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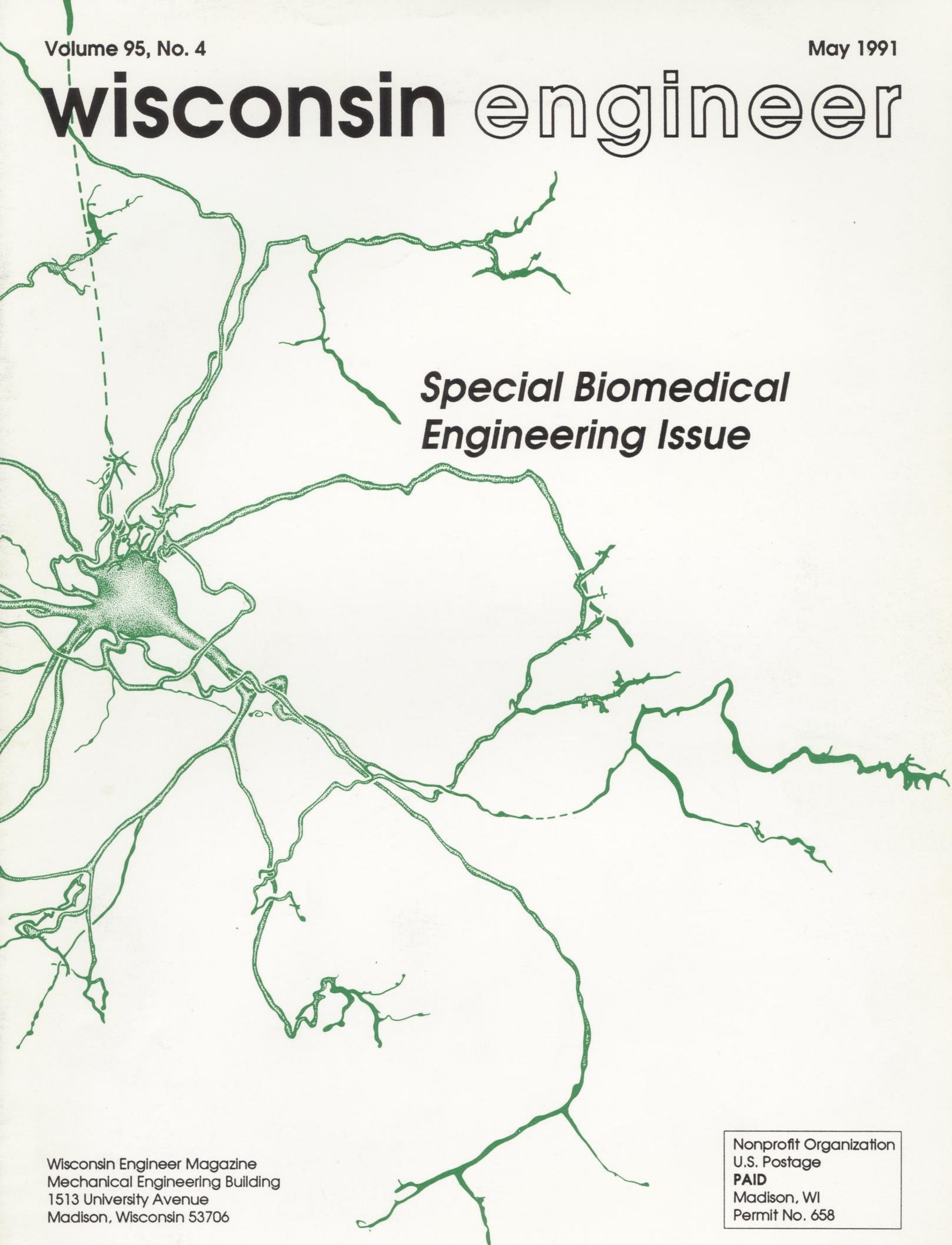

Special Biomedical Engineering Issue

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This neuron is a "giant cell" identified by Su Zhang of the UW-Madison Department of Neurophysiology. It is from the dorsal cochlear nucleus of a mouse. Photography by Terry Stewart. Drawing by Carol Dizack.

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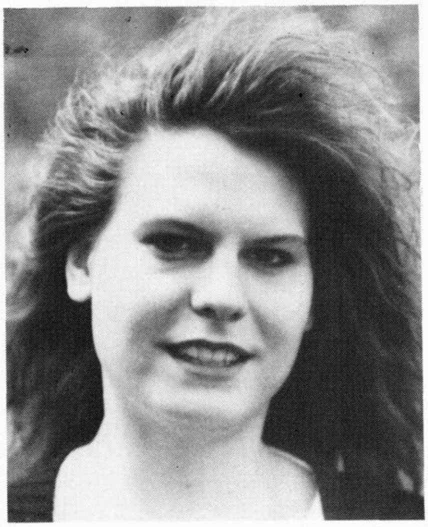
EDITORIAL



Amy Damrow, Co-editor, *Wisconsin Engineer* magazine

Joe Engineer lives in a test tube. He has been there since his freshman year of college. Joe was caught up in an engineering ritual that takes place at most engineering colleges. This ritual is a favorite among engineering educators and administrators. They take intelligent, promising engineers-to-be, drop them into a test tube, cram equations down their throats, and put a stopper on the test tube. This time-honored tradition of techno-isolation has been socially suffocating engineering students for years, and it's time to stop killing these young minds.

Many engineers are finely tuned in technical areas, but do not have an adequate background to deal with the many complicated social issues facing the engineer today. The social sciences are not deemed a part of engineering by many. Some fail to realize the importance of aptitude in social areas. Communication, business, and general "people" skills are all vital in today's world—especially for the engineer. Ecological knowledge is another area often dangerously overlooked in engineering education. Excluding foreign language and cultural study from engineering curricula is especially detrimental to today's engineer, considering the increasingly global trends in technology.

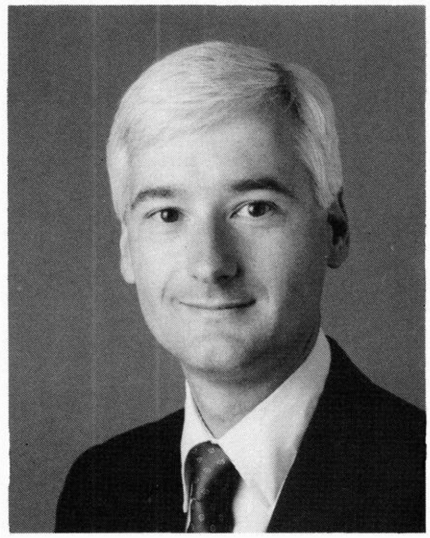
Institutions must realize that social aspects are a part of engineering. They must dispel the attitude that all engineers will spend their lives cooped up in laboratories, and do not really care about society and what's happening on the outside world. Teach them to care. Teach them that the things they design and develop as an engineer will have a lasting impact on all of society. Teach them to be a socially responsible part of society.

Many students are turned off by the pure technicality of engineering education. Maybe if these developing minds were shown that there's more to engineering than equations, so many wouldn't drop out of engineering in their first two years. Engineering colleges sometimes do not realize that they are taking bright minds that were once interested in many areas, such as English, art and music, and boring them to death with mindless equations. Granted, equations are necessary, but couldn't they be supplemented by knowledge in other areas, areas that tie in applications of engineering with the "real world"?

UW-Madison is taking a head start in turning out socially correct engineers. Students entering their engineering departments in the Fall of 1990 or later must take 16 credits of liberal studies in four designated areas: Understanding Other Societies, Races, and Ethnic Groups; Understanding Individuals and Interpersonal Relationships; Understanding American Society; and Enrichment. Although these guidelines are still very confusing, soon they will be a model for other institutions.

Engineering education must change along with the engineering profession. Engineering is now more socially, politically, and economically based than ever. Today's engineer must work to solve more socially dominated problems, such as dealing with the greenhouse effect, finding new and better ways to recycle America's waste, and rebuilding America's failing infrastructure. Today's and tomorrow's engineers must possess the social consciousness to rebuild the American dream—and to make that dream come true. So, please, let Joe Engineer out of his test tube. It's time for him to discover the world.

Dean's Corner



Gregory A. Moses
Associate Dean-Research

Why engineering? It has been said that the difference between scientists and engineers is that scientists *differentiate* a problem to reach their ultimate result and engineers *integrate*. Scientists use *deductive* reasoning and engineers use *inductive* reasoning. Scientists take things apart to better *understand* them and engineers put things together to better *utilize* them. No matter how it is described, engineering requires a *synthesis* of ideas and facts. At its best, the fundamentals of engineering are as much artistry as they are physics or chemistry.

So how does this relate to engineering research? Engineering research is now in its third stage of evolution. Before 1940 the terms engineering and research were largely mutually exclusive. Engineering colleges graduated bachelor's degree holders who went about the jobs of building roads, treating water, designing machines, etc. Engineering faculty were practitioners of these disciplines. Research was done in the basic sciences of physics, chemistry and biology. But since about 1950 there has been an ever increasing emphasis on "engineering research." More and more engineering faculty received Ph.D.'s. With no better role model, engineering research followed the paradigm of the physical sciences where faculty members worked with graduate students on isolated problems of engineering science where they had individual expertise.

What is new? During the past several years, there has emerged a unique *engineering research paradigm*, often called "interdisciplinary research." This new engineering research paradigm allows the research problem to determine the expertise that is brought to bear on its solution. This expertise could include combinations of electrical and mechanical engineering for robotic systems or electrical and materials engineering for microcircuit fabrication, etc.

How are we involved? Our College has established a leadership position in this new engineering research paradigm through a variety of research centers where faculty and students from different departments come together to solve problems that are important for our competitive position in the world marketplace. This new research paradigm closely parallels the synthesis underpinning of the engineering discipline itself and puts into practice the adage: form follows function.

COMBINING ENGINEERING AND MEDICAL TECHNOLOGY

Biomedical engineering is among the most recent additions to the technological professions. This branch of engineering concerns solving and understanding problems in biology and medicine by using principles, methods and approaches from engineering, science and technology. Biomedical engineers apply engineering, science and technology to living systems. They design implants and artificial organs, work with the engineering principles of rehabilitation, improve surgical tools, improve treatment techniques and work on medical instrumentation.

Applying chemistry, physics and mathematics to the human body and its systems is the task of biomedical engineers.

Biomedical engineers have designed artificial limbs, heart valves, blood vessels, kidneys, respirators, pacemakers and many other sophisticated machines that have helped to maintain critically-ill patients' lives. In addition, they have designed instruments to look inside the human skull, hear a fetal heartbeat, record the movement of a rapidly moving eyeball and perform many other useful tasks.

Biomedical engineers work frequently with models, simplified representations of objects or systems. Occasionally, animals are used. A model is constructed first, then reproduced as an actual device or system. The engineers test their new ideas on models to be sure of success when applying the concepts to humans.

Applying chemistry, physics and mathematics to the human body and its systems is the task of biomedical engineers. Biomedical engineers must have a good background in biomedical sciences, such as biochemistry, biology and physiology. They must understand the language and literature in order to communicate with the doctors. They must be able to initiate experiments in the biological and medical field and apply engineering, physics and mathematics to find a reasonable and understandable solution.

