REAL WORLD

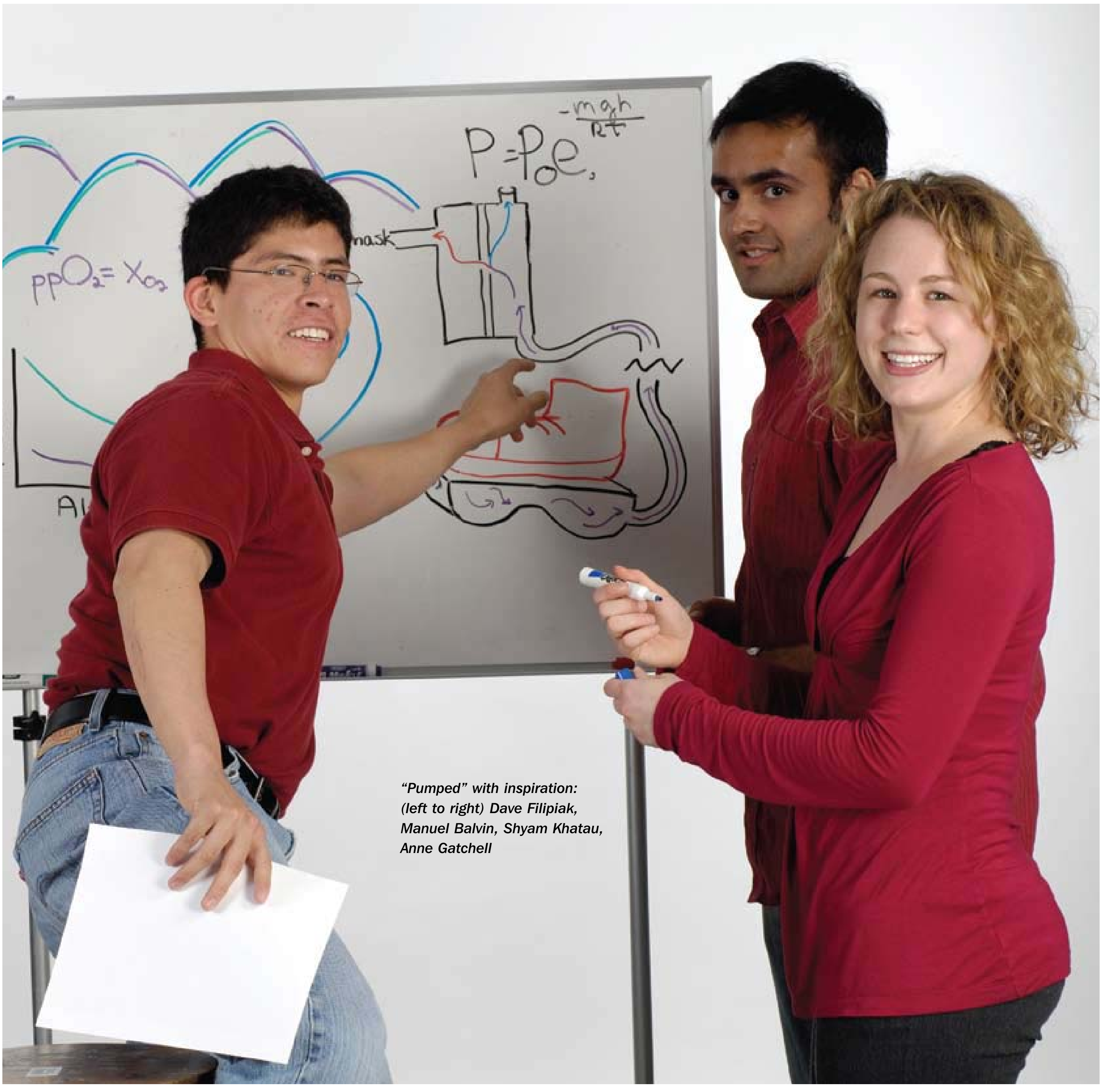
Steeped in theory and fundamentals throughout their four years at the Whiting School, students from all departments get to step out as seniors and, working in teams, apply what they've learned through a senior design project. The projects they tackle, proposed by industry experts, clinical faculty at Hopkins Hospital, and medical device companies, truly test their engineering mettle, forcing them to communicate clearly with nontechnical colleagues and customers to create solutions that not only work but are economically viable.

