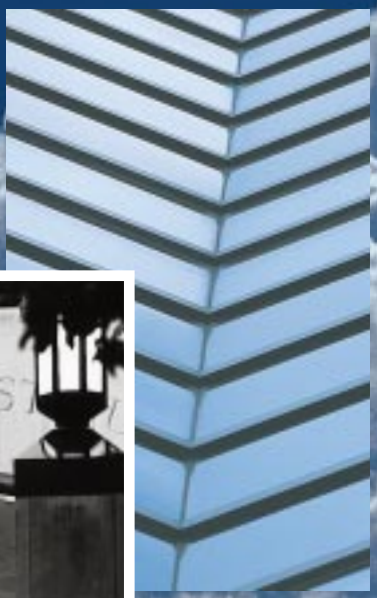
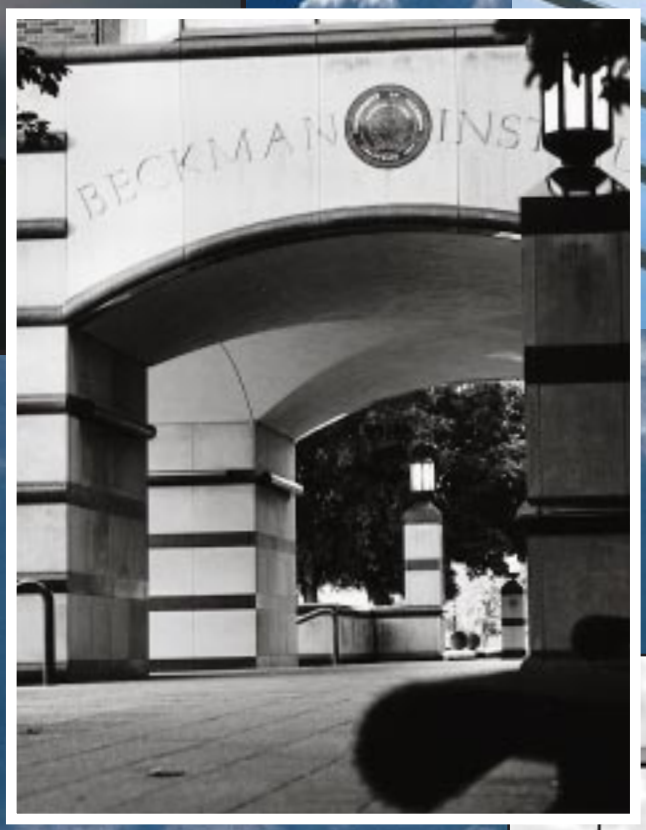
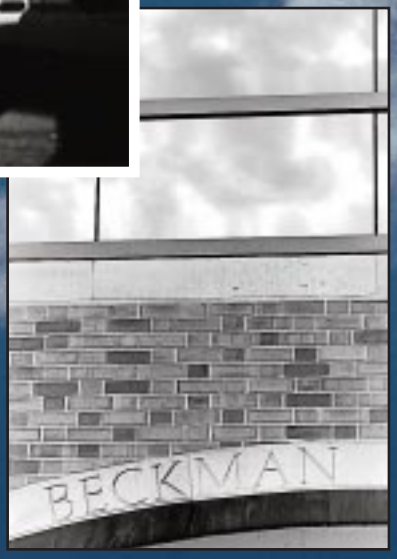
Annual Report 1999







Beckman Institute for Advanced Science and Technology

University of Illinois at Urbana-Champaign

1999

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1999

10 Years

Message from the Director

The Beckman Institute's First Decade

When the Beckman Institute for Advanced Science and Technology at the University of Illinois at Urbana-Champaign celebrated, in April 1999, its first decade of operation, we were provided with an excellent opportunity to reflect on the past ten years. The Beckman Institute officially opened its doors in 1989 with the goal of becoming the world's preeminent multidisciplinary research center. As the Institute completes its first decade, I believe we are well on our way to achieving this goal. It is quite remarkable that the Institute has succeeded in a relatively short time in establishing a truly multidisciplinary culture. In fact, the Beckman faculty, students, and staff enjoy collaborating on multidisciplinary projects, as they are well aware of the importance of pooling their research expertise from different traditional disciplinary fields when trying to study and solve complex problems in science and technology.

The entrepreneurial spirit of founder Dr. Arnold O. Beckman is also flourishing within the Institute. For example, research has led to the development of a new method for processing microchips which significantly extends their lifetime. In a multidisciplinary project sponsored by the Army Research Laboratory, research is being conducted with the aim of providing more effective computer aids to military decision makers and soldiers. A small company has been started by several Beckman researchers to commercialize microcoil NMR technology developed at the Institute.

It is also important at a time like this for the Beckman Institute to acknowledge the many people who contributed to its success in the first decade. First and foremost, it must thank Dr. Beckman, not only for the generous gift that made the Institute possible, but also for his vision in recognizing the importance of multidisciplinary research. This vision has positioned the Institute as a true leader in the area of multidisciplinary research.

There is no question that 1999 had special significance for all of us at the Beckman Institute. Not only did we celebrate our 10th Anniversary, but also we were very fortunate that the Institute's April anniversary date coincided with the 99th birthday of the Institute's founder, Dr. Arnold O. Beckman. Therefore, we were able to celebrate with Dr. Beckman, his family, and the Arnold and Mabel Beckman Foundation Board of Directors both the first decade of the Institute and the 99th birthday of its founder.

Message from the Director

Thanks to the Beckman Foundation's continuing support, the Institute has been able to keep pace in updating its research infrastructure by holding an annual competition for funding of equipment to be used in multidisciplinary research projects. In addition, the Beckman Fellows and the Beckman Graduate Fellowship programs represent two initiatives supported by the Beckman Foundation. Both of these programs are highly competitive and are discussed in detail later in this report.

The Beckman Institute must also recognize Dr. Theodore Brown, the Institute's founding director, who literally oversaw the construction of the building from the ground up and led the Institute through its formative years. The ongoing support of the University's higher administration and academic departments has also been critical. Finally, the Beckman Institute would not be what it is today without its faculty, staff, and students, whose commitment and dedication have made the Institute a model for others to emulate. Many of the multidisciplinary research projects that these faculty, staff, and students are involved in are highlighted throughout this Annual Report, and I hope that after reading the report, you will understand both my enthusiasm for and pride in the remarkable research that is taking place in this Institute.

As a part of its anniversary celebrations, the Beckman Institute sponsored a *First Decade Lecture Series* on the theme "Industry and Academia in the New Economy." The lecture series explored the changing relationship between academia and industry, a relationship that reflects the realities of the 21st century economy. Persons as eminent as Dr. Arthur Kornberg, Nobel Laureate from Stanford University; Dr. Larry Smarr, Director of the National Computational Science Alliance; Dr. Fernando L. Fernandez, Director of DARPA; Dr. William Rutter, Founder of Chiron Corporation; and Dr. Rita Colwell, NSF Director, were invited to speak in the series. Through their lectures, the Beckman Institute has created a forum for discussion of some of the most important issues in science and technology in the United States.

In conclusion, as the Beckman Institute looks forward to its second decade and the new millennium, it feels well prepared to face the many challenges and opportunities for multidisciplinary research that the future is sure to bring.

Jiri Jonas, Director

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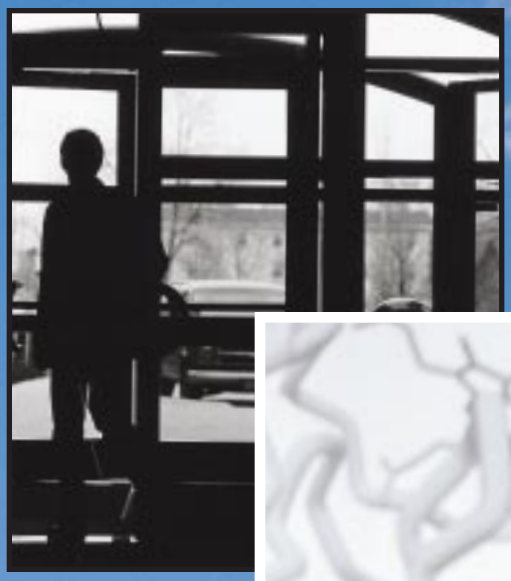
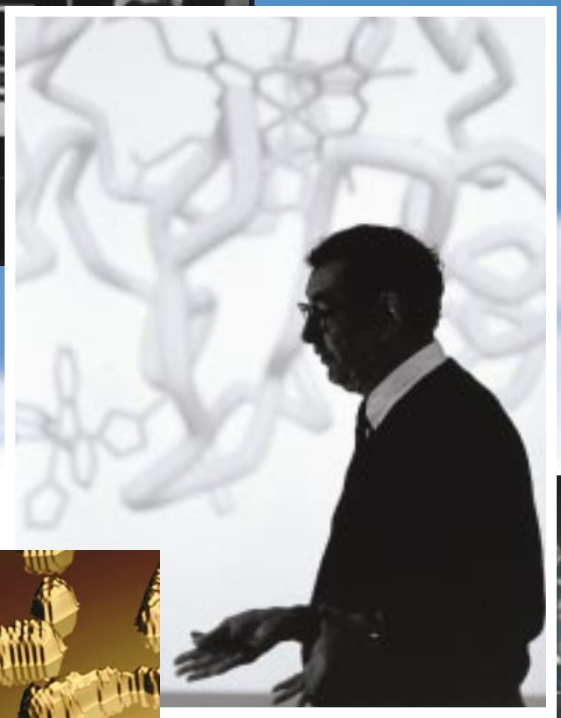




M&ENS

Main Research Theme

M&ENS

Molecular & Electronic Nanostructures

Research on molecular and electronic nanostructures has developed in the Beckman Institute's first ten years with emphasis on areas in which the scientific foundations and the engineering applications are each of great interest and touch each other. A further goal was to stimulate useful interactions between the biological and physical/chemical sciences.

The research projects that have emerged and are currently being pursued are, as a consequence, related to the role of nanostructures in electronics and opto-electronics with a special view on integrated electronic circuits and on sensing; with the experimental and theoretical science concentrating on the atomic level and on manipulations and creations of the smallest possible nanostructures as well as the sensing of the smallest possible quantities. Nanostructure pattern generation has been explored in a variety of ways, including scanning tunneling lithography and, on the side of self organization, the creation of complex dendritic polymers.

One of the unifying themes among the Advanced Chemical Systems, Scanning Tunneling Microscopy, and Computational Electronics groups in the Beckman Institute has been a multidisciplinary effort toward fabricating nanoelectronic integrated circuits (NICs). An attractive approach under investigation is to replace electronic switching by molecular-based phenomena such as conformational effects. This points toward the use of methods of chemistry in addition to electronic physics and engineering. 1999 saw many new developments in molecular synthesis, nanolithographic engineering, nanoscale characterization, condensed matter theory and simulation, nanobiotechnology, and molecular self assembly. For example, precisely defined arrays of molecules such as C_{60} or phthalocyanines have been deposited onto silicon substrates with single molecule precision. New characterization tools have been developed to investigate the structure and dynamics of individual molecules. Soon it will be possible to fabricate systems of interacting molecules on surfaces and perhaps even modulate their molecular behavior with external fields. This progress has brought the group closer to its stated targets, such as an NIC memory device of interconnected quantum dots that could store information within a cell size of only a few square nanometers.

The combination of biological and physical/chemical sciences has been particularly successful in the area of computational science, including interactive molecular dynamics and, most recently, simulations of biological ion channels using the silicon-software of computational electronics.

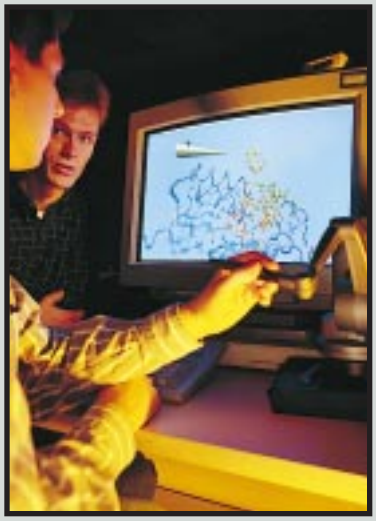
Karl Hess and Jeffrey Moore, Co-chairs

Highlights

M&ENS

The Theoretical Biophysics Group and the National Institutes of Health Resource for Macromolecular Modeling and Bioinformatics (RMMB) at the Beckman Institute (PI: Professor **Klaus Schulten**; co-PIs: professors **Laxmikant Kale**, **Todd Martinez**, **Robert Skeel**) have made great strides in the past year in pursuing novel technologies for structural biology. The group made two major software releases in 1999.

First, the new version of their Visual Molecular Dynamics (VMD) program has been released. VMD 1.4 (http://www.ks.uiuc.edu/Research/vmd/) supports Windows 95/98/NT and offers a variety of efficiency and feature improvements. Currently VMD boasts over 2,200 users worldwide. A new version of the molecular dynamics code, NAMD 2.1 (http://www.ks.uiuc.edu/Research/namd/) has also been released, and is more stable than previous versions. It offers new, highly beneficial features such as a Tclscripting language interface and config file parser, the mollified impulse multiple timestepping method, a faster particle mesh Ewald implementation, periodic boundaries for nonorthogonal cells, and a new interactive molecular dynamics interface to VMD. The NAMD user community is growing very fast, and at present there are over 400 users worldwide.



Two other notable technologies have been developed by the group in the past year. The first is referred to as Interactive Molecular Dynamics (IMD) http://www.ks.uiuc.edu/Research/Method/IMD/). This new technology builds on three components: a haptic device, the molecular visualization program VMD, and the simulation engine NAMD. The haptic device, coupled with VMD's graphical display, gives the researcher a feeling for the response of the system to external perturbations. IMD thus provides a means for efficiently exploring new trajectories in molecular dynamics simulations.

Finally, the group has initiated the development of BioCoRE, a collaboratory for structural biology (http://www.ks.uiuc.edu/Research/collaboratory/). This cutting edge electronic environment will provide a friendly setting in which to learn and use the group's other software and will become an effective distribution mechanism of software tools and applications. To assure quality of the products and user satisfaction, the collaboratory will be regularly evaluated, and user feedback will be systematically sought.

How do you isolate, characterize, and manipulate molecules in amounts so small that Mother Nature created special containers inside single cells just to transport them? In 1999, Beckman Institute faculty members **Jonathan Sweedler** and **Paul Bohn** began a research project to address this question. Sweedler's group had previously pioneered efforts to separate the contents of subcellular vesicles from the intracellular milieu but, problematically, there was no way to isolate and manipulate the molecules once they were separated. Bohn and his coworkers had separately developed a nanoscale valve they termed a "molecular gate," capable of using electrokinetic flow in nanometer-diameter tubes to control transport of molecules across membranes. By interfacing molecular gates with capillary electrophoresis (CE), these researchers are developing powerful new subnanoliter-volume preparative separations operating at the attomole level. Molecular gates can be thought of as intelligent (externally controllable) adsorption membranes, which have the ability to "capture" a single selected analyte, either on-column or exiting from the separation capillary, preserving it for further analysis utilizing powerful off-line molecular identification tools, e.g., mass spectrometry and nuclear magnetic resonance. In effect, the combination of CE and molecular gates converts nanoliter volume separation techniques from analytical methods to preparative methods that allow off-line manipulation of individual selected analyte bands. The experimental approach is quite general and can be applied to any class of biological molecules for which efficient electrophoretic separations can be designed. So far the Beckman Institute group has targeted oligopeptides and oligonucleotides. Work with polysaccharides may be in the future.

