BMES Bulletin

BIOMEDICAL ENGINEERING SOCIETY NEWSLETTER

VOL. 24, NO. 2 2000

President's Column

Herbert F. Voigt, PhD

I am happy to report that the state of the BMES is healthy. And in such healthy times, it is important to think about the future and prepare for times that are not so good. With this in mind, I wish to announce formally the creation of the **BMES Fund** with an initial goal of raising $100,000 for year 2000. The purpose of this fund is to provide an additional revenue stream so that we are able to meet our financial goals as we wean ourselves from Whitaker Foundation support. Some of these funds will supplement our Reserve Fund, which for a healthy Society should equal about the size of the operating budget.

In January, I sent a letter soliciting funds for this new **BMES Fund** to all living former and current BMES Officers and members of the Board of Directors. I am delighted to report that because of this solicitation, we have received contributions or pledges of over $50,000. To date, 94% of our current Board of Directors has supported this activity. I have every faith that before the year is over, we will have 100% support from this group.

A large component of the raised funds have come from the Jen-shih Lee family. Eight members of the Lee family contributed $40,000 to support a distinguished lectureship to be awarded at our Annual Fall Meeting for the next 10 years. The Lee family has specified the nature of the award, which will include a monetary component, an engraved plaque, and a registration to the meeting. The Lee family wants to recognize the contributions of international and industrial biomedical engineers. The procedure for selecting the award winner will follow that specified for the current Distinguished Lectureship sponsored by the Whitaker Foundation. Dr and Mrs Lee will present the first award in Seattle if a suitable candidate is identified. Please make nominations for this prestigious award as soon as possible using the form in this Bulletin.

Now we enter Phase Two of the fund-raising effort – member contributions. I ask you, our members, to contribute generously to the **BMES Fund.** Inside this Bulletin you will find a contribution envelope. Please take a few minutes to consider making a contribution or a pledge to support your professional society. These contributions are tax-deductible and there is no better way I can think of to show your support for our profession.

As we go to press, an ad hoc Committee headed by Jerry Collins is finalizing the details of a new Rita Schaffer Memorial Awards program. Rita Schaffer, our former Executive Director who bequeathed her entire estate to the BMES, had a special place in her heart for the young and upcoming members of the Society. In a very fitting gesture, the Society's Young

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In This Issue

Editorial

Jerry C. Collins, PhD

Seeds of Success

The most recent meeting of the BMES Board of Directors took place at the Experimental Biology 2000 meeting in San Diego in April. San Diego is one of the leading biotechnology and high technology centers in the nation, and is home to one of our best bioengineering departments at the University of California, San Diego (UCSD). UCSD has provided strong leadership to the BMES: presidents, board members, committee chairs. UCSD recently hosted the BMES fall meeting.

Twenty years ago the perception of San Diego was quite different. San Diego was the home of General Dynamics, a large military presence, and a significant tourism industry. One was more likely to go to San Diego for a taco, a tan, or a tattoo than for technology.

The business and intellectual leadership of the community, however, had the foresight to see the enormous potential for growth in a major city with world-class research potential, an unexcelled climate, and educational, industrial, and civic leaders committed to change. In the early 1980s, a number of cities competed to become the site for the Microelectronics and Computer Technology Corporation (MCC), a $40 million research and development enterprise which would link research, industrial, and business resources in the city to which it was awarded. Although San Diego competed vigorously for MCC, it was awarded to Austin, TX, in no small measure because the University of Texas created more than 30 endowed professorships in technology-related disciplines in preparation for the award.

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President's Column

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Investigator Award will be renamed "The Rita Schaffer Young Investigator Award." Candidates who have been nominated for this year's Young Investigator Award will automatically be considered for this new honor. The recipient will be expected to give "The Rita Schaffer Memorial Lecture" at our fall meeting in Seattle. Arrangements are being made to have Rita's parents present at the awards ceremony. In addition, Rita's name will be associated with an undergraduate awards program at each of the accredited undergraduate biomedical engineering programs in the United States. Please look out for further details of this program honoring Rita.

I am looking forward to our upcoming **Annual Fall Meeting BMES 2000 –Biomedical Engineering: The Millennial Frontier**, hosted by Sandy Spelman and the University of Washington in Seattle from October 12-14, 2000. Please make your plans now to attend your Society's meeting. Please check the BMES 2000 website for the latest information: **www.engr.washington.edu/epp/bmes/.**

At the invitation of IEEE/EMBS President, Andrew Szeto, I attended part of the March Administrative Committee meeting of the EMBS in Vas Vegas. I was graciously received and allowed to make a short presentation of our goals for the future and to express some of the results of our survey regarding the First Joint meeting of BMES and EMBS in Atlanta last year. At this meeting, the AdCom voted to accept a memorandum of understanding (MOU) regarding a Second Joint meeting of BMES and EMBS in 2002 in Houston, Texas, under the leadership of John Clark and former BMES President Larry McIntire. Two weeks later, Dr Szeto attended part of the BMES Board of Director's meeting in San Diego, where our Board voted to accept the MOU. It was at this meeting that Dr Szeto and I signed the MOU that will, for the second time, join EMBS with BMES through a joint scientific meeting. With Drs Clark and McIntire at the helm, we are assured that this conference will be a great success.

I invite your comments about the form and substance of this Bulletin. Please send your comments to **hfv@bu.edu.** ■

Erratum

The equations in the Hemodynamic Effects on Blood Coagulation and Thrombosis article by Steven Slack in the last issue of the *Bulletin*, Vol.24, No. 1 should read as follows:

(1) $u(r) = u_{max}\left[1-\left(\frac{r}{R}\right)^2\right]$

(2) $\gamma_w = \frac{4Q}{\pi R^3}$

(3) $\tau_w = \mu\gamma_w$

We apologize to Dr Slack for the error.

BMES Bulletin

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Editorial

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In June 1984, Dr Richard C. Atkinson, then Chancellor of UCSD and now President of the University of California system, asked Dr Mary Walshok, Dean & Associate Vice Chancellor of UCSD, to prepare a plan for an infrastructure that would make UCSD and San Diego more hospitable for enterprises that would bring university, industry and business resources together. By August Dr Walshok was preparing goals for the Center for Entrepreneurial Development (EDC) at UCSD.

In June 1985, the campus-based organization rechristened UCSD CONNECT was formed. Its purpose, from the CONNECT 2000 Directory, was and is "to enhance regional economic development by accelerating the growth of high technology enterprises in San Diego. CONNECT networks all partners in the technology development process and as such is an 'incubator without walls,' linking business service providers with leadership in information technologies, software, and the life sciences….CONNECT is a catalyst for economic growth….is entirely supported by membership dues, course fees, and corporate underwriting for specific programs. It receives no state or university funding.

"CONNECT's core programs focus on the needs of start-up and early stage companies….Through various screening processes, promising entrepreneurs can qualify to participate in programs for start-ups such as Springboard, major financial forums such as the San Diego Technology Financial Forum and the San Diego Biotechnology Corporate Partnership Forum."

CONNECT offers annual awards through the Most Innovative New Products program, encourages women entrepreneurs through the Athena program, and offers seminars, roundtables, and luncheons to provide educational and networking opportunities. University and civic leadership are vitally connected and open to needs and ideas through CONNECT.

CONNECT's members consist of hundreds of local and regional companies and fourteen regional organizations, including BIOCOM/San Diego. BIOCOM is a trade association with more than 300 members from biotechnology, bioscience, and bioagriculture industries, and support companies. They advocate at federal, state, and local levels for regulatory, tort, and economic reform and work for infrastructure improvement in areas such as housing, transportation, water, and workforce.

No one would dispute that CONNECT has been good for the San Diego community. Its success is attributable to the wisdom and energy of a number of talented and dedicated people. In addition to Dr Atkinson and Dr Walshok, critical leadership was supplied by Dr Monroe Trout, who served on the advisory board of CONNECT for many years before retiring and moving to Knoxville, TN, where he and his wife now reside. I first learned of CONNECT while having lunch with Dr Trout in Knoxville last month. Dr Trout, trained as a physician, served as Director of Research for Sterling Drug Company for 10 years and more recently as Chairman of the Board of CYTYC, Inc. Dr Trout had strong friendships in both academic and business circles and worked tirelessly to build constructive relationships between them. One barometer of CONNECT's success during his tenure is that corporate giving to UCSD increased from about $40 million to almost $90 million in two successive years.

Although CONNECT began in 1985, its first director, William W. Otterson, was not hired until six months later. Bill Otterson, a Stanford-trained engineer, had been in sales for IBM, but had become disillusioned with his career path within the company and had resigned. His entrepreneurial and networking skills were a great match for CONNECT, and he continued to provide high-profile leadership for many years while battling a severe form of cancer until his death only recently. Complementary organizational leadership was provided by Barbara Bry, a Harvard-educated reporter for the *Los Angeles Times* who resigned to work with CONNECT shortly after its founding. Barbara is now Executive Director of the CONNECT Athena program and is a successful entrepreneur in her own right.

