DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
NATIONAL INSTITUTES OF HEALTH

NATIONAL ADVISORY COUNCIL FOR BIOMEDICAL IMAGING AND BIOENGINEERING

Summary of Meeting[1]
September 12, 2011

The National Advisory Council for Biomedical Imaging and Bioengineering (NACBIB) was convened for its 27th meeting on September 12, 2011, at the Bethesda Marriott Suites in Bethesda, Maryland. Dr. Roderic I. Pettigrew, Director of the National Institute of Biomedical Imaging and Bioengineering (NIBIB), presided as Council chairperson. In accordance with Public Law 92-463, the meeting was open to the public from 9:00 a.m. to 11:45 a.m. for review and discussion of program development, needs, and policy. The meeting was closed to the public from 1:00 p.m. to 1:30 p.m. for consideration of individual grant applications.

Council members present:
Dr. Philip Alderson, Saint Louis University, St. Louis, MO
Dr. John C. Gore, Vanderbilt University, Nashville, TN
Dr. W. Eric L. Grimson, Massachusetts Institute of Technology, Cambridge, MA
Dr. Nola M. Hylton, University of California, San Francisco, CA
Dr. Cato T. Laurencin, The University of Connecticut, Farmington, CT
Dr. Mark Musen, Stanford University, Stanford, CA
Dr. Cherri Pancake, Oregon State University, Corvallis, OR
Dr. Etta D. Pisano, Medical University of South Carolina, Charleston, SC
Dr. Buddy Ratner, University of Washington, Seattle, WA
Dr. Michael Yaszemski, Mayo Clinic College of Medicine, Rochester, MN

Ex officio members present:
Dr. P. Hunter Peckham, U.S. Department of Veterans Affairs, Cleveland, OH
Dr. James G. Smirniotopoulos, Uniformed Services University of the Health Sciences, Bethesda, MD
Dr. Andrew Watkins, Centers for Disease Control and Prevention, Atlanta, GA

Council members absent:
Dr. Hedvig Hricak, Memorial Sloan-Kettering Cancer Center, New York, NY

Ex officio members absent:
Dr. Francis Collins, National Institutes of Health, Bethesda, MD
Dr. John McGrath, National Science Foundation, Arlington, VA
Dr. Anne Plant, National Institute of Standards and Technology, Gaithersburg, MD
Ms. Kathleen Sebelius, U.S. Department of Health and Human Services, Washington, DC

Chairperson:
Dr. Roderic I. Pettigrew

Executive Secretary:
Dr. Anthony Demsey

[1] For the record, it is noted that members absent themselves from the meeting when the Council is discussing applications (a) from their respective institutions or (b) in which a conflict of interest may occur. This procedure only applies to applications that are discussed individually, not to "en bloc" actions.

Also present:
NIBIB staff present for portions of the meeting:

Mr. Angelos Bacas
Dr. Richard A. Baird
Ms. Sheila Barrett
Ms. Angie Burks
Ms. Michelle Byrd
Ms. Barbara Cantilena
Ms. Patty Clements
Ms. Shirley Coney-Johnson
Dr. Richard Conroy
Ms. Zoe-Ann Copeland
Ms. Nancy Curling
Ms. Marilyn Daly
Mr. Jeff Domanski
Mr. Antoine Durham
Dr. Henry Eden
Ms. Angela Eldridge
Ms. Kathryn Ellis
Dr. Zeynep Erim
Ms. Carol Fitzpatrick
Dr. David George
Ms. Marie Gill
Ms. Pam Glikman
Dr. Valery Gordon
Dr. Ruth Grossman
Ms. Jude Gustafson
Dr. John Haller
Dr. John Hayes
Ms. Eunica Haynes
Dr. William Heetderks
Mr. James Huff
Mr. Tom Izzard
Dr. Thomas Johnson
Dr. Chris Kelley
Ms. Mary Beth Kester
Dr. Brenda Korte
Ms. Truc Le
Dr. Richard Leapman
Mr. Eugene Lee
Dr. Guoying Liu
Dr. Hector Lopez
Dr. James Luo
Dr. Alan McLaughlin
Mr. Todd Merchak
Mr. Larry Morton
Mr. Joe Mosimann
Dr. Grace Peng
Dr. Karen Peterson
Mr. Mohammed Rahamatullah
Ms. Vicki Rein
Dr. Mary Rodgers
Mr. Rolando Romero
Ms. Stephanie Sabourin
Dr. Belinda P. Seto
Mr. Shaun Sims
Dr. Manana Sukhareva
Ms. Florence Turska
Ms. Keisha Whitaker-Duncan
Mr. Kwesi Wright
Ms. Li-Yin Xi
Dr. Yantian Zhang
Dr. Ruixia Zhou
Dr. Steven Zullo