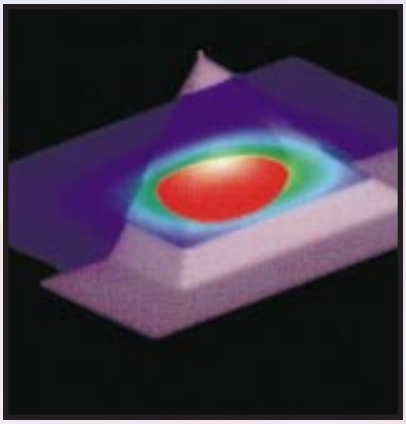
From novel coatings and adhesives to monomolecular imprints, the Army Research Office-supported MURI (Multidisciplinary University Research Initiative) on dendritic materials made many exciting advances in the past year. In addition to progress on the research front, Professor **Jeffrey Moore** was awarded a Defense University Research

Instrumentation Program equipment grant to augment the MURI funding. This award has been used to establish a state-of-the-art polymer characterization laboratory in the Beckman Institute. One of this year's major scientific highlights has been Professor Ken Suslick's (Chemistry) demonstration of "smell-seeing" as a new class of parallel sensors. A 2D array of porphyrin-based receptors has been shown to acquire characteristic visual patterns upon exposure to volatile organic compounds. These devices are of interest for rapid detection of air-borne chemical toxins. Collaboration with Professor Steven Zimmerman (Chemistry) and his group is underway to extend the scope of these receptors, and work is planned with Professor **David Beebe's** group to fabricate functional microdevices based on Suslick's prototype.

Another major highlight of the past year has been Zimmerman's demonstration that a single molecular structure can be imprinted into a single dendritic molecule. Unlike the heterogeneous molecular imprints prepared from conventional polymeric materials, Zimmerman's monomolecular imprints should exhibit much more uniform binding specificity. This opens many potential analytical applications, while related technology may also find use in drug delivery.

This past year the scale-up laboratory in the Beckman Institute developed a family of architecturally varied high temperature hyperbranched copolymers. These materials are being studied jointly by Professor Moore's and Professor Tony McHugh's (Chemical Engineering) groups with the aim of designing materials optimized for performance and processibility. As the degree of branching changes from dendritic-like to linear, an abrupt transformation in molecular architecture, from globular to wormlike, takes place. It is in the vicinity of this transition that the material may have low viscosity typical of dendritic polymers while exhibiting excellent mechanical properties typical of commodity polymers. Endgroup modified versions of these hyperbranched polymers are now under investigation in collaboration with McWhorter Technologies for applications as adhesion promoters on polyolefin substrates.

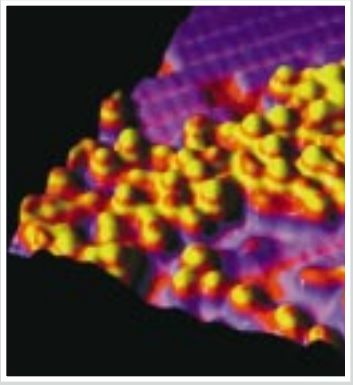
Professors **Jean-Pierre Leburton** and **Richard Martin** are investigating novel physical properties of semiconductor quantum dots based on Density Functional Theory. During the last year, this effort has focused on establishing the validity of this theoretical approach for nanosystems in collaboration with Professor David Ceperley (NCSA). Recent work involves the study of spin effects and the electrostatic manipulation of the spin degrees of freedom



with external gates in single and coupled quantum dot field-effect devices. This collaboration has resulted in the most advanced software for the investigation and modeling of a wide variety of electronic nanostructures. Potential applications of this research are anticipated in the area of semiconductor memories, high functionality quantum dot lasers and detectors, as well as in quantum information processing. Experimental confirmation of the basic physical phenomena is done in close collaboration with Professor S. Tarucha at the University of Tokyo and Dr. Austing at NTT, Japan.

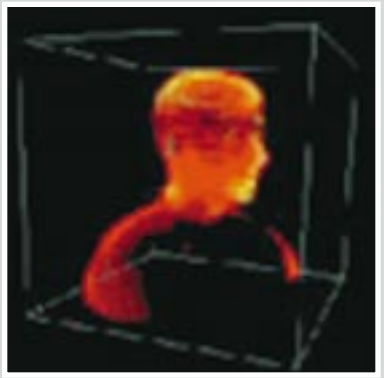
■ We have applied our scientific understanding of silicon surfaces and interfaces to deuterium processing to enhance the lifetime of microchips. This has received considerable attention by industrial laboratories over the past several years, after the initial report by Beckman Institute researchers in 1995. Particularly, IBM published a number of papers on methods to successfully fabricate hot electron resistant transistors using deuterium. Professor **Joseph Lyding** and his research group have now developed high-pressure equipment to enhance the diffusion of deuterium to the silicon/silicon-dioxide interface. Improved transistor lifetimes have been found at anneal conditions above atmospheric pressure, even for lower anneal temperatures. Detailed measurements of hot electron aging with and without deuterium have also confirmed the close analogy to the scanning tunneling microscopy (STM) experiment of hydrogen/deuterium desorption.

In contrast to widespread belief, the Beckman Institute researchers have shown that much of the desorption is due to channel hot electrons that do not necessarily propagate into the oxide. The groups of professors Lyding and **Karl Hess** are collaborating to develop a detailed and predictive theory of transistor aging through hydrogen desorption based on atomistic models. This theory also includes effects of statistical variations of the defect energies and predicts the necessity of more stringent design requirements for future silicon technology, particularly for transistor channel length around 0.1 micrometer.



■ Significant progress has been made during the past year in the Office of Naval Research MURI nanoelectronics program at Beckman Institute. In new experiments, Professor **Joseph Lyding** and his group demonstrated the use of scanning tunneling microscopy (STM) to create arrays of single dangling Si bonds on an H-passivated Si(100) surface. To these bonds, individual molecules, such as norbornadiene, copper phthalocyanine, and C_{60}, have been tethered and STM spectroscopy has been used to study intramolecular electronic structure. Furthermore, by changing the oxidation state of the central copper atom in copper phthalocyanine, both stationary and rotational

surface binding configurations have been observed. These experiments are providing fundamental insight into pathways for developing silicon-based molecular nanoelectronics. On the theory side, Professor **Karl Hess** and his group have implemented known methods to interpret STM images based on the work by Tersoff and Hamann. They also have performed calculations of the charge density of molecules (norbornadiene) on Si(100) surfaces using methods of local density functional theory as implemented in the Vienna A*b* I*nitio* Simulation Package. This project aims at an atomistic understanding of molecules or quantum dots bound to semiconductor surfaces (interfaces) and at applications related to electronic functionality. A second and related project deals with thin oxides (6-20 Angstrom) sandwiched between silicon substrates and tunneling through these oxides. The structure of thin silicon dioxide sandwiches, the electronic states using tight binding methods, and a detailed tunneling theory are being developed. These results are directly related to silicon transistor technology of near future generations and also to general interface physics and chemistry of nanostructures.

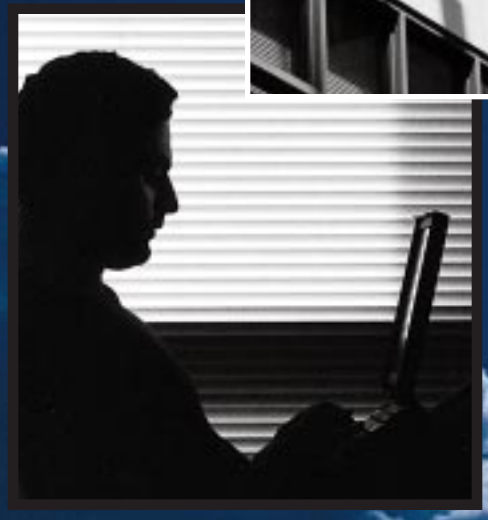


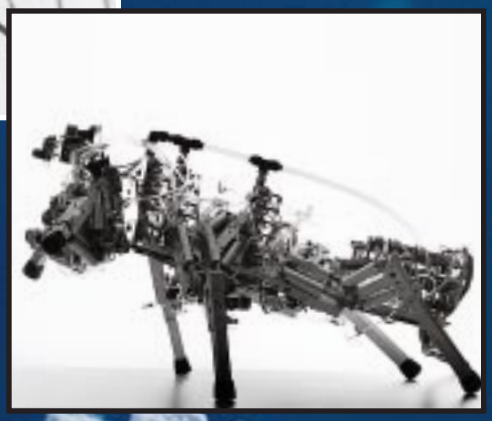
The Illinois Interferometric Imaging Initiative (4Is) is a DARPA-funded project in the Photonic Systems (professors **David Brady**, **Eric Michielssen**, **Margery Osborne**) and the Image Formation and Processing (Professor **David Munson**) groups which focuses on visible and infrared imaging system design for digital systems. Imaging consists of three separate processes: communication of object information to the measurement system, analysis of measured information, and display of the reconstructed object. In conventional cameras, all three of these steps are integrated on the focal plane. In digital systems, these three steps can be separated and independently optimized. The goal of 4Is projects is to maximize the quantity of sensed information without requiring analog image formation. Image analysis and display is then implemented digitally. This approach blends naturally into sensor data fusion for multidimensional image reconstruction. In 1999, the 4Is program demonstrated the advantages of nonfocal and distributed imaging in 3D tomographic imaging with a lensless camera, tomographic imaging from large camera arrays, and 4D spatiospectral imaging. In addition to optical systems design issues, digital imaging raises questions of image utility and integration of visual information in human communications. These questions are addressed through collaboration between design engineers and groups in education and psychology.

MRT

HCII

Main Research Theme





Human-Computer Intelligent Interaction

HCII

The Human-Computer Intelligent Interaction (HCII) main research theme is truly interdisciplinary, involving the close collaboration of cognitive scientists, computer scientists, electrical engineers, human factors researchers, educational psychologists, kinesiologists, and linguists in pursuit of knowledge relevant to the design of interfaces for complex systems. A major goal of the MRT is the integration of the engineering and computer science expertise of the HCII faculty and students in the design and construction of hardware and software interfaces with the development of formal models of human perception, cognition, and action. To this end, HCII members have been working together, often in collaboration with members of the Biological Intelligence and Molecular and Electronic Nanostructures MRTs, as well as with colleagues in government and industrial laboratories, on a number of large-scale efforts in the development of knowledge and concepts relevant to next generation human-computer interfaces.

For example, the Army Research Laboratory Federated Lab for Advanced and Interactive Displays, which is an Army-funded project with academic, industrial, and military research partners, has produced a number of important products in the past year. These include the continued development of decision planning and management tools, some of which have already been transitioned to industry; the development of a knowledge base of display parameters which have an impact on the efficiency and accuracy with which humans can extract information from cluttered multimodal displays; the continued development of eyetracking, gesture and speech

recognition, and production algorithms which will ultimately lead to alternative modes of communication between humans and computers; and the continued development of a knowledge base relevant to the design of navigational and wayfinding aids for ground- and air-based navigational tasks and human situational awareness. The Computer Companion project sponsored by the Yamaha Motor Corporation involves a number of HCII faculty members and students. They have completed the development of and begun testing a computer-based system which learns users' preferences for recreational pursuits and presents them with custom-tailored suggestions for activities that they might enjoy.

When the HCII MRT was first established in 1994, it was composed of a diverse group of scientists and engineers who shared a common vision of integrated research teams pursuing basic and applied issues relevant to the design of better interfaces for human users of recreational, educational, industrial, and military systems. In the short time that the theme has been in existence, these researchers have been able to turn their dream into a reality as evidenced by their success in obtaining funding for a variety of both large and small research and engineering projects whose goal has been to develop better interfaces. We fully expect that the next decade will see continued development of a truly multidisciplinary approach to the study and design of intelligent human-computer interfaces.

Thomas Huang and Arthur F. Kramer, Co-chairs

Highlights

HCII

Institute researchers have just completed the third year of a five-year project as part of the Federated Laboratory for Advanced Displays and Interactive Displays funded by the Army Research Laboratory. The large interdisciplinary project involves the collaboration of researchers from the Beckman Institute (departments of Psychology, Linguistics, Educational Psychology, Electrical and Computer Engineering, Computer Science, Mechanical and Industrial Engineering, and the Institute of Aviation); with industry researchers from Rockwell, Sytronics, and the Microelectronics Center of North Carolina; and other universities including Pennsylvania State University, University of Minnesota, University of California at Irvine, Villanova University, Free University (Amsterdam), and North Carolina Agricultural and Technical College, along with military researchers from the Army and Air Force. In the past year, a number of research projects have been transitioned to industrial and military laboratories for development into products, and a number of basic and applied lines of research continue to yield important theoretical and applied knowledge related to the development and use of advanced multimodal displays.

This year has also seen the establishment of the Integrated Systems Laboratory (ISL) at the Beckman Institute under the direction of Ms. Rachael Brady. The ISL provides a state-of-the-art facility for scientific and technical investigation related to the human use of multimodal displays and complex systems. The human factors group, which includes professors **Arthur Kramer**, **Christopher Wickens**, **David Irwin**, **Ranxiao Wang**, and **George McConkie**, has also made substantial progress this year on the explication of human perception and representation of complex real-world scenes, the understanding of the relationship between covert and overt attention in multimodal environments, and the cognitive processes necessary for human navigation in complex environments. In 1999, the decision analysis group under the direction of professors Caroline Hayes, **Patricia Jones**, **Janet Sniezek**, and **David Wilkins** has continued to refine a number of decision analysis and planning tools, as well as to examine

the usability of these tools with human decision makers. Finally, the engineering group, including professors **Thomas Huang**, **Steve Levinson**, and **Narendra Ahuja**, with Drs. Polly Baker, Rajeev Sharma, and Robin Bargar, has made significant progress this year in a number of projects related to human-computer interface. These include integration of speech and gesture in display control; use of visual lip reading to enhance audio speech recognition in noisy environments; 3D visual and audio display; registration of virtual and real scenes in augmented reality; and 3D modeling of human face/head for applications to very low bitrate video transmission and to avatars in virtual space conferencing.

Researchers at the Beckman Institute have been working since 1997 on a project funded by the Yamaha Motor Corporation, Japan, to conduct basic research that will lead to the development of "computer companions," interfaces that will make the interaction with computers more enjoyable. This project has conducted research and development on novel ways to integrate multimodal inputs and outputs, to recognize users' emotional states, to provide for different interactional styles for the computer, to develop innovative models of learning, and to implement and evaluate ways to interact with Internet resources. The project has developed several demonstration implementations that have illustrated the progress made and that provide the basis for further research and development. Over the past year, systems have been

developed that detect the emotional state of the user based on visual and vocal cues, and this has been implemented in a restaurant companion that responds adaptively to different users. Gestural, positional, and eye movement indicators of the users' emotional and cognitive states have also been identified, and new visualization techniques for displaying information from the Internet in the most comprehensible manner have also been developed. The project involves seven faculty members from four departments: educational psychologists James Levin (co-PI) and Michelle Perry; electrical and computer engineers **Thomas Huang** (co-PI) and **Steve Levinson**; linguists **Jerry Morgan** and **Georgia Green**; computer scientist **Jerry DeJong**; and audio specialist Robin Bargar, together with their graduate students and postdoctoral fellows.