As I visited with Jennifer Andrews, Dr Abigail Barrow, Director of Programs, and Carole Ekstrom, Director of Membership & Sponsors, at CONNECT last month, I was grateful for the insight of Dr Atkinson and Dr Walshok, for the energy of Dr Trout, for the enthusiasm and skills of Mr Otterson and Ms Bry, and for the excitement of Jen, Abi, and Carole as they shared the past and their vision of the future with me. I thought about friends like Geert Schmid-Schonbein, Shu Chien, Andy McCulloch, and John Frangos and about how much they had benefited from and contributed to the wonderful bioengineering environment in San Diego and at UCSD. I wondered: How many other communities have stories like San Diego's to tell? In how many communities are there similar seeds of success, waiting for the right circumstances to germinate and ripen?

My enduring impression from CONNECT is the close connection of apparent failure to success. A second-place finish in a national competition—a poor prognosis in a lethal disease process—an unpleasant job prospect—culminated in unimaginable fruition and satisfaction, because good people refused to take "no" for an answer. I remember those times in my life of greatest apparent failure and subsequent opportunities for accomplishment and success. And I recall once more the words of Winston Churchill, himself a failure at several of his enterprises, to the boys at Harrow School in October 1941. "Never give in, never give in, never, never, never, never…." ■

BMES Members Deliver Cell Adhesion Course at Industrial Site

Kevin C. Warnke, PhD, Abbott Laboratories

One of the most promising avenues for increasing the level of interaction between the BMES and industry is through the delivery of scientific education courses. As a demonstration of this capability, BMES member Dr Klaus Ley of the University of Virginia and myself from Abbott Laboratories organized a 2-day course on cell adhesion delivered at Abbott last June.

Selection of the topic was a crucial decision for this pilot demonstration. Cell adhesion was chosen, as it is of high interest to BMES members and to several organizations within Abbott's pharmaceutical and diagnostics divisions. Further definition of the course content was helped by my communication with R&D group leaders most involved with cell adhesion research. That this topic was appropriately chosen was reflected by the immediate registration of the full course capacity of 30 attendees within 2 days of the course's announcement to Abbott scientists.

Dr Ley delivered the course at Abbott's corporate headquarters, assisted by his postdoctoral student Brad Forlow. Their presentations were followed by a seminar with one of Abbott's primary researchers in the field, Greg Okasinski, who focused on the Abbott Pharmaceutical Products Division's current investigations in cell adhesion. This presentation stimulated a productive interchange between Abbott scientists from different divisions and the guests. Overall assessments from the attendees gave the course a strong endorsement as being interesting and valuable.

The demonstration nature of this project, at least as far as the BMES is concerned, yielded several useful lessons for future courses. Confidentiality agreements executed in advance enable productive interaction between the academic and industrial scientists. Adding a postdoctoral or graduate student as a second instructor proved to be valuable, giving him experience in the corporate environment and giving the attendees some variety in the instruction. Both the guest instructors and the course attendees appreciated the related presentation by a company scientist.

One weakness in the project was the lack of information to the instructors on the backgrounds and areas of interest of the course attendees. At a large company such as Abbott, attendees will (and did) range from newly assigned researchers seeking basic knowledge to senior researchers who had been working in the field for many years. A summary of attendees' interests and backgrounds, provided to the instructors in advance, would have yielded more effective preparation and delivery.

The big lesson for BMES, however, is that courses such as this will find an enthusiastic audience in the industrial world. A worthwhile objective for the Society is to develop a menu of courses in BMES members' areas of research that can be disseminated to large and small companies in the medical products and pharmaceutical industry. This effort should pay dividends in increasing the amount of scientific interaction between academic and industrial researchers and enhance BMES' reputation as the leading scientific organization in the Biomedical Engineering field. ■

Kevin Warnke is a member of the BMES Board of Directors and Chair of the BMES Industrial Affairs Committee.

BMES Fund

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Biomedical Engineering in the 21st Century: Medical Imaging

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Keywords: Diagnostic imaging, magnetic resonance imaging, computed tomography, kinestatic charge detector

Introduction

The start of a new millennium in western civilization also represents the beginning of the second century of medical imaging. Just over a hundred years ago, the first in vivo images of internal human anatomy were made using newly-discovered x-ray beams and photographic film. Several technological improvements were made in x-ray imaging technology in the first half of the twentieth century. However, no fundamentally new imaging techniques were developed until the second half of the last century, when ultrasonography, nuclear imaging, computed tomography (CT) and magnetic resonance imaging (MRI) became part of the arsenal of diagnostic medicine. Since that time, the performance and capabilities of medical imaging instruments have improved at a remarkable rate. Medical imaging now represents a major focus of activity in the field of biomedical engineering in academia, industry and medicine. Biomedical engineers are involved in virtually every aspect of medical imaging technology, from the development of innovative instrumentation, through production of reliable equipment for clinical applications, to cutting-edge biomedical research to expand the knowledge of living systems in health and disease. In this review we will briefly outline some basic characteristics that distinguish the primary medical imaging modalities, then summarize research interests of the authors that are illustrative of the wide range of roles that biomedical engineers can play in the continuing development of medical imaging technology.

Imaging Parameters

Medical imaging modalities are characterized by the ways in which they facilitate medical diagnosis. A summary of most of the important parameters follows. See the textbook by Macovski for a quantitative treatment of the fundamental principles of modern medical imaging instruments (1).

Spatial resolution: The ability to visualize and differentiate fine structure. Here, x-radiography is premier, with clinical mammographic resolution of 25 µm. Clinical CT and MRI scanners have resolution of hundreds of microns, and small-field versions (including microscopes) of tens of microns. Nuclear medicine and ultrasound typically have much lower resolution (hundreds of microns to millimeters).

Contrast resolution: The ability to visualize differences in material (tissue) composition. This parameter is more difficult to specify because, unlike physical size, contrast is not a single property of tissue. Contrast resolution involves several issues, including the facts that: (i) the material parameter discriminated by every modality is different; (ii) some modalities, like nuclear medicine, do not visualize the tissue itself, but detect radiopharmaceutical agents administered into the tissue; (iii) some, like ultrasound, mainly detect tissue difference at the interfaces between tissues; and (iv) others, like X-ray and MRI, can achieve improved contrast resolution when specific types of pharmaceuticals (contrast agents) are administered.

Sensitivity: The ability to visualize the least alterations to tissue. Here, nuclear medicine is the uncontested winner, since it can detect and visualize the location of individual molecules of a radiopharmaceutical administered (usually intravenously) into tissue. Hence, in a sense, the radiopharmaceutical plays the role of a "super contrast agent."

Temporal resolution: The ability to collect the image data in the least amount of time. In practice, this is important for rapidly moving anatomical organs, such as the heart and its surrounding structures. Digital x-rays can be made in a few milliseconds and specialty CT scans (such as dedicated cardiac scanners) in a few tens of milliseconds. Microsecond-speed CT scanners have been designed but not built. Cardiac ultrasonography is often useful.

Visualization of motion: The ability to perform "real-time" imaging. Many modalities allow real-time imaging and are used for cardiology and blood flow studies, swallowing, peristalsis, and similar uses. These include radiography (using image intensifiers or some flat-plate detectors), ultrasonography (including Doppler ultrasound), and MRI.

Visualization of function: The ability to observe metabolic, neuronal or other biochemical or biophysical activity. A form of nuclear imaging (positron-emission tomography, PET) was the first to enable the visualization of metabolism because positron emitters are usually low-atomic number elements and hence are present in biologically-active molecules. Since then, functional MRI has made rapid advances in this field, based on the relation of neuronal activity to microvascular activity and oxygenation.

Generality of imaging: The ability to visualize the widest class of anatomy. The leading candidate here is probably CT because all bodily tissues attenuate x-ray photons and the capability to image specific anatomical regions is never blocked (unless highly-attenuating, foreign materials such as metallic implants are present). This parameter is considered to be inde-

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pendent of contrast resolution.
Invasiveness: The ability to make repeated examinations with no apparent health effects. In this classification, the leading imaging modalities are those that avoid ionizing radiation, namely, ultrasonography and MRI.

Brain Iron and MRI

Magnetic resonance imaging has emerged as one of the most important imaging modalities for clinical application and biomedical research. MRI is noninvasive, affords good spatial and temporal resolution, and unrivaled contrast resolution. The tremendous range of tissue contrasts that can be achieved with MRI derives from the number of material properties that can modulate tissue signal intensity in MR images. These properties include water proton density (PD), proton magnetic relaxation times (T1, T2), motion, and magnetic susceptibility. Fortunately, these physical properties are closely coupled to many important physiological properties of tissue, so MRI signal intensity can reflect a wide range of functional information about tissue. An interesting example, the use of MRI to investigate distribution of iron in the human brain, is described below.

Brain Iron

Iron is essential to many developmental and functional processes in the brain (2-4), but free iron can also play a major role in oxidative injury to the brain via lipid peroxidation (5-8). Therefore, stringent regulation of iron in the brain is necessary to maintain homeostasis. The amount of iron in the brain varies widely by region and generally increases with age, with concentrations in the adult ranging from nearly zero in the medulla oblongota to levels in the globus pallidus that may exceed those found in the liver (9,10). Iron and the iron regulatory proteins ferritin and transferrin are found primarily in oligodendrocytes and in relative amounts that vary with age and among regions within the brain (11-20). The work of Hallgren and Sourander (9) still stands as the reference for age-related changes in regional brain iron concentration. This paper is particularly useful because it includes regression equations for the age-related changes in regional brain iron concentration that can be used for analysis of other brain tissue parameters of experimental interest.