Non-NIBIB NIH employees:
Ms. Chau Pham, Office of the Director, NIH

Non-NIH Federal employees:
None

Members of the public present for portions of the meeting:
Ms. Renee Cruea, Academy of Radiology Research
Dr. Anna Fernandez, Booz Allen Hamilton
Mr. Ricardo Henriques, Event Technology Solutions
Mr. Vhic Mata, Event Technology Solutions
Mr. Stephen Murphy, IQ Solutions
Ms. Virginia Neale, Lewis-Burke Associates
Mr. Michael Peters, American College of Radiology
Ms. Kathy Sedgwick, NOVA Research Company
Mr. Matt Sherman, National Capital Captioning
Dr. Daniel K. Sodickson, New York University Langone Medical Center
Ms. Margot Walker, Research Councils UK
Mr. Brian Washington, Event Technology Solutions

I. Call to Order: Dr. Anthony Demsey

Dr. Demsey called to order the 27th meeting of the National Advisory Council for Biomedical Imaging and Bioengineering. He reminded attendees that the morning session of the meeting was open to the public, welcomed attendees, and introduced Dr. Pettigrew, who formally welcomed all participants.

II. Director's Remarks: Dr. Roderic I. Pettigrew

A. New Council Members

Dr. Pettigrew introduced three new Council members. Dr. John Gore is Chancellor's University Professor in Medicine; Director of the Institute of Imaging Science; professor of radiology and radiological sciences, biomedical engineering, and molecular physiology and biophysics; and director of the Institute for Imaging Science at Vanderbilt University. Dr. Gore is internationally known for his expertise in and contributions to the field of magnetic resonance imaging (MRI). A pioneer in investigating the physical and physiological factors that affect MRI signals and in using this knowledge to devise noninvasive imaging methods to provide new types of information, he has been a leader in integrating functional MRI (fMRI) data with other imaging methods such as magnetoencephalography and electroencephalography. Dr. Gore is a fellow of the American Institute for Medical Biological Engineering and the International Society of Magnetic Resonance in Medicine, and a member of the National Academy of Engineering.

Dr. Cato Laurencin is the chief executive officer of the Connecticut Institute for Clinical and Translational Science and director of the Institute for Regenerative Engineering at the University of Connecticut. Dr. Laurencin is also the Van Dusen Endowed Chair in Orthopedic Surgery and professor of chemical materials and biomolecular engineering at the University of Connecticut. He is recognized for his expertise in shoulder and knee surgery and related tissue engineering research, holding approximately 20 patents in this area. He is a fellow of the American College of Surgeons and the American College of Orthopedic Surgeons and a member of the Institute of Medicine. Dr. Laurencin has received the Presidential Award for Excellence and the Pierre Galletti Award from the American Institute for Medical and Biological Engineering.

The final new member, Dr. Mark Musen, is head of the Stanford Center for Biomedical Informatics Research and professor of medical informatics and computer science at Stanford University. Dr. Musen conducts research related to intelligence systems, the semantic web, knowledge representations, and biomedical decision support. His current work addresses mechanisms by which computers can assist in the development of large, electronic biomedical knowledge bases. His work on the Protégé Ontology Editor and Knowledge Acquisition System has led to open-source technology used by thousands of developers around the world. Dr. Musen is a fellow of the American College of Informatics, has been elected into the American Society of Chemical Investigation and the Association of American Physicians, and is the recipient of the Donald A.B. Lindberg Award for Innovation in Informatics from the American Medical Informatics Association.