Professor **David Kriegman's** current research in computer vision and robotics focuses on object recognition, illumination modeling, scene reconstruction, image-based

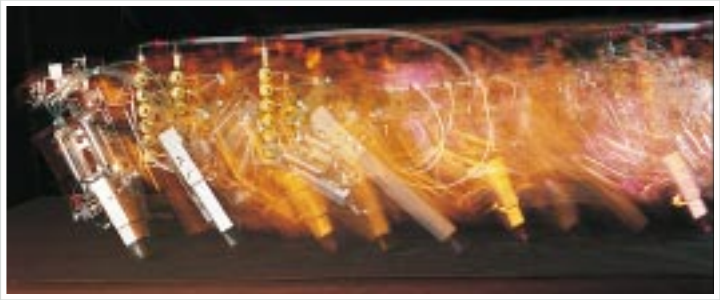
rendering, and multi-sensor mobile robot mapping and navigation. With Professor **Jean Ponce**, he is studying the use of invariants derived from viewpoint-dependent image features as indexes into large databases of models for object recognition. Kriegman has also developed the illumination cone model, which captures the set of images of an object under all possible lighting conditions, e.g., sunlight at different times of day or diffuse indoor lighting. Toward building more intelligent human-computer interfaces, Kriegman is applying this model for recognizing people from facial images, and the current techniques result in an order of magnitude lower error rates than standard methods under extreme conditions. In 1999, he began to collaborate with Clint Potter and Bridget Carragher, co-directors of the Beckman Institute's Imaging Technology Group, on applying some of these techniques to construct an intelligent transmission electron microscope. With a fleet of five mobile

robots, Kriegman's group is also developing methods for vision-based navigation, exploration, and mapping. Rather than reconstructing detailed Cartesian maps from depth information, his robots will recognize natural landmarks and construct a representation, which encodes the relation between landmarks, obstacle boundaries, and symbolic annotations.

Professor **George McConkie** spent the 1998-99 academic year on sabbatical leave: six months at the Cognitive Neuropsychology Laboratory at National Yang Ming University in Taipei, and six months at the Cognitive Research Laboratory at Beijing Normal University, supported as a Fulbright Fellow and as a Senior Research Fellow of the Chiang Ching-kuo Foundation. This was part of an effort to establish collaboration with and between these institutions in the study of the perceptual processes in reading Chinese. In Taipei, an eye movement laboratory was established (a similar eye movement lab had been previously set up in Beijing) and laboratory personnel at both locations were trained in research methodology. Software for eye movement contingent display control methods has been developed, and an active research collaboration with people at both locations now exists.

Much of Professor **Narendra Ahuja's** work in 1999 has been in the areas of computer vision and robotics. In computer vision, Ahuja is working on object detection

and recognition. With Professor **David Kriegman**, work is underway on human face detection and recognition from images showing faces in different poses and expressions and under different lighting conditions. Work with Professor **Dan Roth** involves developing a learning theory for object detection and recognition using the SNoW learning architecture to learn representations. In another computer vision project in collaboration with professors **Art Kramer** and **David Brady**, work has been initiated on a sketch-based visual interface, which would serve as an aid for working with images. The interface is aimed at helping interhuman/machine communication involving images, using mechanisms similar to those used by humans, e.g., pointing to its parts and accessing and manipulating them by drawing publisher-like symbols on them. In robotics, Ahuja has made further progress in the ongoing hexapod project which is in collaboration with professors **Mark Nelson** and Fred Delcomyn (Entomology), and is concerned with the design and implementation of a biologically inspired six-legged robot. Recent progress is concerned with controlling the robot leg motion using a network of onboard microcontrollers, and for acceptance of high-level commands sent to the robot by remote users via internet.



Professors **Janet Sniezek**, a member of the Beckman Institute Human Perception and Performance Group, and **David Wilkins**, a member of the Beckman Institute Artificial Intelligence Group, continued development of an immersive simulator and automated reasoning system for shipboard damage control, and research on damage control performance. One focus of this effort is the creation of an immersive simulator-trainer called DC-TRAIN, which allows Navy officers to practice the decision making involved in dealing with crises that involve fire, smoke, flooding, system deactivation, and the like. During 1999, the use of DC-TRAIN became an integral part of the damage control course at the SWOS Navy officer school in Newport, Rhode Island. Another focus of this effort is the creation of an automated reasoning system called DC-SCS (Damage Control: Supervisory Control System). The goal of DC-SCS is to use intelligent reasoning to reduce the number of personnel required for damage control on the next generation of Navy ships by over 100 personnel. One important research issue is how to enable DC-SCS effectively to communicate situation and system assessment to a human supervisor. Another important research issue is how to allow effective human override of DC-SCS. More generally, the goal is to demonstrate effective group decision making when an automated system and a human decision maker are cooperating to solve a complex problem. Over 40 faculty,

students, and research staff in the Beckman Institute and the Department of Psychology are involved with the DC-TRAIN and DC-SCS projects, which are funded by the Office of Naval Research and the Naval Research Laboratory.

Professor **Pierre Moulin** and his collaborators have recently been developing the basis of an information-hiding theory, and applying this theory to image processing problems. The goal of information hiding is to conceal a message in a host data set such as an image, in a way that introduces only a small (e.g., visually imperceptible) perturbation to these data, and is resistant to additional perturbations introduced by a potential adversary. With the extraordinary growth of the Internet and digital image transmission and storage technologies, security and protection of intellectual property have become concerns of paramount importance. It has thus become desirable to hide information such as owner identification and a digital time stamp within valuable images. Until recently, it was not known whether this could reliably be done. The new theory of information hiding developed by Professor Moulin and his collaborator Professor O'Sullivan at Washington University in Saint Louis, not only answers this question, but also provides a precise figure for the number of bits of information that can be hidden in that fashion.

BI

Main Research Theme

MRT

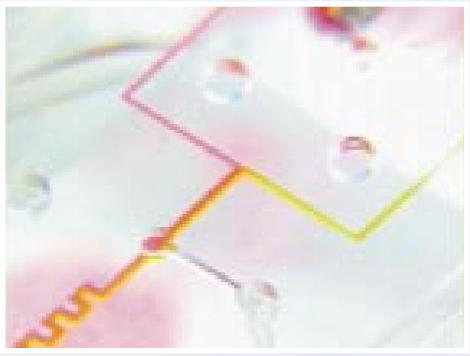
BI

Biological Intelligence

The evolution of the Biological Intelligence MRT during the first ten years of the Beckman Institute reflects an explosion of knowledge and new scientific tools. Exciting breakthroughs in neuroscience and molecular biology have transformed our ability to understand the linkage between the brain and intelligent behavior. More sophisticated computational methods have dramatically changed the analysis of complicated data. Biological Intelligence researchers have been particularly successful in capitalizing on new developments because the infrastructure of the Beckman Institute easily allows researchers to organize themselves into new research teams and provides seed monies necessary to explore the potential of new findings. A telling measure of the success of Beckman Biological Intelligence researchers is their ability to obtain highly competitive funding for multidisciplinary research.

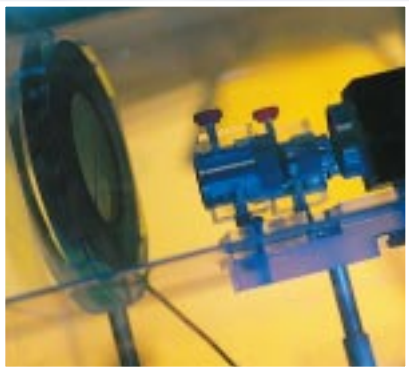
A major development within Biological Intelligence has been the creation of new brain imaging techniques

which have revolutionized our ability to understand how brain function underlies mental processing. Traditionally, scientists examined patients with brain damage, inferring that the damaged regions were critical for whatever functions were disrupted. New functional magnetic resonance imaging (fMRI) techniques allow brain function to be observed in normal, neurologically intact individuals and can identify many brain regions involved in a mental function, not just the critical ones. The Beckman Institute assembled a team of cognitive neuroscientists and engineers to master fMRI and provided substantial startup funding. As a result, these researchers have identified brain regions involved in attending to specific information processing and remembering information about faces or skills, simultaneously performing different tasks, acquiring a new language, and processing emotional information. These researchers are also increasing our understanding of age-related lifespan changes in neural activity.



Biological Intelligence researchers have used converging technologies to provide a much deeper understanding than single approaches can offer. For example, although fMRI provides excellent information about *where* brain activity occurs, it provides little information about *when* it occurs. To overcome this limitation, Beckman researchers have begun to integrate fMRI

investigations with information from other technologies that provide good temporal resolution, such as EEG, eyetracking, and optical imaging of the brain. Likewise, Beckman Institute psychologists and linguists, who work in a field traditionally relying on examining behavior or on computational modeling, are embracing new methods from cognitive neuroscience. These include studying patients with focal brain lesions, eyetracking, and event-related brain potentials (ERPs). At the level of nerve cells, Biological Intelligence researchers are combining behavioral technology, electrical recording, molecular biology, and the latest microscopic imaging procedures to understand mechanisms underlying learning and memory.



The first decade of the Beckman Institute has seen a burgeoning of integrative projects that span widely different domains within Biological Intelligence. For example, the intelligent hearing aid project involves disciplines ranging from physiology to signal processing to speech and hearing sciences. Beckman researchers have been highly competitive in obtaining funds for interdisciplinary research. One project designed to understand learning in people and computers involves scientists from psychology, development, and computer science. Another research team studying how learning modulates language processing is composed of linguists,

psychologists, and computer scientists. On the "wetware" side, studies at the neuronal level involve collaboration among psychologists, physiologists, cell biologists, analytical chemists, physicist modelers, and electrical and computer engineers. We expect that the national trend for increased funding for integrative projects will continue, and see researchers within the Biological Intelligence program as perfectly poised to take advantage of this.

Marie Banich and William T. Greenough, Co-chairs

Highlights

BI

Significant progress was made on the fabrication of new sensors targeted toward biological systems or based on the principles of adaptability in biological systems. In 1999, the fabrication of functional components from stimuli-responsive hydrogel materials within microscale fluid channels has been demonstrated in the laboratories of professors **David Beebe** and **Jeffrey Moore**. Hydrogel components serve as both sensor and actuator to regulate fluid flow without the need for external monitoring and control. Photopolymerization within prefabricated microchannels irradiated through a photomask defines the geometry of the components. Mass transport by diffusion governs the rate of the volumetric transition, leading to rapid response times at the micron scale. A pH sensitive throttle valve, a shut-off valve, and a flow sorter that operates over the range 5≤pH≤8 have been demonstrated. This work opens the way to complex microfluidic systems that are self-regulated via feedback control mechanisms.

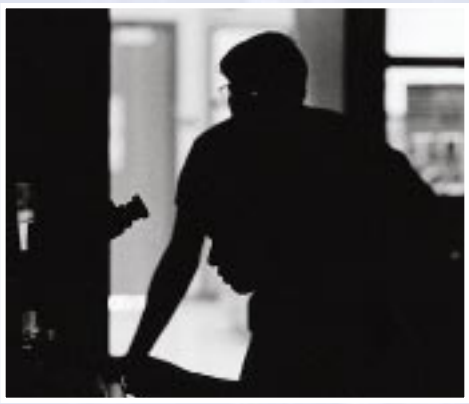
Over the past five years, the laboratories of professors **Jonathan Sweedler** and **Andrew Webb** have developed systems capable of performing high resolution nuclear magnetic resonance (NMR) spectroscopy on the picomole mass and nanoliter volume scale. This is between one and two orders of magnitude smaller than the capability of any other academic or commercial research facility. Over a dozen journal articles, four patents, and the formation of a spin-off company, Magnetic Resonance Microsensors, have followed their initial report in *Science*. In the past year, their groups have designed NMR probes containing multiple micro-receivers, have obtained the first ever localized NMR spectra from a single neuron, and have reported the lowest limits of detection in capillary liquid chromatography hyphenated to nuclear magnetic resonance spectroscopy.

The intelligent hearing aid project is aimed toward developing efficient algorithms that can extract a desired

speech signal with high fidelity in the presence of multiple interfering sounds. Over the last three years, the interdisciplinary team on this project, professors **Albert Feng**, Robert Bilger, Charissa Lansing, Doug Jones, **William O'Brien** and **Bruce Wheeler**, and Beckman Fellow Chen Liu has successfully created two very effective computational algorithms for this purpose via computer simulation. In 1999, this team made an important breakthrough by developing a real time prototype of one of the two algorithms to validate the concept and demonstrate that the system can work in real time and perform very well in real environments using the currently available DSP (Digital Signal Processing) chip from Texas Instruments, Inc. They have also devised and carried out preliminary human subjects testing on the speech processed with the algorithms, finding significant gains in perceived intelligibility of the processed sounds.

1999 saw the renewal of a five-year grant from the National Institutes of Health (NIH) for a Beckman Institute research project which explores the relationship between neuronal gene expression and information processing. An active role for gene expression in learning and memory emerged from earlier studies of Professor **David Clayton**, who was observing the biochemical response of zebra finches to the sound of tape-recorded birdsong. When birds hear a novel song, a pulse of gene expression occurs in specific parts of the brain. Clayton refers to this as a "genomic action potential." Research into this phenomenon links a range of traditional disciplines and involves a number of collaborations at the Beckman Institute. The generality of this phenomenon was demonstrated earlier in part through a collaboration with Professor **William Greenough**, which showed a similar relationship in rats between gene expression and early rearing environment. To investigate the relationship of gene activation to neural circuit function, Clayton worked with professors **Albert Feng** and **Michael Gabriel**, Susan Volman (NIH), and electrical engineering Professor **Bruce Wheeler**. These studies suggest that gene activation integrates signals reaching neurons across multiple channels (e.g., receptor types), and serves to modulate the rate or efficiency of information storage in neural circuits. The current focus is to understand the molecular and cellular basis for this integrative process and how it may be related to psychological mechanisms of attention and discrimination.

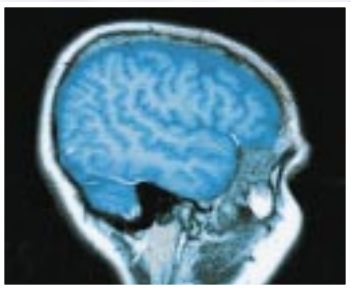
Bill Greenough's laboratory has made a major breakthrough in understanding the function of FMRP, the protein that is missing in Fragile X mental retardation syndrome. Recently, he and associate Ivan Jeanne Weiler found that this protein is essential to the local synthesis of other proteins at the synapses through which nerve cells communicate.



