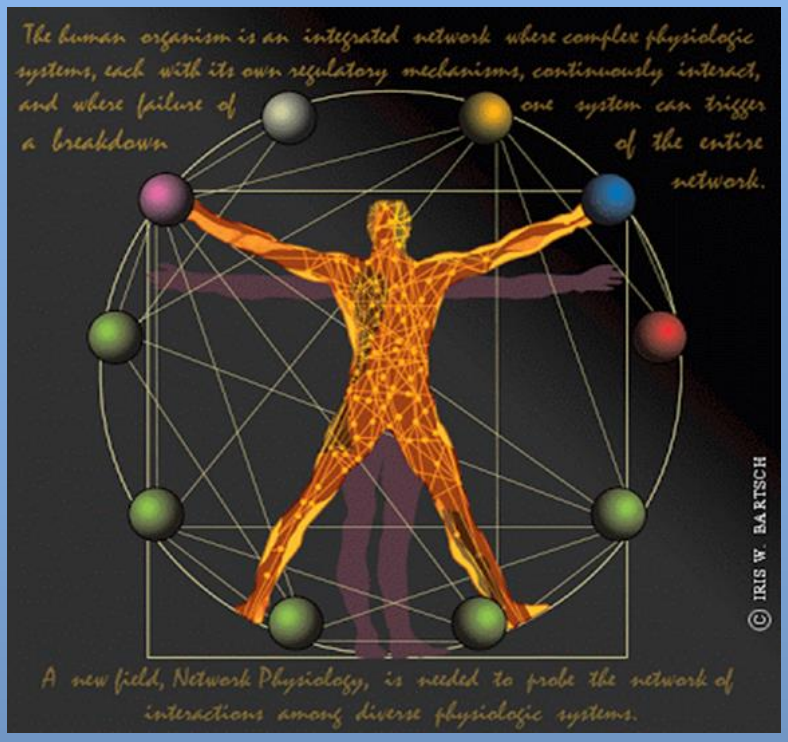
Second International Summer Institute on Network Physiology (ISINP)

Lake Como School of Advanced Studies, 28 July – 2 August, 2019



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Welcome to ISINP

The human organism is an integrated network, where multi-component organ systems, each with its own regulatory mechanism, continuously interact to coordinate their function. Physiological interactions occur at multiple levels and spatiotemporal scales to produce distinct physiologic states, e.g. wake and sleep, consciousness and unconsciousness. Disrupting organ communications can lead to dysfunction of individual systems or collapse of the entire organism, as observed under clinical conditions such as sepsis, coma and multiple organ failure. Yet, despite its importance to basic physiologic functions, the nature of interactions between diverse organ systems and sub-systems, and their collective role in maintaining health is not known. Further, there are no adequate analytic tools and theoretical framework to probe these interactions.

Despite the vast progress and achievements in systems biology and integrative physiology in the last decades, we do not know the basic principles and mechanisms through which diverse physiological systems and organs dynamically interact and integrate their functions to generate a variety of physiologic states at the organism level.

The emerging new interdisciplinary field of *Network Physiology* aims to address this fundamental question. In addition to defining health and disease through structural, dynamical and regulatory changes in individual physiological systems, the new conceptual framework of Network Physiology focuses on the coordination and network interactions among diverse organ systems and sub-systems as a hallmark of physiologic state and function.

Novel concepts and approaches derived from recent advances in network theory, coupled dynamical systems, statistical and computational physics, signal processing and biological engineering show promise to provide new insights into the complexity of physiological structure and function in health and disease, bridging sub-cellular level signaling with inter-cellular interactions and communications among integrated organ systems and sub-systems. These advances form first building blocks in the methodological formalism and theoretical framework necessary to address the problems and challenges in the field of Network Physiology.

This international summer institute will integrate empirical and theoretical knowledge across disciplines with the aim to understand in different contexts, from extensive data analysis and modeling approaches to clinical practice, how diverse physiological systems and sub-systems dynamically interact to produce health and disease.

This will be an interactive event with lectures ranging from physics and applied mathematics to neuroscience, physiology and medicine, covering a range of physiological systems from the cellular to the organ level, and will discuss the challenges, current frontiers and future developments in the emerging field of Network Physiology.

Presentations on basic research will be combined with lectures by leading physiologists and clinicians, working with large medical and ICU databases.

This International Summer Institute aims to provide a relaxed setting where lecturers and attendees interact throughout the course of the week. We have speakers, prominent leaders in their respective fields, who will

present new directions in the theory of networks of dynamical systems, brain and neuronal dynamics, tissues and cell assemblies, pair-wise and network interactions of organ systems and sub-systems, and advanced methods from non-linear dynamics and synchronization phenomena.

The Summer Institute will address a diverse audience of graduate students, postdoctoral fellows, research scientists and faculty across a broad range of disciplines and fields from physics, applied mathematics and biomedical engineering to neuroscience, physiology and clinical medicine.

We look forward to a product meeting in Como!

Plamen Ch. Ivanov, Ph.D., D.Sc.

Director, Keck Laboratory for Network Physiology, Boston University
Director, Second International Summer Institute on Network Physiology (ISINP)

28 July 2019, Como, Italy

Sponsors

Fondazione Alessandro Volta

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This international institute builds on groundbreaking research in Network Physiology that has been made possible by support from the W.M. Keck Foundation.

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The ISINP international institute builds on groundbreaking research in Network Physiology that has been made possible by support from the W.M. Keck Foundation.

This initiative is supported by an educational grant from Philips

The international institute is supported also by:
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School Director

Plamen Ch. Ivanov

Professor Ivanov, PhD, DSc, is Director of the Keck Laboratory for Network Physiology at Boston University, Associate Physiologist at the Division of Sleep Medicine, Brigham and Women's Hospital, and Lecturer in Medicine at Harvard Medical School.

He has introduced innovative ways of analyzing and modeling physiologic systems, adapting and developing concepts and methods from modern statistical physics and nonlinear dynamics. He has investigated the complex dynamics and underlying control mechanisms of a range of physiological systems, including studies on cardiac and respiratory dynamics, sleep-stage transitions, circadian rhythms, locomotion and brain dynamics, and has uncovered basic laws of physiologic regulation.

Dr. Ivanov has pioneered the study of dynamical network interactions of physiological organ systems, and has initiated Network Physiology as a new field of research. His current research focuses on developing methods of data analysis and a theoretical framework to understand how physiologic states and functions emerge out of organ network interactions, and how diverse organ systems coordinate and integrate their functions to produce health or disease.

His discoveries have been featured in the media, including New Scientist, Nature Science Update, Nature Medicine: Research Highlights, The Washington Post, Science News, The Boston Globe, Physics World. He has served on the Editorial and Advisory Boards of nine scientific journals, including EPL (Europhysics Letters), EPJ Nonlinear Biomedical Physics, Journal of Biological Physics (JOBP), Frontiers in Fractal Physiology, Physiological Measurement, and has organized, co-chaired and chaired international workshops, symposia and conferences.

For his pioneering applications of statistical physics and nonlinear dynamics to physiology and biomedicine, and for uncovering fundamental scaling and multifractal properties, self-organized criticality, sleep- and circadian-related phase transitions in physiologic dynamics, he was elected Fellow of the American Physical Society in 2010. He is recipient of the Sustained Research Excellence Award of the Biomedical Research Institute at Harvard Medical School, the Georgi Nadjakov Medal of the Bulgarian Academy of Sciences, the Pythagoras (Pitagor) Prize for scientific achievements and the W. M. Keck Foundation Award.

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Speakers

Fran çoise Argoul

Professor Fran çoise Argoul (DR CNRS first class) received her PhD in Dynamical Systems Study of Chemical Chaos at the University of Bordeaux (France) in 1986. Then, she switched her scientific interest to fractal growth processes in cristallization and electrodeposition and shared her time between the Centre de Recherche Paul Pascal (CNRS) in Bordeaux (France) and the Center for Nonlinear Dynamics of the University of Texas at Austin, to collaborate with the experimental group headed by Professor H.L. Swinney. Later on (October 2002), she joined the Ecole Normale Sup érieure of Lyon (France) to build a new laboratory (Laboratoire Joliot-Curie) at the physics-biology interface. Very recently (January 2016), she moved back to Bordeaux to join the Laboratoire Ondes et Mati ère d'Aquitaine (LOMA). Her scientific contribution encompasses many fields of modern physics, including statistical mechanics, dynamical systems theory, chemical chaos, pattern formation in reaction-diffusion systems, the physics of fractals and multifractals, fractal growth phenomena, signal and image processing, wavelet transform analysis and its applications in physics, chemistry and biology, and is presented in 144 peer-reviewed publications. Professor Argoul's current scientific projects concern the experimental characterization and modeling of the mechanical properties of living cells and tissues and their alteration under stress and/or pathological situations. Her research program combines (i) biophysical experiments on living cells (single or in populations) such as mechanical shear-stress and indentation tools, surface plasmon, phase contrast, quantitative phase imaging, high resolution fluorescence microscopies, (ii) modeling the impact of physical constraints on the fractional rheology (complex dynamics) of living systems and their modifications in pathologies (cancer, myopathies), and (iii) extending the classical formalism for amorphous (stationary) material rheology to a time-frequency rheology of living (active) materials. Professor Argoul is member of the Optical Society of America, the International Society for Optics and Photonics (SPIE), the American Biophysical Society and the European Biophysical Society. In 1990, she received a national recognition for her research (CNRS bronze medal).