B. Budget

The President's budget request for the National Institutes of Health (NIH) contains a request of $322.1 million for NIBIB, a 1.8 percent increase over fiscal year 2011. Given the current economic climate, Dr. Pettigrew does not expect the full request to be approved. The Senate has set allocation for Labor/Health and Human Services at 0.2 percent below the 2011 level. The Congressional Joint Select Committee on Deficit Reduction (colloquially, the Supercommittee) has been tasked with identifying $1.5 trillion in budgetary savings over ten years; Congress is required to vote on its proposed legislation by December 23, 2011. If the required savings are not achieved through the Joint Committee process, then most nonsecurity programs, including NIH, could be cut by approximately 8 percent per sequestration.

As noted in previous Council meetings, there has been a significant increase (60 percent) in the number of applications scoring in each percentile since September 2009. This increase challenges the NIBIB budget and payline; the 2011 payline is 11 percent for established investigators and 16 percent for new investigators (R01s only).

C. New Conflict-of-Interest Rules

New conflict-of-interest rules for recipients of NIH funding include a new definition of *significant financial interest* (SFI) that a holder must disclose. SFI has been reduced from $10,000 to $5,000. The disclosure must include all interests related to the investigator's institutional responsibilities, not just those related to the NIH-funded research. Grantees also must disclose any reimbursed travel or sponsored travel related to institutional responsibilities, rather than only those related to NIH-funded research; reimbursements from a Federal, state, or local government or an academic entity are exempt from reporting. The new rule requires public disclosure of SFI holdings via publicly accessible Web site or written response to any requestor within five days of request. In addition, each funded investigator must complete conflict-of-interest training prior to engaging in research related to any NIH grant and at least every four years thereafter.

D. New Initiatives

On June 24, President Obama announced the National Robotics Initiative to develop "co-robots" that act in support of individuals and groups, including in health-related activities such as rehabilitation and surgery. The initiative will be supported by the National Science Foundation, the National Aeronautics and Space Administration, the U.S. Department of Agriculture, and NIH; NIBIB will serve as the lead NIH institute. The program will award up to $50,000 per year in direct costs for up to five years, for a maximum total of $250,000. Letters of intent are required by October 1 annually, with applications due November 3 annually.

A Request for Applications (RFA) on point-of-care technologies has been released as an extension of the existing Point of Care Technologies Research Network. Letters of intent were due August 28, with applications due September 28.

In June, the Council of Councils approved a 5-year Common Fund Program to accelerate discovery, development, and translation of technologies for single-cell analysis. The fundamental goal is to understand heterogeneity of cells within populations that may have important functional consequences. The program will be implemented in a phased manner with four components: (1) characterization of cell heterogeneity or biologic noise; (2) acceleration of discovery of new tools for single-cell analysis; (3) acceleration of validation and translation of emerging technologies; and (4) engagement of multidisciplinary teams to address defined challenges. NIBIB and the National Institute of Mental Health will serve as collaborative leads.

In January, President Obama signed into law the America Competes Act, which focuses on advancing technology and technological innovation and gives broad authority to all federal agencies and departments to grant prizes. NIBIB's planned award is in the final stages of approval; Dr. Pettigrew hopes to announce it at October's Biomedical Engineering Society meeting.

E. Meetings

The 5th Multiscale Modeling Consortium meeting will be held October 5–6 in conjunction with the National Heart, Lung, and Blood Institute (NHLBI). The NHLBI Systems Biology grantees have been working for several years to promote modeling across multiple scales.

The NIBIB 10th Anniversary Dinner and Symposium will be held June 21–22, 2012. Speakers will include NIH Director Francis Collins, Nobel Laureate Phillip Sharp, National Medal of Technology Laureate Charles Vest, Nobel Laureate Roger Tsien, and President and Chief Executive Officer of General Electric Jeffrey Immelt.

F. Research in the News

The Washington Post recently highlighted the work of NIBIB grantee V. Reggie Edgerton and his colleagues at the University of California, Los Angeles, on epidural spinal stimulation to facilitate recovery of motor function in patients with spinal cord injury. The Edgerton team presented a case study of the effects of epidural stimulation on voluntary movement, standing, and assisted stepping. A patient suffering from

complete motor paraplegia received electrical stimulator implants in the lumbar sacral region. Over a 1-year period, he received daily electrode stimulating sessions with specific tasks/movements being performed. The procedure resulted in independent standing, some voluntary leg control, and regained bladder, bowel, and sexual function.