The fruits of their labors have been impressive. Over the past three years alone, senior design projects have resulted in at least 16 provisional patents, three full patent applications, four licensing agreements, and two start-up companies.

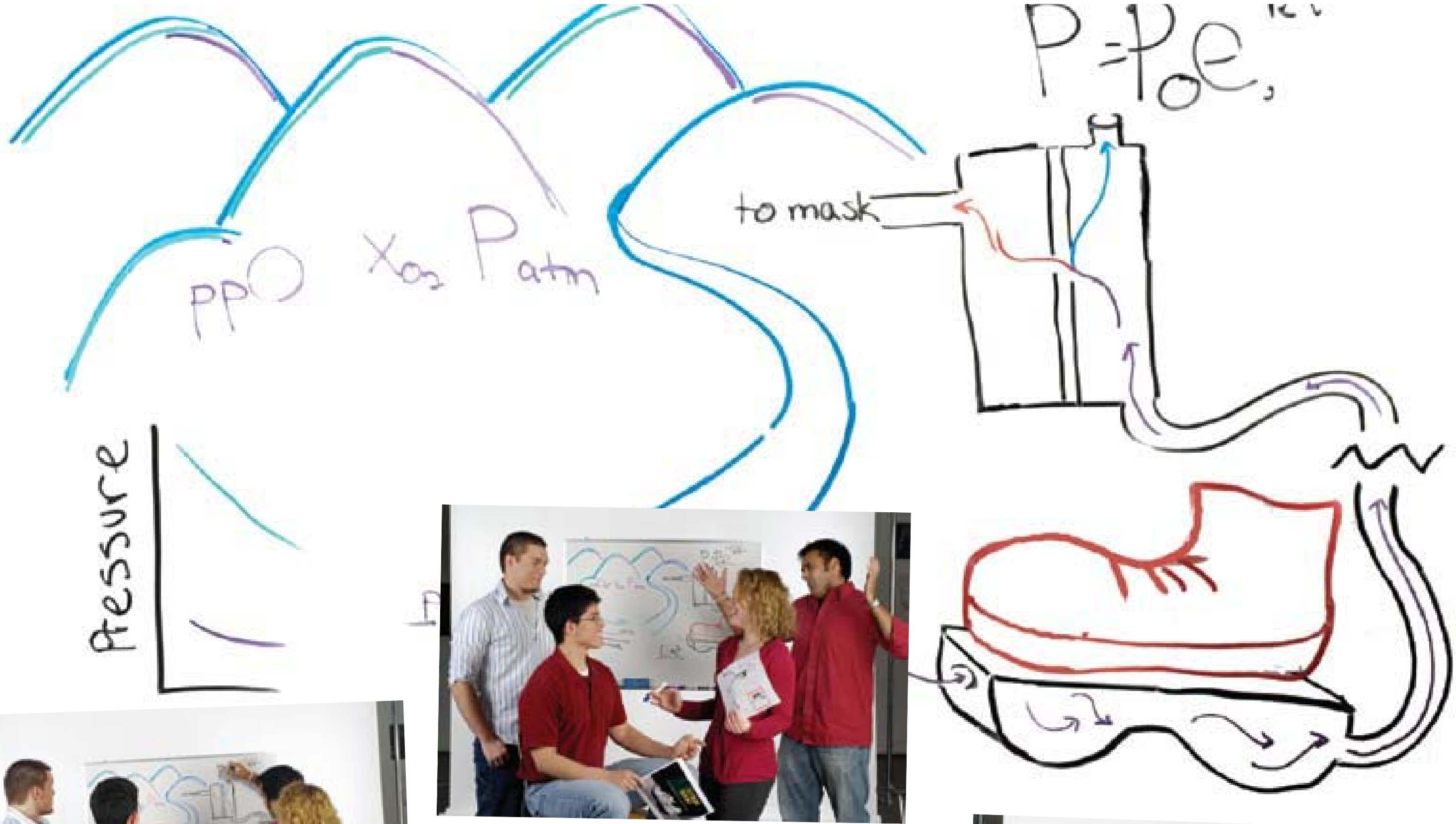
Herewith, meet four design teams from the Class of 2008, whose creative solutions—for everything from cleaner streams to better pain relief—show particular promise.

