Louisiana Tech's NeuroNEM team of investigators at their meeting in the Brain Dynamics Laboratory
From left to right: Dr. Prabhu Arumugam, Dr. Teresa Murray, Dr. Kirk St. Amant, Dr. Mark DeCoster, Dr. Katie Evans and Dr. Leon Iasemidis

NSF BRAIN Initiative: Probing and Understanding the Brain

by Kelsey Phelan, Biomedical Engineering Senior

The National Science Foundation (NSF) funds promising scientific research, which has the potential to generate discoveries and inventions that would benefit humanity. NSF grants are awarded on the basis of "intellectual merit" and the "broader impact" they may have on society. Under the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) initiative, emphasis is given to multidisciplinary grant proposals in neuroscience research.

Dr. Leon Iasemidis, director of Louisiana Tech's Center for Biomedical Engineering and Rehabilitation Science (CBERS) and the Brain Dynamics Laboratory, was awarded a prestigious multi-institutional $6 million NSF grant for brain research through the NSF's Experimental Program to Stimulate Competitive Research (EPSCoR). The project, entitled Probing and Understanding the Brain: Micro and Macro Dynamics of Seizure and Memory Networks, was awarded for a four-year period, starting in September 2016. The project, being part of the NSF Research Infrastructure Improvement (RII) Track-2 program, seeks to build research collaborations between EPSCoR jurisdictions. Denise Barnes, head of NSF's EPSCoR program, explains, "These awards represent a tremendous value for the scientific community, as they foster research into some of the most pressing issues facing U.S. society while simultaneously supporting collaborative research programs and workforce development." Barnes also states that "these projects hold the promise of transforming our daily lives."

Dr. Iasemidis leads a team of six Louisiana Tech professors, eight professors from the University of Arkansas for Medical Science (UAMS) in Little Rock, and the medical center at the University of Alabama, Birmingham and several graduate and undergraduate students. This unique team with diverse specialties and backgrounds will tackle the dynamics of neuronal networks involved in crises of brain function, in particular epileptic seizures. The Louisiana Tech team, known as the Neuronal Networks in Epilepsy and Memory (NeuroNEM) team, includes Dr. Teresa Murray (assistant professor of biomedical engineering with a specialty in neuroscience imaging), Dr. Mark Decoster (professor of biomedical engineering with a specialty in cellular neuroscience), Dr. Prabhu Arumugam (assistant professor of mechanical engineering and nanosystems engineering), Dr. Katie Evans (director of mathematics and statistics and industrial engineering) and Dr. Kirk St. Amant (professor of technical communication).

Epilepsy affects 1 percent of the world population; is the fourth most common neurological disorder following migraine, stroke and Alzheimer's; and severely impacts the quality of life of patients and caregivers. It also constitutes a considerable economic burden to the healthcare system of every society. Even though epilepsy research has been ongoing for a number of decades, scientific understanding of why and how epileptic seizures, the hallmark of epilepsy, develop has yet to be achieved. Although technology has improved over time, there are currently no widely accepted tools for the study of the long-term brain dynamics of the underlying neuronal networks that could cause seizures. "Mapping of the involved brain networks in seizure generation, in the animal and human brain, as well as the impact of seizures on memory networks, are among the goals we will pursue *in vivo* at the molecular, cellular and macroscopic levels," said Dr. Iasemidis. He expects that outcomes of this research effort will also include the

training of a diverse student population and the professional development of postdoctoral fellows and junior faculty, potentially contributing to the economic development of the region.

The proposed research activities are designed to greatly contribute to the understanding of the epileptic brain at multiple scales of space and time in agreement with NSF's special report "Understanding the Brain." In this report, it is clearly mentioned that "the BRAIN Initiative extends beyond the mapping of the brain and bridges scales that span from atoms to thoughts and behavior, linking what is known about single cells and subcellular activities in the brain to whole brain function leading to complex behavior." Dr. Iasemidis summarizes the innovations in this project as follows.

a. A unique animal database with long-term electroencephalographic (EEG) recordings and concurrent in vivo recordings of molecular (neurochemical) and cellular (optical imaging) signals from a cohort of 100+ epileptic rats will be developed.

b. A unique human database with EEG, magnetoencephalographic (MEG) signals and magnetic resonance images (MRI) from 80 epilepsy patients that would also include EEG and MEG signals during testing of working, declarative and recall memory functions will also be developed.

c. Novel tools for analysis of the recorded data will be employed, for example, directional information flow measures for identification of the epileptic networks from EEG and MEG data and machine learning techniques will be used to combine the findings from analysis of EEG and neurochemical biomarkers.

d. Two novel investigations into memory and its neuronal network substrate will be pursued for identification of memory networks from analysis of EEG and MEG and estimation of memory impairment in epilepsy by measuring the overlap between memory and epileptic neuronal networks. The project will generate and analyze data on the order of hundreds of terabytes. New computing and storage machines have been acquired for the demand of the analysis, storage and exchange of this data across all the involved laboratories at the three universities.