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Alain Arneodo

Professor Alain Arneodo (DR CNRS Emeritus) received his PhD in Elementary Particle Physics at the University of Nice (France) in 1978. Then he switched his scientific interest to dynamical system theory and moved to the Centre de Recherche Paul Pascal (CNRS) in Bordeaux (France), to collaborate with the experimental group working at that time on chemical chaos. Later on (October 2002), he joined the Ecole Normale Superieure of Lyon (France) to build a new laboratory (Laboratoire Joliot-Curie) at the physics-biology interface. Very recently (January 2016), he moved back to Bordeaux to join the Laboratoire Ondes et Matière d'Aquitaine (LOMA). His scientific contribution encompasses many fields of modern physics including statistical mechanics, dynamical systems theory, chemical chaos, pattern formation in reaction-diffusion systems, fully-developed turbulence, the mathematics of fractals and multifractals, fractal growth phenomena, signal and image processing, wavelet transform analysis and their applications biological and physiological systems. Major part of his scientific work focuses on bridging the gap between DNA sequence analysis and the study of the structure and dynamics of chromatin as a major actor in the regulation of cell nuclear functions in both health and disease. His

current research involves investigations of the mechanisms underlying cellular networks formation and tissue tears. Professor Arneodo is a fellow of the Société Francaise de Physique and of the Société Européenne de Physique. He received, in December 2005 in Brussels, the Prix de l'Académie Royale des Sciences, Lettres et Beaux-Arts de Belgique.

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György Buzsáki

György Buzsáki is the Biggs Professor of Neuroscience at NYU Langone Health. He received his M.D. in 1974 from the University of Pécs in Hungary, then earned his Ph.D. in Neuroscience in 1984 from the Academy of Sciences in Budapest. Buzsáki's primary interests are mechanisms of memory, sleep and associated diseases. His main focus is "neural syntax", i.e., how segmentation of neural information is organized by the numerous brain rhythms to support cognitive functions. His is best known for his groundbreaking *two-stage model of memory trace consolidation*, which demonstrates how the neocortex-mediated information during learning transiently modifies hippocampal networks, followed by reactivation and consolidation of these memory traces during sleep. To achieve these goals, he has introduced numerous technical innovations from using silicon chips to NeuroGrid to record brain activity. Buzsáki is among the top 1% most-cited neuroscientists, member of the National Academy of Sciences USA, the Academiae Europaeae and the Hungarian Academy of Sciences, Fellow of AAAS and he sits on the editorial boards of several leading neuroscience journals, including Science and Neuron; *honoris causa* at Université Aix-Marseille, France and University of Kaposvar, and University of Pécs, Hungary. Dr. Buzsaki's honors include the 2011 Brain Prize, The Ariëns Kappers Medal (2014), Translational Research Mentor of the Year Award, NYU (2014), Henry Neufeld Memorial Award, Israel (2008); College de France Distinguished Professor, Paris, France (2008); Distinguished Scholarship, Rutgers University (2006); Krieg Cortical Discoverer Award (2001); The Pierre Gloor Award (1997).

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Ronny P. Bartsch

Dr. Bartsch studied physics in Konstanz, Germany where he received a M.Sc. degree in theoretical physics in July 2003, and at Bar-Ilan University, Israel where he received his PhD in June 2009. He was a post-doctoral fellow at the Division of Sleep Medicine, Harvard Medical School from 2008 till 2012, after which he joined the faculty at the same division as an Instructor in Medicine. In April 2014, Dr. Bartsch joined the Physics Department at Boston University as a Research Assistant Professor. Currently he is a Senior Lecturer at the Physics Department, Bar-Ilan University. Dr. Bartsch applies methods from statistical and computational physics and nonlinear dynamics to study physiologic systems, sleep regulation, circadian rhythms, and how physiologic transitions affect coupling between organ systems. He is recipient of the prestigious German DAAD Fellowship for the period 2010-2012. In 2012 he was awarded the Young Investigator of the Year Prize by the German Society of Sleep Medicine, and in 2014 he won a "Marie Curie" fellowship from the European Commission.

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Tjeerd Boonstra

Dr. Boonstra is a Senior Research Fellow at the Graduate School of Biomedical Engineering at the University of New South Wales and Neuroscience Research Australia. He received his MA in Psychology from the University of Amsterdam and his PhD in Human Movement Sciences from the Vrije Universiteit Amsterdam. Since 2007, he is a research scientist at UNSW Sydney where he runs an EEG lab investigating the effects of cognitive tasks and non-invasive brain stimulation on brain functioning. His research includes the use of data analysis techniques such as functional connectivity analysis, multivariate statistics and graph analysis to study brain networks. More recently he applied these techniques to surface electromyography recorded from multiple muscle distributed across the body to map so-called muscle networks and investigate neural pathways involved in motor coordination. In 2018 he received a Future Fellowship from the Australian Research Council to investigate the structure and function of the human spinal connectome. He has published over 50 peer-reviewed publications, including a paper comparing anatomical and functional muscle networks in Science Advances. He has organized BrainModes 2013 in Amsterdam and is the lead guest editor for the special issue on imaging the brain and body in NeuroImage.

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Barbara E. Corkey

Barbara E. Corkey has been the Zoltan Kohn Professor of Medicine and Vice Chair for Research in the Department of Medicine at Boston University. Dr. Corkey has been a leader in the fields of diabetes and obesity research for over 50 years with over 180 related publications and 40 years of continuous government research support. The Corkey laboratory is in engaged in research on obesity and diabetes, with a particular focus on metabolic signal transduction in ß-cells, adipocytes and hepatocytes, intercellular communication via circulating redox and the role of hyperinsulinemia in obesity and diabetes. Projects in metabolic regulation have been ongoing since 1981 using such techniques as single cell imaging, metabolic profiling, ionic fluxes and membrane potential, respiration, redox state, reactive oxygen species generation and diet-induced obesity and diabetes models. She does seminal work on the molecular basis of nutrient signaling that has a major impact on our current understanding of health and disease. Finally, Barbara has received numerous honors including the NIH MERIT Award, National Honorary Membership in Iota Sigma Pi, the National Honor Society of Women in Chemistry, Women in Science Lecturer at the Boston Museum of Science, the George Bray Founders Award of the Obesity Society, the Charles H. Best Lectureship and Award, University of Toronto and the Banting Medal for Scientific Achievement from the American Diabetes Association. A current major focus is on developing clinical/basic collaborative multi-PI grants to explore novel approaches to understand and treat metabolic diseases.

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Kathryn A. Hibbert

Kathryn A. Hibbert is a Pulmonary and Critical Care physician at Massachusetts General Hospital(MGH), where she also serves as the director of the Medical Intensive Care Unit. She received her MD degree from Mount Sinai School of Medicine before residency training in Internal Medicine at MGH and serving as a Chief Resident in Medicine. She completed her fellowship in the Harvard Pulmonary and Critical Care Fellowship.

Her early research focused on translational ARDS research using functional PET-CT imaging to better understand regional pathophysiology. She now runs a critical care clinical research program that includes serving as the site principal investigator for the PETAL network at MGH and a project that examines the novel use of metabolomics to identify drug resistant pneumonia. In addition, she is a course director for the Harvard Medical School Health Sciences & Technology curriculum, serves as the Critical Core Educator for the Department of Medicine at MGH and has developed a novel advanced physiology course for internal medicine residents. She has won multiple teaching awards and serves as the Associate Program Director for the Harvard Pulmonary and Critical Care Fellowship.

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James W. Holsapple

James Holsapple is the Chair of the Department of Neurological Surgery at Boston University School of Medicine and Chief of Neurological Surgery at Boston Medical Center. He is a graduate of the University of Kansas School of Medicine. Dr. Holsapple completed residency training in neurological surgery at SUNY Syracuse where he also served as an intern in general surgery and participated in a NRSA research training fellowship in neuroscience. His research interests include primate motor system anatomy, non-vesicular mechanisms of synaptic acetylcholine storage and secretion, scaling effects of visual stimuli in primate V1, and most recently cerebral blood flow autoregulation and development of non-invasive measurements of intracranial pressure, blood flow, and compliance. Dr. Holsapple is the residency program director for the Beth Israel Deaconess Medical Center/Boston Medical Center training program in neurological surgery. He also serves as the program director of the undergraduate summer program in neuroscience (SPIN) at Boston University School of Medicine.