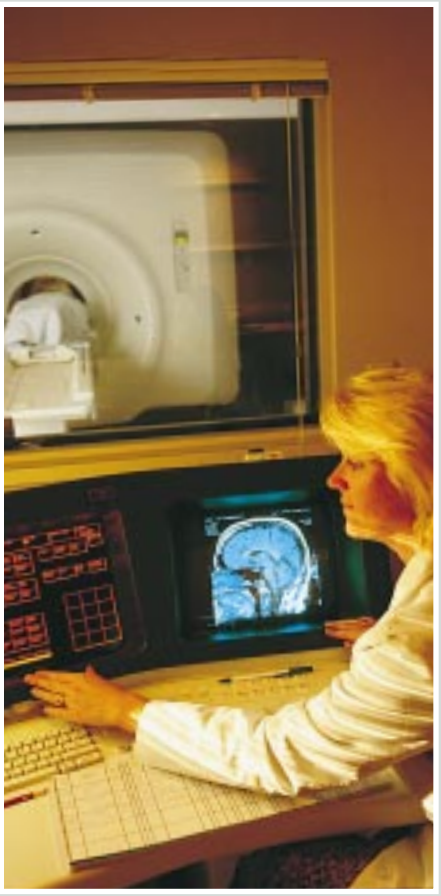
Future work, oriented toward determining what those proteins are and what they do in the cell, may both lead to treatments for the most common genetically inherited form of mental retardation and further our knowledge of the cellular mechanisms underlying learning and memory. In addition, the knockout mouse model of the human mental retardation syndrome is being evaluated behaviorally in a collaborative effort by the CRI-funded mouse behavior unit headed by **David Clayton** and involving Jim Black, Martha Gillette, Jeff Mogil, and postdoctoral associate Bo-Jin Cao.

Beckman Institute researchers (cognitive neuroscientists **Arthur Kramer**, **Marie Banich** and **Neal Cohen**; kinesiologists Edward McAuley and Richard Boileau; and cognitive psychologists Sowon Hahn and Eli Vakil have been working since 1997 on a project funded by the National Institute on Aging to examine the influence of aerobic training on the neurocognitive function of sedentary, but healthy, older adults. The researchers investigated whether improvements in aerobic fitness would improve neurocognitive function and, more specifically, enhance executive control processes (e.g. coordination, scheduling, inhibition, working memory), processes supported in large part by the frontal and prefrontal regions of the brain. One-hundred-twenty-four older adults participated in the study and were divided into two exercise training groups: an aerobic group (walking) and a nonaerobic (stretching and toning) group. The participants were tested on the neurocognitive battery both before and after the six-month exercise intervention. Participants in the aerobic group showed substantial improvements on a variety of tests of executive control, while participants in the anaerobic group did not show such benefits. The researchers, with the addition of Professor **Andrew Webb**, Beckman Fellow **Gregory DiGirolamo**, and colleagues at Carle Clinic, have recently begun the next phase of the project, which entails examining functional changes in brain activity with magnetic resonance imaging between high fit and low fit older adults, as well as with improvements in aerobic fitness.

The human functional brain mapping project utilizes functional magnetic resonance imaging (fMRI) and other psychophysiological measures to assess the functional status of the brain during the performance of different cognitive and emotional tasks. The project combines the efforts of cognitive neuroscientists (**Marie Banich**, **Neal Cohen**, **Susan Garnsey**, **Wendy Heller**, **Arthur Kramer**, and **Gregory Miller**) and electrical and computer engineers (**Zhi-Pei Liang** and



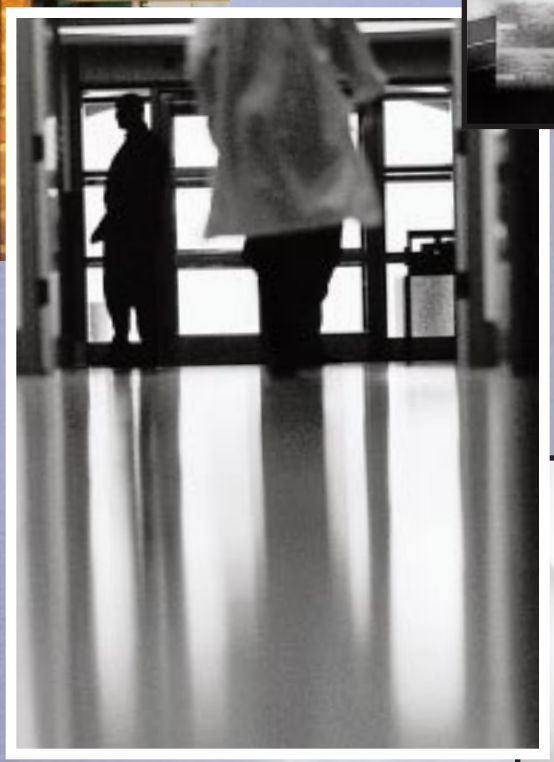
Andrew Webb). Substantial progress has been made in a number of areas. Work by Marie Banich has identified a variety of neural subsystems that are important when individuals need to select information among competing streams of information to which they must pay attention. Research by Art Kramer has identified regions of the brain that are important when people must switch their attention between two distinct tasks. A collaborative project involving Heller, Miller, and Banich has identified brain regions involved in either processing or suppressing emotional information. They intend to pursue the implications of this work for individuals with mood disorders such as depression and anxiety. Work by Cohen has identified brain regions that are important for processing and remembering information about faces and has identified separate brain systems for famous, as compared to unfamiliar, faces. Garnsey is examining whether brain systems that support acquistion of a second language overlap with or are unique from those used to process one's native language.



Language researchers at the Beckman Institute (from the Cognitive Science, Artificial Intelligence, and Image Formation and Processing groups) continue work on their three-year project from the Knowledge and Distributed Intelligence Program of the National Science Foundation. The project, titled "The Role of Experience in Language Processing," brings together psychologists, linguists, and computer scientists with the goal of studying how people produce and understand language, and how this knowledge can be used to develop language technology. The central idea of the project is that a successful language processing system (whether in a person or a machine) is constantly changing. It adapts quickly to recent experience, while continuing to reflect the accumulated experience of a lifetime of speaking, listening, reading, and writing. The group studies how people's speaking and comprehension skills change through a number of methods, including assessments of eye movements, electrical brain potentials, and functional magnetic resonance imaging (fMRI). At the same time, the group is developing computational models of the language processing system, models that learn from experience and adapt to their current

circumstances through these learning mechanisms. The investigators are professors **Gary Dell** (PI), **Kathryn Bock**, **Jennifer Cole**, **Cynthia Fisher**, **Susan Garnsey**, **Adele Goldberg**, **Stephen Levinson**, and **Dan Roth**.

Research is also continuing on a National Science Foundation-funded, cross-disciplinary initiative on Learning and Intelligent Systems. The goal of this project is to construct an integrated theory of concept learning in humans and machine. The theory will be integrated in that (1) it will investigate and account for a wide variety of concept learning results that are often studied separately; and (2) it will pool the research strengths of psychology, artificial intelligence, and computational learning theory (CLT). These goals will lead to a comprehensive theory that is psychologically and computationally plausible, while at the same time sufficiently rigorous to be analyzed with the mathematical tools of CLT. The interdisciplinary focus in 1999 has led Beckman Institute researchers, professors **Jerry DeJong**, **Gregory Murphy**, Leonard Pitt, Karl Rosengren, and **Brian Ross,** to address two issues with computational and experimental techniques. First, a major goal has been the development of a formal neural network model for prior knowledge effects on concept learning. There are models of learning the statistical regularities of concepts and theories of how knowledge may influence concept judgments. However, there is no model that integrates the statistical regularities and knowledge during learning, which is necessary for intelligent functioning (and which people do easily). The model has been successfully applied to a variety of psychological data. Second, to understand the important role of explanations in concept learning, a new formalism has been developed that allows one to keep the well-formedness and formal properties of explanations, but relaxes the requirements for soundness (i.e., logical consistency), since people's explanations often are not logically consistent with all their other knowledge. The researchers are currently investigating natural restrictions on the class that would admit efficient learning algorithms using machine-learning techniques.



10 Years

Facilities and Building

1999

1999

10 Years

Facilities and Building

Evolution of Facilities and Building in the Institute's First Decade

In April of 1999, the Beckman Institute for Advanced Science and Technology celebrated its 10th Anniversary. This represented a major milestone for the building and its research facilities, both of which have experienced tremendous change over the past ten years, and have also played an important role in the overall success of the Beckman Institute in its first decade of operation.

The research facilities within the Institute have grown significantly over the past ten years, in response to needs of the very diverse and successful group of researchers at the Institute. When the Beckman Institute opened its doors in 1989, there were no centralized research facilities, with the exception of a very small digital imaging laboratory that was part of the Systems Services group. Eventually, as demand grew for imaging technology, this small digital imaging lab merged with a newly formed optical imaging lab that at the time housed only very basic microscopes. Over the past four to five years, both the digital and optical imaging laboratories have grown substantially, in large part due to the generous support of the Arnold and Mabel Beckman Foundation. The facilities, which were renamed the Imaging Technology Group in 1998, now represent a truly unique world class facility, which provides Institute researchers

access to state-of-the-art equipment in both digital and optical imaging. The equipment overseen by the Imaging Technology Group includes light microscopes, scanning probe microscopes, electron microscopes, and scientific visualization, multimedia production, image analysis, and 3D modeling/animation equipment.

In 1998, the Beckman Institute formed a new centralized facility, the Integrated Systems Laboratory. That lab, which is part of the Federated Laboratory for Advanced Displays and Interactive Displays funded by the Army Research Laboratory, provides researchers from across the Institute with a state-of-the-art facility for scientific and technical investigation related to the human use of multimodal displays and complex systems. In addition, the facility is designed to provide researchers with the capability for loose coupling of algorithms, data, and technologies from diverse laboratories. The equipment in the Integrated Systems Laboratory includes several virtual reality environments, head and eyetracking systems, various types of displays, and assorted computer hardware and software. It is believed that the Integrated Systems Laboratory will provide Beckman researchers with a truly unique facility to conduct research into the 21st century.

The Beckman Institute also has many smaller research facilities that have been built and are being maintained by individual faculty or groups of faculty which are of major importance to the Institute and the main research themes. For example, one of the most advanced scanning tunneling microscopy (STM) systems in the world has been built at the Institute by researchers in the Molecular and Electronic Nanostructures area, as part of the Office of Naval Research-funded "STM-based Nanolithography" University Research Initiative. Researchers in the Biological Intelligence area also have created or have access to a wide variety of specialized research tools. These include an NIH-funded 1.5 Tesla magnetic resonance imager for animals located in the Institute, and a 1.5 Tesla magnetic resonance imager located in a local hospital for human studies. Several facilities also exist in the Institute to support the needs of the Human-Computer Intelligent Interaction

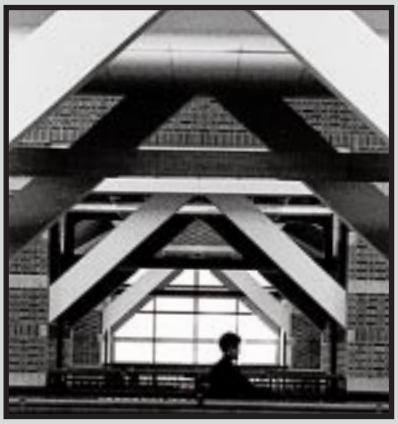
10 Years

main research area, including the image lab which provides an ideal environment for research involving high resolution images and video. All of these facilities have been important contributors to the overall success of the Institute during its first decade of operation.

The building which houses all of these facilities has aged extremely well and lived up to most, if not all, of its expectations. The Institute's conceptual design required that it afford maximum flexibility in terms of laboratory layout and functionality, office accommodations, and general-purpose support areas. It was also intended to provide an extremely diverse user community with the infrastructure necessary to foster interdisciplinary research. This has indeed proved to be the case since the Institute first opened its doors a decade ago.

In 1990, R&D M*agazine* honored the Institute with its coveted Laboratory of the Year award. In 1999, R&D M*agazine* again visited the Institute to review its progress over its first decade of operation. It found that the building had successfully coped with a myriad of programmatic remodeling initiatives over the course of its first ten years, and is well posed to continue that tradition into the next decade. In particular, the building's modular laboratory and office layout arrangements have proved a good fit for the evolving faculty and mission. The offices, in particular, have enabled a level flexibility in converting single faculty offices into double faculty offices, and vice versa. This has allowed people to be placed where they need to be, not just where a certain type of office is located. The building has expanded into existing shell space, as well as revamped the functionality of various laboratories to accommodate specific research apparatus. Additionally, the Institute is currently undergoing a network upgrade in which the capacity of the original network is being enhanced by a factor of ten. This has been facilitated by the extensive use of raised floors, built-in cable trays, and conduit paths incorporated into the building when it was constructed.

In conclusion, the building and its research facilities have weathered their first decade of operation very well. They have proven to be a tremendous resource to all of its faculty, staff, and students, as well as its users from across the campus. The Institute has also fulfilled its mission of being an extraordinary interdisciplinary research facility, one which has evolved over time to foster the needs of both current and future researchers.

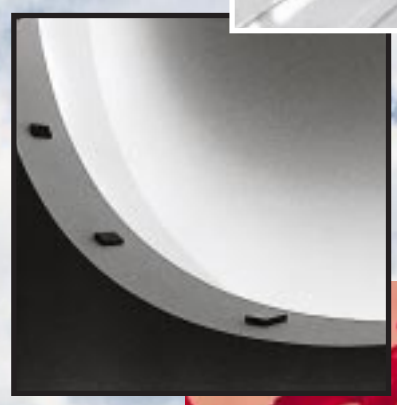


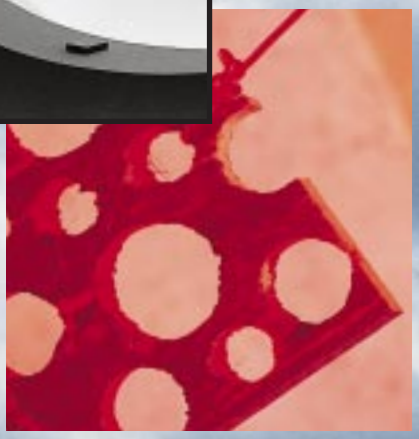
Jennifer Quirk, Associate Director
for External Affairs and Research

Michael D. Smith, Associate Director
for Operations and Systems Services

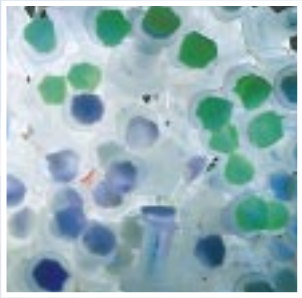
Fellows

1999





Beckman Fellows



The Beckman Institute Fellows Program was initiated in Fall 1991, using funding provided by the Arnold and Mabel Beckman Foundation. It is intended for recent Ph.D.s or students in their final year of predoctoral study in any of the research areas encompassed by the Institute. A competition for the fellowships is held once a year, with two or three Fellows being selected each year to spend a period of up to three years at the Beckman Institute.

Selection of Beckman Fellows is based upon evidence of professional promise, capacity for independent work, interdisciplinary interests, and outstanding achievement during their graduate careers. Because Fellows have no specific administrative or teaching responsibilities during their tenure, they are able to take maximum advantage of the opportunity to launch strong research careers. Past Fellows have competed effectively for research positions in major universities and corporate and governmental laboratories throughout the nation.

The Beckman Graduate Fellows Program, also supported by funding from the Beckman Foundation, is intended for graduate students who are already working at the Beckman Institute and is designed to encourage interdisciplinary research. Research projects must involve at least one Beckman faculty member in addition to a second faculty member, and preference is given to those proposals that involve the active participation of two faculty members from two different Beckman Institute research groups.

