Date: Jan. 4, 2011
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National Academy of Engineering

Developers of 'Directed Evolution,' Pioneer in DNA Sequencing, and Designer of Groundbreaking Curricular Program Win Highest Engineering Honors of 2011

WASHINGTON — The engineering profession's highest honors for 2011, presented by the National Academy of Engineering (NAE), recognize three achievements that led to developments in guiding cell evolution, sequencing the human genome, and better preparing students for the engineering work force.

Frances H. Arnold and Willem P.C. Stemmer will receive the prestigious Charles Stark Draper Prize — a $500,000 annual award that honors engineers whose accomplishments have significantly benefited society — "for directed evolution, a method used worldwide for engineering novel enzymes and biocatalytic processes for pharmaceutical and chemical products."

Leroy Hood will receive the Fritz J. and Dolores H. Russ Prize — a $500,000 biennial award recognizing a bioengineering achievement that significantly improves the human condition — "for automating DNA sequencing that revolutionized biomedicine and forensic science."

Edward Crawley will receive the Bernard M. Gordon Prize — a $500,000 award issued annually that recognizes innovation in engineering and technology education — "for leadership, creativity, and energy in defining and guiding the CDIO (Conceive-Design-Implement-Operate) Initiative, which has been widely adopted internationally for engineering education." Half of each Gordon prize is granted to the recipient and the remainder is granted to the recipient's institution to support the continued development, refinement, and dissemination of the recognized innovation.

"The NAE is delighted to honor these awardees," said NAE president Charles Vest. "Their contributions as engineers have advanced health and quality of life in the U.S. and around the world, and have enhanced the education of future engineering leaders. Recognizing these outstanding engineers not only rewards great accomplishments but also shines a light on the importance of work that may inspire others to build on their achievements."

The prizes will be presented during a gala black-tie dinner event at Union Station in Washington, D.C., on the evening of Tuesday, Feb. 22. Also, at 12:30 p.m. that day, the prize winners will have a discussion with middle school students participating in the National Engineers Week Future City competition. Media may cover either event by

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The Charles Stark Draper Prize

Frances H. Arnold and Willem P.C. Stemmer individually contributed to a process called "directed evolution," which allows researchers to guide the creation of certain properties in proteins and cells. The process is used today in laboratories around the world.

At the heart of directed evolution is the concept that the mutation and selection processes that occur in nature can be vastly accelerated in the laboratory to obtain specific, targeted improvements in the function of single proteins and multiprotein pathways. Arnold showed that randomly mutating genes of a targeted protein, especially enzymes, would result in some new proteins having more desirable traits than they did before the mutation. She selected the best proteins and repeated this process multiple times, essentially directing the evolution of the proteins until they had properties desirable for a particular use.

Taking his cues from traditional breeding of plants and animals, Stemmer focused on a different natural process for creating diversity, concentrating on the recombination of pre-existing natural diversity, which he called "DNA shuffling." Instead of causing random mutations, he shuffled the same gene from diverse but related species to create clones that were as good as or better than the parental genes in a given targeted property.

One of the most important aspects of directed evolution is that it allows for a practical and cost-effective way for improving protein function. Previous efforts, particularly those involving a design based on the structures of enzymes and the predicted effects of mutations, were often not successful. They were poor at improving the sought-after complex combinations of properties and were labor- and cost-intensive.

Both techniques — and several variants — are in wide use, impacting the fields of engineering, chemistry, and biochemistry. Directed evolution has been used to find solutions in such areas as food ingredients, pharmaceuticals, toxicology, agricultural products, gene delivery systems, laundry aids, and biofuels, among others.

"Arnold and Stemmer's joint development of directed protein evolution was a milestone in biological research," said George Georgiou, a professor at the University of Texas at Austin. "It is impossible to overstate the impact of their discoveries for science, technology, and society; nearly every industrial product and application involving proteins relies on directed evolution."

Arnold is the Dick and Barbara Dickinson Professor of Chemical Engineering and Biochemistry at the California Institute of Technology. She is the only woman to have been elected to all three membership organizations of the National Academies -- the NAE in 2000, the Institute of Medicine in 2004, and the National Academy of Sciences in 2008.

Stemmer is the CEO of Amunix. In 1997 he co-founded Maxygen to further develop his research on DNA shuffling, which also became the core technology on which spin-outs Codexis and Verdia were founded. In 2003 he founded Avidia Research Institute. He has over 68 research publications and 97 U.S. patents and holds a Ph.D. from the University of Wisconsin.

The Fritz J. and Dolores H. Russ Prize
Leroy Hood developed the automated DNA sequencer, which allowed for the rapid, automated sequencing of DNA, making a significant contribution to the mapping of the human genome and revolutionizing the field of genomics. It accelerated the pace of scientific discovery in ways that will have an even more profound impact on biomedical research in the coming decades.

With a research interest in genetics, Hood recognized the need for new tools to decipher biological information. Integrating new ideas in chemistry, engineering, and software, he led a team at the California Institute of Technology that developed the sequencer in the 1980s. In 1981, he founded Applied Biosystems, Inc (ABI), an instrument company to commercialize the DNA sequencer and three other instruments developed in the Hood lab. By the late 1980s, ABI had developed a commercial DNA sequencer that could be used in any laboratory.