Ralph Weissleder and his colleagues have developed a handheld MRI unit used for point-of-care analysis of a variety of biologics, from bacteria identification in small fluid samples to protein markers of cancer. The device uses reagent ligands that bind paramagnetic molecules to targets of interest. When binding occurs, clustering of the paramagnetic molecules locally causes a change in the magnetic field such that the relaxation time for water substantially changes. Detection of a shortened relaxation time is a positive test indicator. The device employs a small permanent magnet, eight microfluidic channels, and eight microcoil arrays. The smartphone-powered device can investigate up to eight targets and diagnose within one hour.

Sangeeta N. Bhatia and Christopher Chen have developed a functional three-dimensional liver model to facilitate drug development and investigation. Primary human hepatocytes are co-cultured with human ectopic artificial liver (HEAL) and implanted into a mouse. The model vascularizes, grows, and functions the way a human liver would, producing human metabolites and demonstrating human liver response to a given agent.

III. Review of Council Procedures and Regulations: Dr. Anthony Demsey

Dr. Demsey noted for the record that a quorum was present for this Council meeting. Council member Dr. Hedvig Hricak was unable to attend. Dr. Demsey welcomed visitors and members of the science press and scientific society constituencies. He thanked Ms. Carol Fitzpatrick and Ms. Pam Glikman for meeting planning and logistics.

A. Council Regulations, Policies, and Procedures

Dr. Demsey summarized elements of the Government in the Sunshine Act and the Federal Advisory Committee Act that govern all Advisory Council meetings. These Acts require the U.S. Department of Health and Human Services to open Advisory Council meetings to the public except when proprietary or personal information is discussed. To comply with these regulations, NACBIB meetings are open to the public for everything except the review of grant applications. Dr. Demsey reviewed conflict-of-interest, confidentiality, and lobbying guidelines.

B. Future NACBIB Meeting Dates

The next NACBIB meeting is scheduled for Friday, January 20, 2012, with the site to be determined. Dr. Demsey asked Council members to inform him about conflicts with any of the upcoming meeting dates listed at the bottom of the agenda.

C. Approval of the May 20, 2011, NACBIB Meeting Minutes

A motion to approve minutes of the May 20, 2011, NACBIB meeting was forwarded, seconded, and approved unanimously.

IV. Strategic Plan Implementation Working Group Report: Dr. William Heetderks

The Working Group met on August 19 to discuss implementation of NIBIB's strategic plan. The strategic plan comprises six goals, each of which was discussed at length. A full report is forthcoming; Dr. Heetderks reviewed the main discussion points.

A. Goal 1: Improve human health through the development of emerging biomedical technologies at the interface of engineering and the physical and life sciences.

The grant review process should be refined to acknowledge the value of interdisciplinary research; for example, study sections should assess and comment on convergence in applications. Translation initiatives should be directed and targeted towards areas of need, with regular milestones and stringent reporting.

Solving medical problems relevant to the patients should be central to NIBIB's funding strategy. Large grants should be limited to the problems that can be solved only through large grants rather than encouraged for their own sake. NIBIB should maintain the ability to fund based on scientific priorities, keeping in mind portfolio balance; there should be a soft zone in addition to a hard payline, with the explicit purpose of funding projects based on programmatic need.

B. Goal 2: Enable patient-centered health care through development of health informatics and mobile and point-of-care technologies.

NIBIB should use its convening power to bring together practitioners and technologists to develop standards for interoperability, and increase partnerships with important industry stakeholders, federal organizations, and the Department of Veterans Affairs. NIBIB should also focus on "sweet spots" instead of tackling overarching technologies and systems. Program announcements should focus on key technological barriers to patient-centered health care rather than specifying "through point-of-care technologies" or "through mobile technology."

C. Goal 3: Transform advances in medicine at the molecular and cellular levels into therapeutic and diagnostic technologies that target an individual's personal state of health.

To transform advances in medicine at the molecular level, technologies for prevention and early detection will be important areas of emphasis. Single-cell, multi-cell, or system approaches including genetic variants and phenotypes can be seen as a key to disease and should be pursued. Images can be used as biomarkers; in addition to directly identifying genetic or cellular signatures, some surrogates may be detected through image characteristics. Cancer therapeutics and diagnostics may be a particular opportunity, and NIBIB should continue to partner with the National Cancer Institute (NCI).