Ferritin

The mechanisms of iron homeostasis in the brain are poorly understood. The ferritin protein plays a major role in storage and utilization of iron in the brain and has been shown to have a major impact on brain MRI. Each ferritin molecule consists of different ratios of H (heavy) and L (light) chain subunits. The subunits are coded on different chromosomes, and appear to play different roles in the function of the ferritin molecule. The H-rich ferritin is efficient at iron sequestration and is predominant in organs with high iron utilization and little iron storage (21). In contrast, L-rich ferritin is efficient at iron nucleation and is associated with iron storage. In the brain, various cell types contain ferritin isoforms that are consistent with their functional roles (20,22). Mossbauer spectroscopy of brain tissue samples indicate that approximately 80% of brain iron is in ferritin, at least in the iron-rich basal ganglia (23). Ferritin has unique magnetic properties (24) and is believed to be the major source of iron-induced changes in MR tissue relaxation times (23).

Brain Iron and Disease

Disruptions of iron metabolism are associated with many central nervous system (CNS) pathologies (10, 20, 25-31), including Parkinson's Disease, Alzheimer's Disease, radiation injury, fetal alcohol syndrome, ischemic-anoxic insults in children, and Friedreich's ataxia. It is unclear to what extent, and in what diseases, iron disregulation has a primary role in pathogenesis or is secondary to other pathological processes. A major motivation for development of MRI methods in this area is to investigate brain iron in relation to human CNS pathology, where invasive iron measurements are impossible.

MRI

In the following, note that relaxation times, T1 and T2, characterize the rates at which the water protons in tissue (or any material) approach equilibrium with the applied magnetic field of the MRI system. The longitudinal relaxation time, T1, is the rate constant for recovery of magnetization components parallel to the applied field, and the transverse relaxation time, T2, is the rate constant for decay of magnetization components orthogonal to the applied field. T2' is the rate constant for decay of magnetization caused by static inhomogeneity of the local magnetic field, e.g., susceptibility effects of brain iron. Readers are referred to the excellent monograph by Haacke et al. for a comprehensive review of the physical principles of MRI (32).

Most work in the field has focused on the relationship between T2 and brain iron. Signal loss on T2-weighted imaging has been associated with regions of high iron deposition, particularly in the basal ganglia and dentate nucleus of the cerebellum (33-38). The signal loss in regions of high iron deposition has been attributed to apparent T2 shortening caused by diffusion through local iron-induced magnetic field gradients. In field dependent T2-weighted image measurements in rhesus monkeys, gray/white matter signal intensity ratios (SIR) were correlated with a signal model based on iron concentration as determined by optical density of brain sections stained with Perl's method (37). Field-dependent increases in transverse relaxation rate in several brain regions (39, 40), differences in T2' in the substantia nigra between Parkinson's disease patients and age-matched control subjects (41), and changes in measured transverse relaxation rate with respect to inter-echo time intervals (42) have been correlated with brain iron. In phantom measurements with iron, ferritin, transferrin, apoferritin, and apotransferrin, only ferritin in physiological concentrations caused field dependent relaxation rate changes similar to those observed *in vivo* (39). However, the transverse relaxation rate for ferritin in solution and for tissue samples from iron-rich brain structures has a linear

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dependence on field strength, contrary to the quadratic increase predicted by a model assuming diffusion as the primary relaxation mechanism (43-46).

Fewer studies have investigated the relationship between T1 relaxation and brain iron. A retrospective analysis of standard T1- and T2-weighted images showed that gray/white signal intensity ratio (SIR) was correlated with putative regional and age-related changes in brain iron concentration (47). We analyzed age-related changes in brain T1 from 115 healthy subjects (4.5 – 71.9 yr) in relation to published regional brain iron concentration in cortex, caudate, putamen and frontal white matter (48). The relaxation rate in these structures was linear with respect to iron concentration. The large number of subjects included in this study permitted accurate estimation of regional iron relaxivity. The iron relaxivity, k_1 (s^{-1}/mg iron/g wet weight), was much higher in cortex (5.5) and white matter (6.1) than in caudate (1.7) and putamen (1.0). These results are consistent with evidence that iron is an important factor in determining the relaxation properties of brain tissue. Differences in iron relaxivity may reflect regional differences in the magnetic state of brain iron and/or in the interaction of brain iron with tissue water.

To investigate the relationship between the magnetic susceptibility of brain tissue and iron concentration, we measured phase shifts in gradient-echo images and compared them with published values of regional brain iron concentration (49). Our hypothesis was that MR signal phase would reflect iron-induced differences in tissue magnetic susceptibility. We found that phase was correlated with brain iron concentration in putamen, caudate, motor cortex, globus pallidus, and frontal cortex, but not in white matter. Figure 1A shows representative images at the level of the substantia nigra and red nucleus. Note the striking contrast of these iron-rich structures in the phase image. Figure 1B shows graphs of phase vs. iron concentration from the motor cortex and caudate nucleus. These results suggest that magnetic resonance phase reflects iron-induced differences in brain tissue susceptibility in gray matter. The lack of correlation in white matter may reflect important differences between gray and white matter in the cellular distribution and the metabolic functions of iron. Magnetic resonance phase images provide insight into the magnetic state of brain tissue and are expected to be useful in elucidating the relationship between brain iron and tissue relaxation properties.

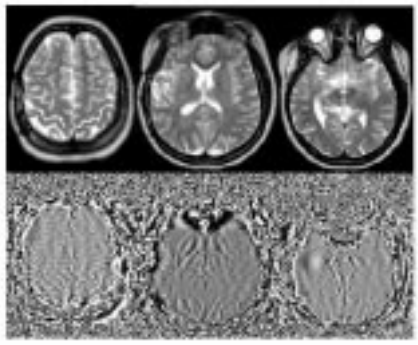

Figure 1-A Representative T2-weighted and phase images from a 16 year old subject.

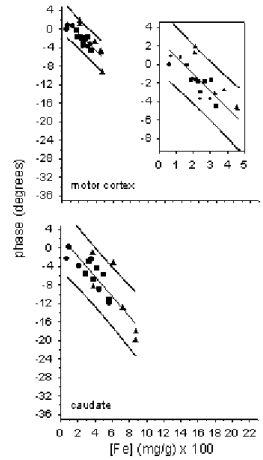

Figure 1-B Plots of phase vs iron concentration for caudate nucleus and motor cortex.

Relatively little has been published regarding the magnetic properties of white matter or the relationship of white matter relaxation times to tissue iron concentration. Quantitative studies of brain iron indicate that white matter iron concentration is equal to, or may exceed, gray matter iron concentration, and that it changes with age in a similar way (9,50). Field-dependent changes in white matter T2 relaxation rate were consistent with iron concentration (39). Measurements of T2' in the white matter at 3.0 Tesla were well correlated with iron concentration, even though measurements of T2 were not (51). In our study of age-related changes in T1 (48) white matter T1 was highly correlated with putative iron concentration. However, in our pilot study with gradient-echo phase imaging (49), we observed no systematic change in white matter phase with age. This discrepancy may be related to important structural and functional differences between white and gray matter in the brain (14,52).

Summary

Ongoing research into the relationship between brain iron and MRI promises exciting new developments in areas ranging from basic neuroscience to clinical neuroimaging. Despite the importance of iron in brain development and function, and its association with many CNS diseases, the fundamental mechanisms of iron regulation and distribution in the brain are not well understood. MRI methods to measure noninvasively the amount and biochemical form of iron in the human brain will shed new light on this important area of biomedical research. Conversely, the natural temporal and regional patterns of iron accumulation in the brain offer unique opportunities to investigate the role of brain iron in tissue MR relaxation processes. Understanding the fundamental determinants of tissue relaxation times will improve the interpretation of standard clinical images and facilitate the development of more quantitative methods for routine diagnostic imaging. Finally, important new methods for functional neuroimaging that rely on rapid echo-planar imaging (e.g., perfusion, diffusion, activation) will be improved by evaluating the confounding effects of iron-induced changes in brain tissue magnetic susceptibility.

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New Instrumentation for Medical Imaging

Digital Radiography

The motivation for digital radiography is well-known and includes improved detector performance, including spatial, contrast and temporal resolution, linearity and dynamic range, and a host of benefits of on-line, digital imaging (53-69). The Kinestatic Charge Detector (KCD) uses a strip- (or slot-) beam geometry and was developed in an attempt to achieve optimum radiographic image quality (spatial resolution, detective quantum efficiency, compromise between scatter rejection and x-ray tube loading, and image field size) (70-74). The KCD employs a high-pressure krypton drift chamber. The chamber is scanned at the same velocity, but in the opposite direction to that of the ions produced in the chamber by detected x-ray photons. Thus, the ions are moving (kinetic) in the chamber reference system but stationary (static) in the patient reference system, and hence, "kinestatic." This allows signal integration during the entire time that the active part of the chamber sweeps past a point in the patient anatomy without ionic-motion blurring.