Prior to automated sequencing, the process of manual sequencing was slow and laborious; it took 30 years, for instance, to sequence the genome of a cold virus. Today, the genome of a virus of the same size can be sequenced in less than an hour.

“No single person has done more to create the genomics era than Leroy Hood,” said Ed Lazowska, a professor at the University of Washington. “Lee is a visionary who integrated science and technology, creating instruments that allow us to tackle some of the most fundamental problems in modern biology and medicine.”

To date, more than 1,000 genomes have been revealed using the automated DNA sequencer, transforming many areas of biology. The advancement has also led to expressed sequence tagging, which ultimately helped to predict gene function; the ability to identify genes involved in diseases; a change in how pharmaceutical companies make drugs; and an economic impact in the life sciences and healthcare estimated to be in the hundreds of billions of dollars.

Hood was an early pioneer in promoting the Human Genome Project and served on a National Academies committee that ultimately made the recommendations that led to the project’s start in 1990. He is president and co-founder of the Institute for Systems Biology, a non-profit dedicated to pioneering systems science for the advancement of global health, energy and the environment, and “P4” medicine (predictive, preventive, personalized and participatory), which aims to transform medicine to a discipline that emphasizes health and wellness. Hood and his colleagues are utilizing advances in genomics, proteomics, and molecular diagnostics to pioneer advances in diagnostics,

therapeutics, and prevention that will focus increasingly on promoting wellness rather than merely treating disease.

He has won numerous awards in recognition for his work, including the Albert Lasker Award (1987), Kyoto Prize (2002), the Lemelson–MIT Prize (2003), and the Heinz Award (2006). He is a member of all three membership organizations of the National Academies, elected to the NAE in 2007, the IOM in 2003 and the NAS in 1982.

The Bernard M. Gordon Prize

Edward Crawley created the Conceive-Design-Implement-Operate (CDIO) Initiative at the Massachusetts Institute of Technology in 2000. CDIO places the traditional engineering curriculum in the context of problem-solving exercises and hands-on assignments, taking students out of theoretical classroom discussions to create experiences based on the needs of engineering in the 21st century. It has been praised by industry for developing more well-rounded graduates with a foundation in teamwork, problem solving, and product development.

Designed to be widely disseminated and shared, a feature of CDIO is that it uses an "open architecture" model, allowing it to be modified and adapted to a particular university's needs. Schools that are part of the Initiative openly collaborate, sharing best practices and materials, and the Initiative has international reach, with over 50 universities in 25 countries participating. The Initiative holds an annual international conference as well as workshops throughout the year, bringing together current and potential collaborators.

"Ed Crawley has a remarkable record of major innovations in engineering education," said Edward Greitzer, a professor at the Massachusetts Institute of Technology. "CDIO integrates an education based in engineering science into the context of engineering practice; students leave the university fully prepared to contribute to product, process, or system development as an initial step towards engineering leadership."

To ensure uniformity CDIO outlines 12 standards to be used as a tool for program adoption, evaluation, and continuous improvement. In addition, the Initiative provides a detailed syllabus to provide a road map and process for establishing a program.

Crawley is the Ford Professor of Engineering at MIT, and is a professor of aeronautics and astronautics and of engineering systems. He has been the executive director of the Cambridge – MIT Institute, the department head of aeronautics and astronautics at MIT, an adviser to the NAE Committee on the Space Station, and a member of the Presidential Advisory Committee on the Space Station Redesign. He has a Ph.D. in structural dynamics from MIT.

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The Draper Prize was established in 1988 at the request of the Charles Stark Draper Laboratory Inc., Cambridge, Mass., to honor the memory of "Doc" Draper, the "father of

inertial navigation," and to increase public understanding of the contributions of engineering and technology. The prize is awarded annually.

The Russ Prize was established in 1999 at the request of Ohio University to honor alumnus and esteemed engineer Fritz Russ and his wife, Dolores. Their multimillion dollar endowment for the prize promotes engineering education and recognizes outstanding achievement in a critically important engineering discipline that contributes to the advancement of the human condition. The prize is awarded every two years.

The Gordon Prize was established in 2001 as a biennial prize recognizing new modalities and experiments in education that develop effective engineering leaders. Recognizing the potential to spur a revolution in engineering education, NAE announced in 2003 that the prize would be awarded annually.

The National Academy of Engineering is an independent, nonprofit institution. Its members consist of the nation's premier engineers, who are elected by their peers for seminal contributions to engineering. The academy provides leadership and guidance to government on the application of engineering resources to social, economic, and security problems. Established in 1964, NAE operates under the congressional charter granted to the National Academy of Sciences in 1863.

For additional information about any of the prizes, contact Deborah Young, NAE awards administrator, at 202-334-1266 or e-mail dyoung@nae.edu, or Randy Atkins, NAE senior media relations officer at 202-334-1508 or e-mail atkins@nae.edu. Visit the NAE awards site at *http://www.nae.edu/awards*.