The biomedical engineering program at the University of Wisconsin Madison is not well known, which is unusual considering its excellent reputation in engineering and medical education. Although UW-Madison does not offer a bachelor's degree n biomedical engineering, it does offer a graduate program in this area. As a matter of fact, many schools offer master's and Ph.D. degrees in biomedical engineering, and more and more universities are offering biomedical engineering as an undergraduate program.

Most people who get their master's degree in biomedical engineering, have a bachelor of science degree in electrical and computer engineering or mechanical engineering. The classes recommended for university students at UW-Madison who have an interest in biomedical engineering are ECE 462, ECE 463, ECE 625 and Med 461.

There are three main branches of biomedical engineering at UW-Madison: devices, models and computers in medicine. The professors associated with biomedical engineering and their area of expertise at UW-Madison are Professor John Webster, specializing in devices and biomedical instrumentation, Professor Daniel Geisler, specializing in models and sensory communication and Professor Willis Tompkins, specializing in computers in medicine.

The following schools offer a bachelor of science degree in biomedical engineering:

Marquette University (Milwaukee)
Milwaukee School of Engineering
Northwestern University (Illinois)
University of Iowa
California State University- Long Beach
University of Southern California
University of Bridgeport (Connecticut)
Mercer University (Georgia)
Louisiana Technical University
*John Hopkins University (Maryland)
Boston University
University of New Mexico
New York Institute of Technology
Rensselaer Polytechnic Institute (New York)
*Duke University (North Carolina)
*Case Western Reserve University (Ohio)
Wright State University (Ohio)
Oral Roberts University (Oklahoma)
Carnegie Mellon University (Pennsylvania)
*University of Pennsylvania
Brown University (Rhode Island)
Vanderbilt University (Tennessee)
Southern Methodist University (Texas)

* denotes the top five grad schools in 1989-1990, with the addition of *Massachusetts Institute of Technology, according to U.S. News and World Report.

AUTHOR

Amy Erickson, EGR-1, plans to hang out with friends and work a a restaurant called Trump's this summer.

THE CONTROVERSY BEHIND THE TECHNOLOGY

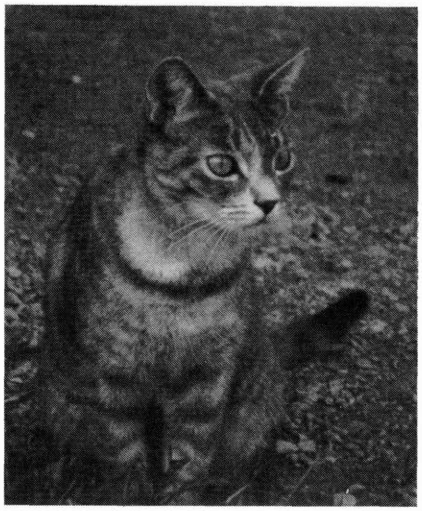
As said in Webster's dictionary, "Ethics is a theory or a system of moral values": the question of right or wrong. Ethics play a strong role in many of the procedures used in the medical profession. The ethical problems found in the advancement of medical technology have affected many biomedical engineers. Euthanasia, human research, and animal experimentation are three controversial issues often faced by biomedical engineers.

Euthanasia

The medical field has been able to prolong the life of many patients through recent technollogical advances. With pacemakers, artificial kidneys and ventiltors, many men and women have led productive lives. By maintaining the lives of some people, however, the doctors and family members must make a choice about the quality of life of the patient. Although these machines prolong life, they may also extend the pain of living. Some people feel it is better to let the patients die rather than making them suffer through a life of pain. This act of "mercy killing" is known as euthanasia. As stated by Professor John Webster at the University of Wisconsin-Madison, the instruments designed by biomedical engineers must be developed so the doctor has the choice to use them. Although biomedical engineers are indirectly affected by euthanasia, they are directly affected by both human and animal research.

Human and Animal Research

Human research leading to technological advances has many ethical side effects. Human research has been used in all areas of medical advancement. Products of this research include the cure for polio and the development of artificial and transplant organs. There is a fine line in deciding when to test newly discovered devices on humans. However, human testing is inevitable. For example, a 50 year old female has severe coronary artery disease, and there are no present drugs known to cure this disease. Should untested drugs be used on her? Fetal tissue research causes another research controversy. With legalized abortion, fetal tissue research has developed into a large field. This aspect sparks another battle between pro life and pro choice activists. The moral questions of research ethics have no concrete answers.



Animals like this cat improve our lives by letting us study them.

In many cases animal experimentation is done before any testing is performed on humans. Many biomedical engineers use modeling to simulate a biological process or system. These models are extremely helpful, yet they cannot replace the use of biological systems. Animals become the subject of biomedical research. With growing concern about the humane treatment of animals, biomedical engineers are caught in a debate of ethics. Although some research is not harmful to the animals, there are experiments that cause the animals pain. Should an animal be sacrificed for the sake of humans?

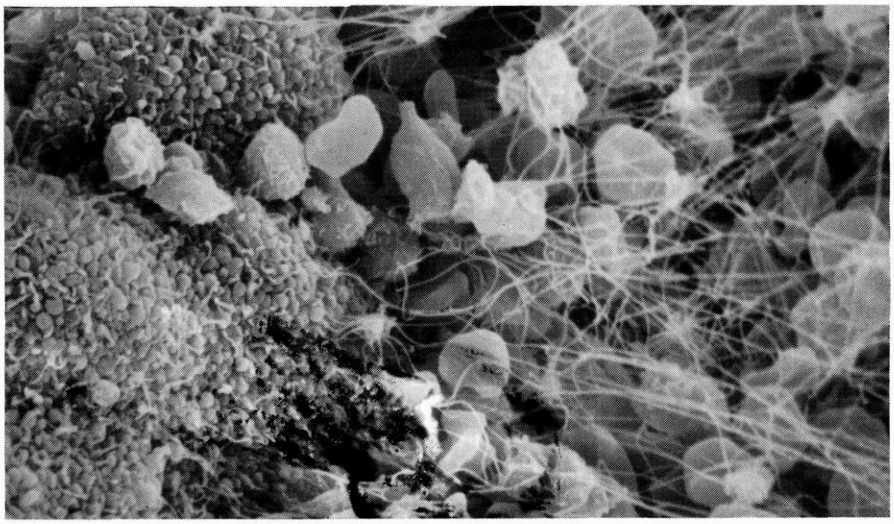
"This is something that human activists will say 'yes' to", says Webster, "while animal activists will say 'no.'" Research projects done on animals must be approved by animal rights groups before any experiments take place. A question of humankind's right to control the animal kingdom still remains.

Biomedical engineering has brought many life saving and life enhancing technologies to humankind. However, after solving one problem, biomedical engineers are faced with another. Ethics is the second round of problems - problems which cannot be solved by any equations. Engineers must use their consciences to work their way through the problem set of ethics. ▮▮

AUTHOR

Jim Webb, EGR-2 plans to paint houses and play the saxophone this summer.

SYNTHETIC ARTERIES ATTEMPT TO DUPLICATE NATURE



Scanning Electron Micrograph shows a thrombus deposited on the wall of a polyurethane biomaterial. It consists of white blood cells(ruffled), red blood cells(smooth), fibrin strands and platelet aggregation(on left).

The heart beats about 70 times and pumps over five liters of blood through the human body's myriad of blood vessels every minute. Maintaining a healthy supply of oxygen-rich blood to every part of the body, the human circulatory system is a marvelous network of muscle, valves and tissue, all coordinated in the brain and linked by a flow of blood that provides nutrients and removes wastes. But what happens when this complex system, so vital to human survival, breaks down? Serious injuries and even death may result. Fortunately, however, technical advances in medicine ranging from bypass surgery and pacemaker devices to artificial and implanted hearts have prolonged and improved the quality of life for many people. Although these procedures and devices have proven successful, problems in their production and implementation remain.

One particular area under study involves the production of synthetic blood carriers, primarily veins and arteries. UW-Madison Chemical Engineering Professor Stuart Cooper in conjunction with associates in the UW Medical and Veterinary Schools is investigating the use of polymers as biomaterials, searching for a substance that can simulate the functions and characteristics of a human blood vessel as closely as possible. Cooper is working with Professor Deane Mosher in the Department of Medicine and Dr. Ralph Albrecht in the Department of Veterinary Science.

Explaining the primary focus of their research, Cooper says, "We're interested in the interactions of blood with artificial materials." One of the major problems encountered with artificial implants, no matter what shape or size, is the human body's rejection of the foreign part or substance. Blood tends to clot on foreign substances in the body. This clotting, although intended to be beneficial in wound healing, tends to be dangerous on artificial surfaces when the clots reach such a size that they alter the blood flow to other parts of the body.

Therefore, the basis of Cooper's research centers on determining chemical combinations of polymers which react favorably with the body's physiological fluids and resist clotting. "I've had students over the years study protein adsorption characteristics as well as blood clotting or thrombus deposition on various kinds of polymers," states Cooper. Considerably simplified, clotting involves the basic steps of protein adsorption and platelet and cell adhesion, along with the polymerization of fibrinogen, a blood protein, into fibrin.

The result is a combination of a synthetic component (the structural wall) and a biological component (the living cells growing on the wall), resulting in a semi-artificial artery.

Generally, clots formed due to the presence of a synthetic material do not cause damage at their point of formation. Although the blockage due to a clot in an artery may potentially close off an entire blood conduit, more frequently, the blood flow dislodges the clot and sweeps it down the bloodstream. Problems arise when the clot reaches smaller blood vessels which it cannot pass through and blocks the flow of blood. Potential problems resulting from this blockage include lung congestion or phlebitis, a condition of capillary blockage in the legs. Most seriously, blockage in the brain can cause a stroke leading to brain damage, paralysis and possibly death.

To counteract the formation of such hazardous clots, many patients who have prosthetic devices exposed to blood must periodically take anticoagulants such as aspirin to thin the blood. This practice is fairly common, yet Cooper reasons, "It would be better if you had a material that would work well enough so you wouldn't have to take any supplemental drugs."

The research thus far has been successful as Cooper notes, "We have developed some polymers that have anticoagulant character." Tests involve adding a small amount of the polymer in soluble form to whole blood and measuring the clotting times. These materials have been found to prolong clotting times. The next step is to create a synthetic artery that has these anticlotting characteristics.

Although Cooper's research has not involved human test subjects yet, he claims, "We have made various kinds of tubing that we can evaluate for use of this kind of application." Several of the tests involve the study of chemical reactions and processes such as how proteins and platelets interact with various biomaterials outside the body or in-vitro.

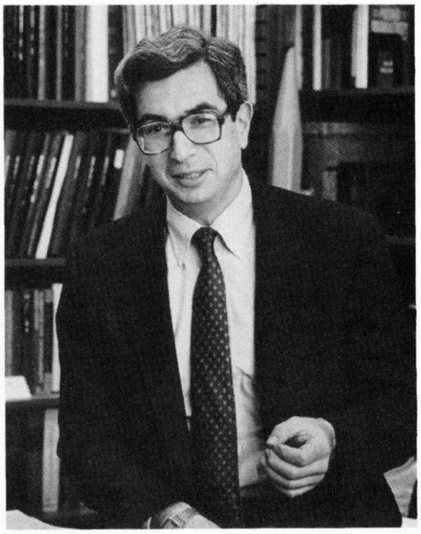
Another stage of the research involves implant biostability and animal testing. One of Cooper's graduate students is specializing in this area. Presently, researchers implant small films of polymer samples into rats. After a specified amount of time ranging anywhere from two weeks to six months, the sample is removed and studied. Changes in the physical properties and the molecular weight of the polymer are analyzed. The most important data reveal the kinetics and mechanism of the degradation of the polymer.