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Marina de Tommaso

Marina de Tommaso is Professor of Neurology at the Psychiatric and Neurologic Sciences Department of the Bari University, head of the Applied Neurophysiology and Pain Unit. She graduated in Medicine in 1982, specialised in Neurology in 1986 and in Phisioterapy in 1993 with full marks cum laude at Bari University. In 1994 she received the title of Research Doctor in Human Relational Sciences. From 1995 to 2005 she has been Researcher in Neurology. Since 2008 she is the coordinator of the diploma in neurophysiopathology techniques. She is the Head of the regional referral Center for Huntington's disease and Neuropathic Pain. She is Editor of BMC Neurology and Pain Research and treatment and Associate editor of Journal headache and Pain journals. She is the President of the Italian Psychophysiology and Cognitive Neuroscience Society. She is author of 170 publications in extenso, concerning the field of Clinical and Applied Neurophysiology, Clinical Neurology, Migraine, Fibromyalgia, Huntington's disease. She is responsible for more than 20 funded projects from private and public committees (European Commission, Italian Research Ministry, CHDI foundation)

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Luca Faes

Dr. Faes is Senior Researcher at the Bruno Kessler Foundation and the BIOtech Center of the University of Trento, Italy. He obtained his PhD in Electronic Engineering at the University of Trento (2003). He has been research fellow at the Department of Physics of the University of Trento (2004-2008) and visiting scientist at the State University of New York (2007), Worcester Polytechnic Institute (2010), University of Gent (Belgium, 2013), University of Minas Gerais (Brazil, 2015), and Boston University (2016). He is a member of the IEEE Engineering in Medicine and Biology Society (IEEE-EMBS), the European Study Group on Cardiovascular Oscillations (ESGCO) and served on the Program Committee of several conferences on medical signal processing. He is Associate Editor of the journal Computational and Mathematical Methods in Medicine, and of the Annual International Conference of the IEEE-EMBS, where he regularly organizes symposia and invited sessions. He was organizer and Program Chair of the 8th ESGCO conference (Trento, Italy, 2014). He works in the fields of statistical physics, computational physiology and neuroscience with focus on developing methods for multivariate time series analysis in the time, frequency and information domains, with applications to cardiovascular neuroscience, brain connectivity and brain-heart interactions. His recent research covers the information-theoretic analysis of physiological networks aimed at the characterization of brain, cardiac and multi-organ physiological mechanisms in physiological states and pathological conditions.
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Brandon Foreman

Brandon Foreman, MD FACNS is Assistant Professor of Neurology & Rehabilitation Medicine and Neurosurgery at the University of Cincinnati and serves as Associate Director for Neurocritical Care Research with the Division of Neurocritical Care. Dr. Foreman was trained in both clinical neurophysiology and neurocritical care at the Columbia University Medical Center in New York, following which he joined the University of Cincinnati's Gardner Neuroscience Institute in 2014. Dr. Foreman is an expert in comprehensive intracranial neuromonitoring, and he was integral in developing and implementing the clinical neuromonitoring program at the University of Cincinnati. Dr. Foreman is a member of several multi-center collaboratives, including the Critical Care EEG Monitoring Research Consortium (CCEMRC) and the Co-Operative Spreading Brain Injury Depolarizations consortium (COSBID), and he has specific expertise in continuous EEG monitoring and in detecting seizures and spreading depolarizations after brain injury. He is a co-founder of the Collaborative for Research on Acute Brain Injuries (CRANI), a translational neuroscience research community at the University of Cincinnati that links translational, clinical, and data scientists. Through CRANI, he works closely with the College of Engineering and Applied Sciences and the Center for Intelligent Maintenance Systems at the University of Cincinnati and with partners at the University of Arizona and Boston University to develop machine learning and network connectivity approaches to understanding brain injury physiology. Dr. Foreman's research focuses on how cortical physiology – pressure, flow, and synaptic signaling – can be recorded and integrated with clinical data at the bedside in order to understand an individual patient's physiolome and to uncover potential targets for precision critical care.
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Jürgen Kurths

Jürgen Kurths studied mathematics at the University of Rostock and got his PhD in 1983 at the GDR Academy of Sciences and his Dr. habil. in 1990. He was full Professor at the University of Potsdam from 1994-2008 and has been Professor of Nonlinear Dynamics at the Humboldt University, Berlin and chair of the research domain Transdisciplinary Concepts of the Potsdam Institute for Climate Impact Research since 2008 and a 6th century chair at the Institute for Complex Systems and Mathematical Biology at Kings College of the Aberdeen University (UK) 2009-2017. He is a fellow of the American Physical Society and is a member of the Academia Europaea. He got an Alexander von Humboldt research award and a 1000 Talents award for foreign experts from China and was awarded the L.F. Richardson Medal of the European Geosciences Union. He got several Honory Doctorates and Honorary Professors. He was a Burgers Visiting Professor at University of Maryland and is a Chapman Professor at the University of Alaska (Fairbanks). Jürgen has supervised more than 75 PhD students from about 20 countries; more than 40 of them have now tenured positions in various countries. He has published more than 650 papers in peer-reviewed journals and two monographs which are cited more than 35.000 times (H-index: 85). He is editor-in-chief of the AIP journal CHAOS and is in the editorial board of more than further 10 journals. His main research interests are complex synchronization phenomena, complex networks, time series analysis and their applications in neuroscience and physiology. He works on inferring complex networks from spatio-temporal data in neuroscience to characterize the underlying dynamics and to get new kinds of predictions of extreme events, such as episodes of migraine. Moreover, he is developing multilayer neural networks with time delay to model brain activity, in particular cognitive processes. Another main direction is to develop measures of causality and their applications to physiological signals. He coordinated several large projects in EU and DFG and is now speaker of an International Research Training Group on complex networks (DFG and Brazil), of a Megagrant on inferring models from climate spatio-temporal data (Russia) and of a joint project on collective nonlinear dynamics of complex power grids (BMBF, Germany).

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Klaus Lehnertz

Professor Lehnertz, PhD, is a Physicist and Director of the Neurophysics Group at the Department of Epileptology at Bonn University Medical Center. In addition, he is Co-Director of the Interdisciplinary Centre for Complex Systems and an affiliated member of the Helmholtz-Institute for Radiation and Nuclear Physics at Bonn University. He is Co-initiator of the International Seizure Prediction Group, which brings together researchers from a wide range of backgrounds including epileptology, neurosurgery, neurosciences, physics, mathematics, computer science, and engineering to deepen scientific and medical understanding of epilepsy and to develop new diagnosis, treatment and intervention options for patients with epilepsy. For more than two decades, his research group has been developing methods of data analysis and a theoretical framework to understand how brain sub-systems dynamically interact and coordinate functions under physiological and pathophysiological activities. His research interests include nonlinear dynamics, complex networks, statistical physics, neurophysics, computational physics, physics of imaging, medical physics, and epilepsy. He is the author of more than 200 original publications in international peer-reviewed journals, reviews, book chapters, and books.

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Fabrizio Lombardi

Dr. Lombardi studied physics at the University of Naples “Federico II” and received his PhD in physics from ETH Zurich. He is presently working as a research scientist at the Keck Laboratory for Network Physiology at Boston University. His research activity aims to uncover the basic physical principles underlying emergent collective dynamics and functions in biological and physiological systems. To this end, he uses methods and ideas from statistical mechanics and nonlinear dynamics. Currently, Dr. Lombardi focuses on ongoing brain activity and criticality, with the objective of enlightening the relation between emergent scale invariance, network collective behavior, and brain functions. He is studying neuronal avalanches and bursting dynamics of brain rhythms across the sleep-wake cycle, and developing a novel theoretical and modeling approach to understand the non-equilibrium features of sleep regulation, e.g. nocturnal arousals. In parallel, Dr. Lombardi is investigating the dynamical organ network interactions characteristic of physiologic states, and their reorganization and breakdown with ageing and pathological conditions. By means of such a holistic approach to human physiology, he ultimately aims to associate distinct physiologic states and conditions with networks of interactions inferred from synchronous recordings of key organs of the human body, and predict their evolution in response to perturbations (e.g. organ failure, medical treatments).

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Hagen Malberg

Professor Malberg, PhD, is Chair and Director of the Institute for Biomedical Engineering at Dresden University of Technology, Director of Steinbeis Research Center of Applied Biomedical Engineering, Dresden, and member of the Faculty of Electrical and Computer Engineering and the Medical Faculty “Carl Gustav Carus”, Germany. He received his PhD from Max-Delbrück-Center for Molecular Medicine in 1999. His work focuses on medical sensor technologies (contactless sensing, biosignal processing, decision support machines, automatic control in medicine, medical robotics, medical imaging and image processing) with clinical applications in cardiovascular medicine (cardiology, intensive care, cardiac surgery, sleep medicine), ambient assisted living, neurosurgery and rehabilitation medicine. He is the inventor of 17 patents. His vision is to support the development of a new generation of medical devices — being comfortable, reliable, clinical suitable and predictive, cheaper and mobile. Dr. Malberg is a member of IEEE-EMBS, German Society of Biomedical Engineering (DGBMT), European Society of Cardiology, German Hypertension League, European Sleep Research Society (ESRS). He is Chair of the 24th annual congress of the German Society of Sleep Research and Sleep Medicine (DGSM) 2016 and the Joint Congress of the German Society of Biomedical Engineering (DGBMT) and the German, Austrian and Swiss Societies of Medical Physics (DGMP) 2017.