By Mike Field
Photos by Will Kirk

SOLUTIONS



"Pumped" with inspiration: (left to right) Dave Filipiak, Manuel Balvin, Shyam Khatau, Anne Gatchell



AIR HOPKINS

On paper it looks like someone tried to cross the Reebok Pump athletic shoe with one of those oxygen masks that drops from overhead when your plane is going down. But as senior chemical and biomolecular engineering major Anne Gatchell is quick to point out, looks can be deceiving.

"It is often the inventor who comes up with an idea and convinces people there is a need," she says with true entrepreneurial brio. Gatchell and fellow chemical and biomolecular engineering majors Manuel Balvin, Dave Filipiak, and Shyam Khatau believe they have identified a need currently unmet: how to ameliorate the effects of acute mountain sickness among the estimated 100 million travelers who visit high-altitude mountainous regions across the globe every year.

Gatchell, who is from mile-high Denver, and Balvin, a native Peruvian, were familiar with the headaches, dizziness, nausea, lethargy, and other symptoms that unacclimated visitors to their mountainous countrysides can sometimes experience. At high altitudes—defined as elevations of 5,000 feet or more above sea level—lower atmospheric pressure means less oxygen is available in every breath, and hemoglobin in the blood becomes less efficient at delivering oxygen to muscles and tissues. Lower atmospheric pressure can also cause blood vessels to extend, releasing fluid into surrounding tissues. A sudden change, as for instance when a coastal visitor flies into a high altitude city, can cause feelings of physical exhaustion, pain and discomfort, gastro-intestinal difficulties, and in extreme cases, pulmonary and cerebral edemas.

The Altitude Alright Supplemental Oxygen System uses a commercially available gas separation membrane to increase the amount of oxygen inhaled by at least 25 percent.

Currently, the vast majority of people who experience difficulties at high altitudes must simply suffer through until their bodies adapt to the change in pressure. But studies have shown that by increasing the percentage of oxygen in each breath, the effective change in elevation can be reduced to a range in which there are few, if any, side effects.

Combining creative thinking with a little chemical and biomolecular engineering know-how, Gatchell and her classmates devised the Altitude Alright Supplemental Oxygen System, which uses a commercially available gas separation membrane to increase the amount of oxygen inhaled by at least 25 percent. Pumps attached to the user's feet drive air through the membrane stored in a small backpack. Oxygen-enriched air then travels by flexible tubing to a plastic mask worn over the mouth and nose. "The system would be lightweight, portable, and would cost less than $100 per unit to produce," Gatchell says. "We see a ready market for high altitude resort owners, or tour groups visiting elevations between 8,000 to 18,000 feet above sea level."

SWAMP THING

Tropical fish enthusiasts prize the black ghost knifefish, a jet black river dweller from South America marked by two white rings on its tail, a white blaze on its nose, and a long undulating fin running along its belly. That fin—called a ribbon fin—allows the fish to hover or advance or change direction almost instantaneously by propagating different waveforms down the length of its underside. So effective is this mechanism that the fish catches its food by gliding past unwary targets and then suddenly changing course and attacking in the blink of an eye: up, down, forward, back, or side to side.