Results of these tests may not necessarily lead to materials for artificial blood vessels, but rather for catheters and pacemaker insulation. Cooper explains, "The problem there is biostability and infection potential." Biostability refers to the lifetime of a synthetic material within the human body. "If you have an implant, such as an artificial artery, it has to last for your lifetime. We're talking about needing upwards of a 10 year lifetime for an implanted material. That's asking a lot. It turns out that the human body is a very hostile environment for synthetic materials."

Keeping this point in mind, another one of Cooper's graduate students is approaching the problem from a somewhat different angle. Instead of trying to duplicate nature, Cooper says this approach tries to work with nature. Blood vessels are naturally lined with tiny endothelial cells. Rather than work to create a material which can emulate the functions of these cells, it makes more sense to develop materials on which these endothelial cells can grow, according to Cooper. He relates, "We have one project now where we are grafting small peptide sequences onto polyurethanes that would enhance the ability of endothelial cells to adhere to and grow and to multiply." The result is a combination of a synthetic component (the structural wall) and a biological component (the living cells growing on the wall), resulting in a semi-artificial artery.

"I would say the search for a truly blood compatible material is like looking for the philosopher's stone."

Indicating the odds working against him, Cooper explains, "I would say the search for a truly blood-compatible material is like looking for the philosopher's stone. It's a very difficult goal... To get a material to duplicate even some of the functions of these cells is a very formidable task."



Chemical Engineering professor Stuart Cooper.

Illustrating the success rate of mother nature, Cooper refers to the current options available for replacing damaged blood vessels. "If a person needs to have a vein or artery replacement, the best option at this time is to essentially have a bypass operation," he says. The typical bypass involves harvesting a vein from the leg, or in more recent procedures is a mammary artery from the chest area, cutting out the diseased artery, and replacing it with the host's own material.

The success of this auto-grafting process lies in the fact that it does not have the clotting and possibly rejection phenomena associated with it that prosthetic devices do. According to Cooper, the bypass operation is now 98 percent successful, but a common problem is that some patients must undergo a second operation, and at that time, there may not be any 'good' veins left to harvest. Other complications tend toward rather slow recovery rates marked by serious discomfort, especially in the leg region, due to the surgery.

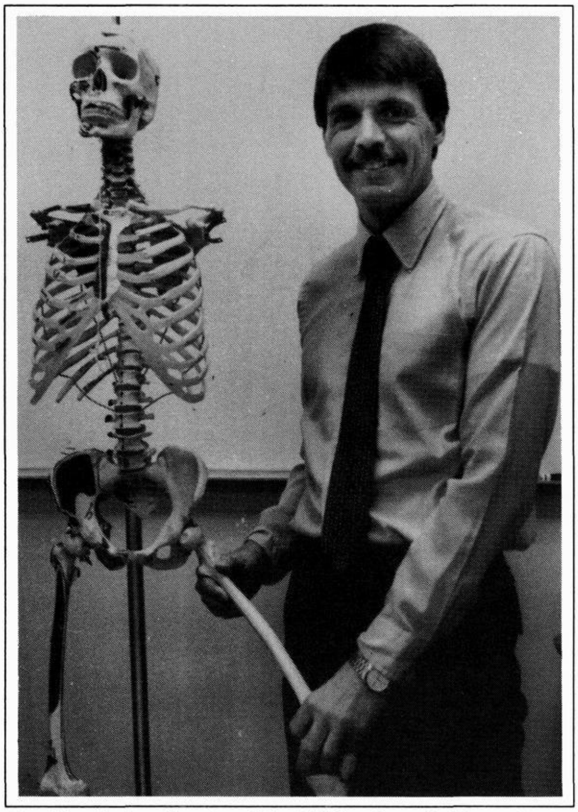
With the high performance rate of the natural human blood vessels, withstanding normal pressures of over 120 mmHg, Cooper emphasizes, "The great success rate for a person's own arteries makes you realize that you would have to have a really good synthetic material for this procedure."

But the future looks bright and full of potential as studies and collaboration continue. Cooper says, "I was trained more in classical engineering and in polymer science so this is a new area for me. It's a new area for each generation of graduate students, but certainly we have learned enough to communicate with colleagues in the Medical School. I don't think we try to duplicate their expertise, but we try to tap into it so that we can apply what we know to help solve some significant biomedical problems." ▮▮

AUTHOR

Nancy Hromadka, ECE-3, has a summer internship with IBM in Endicott, New York.

UW Research Improves Hip Implants



Ray Vanderby, director of the UW orthopedic biomechanics lab and an associate professor of orthopedic surgery, does research on improving the design of hip implants.

Of the patients who receive hip replacement surgery, approximately 99 percent suffer from arthritis. The arthritis is usually caused by such things as trauma, cartilage injury, age or one of many diseases. The surgery should not be

According to Vanderby, computer modeling and lab experiments complement each other well because "you see if what you thought conceptually in an idealized case holds true in the real world which is much different."

taken lightly. Because the procedure costs about $20,000 and the replacement of an implant lasts only half as long as an original implant, patients do not want to undergo the surgery a second time because of discomfort or wear and tear of the original replacement.

Ray Vanderby, director of the UW orthopedic biomechanics lab and an associate professor of orthopedic surgery, is conducting experiments to make better implants by decreasing discomfort and prolonging the life of hip implants.

Vanderby became interested inthis field while doing his thesis on a bioengineering related topic. He has a Ph.D. in applied mechanics from Purdue University and has been doing orthopedic research for more than 15 years. Vanderby came to the UW in 1985 to continue doing experimental study designs of hip implants.

He has two objectives in mind when trying to create a perfect implant. "The first goal is to avoid any change in normal physiological stress the implant may cause to the bone," says Vanderby. The second objective is to create an implant that will remain fixed so that the bone may adapt to the implant over time. Fixed implants are especially important to maintain in young patients whose bones are constantly changing.

Vanderby first uses computer models to simulate stress on the bone and to observe the contact and fit of the implant. But the problem, according to Vanderby, is that every femur, a bone in the leg extending from the pelvis to the knee, is shaped differently, so even though the computer may show an idealized fit, it may be far from reality. "You can gather lots of information from the computer, but it may not give you the whole story," says Vanderby.

After working on the computer, Vanderby then tests cadaver bones. According to Vanderby, computer modeling and lab experiments complement each other well because "you see if what you thought conceptually in an idealized case holds true in the real world which is much different."

But since he cannot see how the cadaver bones adapt to an implant over time, experiments are also done with dogs. Muscle forces are artificially applied at the insertion to balance the load on the femur and create muscle stabiliza-

The biological application and the technical challenges are aspects of Vanderby's job that he enjoys. "Contributing in a positive way to people is part of the satisfaction."

tion. The bone which is marked with a fluorochrome label is then examined to see if there has been any dramatic remodeling and if the implant is rigidly intact.

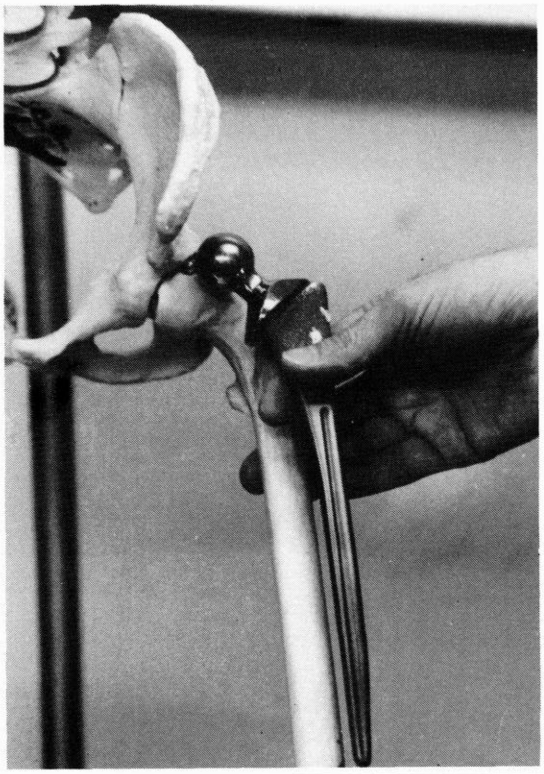
The next step is to hypothesize what

is causing problems and design models to solve any problems.

Implants were once made from stainless steel, but now they are usually made from titanium alloy or chrome cobalt with a polyurethane coating. Research is looking into using a more porous coating. According to Vanderby, a person's immune system amazingly will not reject a large chunk of metal, but will respond to metal filings.

Animal models are helpful, says Vanderby, but there are also plenty of limitations in applying findings to humans. For example, a dog can walk well on three legs, but a human cannot walk on one. And although you can see things happen faster in dogs, it can sometimes be misleading. "Animal bone is not human bone," says Vanderby.

The success rate of implants in humans is good, according to Vanderby. The progress of human patients is made through the use of low dose radiation x-rays in which bone loss can be quantitatively seen.



Vanderby demonstrates the position of a human hip implant.

Vanderby is primarily working on perfecting hip implants which are ball and socket joints because they are easier to work with than knee implants which have a higher incidence of failure.

As for his dislikes about the job, Vanderby says the research is slow and there are also frustrations in this type of research. "After all the time and effort that you put into the study, you might find out that the results are neither better nor worse. You also don't have the technological tools to sort out fine design changes to see if a new concept is advantageous," says Vanderby.

Vanderby says the most satisfying part of his work is the technical challenge. The biological material he works with is "not inert, is viscous, and has adaptive properties." What other material have you seen that becomes stronger when you put more load on it?" asks Vanderby. He also adds that he enjoys working with his lab students.

The biological application is another aspect of Vanderby's job that he enjoys.

Animal models are helpful, says Vanderby, but there are also plenty of limitations in applying findings to humans. "Animal bone is not human bone."

"Contributing in a positive way to people is part of the satisfaction," says Vanderby.

Photos by Jason Shirk

AUTHOR

Nazima Jaffer will be graduating this semester with a master's degree in journalism and a certificte in technical communications. She will be working as a science writer for AT&T Bell Labs in Short Hills, NJ during the summer.

UW Auditory Research: Making Clear How We Hear

If a tree falls in a forest and no one is there to hear it, does it make a sound? This apparently simple question has been the topic of trivial debate over the years. Deaf people experience this questionable phenomenon every day of their lives: Sound is happening all around them, yet they cannot hear any of it. UW professor C. Daniel Geisler and his research team are trying to understand the workings of the inner ear. Not only is that of theoretical value, but it has potentially great practical usage: The design of better hearing aids.

Understanding the Ear

The ear consists of three main parts: the outer, middle and inner ear. Sound enters the outer ear, passes through the middle ear, and eventually reaches the inner ear. The middle ear is an open, air-filled cavity with three bones which connect the input to the eardrum. The three delicate bones, the hammer, anvil and stirrup receive sound waves from the ear drum and relay the vibrations to the cochlea.