Several generations of KCD systems, including single-channel and few-channel non-imaging test bench detectors, as well as small-field and full-field (2016-channels) imaging prototypes, have been developed and evaluated (79-78). The full-field KCD scanner yielded 9 lp/mm spatial resolution coupled with high contrast resolution and extremely low scatter acceptance. Sample images from the full-field prototype KCD scanner are illustrated in Figure 2. Figure 2A shows a KCD scan of a volunteer subject and Figure 2B shows a film radiograph of the same subject. Enhanced visibility of internal anatomy is evident in the KCD scan.

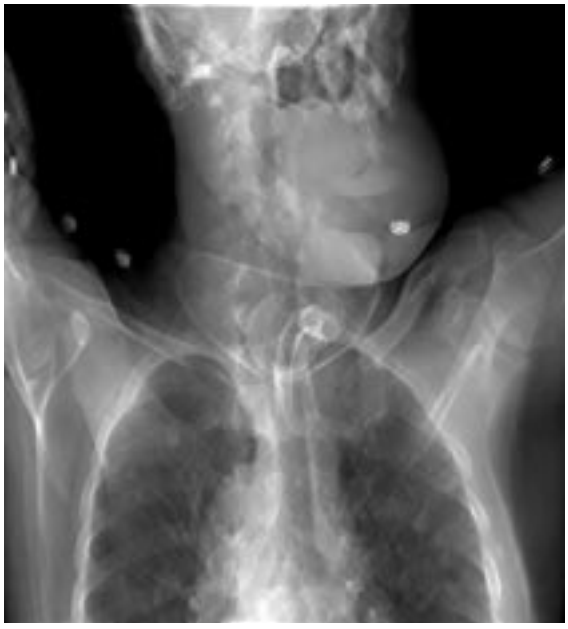

Figure 2A In vivo head and chest images using the kinestatic charge detector (KCD).

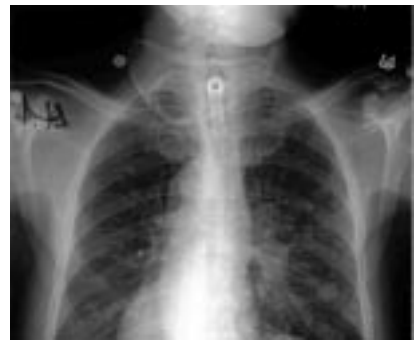

Figure 2B (Plots of phase vs iron concentration for caudate nucleus and motor cortex.) Film radiograph of the same subject.

Variable High-resolution CT

The CT scanner provided the first 3-dimensional digital images of internal human anatomy and initiated the "computer revolution" in diagnostic imaging (79,80). After major gains in clinical imaging performance in the first fifteen years (1970-1985), progress has abated somewhat in the last fifteen years (1985-2000). In the earlier period, resolution increased by more than a factor of 12 from ~ 5 mm to ~ 0.4 mm, whereas in the latter period, it only further increased by less than a factor of 2 to ~ 0.25 mm. Likewise, slice scan time decreased by a factor of 300 from ~ 5 min to ~ 1 s in the earlier period, but only by perhaps a factor of two to ~ 0.5 s in the latter period. This comparison excludes special-purpose instruments such as electron beam heart scanners and small-field CT microscopes (81-86).

One major deficiency of all clinical CT scanners is that the detector arrays are tailored to the largest anatomical field size expected (usually about 50 cm). For small anatomy, such as a 10 cm diameter neck, constricted breast, extremity or pediatric subject, 80% of the detector capacity is wasted. Moreover, there is no improvement in spatial resolution even though the reconstruction field required is 5 times smaller. This deficiency could be overcome if there were a way to "shrink" the detector array to match the anatomical field size. The Variable-Resolution X-ray (VRX) CT detector accomplishes this by changing the detector's projected size to match any reduced field size and proportionately boosts the detector's spatial resolution (87,88). This is achieved by either detector angulation or by using a stair-stepped geometry. The VRX geometry is ideally-suited for rotating detector (third generation) CT scanning.

Initial measurements of the limiting spatial resolution of VRX test detectors have yielded 63 cy/mm (8 µm). Analysis and computer modeling indicates that total CT system resolution exceeding 100 cy/mm (5 µm) is possible with a 100 µm X-ray focal spot. Ultimate VRX detector resolution for 0.6 mm cells is approximately 700 nm limited (for the angulated geometry only) by x-ray reflection.

For the prototype VRX CT system, the scan subject is rotated on a turntable while an angulated storage-phosphor detector is translated to record a CT sinogram from which the CT image is

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reconstructed. Scan time with this system is 4.8 s. Figures 3A and 3B show CT reconstructions of a plasticized section of a human forearm made with the prototype VRX CT scanner and a clinical CT scanner, respectively. The improved resolution of the VRX CT is evident.

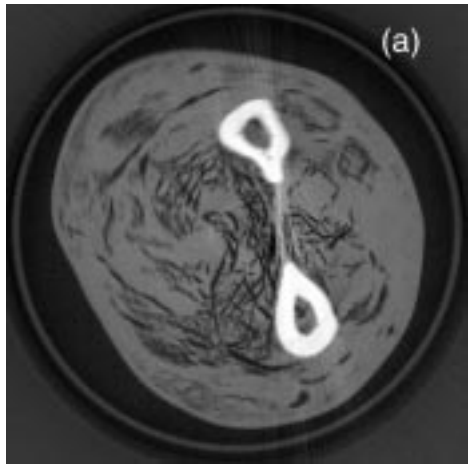

Figure 3A Variable-resolution X-ray CT scan of plasticized human forearm.

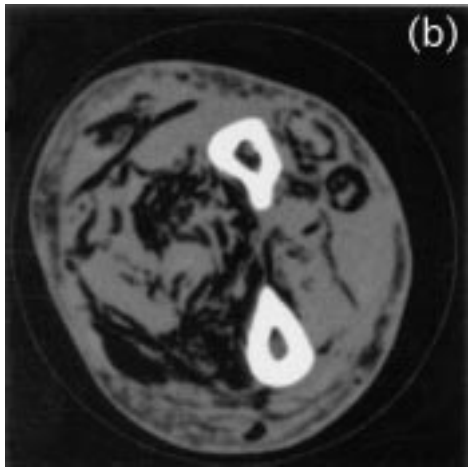

Figure 3B Clinical CT scan of same subject.

Summary

In summary, dozens of technologies have undergone research for digital radiography over the past 25 years and which method is best for clinical use remains to be seen. Certainly, intensifying screens coupled to amorphous silicon arrays, selenium charge plates and the kinestatic charge detector have given the most impressive images to date in the diagnostic regime. For mega-voltage portal imaging, good results have been obtained with electronic detectors including clear scintillators coupled to CCD arrays and also with the kinestatic charge detector. Regarding CT imaging, which represents a much more mature technology, there has been less research on the detection device physics of late. Most of the focus has been on improving x-ray tube technology and reducing total scan time via spiral scanning using multi-slice detectors along with the associated research in image reconstruction techniques.

Conclusions

The rate of improvements of medical imaging technology that occurred in the last half of the twentieth century shows no signs of slowing in the new millennium. The four basic imaging modalities (x-ray/CT, nuclear medicine, ultrasound and MRI) have all become irreplaceable for medical diagnosis. The development of quantitative methods in all imaging modalities has the potential to allow physicians to monitor disease development and therapy with greater precision than was heretofore possible. Functional and metabolic imaging (magnetic resonance and positron nuclear imaging) has opened new vistas previously thought unattainable, and have created new applications for medical imaging instruments in basic biomedical research. The ongoing development of medical imaging technology will create exciting opportunities for biomedical engineers in the 21st Century.

Acknowledgments

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References

1. Macovski, A., Medical Imaging Systems, Prentice Hall, Englewood Cliffs, NJ, 1983.
2. Octave, J.N., Schneider, Y.J., Trouet, A. and Crichton, R.R. *TIBS* 8:217-220, 1983.
3. Crichton, R.R. *TIBS* 9:283-286, 1984.
4. Youdim, M.B.H. Brain Iron Metabolism: Biochemical and Behavioral Aspects in Relation to Dopaminergic Neurotransmission. In: *Handbook of Neurochemistry*, edited by Lajtha, A. New York: Plenum Press, 1985, p. 731-755.
5. Zhang, J.R., Scherch, H.M. and Hall, E.D. *J. Neurochem.* 66:355-361, 1996.
6. Michel, P.P., Vyas, S. and Agid, Y. *J. Neurochem.* 59:118-127, 1992.
7. Ben-Shachar, D., Riederer, P. and Youdim, M.B.H. *J. Neurochem.* 57:1609-1614, 1991.
8. Halliwell, B. and Gutteridge, J.M.C. *TIBS* 11:372-375, 1986.
9. Hallgren, B. and Sourander, P. *J. Neurochem.* 3:41-51, 1958.
10. Loeffler, D.A., Connor, J.R., Juneau, P.L., et al. *J. Neurochem.* 65:710-716, 1995.
11. Hill, J.M. and Switzer, R.C.I. *Neurosci.* 11:595-603, 1984.
12. Dwork, A.J., Schon, E.A. and Herbert, J. *Neurosci.* 27:333-345, 1988.
13. Gerber, M.R. and Connor, J.R. *Ann. Neurol.* 26:95-98, 1989.
14. Connor, J.R., Menzies, S.L., St.Martin, S.M. and Mufson, E.J. *J. Neurosci. Res.* 27:595-611, 1990.
15. Taylor, E.M., Crowe, A. and Morgan, E.H. *J. Neurochem.* 57:1584-1592, 1991.
16. Morris, C.M., Keith, A.B., Edwardson, J.A. and Pullen, R.G.L. *J. Neurochem.* 59:300-306, 1992.