Watching one of these knifefish pivot through the water can be an amazing sight (check out the dozens of black ghost knifefish home videos on YouTube to see), but it was also bound to get scientists thinking …can we design an underwater vehicle to do that? And so the quest was on for SWAMP, the Submersible Wavelength/Amplitude Modulating Propulsion system. Scientists in Japan and at Northwestern University have already had a go at it. Now enter Johns Hopkins Team SWAMP—mechanical engineering majors Chris Blizzard, Ross Burns, and Makibi Takagi—with a uniquely different approach to the challenge.

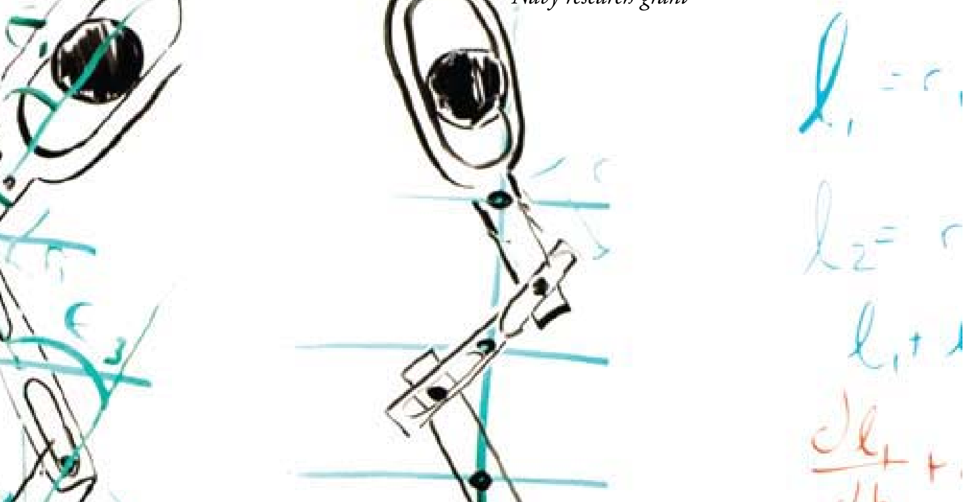
"Nothing like this had been tried before," says Burns. The other groups tackling the problem started with a parallel row of closely-spaced rods that approximate the bones in the fish's ribbon fin. But while the Japanese and Northwestern groups utilized a series of independent actuators to move each rod back and forth, Team SWAMP took a more traditionally mechanical engineering approach, utilizing revolving shafts linked to a row of 18 parallel plastic bars. A complex system of gears and actuators link the shafts to independent electric motors that can be used to vary the speed and direction of the bars' movement. A third shaft controls the amplitude (the height of the wave motion) by raising or lowering the fulcrum point for each bar. The entire unit is controlled by a variable power supply and a simple switching circuit.

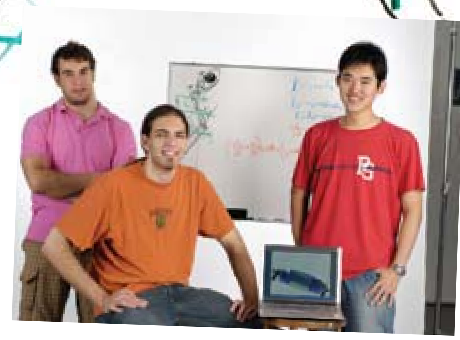
"This kind of system underwater could allow far greater maneuverability than a standard propeller."

—Ross Burns

"This kind of system underwater could allow far greater maneuverability than a standard propeller," Burns says of the prototype he and his classmates designed, machined, and assembled themselves. "The hardest challenge for the team was actually putting it together. We had to build it and rebuild it several times to get it to work." At one point the group fell behind schedule by more than a month when gears on parallel shafts refused to mesh properly and the mechanism seized. Team SWAMP's final report notes tersely: "It was then that the panic set in." In the nick of time the group entirely redesigned the base unit, which effectively eliminated the problem and allowed work to resume. There were many long nights in the lab getting the device in working order, but in the end, they had a functioning prototype for their project sponsors to test drive. "They were in awe that we were able to do it," says Burns with a trace of pride bordering on relief. "The greatest thing we learned was how to take ideas and actually make them real."