The cochlea, a helically shaped part of the inner ear, is divided into two channels, top and bottom. The channels are separated by a thin membrane. When sound vibrations enter the middle ear, the stirrup transmits the sound to the upper channel of the cochlea. This sound propagates through the top channel until it reaches a point on the membrane which is tuned to that particular frequency. Different frequencies travel different distances because the membrane is tuned like the strings of a piano, different parts of the membrane vibrate for different frequencies. The membrane is tuned like the strings of a piano; different parts of the membrane vibrate for different frequencies.

At any one point along this membrane, special cells exist which translate the incoming vibrations into a "code," which is then sent through nerve fibers to the brain. The cochlea is mechanically

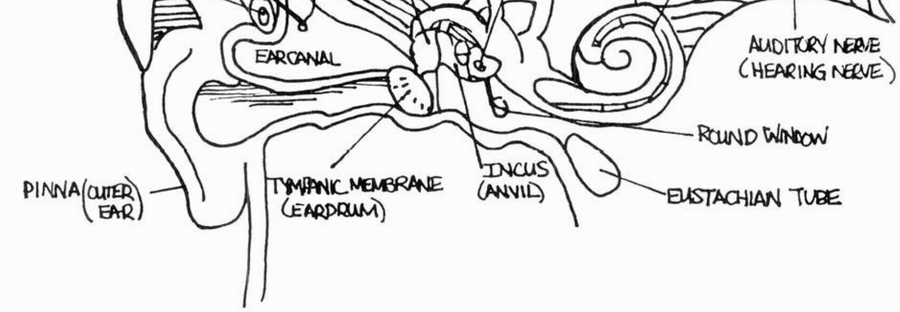
> ***This task proves to be difficult and tedious, as there are several models and as many as 1400 second-order differential equations.***

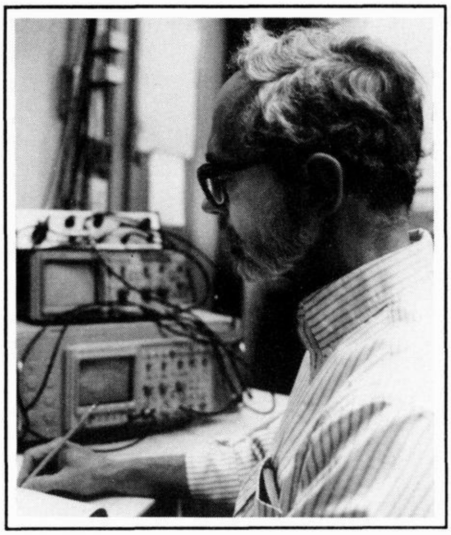
designed to take in acoustic signals and generate a pulse code. This code, according to Geisler, is "sort of a Morse code without the dashes, only the pulses." Each pulse created by the cochlea is transmitted along a single nerve fiber which joins approximately 30,000 other nerve fibers of the auditory nerve on its way to the brain.

This basic outline of how sound is processed in the ear has been known for more than 50 years, but according to Geisler, "there have been many surprises along the way." Geisler's study concentrates on understanding all of the mechanisms in the ear. He and his research team spend their time looking at the different aspects of the inner ear.

One type of research Geisler is performing consists of inserting tiny electrodes into the auditory nerve. These electrodes record pulses as they go by on a particular nerve fiber. From these data, they try to translate the "code." Researchers investigate the properties of the code as well as the translation mechanisms in the ear and brain.

The code is very intriguing to Geisler, not only because of its practical





Professor Daniel Geisler of Electrical and Computer Engineering.

value, but because it reveals a great deal about how the cochlea works. To know what the system is, you have to know both the output and the input. Geisler has spent a lot to time in the last 10 years measuring the output for various inputs. He now has a very good idea about the various inputs and outputs, but still has questions about the inner ear mechanisms which makes the inputs into outputs. He explains, "We've made many measurements, both electrical and mechanical, to try to figure out what's going on in there."

The research team continually takes in knowledge from various other people in the field. They are now assembling all of this information into a computer model which simulates the ear. For this model, they generate equations. This task proves to be difficult and tedious, as there are several models and as many as 1400 second-order differential equations.

Researchers, including Geisler, had been perplexed by the workings of the inner ear for many years. About eight years ago, researchers discovered that a certain type of cell in the cochlea actually vibrates. This cell is not a typical sensor, but has a sort of piezoelectric reaction. When it takes in sound energy, it creates an electric potential which in turn causes the cell to vibrate, thereby "amplifying" the incoming sound. Since this astonishing discovery was integrated into the models, the models have become much more accurate. With these models, researchers feel that they are much closer to understanding the important mechanisms of the inner ear.

For several years, Geisler worked with the Nicolet Instrument Corporation on the design of a new class of hearing aids. The aim of that research was to understand the speech signals of normal and abnormal ears and to determine how partial damage changes the code in the hearing process. With new technologies and discoveries constantly improving research models, Geisler and his team are now even closer to solving the mysteries of the inner ear. They hope that their research will be used to improve hearing aids in the near future.

AUTHOR

Amy Damrow, EGR-2, looks forward to a summer working for the Department of Transportation in Waukesha.

Hearing Loss and Cochlear Implants

There are two basic types of hearing loss. The first, and least difficult to correct is middle ear, or conductive, hearing loss. To hear, an acoustic signal has to reach the cochlea to cause a vibration. In the case of conductive hearing loss, the middle ear is "gunked" up, usually as a result of a middle ear disease, and the signal cannot get through. This condition can be overcome by a hearing aid, which amplifies the signals so they can pass through the middle ear.

The second, and most difficult to correct, is sensorineural hearing loss. In this type of hearing loss, the actual cells of the inner ear are degenerate. This can be caused by aging or listening to excessive loud music. The "sensory" aspect of this type of loss occurs when the cells in the cochlea are damaged. When there is damage to nerve fibers, "neural" loss occurs. The most common neural losses are caused by old age. Another type of neural loss occurs when a tumor grows on the auditory nerve. The tumor smashes the nerves together, so the auditory signals never reach the brain.

In the case of sensory hearing loss, a cochlear implant may be used to restore hearing. Cochlear implants are used only in totally deaf people, "totally deaf" meaning that ,effectively, all of the sensing cells along the cochlear membrane are damaged or missing. In this case, the acoustic signal goes into the ear, and the nerves are intact to transmit pulses to the brain, but the translation device is gone, so the signal never reaches the nerve.

The cochlear implant consists of a series of wires inserted into the cochlea. As many as 20 or 25 wires may be used. Different wires are used for particular frequencies and stimulate different nerves.

Cochlear implants are only feasible for totally deaf people. According to UW Professor C. Daniel Geisler, if a person can hear even a little, he or she should not get an implant, as the sensation is reported to be very hard to interpret. Geisler states that cochlear implant patients apparently hear "muffled, garbled signals—nothing like you and I hear."

Approximately 2,000-3,000 deaf people have had cochlear implants. The implants have had a tremendous impact on their lives. People who once heard only silence can now sense the presence of someone in the same room, detect the motor of an oncoming car or hear the ringing of a telephone. Few, around 20 percent, of the people with implants get enough information to carry on a telephone conversation. Cochlear implants are costly and do not create the sound quality of a normal ear, but to a person who knew only silence before an implant, they make a world of difference.

"Renewable Energy: Powering Wisconsin's Future"

Can we find an escape from the dead-end policy of feeding a giant, growing industrial complex on energy supplies destined to run out? Ever since human beings have been harnessing energy to further their desires, the consumption of energy has roughly followed an exponential climb. However, since our energy habit is not fueled by infinite resources, it appears we are on a crash course. The demand for energy is tending toward infinity, and the supply of energy is tending toward zero.

As explained by Assistant Professor Mark Hanson of the Institute for Environmental Studies and the Department of Urban and Regional Planning at the University of Wisconsin-Madison, the only questions about the switch to renewable energy sources are when and how.

In recent years and up until today, the energy policy in the United States could be summarized simply as "import oil." According to Hanson, "We will be lucky to supply one half of our oil demand in the next few years." In Wisconsin, we spend $8 billion a year on energy; roughly 75 percent of that expenditure is attributed to imported fuel. As seen by current events in the Middle East, such a policy can have far-reaching implications.

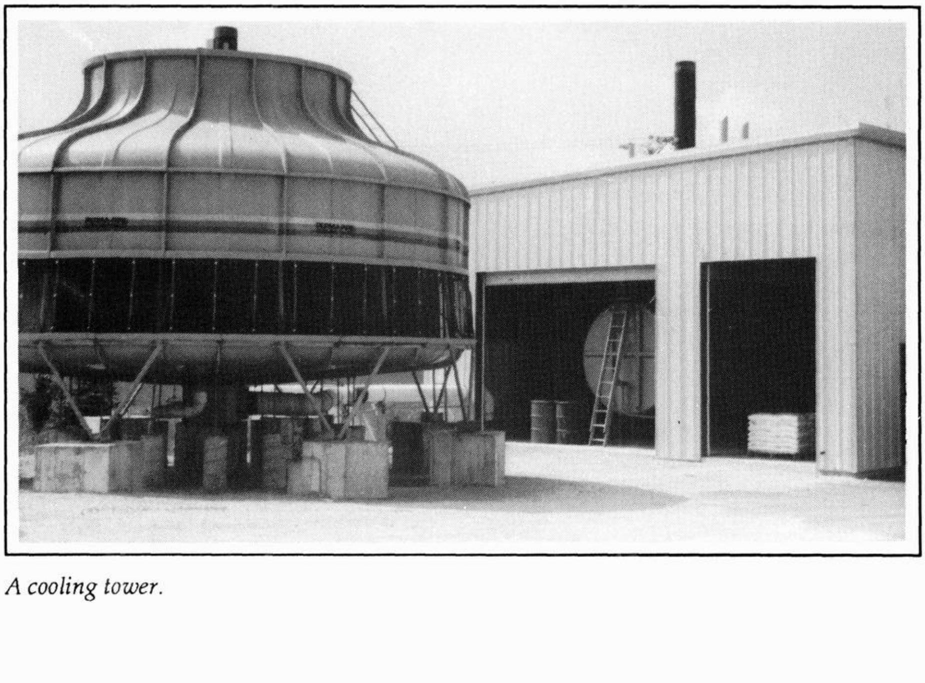
In order to address this country's energy problems, the Bush Administration is hammering out a national energy policy, the first since the Carter Administration. The loudest voices in preliminary hearings held by the Department of Energy called for the development of renewable energy sources and the improvement of efficiency, according to Donald Wichert, Chief of the Fuels Section of the Wisconsin Energy Bureau. However, the first draft released publicly by the Bush Administration on February 8, 1991 did not emphasize these areas. Rather than reduce our energy appetite, the plan calls for increased energy production by relaxing limits on opening nuclear power plants and allowing oil exploration in the Arctic National Wildlife Refuge in Alaska.

Renewable energy sources are crucial to a long term energy policy. The sources are becoming increasingly important to the total energy supply as their economic feasibility is discovered. Today renewables make up 4.6 percent of the fuels that supply all forms of energy for Wisconsin.