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17. Benkovic, S.A. and Connor, J.R. *J. Compar. Neurol.* 338:97-113, 1993.
18. Roskams, A.J.I. and Connor, J.R. *J. Neurochem.* 63:709-716, 1994.
19. Skarlatos, S., Yoshikawa, T. and Pardridge, W.M. *Brain Res.* 683:164-171, 1995.
20. Connor, J.R., Snyder, B.S., Arosio, P., Loeffler, D.A. and LeWitt, P. A. *J. Neurochem.* 65:717-724, 1995.
21. Levi, S., Yewdall, S.J., Harrison, P.M., et al. *Biochem. J.* 288:591-596, 1992.
22. Connor, J.R., Boeshore, S.A., Benkovic, S.A. and Menzies, S.L. *J. Neurosci. Res.* 37:461-465, 1994.
23. Brooks, R.A., Vymazal, J., Goldfarb, R.B., Bulte, J.W.M. and Aisen, P. *Magn. Reson. Med.* 40:227-235, 1998.
24. Makhlouf, S.A. and Parker, F.T. *Phys. Rev. B* 55:14717-14720, 1997.
25. Jenner, P. *The Lancet* 344:796-798, 1994.
26. Hallgren, B. and Sourander, P. *J. Neurochem.* 5:307-310, 1960.
27. Gerlach, M., Ben-Shachar, D., Riederer, P. and Youdim, M.B.H. *J. Neurochem.* 63:793-807, 1994.
28. Miller, M.W., Roskams, A.J.I. and Connor, J.R. *J. Neurochem.* 65:373-380, 1995.
29. Kennard, M.L., Feldman, H., Yamada, T. and Jefferies, W.A. *Nature Med.* 2:1230-1235, 1996.
30. Dietrich, R.B. and Bradley, W.G. *Radiology* 168:203-206, 1988.
31. Babcock, M., de Silva, D., Oaks, R., et al. *Science* 276:1709-1712, 1997.
32. Haacke, E.M., Brown, R.W., Thompson, M.R., and Venkatesan, R., Magnetic Resonance Imaging: Physical Principles and Sequence Design, Wiley-Liss, New York, 1999.
33. Drayer, B.P., Burger, P., Darwin, R.H., Riederer, S.J., Herfkens, R. and Johnson, G.A. *Am. J. Roentgenology* 147:103-110, 1986.
34. Drayer, B.P. *Radiology* 166:785-796, 1988.
35. Curnes, J.T., Burger, P.C., Djang, W.T. and Boyko, O.B. *Am. J. Neuroradiol.* 9:1061-1068, 1988.
36. Aoki, S., Okada, Y., Nishimura, K., et al. *Radiology* 172:381-385, 1989.
37. Bizzi, A., Brooks, R.A., Brunetti, A., et al. *Radiology* 177:59-65, 1990.
38. Thomas, L.O., Boyko, O.B., Anthony, D.C. and Burger, P.C. *Am. J. Neuroradiol.* 14:1043-1048, 1993.
39. Bartzokis, G., Aravagiri, M., Oldendorf, W.H., Mintz, J. and Marder, S.R. *Magn. Reson. Med.* 29:459-464, 1993.
40. Bartzokis, G., Beckson, M., Hance, D.B., Marx, P., Foster, J.A. and Marder, S.R. *Magn. Reson. Imag.* 15:29-35, 1997.
41. Ordidge, R.J., Gorell, J.M., Deniau, J.C., Knight, R.A. and Helpern, J.A. *Magn. Reson. Med.* 32:335-341, 1994.
42. Ye, F.Q., Martin, W.R.W. and Allen, P.S. *Proc. SMR* 3:1234-1234, 1995. (Abstract)
43. Vymazal, J., Hajek, M., Patronas, N., et al. *J. Magn. Reson. Imag.* 5:554-560, 1995.
44. Vymazal, J., Brooks, R.A., Zak, O., McRill, C., Shen, C. and Di Chiro, G. *Magn. Reson. Med.* 27:368-374, 1997.
45. Vymazal, J., Zak, O., Bulte, J.W.M., Aisen, P. and Brooks, R.A. *Magn. Reson. Med.* 36:61-65, 1996.
46. Vymazal, J., Brooks, R.A., Baumgarner, C., et al. *Magn. Reson. Med.* 35:56-61, 1996.
47. Brooks, R.A., Vymazal, J., Bulte, J.W.M., Baumgarner, C. and Tran, V. *J. Magn. Reson. Imag.* 4:446-450, 1995.
48. Ogg, R.J. and Steen, R.G. *Magn. Reson. Med.* 1998.(in press)
49. Ogg, R.J., Langston, J.W., Haacke, E.M., Steen, R.G. and Taylor, J.S. *Magn. Reson. Imag.* 1998 (submitted).
50. Connor, J.R., Snyder, B.S., Beard, J.L., Fine, R.E. and Mufson, E.J. *J. Neurosci. Res.* 31:327-335, 1992.
51. Gelman, N., Gorell, J.M., Barker, P.B., Savage, R.M., Spickler, E.M., Windham, J.P., and Knight, R.A. *Radiology* 210:759-767, 1999.
52. Connor, J.R. and Menzies, S.L. *GLIA* 17:83-93, 1996.
53. Stein, J.A. *Radiology* 117:713, 1975.
54. Kruger, R.A, Mistretta, C.A., Lancaster, J. et al. *Opt. Eng.* 17:652-657, 1978.
55. Foley, W.D., Lawson, T.L., Scanlon, G.T., Heeschen, R.C. and DiBianca, F.A. *Radiology* 133:213-234, 1979.
56. Mattson, R.A., Sones, R.A., Stickney, J.B. et al. *Proc. Int. Soc. Opt. Eng. (SPIE)* 314:160-163, 1981.
57. Drost, D.J. and Fenster, A. *Med. Phys.* 9:224-230, 1982.
58. Sonoda, M., Takano, M., Miyahara, J. and Kato, H. *Radiology* 148:833-838, 1983.
59. Papin, P.J., Mankovich, N.J., Barbaric, Z. and Huang, H.K. *Proc. Int. Soc. Opt. Eng. (SPIE)* 454:265-270, 1984.
60. Wang, S.P., Zeilinga, J., Hunt, R.P., Specht, D.F. and Enck, R.S. *Proc. Int. Soc. Opt. Eng. (SPIE)* 454:250-256, 1984.
61. Meertens, H., van Herk, M. and Weeda, J. *Phys. Med. Biol.* 30:313, 1985.
62. Kennedy, W.H., Herron, J.M., Gur, D., Miller, S.L., Good, W.F. and Good, B.C. *Med. Phys.* 12:494, 1985.
63. Beerlage, M.J.M., Levels, H.P.L. and Mulder, H. *Proc. Int. Soc. Opt. Eng. (SPIE)* 626:161-169, 1986.
64. Nelson, R.S., Barbaric, Z., Bassett, L.W. and Zach, R. *Proc. Int. Soc. Opt. Eng. (SPIE)* 767:102-108, 1987.
65. Holdsworth, D.W., Nishikawa, R.M., Mawdsley, G.E., Yaffe, M.J. and Fenster, A. *Proc. Int. Soc. Opt. Eng. (SPIE)* 1090:306-313, 1989.
66. Nishikawa, R.M., Mawdsley, G.E., Fenster, A. and Yaffe, M.J. *Med. Phys.* 17:717-727, 1990.
67. Munro, P., Rawlinson, J.A. and Fenster, A. *Int. J. Rad. Oncol. Biol. Phys.* 18:641, 1990.
68. Antonuk, L.E., Yorkston, J., Morton, E.J., Boudry, J., Kim, C.W. and Longo, M.J. *Med. Phys.* 18:610, 1991.
69. Que, W. and Rowlands, J.A. *Med. Phys.* 22:361, 1995.
70. DiBianca, F.A. and Barker, M.B. *Med. Phys.* 12(3):339-343, 1985.
71. Peyret, O. Ph.D. Dissertation, National Polytechnic Institute of Grenoble. 1985 (unpublished).
72. Wagenaar, D.J., DiBianca, F.A., Tenney, C.R., Vance, J.E., Reed, M.S.C., Wilson, D.W. and Dollas, A. *Rev. Sci. Instr.* 61(2):701-711, 1990.
73. Jordan, L. and DiBianca, F. *J. X-ray Sci. and Tech.* 5 (2):228-247, 1995.
74. Tenney, C. Ph.D. Dissertation, University of North Carolina at Chapel Hill, 1997.
75. DiBianca, F.A., Wagenaar, D.J., Fetter, J.E., Vance, J.E., Bolz, M.J., McDaniel, D.L. and Granfors, P. *Proc. Int. Soc. Opt. Eng. (SPIE)* 626:150-160, 1986.
76. DiBianca, F.A., Fetter, J.E., Tenney, C.R., Vance, D.J., McDaniel, D.L. and Granfors, P. *Proc. Int. Soc. Opt. Eng. (SPIE)* 767:92-101, 1987.
77. DiBianca, F.A., Devidas, S., Giakos, G., Kollipara, S., Laughter, J., Mahmud, A., Nagarajan, S., Peng, Q., Rodriguez, C. and Zeman, H. *Proc. Int. Soc. Opt. Eng. (SPIE)* 2432:402-413, 1995.
78. DiBianca, F.A., Rodriguez, C., Devidas, S., Emerson, D., Gaber, M., Giakos, G., Gold, R., Jordan, L., Kaufman, R., Kollipara, S., Laughter, J., Mahmud, A., Nagarajan, S., Peng, Q., Jamieson-Price, P., Sebes, J.I., Zeman, H. and Zhu, Z. *Proc. Int. Soc. Opt. Eng. (SPIE)* 2708:826-836, 1996.
79. Cormack, A.M. *J. App. Phys.* 34, 2722, 1963.
80. Hounsfield, G.N. Br. *J. Radiol.* 46, 1016, 1973.
81. Boyd, D.P. and Lipton, M.J. *Proceedings of the IEEE*, 71: 298-307, 1983.
82. Boyd, D.P. and Haugland, C. *Med. Imag. Tech.* 11: 578-585, 1993.
83. Feldkamp, L.A., Goldstein, S. A. , Parfitt, A. M., Jesion, G. and Kleerekoper, M. *J. Bone Miner. Res.* 4(1):3-11, 1989.
84. Engelke, K., Graeff, W., Meiss, L., Hahn, M. and Delling, G. *Invest. Radiol.* 28(4):341-349, 1993.
85. Paulus, M. J., Sari-Sarraf, H., Gleason, S. S., Bobrek, M., Hicks, J. S., Johnson, D. K., Behel, J. K., Thompson, L. *Proc. of IEEE Nuclear Science Symposium*, 1998.
86. Sasov, A. and Van Dyck, D. *J. Microscopy* 191 (2), 151-158, 1998.
87. Gupta, V. M.S. Thesis, University of Tennessee, Memphis, 1998.
88. DiBianca, F.A., Gupta, V., Zou, P., Jordan, L.M., Laughter, J.S., Zeman, H.D. and Sebes, J. I. *Proc. Int. Soc. Opt. Eng. (SPIE)* 3659, 56-64 , 1999. ■

