S. Mott Children's Hospital — creates what surgeons call a flap. It's made from cut-up pieces of the patient's fibula, or leg bone, which he puts together like a puzzle to create a new jaw, cheek or eye socket. Once the underlying skeletal structure is in place, he adds pieces of muscle and soft tissue and then connects the flap to an artery in the neck to keep the transplanted tissue alive. The operation can take 15 to 18 hours and, in spite of his best efforts, often produces mixed results.

"The problem is that the fibula doesn't look like the face," explains Edwards. "I can cut it into pieces and shape it to the face, but it's not perfect. When I put bone in, I have to put it precisely in the right space in all three dimensions. Where I put the pieces is vital to what the patient will look like and to the quality of function he gets from the reconstruction."

Like most surgeons, Edwards is always looking for new ways to improve outcomes for his patients. About five years ago, he heard another pediatric surgeon talking about a U-M researcher who was experimenting with tissue-engineered tracheas for children born with tracheal abnormalities that make it difficult to breathe and swallow.

"I was like, 'Wow, he can do this kind of stuff? Who is this guy?'" recalls Edwards. "Good ideas spread like viruses at Michigan."

That researcher was Scott Hollister, Ph.D., a professor of biomedical engineering and associate professor of surgery. Hollister and Edwards got together and started talking about how to build a better flap. Their first job was learning how to communicate. Hollister had to learn about facial reconstruction surgery. Edwards needed to understand how computer modeling worked and what was possible in the field of tissue engineering. So they read each other's papers and presentations. They drew pictures and passed them back and forth. When Edwards was tied up in surgery, they held meetings in the OR.

Together they created a library of algorithms to define human facial anatomy in terms that computers can understand. Because everyone's face is different, Hollister wrote software to incorporate measurements from patient CT scans into his computer modeling system and create a three-dimensional computer image of each patient's skull. The data was sent to a 3-D rapid prototyping machine, which used a laser beam to build an exact plastic replica of the patient's skull.

"With our computer model, digital scans of the patient's face and fibula, and the 3-D replica of the patient's skull, we can plan the surgery in advance," Hollister explains. "We sit down with Dr. Edwards and his residents to digitally cut the fibula and determine the best way to resurface it and place it in the patient's face. We have done this for about 15 patients now and find it cuts several hours off the time required for the surgery."

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Encouraged by their success on composite bone reconstruction for facial injuries, Hollister and Edwards are taking the project to the next level. Their goal is to build a prefabricated reconstructive flap using a biodegradable polymer scaffold seeded with a patient's bone and tissue cells. The flap would be inserted in the patient's back muscle to grow until it's ready to be implanted in the patient's face. The project is still in the animal research stage, but Edwards soon plans to implant the first experimental flaps in pigs. If it works in pigs, the U-M researchers believe tissue-engineered flaps could revolutionize the field of facial reconstructive surgery.

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"It's exciting to work with surgeons, because they are so open and amenable to collaboration and they really want to push the field forward," adds Hollister. "We each have a piece of the puzzle."

Hollister's collaboration with Edwards came about through serendipity, he says. A U-M development officer who was working with another pediatric surgeon — Glenn Green, M.D. — knew about Hollister's work in tissue engineering. She introduced Green to Hollister and Green told Edwards. These informal word-of-mouth connections have been generating productive collaborations between U-M physicians and biomedical engineers for years.

But faculty and students will have more formal opportunities to collaborate, now that the Department of Biomedical Engineering is officially part of both the Medical School and the College of Engineering. The joint BME department is a first for the U-M — one department that is part of two schools or colleges.

"It's the first time this has been done at the University of Michigan, but there are about eight other universities with similar joint department structures between medicine and engineering," says Douglas Noll, Ph.D., the Ann and Robert H. Lurie Professor of Biomedical Engineering and BME department chair.