The United States is not presently using more renewable energy sources because we have inherited a legacy of cheap fossil fuels, and currently find conservation investments more economically attractive than new energy supplies, either conventional or renewable. Industrial equipment can be very costly, and managers often want a payback of a few years. Equipment installed new, however, uses renewable fuels more often. Such equipment has been installed in Wisconsin by Northern States Power, burning 350,000 tons of wood waste per year in plants at Ashland and La Crosse.

There are five viable options for renewable energy, as described by Wichert, who earned a graduate degree in Energy Analysis and Policy at UW-Madison, and now works for the state specializing in renewable energy sources. Although wind and solar energy may be the first possibilities that come to mind, Wichert clarifies that "neither have great potential in Wisconsin in the near future."

The first option is wind power. Wind speeds have been monitored at numerous locations across Wisconsin by the state and utilities. The measurements recorded show that the cost of wind energy is generally not competitive with existing plants on the grid. For this reason, wind turbines tend to be used



A cooling tower.

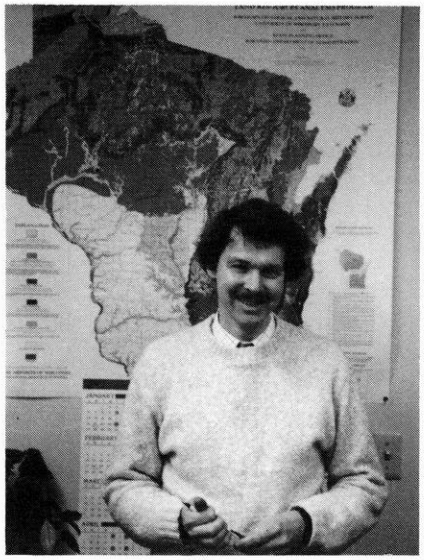
only in areas that are far from existing transmission lines, such as remote farms.

Although a second option, solar energy has a potential output of 46 trillion British Thermal Units per year in Wisconsin, its use is limited in practice. Equipment for solar energy conversion is still prohibitively expensive. Nonetheless, solar energy can be easily used in such "passive solar systems" as windows on the south side of a house.

A third renewable energy source is hydroelectric energy. Currently five percent of our electricity in Wisconsin is generated at water dams. The advantage of hydropower is that it is generated cleanly and inexpensively. However, only so many dams can be built, and Wisconsin is reaching its limit of 11 trillion BTUs annually. Furthermore, tough Federal Energy Regulatory Commission regulations designed to protect natural habitats and protect fish spawning grounds make it difficult to license new plants and re-license existing ones.

The last two options, burning biomass and burning wastes for energy, have the greatest immediate potential in Wisconsin, according to Wichert. In this state, the most abundant source of biomass is trees. Fifteen million tons of biomass are available annually in Wisconsin forests, containing 10 million BTUs per ton. With proper forest management, forests can supply this much wood and actually experience growth while meeting the needs of existing wood users; though with improper management, cautions Wichert, the forests can be damaged. Contrary to fossil fuels, the carbon dioxide released by power generation from biomass sums to zero in the steady state because new trees absorb as much carbon dioxide as they produce when burned. Carbon dioxide is a "greenhouse" gas that blocks the escape of heat from the atmosphere to the environment.

In many cases, waste can be burned to generate electricity and process steam or space heat with the advantage of negative fuel cost, meaning some



Donald Wichert, chief of the fuels section of the Wisconsin Energy Bureau.

companies will pay to have their wastes hauled off. Thus, if properly controlled, some wastes can be burned for their energy with a net positive impact on the environment. The total potential energy from wastes in Wisconsin is 177 trillion BTUs per year.

Waste of the forest products industry can be used as fuel. As many as 1,400 companies in Wisconsin cover acre upon acre of land with unwanted lumber scraps, and some even burn it off illegally. On the other hand, if the scraps are burned in a controlled environment, the heat can be used to generate electricity.

Old tires are another example of waste used as fuel. Tires can be stacked up on hillsides taking centuries to decay and posing a fire hazard, or they can be processed for burning in a boiler with coal.

Tires have a higher heat content than coal, a lower sulfur content, and if burned completely, will not give off ugly black smoke.

Landfill gases are burned for energy more often today because the Department of Natural Resources regulations now require that gases produced in landfills must be contained before they leak into the atmosphere. Trace gases are removed from gases collected to preserve the environment and prevent corrosion of the boilers. Roughly 60 percent methane and 40 percent carbon dioxide remain. Methane burns efficiently and cleanly.

Even if fossil fuels and nuclear fission fuels can supply all energy needs for our lifetimes, they will inevitably be exhausted. The question in the minds of researchers at UW-Madison and elsewhere is, in Hanson's words, "Will the transition from fossil fuels to renewable fuels be smooth or bumpy?" We are off to a bumpy start, but it is within our means to make investments in research and development of renewables to help smooth the transition. ▮

AUTHOR

Doug Maly is currently finishing his thesis for his Master's Degree. He is looking for a job this summer.

Probing Peptides

Chemical Engineering Professor Investigates Clues to the Alzheimer's Mystery

Professor Regina Murphy of Chemical Engineering at the University of Wisconsin - Madison.

In the on-going search for the secret to Alzheimer's disease, a UW-Madison chemical engineering professor is investigating possible clues. Professor Regina Murphy, the department's first and only female professor, is studying the development of protein deposits found in the brains of Alzheimer's patients.

The only definitive way to diagnose a patient with Alzheimer's is by performing an autopsy, according to Murphy. At that time, deposits of a protein known as the beta-amyloid peptide have been found in the brain and appear as plaques, which are bundles of long fibrils, surrounded by dead or degenerating nerve cells.

The beta-amyloid peptide has also been found in the skin and intestine of Alzheimer's patients. Murphy is studying the way in which the protein aggregates into the dangerous fibrils and how this then leads to the destruction of the neurites of the brain cells.

The research is being done by Murphy and two graduate students: Sharon Tomski and Jerome Shen. Two undergraduates, Eric Podlogar and George Borovas, are also assisting in the study.

The only definitive way to diagnose a patient with Alzheimer's is to perform an autopsy, according to Murphy.

Murphy says a great deal of evidence, though not conclusive, shows that the formation of the amyloid deposit in the brain is an early step in the progression of the disease which kills 100,000 people every year.

"There is some evidence that suggests they are important in the development of the disease so not only are they a sign of the disease but they're a step in the subsequent damage to the nerve cells," adds Murphy.

According to Murphy, the beta-amyloid peptide is a "little piece" of a protein that everyone has in their brain, called the beta-amyloid precursor protein. "Somehow," says Murphy, "this bigger protein gets clipped up and forms this little protein." Then, this little protein along with several thousand others forms into long, thin fibrils. The aggregation process in the brain is thus the primary focus of Murphy's research.

In her experiments, Murphy and her research staff have chemically synthesized the protein similar to beta-amyloid peptide and have studied its effects on nerve cells grown in the laboratory. Conclusions of the study show that, indeed, the cells begin to die off as soon as two to three days following the introduction of the peptide.

Before the cells die, they change in appearance, according to Murphy. The nerve cells have long, thin "fingers", called neurites, which are important in the connections between cells and permit information to be transmitted. "The ability to form good connections is obviously important in how your brain behaves," said Murphy. What she has found is that the addition of the peptide causes the cells' neurites to get thicker and, consequently, to decrease in number. This decrease means there is less branching and less communication.

Next, Murphy studied the physical chemistry involved in the formation of the aggregated fibrils. This aspect involved two different methods: circular dichroism and several light scattering techniques.

A great deal of evidence, though not conclusive, shows that the formation of the amyloid deposit in the brain is an early step in the progression of the disease which kills 100,000 people every year.

Circular dichroism is a process which gives information on how a protein folds. The structure, known as the protein's secondary structure, is important in classification of the protein. Two of the possible structures formed from folding are the alpha-helix, which is a coil shape, or the beta sheet, which is shaped like a stack. Murphy has found that the fibrils formed from the peptide have lots of beta-sheet structure. "The alpha-helix doesn't form into the ordered structure," adds Murphy. This ordered structure of the beta-sheet enhances the formation of the long, thin fibrils.

In the light scattering experiments, the protein is dissolved in a buffer and is observed over several days to determine the size and shape of the molecule. Murphy reveals, "We've seen with synthetic peptide that we do form long rod-like fibrils and they look a lot like the ones that form in the brain." This technique not only determines the size, but also the length of time required for it to get to that size. Murphy adds, "We've come up with an idea for how the peptides form together."

By combining the two processes' results, Murphy and her team have developed a model of the aggregation process.

The next step in her research involves the study of how varying conditions or varying components might alter the aggregation process in the brain.

"For instance," says Murphy, "a lot of people think that there might be some connection with aluminum." Studies have shown that there is evidence of high concentrations of aluminum found in the brains of Alzheimer's patients. Murphy continues, "We have an idea that there is a spot on the synthetic protein where the aluminum would just fit right in real nicely."

The question Murphy hopes to answer is whether aluminum affects the aggregation process or is a side effect of it. Right now, she is studying the data collected from observations of the aluminum and the peptide. "[Initial] data suggests that it does [affect the process] but it is really too early to say for sure," says Murphy.

Another focus of Murphy's study is the conditions that affect the formation of the fibrillar deposits, which are responsible for the destruction of the nerve cells, as opposed to the formation of the non-fibrillar deposits. Thus, it is possible to discover methods to keep the peptide from aggregating in such a way to prevent the nerve damage. "If we can interfere with the conditions, then we can interfere with the formation of the deposits," says Murphy. Such a discovery could prevent or aid in the treatment of Alzheimer's disease in the future.

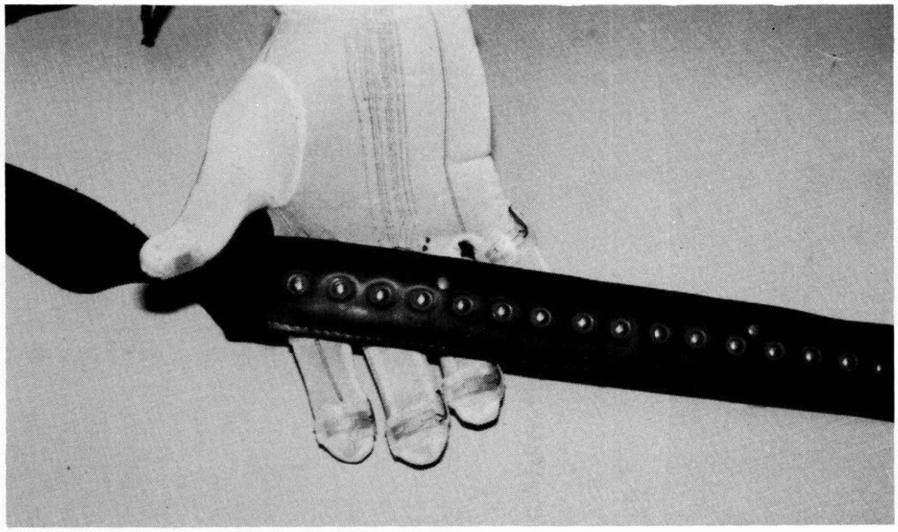
Murphy began her research in April of1990 with a two-year research grant from the American Health Assistance Foundation and start-up funds from UW-Madison. Since then she has received a grant from the Robert A. Schiller Memorial Fund, a fund set up for the husband of a UW-Madison alumna who died from Alzheimer's disease.