Team sponsor: Applied Physics Lab through a Navy research grant





"Propelled" to finish: (left to right) Chris Blizzard, Ross Burns, Makibi Takagi

STREAM CLEAN-UP

A good strategy for cleaning up the Chesapeake Bay is to first clean up all the rivers and streams that flow into it. The Bay's watershed, or "reach," extends miles beyond the shoreline and includes all the streams and waterways flowing through Baltimore—including East Stony Run, a picturesque babbling rill that is a central landscape feature on the university's historic Evergreen property. The stream provides unique challenges and opportunities for clean-up efforts.

"If you look on Google Maps, half the stream on the property flows through a manicured lawn, and the other half is undeveloped," notes Department of Geography and Environmental Engineering professor Peter Wilcock. The city is already engaged in rebuilding the culvert that carries the water flowing out of the property under Charles Street and has been extensively monitoring the water quality of the Stony Run for some time, creating, says Wilcock, a perfect opportunity. "We want to see if we can figure a way to reduce sediment and nutrient loading to the Bay coming out of this property."

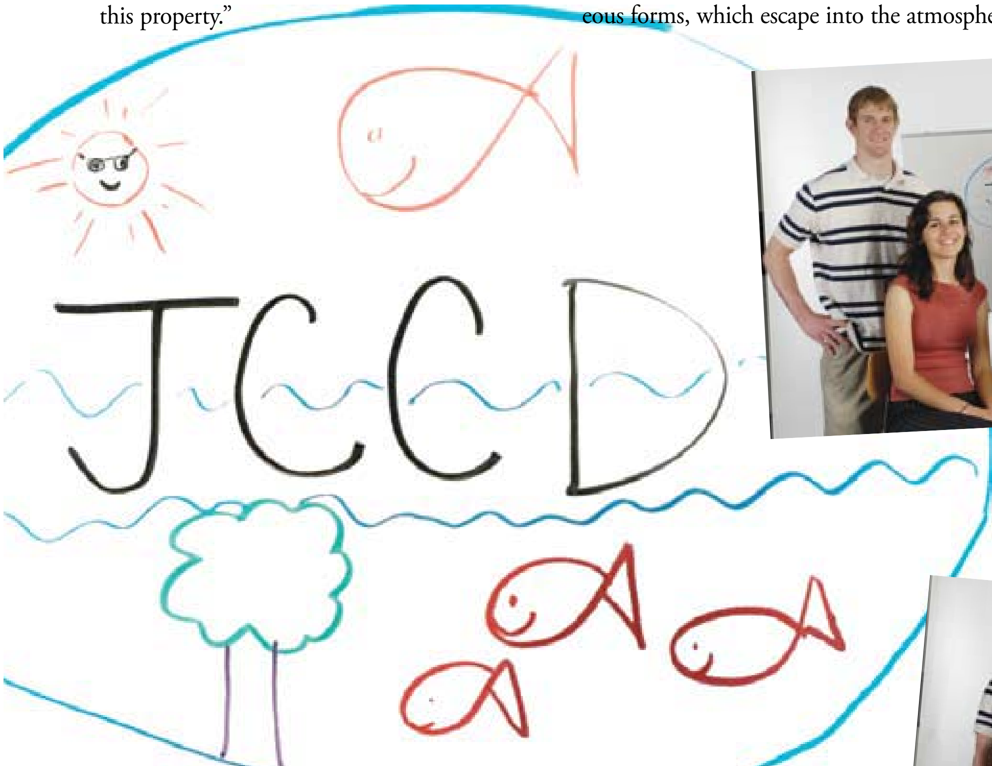
Wilcock's one page charge to his class: Find the most cost-effective way to restore East Stony Run to health. Team members Colin Beck, Daniela Martinez, Jasmine Serlemitsos, and Carol Zuerndorfer were charged with considering the history, location, aesthetics, and water chemistry of the stream in crafting a comprehensive plan of action. "What they are now calling 'stream restoration' is such a new field that almost all the literature is still very recent," says Serlemitsos, spokesperson for the group. "So starting out we didn't have much to go on."