D. Goal 4: Develop medical technologies that are low-cost, effective, and accessible to everyone.

Standards of diagnostic effectiveness must be maintained; "low cost" does not equal "less effective." NIBIB should release a call to action—not necessarily an RFA—that encourages a variety of innovative solutions to improve as well as solve the problem. NIBIB must strategize specific ways to gain cultural acceptance of technologies that are outside of the norm for target populations, perhaps by encouraging principal investigators (PIs) to address cultural differences more directly, or by finding partners to help them understand cultural norms and health beliefs.

E. Goal 5: Develop training programs to prepare a new generation of interdisciplinary engineers, scientists, and health care providers.

There is a trend in engineering academia toward more flexible undergraduate degrees. For instance, students can focus on biomedical studies while pursuing degrees in biological engineering, mechanical engineering, or computer science. Students are interested in cross-disciplinary education in fields with impact on the world. In addition, radiologists and pathologists are starting to converge as diagnostic imaging, molecular imaging, and molecular medicine become more common, creating opportunities for better teamwork.

NIBIB must find a way to engage leaders in radiology such that more clinical radiologists are transformed into researchers. NIBIB should encourage "wayward" engineers—those who have moved into medicine—to bring their new expertise to bioengineering research. Existing educational and training programs that pursue new interdisciplinary projects and culture change should be sustained.

F. Goal 6: Expand public knowledge about the medical, social, and economic value of bioengineering, biomedical imaging, and biomedical informatics.

NIBIB should be using new media and social media to underscore the message that NIBIB is the "institute of cool stuff." NIBIB should encourage grantees, trainees, fellows, postbaccalaureates, etc., to blog about their experiences in research laboratories; NIBIB also should find ways for investigators, advisors, advocacy groups, patients, and other leaders in the field to become engaged in the process. NIBIB must appeal to

people's passions; for the professional research community, this translates into Requests for Applications and funding for the work in progress or funding to train students. The Institute can illustrate the position of imaging and bioengineering in our culture by moving beyond the technical aspects of a story to reveal the people behind it. New media could be ideal for disseminating audio or video interviews with researchers.

G. Metrics

NIBIB should not expend a great deal of funds or effort on the big metrics efforts others already are doing (e.g., STAR Metrics). Rather than focusing on numbers, NIBIB should attempt to measure the impact of its activities. Success could be measured by asking principal investigators, "What difference have you made?" This kind of self-examination has value to the investigators as well. Program staff can critically review self-reports. Peer review of impact could be conducted at the end of each project.

H. New Concepts/Initiatives

NIBIB is already developing several concepts and initiatives that address strategic plan goals. A residency research training opportunity should be announced within the next two weeks. A competition for student design projects is also under development.

An initiative for low-cost, effective medical technologies is in the early design stage. This initiative will promote the development and translation of low-cost, high-impact medical technologies that are both effective and accessible to everyone. Projects may include proof-of-concept proposals. Proposed work will be milestone-driven and will include an industry partner to encourage translation of technologies for clinical use. Applicants will be expected to describe how the proposed technology development will reduce the cost of the end product, as well as the anticipated magnitude of the reduction. Applicants also will be expected to demonstrate how the proposed technology would be placed, maintained, operated, and culturally accepted in the target setting.

NIBIB is also developing an Innovative Centers for Translation program, which will bring together participants from different scientific, engineering, and medical fields to develop interdisciplinary solutions to medical problems. Building on experience from the NIBIB/Howard Hughes Medical Institute interdisciplinary training program, the Centers will provide rapid-decision, short-term funding for high-impact research with a philosophy that accepts high risk and recognizes the possibility of failure. The cooperative agreement mechanism will be used so that program staff can be involved in Center decisions.

Questions and Discussion

Dr. Yaszemski commented that bringing engineers in medicine back to engineering will require winning over department chairs, who generally want them to stay focused on medicine. Dr. Peckham responded that it is his experience that chairs often promote cross-disciplinary training and work in the academic medical centers.