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Daniele Marinazzo

Daniele Marinazzo (PhD in Physics 2007) is a Professor in the Department of Data Analysis at the University of Ghent, Belgium. His research covers methodological aspects of neuroimaging data analysis, computational neuroscience, graph theory, and statistical physics. Together with his research team, Dr. Marinazzo develops new techniques for inferring connectivity architectures from the dynamics of recorded

brain data, in challenging cases of short, noisy and redundant time series, as those encountered in neuroimaging. He is active and enthusiastic about open science and ways to improve the review and editorial process of scientific research. He serves as editor at several peer-review journals, including PLOS Computational Biology, PLOS One, NeuroImage, Brain Topography, Network Neuroscience, and is recognized as top reviewer (Publons 2016, 2017, 2018) in his field.
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Dick Moberg

Dick Moberg has degrees in Electrical Engineering and Biomedical Engineering from the University of Pennsylvania in Philadelphia. He is the founder and CEO of Moberg Research, Inc. which performs research and development in the field of neurocritical care. He has been actively involved in clinical neuromonitoring for over 40 years with most of that time in industry. He and his colleagues have developed three generations of commercial brain monitors used in surgery and critical care. The most recent focus has been to develop a system to collect and time-synchronize high-resolution data from patients in neurocritical care. The data from this device reveals important dynamics of the injured brain. He is leading an international collaboration to develop a new "medical record for the brain". The data in this record greatly improves the existing medical record with better visualization and detection of events as well as patient state transitions. The hope is that with new analytic techniques and new concepts such as network physiology, clinicians will be able to provide more precise management for these brain injured patients.
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J. Randall Moorman

Randall Moorman, M.D., is Professor of Medicine, Physiology, and Biomedical Engineering at the University of Virginia where he is a clinical cardiologist and founding Director of the UVa Center for Advanced Medical Analytics. He completed his undergraduate and medical degrees at the University of Mississippi, did clinical training at Duke Hospital where he was Chief Medical Resident, and undertook basic science research training at Baylor in molecular electrophysiology and membrane biophysics. His research focuses on bedside prediction of subacute, potentially catastrophic illnesses using advanced mathematical and statistical pattern recognition analyses of time series data from clinical monitors. His work initially centered on neonatal sepsis, a life-threatening infection of the bloodstream, and now on adult patient deterioration in ICUs and hospital wards. He developed sample entropy for use in physiological time series, and he introduced coefficient of sample entropy for detection of atrial fibrillation. He is an inventor on 9 issued US patents, the 2014 UVa Innovator of the Year, and Chief Medical Officer of Advanced Medical Predictive Devices, Diagnostics, and Displays. He is vice-president of the Society for Complex Acute Illness and Editor-in-Chief of Physiological Measurement.
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Ulrich Parlitz

Ulrich Parlitz is a research scientist at the Max Planck Institute for Dynamics and Self-Organization, Göttingen (Germany) and an adjunct professor of Physics at the University of Göttingen. He received his PhD in 1987

at the University of Göttingen. From 1989 to 1994 he was with the Institute for Applied Physics at the Technical University of Darmstadt, Germany, and in 1994 he became a scientific assistant at the Third Institute of Physics of the University of Göttingen where received his habilitation in 1997. His main research areas are nonlinear dynamics and data analysis with applications in life sciences, nonlinear oscillators, networks, cavitation, and laser dynamics. In 2010 Ulrich Parlitz joined the Research Group Biomedical Physics at the Max Planck Institute for Dynamics and Self-Organization. There he is involved in theoretical and experimental studies for understanding the nonlinear dynamics of the heart focusing on cardiac arrhythmias. This research includes numerical studies of (transient) spatio-temporal chaos in excitable media and the application of data assimilation methods for fusing experimental measurements (e.g., multichannel ECG time series) with mathematical models of electro-mechanical excitation waves in cardiac tissue. Ulrich Parlitz has published over 170 peer-review publications, including 13 papers in Physical Review Letters. He serves as a panel member of the German Science Foundation (DFG) for Statistical Physics, Soft Matter, Biological Physics and Nonlinear Dynamics, and he is member of the Editorial Board of Frontiers in Applied Mathematics and Statistics (Dynamical Systems) and the Editorial Advisory Board of Chaos: Int. J. of Nonlinear Science.

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Louis M. Pecora

Dr. Pecora is currently a research physicist at the Naval Research Laboratory, Washington, DC, where he heads the section for Magnetic Materials and Nonlinear Dynamics in the Materials and Sensors branch. He received his B.S. degree in physics from Wilkes College and he then enrolled in the Syracuse University Solid State Science program from which he received a Ph.D. in 1977. In the same year, he was awarded an NRC postdoctoral fellowship at the Naval Research Laboratory where he worked on applications of positron annihilation techniques in determining electronic states in copper alloys. This led to a permanent position at NRL. In the mid-1980's Dr. Pecora moved into the field of nonlinear dynamics in solid state systems. Subsequent work has focused on the applications of chaotic behavior, especially the effects of driving systems with chaotic signals and coupling nonlinear dynamical systems in complex networks. This has resulted in the discovery of synchronization of chaotic systems, control and tracking, and dynamics of many coupled, nonlinear systems. Recently his research interests have turned to quantum chaos and collective behavior of oscillators in large complex networks, especially using the techniques of computational group theory. Dr. Pecora has published over 150 scientific papers and has 5 US patents for the applications of chaos. His original paper on the synchronization of chaotic systems has over 5000 citations and is the 10th most cited paper ever in Physical Review Letters. In 1995 he received the Sigma Xi award for Pure Science for the study of synchronization in chaotic systems.

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Arkady S. Pikovsky

Professor Pikovsky, PhD, is Chair of the Departmant of Physics and Astronomy, University of Potsdam, Germany. He graduated from the Gorky State University (USSR) in 1987, and worked in the field of nonlinear dynamics and theory of chaos in the Institute of Applied Physics of the Soviet Academy of Sciences. In 1990-

1992 was an Alexander von Humboldt fellow at the University of Wuppertal, Germany. Since 1992 he is with the University of Potsdam, first as a research fellow and since 1997 as Professor. His work is in the fields of space-time chaos, dynamical regimes at the border of chaos and order, synchronization theory, noise-induced effects in nonlinear systems, methods of nonlinear data analysis of complex systems, patterns and structures, nonlinear and chaotic effects in disordered Hamiltonian dynamics. He is co-author of three monographs: “Synchronization: A Universal Concept in Nonlinear Sciences”, together with M. Rosenblum and J. Kurths, published by CUP in 2001; “Strange Nonchaotic Attractors” together with U. Feudel and S. Kuznetsov, published by World Sci. in 2006; “Lyapunov Exponents” together with A. Politi, published by CUP in 2016, and of more than 250 papers in refereed journals. Current research interests include study of complex synchronization regimes in networks of dynamical systems, with applications to life sciences. He served as panel member of the German Science Foundation (DFG) for Statistical Physics and Nonlinear Dynamics. A. Pikovsky is Fellow of the American Physical Society and Chaotic and Complex Systems Editor of Journal of Physics A: Mathematical and Theoretical.

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Michael G. Rosenblum

Professor Rosenblum, PhD, has been a research scientist and Professor in the Department of Physics and Astronomy, University of Potsdam, Germany, since 1997. His main research areas are nonlinear dynamics, synchronization theory, and time series analysis, with application to biological systems. The most important results include description of phase synchronization of chaotic systems, analysis of complex collective dynamics in large networks of interacting oscillators, development of feedback techniques for control of collective synchrony in neuronal networks (as a model of deep brain stimulation of parkinsonian patients), methods for reconstruction of oscillatory networks from observations, application of these methods to analysis of cardio-respiratory interaction in humans. He studied physics at Moscow Pedagogical University, and went on to work in the Mechanical Engineering Research Institute of the USSR Academy of Sciences, where he was awarded a PhD in physics and mathematics. He was a Humboldt fellow in the Max-Planck research group on nonlinear dynamics, and a visiting scientist at Boston University. He is a co-author (with A. Pikovsky and J. Kurths) of the book “Synchronization: A Universal Concept in Nonlinear Sciences”, Cambridge University Press, 2001 and has published over 100 peer-review publications, including 5 papers in the journals of the Nature Group and 11 papers in Physical Review Letters. Michael Rosenblum served as a member of the Editorial Board of Physical Review E. Since 2014 he is on the Editorial Board of Chaos: Int. J. of Nonlinear Science. He was named an American Physical Society Outstanding Referee for 2015.

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Andrei Ruckenstein

Andrei Ruckenstein served as Founding Vice President and Associate Provost for Research at Boston University from 2007 to 2013, and he is currently Chair of BU’s Physics Department. He received his PhD in Physics from Cornell, was a member of the Theoretical Physics group at AT&T Bell Laboratories, and held faculty positions in Physics at the University of California, San Diego, and Rutgers University. At Rutgers he was the founding Director of BioMaPS, a University-wide initiative focused on interdisciplinary research in

Biology at the Interface with the Mathematical and Physical Sciences, and the first Director of the associated BioMaPS Graduate Program. He also served as Director of the Superconductivity Summer School at the International Center for Theoretical Physics in Trieste, and as President of the Aspen Center for Physics where he was elected as an honorary life-time trustee. He is the co-founder of the Aspen Science Center, a non-profit organization promoting K-12 science education and the public understanding of science. He was also the Chair of the Executive Committee and the founding President of the Massachusetts Green High Performance Computing Center, Inc., a collaboration between Boston University, Harvard, MIT, Northeastern, UMass, the State of Massachusetts, and Cisco and EMC. Currently he serves on the Executive Committee and is a member of the Board of Directors of the Corporation, and as a member of Big Data Organizing Committee for the Commonwealth of Massachusetts. He currently serves as the Chair of the Governance Committee of the Board of CASIS, a Congress designated not-for-profit which manages the research and entrepreneurial activities on the International Space Station National Laboratory, and as a member of the Board of Directors of the Massachusetts Technology Collaborative. Andrei is a theoretical condensed matter physicist by training, whose research interests focused primarily on the study of collective effects in atomic gases at low temperature, and the physics of strongly correlated many-body systems. A decade ago his research direction shifted from theoretical condensed matter physics to Biological Physics, an area that would be more appropriately described as “Biology from a Physicist’s Perspective”. His biology research has been concerned with understanding the mechanisms governing the behavior of RNA polymerase, the molecular motor that transcribes the genetic information encoded in DNA into RNA. He is the recipient of a Sloan Fellowship, an ONR Young Investigator Award, and a Senior Humboldt Prize, and he is a Fellow of the American Physical Society.