Of Interest

Office of the Director National Institutes of Health Department of Health & Human Services

Position: The Office of the Director (OD), National Institutes of Health (NIH), is seeking exceptional candidates for the position of Director, Office of Bioengineering, Bioimaging & Bioinformatics (OBBB). The incumbent will provide a focus for stimulating and coordinating the development of biomedical engineering, bioimaging & bioinformatics activities among the 25 Institutes & Centers (ICs) at NIH; and will facilitate the overall planning, development, and implementation of NIH biomedical engineering, bioimaging & bioinformatics research programs and activities. The Director, OBBB, will serve as a focal point for improving the quality of human health by increasing biological knowledge and facilitating development of novel devices and drugs through the use of engineering and physical science principles and techniques.

Challenge: This position offers a unique opportunity to create and direct the new Office of Bioengineering, Bioimaging & Bioinformatics that will report to the Director, NIH. With respect to bioengineering/bioimaging/bioinformatics research programs and activities, the incumbent will provide leadership in the development, refinement, and implementation of trans-NIH plans to increase the scope and support of activities in these areas; and will advise the NIH Director and other key officials regarding trends and developments having significant bearing on these programs. The Director, OBBB, will serve as spokesperson and liaison between the NIH intramural and extramural communities, other Federal agencies, academic and scientific societies, and other audiences on matters pertaining to biomedical engineering, bioimaging & bioinformatics research.

Qualifications Required: Applicants must possess a PhD, or equivalent in biomedical, bioengineering, bioinformatics, or health sciences, plus (1) demonstrated scientific leqadership, broad vision, and research excellence as a distinguished and recognized authority in bioengineering, bioimaging and/or bioinformatics; (2) executive-level management skills including the ability to build and maintain a culturally diverse staff; and (3) skill in oral and written presentation including negotiation and presentation skills, and the ability to represent the organization. Please submit current CV and bibliography to: Susan D. Elder, National Institutes of Health, Office of the Director Executive Office, 2 Center Dr, Rm 1W14, MSC 0205, Bethesda, MD 20892-0205. Questions may be addressed to **Susan-Elder@nih.gov** or 301-594-8258. Fax is 302-402-1368. TDD is 301-402-1970. Applicants may browse the NIH Home Page at **http://www.nih.gov**. ***Applications must be received no later than August 18, 2000.***

IUPS Congress Travel Awards…The US National Committee for the International Union of Physiological Sciences is seeking applications for travel awards for the XXXIV IUPS Congress in Christchurch, New Zealand, August 26-31, 2001. Information about the Congress is available at **http://www.iups2001.org.nz.** Travel award application forms are available on the APS web site at **http://www.faseb.org/aps/NewZealand.PDF.** The deadline for submission of applications for travel awards is January 31, 2001.

Eng-Tips Forums…are independent online discussion groups designed to help engineers of all disciplines solve work-related problems. Eng-Tips Forums are free and confidential discussions on any subject, product, or strategy within the engineering discipline. Membership in the forums is over 6,000, with new members signing on daily. The forums recently added a suite of Bioengineering forums for Bioengineers to meet and talk in. “Engineers, like other professionals, need a ‘safe,’ non-political place to go to solve technical issues that arise daily at work,” said Dave Murphy, president of Eng-Tips Forums. “On Eng-Tips, you can post a question within a particular discipline, and members respond with their collective experience to solve the problem. It’s like having your own staff of qualified experts on call.” Selling and recruiting are prohibited within the forums. Eng-Tips Forums make discussion easy for members and visitors, and members can remain anonymous. Unlike other online forums that have a high “noise level” from extraneous chatter, marketer intrusions, or “flaming” (criticizing) other people, Eng-Tips members enjoy a very focused and responsible level of discussion. Visit Eng-Tips Forums at **http://www.eng-tips.com**. ■

Committee Reports

Publications Board

Shu Chien, MD PhD, Chair

The Publications Board, composed of Carol Lucas, John Tarbell, and Shu Chien (Chair), is pleased to report recent progress, the current status, and future developments.

Our official journal, the *Annals of Biomedical Engineering* (ABME), under the Chief Editorship of Jim Bassingthwaighte, has continued to make excellent progress. It is the consensus of the community that ABME has become a top journal in the field. The rating from ISI, the Science Citation Impact Factor of ABME has continued to rise from 0.69 in 1994 to 1.38 in 1999, a remarkable doubling in 5 years. In 2000, ABME has gone from bimonthly (6 issues per year) to monthly (12 issues per year), with significant increases in the numbers of papers and pages to be published. This important change, which has been made possible by the generous support of the Whitaker Foundation, will further shorten the turnover time for manuscript publication and offer additional incentives for the submission of high-quality papers. Even prior to the implementation of this change to monthly publication, the submission rate already had increased at a significant rate. It is projected that it will increase to 240 submissions for year 2000, as compared to 175 in 1999. In addition to the regular submissions, the Journal will publish the manuscripts resulting from scientific symposia, as approved by the Editorial Board, and these manuscripts also will be subject to the same rigorous review. The Editorial Board and the reviewers continue to do an excellent job in assuring the high quality of ABME publication. The acceptance rate is about 50%, and it is anticipated that this will be maintained with the parallel rises in submission rate, quality of the submitted papers, and the number of pages to be published. While the success of the Journal is the result of outstanding teamwork by the BMES leadership, the editorial leadership, scientists working on the Editorial Board and as reviewers, the staff in the editorial office and Society office, and our publishing partner, a very critical factor is the number of high-quality manuscripts submitted. The journal cannot be better than the manuscripts it receives. The Publications Board respectfully requests all of our members to consider submitting your best papers to ABME.

An important ongoing event is the implementation of the BMES Board of Directors decision to move the ABME Editorial Office to the BMES National Office in Landover, MD. This will allow the close coordination of editorial functions with the Society headquarters, thus resulting in increases in efficiency and cost-effectiveness. The Editor-in-Chief (Jim Bassingthwaighte and his successors) will continue to function at his/her institution, but there will be close electronic link between the Editor-in-Chief and the BMES editorial office in Landover. As a result of the excellent recruiting efforts by our Executive Director Pat Horner, we are fortunate to have Charles Annecillo to work in the National Office as the Managing Editor of ABME beginning on April 3, 2000. Charles has an impressive background in both science and publication (see biographical sketch in this issue). We look forward to Charles' contributions to the continued progress of ABME at this critical juncture of its exciting development. Pat and Charles have worked closely with Jim in the transfer of files and programs to the new Editorial Office site, and they have made excellent progress. In order to further enhance our efficiency in manuscript review, we are exploring the various options of on-line review, which will be an important goal for this year. The implementation of on-line review will accelerate the turnover time for manuscript review and facilitate the coordination between the Editor-in-Chief's office and the Managing Editor's office, and communications with the Associate Editors, the Editorial Board, and reviewers, as well as the authors.