Fellows

Fellows in Residence in 1999

Dale J. Barr, 1999 Fellow

Ph.D. 1999, University of Chicago

Barr investigates how people coordinate meaning in conversation, applying eyetracking techniques to observe the rapid and evanescent processes of language production and comprehension as they unfold.

As a graduate student, Barr used eyetracking to investigate the use of mutual knowledge in language comprehension. At the Beckman Institute, working with Professor Kathryn Bock, he has begun to extend the methodology to the area of language production. The goal of this work is to understand how speakers use pragmatic knowledge to design and adapt their utterances for listeners. An important focus of this work concerns the evolution and use of linguistic conventions in discourse.

Barr also plans to take advantage of the unique interdisciplinary environment of the Beckman Institute to study the relationship between language processing and conceptual structure. This research, done in collaboration with professors Gary Dell, Gregory Murphy, and Brian Ross, explores how interlocutors develop shared conceptual representations that support linguistic coordination, bringing together theories of language processing and theories of concept formation and categorization.

Hong Hua, 1999 Fellow

Ph.D. 1999, Beijing Institute of Technology

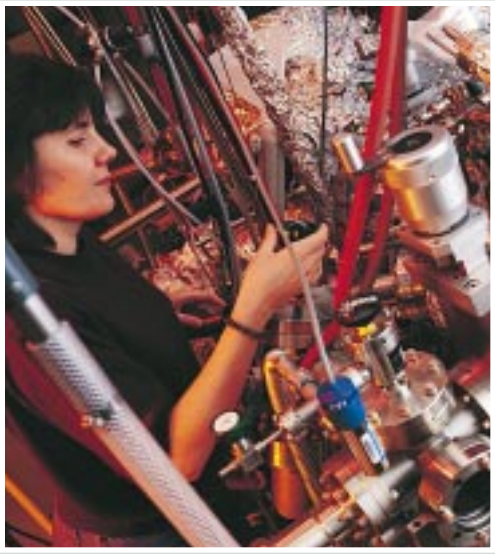
Hua's work has been focused on the research and development of novel head-mounted displays (HMDs) and human-computer interaction devices. As a Beckman Fellow, one of her major goals is to develop an HMD system with fully-integrated eye-tracking capability and to exploit this system for visual interaction with virtual environments and to develop a multi-resolution display scheme. She is working with the Beckman's Human Perception and Performance (HPP) Group to evaluate visual perception performance, such as the effectiveness of visual interaction and depth perception accuracy, and to explore psychological issues, such as the adaptive capability of subjects. She is also working on a novel head-mounted projective display technology with applications in tele-collaboration and tele-education, in conjunction with members of the Institute's Artificial Intelligence and HPP groups, the University of Central Florida, and Michigan State University.

Lolita Rotkina, 1999 Fellow

Ph.D. 1996, Ioffe Physico-technical Institute, St. Petersburg

Rotkina's main professional interest is in the development of practical nanotechnology approaches for implementing new functions and capabilities in electronic, optoelectronic, and biologically based systems. An example

Fellows



of this was her work in Russia on the use of thin layers of fullerene (C_{60}) molecules as a novel electron beam resist. In this work, she demonstrated high contrast pattern transfer by plasma enhanced chemical etching. At the Beckman Institute, Rotkina is working to integrate C_{60} and the related carbon nanotubes into nanoscale molecular electronic devices. Similarly, she is working with the Scanning Tuneling Microscopy Group to fabricate single wall nanotube STM tips that promise increased resolution and stability.

Jason S. McCarley, 1999 Fellow

Ph.D. 1997, University of Louisville

After receiving his Ph.D., McCarley spent a year at the Naval Postgraduate School in Monterey, California where, as a postdoc for the Office of Naval Research, he collaborated with psychologists, engineers, and physicists to explore techniques for improving military imaging sensors.

At the Beckman Institute, McCarley works closely with Professor Arthur Kramer and others, employing behavioral methods and eyetracking to study various basic and applied aspects of visual attention. Current topics of interest include the relationship between space-based and object-based attention, control of attention in 3D space, and the interaction between visual and auditory attention. Can object-based selection, for example, occur independently of spatial selection? Does attentional selection in 2D and 3D space involve similar mechanisms? Are common object representations available for visual and auditory attention, or are the representations underlying object-based attention modality specific? Finally, how can knowledge of basic attentional mechanisms be applied to facilitate human performance in real-world environments?

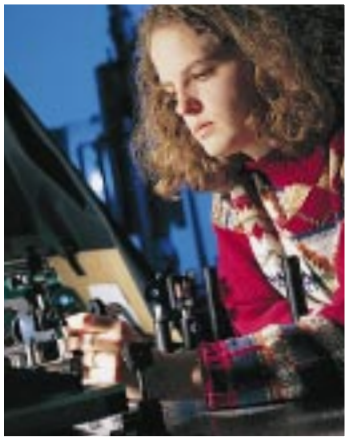
Michal Balberg, 1998 Fellow

Ph.D. 1998, Hebrew University of Jerusalem

Balberg's thesis focused on the implementation of electro-optic devices in a hardware system for artificial neural networks. The devices were based on electrically-controlled volume holograms in novel KLTN crystals, and performed parallel analog and binary computations.

As a Beckman Fellow, Balberg is studying, in collaboration with Professor David Brady, new imaging and light detection systems for biological applications. Her motivation is to construct application related optical

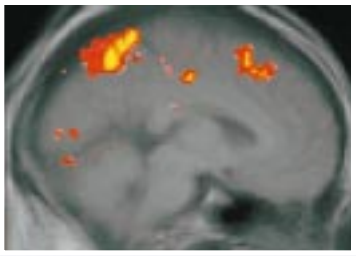
systems that can capture more information about the object than do conventional detectors or microscopes. In collaboration with G. Barbastathis, a novel confocal microscope was designed and tested in which a 3D holographic filter replaced the conventional pinhole. Balberg is also investigating, with others, the integration of optical detectors with microfluidic devices, in order to enable new analytic techniques based on novel molecular probes. The miniature device will achieve high detection sensitivities and perform spectral analysis of fluorescently labeled ribosomal-RNA of microorganisms extracted from environmental solutions.



Gregory J. DiGirolamo, 1998 Fellow

Ph.D. 1998, University of Oregon

DiGirolamo's research at the Beckman Institute focuses on three major interrelated areas: 1) higher-level attention and the interaction of attention and memory; 2) executive control, that to which one's brain gives priority; and 3) visual cognition. In collaboration with members of the Cognitive Neuroscience and Human Perception and Performance groups, DiGirolamo is seeking answers to such questions as: What are the effects of previous exposure of a stimulus on attention and memory? What role does expectation play in perception, attention, and memory? How does the cognitive/neural system switch from one task to another? How does dysfunction in executive control relate to schizophrenia and other psychiatric disorders? How are spatial relations computed, and what neural areas subserve these computations?

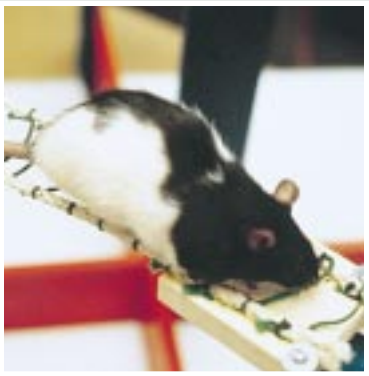


DiGirolamo has recently received grants from the McDonnel-Pew Program in Cognitive Neuroscience and the James S. McDonnell Foundation Program in Cognitive Rehabilitation to study some of these problems.

Tammy L. Ivanco, 1997 Fellow

Ph.D. 1997, McMaster University

As a Beckman Fellow, Ivanco is currently investigating the effects of learning and experience on the physiology of the mammalian cerebral cortex, using electrophysiological and anatomical techniques. One goal of this research is to examine whether experience-induced morphological changes are accompanied by physiological changes that indicate a functional



reorganization of the brain. Interestingly, the kinds of anatomical changes observed following brain injury appear very similar to those seen after learning, indicating that the methods used to examine experience-induced plasticity may be used to measure recovery from brain injury.

Her interests have also extended to include examining the role of the Fragile Mental Retardation Protein using electrophysiology, anatomy, histology, molecular biology, and tissue culture techniques. This protein is absent in individuals with Fragile X syndrome. Although Ivanco works mainly with Professor William Greenough, additional efforts have been undertaken with Dr. Ivan Jeanne Weiler and Professor Bruce Wheeler.

Beckman Graduate Fellowships Awarded in 1999

Gang Feng: *"From Print to Sound: New Approaches to an Old Problem"*

Feng's project concerns the cognitive processes involved in oral word reading and how they develop. Advisors are professors Kevin Miller (Psychology) and Kathryn Bock (Psychology), both in the Cognitive Science Group; and George McConkie (Educational Psychology) and a member of the Human Perception and Performance (HPP) Group.

Pengyu Hong: *"3D Human Face Modeling, Analysis, and Animation with Application to Multimodal Speech Perception"*

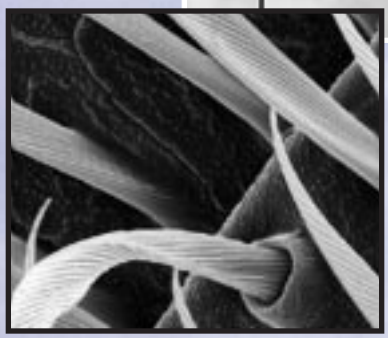
Hong is carrying out basic research leading to the development of methodologies and algorithms for constructing "realistic" 3D face models suitable for human lip reading. Advisors are professors Thomas Huang (Electrical and Computer Engineering (ECE)) and Image Formation and Processing Group; and Art Kramer (Psychology), HPP Group.

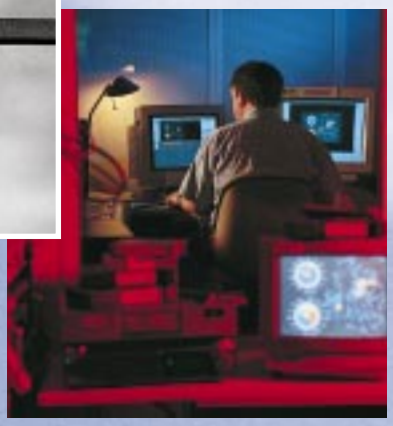
Darrell S. Rudmann: *"Multimodal Speech Perception"*

The goal of Rudmann's research is to investigate how human speech is perceived in multiple modalities. Professors Kramer and Huang and Dr. Robin Bargar (NCSA) are serving as his faculty mentors.

Kar-Han Tan: *"A Perceptual Interface for Rapid Object Selection from Images and Video Streams"*

Tan's research project proposes to develop a real-time high-fidelity image segmentation algorithm. He also intends to conduct psychophysical experiments to validate the results of the segmentation algorithm. Faculty advisors are professors Kramer, Narendra Ahuja (ECE), Artificial Intelligence Group; and David Brady (ECE), Photonic Systems Group.





ITG

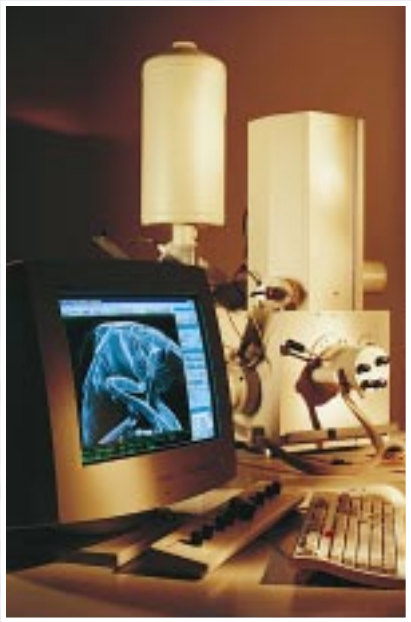
Imaging Technology Group

ITG

Imaging Technology Group

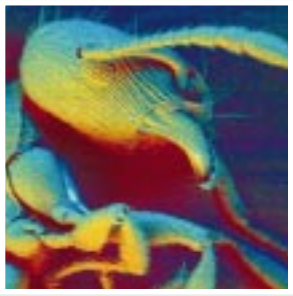
ITG

The primary mission of the Imaging Technology Group (ITG) is to provide Beckman researchers with state-of-the-art service facilities in the Microscopy Suite and the Visualization, Media, and Imaging Laboratory. There are currently over 300 active users of these facilities drawn from almost every department on campus. A secondary focus of the group is to develop advanced imaging technologies, primarily in the area of microscope control and automation.



Highlights in 1999

- *Environmental Scanning Electron Microscope* (ESEM): With a grant from the National Science Foundation's Major Research Instrumentation Program and matching funds from the Beckman Foundation, a Philips XL-30 field emission environmental scanning electron microscope was purchased and installed in January. The system is capable of imaging under wet and low vacuum conditions and is the only one of its kind in this geographical area. This system is now in use by over 40 researchers from a wide range of disciplines. Since its installation, a variety of additional equipment has been acquired or developed to support this instrument, including a micro-manipulator and micro-injection system; a 1500C heating stage; a device for examining pin-mounted specimens; and a sputter coater.

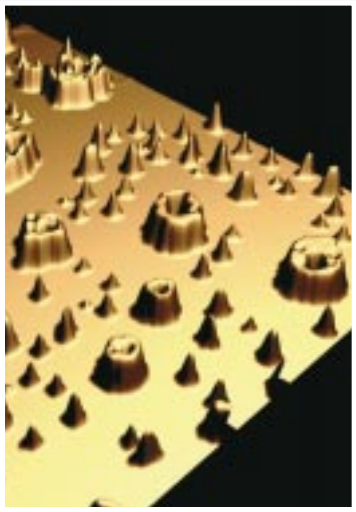


■ *Bugscope*: This is a project that allows K-12 students remotely to control the ESEM using a Web browser from their classroom. The primary goal of Bugscope is to demonstrate the possibility of relatively low cost and sustainable access to remote instrumentation. To implement this project, a Java-based remote control interface to the instrument was developed by ITG personnel. This fast track software development project was completed in only six weeks, with the first school using the instrument in early March. Since then, over 25 classrooms from around the nation have participated in the project. At a national level, there is a very significant interest in Bugscope, and the project has received favorable press coverage (NY *Times*, LA *Times*, *Chicago Sun Times*, *National Public Radio*, etc.). Bugscope is partially supported by grants from the Illinois Consolidated Telephone Company and the IBM Shared University Research Program.

■ *Visualization, Media, and Imaging Laboratory*: New capabilities in this facility include a high resolution digital camera; an upgrade of the video editing suite to support broadcast quality productions; a new film recorder; and new high speed graphics workstations. In response to interest from users, a system has recently been purchased that provides a capability for "printing" 3D plastic solid models. The device was purchased with funding from the Campus Research Board and the Beckman Institute.

■ *Automated and Intelligent Electron Microscopy*: These NSF-sponsored projects support the development of technology for the automated and intelligent acquisition of images from a transmission electron microscope. This project is a collaboration between the ITG, Professor David Kriegman (HCII), and the Scripps Research Institute.

■ *Outreach*: The ITG Forum series provides an opportunity to learn about the tools, techniques, and technologies available within the group. Forty-one forums were presented during 1999 and included presentations from members of the ITG, users of the facilities, and members of the Beckman Institute, university campus, and local community. In addition, a total of ten technical reports were published to document the techniques and applications developed within the Imaging Technology Group.