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Antonio Scala

Dr. Scala, holds a Master degree in Physics and Computer Science from the University of Napoli “Federico II”, a PhD in condensed matter Physics from Boston University. He is a specialist in Operational Research and Decisional Strategies at the department of Statistics of Roma “La Sapienza”. He is also a research scientist in the CNR Institute for Complex Systems at the University of Roma “La Sapienza”, associate professor at IMT Alti Studi Lucca and research Fellow at the London Institute for Mathematical Sciences, LIMC. Dr. Scala is an interdisciplinary scientist with background in statistical physics and computer science. He has published seminal papers on complex networks and has edited the first book on networks of networks (“Networks of Networks: The Last Frontier of Complexity”, Springer 2014). Recently, he has worked on the problem of online misinformation on vaccines. Dr. Scala has applied network science to set up a framework for representation and understanding of medical data in clinical dentistry, and has published first case studies on applications of networks in childhood orthodontics; building up on this experience, he is now working of the network approach to Big Data in Health. His research focuses on developing tools and metrics to derive knowledge from medical records, and complementing clinical trials with statistical analyses of large medical databases.

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Michael F. Shlesinger

Dr. Michael Shlesinger created the Nonlinear Physics program at the Office of Naval Research in 1983. That program initially focused on the concept of chaos and its applications, including health monitoring. The program now has an emphasis on device physics. Today research in the program includes network control and network-to-network interactions. His own research included work in the 70's and 80's on noise properties of potassium channels, and in the 2000's the design of peptides to bind to G-7 transmembrane receptors. He has published over 200 scientific works on topics of fractals, Levy flights and other scale invariant phenomena from charge movement in amorphous semiconductors to turbulent diffusion. More recent work involves conductivity, dielectric relaxation, and viscosity of polymers as a function of temperature and pressure near the glass transition. He received the US Government Presidential Rank Award in 2004, ONR's Saalfeld award for Outstanding Lifetime Achievement in Science in 2006, and in 2013 the American Physical Society Outstanding Referee Award. He is a Fellow of the APS and he held the Kinnear Chair in Physics at the US Naval Academy.

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Olga Sosnovtseva

Olga Sosnovtseva, PhD, is Professor with Special Duties at the Department of Biomedical Sciences, University of Copenhagen, Denmark. She received her M.S. and PhD degree in physics from Saratov State University (Russia) and worked in the field of nonlinear dynamics and theory of chaos. She received her second PhD degree in Human Biology from the Faculty of Medicine, University of Marburg, German, and worked in the field of biophysics and mathematical physiology. The most important results include development of nano-sensors to study heme protein properties and signalling pathways in living cells, development of biophotonics tools to study blood flow regulation in microcirculation, introduction of the concept of synchronization to renal physiology, methods to study interaction of physiological oscillations, development of the first nephro-vascular dynamical model of renal autroregulation. She is a co-author of the book "Synchronization: From Simple to Complex" (Springer, 2009), co-editor of the book "Biosimulation in Biomedical Research, Health Care and Drug Development (Springer, 2012) and has published over 150 peer-review publications. She received Skou fellowship (Denmark) for development of mechanism-based models of intercellular interactions and became Edmund Optics Educational Award finalist. She serves as a panel member of Swedish Research Council for Basic disease mechanisms: Molecular, cellular and biochemical aspects, and for Consolidator Interdisciplinary Grants.

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Ruedi Stoop

Professor Stoop studied mathematics at the University of Zurich and completed his PhD in computational physics at the same university in 1991. After obtaining grants from the Swiss National Science Foundation, he became a reader in computer science at the School of Life Sciences, University of Applied Science Northwest Switzerland, and worked in parallel as a scientific advisor and designer for several industrial companies. He became an Associate Professor in physics at the University of Berne in 1997, Adjunct Professor in mathematics at the University of Zurich in 2004 and soon after also in theoretical physics at the

Swiss Federal Institute of Technology (ETH). In 2008 he obtained tenure in Neuroscience and Physics at the Institute of Neuroinformatics, run jointly by the University of Zurich and the Swiss Federal Institute of Technology (ETH). His main research directions lie along two related paths: Nonlinear dynamics of biological systems, and principles and applications of biocomputation, seen as domains of mathematics, physics and information science. Prof. Stoop has published a large number of peer reviewed papers documenting a true interdisciplinary approach, from physics over mathematics, engineering, biology to data science. He authored and co-authored books published by Springer, Birkhäuser and World Scientific.
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Sebastiano Stramaglia

Dr. Stramaglia is an Associate Professor of Applied Physics at the University of Bari, Italy, and External Scientific Member of the Basque Center for Applied Mathematics, Bilbao, Spain. He received his Ph.D. in Statistical Mechanics of random surfaces from the University of Bari in 1995, and the Laurea degree in models of strongly correlated electronic systems in 1991. Since 2001 he is a member of the Center of Excellence “Innovative Technologies for Signal Detection and Processing”, funded by the Italian Ministry for Scientific Research; since 2002 he is a member of the V National Scientific Commission of INFN-Istituto Nazionale di Fisica Nucleare, Italy. He chaired several international events, including “Modeling Migraine: from nonlinear dynamics to clinical neurology” July 2009, Berlin, and “Nonlinear dynamics in electronic systems” July 2013, Bari. Editor of the books “Modelling Biomedical Signals”, World Scientific 2002, and “Emergent Complexity from Nonlinearity, in Physics, Engineering and the Life Sciences”, Springer 2017. He has been visiting scientist at the Institute for Theoretical Physics NORDITA and at the Department of Data Analysis of the University of Gent, Belgium, and visiting professor at Biocruces Health Institute, Bilbao, Spain. Since 2003 he is team leader of the INFN project “Biological applications of Theoretical Physics Methods”. His research focuses on dynamical networks and Granger causality approaches to physiological interactions, in particular he developed a kernel approach for the inference of nonlinear coupling among dynamical systems with applications to brain function and brain-heart interactions.
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Béla Suki

Professor Suki received BS in Physics (1982) and PhD in Biomechanics (1987) from the University of Szeged, Hungary. He worked at INSERM, Nancy, France in 1988 and in the Meakins-Christie Laboratories, McGill University, Montreal in 1990. He received the Dean’s special research associate position at the Department of Biomedical Engineering at Boston University where he became assistant professor in 1996, associate professor in 2001 and full professor in 2007. In 2007, he was elected Fellow of the American Institute for Medical and Biological Engineering. In 2009, he received presidential award from the National Institutes of Health and became honorary professor of Medical Physics and Informatics, University of Szeged, Hungary. He is Fellow of the Biomedical Engineering Society. He was visiting professor at Kyoto University, Japan, University Hospital of Bern, Switzerland, University of Western Australia, Perth, and the University of Ceara, Fortaleza, Brazil. Dr. Suki has published work in morphometric and acoustic network modeling of the lungs airway branching tree. His group introduced elastic networks to describe the mechanics and failure of

extracellular matrices to understand how lungs deteriorate during diseases such as emphysema and fibrosis. He developed network modeling approaches to predict the long-term outcome and quality of life following lung surgery, and has implemented a neural network model of the brain respiratory center to describe the variability of breathing patterns. Dr Suki's current research interests include respiratory physiology, tissue homeostasis and modeling nonlinear and network phenomena in physiology and biology.
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Murad Taqqu

Professor Murad Taqqu is a probabilist and statistician specializing in time series and stochastic processes. His research areas have included long-range dependence, self-similar processes, and heavy tails. He is a Professor of Mathematics at Boston University and received his Ph.D. from Columbia University. He has published over 250 papers, many of which are considered seminal work. He has co-authored or co-edited 9 books.
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Franca Tecchio

Professor Franca Tecchio is a Senior Researcher at the National Research Council (CNR) in Italy, where she is the Director of the Laboratory of Electrophysiology for Translational Neuroscience (Let's Laboratory). Her work focuses on methods of brain complexity analysis and therapeutic interventions via precision electroceuticals. Her laboratory utilizes magneto- and electroencephalography (MEG, EEG, EMG) and non-invasive neuromodulation techniques to investigate neuronal electrical activity (TMS, tES, tDCS, tIDS). Dr. Tecchio has seminal contributions to understanding brain function and dynamics through network approaches and to elucidating coupling forms and interactions with other peripheral systems and environment, including brain somatosensory activation and processing in response to body movement; sensory cortex activity in anesthesia; coupling of neural activation and local hemodynamics; cortical responses to auditory stimuli etc. Her work is presented in more than 250 publications. Dr. Tecchio is among the 10 most active Italian researchers in Clinical Neurology ('La Repubblica Salute', 2003), and her discoveries are broadly featured in the media, including in 'Il Venerdì di Repubblica' (2016), one of the most read weekly magazines in Italy. She appeared as a speaker at the TEDx lecture series in 2016 with more than 42,000 views. She served as the Primary investigator of 32 grant projects, expert evaluator of 18 European funding initiatives (including ERC), and was a Chairwoman of 10 scientific congresses and speaker at numerous international conferences. She is an Associate Editor of the journals Neuroscience and Restorative Neurology.
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Robert J. Thomas