AUTHOR

Amy Nelson is a junior in the School of Journalism and has an internship this summer.

Tactile Sensing Research

Touching The Lives Of Those Who Have Lost The Ability To Feel



The glove and belt of the electrotactile feedback system.

"It seems that every imaginable medical disorder can lead to reduced tactile sensing ability, and this indicates the need for miniature replacement sensors" (Webster, 1988).

It is for this reason that Professor John Webster, in the Department of, Electrical and Computer Engineering at UW-Madison, is currently working on the design and development of a functioning tactile sensing system. A system such as this would be able to restore tactile sensing ability to people who have either partially or completely lost this ability, as well as robots and robotic manipulators which presently lack this ability entirely.

Tactile sensors differ from touch sensors in that they not only detect

Human sensors that provide the body with tactile sensory information are also able to detect changing pressures and aid the body with the recognition of such things as velocity, texture and vibration.

pressures that indicate whether or not an object is being touched, but they also detect the magnitude of pressure on the contact surface of the object that is being touched. Human sensors that provide the body with tactile sensory information are also able to detect changing pressures and aid the body with the recognition of such things as velocity, texture and vibration.

People lose natural tactile sensory abilities as the result of a wide variety of injuries and diseases. The absence of this ability can lead to a reduced sense of balance and to bodily tissues and bones that are more susceptible to further injury caused by dangerously high undetected pressures and forces. A tactile sensing system suitable for human use would provide additional safety and knowledge to an individual that lacks this ability.

Robotic manipulators completely lack the ability of tactile sensing. A functioning tactile sensing system would be able to provide robots with information that a grasped object is slipping and more pressure needs to be exerted to prevent the object from being dropped. Since an increase in applied pressure eventually translates into an increase in consumed energy, a tactile sensing system may also provide robots with the ability to apply just enough pressure, without waste, so that an object will not be dropped.

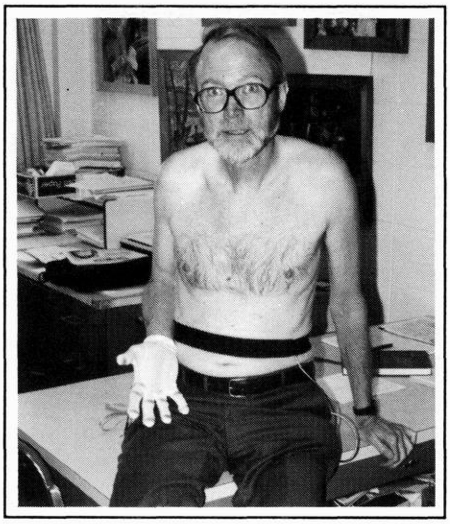
In the development of tactile sensors, a physical deformation of the sensor material must be transformed into a detectable electrical quantity, such as voltage, current, resistance, capacitance, inductance, etc. The changing electrical quantity of the sensor material should have as linear a relationship as possible with the applied pressure. This behavior ensures a distinction between large and small pressures. Eventually, the change of the electrical quantity must produce a signal that can be detected and either displayed or reintroduced to an area of the body with functioning tactile sensors.

Sensors can be divided into groups characterized by the electrical quantity that is varied in relation to the amount of detected pressure. The ability of a sensor to transform a mechanical deformation into an detectable electrical quantity is dependent upon the physical characteristics of the sensor material. "Lots of parameters have been investigated to determine which materials work the best," adds Professor Webster, "we would like to enlarge the nonpainful range, while optimizing comfort and

The choice of relaying tactile sensory information to other functioning tactile sensors of the body was chosen over visual or audible messages in order to limit the confusion between different senses.

amount of information." Such parameters include sensitivity, pressure range, repeatability, size, frequency response, reliability, geometry and cost (Webster, 1988). The environment of the application also directly influences the choice of sensor and sensor material that can be used.

One such electrotactile feedback system developed under Webster employs the use of piezoresistive sensors made from conductive elastomers whose resistance changes in accordance with applied pressure. These sensors are very thin and are positioned at various locations on the inside of the hand in the material of a glove. The signal produced by a change of the elastomer's resistance, representative of the detected pressure, is then processed and reintroduced to the body on the skin of the abdomen through a belt worn by the user. This belt has 16 electrodes and can produce a large



Professor Webster with electrotactile feedback system.

number of distinguishable signals that represent pressures that could otherwise not be sensed by the insensate hand.

The choice of relaying tactile sensory information to other functioning tactile sensors of the body was chosen over visual or audible messages in order to limit the confusion between different senses. The abdominal area was chosen because it is an area of hairless skin that maintains good contact with the electrodes of the belt. The study of this system is currently being conducted by graduate student Kurt Kaczmarek.

The research under Webster has recently shifted from using tactile sensors made of conductive elastomers to developing and using sensors made of silicon. Silicon sensors provide an increase in linearity, but a high temperature dependence has so far limited their use in physical applications. This area is currently being researched by graduate student David Beebe with additional help from Professor Denice Denton, Electrical and Computer Engineering.

Although the study of tactile sensors and electrotactile feedback systems has come a long way, "we must emphasize that tactile sensing technology is in its infancy, and that none of the applications that we describe are fully developed working systems," (Webster, 1988).

References: Tactile Sensors for Robotics and Medicine, Edited by John Webster, Department of Electrical and Computer Engineering, University of Wisconsin - Madison, 1988 by John Wiley and Sons, Inc.

AUTHOR

Dan Grellinger, a junior in electrical engineering, is going to be in Madison this summer working for a professor.

SMES: High-Tech Energy Storage

SMES is a highly efficient means of storing extra energy produced during off-peak times which is then used during high-demand times . It is a major joint research effort between UW-Madison, The Department of Defense and private industry.

Picture yourself with a chance to win over $25,000 in the Final Jeopardy round. Today's Final Jeopardy answer: SMES. What would you state as your question? You will probably be embarrassed to find out that SMES is a major joint research effort between UW-Madison, the Department of Defense and private industry. The effort is largely funded by the federal government.

The correct Final Jeopardy question, and probably the question going through your mind right now: "What is Superconducting Magnetic Energy Storage?"

Before looking more closely at the principles behind SMES, those involved in the research effort and the proposed implementation dates and benefits, you should have a brief definition of SMES. SMES is a highly efficient means of storing extra energy produced during off-peak times which is then used during high-demand times .

Design Principles

The basic design utilizes a solenoid. This solenoid is essentially a ring of magnetic material with superconducting wire coiled around it. This wire is a niobium-titanium-copper strand development which is cooled to four degrees Kelvin using liquid nitrogen. The coil is charged and discharged through an alternating current to direct current power converter.

The DC current flowing through the coil produces a magnetic field. Energy is stored in this magnetic field. This energy is stored until the control computer detects the need for additional power requirements on part of the electric utility. Then the DC to AC converter supplies the added power requirements by drawing the energy out of the magnetic field. The overall system has a 95 percent efficiency.

UW-Madison has a small scale SMES system that is on-line with Madison Gas and Electric Company's power system. The system handles up to 250 amperes DC and can store a maximum of 250 kiloJoules of energy.

Research Effort

The SMES research effort is a joint effort between approximately 60 utilities, the Electric Power Research Institute, the Department of Defense and various other industries. The DOD has many applications for such a device, one of which is the Strategic Defense Initiative. Initially, two groups are competing for the government funding. The Ebasco group is being headed by UW-Madison and MG&E, and is also being funded by many midwest utilities and industrial companies. The government is currently looking at each group's proposal and will soon decide which group will receive funding.

After funding is received, construction of an Engineering Test Model is to begin in 1992 at a site in either Wisconsin, New Mexico, Washington or Texas. Testing is to begin sometime in 1995. After successful completion of the ETM testing, the government will commence with the building of an actual working model.

Benefits and Uses

There are a variety of benefits and uses inherent to the SMES project. Some of the primary benefits and commercial applications include energy storage, load following, system frequency stability and automatic power generation control. Spinning reserve, black start capability and bulk energy management are a few other primary benefits. Secondary benefits include lower use of oil and gas, increased efficiency, reduced maintenance and increased availability of current generating devices.

Conclusion

The SMES venture shows how well the university, the government and private industry can, and do, interact. SMES is a more efficient means of handling electric power demands, and can effectively reduce the operating costs of many power producing facilities. The fairly simple design and the vast number of participants will help to bring the SMES concept to reality by 1995. The benefits will surely help meet ever increasing energy demands for the year 2000 and beyond.

AUTHOR

Paul Derbique is a senior in electrical engineering. As far as we know, Paul might be leading a safari in the Amazon...

Professor Tompkins: The 'Magician'

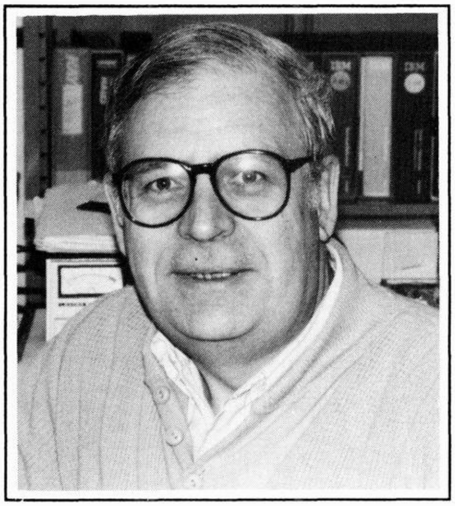
Professor Willis Tompkins begins each of his lectures or speeches with a magic trick. Some of these illusions involve a magic word - microprocessor. Tompkins applies the same enthusiasm to his work as he does to gaining the attention of his lecture audiences.

Tompkins recieved his undergraduate B.S. degree and his M.S. degree in electrical engineering from the University of Maine. He then went to work at a military electronics company, Sanders Associates Inc., as an electrical engineer. "I developed an interest in biomedical engineering while I was there, and I decided that I didn't want to be pigeonholed as an engineer for the rest of my life, designing the same circuit over and over again," he says.

Several years later, he recieved a Ph.D. degree in biomedical engineering from the University of Pennsylvania. At the Hospital of the University of Pennsylvania, he worked as a biomedical engineer, doing pulmonary research using a computer system. Tompkins then came to the University of Wisconsin.

He taught a course about the medical applications of computers. "When I came here, I thought it would be interesting to teach students some of the things I knew of the problems of computers in hospitals. The first year that I taught that course, it was mostly dealing with the applications of minicomputers in different environments in the UW system," he says. That course has changed with time and technology. "I evolved the course so that now it's principally about hardware and software design and techniques for medical instruments."

According to Tompkins, biomedical engineering will continue to change. He relates, "One of the founders of the Intel Corporation, the company that introduced the first microprocessor, observed that the number of transistors on a microprocessor on a piece of silicon doubles once about every 18 months to two years... The doubling is going to lead to overwhelming changes." These changes include a silicon chip that holds 100 million transistors, dwarfing today's one million transistor chip. "That leads to a future with a microprocessor that has more components than the fastest supercomputer in the world. We have the potential to put that in our pockets," says Tompkins.



ECE Professor Willis Tompkins specializes in the design of microcomputer based medical instruments.