Bridget Carragher and Clint Potter,
Co-directors

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University Administration

University of Illinois
President:
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Michael T. Aiken

Provost and Vice-Chancellor for Academic Affairs:
Richard H. Herman

Vice-Chancellor for Research:
Tony G. Waldrop

1999

Facts & Figures

1999

95-99 Beckman Institute Funding[1]

Funding Awarded to Beckman Institute Faculty Administered by the Beckman Institute[2]

	FY95	FY96	FY97	FY98	FY99
Department of Defense	1,283,925.00	2,942,604.00	3,018,926.00	4,244,105.00	8,596,145.00
National Institutes of Health	1,083,260.00	1,841,717.00	1,907,009.00	2,024,355.00	3,096,564.00
National Science Foundation	1,296,212.00	1,782,607.00	3,447,156.00	1,823,786.00	3,714,184.00
Other	922,840.00	1,016,751.00	1,645,026.00	817,864.00	1,161,601.00
Total	4,586,237.00	7,583,679.00	10,018,117.00	8,910,110.00	16,568,601.00

Funding Awarded to Beckman Institute Faculty Administered by Other Departments[3]

Department of Defense	1,811,671.00	4,435,872.00	4,524,577.00	6,475,573.00	7,480,679.00
National Institutes of Health	4,057,225.00	4,982,368.00	4,752,157.00	5,614,090.00	5,316,533.00
National Science Foundation	5,400,368.00	1,754,112.00	3,176,276.00	1,837,054.00	1,937,805.00
Other	2,170,321.00	2,240,345.00	2,218,587.00	2,452,133.00	632,688.00
Total	13,439,585.00	13,412,697.00	14,671,597.00	16,378,850.00	15,367,705.00

[1]In addition to the sources itemized in the chart, funding for the Institute is received from the following:

1. The state of Illinois to the University of Illinois and allocated through individual departments:
   Faculty Salaries
2. The state of Illinois to the Beckman Institute:
   Daily Operating Expenses
3. The Arnold and Mabel Beckman Foundation:
   Beckman Institute Fellows Program
   Beckman Institute Graduate Fellows Program
   Beckman Institute Equipment Competition

[2]All interdisciplinary grants with faculty investigators from multiple departments are administered by the Beckman Institute.

[3]All single investigator grants are administered by the investigator's home department.

1999

M&ENS

Molecular & Electronic Nanostructures

Faculty by Beckman Institute Group

Advanced Chemical Systems Group • Paul W. Bohn: Chemistry • Paul V. Braun: Materials Science and Engineering • Theodore L. Brown: Emeritus, Chemistry • Jiri Jonas (Institute Director): Chemistry • Jeffrey S. Moore: Chemistry • Stephen G. Sligar: Biochemistry • **Computational Electronics Group** • Narayana R. Aluru: General Engineering • Karl Hess: Electrical and Computer Engineering • Jean-Pierre Leburton: Electrical and Computer Engineering • Richard M. Martin: Physics • Umberto Ravaioli: Electrical and Computer Engineering • **Photonic Systems Group** • David Brady: Electrical and Computer Engineering • Martin Gruebele: Chemistry • Nancy Makri: Chemistry • Eric Michielssen: Electrical and Computer Engineering • Margery Osborne: Curriculum and Instruction • **Scanning Tunneling Microscopy Group** • Ilesanmi Adesida: Electrical and Computer Engineering • Joseph W. Lyding: Electrical and Computer Engineering • **Theoretical Biophysics Group** • Laxmikant V. Kale: Computer Science • Todd J. Martinez: Chemistry • Klaus J. Schulten: Physics • Robert D. Skeel: Computer Science • **No Group**: Sung-Mo (Steve) Kan: Electrical and Computer Engineering

Major Awards

Ilesanmi Adesida
Fellow, IEEE

Narayana Aluru
CAREER Award, National Science Foundation

David Brady
Xerox Award for Faculty Research, UIUC College of Engineering

Paul Braun
Racheff Assistant Professor, UIUC

Martin Gruebele
Coblentz Award, Coblentz Society

Sung-Mo (Steve) Kang
Technical Excellence Award, SRC
Golden Jubilee Medal, IEEE Circuits and Systems Society

Jean-Pierre Leburton
Associate, UIUC Center for Advanced Study
Fellow, American Physical Society

Nancy Makri
University Scholar, UIUC
Agnes Fay Morgan Research Award, Iota Sigma Pi

Richard Martin
Associate Editor, *Reviews of Modern Physics*, area of Condensed Matter Theory

Todd Martinez
Sloan Fellow, Sloan Foundation
Beckman Young Investigator Award, Beckman Foundation
Packard Fellow, Packard Foundation

Eric Michielssen
United States National Committee Henry G. Booker Fellow, International Union of Radio Scientists
Issac Koga Gold Medal Award, International Union of Radio Scientists
Senior Member, IEEE
Sackler Scholar, Mortimer and Raymond Sackler Institute for Advanced Studies, Tel-Aviv University, Tel Aviv, Israel (appointment for 2002)

Jeffrey Moore
Associate Editor, *Journal of the American Chemical Society*

Umberto Ravaioli
Fellow, Institute of Physics

Stephen Sligar
First Vallee Visiting Professor, Oxford University, Department of Chemistry
Fellowship, Japan Society for the Promotion of Science
MERIT Award, National Institutes of Health

Patents and Patent Applications

(Beckman Institute faculty in boldface)

Jeffrey Moore and **David Beebe**: "Microfabricated Devices and Method of Manufacturing the Same," File date (year only): 1999.

Yoram Bresler, **Eric Michielssen**, and Amir Boag: "A Multilevel Domain Decomposition Method for Fast Projection of Images," File date (year only): 1999.

Joseph Lyding and **Karl Hess**: "Deuterium-treated Semiconductor Devices," Issue date: February 16, 1999, Patent No. 5,872,387.

Patents and Patent Applications

(Beckman Institute faculty in boldface)

Steve Kang, Haoran Duan, and John Lockwood: "Scalable Broadband Input-queued ATM Switch Including Weight Driven Cell Scheduler," Issue date: July 13, 1999, Patent No. 5,923,656.

Grants Awarded

(Only Principal Investigator listed)

Ilesanmi Adesida: Department of Defense/Army, "Processing Technologies for ALXGA1-XN Photodetector Arrays," 15-Apr-99 to 14-Apr-02.

Narayana Aluru: National Science Foundation, "Career: Integrated Computational MEMS," 01-Aug-99 to 31-Jul-03.

Paul Bohn: National Science Foundation, "Purchase of Rapid Kinetics Instrumentation for Mechanistic Studies of Catalysis," 01-Feb-99 to 31-Jan-00.

David Brady: Department of Defense/Air Force, "Distributed Optoelectronic Processing for Multidimensional Digital Imaging," 01-Apr-99 to 30-Sep-00.

Karl Hess: Department of Defense/Navy, "Third Workshop on Surfaces and Interfaces of Mesoscopic Devices," 01-Oct-99 to 30-Nov-00.

Jean-Pierre Leburton: NTT Basic Research Lab, "Computation of Many Body Effects in Quantum Nanostructures," 01-Apr-99 to 31-Mar-01.

Jean-Pierre Leburton: Department of Defense/Army, "Quantum Transport and Scattering Time Engineering in Nanostructures," 01-Apr-99 to 31-Mar-02.

Nancy Makri: National Science Foundation, "Path Integral and Semiclassical Approaches to the Dynamics of Large Chemical Systems," 01-Jun-99 to 31-May-00.

Todd Martinez: Sloan Foundation, Research Fellowship, 16-Sep-99 to 15-Sep-01.

Todd Martinez: Beckman Foundation, "First Principles Quantum Reaction Dynamics on Multiple Electronic States," 01-Sep-99 to 31-Aug-02.

Todd Martinez: Packard Foundation, Fellowship, 01-Jun-99 to 31-May-04.

Jeffrey Moore: Department of Defense/Army, "Polymer Synthesis and Characterization Facility," 01-Apr-99 to 31-Mar-00.

Jeffrey Moore: American Chemical Society, Associate Editor of *Journal of the American Chemical Society*, 01-Jul-99 to 31-Dec-01.

Margery Osborne: Spencer Foundation, "A Relational Analysis of Early Childhood Science Education in At-risk Settings," 01-Jan-00 to 31-Dec-00.

Margery Osborne: Illinois Board of Education, "SAGES, Science as Guided by Education Standards (Monticello C.U.S.D. #25)," 01-Sep-99 to 31-Aug-00.

Klaus Schulten: National Institutes of Health, "Workshop on Opportunities in Molecular Biomedicine in the Era of Teraflop Computing," 01-Aug-98 to 31-Jul-99.*

Klaus Schulten: National Institutes of Health, "Collaboratory for Structural Biology," 01-Feb-99 to 31-Jul-02.

**Included in 1999 Annual Report because the award notice was not received until '99.*

Robert Skeel: National Science Foundation, "Numerical Methods for Molecular Dynamics," 15-Jul-99 to 30-Jun-02.

Robert Skeel: National Science Foundation, "Algorithms for Simulation of Macromolecular Diffusion and Association," 01-Oct-99 to 30-Sep-02.

Stephen Sligar: National Institutes of Health, "Heme Protein Reductases," 01-Aug-99 to 31-Jul-04.

Selected Publications

(Beckman Institute faculty in boldface)

- Youtsey, C., Romano, L. T., Molnar, R. J., and **Adesida, I.** (1999), "Rapid Evaluation of Dislocation Densities in N-type GaN Films Using Photoenhanced Etching," *Applied Physics Letters*, **74**, pp. 3537-3539.

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- Zhang, Y., Terrill, R. H., and **Bohn, P. W.** (1999), "Manipulating the Resistivity of Ultrathin Gold Films by Chemisorption and Chemical Reactions at the Liquid-solid Interface," *Analytical Chemistry*, **71**, pp. 119-125.

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- Yu, A., Ballard, L., Smillie, L., Pearlstone, J., Foguel, D., Silva, J., Jonas, A., and **Jonas, J.** (1999), "Effects of High Pressure on the Wild-type and F29W Mutant Forms of the N-Domain of Avian Troponin C," B*iochimica et Biophysica Acta*, **1431**, pp. 53-63.

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- Mena, P. V., Morikuni, J. J., **Kang, S. M.**, Harton, A. V., and Wyatt, K. W. (1999), "A Comprehensive Circuit-level Model of Vertical-cavity Surface-emitting Lasers," IEEE J*ournal of Lightwave Technology*, **17/2**, pp. 2612-2632.

- **Leburton, J.-P.** (1999), "Photo-refractive Properties of GaAs and Superlattices," in J. Webster, ed., E*ncyclopedia of Electrical and Electronic Engineers*, Vol. 16 (Wiley Publ. Corp.), pp. 366-377.

- **Leburton, J.-P.**, Fonseca, L. R. C., Shumway, J., Ceperley, D., and **Martin, R. M.** (1999), "Electronic Properties and Mid-infrared Transitions in Self-assembled Quantum Dots," *Japanese Journal of Applied Physics*, **38**, p. 357.

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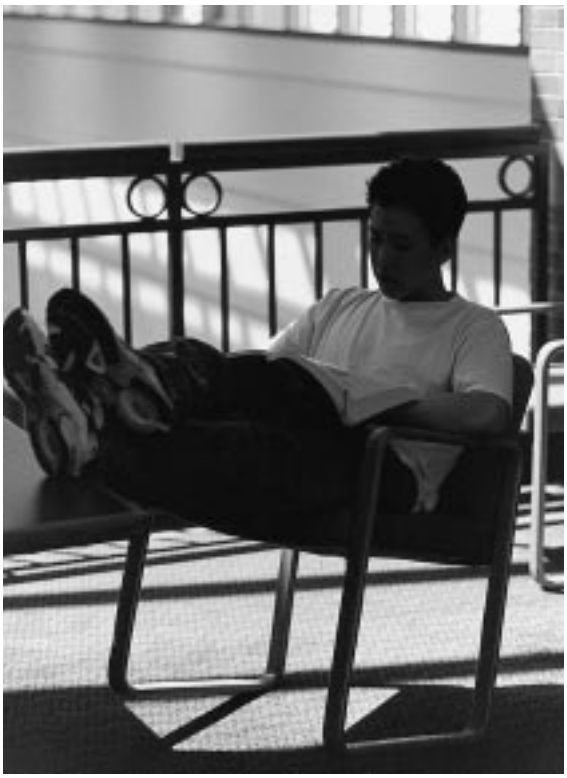

HCII

Human-computer intelligent interaction

Faculty by Beckman Institute Group

Artificial Intelligence Group • Narendra Ahuja: Electrical and Computer Engineering • Gerald F. DeJong: Computer Science • Mehdi T. Harandi: Computer Science • Mark A. Hasegawa-Johnson: Electrical and Computer Engineering • Thomas S. Huang: Electrical and Computer Engineering • Seth Hutchinson: Electrical and Computer Engineering • Patricia M. Jones: Mechanical and Industrial Engineering • David J. Kriegman: Computer Science • Stephen E. Levinson: Electrical and Computer Engineering • Jean A. Ponce: Computer Science • Larry A. Rendell: Computer Science • Dan Roth: Computer Science • Michael J. Shaw: Business Administration • David C. Wilkins: Institute of Aviation • **Human Perception and Performance Group** • David E. Irwin: Psychology • Arthur F. Kramer: Psychology • George W. McConkie: Educational Psychology • Tamara A. Rahhal: Psychology • Janet A. Sniezek: Psychology • Ranxiao Wang: Psychology • Stanley Wasserman: Psychology • Christopher D. Wickens: Institute of Aviation • **Image Formation and Processing Group** • Nigel Boston: Mathematics • Weng C. Chew: Electrical and Computer Engineering • Thomas S. Huang: Electrical and Computer Engineering • Zhi-Pei Liang: Electrical and Computer Engineering • Pierre Moulin: Electrical and Computer Engineering • David C. Munson: Electrical and Computer Engineering • Benjamin Wah: Electrical and Computer Engineering

Major Awards

Narendra Ahuja

Donald Biggar Willet Professorship, UIUC College of Engineering

Emanuel R. Piore Award, IEEE

Weng Cho Chew

Founders Professorship, UIUC College of Engineering

Year 2000 Graduate Teaching Award, IEEE

Gerald DeJong

Achievement Award, National Aeronautics and Space Administration

Thomas Huang

Keynote Speaker, *International Workshop on Gesture*, March 17-19, Paris, France

Keynote Speaker, *International Conference on Audio and Visual-based Biometric Person Identification*, March 22-24, Washington, DC

Keynote Speaker, IEEE *International Neuronets for Signal Processing Workshop*, August 23-25, Madison, WI

Keynote Speaker, *International Conference on Image Analysis and Processing* (CAIP), September 1-3, Ljubljana, Slovenia

Patricia Jones

Rose Award for Teaching Excellence, UIUC College of Engineering

Arthur Kramer

Fellow, American Psychological Association

David Kriegman

Editor, IEEE *Transactions on Pattern Analysis and Machine Intelligence*

Program Co-chair, IEEE *Conference on Computer Vision and Pattern Recognition*

Zhi-Pei Liang

Early Career Achievement Award, IEEE Engineering in Biology and Medicine Society

Henry Magnuski Scholar, UIUC Electrical and Computer Engineering Department

Pierre Moulin

Associate Editor, IEEE *Transactions on Image Processing*

David Munson

Distinguished Lecturer, IEEE Signal Processing Society

Dan Roth

Best Paper Award, IJCAI'99, *16th International Joint Conference on Artificial Intelligence*

Benjamin Wah

Elected President, IEEE Computer Society (term 2001)

Robert T. Chien Professor of Electrical and Computer Engineering, UIUC

Stanley Wasserman

Presidential Nominee, Classification Society of North America

David Wilkins

Deployed Innovative Application Award, *Eleventh Conference on Innovative Applications of Artificial Intelligence*

Patents and Patent Applications

(Beckman Institute faculty in boldface)

Douglas Jones, **Kannan Ramchandran**, and Brian Scott Krongold, "Section Division Operating Point Slope Determination Method for Multicarrier," File date (year only): 1999.