Robert Joseph Thomas, M.D., M.M.Sc, is Associate Professor of Medicine, Harvard Medical School & The Division of Pulmonary, Critical Care & Sleep, Beth Israel Deaconess Medical Center, Boston, Massachusetts, USA, His background includes Internal Medicine, Neurology and Sleep Medicine. His research spans mood, cognition (translational and epidemiology), sleep epidemiology, signal analysis in sleep medicine, and sleep-breathing outcomes, and functional imaging of cognition in sleep disorders. He has articulated a new approach to sleep physiology termed "sleep effectiveness", which is a cross-physiology, networked, integrative approach to characterizing sleep state using cardiopulmonary coupling estimates (patented). His

laboratory generates novel approaches and analysis tools for probing several sleep signals – ECG, EEG, respiration and multi-signal integration approaches. He funding sources are the NHLBI, NINDS and the American Sleep Medicine Foundation. He was key in the development of a FDA approved wearable device, the M1/SleepImage system, for dynamic sleep quality tracking. He is an acknowledged expert in the area of treatment of central and complex sleep apnea and periodic breathing, utilizing CO_2 regulation approaches (patented). He studies brain health in the context of sleep disorders in the USA and South Korea. He directs the AASM accredited clinical sleep center and sleep laboratory, and the sleep medicine training program at the Beth Israel Deaconess Medical Center. I worked in the development and implementation (patented) of auto CPAP algorithms from concept through regulatory submission, which are now in FDA approved products.
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B. Taylor Thompson

Taylor Thompson, MD, is a Professor of Medicine at Harvard Medical School and the Director of Translational Research for the Division of Pulmonary and Critical Care Unit at the Massachusetts General Hospital (MGH), Boston. Dr Thompson served as the Director of the MGH Medical Intensive Care Unit for over 20 years and currently serves as an Associate Editor for Critical Care for the American Journal of Respiratory and Critical Care Medicine. Dr. Thompson is an expert in the design, conduct, and analysisof clinical trials for the critically ill and has coordinate a number of complex clinical trials that have influenced the care of patients with ARDS worldwide. He serves as Medical Director of the Clinical Coordinating Center for the NHLBI's Prevention and Early Treatment of Acute Lung Injury (PETAL) Clinical Trials Network. This network is currently involved with three large randomized trials of for ARDS and sepsis and for the prevention of critical illness. In addition to ARDS, Dr. Thompson's clinicaland research interests include functional imaging of the lung using positron emission tomography, diagnostic approaches to pulmonary thromboembolism, and the use of computerized decision support tools in the ICU.
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Stefan Thurner

Stefan Thurner **i**s full professor for Science of Complex Systems at the Medical University of Vienna, where he chairs Section for Science of Complex Systems. He is and the president of the Complexity Science Hub Vienna, external professor at the Santa Fe Institute, and a senior researcher at IIASA. Stefan obtained a PhD in theoretical physics from the Technical University of Vienna and a PhD in economics from the University of Vienna. He held postdoc positions at Humboldt University of Berlin and Boston University before joining the faculty of the University of Vienna and later Medical University. His habilitation is in theoretical physics. Stefan started his career with contributions to theoretical particle physics and gradually shifted his research focus to the understanding of complex systems. Stefan has published more than 200 scientific articles in fundamental physics (topological excitations in quantum field theories, statistics and entropy of complex systems), applied mathematics (wavelet statistics, fractal harmonic analysis, anomalous diffusion), network theory, evolutionary systems, life sciences (network medicine, gene regulatory networks, bioinformatics, heart beat dynamics, cell motility), economics and finance (price formation, regulation, systemic risk) and lately in social sciences (opinion formation, buerocratic inefficiency, collective human behavior, efficiency of healthcare systems). He

holds two patents. His work has been covered extensively by international media such as the New York Times, BBC world, Nature, New Scientist, Physics World, and is featured in more than 400 newspapers, radio and television reports. For his ongoing efforts and his skills to communicate complexity science to an interested public Stefan was elected Austrian “scientist of the year” in 2018.

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Andreas Voss

Andreas Voss (Male) is since 1997 Full Professor in Biosignal Processing and Medical Informatics at the Ernst-Abbe-Hochschule (EAH) in Jena, Germany. Before that, he worked as leader of the Biosignal Processing research group at the Max-Delbrueck-Centre for Molecular Medicine in Berlin. In 2015, he founded the Institute of Innovative Health Technologies IGHT at the EAH where he acts up to now as the director and coordinates the research between five different departments. His research interest are linear and non-linear analysis of multivariate and multiscale data and systems analysis (e.g. risk stratification in different diseases), characterizing autonomic regulation (heart diseases, schizophrenia, depression, stress…), time-frequency analyses, knowledge based interpretation of physiological and pathophysiological regulations, and electronic senses (electronic nose). Prof. Voss published more than 300 papers in peer reviewed journals. He is member of scientific societies (DGBMT, European Society of Cardiology, and IEEE), organizer, co-organizer and associated editor of various national and international conferences as well as member of scientific boards of various other academic events and scientific journals. He acts as reviewer and for many international journals, conferences and grant agencies.

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Xiyun Zhang

Dr. Zhang received his PhD in theoretical physics at East China Normal University in June 2016. Currently he is a post-doctoral fellow (supported by W.M. Keck Foundation) at Keck Laboratory for Network Physiology, Boston University. Dr. Zhang’s main research interest is to understand complex phenomena and collective behaviors in physical, physiological and biological systems utilizing methods and concepts from nonlinear dynamics and statistical physics. His research focuses on synchronization in coupled oscillators in complex networks; developing novel time series analysis methodology to probe network interactions among physiological systems; building new biomarkers based on organ interactions for early diagnosis; understanding regulatory mechanism underlying different physiological states from the point of view of Network Physiology.

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Scientific Program

Registration **12:00-14:00** **Sunday, 28 July, 2019**

Opening **Plamen Ch. Ivanov** **14:00-14:25** **Sunday, 28 July, 2019**

Session Chair **Plamen Ch. Ivanov**

Plamen Ch. Ivanov **14:25-15:05** **Sunday, 28 July, 2019**

Title: ***The New Field of Network Physiology: Mapping the Human Physiolome***

Abstract: The human organism is an integrated network where complex physiological systems, each with its own regulatory mechanism, continuously interact to optimize and coordinate their function. Organ-to-organ interactions occur at multiple levels and spatiotemporal scales to produce distinct physiologic states: wake and sleep; light and deep sleep; consciousness and unconsciousness. Disrupting organ communications can lead to dysfunction of individual systems or to collapse of the entire organism (coma, multiple organ failure). Yet, we know almost nothing about the nature of interactions among diverse organ systems and sub-systems, and their collective role as a network in maintaining health.

The emerging new field of Network Physiology aims to address these fundamental questions. In addition to defining health and disease through structural, dynamical and regulatory changes in individual systems, the network physiology approach focuses on the coordination and interactions among diverse organ systems as a hallmark of physiologic state and function.

Through the prism of concepts and approaches originating in statistical and computational physics and nonlinear dynamics, we will present basic characteristics of individual organ systems, distinct forms of pairwise coupling between systems, and a new framework to identify and quantify dynamic networks of organ interactions.

We will demonstrate how physiologic network topology and systems connectivity lead to integrated global behaviors representative of distinct states and functions. We will also show that universal laws govern physiological networks at different levels of integration in the human body (brain-brain, brain-organ and organ-organ), and that transitions across physiological states are associated with specific modules of hierarchical network reorganization.

We will outline implications for new theoretical developments, basic physiology and clinical medicine, novel platforms of integrated biomedical devices, robotics and cyborg technology.

The presented investigations are initial steps in building a first Atlas of dynamic interactions among organ systems and the Human Physiolome, a new kind of BigData of blue-print reference maps that uniquely represent physiologic states and functions under health and disease.

B. Taylor Thompson **15:05-15:45** **Sunday, 28 July, 2019**

Title: ***Lung injury begets multiorgan failure and death: lessons learned from the Acute Respiratory Distress Syndrome.***

Abstract: The Acute Respiratory Distress Syndrome (ARDS) is a devastating complication of viral or bacterial pneumonia, sepsis, major trauma, and many other illnesses or exposures, such as smoke or chlorine gas inhalation. Nearly some quarter-million patients per year develop ARDS and 40% die annually in the US. ARDS is triggered by activation of resident lung inflammatory cells that entice other inflammatory cells into the lung. These cells release injurious mediators causing destruction of the lung epithelium and endothelium resulting in flooding of airspaces with plasma and blood. Suffocation follows without treatment with high concentrations of

oxygen administered by mechanical ventilators in intensive care units. Both oxygen and the breaths delivered by the ventilator can cause additional lung injury and guidelines for the judicious application of each have been developed based on high quality randomized trials. This presentation will discuss several the unanswered questions related to ARDS pathogenesis and treatment with implications for systems biology. Why do only a minority of patients with pneumonia, sepsis and ARDS develop ARDS while others are spared? What might the resiliency or susceptibility factors be? The majority deaths are due to multisystem organ failure after initial stabilization of the lungs. Why do the kidneys, heart, brain, skeletal muscle, coagulation system follow the lungs to failure? Why do survivors have residual cognitive impairments and skeletal muscle dysfunction years later? Potential answers lie in the genome, the vascular bed, the peripheral nervous system, and the mitochondria though the understanding of multiorgan failure is just beginning. A Network Physiology approach will likely be necessary to understand this multi-organ multi-scale problem.

