Bioengineering research teams at UCSB are developing some of the world's most advanced and sophisticated techniques and devices for the detection and diagnosis of pathogens and harmful substances.

The tools they are working on have extraordinary potential, from sensing and eliminating a single cancer-causing tumor cell in an otherwise healthy body, to detecting traces of drugs, explosives, and other hazardous materials at concentrations of parts-
per-trillion.

Some similar results may be achievable already in a laboratory. ?Given a fully-equipped laboratory and enough time, you can detect almost anything,? says Kevin Plaxco, Professor of Chemistry and Biochemistry. What sets UCSB?s latest research apart is the goal of providing the same or better information much faster and much more conveniently?in many cases using mobile, hand-held devices.

?What has been a slow, lab-bound approach, we want to convert to less than 15 minutes?that?s typically how long, for example, someone has with their doctor?and hand held.? Plaxco says.

While that?s a clear reference to the medical implications of this biotechnology, potential applications are very much broader: researchers are working on projects that will impact food safety, the environment, industry, security, the military and more.

According to Martin Moskovits, former Dean of Science and currently Professor of Chemistry and Biochemistry, the need for detection and diagnostics is not new ? he says it was an issue even back in the Middle Ages. As modern life becomes ever faster and more complex, however, detection and diagnostics are racing to keep pace.

Biotechnology has also become a rapidly evolving field in part because of the increasing numbers and varieties of hazards out there?infectious diseases, security and military threats, chemical and biological agents?that we need to be aware of so they can be dealt with or avoided.

Professor Kevin Plaxco and his research team are focused on studying detection devices more sensitive and still with hand-held convenience and price.

The interdisciplinary research teams working in this area draw from chemical, electrical, and mechanical engineering, computer science, and materials; and chemistry, biochemistry, physics, and molecular biology. The teams include scientists from UCSB?s Institute for Collaborative Biotechnologies (ICB), Materials Research Laboratory (MRL,) and the California NanoSystems Institute (CNSI).

ICB, a UCSB-led collaboration with the Massachusetts Institute of Technology (MIT) and the California Institute of Technology (Caltech), acts as the base for some 200 faculty members and researchers. Seeking to adapt and replicate some of the processes and biomolecular behaviors found in the natural world, many of these researchers are working at or close to the nanoscale.

Using state-of-the-art equipment available at UCSB, they are developing more easily
managed and controlled ways of detecting and analyzing a broad range of molecules and microbes found in water, blood, air and food.

This process of separating, identifying, and counting the components in such materials invites a number of possible approaches, including many based on biological recognition. Examples of this include the binding of one strand of DNA to its complement (to form a double helix), the binding of an antibody to the virus it neutralizes, both of which are high affinity and specificity.

Other approaches depend on the specific optical (spectroscopic) signatures produced when target molecules bind to specially prepared nano surfaces, and the concentrated light emitted when specific nano particles are brought into close contact via a bio-recognition event.

Moskovits has been part of a team researching how these electrical and light signals can be used to detect and analyze even low concentrations of certain molecules.

The technology has clear medical potential?molecules being constantly released by the body in breath and perspiration, for example, could tell a doctor much about a patient?s health. Initially, however, Moskovits has his sights set on detecting explosives.

He and Carl Meinhart, Associate Professor of Mechanical Engineering and Director of UCSB?s Microfluidics Laboratory, are the principals of SpectraFluidics. The Goleta-based company, launched about a year ago, aims to develop inexpensive yet sensitive and highly accurate means of instantly detecting airborne explosives molecules. SpectraFluidics? hand-held and stationary sensors will feature onboard computers with programs set to recognize only the specific light or electrical patterns caused by the presence of the target molecules.

Moskovits sees a security role for such sophisticated technology, at places like airports, and a military role during conflicts, such as the wars in Iraq and Afghanistan, where the accurate sensing of trace molecules in the air could, for instance, alert troops to roadside bombs.

?Now we need about one billion cells grouped together before we can see them and detect a tumor,? explains Daugherty. ?Our plan is to drop that number down, by a factor of ten or 100 or more.?

SpectraFluidics is just one of a burgeoning number of UCSB-based biotech start-ups, many of them in the Santa Barbara area, looking for ways to transform an idea that works in the laboratory into a piece of technology that people are willing to buy.

Another local venture, Nanex, working in conjunction with ICB researchers, is developing what it describes as ?a lab-on-a-chip? solution for medical diagnostics at hospitals, clinics and other health facilities.

?Our solution is a low cost, low power, lightweight instrument, well-suited for point-of-
care detection of pathogens and genetic markers, says the company website, describing a sensor equipped for a range of bio-assays and molecular diagnostics.

The road to market can be a long, difficult, and expensive journey. Plaxco says research into biotechnology devices has been going on for more than 50 years, but little has so far seen the commercial light of day: the best example that has is the blood glucose monitor for diabetics.

Plaxco has been working alongside Professor of Physics and Nobel laureate Alan Heeger, and H. Tom Soh, Associate Professor of Materials and of Mechanical Engineering, on biomolecular sensors designed for real-time detection at the point of care. The three men also collaborated closely with Nanex on product development.

Their point of departure is that current methods for the detection of pathogens are cumbersome, laboratory-bound procedures that typically require days to return an answer.