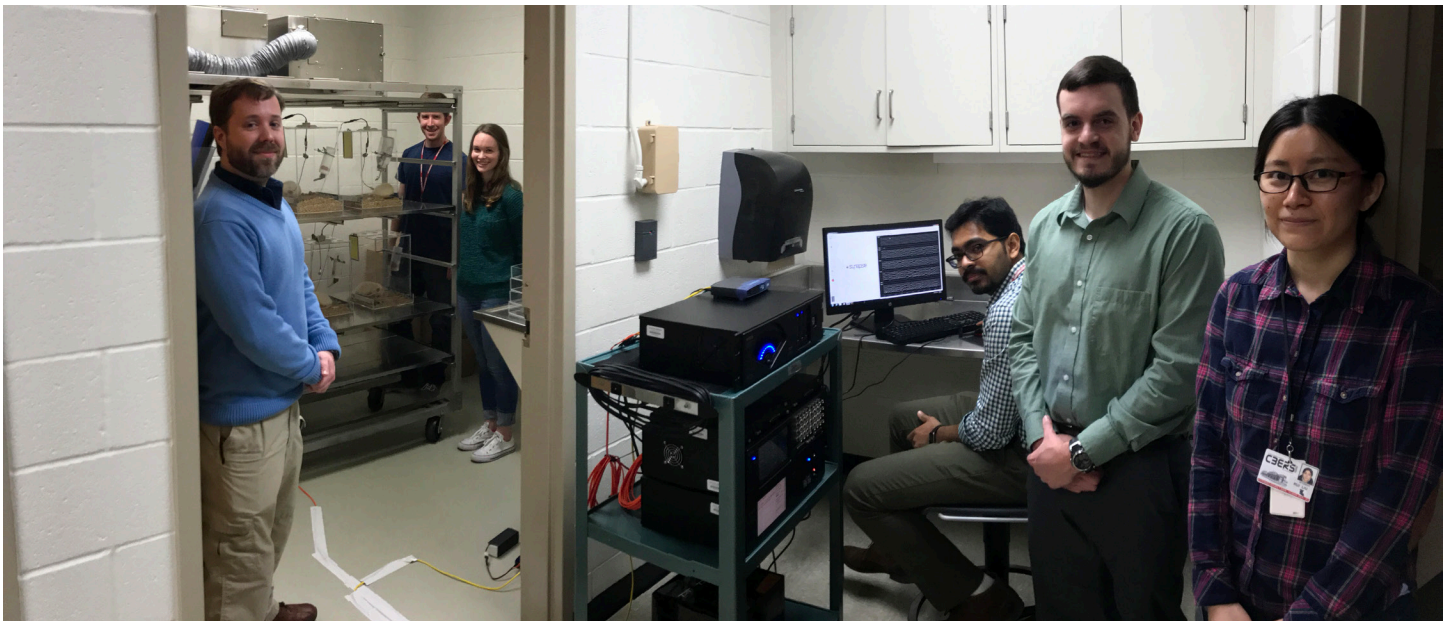
The awarded grant also puts a major emphasis on outreach, the fostering of careers of young scientists and the promotion of students in the science, technology, engineering and mathematic (STEM) fields. Each faculty member, graduate student and undergraduate student involved in this grant has already seen positive changes in this direction. Tim Doughty, a biomedical engineering doctoral student at Louisiana Tech who researches under Dr. Murray, prepares and implants electrodes into the brains of rats for the project. The project has stimulated his interest in pursuing an M.D. degree as well. He is training an undergraduate student, Anthony Ellis, for the project and foresees that undergraduates will enjoy learning about brain research in this manner.

Noah Hutson, a senior undergraduate biomedical engineering student, researches under Dr. Iasemidis. Hutson has been a member of Dr. Iasemidis's Brain Dynamics Lab (BDL) since he was a freshman. Since the grant was received, he has noticed increased research activity in the lab. He has been able to attend meetings with other investigators of the grant and gain a broader understanding of the contribution of each lab that participates in the project. He believes this research is "an excellent opportunity for undergraduates to advance their skills for academic or professional careers" due to the multifaceted experience they will gain. He is excited to see the new research associates, such as the three undergraduate students who recently joined the BDL, bring new ideas and different perspectives.