Coffee Break **15:45-16:15** **Sunday, 28 July, 2019**

Barbara Corkey **16:15-16:55** **Sunday, 28 July, 2019**

Title: ***The Redox Communication Network as a Master Regulator of Metabolism***

Abstract: Key metabolic tissues are dysfunctional in obesity, diabetes, fatty liver, PCOS and vascular stiffness, both singly and in combination. Research has focused on the individual organs involved in each disease, as though each was isolated. Much attention has been paid to insulin resistance as the key relevant pathosis, with a detailed focus on insulin receptor signaling in sensitive tissues. However, the tissues involved in these diseases play an important role in synergistically regulating metabolic homeostasis, and need to be considered as a network. The approach I will discuss and the model I will present introduces the novel concept of redox as a master regulator of metabolism. Redox refers to shared molecules reflective of metabolic state that can readily lose electrons to increase the oxidation state or gain electrons to decrease the oxidation state of molecules or ions. Metabolism generates redox molecules that alter metabolic function in ß-cells, liver, adipose and other tissues, thus, responding to anabolic and catabolic stimuli appropriately and synergistically. This is perhaps analogous to the generally accepted concept of transcriptional master switches that regulate families of anabolic and catabolic genes. Data also suggest that it is important to assess environmental factors that have arisen in recent decades as modifiers of redox or ROS and thus metabolic state. ROS refers to reactive oxygen species produced in response to altered redox state in the mitochondria. These are highly reactive and control the thiol redox state and function of many proteins.

Within each cell, lactate (L) and pyruvate (P) are present in a ratio of about 10 that reflects the cytosolic redox state (NADH to NAD ratio). Equilibrium is maintained in most cells because the enzyme lactate dehydrogenase is highly expressed. The major source of lactate and pyruvate in the blood is muscle, although many other tissues also contribute. Acetoacetate (A) is produced primarily in liver mitochondria where ß-hydroxybutyrate dehydrogenase is highly expressed, and maintains a ratio of ß-hydroxybutyrate (ß) to A of about 1, dependent on the mitochondrial redox state (NADH to NAD ratio). All four metabolites as well as thiol indicators are generally readily transported into and out of cells, due to high expression of the requisite anion transporters. The lactate/pyruvate (L/P), ß/A and thiol (SH/SS) ratios have been used in the past to reflect various metabolic disease states. Validation of this model would support simultaneous regulation of all collaborating metabolic organs through changes in the circulating metabolites, regardless of whether change was initiated exogenously or by a single organ. Such validation would also suggest novel ways to impact disease by manipulating the redox state.

James W. Holsapple **16:55-17:35** **Sunday, 28 July, 2019**

Title: ***Neurosurgery: A Testing Ground for Network Physiology***

Abstract: Medical decision-making largely depends on the value of a small number of visible physiologic

variables easily acquired in the clinic, at the bedside, and in the operating room. As a result, diagnosis, assessment and management are often based entirely on the measurement and restoration of nominal values of parameters that may capture only a partial view of the physical state and function of individual body systems and organs in isolation from others. Although methods of clinical analysis and treatment based on a relatively small set of physiological parameters may be sufficient in some instances, the approach can lead to the misclassification or incomplete specification of pathophysiologic states and less than ideal treatment outcomes. Patients with similar "vital signs", laboratory results, radiographic abnormalities, and physical findings, for example, may harbor distinct and variably severe disease states difficult to detect using methods of data selection, analysis and representation that ignore dynamic, physiologic relationships. This limitation can have a significant impact on management decisions throughout the course of an illness. Many real-life clinical situations suggest that representations of the time-varying relationships between organs and organ subsystems could be used to define or differentiate disease states, customize clinical decision-making, measure the severity of disease, and more accurately assess the effectiveness of treatment. The extensive coupling of the nervous system to nearly every other organ and body system, as well as to its own subsystems, presents a natural clinical testing ground for this concept. In neurosurgical practice, many opportunities arise to test this possibility in and outside the operating room, including the management of unconscious states, characterizing and managing traumatic brain injury (TBI, concussion), tracking the evolution of subarachnoid hemorrhage and ischemic stroke, monitoring the integrity and function of the nervous system during surgery, detecting and correcting defects in autonomic control, differentiating lethal and progressive forms hydrocephalus from benign ventriculomegaly, identifying subsets of children with hindbrain congenital anomalies requiring decompression, and the optimal placement of neuromodulating (deep brain stimulators) devices in patients with Parkinson's Disease and psychiatric disorders. Cases will be presented to highlight current neurosurgical decision-making and introduce the potential advantages of utilizing network physiological data intraoperatively.

Sebastiano Stramaglia **17:35-18:15** **Sunday, 28 July, 2019**

Title: ***Physiological aging in brain networks***

Abstract: The Network Physiology of the brain offers a further challenge, the relation between structure and function: how is the network of communications between brain districts influenced by the underlying structural connections between them? A related question is: how this relation evolves with aging? The combination of structural and functional brain data, analysed by complex network approaches, have led to the conceptualization of brain networks as a connectome, and its correlates with age and disease has gained major attention in recent years. Complex network approaches have highlighted the key role played by several network features in aging and brain diseases, such as network hubness, node efficiency, network modularity, and hierarchical organization. The effects of aging on network modularity have shown a decrease in network segregation along the lifespan, a mechanism supporting the loss of functional specialization at the cognitive level. After an introduction to current approaches and their limitations, I will describe recent works where we highlighted the role of the fronto-striato-thalamic informational circuit in brain aging and the redundant role of the default mode network. These findings resulted in the definition of the brain connectome age (BCA) to be compared with the chronological age.

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Registration **8:00-9:00** **Monday, 29 July, 2019**

Session Chair: **B. Taylor Thompson**

György Buzsáki **9:00-9:35** **Monday, 29 July, 2019**

Title: ***Visualizing network dynamics in cognition***

Abstract: Direct investigation of the temporal dynamics of neuronal populations can only be based on

simultaneous observation of many individual neurons in the behaving animal. Advancement in this field has been accelerated by the availability of silicon microtechnology-based
multichannel recording arrays. These arrays allow for simultaneous recording of action potentials from the soma and dendrites of single neurons as well as for 2-dimensional mapping of current fields superimposed on anatomical structure. The combination of the field and unit information for studying various oscillatory and intermittent population events in the hippocampus and neocortex can be monitored at the speed of neuronal communication. These tools are essential for addressing the extent by which activity in cortical networks is driven by sensory stimuli or internally generated, self-organized activity.
The fundamental goal of the brain is to predict the future. More complex brains evolved multiple hierarchical loops between their outputs and inputs to make prediction more reliable in more complex environments and at longer time scales. With extensive training these prediction mechanisms have become 'internalized'. At the center of this model are self-propagating loops of neuronal coalitions connected by modifiable synapses that can be propelled forward without external cues. The implication of this conjecture is that brain networks are endowed with internal mechanisms that can generate a perpetually changing neuronal activity even in the absence of environmental inputs. I will discuss examples and mechanisms of this framework.

Alain Arneodo **9:35-10:10** **Monday, 29 July, 2019**

Title: ***From power-law to log-normal rupture cascades in random network modeling of living cell plasticity***

Abstract: When submitted to an external mechanical stress, the cytoskeleton (CSK) of living cells was shown to experience avalanches of rupture events likely resulting from the unbinding of crosslinker proteins. Surprisingly, as regards to the ubiquity of power-law statistics for avalanches in solids, these cascades of CSK failure events display log-normal statistics. In this talk, we show that in simple random network models like the Erdös-Reyni model or the random-field Ising model, similar log-normal statistics of rupture avalanches can be obtained when explicitly taking into account the viscoelastic soft-glassy fractional rheology of the CSK. This minimal modeling is a very promising first attempt to elucidate the impact of the CSK network architecture and dynamics on living cell plasticity in both health and disease

Coffee Break **10:10-10:40** **Monday, 29 July, 2019**

Jürgen Kurths **10:40-11:15** **Monday, 29 July, 2019**

Title: ***Brain oscillations via rhythmic stimulation – synchronization or superposition?***

Abstract: In extension of the concept of phase synchronization introduced in my first talk, I will also explain some phenomena of superposition, in particular concerning event related responses in the brain activity. Techniques to identify both regimes will be presented. This methodology will then be applied to experiments with visual rhythmic stimulation measured by EEG. Based on a critical comparison of these methods, we identify the underlying mechanism of brain activity.

Antonio Scala **11:15-11:50** **Monday, 29 July, 2019**

Title: ***Network Physiology: a case study in Dental Medicine and an overview of applications to Big Data in Health***

Abstract: We are in the era of the data deluge: however, to transform data into information we have to "data-mine" patterns and correlations in our data bases. In such an approach, data become the basis for experiments in which models can be validated and hypothesis can be tested. At different with the standard scientific methodology, where first an experiment is designed and then data are collected, in the "big data" approach experiments must be designed taking the already collected data set as a constrain.

One of the most exciting field of investigation for such an approach is medical knowledge discovery based on the analysis of Electronic Medical Records (EMRs). In fact, the classification of human disease builds on the observation of correlations between the analysis of pathologies and clinical syndromes: while up to now this process has relied on the single doctors' observational skills, we are now in the position of extending the observation field. However, the huge among of data and the consequent explosion of the number of possible correlations to be considered calls for adequate tools and methodologies to reduce possible hypothesis to a finite number.
Notice that an important feature of EMRs based medical knowledge discovery is that in such framework we do not rely on clinical experiments where patients are subject to experimental protocols, but innovation stems from the observation of standard practices, at the same time also helping to improve their effectiveness.
In this lecture we will show an application of these concepts to the interpretation of clinical signs in a childhood orthodontics case study. We will show that such methodology is validated by confirming the robustness of well know concepts of the fields (the dental classes) while enlarging and clarifying such concepts and allowing for a quantitative description. We show that such process of re-discovery of dental classes while creating new questions to be answered also builds up the basis for their resolution.
We will further show how the same framework, by network analysis of EMRs, can be applied to tackle the problem of drug prescription or to predict comorbidities.