"Advances in medicine increasingly are dependent upon engineering," says James Woolliscroft, M.D. (Residency 1980), the Lyle C. Roll Professor of Medicine and dean of the U-M Medical School. "Similarly, engineering increasingly is moving into biological systems. And so it just seemed natural and appropriate to facilitate that interaction."

"The Medical School is the College of Engineering's largest research partner on campus," adds David Munson Jr., Ph.D., the Robert J. Vlasic Dean of Engineering. "At any given time, we have a quarter-billion dollars in research contracts and grants underway. If we are working that closely together, we should be joined in a more formal way."


Sean Edwards and Scott Hollister

SCOTT SODERBERG, MICHIGAN PHOTOGRAPHY

Still, figuring out how to merge two academic units with different faculty cultures, financial models and tenure requirements was not easy.

The idea originated in 2005 during an external committee review of the College of Engineering's Department of Biomedical Engineering. The committee's report noted that joint departments worked for other universities, including the University of Washington, the University of Virginia and Johns Hopkins. Why not at the U-M?

Woolliscroft and Munson were sold on the idea from the beginning. But as Noll points out, "A lot of people had to have their say in this." The deans appointed a faculty committee to study how other universities handled issues associated with this type of department structure and make recommendations on what would work best at U-M. Then an implementation committee was created to work out the details of how to handle budgets, funding, promotions, faculty appointments, tenure and a myriad of other issues. Executive faculty in the Medical School and BME faculty had to vote to accept the new structure. Then it had to be approved by the provost and the U-M Board of Regents. It took seven years to work through the process, but Woolliscroft maintains it was time well spent.

"We were setting precedent and it was important to think through all these issues very carefully," Noll says. "Academic governance was a big part of this. The faculty had to be comfortable with the idea and that takes time."

One result of the department's new status will be access to space on the medical campus close to physicians, clinical researchers and patients where it will be easier to develop and test new technologies for clinical use. Getting U-M medical devices and technologies into clinical trials and approved by the Food & Drug Administration for use in patients is a major goal for the department. Another goal is recruiting and hiring about 20 new faculty members.


Doug Noll

Munson points out that the expanded department will benefit from the Coulter Translational Research Partnership — an endowed program in the College of Engineering and Medical School that helps teams of engineers and clinicians move new technology from the laboratory to the market. "Most private companies that spin-off from U-M research come from either medicine or engineering," he says.

Coulter funding has already produced U-M spin-off companies. One such company, Tissue Regenerative Systems, markets technology developed by Hollister and Stephen Feinberg, D.D.S., a professor of dentistry and surgery. TRS currently is preparing for clinical trials of tissue-engineered jawbones.

"U-M is an incredibly collaborative place," says Munson. "People here aren't just interested in collaborating; they actively seek out opportunities to work together. This walk we've done with the Medical School has worked out beautifully,

SCOTT SODERBERG, MICHIGAN PHOTOGRAPHY

because both sides are working toward the same goal. There's no competition. We're just trying to make the U-M a better place."

Most UMHS otolaryngology residents learn how to repair damaged ears and noses in the OR. David Zopf, M.D., is also learning how to grow new ones in the laboratory.

Zopf is an otolaryngology-head and neck surgery resident who spent six months of his residency doing research in Scott Hollister's tissue engineering lab. Growing artificial ears and noses in a bioreactor is not part of a resident's normal training, but for Zopf, whose undergraduate work focused on biomedical engineering, it's a perfect match. "I'm very fortunate that our department provides this time for research," he says.

He's so enthusiastic about his work that he carries ears and noses around in the pocket of his lab coat to show visitors.

The ear Zopf carries is actually a scaffold on which cells and tissue are grown. Made from a biodegradable polymer that is resorbed by the body, it contains many small pores. The scaffolds are made in all shapes and sizes and line the shelves and counters of Hollister's lab. They are built layer-by-layer on a computer-controlled 3-D printer in the lab.