The Editor-in-Chief's Office has worked closely with the BMES Office and the American Institute of Physics (AIP) to implement the closing of free access to the on-line journal on April 3, 2000. The on-line journal will continue to be accessible to its subscribers, which include the BMES members, but non-subscribers now have to pay a fee to gain access.

AIP continues to be an effective publisher and has an excellent working relationship with our Editor-in-Chief's Office and with the new Managing Editor's office. The number of institutional subscriptions was maintained during the past year, even though we did not mount any significant marketing effort. This is quite remarkable considering the national trend of decreases in library subscriptions to journals; it probably reflects the high quality of the journal and the expansion of the field of biomedical engineering. It is our pleasure to report that a new agreement has recently been signed between BMES and AIP to implement new marketing initiatives for ABME. This agreement incurs relatively little expense for BMES and involves an incentive for AIP on the basis of net increase in institutional subscriptions. AIP has appointed a customer service representative to coordinate and liaison with each of the journals that AIP publishes, including ABME. This is a positive development to further enhance our interactions with AIP in publication and marketing. AIP will have exhibitor booths to display ABME in various meetings related to biomedical engineering, including the upcoming World Congress 2000 (World Congress on Medical Physics & Biomedical Engineering), July 23-28 in Chicago.

The BMES Bulletin, which has been under the excellent editorship of Jerry Collins, is produced in the Society's Office by Pat Horner and her dedicated staff. This marks the second year that they have produced the Bulletin.

In summary, we are pleased to report that our journal publications, which are one of the major functions of the

Society, are doing extremely well. Your active participation in this endeavor, as authors, reviewers, readers, and advocators at your institution libraries, is extremely important for our growth and development.

National Program Committee

Gerald M. Saidel, PhD, Chair

In the past year, the main task of the BMES National Program Committee has been to encourage and assist in the development of BMES annual fall meetings. We have tried to build on the successful experiences of the 1998 Cleveland meeting by (a) encouraging strategic alliances among educational and medical institutions in hosting and planning the meeting; (b) identifying at an early stage co-chairs of meeting tracks and sessions for recruitment of presenters from outside as well as within BMES; (c) obtaining substantial sponsorships from industry to provide maximal benefits with minimal costs to presenters, attendees, and to BMES; (d) developing a job fair to assist BME students and industry. As part of the BMES outreach for cooperation with other professional societies, we continue to cooperate with American Physiological Society in developing technical sessions at the Experimental Biology annual spring meeting. Furthermore, we are building on the success of the 1999 joint meeting with IEEE/EMBS in Atlanta to develop a joint 2002 meeting in Houston. At the BMES annual fall meeting, we continue to have the participation of the US National Committee for Biomechanics (USNCB). At the BMES 2000 meeting in Seattle,we have made a cooperative arrangement with the Institute for Biological Engineering (IBE). Furthermore, we are in the process of working out cross-participation in meetings with the Society for Biomaterials. Definite sites have been chosen for future meetings: Spring 2001 with EB, Orlando, FL; Fall 2001, Research Triangle Park, NC; Fall 2002, Houston, TX, with IEEE/EMBS; Fall 2003, Nashville, TN. ■

People

Charles Annecillo, ScD

New ABME Managing Editor

Charles Annecillo joined BMES on April 3, 2000, as Managing Editor for the *Annals of Biomedical Engineering* (ABME). He has a Master of Arts degree in Psychology and a Doctor of Science degree in Medical Psychology. His research at Johns Hopkins University and Hospital and work in the Maryland Veterans Administration Health Care System resulted in 11 publications. His research and clinical background involved multidisciplinary psychiatric and medical professional experience. At the Perry Point VAMC in Northeast Maryland, he provided hardware and software support for the Psychiatry Service which exposed him to state of the art education about stand-alone and mainframe applications including database systems. Dr Annecillo has devoted extensive energy into establishing an efficient online peer review system for the journal. He will be working closely with the current editorial office and Jim Bassingthwaighte, ABME editor, during the transition of the editorial office to the BMES National Office in Maryland later this year. Charles also will coordinate the development of web-based activities planned for BMES. ■

Rita Schaffer Memorial Fund

The Biomedical Engineering Society (BMES)gratefully acknowledges the following contributors to the Rita Schaffer Memorial Fund.

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Susan M Bowley
Gary L Bowlin
Donald G Buerk
Shu Chien
Thomas Q Dinh
Mary T Draney
Theodore M Fitzpatrick
Morton H Friedman
Bingmei Fu
Alan Garfinkel
Elizabeth A George
Thomas K Goldstick
Anthony J Hance
Robert M Hochmuth
Patricia I Horner
Denise Horrilleno
Roger D Kamm
J Lawrence Katz
Kyle Kepple
Mitchell Litt
Hong-Tong Low
Lana J Luccitti
Irving F Miller
Joachim H Nagel
Chi-Sang Poon
Stephen M Retta
Peter D Richardson
Yoram Rudy
Gerald M Saidel
Thomas C Skalak
Martin J Sklar
Steven M Slack
Ramachandra S Srinivasan
Hun H Sun
Bruce C Taylor
Charles S Tritt
Shunichi Usami
Herbert F Voigt
Nicolaas Westerhof

A New Face for the BMES Web Site

Charles Annecillo, ScD

The web site for the Biomedical Engineering Society (BMES) has been in existence for almost 5 years. The web site was first set-up with an educational initiative that provided an academic link to Purdue University and online access to the Bulletin. This site was a service offered to BMES under the auspices of the Memphis Educational Computer Connectivity Alliance (MECCA), an NSF-funded project awarded to the University of Tennessee, Memphis to improve the flow of medical information among Memphis area hospitals. We are grateful to the students and faculty of the joint BME program at the University of Tennessee, Memphis and the University of Memphis for their efforts in establishing and maintaining the site. The BMES site has been expanded to include student chapters, membership, publications, awards, careers, conference and meetings. The BMES journal, the Annals of Biomedical Engineering, was free to public access until April 2000 and it now provides full online journal access for members. Online journal access is available to nonmembers by subscription. The Bulletin continues to be published quarterly online with free public access.

I recently explored the site and discovered hyperlinks through BMES that suggested we might be linked to a broad range of web sites that could end up somewhere in Martha Stewart's garden of home etiquette or any book that you might ever conceive of wanting through Amazon.com. The domain links do provide for an expansive array of explorations. However, in keeping with the generosity of the Whitaker Foundation grant in support of the mission that the Biomedical Engineering Society become a full service professional society, a new face is being added to the central components of the site.

A web site expansion proposal has been approved by the BMES Executive Committee to expand the BMES web services to include a relational database with three interconnected web interfaces. These additional sites will establish web-based activities that will provide biomedical engineering services to the "general public, biomedical engineering practitioners, industry, faculty, and students." Specifically, these sites will provide searchable directories for 1) BME academic programs and faculty, 2) BME companies, and 3) BME internships. Members, students and faculty, within the United States, will be able to identify BME academic programs and faculty and be able to obtain information about programs, accreditation, student organizations, and admissions and placement services.

An announcement will be sent to BMES members and faculty via e-mail requesting their support in completing an online questionnaire. A list of existing and potential BME companies will be developed for inclusion in the companies segment of the database with a subsequent e-mail request for completion of an online questionnaire. Searchable company information will include a brief description of the company, product specialties, and contact information. The companies segment of the database also will contain hospitals and government agencies. Both questionnaires will provide for a listing of academic, institutional, and company based internships, which will be searchable by category. A centrally located hyperlink to an independent vendor will be established for categorical BME employment searches. The request for information will be for a one-time submission of data which will be followed by maintenance of the database through a web site coordinator at the BMES headquarters near Washington, DC. ■

BE SURE TO ATTEND...

"Biomedical Engineering—The Millennial Frontier"

2000 Annual Fall Meeting of the Biomedical Engineering Society

October 12-14, 2000
Seattle, Washington
DoubleTree Hotel-Seattle Airport

Hosted by
University of Washington
Department of Bioengineering

www.engr.washington.edu/epp/bmes/

Student Affairs

James Sweeney, PhD

…Student Chapter Development Workshop BMES Student Chapters should plan to send representatives to a Student Chapter Development Workshop during the BMES 2000 Annual Fall Meeting in Seattle, WA. The workshop will focus on potential chapter development activities, including how to plan and carry out 'BME Days' and open houses, and other professional and community outreach efforts. Look for further details on the Workshop in the mail soon and in the Final Program for the Fall Meeting.