Grants Awarded

(Only Principal Investigator listed)

Narendra Ahuja: Department of Defense/Navy, "Recognition- and Contents-based Retrieval of Hand Gestures from Video," 15-Oct-99 to 30-Sep-02.

Nigel Boston: National Science Foundation, "The Unramified Fontain-Mazur Conjecture," 01-Jun-99 to 31-May-02.

Nigel Boston: National Science Foundation, "Special Year in Number Theory," 15-Jun-99 to 31-May-00.

Weng Chew: National Science Foundation, "Nonlinear Inverse Scattering Methods for Three-dimensional Objects," 01-Oct-99 to 30-Sep-00.

Mehdi Harandi: National Science Foundation, "Modular Combination of Satisfiability Procedures," 01-Sep-99 to 31-Aug-01.

Pierre Moulin: Department of Defense/Army, Subcontract to #8908-48167, 01-Mar-99 to 31-Oct-99.

Jean Ponce: National Science Foundation, "Capture Regions for Grasping, Manipulating, and Reorienting Parts," 15-Sep-99 to 31-Aug-00.

Christopher Wickens: Department of Defense/Air Force, "Air Force (AF Academy) IPA Assignments," 23-Jul-99 to 05-Jan-00.

Selected Publications

(Beckman Institute faculty in boldface)

- Yang, M.-H. and **Ahuja, N.** (1999), "Recognizing Hand Gesture Using Motion Trajectories," IEEE *Conference on Computer Vision and Pattern Recognition*, Ft. Collins, CO, June, pp. I 466-472.

- Yoon, S. C., Ratakonda, K., and **Ahuja, N.** (1999), "Low Bit-rate Video Coding with Implicit Multiscale Image Segmentation," IEEE *Transactions on Circuits and Systems for Video Technology*, **9/7**, pp. 1115-1129.

- **Boston, N.** (1999), "The Minimum Distance of the [137,69] Binary Quadratic Residue Code," IEEE *Transactions in Information Theory*, **45/1**, p. 282.

- **Boston, N.** (1999), "Some Cases of the Fontaine-Mazur Conjecture, II," *Journal of Number Theory*, **75/2**, pp. 161-169.

- Cui, T. J. and **Chew, W. C.** (1999), "Fast Algorithm for Electromagnetic Scattering by Buried Conducting Plates of Large Size," IEEE *Transactions on Antennas and Propagation* (Letter), **47/6**, pp. 1116-1118.

- Hu, B., **Chew, W. C.**, **Michielssen, E.** and Zhao, J. (1999), "An Improved Fast Steepest Descent Algorithm for the Fast Analysis of Two-dimensional Scattering Problems," *Radio Science*, **34/4**, pp. 759-772.

- **DeJong, G.** (1999), "AI Can Rival Control Theory for Goal Achievement in a Challenging Dynamical System," *Computational Intelligence*, **15/4**, pp. 333-366.

- Brodie, M. and **DeJong, G.** (1999), "Learning to Ride a Bicycle Using Iterated Phantom Induction," *Proceedings of the International Conference on Machine Learning* (Bled, Slovenia: Morgan Kaufmann), pp. 57-66.

- **Hasegawa-Johnson, M. A.**, Cha, J. S., Pizza, S., and Haker, K. (1999), "CTMRedit: A Case Study in Human-Computer Interface Design," *Proceedings of the International Conference on Public Participation and Information Technology*, Lisbon, Portugal, October.

- **Hasegawa-Johnson, M. A.** (1999), "Combining Magnetic Resonance Image Planes in the Fourier Domain for Increased Spatial Resolution," *International Conference on Signal Processing Applications and Technologies*, Orlando, Florida, November.

- Jojic, N., Gu, J., Shen, H. C., and **Huang, T. S.** (1999), "Computer Modeling, Analysis, and Synthesis of Dressed Humans," IEEE *Transactions on Circuits and Systems for Video Technology*, **9/2**, pp. 378-388.

- Chang, S. F., Huang, Q., **Huang, T. S.**, Puri, A., and Shahraray, B. (1999), "Multimedia Search and Retrieval," in A. Puri and T. Chen, eds., *Advances in Multimedia: Systems, Standards, and Networks* (Marcel Dekker).

- Rifai, H., Bloch, I., **Hutchinson, S. A.**, Wiart, J., and Garnero, L. (1999), "Segmentation of the Skull in MRI Volumes Using Deformable Models and Taking the Partial Volume Effect into Account," *Proceedings*, SPIE *Medical Imaging Symposium*, San Diego, pp. 288-299.

- **Shaw, M. J.**, **Ahuja, N.**, and **Hutchinson, S. A.** (1999), "Coordination, Collaboration, and Control of Multirobot Systems," in S. Y. Nof, ed., *Handbook of Industrial Robotics* (John Wiley and Sons Ltd.), pp. 423-438.

- Deubel, H., **Irwin, D. E.**, and Schneider, W. X. (1999), "The Subjective Direction of Gaze Shifts Long Before the Saccade," in W. Becker, H. Deubel, and T. Mergner, eds., *Current Oculomotor Research: Physiological and Psychological Aspects* (New York: Plenum), pp. 65-70.

- **Kramer, A. F.**, Hahn, S., **Irwin, D. E.**, and Theeuwes, J. (1999), "Attentional Capture and Aging: Implications for Visual Search Performance and Oculomotor Control," *Psychology and Aging*, **14**, pp. 135-154.

- **Jones, P. M.** (1999), "Human Error and Its Amelioration," in A. P. Sage and W. B. Rouse, eds., *Handbook of Systems Engineering and Management* (Wiley), pp. 687-702.

- Jasek, C. A. and **Jones, P. M.** (1999), "Cooperative Work in Distributed Supervisory Control," in G. Olson, T. Malone, and J. B. Smith, eds., *Coordination Theory and Collaboration Technology* (Lawrence Erlbaum Associates).

- Watson, S. and **Kramer, A. F.** (1999), "Object-based Visual Selective Attention and Perceptual Organization," *Perception and Psychophysics*, **61/1**, pp. 31-49.

- **Kramer, A. F.**, Hahn, S., **Cohen, N.**, **Banich, M.**, McAuley, E., Harrison, C., Chason, J., Vakil, E., Bardell, L., Boileau, R. A. and Colcombe, A. (1999), "Aging, Fitness, and Neurocognitive Function," *Nature*, **400**, pp. 418-419.

- Belhumeur, P., **Kriegman, D.**, and Yuille, A. (1999), "The Bas-relief Ambiguity," *International Journal of Computer Vision*, **35/1**, pp. 33-44.

- **Kriegman, D.**, Belhumeur, P., and Georgiades, A. (1999), "Representations for Recognition Under Variable Illumination," in D. A. Forsyth, J. L. Mundy, V. Gesu, and R. Cipolla, eds., *Shape, Contour, and Grouping in Computer Vision* (New York: Springer-Verlag).

- Huang, J. and **Levinson, S.** (1999), "Estimation of Articulatory Movement and Its Application to Speech Synthesis," *Acoustical Society of America*, Columbus, OH, November.

- Huang, J., Zhao, Y., and **Levinson, S.** (1999), "A DCT-based Fast Enhancement Technique for Robust Speech Recognition in Automobile Usage," *Proceedings-Eurospeech*, Budapest, Hungary, September, pp. 1947-1950.

- **Liang, Z.-P.** and **Lauterbur, P. C.** (1999), *Principles of Magnetic Resonance Imaging* (IEEE Press).

- Hess, C. P., **Liang, Z.-P.**, and **Lauterbur, P. C.** (1999), "Maximum Cross-entropy Generalized Series Reconstruction," *International Journal of Imaging Systems and Technology*, **10/3**, pp. 258-265.

- Yang, H. M. and **McConkie, G. W.** (1999), "Reading Chinese: Some Basic Eye Movement Characteristics," in J. Wang, A. Inhoff, and H. C. Chen, eds., *Reading Chinese Script: A Cognitive Analysis* (Mahwah, N. J.: Lawrence Erlbaum).

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- **Moulin, P.** and Liu, J. (1999), "Analysis of Multiresolution Image Denoising Schemes Using Generalized-Gaussian and Complexity Priors," IEEE *Transactions on Information Theory, Special Issue on Multiscale Analysis*, **45/3**, pp. 909-919.

- **Munson, Jr., D. C.** and Arikan, O. (1999), "Interpolation and the Chirp Transform: DSP Meets Optics," *Proceedings*, IEEE *International Conference on Acoustics, Speech, and Signal Processing*, Phoenix, AZ, March, pp. 2099-2102.

- Marks, D. L., Stack, R. A., **Brady, D. J.**, **Munson, Jr., D. C.,** and Brady, R. A. (1999), "Visible Cone-beam Tomography with a Lensless Interferometric Camera," *Science*, **284**, pp. 2164-2166.

- Sudsang, A., **Ponce, J.**, Hyman, M., and **Kriegman, D. J.** (1999), "On Manipulating Polygonal Objects with Three 2-DOF Robots in the Plane," *Proceedings*, IEEE *International Conference on Robotics and Automation*, Detroit, MI, May, pp. 2227-2233.

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- Rubin, D., Schulkind, M. D., and **Rahhal, T. A.** (1999), "A Study of Gender Differences in Autobiographical Memory: Broken Down by Age and Sex," *Journal of Adult Development*, **6**, pp. 61-71.

- Hasher, L., Zacks, R. T., and **Rahhal, T. A.** (1999), "Timing, Instructions, and Inhibitory Control: Some Missing Factors in the Age and Memory Debate," *Gerontology*, **45/6**, pp. 355-57.

- Golding, A. R. and **Roth, D.** (1999), "A Winnow-based Approach to Spelling Correction," *Machine Learning, Special Issue on Machine Learning and Natural Language Processing*, **34:1/3**, pp. 107-130.

- **Roth, D.** (1999), "Learning in Natural Language," IJCAI'99, *the 16th International Joint Conference on Artificial Intelligence*, August, pp. 898-904.

- **M. Shaw**, R. Blanning, T. Strader, and A. Whinston, eds. (1999), *Handbook on Electronic Commerce* (Springer-Verlag).

- **M. Shaw**, guest editor, with R. King (1999), *The Journal of Organizational Computing and Electronic Commerce, Special Issue on Enterprise Modeling and Knowledge Management*, **9/1**, pp. 7-32.

- **Sniezek, J. A.** (1999), "Issues in Self-control Theory and Research: Confidence, Doubt, Expectancy Bias, and Opposing Forces," in R. S. Wyer, ed., *Themes and Issues in the Self-regulation of Behavior: Advances in Social Cognition*, Vol. l2 (Mahwah, NJ: Erlbaum).

- Gelfand, M., Spurlock, D. G., **Sniezek, J. A.**, and Shao, L. (1999), "Culture and Social Prediction: The Role of Information in Enhancing Prediction in Social Interactions in the U.S. and China," *Journal of Cross-Cultural Psychology*.

- **Wah, B. W.** and Lin, D. (1999), "Transformation-based Reconstruction for Real-time Voice Transmissions over the Internet," IEEE *Transactions on Multimedia*.

- **Wah, B. W.** (1999), "Generalization and Generalizability Measures," IEEE *Transactions on Knowledge and Data Engineering*, **11/1**, pp. 175-186.

- **Wang, R. F.** and Cutting, J. E. (1999), "Where We Go with a Little, Good Information," *Psychological Science*, **10**, pp. 72-76.

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- Pattison, P. E., **Wasserman, S.**, Robins, G., and Kanfer, A. M. (1999), "Statistical Evaluation of Algebraic Constraints for Social Networks," *Journal of Mathematical Psychology*.

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- Bulitko, V. V. and **Wilkins, D. C.** (1999), "Automated Instructor Assistant for Ship Damage Control," *Proceedings, Eleventh Conference on Innovative Applications of Artificial Intelligence*, IAAI-99, Orlando, FL, July, pp. 778-785.

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BI

biological intelligence

Faculty by Beckman Institute Group

Bioacoustics Research Laboratory • Floyd Dunn: Emeritus: Electrical and Computer Engineering • Leon A. Frizzell: Electrical and Computer Engineering • William D. O'Brien: Electrical and Computer Engineering • **Biological Sensors Group** • Ronald Adrian: Theoretical and Applied Mechanics • David J. Beebe: Electrical and Computer Engineering • Chang Liu: Electrical and Computer Engineering • Mark Shannon: Mechanical and Industrial Engineering • Jonathan V. Sweedler: Chemistry • Andrew G. Webb: Electrical and Computer Engineering • Bruce C. Wheeler: Electrical and Computer Engineering • **Cognitive Neuroscience Group** • Marie T. Banich: Psychology • Neal J. Cohen: Psychology • Michael G. Coles: Psychology • Emanuel E. Donchin: Psychology • Susan M. Garnsey: Psychology • Wendy Heller: Psychology • Gregory A. Miller: Psychology • **Cognitive Science Group** • Kathryn J. Bock: Psychology • William F. Brewer: Psychology • Jennifer S. Cole: Linguistics • Gary S. Dell: Psychology • Cynthia L. Fisher: Psychology • Adele E. Goldberg: Linguistics • Georgia M. Green: Linguistics • Kevin Miller: Psychology • Gregory L. Murphy: Psychology • Brian H. Ross: Psychology • Edward J. Shoben: Psychology • Daniel D. Silverman: Linguistics • Robert A. Wilson: Philosophy • **Magnetic Resonance Imaging and Spectroscopy Group** • Paul C. Lauterbur: Medical Information Sciences • Erik Wiener: Nuclear Engineering • **Neuronal Pattern Analysis Group** • Thomas J. Anastasio: Molecular and Integrative Physiology • David F. Clayton: Cell and Structural Biology • Albert S. Feng: Molecular and Integrative Physiology • Michael Gabriel: Psychology • William T. Greenough: Psychology • Yuqing Li: Molecular and Integrative Physiology • Mark E. Nelson: Molecular and Integrative Physiology • Jonathan V. Sweedler: Chemistry • Bruce C. Wheeler: Electrical and Computer Engineering • **No Group** • Eric G. Jakobsson: Molecular and Integrative Physiology

Major Awards

David Clayton
Scientific Advisory Board, National Parkinson Foundation

Michael Coles
Associate Member, UIUC Center for Advanced Study

Cynthia Fisher
Visiting Scholar, Max Planck Institute for Psycholinguistics, Nijmegen, NL

Michael Gabriel
Editorial Board, *Neurobiology of Learning and Memory*

Adele Goldberg
Fellow, Center for Advanced Study in the Behavior Sciences, Stanford, California

Georgia Green
Program Committee, Linguistic Society of America

Paul Lauterbur
Gold Medal for Significant Contribution to Progress of Radiology, European Congress of Radiology
Gray Medal, International Commission on Radiation Units and Measures

Gregory Miller
Reappointment as Editor, *Psychophysiology*, extending term to 12/31/2003

Jonathan Sweedler
Beneddetti-Pichler Award in Microanalysis, American Microchemical Society

Patents and Patent Applications

(Beckman Institute faculty in boldface)

David Beebe and **Jeffrey Moore**: "Microfabricated Devices and Method of Manufacturing the Same," File date (year only): 1999.