After the scaffolds are fabricated and sterilized, Zopf incubates them in a bioreactor for several weeks while they soak in a cocktail of cells, growth factors and collagen. During their time in the bioreactor, cartilage grows around and through the scaffold holes until the ear is ready to be implanted under the skin of a rat or pig. If all goes well, the scaffold will be resorbed by the animal's body, leaving healthy cartilage that looks just like a normal ear.

David Zopf

Zopf hopes that tissue-engineered ears and noses will one day be ready for use in human patients — children with congenital defects who are born without ears, for example, or adults whose noses or ears were destroyed by fire, traumatic injuries or cancer.

"The current gold standard for ear reconstruction is to take rib cartilage from the patient and carve it into the shape of an ear," says Zopf. "The problem is this involves multiple

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Rachael Schmedlen

operations, which increases risk, especially in a small child. It also requires carving this complex geometric shape from rib cartilage and there are just a handful of surgeons who have mastered that."

The ability to grow cartilage in a bioreactor is a big step forward in the field of tissue engineering, according to Hollister. Researchers have figured out how to build polymer scaffolds that can safely be implanted in the body, but are still working on how to stimulate and control the growth of specific types of cells and tissue on the scaffold. No one has succeeded yet at growing a blood vessel, for example, but one of Hollister's graduate students is working on the problem.

"It's been great to have Dave here for six months," says Hollister. "We got his clinical experience and insight into clinical problems; he learned about cell cultures and rapid prototyping. It's a win-win for everyone."

Educating up-and-coming physicians like Zopf and the next generation of biomedical engineers is a major goal of the Department of Biomedical Engineering. There are close connections between the two professions. At least one-third of U-M BME undergraduate students go to medical school after they graduate, according to Munson.

The department offers courses for undergraduates and graduate students that give them experience in a hospital environment and opportunities to work with physicians as they design, build and test new types of medical devices in their senior design class.

Rachael Schmedlen, Ph.D., a lecturer in biomedical engineering, is on the front lines of collaborative education. She teaches a new course for engineering undergraduates called Clinical Observation and Needs Finding, which was piloted in the spring of 2011. Undergraduate students who take the course spend eight to 10 hours per week observing and shadowing physicians and nurses in several clinical departments at University Hospital. They learn how to talk to physicians, how to ask questions, and what it's like to work in a busy hospital.

"The feedback from our students has been overwhelmingly positive," says Schmedlen. "Sometimes the students go

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THE NEW DEPARTMENT STRUCTURE WILL GIVE ENGINEERING STUDENTS MORE OPPORTUNITIES TO INTERACT WITH MEDICAL PROFESSIONALS IN THE CLASSROOM AND THE CLINIC — PARTICULARLY IMPORTANT FOR BIOMEDICAL ENGINEERS WHO DESIGN DEVICES AND TECHNOLOGY TO BE USED IN A CLINICAL ENVIRONMENT.

James Woolliscroft and David Munson

SCOTT SODERBERG, MICHIGAN PHOTOGRAPHY

on grand rounds and hear all the medical jargon. They see how hectic it is in the ER and how frustrating it can be to deal with the electronic systems and pagers going off every 10 minutes."

Schmedlen believes the new department structure will give engineering students more opportunities to interact with medical professionals in the classroom and the clinic — something that's particularly important for biomedical engineers who design devices and technology to be used in a clinical environment.

Woolliscroft and Munson say the department's joint administrative structure and increased funding will make it possible to expand the BME curriculum and develop new courses for medical students who want to learn about biomedical engineering. It's all still in the planning stages, but faculty and administrators are anticipating more engineering courses taught by physicians and new master's degree programs in regulatory affairs or medical device development. Maybe even a new pre-med curriculum.

"There is a huge demand from students for educational experiences that combine biology and engineering," says Woolliscroft. "These students are incredibly capable and we want to do everything we can to meet their needs and expectations." [M]