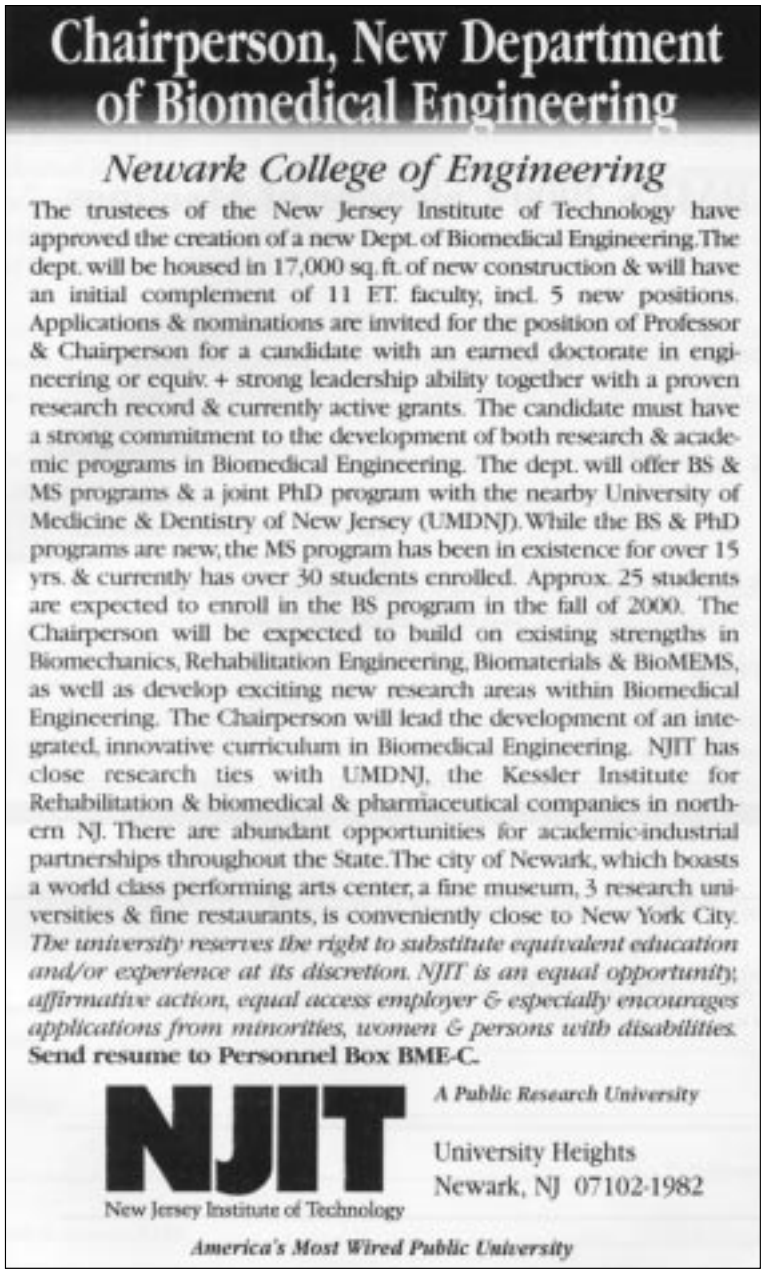
…New Young Investigator Award The BMES Young Investigator Award has recently been renamed "The Rita Schaffer Young Investigator Award" in honor of Rita Schaffer, BMES Executive Director from 1981 to 1998. This new award will carry the requirement to present "The Rita Schaffer Memorial Lecture" at the BMES Annual Fall Meeting on Friday, October 13, 2000. Candidates nominated for this year's Young Investigator Award will automatically be considered for the new award.

…Alpha Eta Mu Beta to Meet in Seattle The BME National Honor Society, will meet on Friday, October 13, 2000, during the BMES Annual Fall Meeting in Seattle. Faculty advisors and student representatives are invited to attend.

…BMES Membership Pins and Tee-Shirts Available Membership pins and tee-shirts will be on sale at the BMES Annual Fall Meeting. BMES Student Chapters are encouraged to sell these items and enable their chapters to share in the profits with BMES.

…Student Awards Student Awards and Chapter Meritorious Achievement Awards will be presented at the BMES Business Meeting at 3:30pm on Friday, October 13, 2000 in Seattle. New Rita Schaffer awards for undergraduates also will be announced at the meeting.

…Dobelle Institute Internships A new device that provides artificial vision for the blind has resulted in extensive expansion at the Dobelle Institute. Opportunities exist for both interns and full-time employees, particularly those skilled in electrical or computer engineering are needed. Experience with analog and/or digital hardware, and software (C++) controlled devices is helpful. Fax resume and cover letter to the Dobelle Institute at the Columbia-Presbyterian Medical Center, 3960 Broadway, New York, NY 10032, 212-927-4000, fax 212-927-6300, **www.dobelle.com.** ■



BMES Membership Directory

The BMES Membership Directory for 2000-2001 will be published in October. Remember to pay your membership dues so you won't miss the opportunity to be listed in the directory.

Assistant/Associate Professor of Biological Engineering University of Missouri

Description: This is a tenure-track, biological engineer position at the assistant or associate professor level. This faculty position is associated with the prominent Food for the 21st Century program at the University of Missouri-Columbia. The successful candidate is expected to establish a strong interdisciplinary research program at the interface between engineering and life sciences. The research should address fundamental issues in bioprocess engineering or biomedical engineering. Potential applications include new products, bioprocesses or biomaterials; biosensors; and new equipment or treatment methods for human and animal health. The candidate is expected to obtain external funding and collaborate with other research faculty in one or more divisions including Engineering; Agriculture, Food and Natural Resources; Medicine; Veterinary Medicine; Biological Sciences; and Physics. The new faculty member will teach undergraduate- and graduate-level courses in biological engineering.

Qualifications: Applicants should have a BS degree in engineering and an earned Ph.D. degree in a field that supports an area of biological engineering research. A strong background in engineering and related life sciences is essential. Those applying for the associate professor rank must have adequate research and/or related industrial experiences.

Closing Date: September 15, 2000 or until the position is filled.

Application: Applicants should submit a detailed resume, a statement of research plan, a statement of teaching philosophy, degree transcripts, a list of three professional references to: Dr. Jinglu Tan, Search Committee Chair, Dept. of Biological & Ag Engineering, University of Missouri, Columbia, MO 65211. Ph: (573) 882-7778, Fax: (573) 884-5650, Email: **TanJ@missouri.edu.** Dept. website: **www.fse.missouri.edu/BEprogram.htm**

The University of Missouri is an Equal Opportunity/Affirmative Action and ADA Employer, and specifically invites, and encourages applications from qualified women and minorities.

Calendar

BMES 2000 Calendar of Meetings

September 23-26 **BioMEMS & Biomed Nanotechnology World 2000**
Columbus, OH
www.healthtech.com

September 24-27 **Computers in Cardiology 2000**
Cambridge, MA
www.cinc.mit.edu

September 26-28 **IEEE-EMBS Asia-Pacific Conf on Biomedical Engineering**
Hangzhou, China
www.ee.cuhk.edu.hk/~APBME

October 12-l5 **BMES Annual Fall Meeting**
DoubleTree Hotel
Seattle, WA
BMES 301-459-1999
www.engr.washington.edu/epp/bmes

October 25-30 **First Maldives Updates in Neurology Internat Conference**
Sun Island, Maldives
www.ami-lloyd.co.il/ami-lloyd/conference.html

BMES Membership Nomination

I would like to nominate a colleague for membership in the Biomedical Engineering Society. Please send a membership invitation in my name to:

Name _____

Address _____

City/State/Zip _____

Member's Name (Please Print) _____

Return to: Membership Dept, BMES, 8401 Corporate Dr, Ste 110, Landover, MD 20785

Announcing a New Award

Biomedical Engineering Society BME International Award

The BMES Biomedical Engineering (BME) International Award is to be awarded each year by the Biomedical Engineering Society to an individual in a university, industry, or government to recognize his/her contributions to the advancement of biomedical engineering. The award is intended to honor the worldwide effort of promoting biomedical engineering as a profession with the aim to improve people's health. This new award is made possible by a gift from the Lee family, including Jen-shih and Lian-pin Lee, Grace T. Lee and David Ludena, Albert L. Lee,
Frank and Ting Lee, Joseph and Doris Cheng, Ta-Fang and Alice Fang, and Eric and Rena Lee.

The awardee is expected to deliver a plenary lecture at the BMES Annual Fall Meeting and to publish the text of the lecture in the *Annals of Biomedical Engineering*. A very important purpose of the lecture is to review critically a field of biomedical engineering and to offer a vision on the challenges and opportunities in biomedical engineering.

The award will consist of a plaque, the registration fee for the meeting, and a $3,200 honorarium from which the awardee pays travel expenses.

Conditions:

1. It is the expressed desire of the Lee family that this award be used to recognize international biomedical engineers and industrial biomedical engineers. It is expected that at least 25% of the awardees will come from the biomedical industry. The worldwide distribution will be about 25% from Asia, 25% from Europe, and 50% from North, Central, and South America, Africa and Australia.
2. The contributions of the awardee do not need to precede the award date by any specific period of time.
3. The Awards Committee will screen the nominations, critically evaluate the nominee's records, and submit a rank ordered list of the top three nominees to the BMES President. The President, in consultation with Long Range Planning Committee, will select the awardee.

Biomedical Engineering Society BME International Award
Nomination Form
Deadline: August 30, 2000

I nominate:

Name _____

Address _____

_____ Telephone _____

Contribution to BME _____

_____

Signed _____
nominee or with nominee's permission

Please complete this form and attach supporting documentation or submit a letter describing the nominee's contributions to biomedical engineering by August 30, 2000 to: BME International Award, Awards Chair, BMES, 8401 Corporate Drive, Suite 110, Landover, MD 20785-2224, 301-459-1999 • fax 301-459-2444 • www.bmes.org

BMES

8401 Corporate Drive, Suite 110
Landover, MD 20785-2224

Address Correction Requested