Richard Masel and **Mark Shannon**: "Microcombustor Having Submillimeter Critical Dimensions," File date (year only): 1999.

Chang Liu and Yong Wu Yi: "A Method for Assembly of Microelectromechanical Systems Using Magnetic Actuation," File date (year only): 1999.

Mathew Wheeler, Ian Glasgow, and **David Beebe**, "Microfluidic Embryo and/or Oocyte Handling Device and Method," File date (year only): 1999.

Grants Awarded

(Only Principal Investigator listed)

Marie Banich: National Institutes of Health, "Cingulate Cortex in Selective Attention: An fMRI Study," 21-May-99 to 20-May-06.

David Beebe: Department of Defense/Navy, "Oral Tactile Interfaces: Perception and Device Development," 15-Apr-99 to 14-Apr-01.

David Clayton: National Institutes of Health, "Experience-dependent Changes in the Brain," 01-Mar-99 to 29-Feb-04.

Gary Dell: National Science Foundation, "The Role of Experience in Language Processing," 01-Jan-99 to 31-Dec-01.

Michael Gabriel: National Institutes of Health, "The Medial Temporal Lobe in Learning and Stimulus Processing," 28-Apr-99 to 27-Apr-02.

William Greenough: National Institutes of Health, "Studies of the Function of Fragile X Protein," 08-Feb-99 to 31-Jan-02.

William Greenough: Fraxa Research Foundation, "Mechanisms Regulating Synaptic Protein Translation and a Search for Different Synaptic Protein Synthesis in FMRP Knockout and Wildtype," 01-July-99 to 30-June-00.

William Greenough: Fraxa Research Foundation, "Investigation of the Regulation of the Expression of the FMR-1-Gene," 01-Sep-99 to 31-Aug-00.

Eric Jakobsson: National Science Foundation, "Biology Student Workbench: Inquiry Tools for the Use of Molecular Data in Undergraduate Biology," 15-Jul-99 to 30-Jun-00.

Yuqing Li: National Institutes of Health, "Therapeutic Interventions in Aging: BDNF Transgenic Mice," 01-Aug-99 to 31-Jul-00.

Chang Liu: NASA, "Integrated Biomimetic Sensors Using Artificial Hair Cells," 01-Sep-99 to 31-Aug-01.

Edward Shoben: Cunningham Children's Home (Urbana, IL), "Cunningham Children's Home Internship Agreement," 21-Aug-99 to 20-May-00.

Jonathan V. Sweedler: Department of Energy, "Externally Controllable Sample Capture and Cleanup for DNA in Micromachined Integrated DNA Analysis Systems," 01-Jun-99 to 31-May-02.

Jonathan V. Sweedler: National Science Foundation, "Characterizing Neurotransmitters in Individual Neurons," 15-Jun-99 to 31-May-00.

Jonathan V. Sweedler: National Institutes of Health, "Single Neuron Assays for NOS Related Analytes," 30-Sep-99 to 31-May-03.

Bruce Wheeler: National Science Foundation, "Micropatterned Neural Networks and Microelectrode Arrays," 01-Jul-99 to 30-Jun-01.

Bruce Wheeler: National Institutes of Health, "Micropatterned Neural Networks," 24-Aug-99 to 31-Jul-01.

Selected Publications

(Beckman Institute faculty in boldface)

- Liu, R. H., Stremler, M. A., Sharp, K. V., Olsen, M. G., Santiago, J. G., **Adrian, R. J.**, Aref, H., and **Beebe, D. J.** (1999), "Passive Mixing in a Three-dimensional Serpentine Microchannel," *Journal of Microelectromechanical Systems*.

- Dow, E. R. and **Anastasio, T. J.** (1999), "Analysis and Modeling of Frequency Specific Habituation of the Goldfish Vestibulo-ocular Reflex," *Journal of Computational Neuroscience*, **7**, pp. 55-70.

- Dow, E. R. and **Anastasio, T. J.** (1999), "Dual-frequency Habituation of the Goldfish Vestibulo-ocular Reflex," *NeuroReport*, **10**, pp. 1729-1734.

- Weissman, D. H. and **Banich, M. T.** (1999), "A Role for Interhemispheric Communication in Reducing the Effects of Global-local Interference," *Journal of Experimental Psychology: General*, **128**, pp. 283-308.

- **Banich, M. T.**, Milham, M., Cohen, J., Wszalek, T., **Kramer, A.**, **Liang, Z.-P.**, Gullet, D., Shah, C., and Brown, C. (1999), "Dissociation of Frontal and Cingulate Activity in Attentional Control," *Neuroimage*, **6**, p. S743.

- **Bock, J. K.**, Nicol, J., and Cutting, J. C. (1999), "The Ties That Bind: Creating Number Agreement in Speech," *Journal of Memory and Language*, **40**, pp. 330-346.

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- **Clayton, D. F.** and George, J. M. (1999), "Synucleins in Synaptic Plasticity and Neurodegenerative Disorders," *Journal of Neuroscience Research*, *Special Issue on Synaptic Signaling in Neuronal Plasticity and Apoptosis*, **58**, pp. 120-129.

- **Clayton, D. F.** (1999), "Neural Basis of Avian Song Learning and Perception," in J. Bolhuis, ed., *Brain Mechanisms of Perception, Learning, and Memory* (Oxford University Press).

- **Cohen, N. J.**, Ryan, J., Hunt, C., Romine, L., Wszalek, T., and Nash, C. (1999), "The Hippocampal System and Declarative (Relational) Memory: Summarizing the Data from Functional Neuroimaging Studies," *Hippocampus*, **9**, pp. 83-98.

- Althoff, R. R. and **Cohen, N. J.** (1999), "Eye Movement-based Memory Effect: A Reprocessing Effect in Face Perception," *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **25/4**, pp. 997-1010.

- **Cole, J.** (1999), "Integrating the Phonetics and Phonology of Tone Alignment," in M. Broe and J. Pierrehumbert, eds., *Papers in Laboratory Phonology V: Language Acquisition and the Lexicon* (Cambridge: Cambridge University Press).

- **Cole, J.**, Hualde, J. I., and Iskarous, K. (1999), "Effects of Prosodic and Segmental Context on /g/-Lenition in Spanish," in O. Fujimura, ed., *Proceedings, Fourth International Linguistics and Phonetics Conference*, Columbus, OH, October 1998 (Prague: Charles University Press).

- Scheffers, M. K., Humphrey, D. G., Stanney, R. R., **Kramer, A. F.**, and **Coles, M. G. H.** (1999), "Error-related Processing During a Period of Extended Wakefulness," *Psychophysiology*, **36**, pp. 149-157.

- Spencer, K. M. and **Coles, M. G. H.** (1999), "The Lateralized Readiness Potential: Relationship Between Human Data and Response Activation in a Connectionist Model," *Psychophysiology*, **36**, pp. 364-370.

- **Dell, G. S.**, Ferreira, V. S., and **Bock, J. K.** (1999), "Binding, Attention, and Exchanges," *Behavioral and Brain Sciences*, **22**, pp. 41-42.

- **Dell, G. S.**, Chang, F., and Griffin, Z. M. (1999), "Connectionist Models of Language Production: Lexical Access and Grammatical Encoding," *Cognitive Science*, **23/4**, pp. 517-542.

- Spencer, K., Dien, J. and **Donchin, E.** (1999), "A Componential Analysis of the ERP Elicited by Novel Events Using a Dense Electrode Array," *Psychophysiology*, **36**, pp. 409-414.

- Bischoff, L. and **Donchin, E.** (1999), "Absolute Pitch and the P300: The Question of Task Difficulty and Strategy," in S. W. Yi, ed., *Music, Mind and Science* (Seoul: Seoul National University Press), pp. 123-143

- Zhang, H. M., Xu, J. H., and **Feng, A. S.** (1999), "Effects of GABA-mediated Inhibition on Direction-dependent Frequency Tuning in the Frog Inferior Colliculus," *Journal of Comparative Physiology* A, **184**, pp. 85-98.

- **Fisher, C.** (1999), "From Form to Meaning: A Role for Structural Alignment in the Acquisition of Language," in H. Reese, ed., *Advances in Child Development and Behavior*, Vol. 27 (New York: Academic Press), pp. 1-53.

- **Fisher, C.** (1999), "Simple Structural Guides for Verb Learning: On Starting with Next to Nothing," in E. V. Clark, ed., *Proceedings, 30th Stanford Child Language Research Forum* (Stanford, CA: CSLI Publications).

- Freeman, J. and **Gabriel, M.** (1999), "Changes of Cingulothalamic Topographic Excitation Patterns and Avoidance Response Incubation over Time Following Initial Discriminative Conditioning in Rabbits," *Neurobiology of Learning and Memory*, **72**, pp. 259-272.

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- Pearlmutter, N. J., **Garnsey, S. M.**, and **Bock, K.** (1999), "Agreement Processes in Sentence Comprehension," *Journal of Memory and Language*, **41**, pp. 427-456.

- **Goldberg, A. E.** (1999), "Patient Arguments of Causative Verbs Can Be Omitted: The Role of Information Structure in Argument Distribution," *Language Science*.

- Bencini, G. and **Goldberg, A. E.** (1999), "Constructions as the Main Determinants of Sentence Meaning," *Proceedings, Annual Conference: Cognitive Science Society*, p. 785.

- **G. Green,** co-editor, with R. D. Levine (1999), *Studies in Contemporary Phrase Structure Grammar* (Cambridge University Press).

- **Green, G.** (1999), "HPSG," in R. Wilson and F. Keil, eds., *The MIT Encyclopedia of Cognitive Science* (Cambridge: MIT Press).

- Weiler, I. J. and **Greenough, W. T.** (1999), "Synaptic Synthesis of the Fragile X Protein: Possible Involvement in Synapse Maturation and Elimination," *American Journal of Medical Genetics*, **83**, pp. 248-252.

- Anderson, B. J., Relucio, K., Logan, C., Knowlton, B., Thompson, J., Steinmetz, J., Thompson, R.F., and **Greenough, W. T.** (1999), "The Effects of Paired and Unpaired Eyeblink Conditioning on Purkinje Cell Morphology," *Learning and Memory*, **6**, pp. 128-137.

- Nitschke, J. B., **Heller, W.**, Palmieri, P. A., and **Miller, G. A.** (1999), "Contrasting Patterns of Brain Activity in Anxious Apprehension and Anxious Arousal," *Psychophysiology*, **36**, pp. 628-637.

- Valera, E., **Heller, W.**, and Berenbaum, H. (1999), "A Twin Study of Individual Differences in Perceptual Asymmetry," *Laterality*, **4**, pp. 299-311.

- Chiu, S. W., Subramaniam, S. and **Jakobsson, E.** (1999), "Simulation Study of a Gramicidin/Lipid Bilayer System in Excess Water and Lipid. I. Structure of the Molecular Complex," *Biophysical Journal*, **76**, pp. 1929-1938.

- Chiu, S. W., Subramaniam, S. and **Jakobsson, E.** (1999), "Simulation Study of a Gramicidin/Lipid Bilayer System in Excess Water and Lipid. II. Rates and Mechanisms of Water Transport," *Biophysical Journal*, **76**, pp. 1939-1950.

- Kmiecik, J. A., Gregory, C. D., **Liang, Z.-P.**, **Lauterbur, P. C.**, and Dawson, M. J. (1999), "Lactate Quantitation in a Gerbil Brain Stroke Model by GSLIM of Multiple Quantum-filtered Signals," *Journal of Magnetic Resonance Imaging*, **9**, pp. 539-543.

- Hess, C. P., **Liang, Z.-P.**, and **Lauterbur, P. C.** (1999), "Maximum Cross-entropy Generalized Series Reconstruction," *International Journal of Imaging Systems and Technology*, **10/3**, pp. 258-265.

- **Li, Y.**, Chen, R.-S., Jin, X.-L., and Guo, H. (1999), "Development of Whisker-related Neuronal Patterns in Cerebral Cortex-specific NMDAR1 Knockout Mice," *Society for Neuroscience Abstracts*, **25**, p. 225.

- Chen, R.-S., Jin, X.-L., and **Li, Y.** (1999), "Reduced Non-NMDA Currents in Hippocampal CA1 Neurons of NMDA Receptor Mutant Mice," *Society for Neuroscience Abstracts*, **1311.**

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Fellows

Beckman Institute Fellows in Residence in 1999

Srinivas Akella (1996)
Michal Balberg (1998)
Dale J. Barr (1999)
Gregory J. DiGirolamo (1998)
Hong Hua (1999)
Tammy Ivanco (1997)
Jason S. McCarley (1999)
Lolita Rotkina (1999)

Awards

Srinivas Akella

Finalist, Best Paper Award, IEEE *International Conference on Robotics and Automation*, May.

Gregory DiGirolamo

Section Editor, 1999-2000, *The New Cognitive Neurosciences* (2nd edition).

Grants Awarded

(Only Principal Investigator listed)

Gregory DiGirolamo: McDonnell-Pew Program in Cognitive Neuroscience, "Cognitive and Neuroanatomical Interactions of Attention and Memory," 01-Dec-99 to 01-Dec-02.

Gregory DiGirolamo: James S. McDonnell Foundation Program in Cognitive Rehabilitation, "Using Executive Function to Remediate Memory Disorders," 01-Sep-99 to 01-Sep-01.

Selected Publications

(Beckman Institute fellows and faculty in boldface)

- Lu, L. and **Akella, S.** (1999), "Folding Cartons with Fixtures: A Motion Planning Approach," IEEE *International Conference on Robotics and Automation*, Detroit, MI, May, pp. 1570-1576.

- **Akella, S.** and Mason, M. T. (1999), "Using Partial Sensor Information to Orient Parts," *International Journal of Robotics Research*, **18/10**, pp. 963-997.

- Barbastathis, G., **Balberg, M.**, and **Brady, D. J.** (1999), "Confocal Microscopy with a Volume Holographic Filter," *Optics Letters*, **24/12**, pp. 811-813.

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- **DiGirolamo, G. J.** and Posner, M. I. (1999), "Attention: An Overview," in M. Gazzaniga, ed., *The New Cognitive Neurosciences* (Cambridge, MA: MIT Press, 2nd edition), pp. 621-632.

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1999

Credits

- *Coordinating and Editing*:
  Beckman Institute Office of Publications and Special Events
- *Graphic Design*:
  Amy B. Harten, Cincinnati, OH
- *Photography*:
  Don Hamerman, New York, NY
  Chris Brown Photography, Champaign, IL
- *Film and Printing*:
  Color separations and film:
  Scantech Color Systems, Champaign, IL
  Printing: Illinois Graphics Incorporated, Bloomington, IL, May 2000