Tompkins believes computers will also change in the way that we communicate with them. "The worst possible invention you could have for entering information into a computer is the keyboard, I think, because it requires a translation from the brain to the fingers... The great strides in the next decade will be speech recognizers." Tompkins explains that we have suitable speech recognizers right now, but we do not have the computing power to make using them practical. However, in less than 10 years, we should have the100 million transistor chip that makes talking to a computer possible.

At this time, Tompkins says, "My basic overall interest is in designing microcomputer based medical instruments. I'm particularly interested in the sub-field of measuring the physiological information about a person while he's walking around." His research has involved the development of a portable arrythmia monitor. This device monitors a person's electrocardiogram, and if something is wrong, transmits a signal by telephone to a central hospital.

Tompkins is an active member of the IEEE Engineering in Medicine and Biology Society. He was president of the Engineering in Medicine and Biology Society for two years. Last year he traveled around the world for more than 90 days, lecturing at IEEE chapters in Argentina, Australia, Brazil, Chile, Germany, India, New Zealand, The People's Republic of China, Singapore and Uruguay.

Perhaps sleight-of-hand tricks are only one kind of magic that Tompkins can perform. He also understands the "magic" of the microprocessor and its capabilities and the magic of spreading his knowledge all over the world.

AUTHOR

Annelies Howell, EGR-1, plans to work at Bemis Manufacturing Company in Sheyboygan Falls, WI and be a camp counselor for Phantom Lake YMCA camp. She also intends to sail and windsurf.

State Silences Shaw, Students Plea For No New Fee

Overshadowed by the State Senate Joint Finance Committee's persecution of (soon-to-be *EX-*) UW System President Kenneth Shaw were the presentations by UW-Madison engineering students to plea for much needed improvements for the College of Engineering. Students from Polygon, SWE, WSA and WBESS spoke on behalf of their fellow students to emphasize the need for improvement of computer facilities and equipment in order to maintain the College of Engineering's reputation for excellence in education and research. If the state legislature does not budget money for these improvements, engineering students may be forced to pay a new segregated fee. Polygon sent out a mailing to all engineering students at the end of April encouraging them to write their local representatives and members of the Joint Finance Committee to voice their concerns about the budget issue.

ENGINEERING BRIEFS

by Mike Waters

Out Wiith The OLD!...

...And in with the *NEW*! POLYGON Engineering Council wrapped up this year's agenda by electing next year's executives. The students who will be serving their peers and the College of Engineering in the upcoming year are as follows: President-Mike Waters; Vice President-Bart Heldke; Treasurer-Cecilia Copeland; Secretary-Andrew (Chip) Hogan; Scholarship Chairperson-Mike Hernandez; Survey Chairperson-Roger Theil; Industrial Relations Chairperson-Brian Lofy; Pre-Engineering Relations Chairperson-Pat Barber. The latter four positions have been 'newly' created in hope that they will enable Polygon to better serve their student constituency. Many thanks to this year's executives (Chip Hogan, Tom Wuttke, Tricia Verhagen and Pete Horwich) for all their hard work.

Some of Polygon's accomplishments this year include sponsoring the Engineers' Blood Drive, Career Connection, Fall Luncheon and Spring Banquet. Polygon also conducted the first ever Engineers' Survey, arranged for the production of a 'new' High School Outreach videotape this summer, and set the wheels in motion to establish a scholarship program for needy students seeking admission to an honorary or professional engineering organization. Anyone seeking more information about Polygon should contact one of the old or new executives mentioned above.

Cutting Sports May Not Cut Debt

Despite a presentation of the drawbacks of eliminating five non-revenue sports, the UW Athletic Board voted 10-7 to cut men's and women's gymnastics, men's and women's fencing, and baseball from next year's departmental budget. Gerald Kulcinski, Athletic Board member and professor of nuclear engineering, voiced his concerns about the "Cut 5, Cap 2" budget proposal in hopes that the other board members might reconsider.

Kulcinski's main concern about the proposal was that the negative feedback from students and the general public might reduce donations from alumni and industry. He was also concerned that the Wisconsin Student Association would carry out their threat to try to eliminate the $10 per semester student athletic fee if the sports were cut. The fee provides $750,000 per year for the department, about five percent of the annual budget. Eliminating the five non-revenue sports and placing a 'spending cap' on the crew teams would only save the department $300,000. Kulcinski argued that the money could come from other sources and presented his own proposal to save the sports and cut the athletic debt. His plan, which would have added a $1 sales tax to football tickets, received strong approval from students but was rejected by the other board members.

Grad Student's Gridiron Dream Comes True

Since Don Davey was barely old enough to pick up a football, he has dreamed of playing for the Green Bay Packers. That dream became reality when he was drafted by his favorite NFL team this spring. Although Davey does plan to finish his graduate studies at the UW, he couldn't pass up the opportunity to play professional football (and get paid significantly more than an entry-level engineer) after being selected in the third round of the draft. Projected as a fifth or sixth round choice, Davey set a new UW record for career tackles for a loss with 49. Even more impressive are his past successes in the classroom which made him the only four-time Academic All-American in NCAA history.

Free Drinks!...No Cover Charge!

For the second straight semester, engineering students were able to relieve some of their pre-finals stress with free beer and soda, courtesy of several Polygon-member organizations. In addition to the complementary beverages, this semester's "Engineers' Bash" provided cheap food and prizes, courtesy of Polygon itself. The purpose of the event, held May 3 in the Mechanical Engineering courtyard, was to provide a break for engineering students from academics. Polygon initiated the pre-finals event last semester with an "Engineers' Power Happy Hour" at the Rathskellar in Memorial Union and plans to continue it in future semesters.

THE NATURAL EVOLUTION OF SIGHT

Research at the UW-Madison is revealing unexpected information about the complexity of the human visual system. Most people take their sense of vision for granted, having grown up to rely nearly exclusively upon it for gathering information about the world. It provides an effective method of identifying objects at a distance, and in an arena of evolution driven by natural selection, it is no wonder that most creatures have sight.

Vision imparts a tremendous advantage to both predator and prey. The predator can actively hunt its prey, rather than have to wait for it to wander nearby and hear it. Similarly, prey can identify potentially threatening creatures early enough to be able to run away. The brains of higher animals contain large regions devoted to processing the images received by the eyes, resulting in extremely complex visual systems. An electroencephalogram (EEG), which measures brain activity, shows a substantial change in activity when a human subject merely closes or opens his eyes.

The forces of natural selection have created for humans a visual system with remarkable properties. The visual system is able to join the two stereoscopic images provided by one's eyes and provide a very effective sense of depth, conveying range information to the brain. This information is used automatically, in turn, to control the focusing of the eyes' lenses.

The visual system has substantial variation from human to human, but it still follows general rules in its development. Opthalmology and Psychology Professor Ulker Tulunay-Keesey says, "The eye-brain system doesn't come entirely hard-wired. It is plastic, and it may be adapted and shaped by the environment." The visual system is able to compare what is seen to what it unconsciously thinks "should be" seen, compensating for certain phenomena. In one experiment, research volunteers wore glasses which flipped everything upside-down, and after a certain period of time, the brain inverted the images again, leaving them right-side-up, counteracting the glasses. The glasses were then removed, resulting in an inverted world, and after a while the world was flipped to its proper position. This reaction is only one example of the abilities of the visual system.

Another example of the visual system's flexibility is the eye's sensitivity to an extremely wide range of light levels. The difference in light levels between a sunny afternoon and a starlit night is enormous, but the eye is able to handle both with a little time to adjust. In addition, the eye is more sensitive to changes in brightness over time rather than steady levels. A perfectly stationary image will start to fade away until there is motion. This trait is quite evident in frogs, which must move in order to see. Experiments have shown that frogs respond to moving images of insects, rather than stationary images.

The forces of natural selection have created for humans a visual system with remarkable properties.

Tulunay-Keesey says, "The visual input to the brain has gone through a lot of processing starting at the retina." An example of this processing is that the human eye is always vibrating, even when apparently fixated upon a point. The motion seems to refresh the image upon the eye, providing a constant image, even if there is no apparent motion. Research at the UW-Madison has centered on both the image motion that results from eye movements and adaptation to light which enables the system to respond over the wide range of illumination. The researchers include Tulunay-Keesey, Electrical Engineering Professor Bahaa Saleh, and graduate student Jesse Olson.

One mystery, according to graduate student Jesse Olson, is how the blurry, distorted, shaking image on the retina is processed by the visual system and turned into a rock steady, crystal clear picture. Olson says, "It's as if you took a video camera and shook it; you couldn't get any meaningful picture. But that's the way our eyes work, and you get a nice clear picture. There's some extremely powerful processing happening in there." This oscillation is a stage of the visual processing system, and it may enhance the eye's ability to see certain features. This stage is roughly analogous to looking out through a screened window, as moving one's head back and forth improves the image dramatically. Research is being undertaken here to determine exactly how the eye's motions alter the image sent from the eye's retina.

One aspect of the eye's performance which can be measured is the minimum contrast distinguishable in an image. A pattern of bars with sinusoidally varying brightness is commonly used for measurement of the eye's sensitivity at a given spatial frequency (stripes per unit distance). The human visual system is unequally sensitive to all spatial frequencies below an upper cut-off limit, which is imposed by the size of the light receptors in the retina, the physics of light as it passes through the pupil, the distorting properties of the fluids in the eye and the focusing of the lens.

However, when the visual system is broken down into separate stages, differences in sensitivity become apparent. The system can be viewed as consisting of the autonomous eye movements (the twitches), the lens, the fluids in the eye, the light receptors, a layer of nerve cells in the eye and then even more processing in the brain. When the eye movements are eliminated, the response of the system changes dramatically. The eye movements are a stage of the system, strengthening certain signals in order to give the system a better response characteristic. With the help of electrical engineering professor Bahaa Saleh, the team is developing a mathematical model of how the movements determine the sensitivity of the system.

The eye is normally relatively insensitive to low spatial frequencies, becoming more sensitive as the frequency increases, peaking at a certain frequency, and then falling off sharply as it approaches the physical limits of the eye discussed earlier. The visual system's response changes markedly when the eye movements' effects are eliminated by moving the image so it appears stationary. Overall sensitivity falls significantly, and the frequency of peak sensitivity rises.

To determine exactly how the eye movements change the signal, one must eliminate the motions and their effects. The normal response and the response with a simulated motionless eye can then be compared. In order to remove the effects of the moving eye, either the eye or the image it receives must be stabilized.

When an image is stabilized upon a subject's retina, the eye grows insensitive to that image. However, if the brightness level of the image is then increased, the negative of that image appears.