NIBIB's existing training grants (T32s) are in large, well-established universities; smaller academic centers have a difficult time obtaining that funding. The new residency training program will be smaller, providing research training positions for one or two years for a radiologist or other resident. Dr. Laurencin noted that grant opportunities are often for principal investigators; wayward engineers may not be PIs on larger grants. This program may help clinician engineers work their way into the grant system by serving as PIs on smaller grants.

Dr. Pisano remarked that the culture of procedurally oriented departments (e.g., surgery, orthopedics) is very different from that of medical specialty departments. Because they must maintain technical skills, neurosurgeons, for example, cannot take off the amount of time to do the research required by a career award (K award). Junior faculty need time to conduct research as well as residents. The transition from student to faculty, and the immediate pressure to work clinically, makes it difficult to find time and support for research. There should be protected research time during that crucial transition period. Dr. Pisano's institution (Medical University of South Carolina) and the University of North Carolina have begun "mini-

K" programs that provide support for 40 percent time for research for five years; protecting only 40 percent time allows procedurally focused clinicians 60 percent time to maintain their skills. Interest in the mini-Ks exceeds the funding available. It is too early to tell whether the programs jeopardize advancement, though they should improve chances of continued promotion because they allow time to write grant applications and papers. Dr. Pisano plans to make awards to three grantees for three cycles to better understand outcomes.

Drs. Yaszemski, Laurencin, and Ratner agreed that 40 percent time is appropriate; anything more makes it difficult to keep up needed clinical time.

V. Second Sight—From Magnetic to Electrical Imaging with MRI: Dr. Daniel K. Sodickson

Dr. Sodickson described biomedical imaging techniques that will increase the scope of what can be seen in the realm of tissue electrical properties (rather than magnetic properties that are the traditional MRI domain) and prognosticated about what MR detection and transmission hardware will look like and be able to do in 2020. He drew upon current research supported by NIBIB (5R01EB000447, Parallel Magnetic Resonance Imaging: New Techniques and Technologies; 2R01EB002568, High-Performance High-Field Parallel MRI; and 1R01EB011551, RF Technology Innovation for Advancing High Field MR) to illustrate ongoing work on high-field, high-performance MRI and the need for high-performance radio frequency (RF) transmitter and detector coils.

Because conductivity and permittivity values of biological tissues change with their physiological and pathological conditions, electrical property maps could provide important information in the diagnosis of various diseases. Electrical properties also play an important role in calculation of specific absorption rate (SAR), a major concern in high-field MRI. High-field MRI is accompanied by significant wave propagation effects, and the RF radiation is dependent on the electrical properties of biological tissue. In addition, electrical property tomography (EPT) does not require electrode mounting or external energy deposition, which pose potential safety concerns.

Noninvasive assessment of cardiac structure and function has been a target for all types of imaging modalities. MRI allows a multifaceted assessment of cardiac health, such as cardiac wall motion, cardiac artery anatomy, and myocardial perfusion and viability, and thus offers the prospect of a comprehensive cardiovascular exam with a single, noninvasive entity. However, the procedure is time-consuming and complex, and the selection of planes to be imaged requires training. Dr. Sodickson and his colleagues are using highly accelerated parallel MRI in combination with other rapid imaging techniques to perform a comprehensive cardiac examination in a small number of breath-holds that takes only minutes; this approach provides access to the information richness of MRI with the speed and simplicity of computed tomography (CT). The enabling technologies are high-performance scanners and, to some extent, high magnetic field strength, parallel MRIs, and compressed sensing. The payoff is a rapid, comprehensive, noninvasive, simple assessment without the X-ray exposure encountered during CT scans.

Signal generation, signal detection, and spatial encoding are three essential functions of RF coils and coil arrays employed in MRI. The objective of the current research is to move from a sequential to a parallel imaging approach. Sequential imaging equipment resembles fax machines, which pick up one point of data at one point in time, and users must wait as each line moves through. In contrast, a parallel approach works like a video camera; multiple detectors in an array image different pieces of the body and then combine the data, allowing users to exceed the MR "speed limit." The high degree of spatiotemporal correlation in the cardiac perfusion data allows for compressed sensing to accelerate data acquisition. When multiple receiver coils are available, the extra correlation between coils can be exploited to obtain higher accelerations. A combination of compressed sensing and parallel imaging is employed to substantially increase the spatiotemporal resolution and spatial coverage of first-pass cardiac perfusion MRI studies.