To address this problem, we are developing a reagentless, electronic technology that can detect these materials in seconds with a convenient, hand-held electronic device, Plaxco says.

Sumita Pennathur, Assistant Professor of Mechanical Engineering, is working in the areas of biometric identification and microfluidics, researching the development of biosensors that could be used to detect and diagnose a range of diseases.

Speaking from a conference on molecular bioseparations held recently in Boston, she described a hand-held device she hopes will isolate and identify DNA from a cheek swab in as little as 30 seconds. Such technology could prove valuable in settings as diverse as military checkpoints and medical clinics.

Though Pennathur estimates her research is still three to four years away from commercial development, she sees potential in such areas as AIDS and cancer research, detection of toxic chemicals, and monitoring water quality.

She’s a big fan of the collaborative environment at UCSB, especially the seamless overlapping within the ICB. We talk a lot amongst ourselves; we also hold social events every quarter with the students, to get them sharing ideas as well.

Professor Patrick Daugherty and his colleagues at CytomX Therapeutics (an early stage, privately-funded biotechnology company developing proteolytically-activated biotherapeutics based on UCSB research) have crafted a molecule that is activated by protease at cancer tissue binding sites. After clipping the mask molecule on the antibody, binding occurs on the target molecule. This specificity
enables direct delivery of therapeutic agents to the desired site.

?It all helps spread knowledge and is so easy to do at UCSB where everyone is very helpful and accessible. It?s an awesome atmosphere.? 

Plaxco shares that enthusiasm. ?The ICB has helped us create a strong community of disparate research groups,? he says. ?It?s also been a life-saving source of funding.? 

Those kinds of responses are music to the ears of David Gay, the ICB?s director of technology, who sits at the interface between the institute?s principal funder??the Army Research Office??and academia and industry.

The Army began a five-year funding commitment in August 2003, and has since renewed for a further five years. Gay states that the institute received $44 million during the first five-year period. The Army?s budget for ICB in the second five years, fiscal years 2009 through 2013, totals $84 million, of which $15 million has been received so far for FY 2009.

In both cases, the amounts have gradually increased as the Army responded positively to the results coming out of the ICB. ?The point is, we are delivering,? says Gay.

?Our mission is to accelerate innovation,? he added, pointing to the transition of technology to the marketplace through young companies like CytomX Therapeutics, Cynvenio Biosystems, and Sirigen.

Both CytomX, based in Goleta, and Cynvenio, located in Westlake, were founded by Patrick Daugherty, Associate Professor of Chemical Engineering, Soh, and Heeger.

Cynvenio focuses on advanced instrumentation for bioseparation and cell-sorting applications, using microfluidics technology. ?Integrating multiple steps of a complex assay, all on a chip, to obtain highly sensitive and error-free results rapidly and inexpensively ? that?s the revolution that?s coming,? predicts Soh.

His work at UCSB and Cynvenio was recently recognized at the annual conference of the Association for Laboratory Automation, in Palm Springs, where he won the 2009 ALA Innovation award for the most creative solutions to some of today?s most important problems in biotechnology.

CytomX is addressing the early detection and treatment of tumors and vulnerable plaque. The company hopes to provide diagnostic tools for people at risk from cancerous tumors, and from heart attacks or strokes caused when plaque from artery walls ruptures and enters the bloodstream.
Their teams are using molecular and cellular engineering to achieve this. They have learned how to manipulate certain molecules, blocking their normal function and instead giving them the ability to sniff out and bind only with molecules indicating tumors or at-risk plaque.

These pre-programmed molecules, engineered in vitro, are introduced into the patient’s bloodstream and the results scanned using a magnetic resonance imaging (MRI) machine.

?Now we need about one billion cells grouped together before we can see them and detect a tumor,? explains Daugherty. ?Our plan is to drop that number down, by a factor of ten or 100 or more.? Finding tumors at such an early stage would enable much earlier treatment and far better patient prognoses.

Having proved the concept, Daugherty says the science is now being tested in mice. Many more animal and human trials lie ahead, but he hopes a commercial product could be ready for approval in less than three years.

For Plaxco and the others, the real value in all this research is making products that help people: ?Our focus is on things that we think will directly improve people’s health and safety,? he stated.

Professor Kimberly Turner, Chair of the Department of Mechanical Engineering, shares this vision, and believes biotechnology is going to revolutionize the future of healthcare.

?The technology has matured to the point where it’s right for diagnostics, especially medical diagnostics,? she says. ?I think this is going to be a huge market in the next five to 10 years.?

Turner has been working on the ultra-sensitive detection of carbon monoxide and other gases, developing technology that could potentially also alert users to a range of hazards from toxic chemicals and explosives to food-borne pathogens.

She sees many advantages for this type of detection and diagnostic technology: it’s small, easy to use, works fast, and is sufficiently cheap to manufacture that units could be disposable.

She believes the low cost and high convenience will have a major impact on procedures like lab tests and cancer screening which can become ?much simpler and cheaper?.

Turner also foresees the day when the technology will be readily available off the retail shelf, enabling people to buy self-testing kits at the drug store and do many health-related tests themselves.

**Links:**

Institute for Collaborative Biotechnologies
(All faculty members mentioned are linked at ICB’s site)
[icb.ucsb.edu](http://icb.ucsb.edu)

Cytomx Biosystems
[cytomx.com](http://cytomx.com)