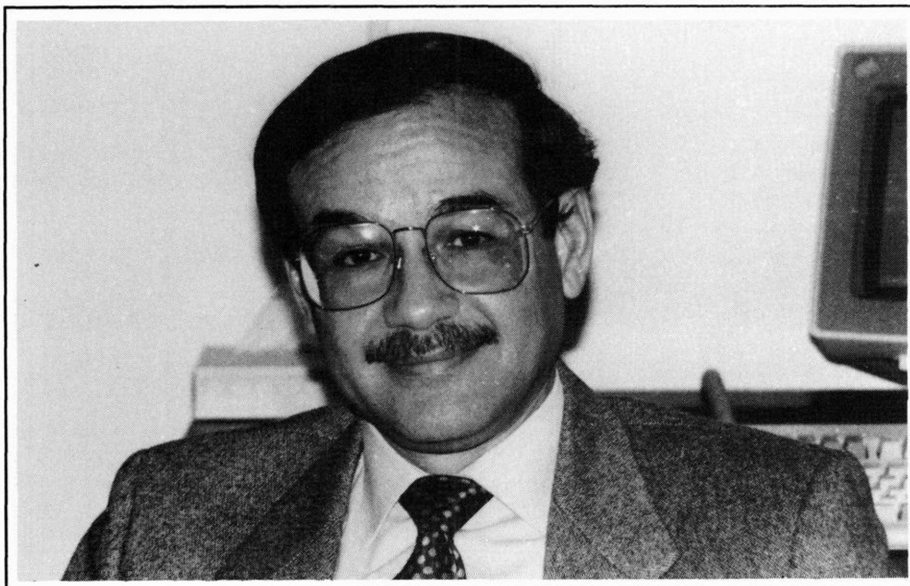
The preferred method is stabilization of the image, and this method uses a system composed of two parts: an eye tracker and an image stabilizer. The eye tracker determines where the subject's eyes are pointed, while the image stabilizer adjusts mirrors in front of the eyes to compensate for their movements, resulting in the presentation of an unmoving image to the eyes.

There are two general methods of sensing the eye's orientation: one involves using a special contact lens on the eye, while the other merely shines a beam of invisible infrared energy into the eye. In the first method a contact lens is fitted with a tiny mirror. A beam of light shines on the mirror and is reflected by an amount proportional to the direction of the eye. A sensor then proceeds to analyze where the reflection is, and determines the eye's orientation from that information. This method has significant drawbacks, as each subject must be fitted with an uncomfortable contact lens. After some time the eye becomes irritated, limiting the frequency and duration of experiments. Another method involves a contact lens fitted with tiny coils. A magnetic field, generated near the eye by additional equipment, induces signals in the coils. These signals are led out of the contact lens on fine wires. Obviously, this is a very intrusive method of determining the eye's position.

A much more attractive method of determining the eye's orientation consists of shining a beam of infrared energy into the eye. This beam creates four reflections, called Purkinje reflections, as it passes from the air into the cornea, from the cornea into the aqueous humour, from the aqueous humor into the lens, and from the lens into the vitreous body. The first and fourth reflections are used in a device called a dual-Purkinje-image eye-tracker. When only a single reflection is used, rotation of the eye and translation (shifting) affect the direction of the reflection, leading to errors in the measurements. However, by using two reflections, the signals can be processed and the two different components of the orientation can be distinguished.

Using the information about where the eyes are pointed, a pair of mirrors can be wiggled in order to exactly compensate for the eye movements, keeping the image on the retina fixed relative to the eye. This allows the pre-emphasis derived from the jiggling eye movements to be eliminated. As a result, one can determine the human visual system's performance with and without the first stage, which enables the measurement of the characteristics of that first stage.

Tulunay-Keesey and Olson, using a



Professor Bahaa Saleh of the Electrical Engineering Department at UW-Madison.

dual-Purkinje-image eyetracker provided by the National Institutes of Health, have been studying the small eye movements. These eye movements, which occur autonomously, consist of a high frequency, low amplitude component called tremor; a slow, cumulative part called drift; and a sudden jump called microsaccade. The tremor is small and non-cumulative, while the drift and microsaccades cancel each other out over time. It seems the latter two compensate for each other, but it is unknown whether the microsaccade is a response to drift or vice-versa. Olson says, "The question is not really answered. Maybe the drift is the compensation and the microsaccades are occurring to upset the system. It's not clear which is the answer." It does seem the signals are complementary, helping to refresh the image on the retina.

Another characteristic of the eye's performance which is being studied at the UW-Madison is related to the fading of stationary images. As mentioned before, when an image is stabilized upon a subject's retina, the eye grows insensitive to that image. However, if the brightness level of the image is then increased, the negative of that image appears. The initial disappearance of the image indicates changing local sensitivities to light in the visual system. The subsequent reversal of the image indicates nonlinearities, or abnormalities, in how the visual system reacts to changes in light levels. Research has shown that both the contrast and the spatial frequency affect the time required for an image to disappear. In fact, images with enough contrast never disappear.

The focus of the research is to better understand how the visual system works, and the resulting knowledge may have some benefits for visually impaired people. For example, an image on a television might be made to vibrate slightly, mimicking the drift and microsaccades normally exhibited by the eye, resulting in improved vision for people with abnormal eye movements. The mysteries of the eye and brain remain largely hidden, but with more research and better tools, they are being uncovered. ▮▮

AUTHOR

Alex Dean, ECE-4, will be doing independent electronics research on sonar this summer.

Visions of Success...

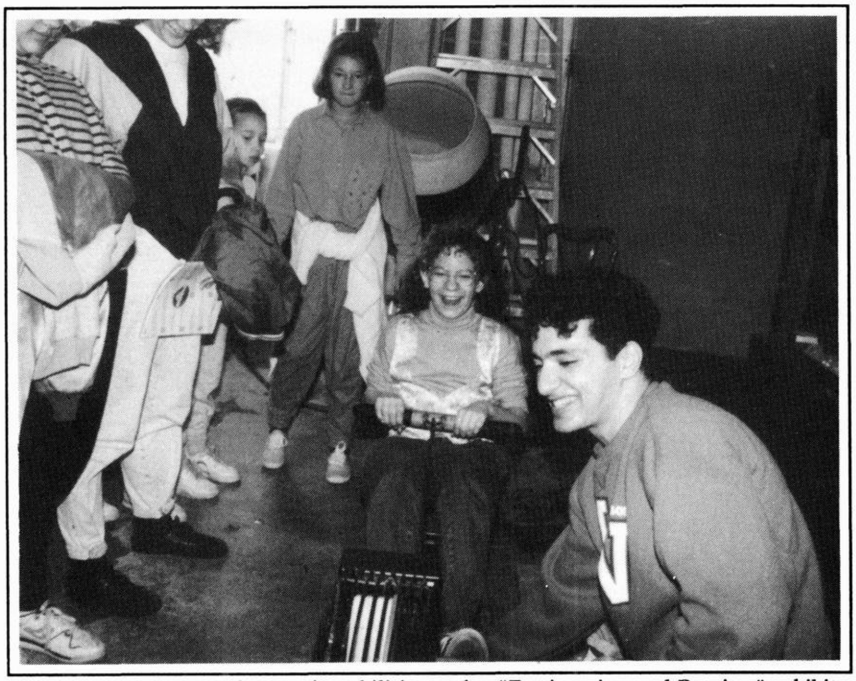
"SLIME! I wanna make SLIME!" This phrase was heard from many children as they read over the exhibit descriptions upon arrival at Expo '91. 'Slime making' was just one of over 100 exhibits featured at the 1991 Engineering Exposition held on the engineering campus April 19-21, 1991.

The exhibits featured a wide variety of topics; however, the special exhibits theme for this year's exposition was "Sports and Engineering." Many exhibits followed this theme. Examples included the Formula SAE Race Car, the Slapshot (an automated hockey puck shooter), the ASCE Concrete Canoe, a Human-Powered Hydrofoil, and Laser Billiards. Other popular exhibits included the Rube Goldberg "Breakfast-Engineering Style," the Automated Candle Dipper, and "Living Light" which featured luminescent bacteria.

Nearly 4,000 elementary, middle, and high school students attended on Student Day, April 19. Overall attendance figures for Expo '91 were over 12,000.

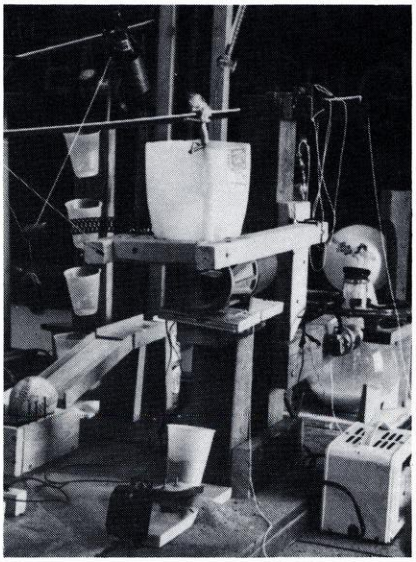
Student exhibitors were competing for cash awards in their separate judging categories, which included student organizations, graduate students, individuals, and small groups. Expo '91 awarded a total of over $6,000 in prizes, with $1,500 for each category, as well as prizes for the People's Choice and Best Sports Exhibit awards.

Thanks to the many hours of hard work put in by the hundreds of students involved, Expo '91 demonstrated to the public what engineering is today. ▮▮



A future engineer tests her rowing abilities at the "Engineering and Rowing" exhibit which was sponsored by members of the nationally-ranked University of Wisconsin Crew Team.

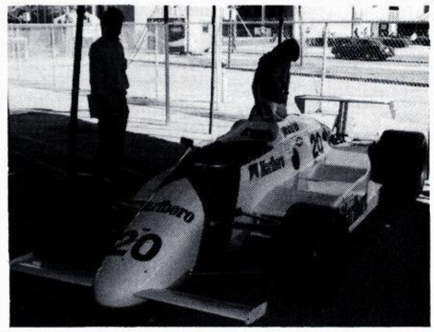
THE 1991 ENGINEERING EXPOSITION



"Breakfast-Engineering Style" was designed by Theta Tau. This exhibit was awarded the 1991 People's Choice Award.

VITAL STATISTICS

- Expo is a non-profit, entirely student-run and organized event
- Expo '91 was held April 19-21, 1991
- Expo '91 set a new record for student (ages 7-18) attendance
- Expo '91 overall attendance: 12,336
- All revenues go towards start-up costs for Expo '93
- Engineering Expositions have been held biennially since 1940
- The Expo Executive Committee consists of nine undergraduate engineering students
- Student exhibitors have the opportunity to earn up to three credits of independent study for designing their exhibits



General Motors, one of the chief sponsors of Expo '91, featured a number of their latest automobiles, including the above race car.

AUTHOR

Dawn Stanton, School Relations Chair for Expo '91 and co-production editor for the *Wisconsin Engineer*, will be co-oping in Chicago this summer with the Environmental Affairs Division of Amoco.

Photos by Jason Shirk and Dawn Stanton

Expo '91 Student Exhibit Awards

Small Group Exhibits:

First Place	The Slapshot
Second Place	Automated Retrieval & Storage
Third Place	Automated Candle Dipper
Honorable Mention	Just Hovering Around
Honorable Mention	Engineering in Rowing
Honorable Mention	Tour de Madison

Individual Exhibits:

First Place	Autonav: Compass with Memory
Second Place	Living Light
Third Place	Injection Molding
Honorable Mention	Computer Controlled Generator
Honorable Mention	Robot Welding

Student Organization Exhibits:

First Place	Pedal Power & Flight
Second Place	Re-Cycle Madison
Third Place	Laser Pool
Honorable Mention	Heads-Up-Display for Swimmers
Honorable Mention	Mechanics in Sports
Honorable Mention	Formula SAE Race Car

Graduate Student Exhibits:

First Place	Prediction of Muscle Action
Second Place	Use Me, But Don't Touch Me
Third Place	Intelligent Robot Grasping
Honorable Mention	S.A.C.S.
Honorable Mention	Music Brain
Honorable Mention	High Speed Material Transport