Parallel transmission in the clinic allows rapid volumetric imaging and anatomy-tailored fields of view. At 7 Tesla (T), much of the brain can be scanned in five to seven minutes. With its vascular sensitivity and spatial resolution, ultra-high-field MRI is poised to provide unique, clinically relevant information from head to toe, making it useful for exploring disease processes (e.g., osteoarthritis, osteoporosis, carpal tunnel syndrome,

tuberous sclerosis, and schizophrenia). It enables resolution of subfields of the human hippocampus, the temporal lobe structure that is intimately involved with memory and implicated in disease processes such as epilepsy, Alzheimer's, and mood disorders.

A specialized coil array allows visualization of elements down to 100 microns thick within acceptable imaging duration; for example, the array can be used to visualize the dentate granule cell layer, which is implicated in memory formation and where neural stem cells are believed to reside. In addition to capturing routine clinical information, this imaging technique could be used to detect cellular disarray and degenerative changes in this sensitive circuit earlier than at 1.5 T or even 3.0 T.

In parallel imaging techniques, coils and coil arrays play a key role in the quality and speed of imaging. Multiple coils are needed for acceleration, flexibility, high signal-to-noise ratio (SNR) over multiple body regions, and simplicity for rapid, comprehensive volumetric imaging. However, the approach to ultimate SNR slows with increasing acceleration. The recent development of arrays with many elements has raised the question of how small array elements can be before the final SNR is dominated by noise from the electronic components. Calculations of the ultimate intrinsic SNR have indicated that there is an intrinsic limit to the acceleration capabilities of parallel imaging. Understanding these limitations can inform selection of an acceptable number and size of coil elements during the design of a coil array and assessment of absolute performance of existing arrays, and eventually it can guide the development of innovative receivers that may operate close to optimum performance.

Moving toward the parallel transmit-receive structures allows very rapid imaging and tailored excitation. Tissue perturbs electromagnetic fields at high field strength, and, at low RF, the tissues' electrical properties become visible.

In ultra-high-field MRI, SAR rises with field strength, and tissue electrical properties and distribution perturb electromagnetic fields, leading to safety management challenges. These challenges can be addressed by using multiple transmitter coils, each transmitting with different amplitude and phase or even a different time course. Using parallel transmission helps to mitigate inhomogeneities. Ultimate SAR can be approached by implementing a constellation coil that supports a customizable configuration. The versatility of the constellation coil promises additional and significant opportunities for employing other interesting and higher performing transmit field patterns.

Electrical conductivity can be used as an additional diagnostic parameter (e.g., tumor diagnosis) and in connection with the electric field to estimate the local SAR distribution during MR measurements. The EPT approach derives the patient's electrical conductivity and corresponding electric fields from the spatial sensitivity distributions of the applied RF coils, which are measured via MRI. Corresponding numerical simulations and initial experiments on a standard clinical MRI system underline EPT's ability to determine the electrical conductivity and the local SAR. In contrast to previous methods, EPT is a practical approach that might lead to significantly higher spatial image resolution. EPT's success resides in an increasingly robust and rapid *in vivo* electrical property mapping at low to moderate field strength. However, EPT phase assumption breaks down at high field strength—precisely where large RF field curvature would otherwise be expected to yield robust electrical property maps (and where local SAR mapping would be essential). A generalized multicoil approach to electrical property mapping (i.e., local Maxwell tomography) uses local expressions for field curvature to determine electrical properties region by region. Multiple transmit-and-receive coils can be used to solve for both the unknown electrical properties and the missing phase.

RF coil array designs for low-to-moderate field strength have advanced to the point that further improvements in performance are unlikely. Therefore, future development of RF coils for use at low-to-moderate field strength is most likely to focus on selection and placement of coil elements and ease of use of coil arrays. One ongoing trend in commercial coil design is an increasing integration of large arrays of coils into scanner structures such as the patient bed or through development of linked sets of elements, which may be combined for easier access to multiple body regions. Increasing the number of coil elements is driven as much by workflow as by performance or parallel imaging acceleration capability. A significant amount of fundamental work remains in the area of high-field coil design, because even relatively large arrays of loop

coils do not approach the ultimate intrinsic limits of SNR at high field strength. This suggests that new coil designs will be required to capture the many potential benefits of high field strength. Additional mechanisms of transmission and detection, such as the propagation of "traveling waves," also come into the picture at high field strength, and these mechanisms must be accounted for in any complete assessment of coil performance. Given the complexity of coil-tissue interactions at high frequency, it may become necessary to combine not only multiple coil elements, but also multiple types of coil elements (e.g., loops, strips, directional antennas) in order to maximize performance.