Bharat Karumuri, a biomedical engineering doctoral student at Dr. Iasemidis's laboratory, is excited about the prospect of collaboration across labs at different institutions. "There are 14 faculty members from three universities involved, including medical doctors . . . this is a large number of senior researchers to be working on a single project," Karumuri states. He especially enjoys the collaboration within Louisiana Tech: "[Timothy Doughty] and I have been collaborating on the recording of the EEG from the animal brains. That has been nice. He works more on the hardware side and I work more on the software side. I also collaborate with the research groups at the other two sites on human EEG data." Karumuri is also excited with the involvement of undergraduates at BD: "They are so fresh; it is wonderful to be able to nurture them into future graduates."

Another avenue for the involvement of undergraduates in this research is the recently initiated NeuroNEM Research Experience for Undergraduates (REU) program. This nine-week program will be first offered in the summer of 2017 at the three university campuses and is nationally advertised. The REU program welcomes underrepresented and minority students and will be available for each year of the NeuroNEM grant. The undergraduates in this program will be directly involved with brain research at one of the project laboratories, will participate in other educational activities related to brain research and will have their work presented at a local conference by the end of the summer.

Existing courses will be enhanced and new courses related to brain research will be developed at Louisiana Tech. Two new courses have already been developed. Molecular and Cellular Neurophysiology (BIEN 557), taught by Dr. DeCoster and Dr. Murray, was offered in Winter Quarter 2017, and Probing and Analysis of Brain Signals and Function (BIEN 450C/557) is being offered this Spring Quarter by the full team of Tech investigators. Existing undergraduate courses that will be enhanced include Biomedical Instrumentation



The newly installed EEG recording system (front room) in NeuroNEM's animal laboratory in full operation while it records long-term EEG signals from implanted electrodes in the brain of epileptic rats (back room). The recording system allows for simultaneous recordings from 8 animals with 10 electrodes in the brain of each animal, at a very high sampling rate (3KHz). Tech undergraduate students Kelly Kneale, Anthony Ellis and Noah Hutson, and graduate students Timothy Doughty, Bharat Karumuri and Rui Liu are members of the teams for recording and analysis of these brain signals.

(BIEN 325) and Biomedical Signals and Systems (BIEN 225) courses. Laboratory experiences will also be supplemented. One example includes the junior-level biomaterials class taught by Dr. Murray, in which she wishes to include better understanding of novel co-culture and pruning system as well as multiphoton, micro-lens enhanced imaging of cellular dynamics (HARS bioreactor).

Through this grant, it is anticipated that Louisiana Tech will also foster its relationship with neighboring universities, like Grambling State University, in terms of student training in research. Dr. St. Amant emphasized the outreach opportunities this grant can offer. He was recruited to participate as an investigator by Dr. Iasemidis after his arrival at Tech last fall. He emphasized the numerous possibilities the interdisciplinary and interinstitutional nature of this grant offers to students and researchers, from development of technical communications skills to presentations at workshops, to generation and licensing of intellectual property and formation of start-up companies. "We can always do more in terms of outreach; this [grant] is a prime opportunity for the development of the region," he explains.

The NeuroNEM team seeks to promote more entrepreneurship and innovation opportunities through this grant. Louisiana Tech's impressive record of promoting innovation is evidenced through its various awards: a national recognition for innovative culture in 2011, a $1.1 million grant from the White House for "Start-Up America" in 2011 and national rankings of fifth in intellectual property licenses and second for start-up businesses per $1 million in research expenditures. As a result of the grant, the innovative culture at Louisiana Tech will be bolstered through the organization of more workshops related to entrepreneurship, innovative venture research and technology commercialization. National leaders in brain research will also be invited to participate in the New Frontiers in Biomedical Research seminar series hosted at Louisiana Tech, as well as in the new seminar series "Probing and Understanding the Brain" organized by CBERS.

By receiving this grant, Louisiana Tech has been recognized as a university capable of undertaking ambitious research projects that benefit the research community, local community and society on a global scale. This is an exciting time at Louisiana Tech University, as such a prestigious grant generates opportunities for the University to provide an even greater influence. Despite the infancy of the project, it has already demonstrated great promise and is expected to continue inspiring young researchers to help others through its intellectual merit and broader effects.

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