Of chief concern is the overabundance of nutrients—primarily nitrogen and phosphorus—that enter streams largely though rain water runoff. Phosphorus is typically removed from water by settling sediment and letting it "fall out" of the water. Denitrification, on the other hand, is a more complicated process that requires standing water and a carbon source, usually from decaying plants. These conditions permit an anaerobic process to occur in which bacteria convert nitrogen in the water to its gaseous forms, which escape into the atmosphere.

"After looking at the history and current condition of the East Stony Run, we concluded there were four possible courses of action," Serlemitsos says. "We could do nothing; re-route the stream through a pipe or culvert; try spot-treating it only in certain places; or spend hundreds of thousands of dollars on a full-scale restoration that would include lowering the banks of the stream, reintroducing native species, and creating marshy areas of standing water for denitrification."

In the end, the group decided a full-scale excavation of the stream was unwarranted, instead opting for spot treatments to prevent erosion and encourage some denitrification. "The challenge in this field is trying to figure out how to measure success," Serlemitsos says. "If you build a building and it falls down, everyone knows. But if you set out to restore a watershed, how do you know when it works? Our spot treatment plan is not conventional. It's a little out there."

Team sponsor: Baltimore City Department of Public Works



A Clean Sweep: (left to right) Colin Beck, Carol Zuerndorfer, Daniela Martinez, Jasmine Serlemitsos

HEALING POUCHES

Good things, it is said, come in small packages. Someday that may be especially true if you are facing surgery.

Each year, more than 3 million laparoscopic surgeries are performed in the U.S., encompassing procedures ranging from coronary artery bypass surgery to gall bladder removal. In most of these operations, the surgical incision required is very small—less than an inch in length. Typically, these minimally invasive surgeries require little or no post-operative hospitalization, and many are performed on an outpatient basis. But even small cuts can hurt a lot, so doctors prescribe systemic oral narcotics for incisional pain.

Doping the whole body to relieve pain in one small location is hardly ideal, however. Side effects of the systemic opiates typically used include nausea, constipation, and temporary dementia, and can sometimes result in extended hospitalizations. With all the advantages of micro-surgery, might there not be a manner of introducing micro pain control as well?

Eight biomedical engineering undergraduates set out to find the answer. Henry Chang, Dhanya Rangaraj, Meet Patel, Vincent Wu, Joseph Wood, Hyun-sun Seo, Shaoi Zhang, and Alice Wu report that there is currently no available technology to deliver extremely focused, localized pain relief for patients of minimally invasive surgery. "We think that the greatest end benefit might be to save additional lives through the increased use of endoscopic exploratory surgery," says Rangaraj, noting that current post-operative pain management issues may inhibit use of the procedure.

The team came up with a novel approach: a postage stamp-sized envelope containing local anesthetic, anti-inflammatory agents, and growth factors impregnated in a commercially available biologic matrix made from the small intestine sub mucosa of pigs. At the end of a procedure the packets are slipped into the existing incision just before suturing. The matrix gradually releases the drugs over time as it is absorbed into the wound, promoting healing and providing round-the-clock pain relief in the process. The design is simple and elegant enough for the group (aided by faculty advisor Malcolm Lloyd '94, a physician and CEO and founder of Device Evolutions, a medical device company) to file a provisional patent application.

"The great thing about this approach is that it potentially offers a way to control post-operative pain without side effects," Rangaraj says. "We had to find novel ways to bind the drugs to the matrix material, and we kept refining the way to fold up and seal the implant. It evolved over the year we were working on it, but in the end we settled on this technology we think has great potential." ■

A Cure for Pain:* *(left to right) Alice Wu, Henry Chang, Joseph Wood, Dhanya Rangara, Shaoi Zhang, Meet Patel, Vincent Wu. Hyun-Sun Seo not pictured.