Interaction between RF fields and tissue is an obstacle for high-field MR, but it is also an opportunity. Whereas, at low frequency all bodies are similar in appearance, at high frequency each body makes a distinct imprint upon the electromagnetic field patterns. Noninvasive maps of the distribution of electrical properties of tissues may be derived, under certain simplifying assumptions, from maps of the curvature of RF transmit fields observed in MR imaging experiments. The use of transmit-and-receive coil arrays enables generalized electrical property mapping at arbitrary field strength. This new area of study represents another manifestation of the power of using multiple coils and the information-richness of the RF fields that can help shape future purposes in MR.

Questions and Discussion

Dr. Yaszemski commented on claustrophobic patients who require some level of anesthesia when undergoing an MRI. Dr. Sodickson stated that the traveling wave approach moves the coils away from the patient's body, so that the patient never feels strapped into a small-bore machine.

Dr. Ratner asked whether recent controversy regarding field strengths, cellular telephones, and brain cancer will have an impact on Dr. Sodickson's work. Dr. Sodickson responded that some researchers are considering using high-field MR to measure the effects of cellular telephone use. Absorption rate—how much energy is deposited in tissue—is a concern, but the risk does not seem to be significant with the duration of time spent in an MR scanner.

Dr. Pettigrew asked Dr. Sodickson to comment on the practicality of moving from the traditional loop coil to the antenna approach. Dr. Sodickson remarked that a wholesale replacement is not necessary; other elements are interspersed and overlaid in certain combinations with loops, creating a buildable mosaic of coils. He will be focusing on building practical arrays during the next funding period.

An audience member asked about efforts to optimize coil structures on the reception side. Dr. Sodickson noted that his approach works for both transmission and reception; the calculations can result in the pattern of currents required either to transmit or receive with maximal efficiency. These optimizations are developed for one point at a time; stringing a group of these optimizations together requires placement of a different coil at each desired position, creating a tiled design. The spatial resolution will not be the same as in MR images, although Dr. Sodickson and his colleagues are finding that they can currently achieve 5-millimeter resolution—much better than any surface-only technique.

Another member of the audience asked whether 7T equipment is required to image electrical properties, taking into consideration that many hospitals are just transitioning from 1.5 to 3T. Dr. Sodickson responded that the technique should be able to migrate down to lower-field magnets such as 3T.

Dr. Gore noted that all of the major manufacturers have produced 7T systems with eight channels of parallel transmit. Dr. Sodickson added that he and his colleagues will be deploying a 32-channel system soon. One can derive the ultimate intrinsic SAR, which allows for discovery of the optimal energy deposition; the more elements, the better spatial selectivity and the lower deposition.

VI. Adjournment

The open session of the NACBIB meeting was adjourned at 11:45 a.m.

VII. Closed Session

The grant application review portion of the meeting was closed to the public in accordance with provisions set forth in Section 552b(c)(4) and 552b(c)(6), Title 5, U.S. Code, and 10(d) of the Federal Advisory Committee Act, as amended (5 U.S.C. appendix 2). The closed session was adjourned at 1:30 p.m.

Certification:

We certify that, to the best of our knowledge, the foregoing minutes are accurate and complete.[1]

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Anthony Demsey, Ph.D.
Executive Secretary,
National Advisory Council for Biomedical Imaging and Bioengineering
Director,
Office of Research Administration
National Institute of Biomedical Imaging and Bioengineering

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Roderic I. Pettigrew, Ph.D., M.D.
Chairperson,
National Advisory Council for Biomedical Imaging and Bioengineering
Director,
National Institute of Biomedical Imaging and Bioengineering

[1] These minutes will be approved formally by the Council at the next meeting on January 20, 2012, and corrections or notations will be stated in the minutes of that meeting.