Tjeerd W. Boonstra **11:50-12:20** **Monday, 29 July, 2019**

Title: ***Functional connectivity in human motor system***

Abstract: The human body is a complex system consisting of many subsystems and regulatory pathways. The musculoskeletal system gives the body structure and creates the ability to move. It is made up of more than 200 skeletal bones and over 300 skeletal muscles. The central nervous system controls these movements through the spinal motor neurons, which serve as the final common pathway to the muscles. While the anatomical and physiological components of the musculoskeletal system are well characterized, the organizational principles of neural control remain incompletely understood. In this presentation I will discuss the use of functional connectivity and network analysis to investigate the functional organization of the distributed neural circuitry from which motor behaviours emerge. Examples will be given of intermuscular and corticomuscular coherence during different motor behaviours, including postural tasks and locomotion, and how coherence is modulated by fatigue and motor learning. By estimating intermuscular coherence between numerous muscle pairs, the weights of so-called muscle networks can be estimated. Network analysis has been widely used to investigate functional integration in the central nervous system and this approach can be extended to investigate the network topology of functional interactions between muscles. When combining both approaches, we can map the brain-body networks involved in human motor control. This combined appraoch fits within the broader framework of network physiology and is well placed to provide new insights and interventions for movement disorders.

Lunch Break **12:20-14:00** **Monday, 29 July, 2019**

Session Chair: **Randall Moorman**

Robert Thomas **14:00-14:35** **Monday, 29 July, 2019**

Title: ***Normal sleep as a multi-component multi-level networked state***

Abstract: Traditional models of sleep and sleep regulation have focused on partially independent sleep homeostatic and circadian drives. As described, the interactions are relatively straight forward, with substantial linear components, but do not explain a number of features noted during recordings from sleep state in health

and disease. For example, the 2-process model does not explain macrofragmentation of sleep common in neurodegenerative diseases or which occurs during jet-lag recovery, the richness of data generated during sleep state is largely discarded but generates the conventional stages, which is a highly reductionist approach. Standard sleep stages and typical metric such as the apnea-hypopnea index do not correlate highly with measurable clinical outcome such as sleepiness and subjective sleep quality.

It is proposed here that sleep is better considered as a networked state, with distinct but interactive networks, each with subnets. Integration of these networks across classic 3 dimension and a 4th of time, makes for a highly complex system. In this conceptual approach, sleep has a generative network (brain) which generates the recognizable sleep state, a downstream synchronized network of largely hemodynamic, motor, respiratory and autonomic components, and a modulated network (neuroendocrine and immune) which is strongly influenced by sleep state and have vast impact on normal and abnormal body functioning. The generative network has cortical, subcortical and brain stem components, each layer with unique network behaviors which are partially captured by conventional sleep recordings. However, the networked interaction between each component is poorly understood but likely a key challenge for network physiology and medicine to decipher. How does, for example, the cortex work with the thalamus and brain stem to create stable and unstable NREM and REM sleep, which are readily recognized on the surface? Synchronization and coupling occur at several distinct time scales. Normal functioning off the large-scale sleep network (all three dimensions) is necessary for brain and body function from conception to death. Data from techniques such as depth recordings, surface high density EEG, intra-cortical recordings, hemodynamics, blood pressure, electrocardiogram, muscle sympathetic nerve activity and optogenetic stimulation will be used to develop a plausible model of sleep as a multi-layered and multicomponent networked state. This presentation will focus on health and development.

Xiyun Zhang **14:35-15:10** **Monday, 29 July, 2019**

Title: ***Network physiology and aging: fundamental laws of physiological regulation of organ networks***

Abstract: Identifying and quantifying dynamical networks of diverse systems with different types of interactions is essential to understand the mechanisms underlying the physiological regulation of organ networks. Utilizing a novel approach based on the concept of Time Delay Stability (TDS), we will demonstrate how diverse physiological systems in the human organism dynamically interact as a network to generate distinct physiological states and functions, and how physiological network topology and function evolve with aging. We will introduce a physiologically-motivated visualization framework to map networks of dynamical organ interactions to graphical objects encoded with information about the coupling strength of network links quantified using the TDS measure. Applying a system-wide integrative approach, we identify distinct patterns in the network of organ interactions across physiological states and age groups, establish first maps representing physiologic network interactions, track the evolution of organ networks with aging, and derive basic rules underlying the complex hierarchical reorganization in subnetworks of physiologic interactions (brain-brain, brain-organ and organ-organ) with transitions across physiologic states. Our findings demonstrate a robust association between network characteristics and physiologic function, reveal previously unknown laws of physiological regulation, and provide new insights into understanding how health and distinct physiologic states emerge from networked interactions among diverse organ systems, and how physiological networks gradually change with aging while preserving key modalities.

Coffee Break **15:10-15:40** **Monday, 29 July, 2019**

Olga Sosnovtseva **15:40-16:15** **Monday, 29 July, 2019**

Title: ***Kidney function: An interplay between structural network topology and network dynamics***

Abstract: The kidney is an efficient filtering “device” that consists of one million units that are connected through

the vascular network and work together to fulfill the overall function. The kidney must be viewed as the champion among organs of the body when it comes to stability of organ blood flow. This regulation is normally attributed to a highly efficient autoregulation of kidney blood flow in response to variations in systemic blood pressure, to complex interactions of vasoconstrictor and vasodilator influences, and to a local feedback system. This system interrelates reabsorption and filtration rate via regulation of kidney vascular resistances. A unique topology of the renal vascular network ensures sufficient filtration rate and interaction between functional units. What are the structural and anatomical features of renal network? Which techniques are available to access its topological and dynamical parameters? How can we relate structural and functional changes in health and disease? These fundamental questions and recent results will be discussed through the prism of structural and dynamic networks approaches to kidney function.

Stefan Thurner **16:15-16:50** **Monday, 29 July, 2019**

Title: ***Network medicine—what do we learn from co-morbidity networks?***

Abstract: Nation-wide claims data we allow us to estimate the state of health of practically every person. In particular, we see who suffers from more than one disease at a given time. This allows us to derive the phenotypical co-morbidity networks that occur in a given population.

The way how these networks change over life-time enables us to understand and predict individual disease trajectories with a high degree of precision.

We will discuss to what extent these networks force us to rethink the current classification of diseases, prevention strategies, usefulness of therapies, and side effects. We will show that knowing phenotypical co-morbidity networks helps to understand if a given disease is of genetic, pathway related, or toxico-genetic origin. We discuss briefly how the same data can be used to access the efficiency of a current healthcare system and how to find strategies to improve it.

Poster Session I **17:00-18:30** **Monday, 29 July, 2019**

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Session Chair: Bela Suki

Klaus Lehnertz **9:00-9:35** **Tuesday, 30 July, 2019**

Title: ***Limitations on inferring couplings and directionality: Lessons learned from evolving epileptic brain networks***

Abstract: The data-driven and time-resolved inference of couplings and directionality between two or more sub-systems is an important first step in representing a complex system as a network. Although a large number of time-series-analysis-techniques is now available to assess strength, direction, and functional form of couplings, there still exist a number of unsolved issues for which there are currently no satisfactory solutions. In this lecture, I will showcase some of these issues at the example of evolving epileptic brain networks.

Barbara Corkey **9:35-10:10** **Tuesday, 30 July, 2019**

Title: ***Network of Glucose-Induced Signals for Insulin Secretion***

Abstract: The main focus of basic scientists and big pharma in diabetes research is on single targets and events observed at a single point in time. However, metabolism plays a crucial role in generating multiple temporally related signals for glucose-stimulated insulin secretion (GSIS). Understanding this process and the defects characteristic of disease requires understanding the entire network and its interactions. Increases in the ATP-to-ADP ratio close ATP dependent K+ (KATP) channels, leading to membrane depolarization and Ca2+ influx through voltage-gated Ca2+ channels. This rise in the cytosolic free Ca2+ is essential for GSIS. Cytosolic free

Ca2+ oscillates as does periodic depolarization of the plasma membrane potential, and they occur in parallel with oscillations in insulin secretion during GSIS. GSIS also occurs with the same concentration dependency even when elevated cytoplasmic Ca2+ is maintained by high K+ in the presence of the KATP channel blockage. This demonstrates that the pathway operates independently of changes in intracellular Ca2+, that are essential but not sufficient. Questions arise as to what other parameters correlate and therefore are likely determinants of full-scale GSIS, when cytoplasmic Ca2+ does not. We compared two responses, cytoplasmic Ca2+ and mitochondrial membrane potential ($\Delta\Psi m$), in single islet cells at glucose concentrations between 4 to 16 mM and compared these responses with insulin secretion under the same conditions. Secretion at all glucose concentrations correlated with $\Delta\Psi m$ but not with Ca2+. Stimulatory glucose and the mitochondrial reductant, ßOHB, also increased the mitochondrial redox state and stimulated ROS production while ROS scavengers abrogated secretion from all stimuli. These data suggest that insulin secretion is stimulated by increased ROS production due to an increase in the mitochondrial redox state that is independent of the other established necessary components of GSIS. Like Ca2+, ROS is also essential. Finally, lipid deprivation blocks GSIS that can be restored with although prolonged lipid excess depletes insulin stores and GSIS. Thus, there are at least four essential and sufficient signals that can stimulate insulin secretion but none alone can explain the oscillatory pattern of GSIS. Developing a model to explain GSIS involves understanding the detailed time course to determine both the sequence and pattern of change, detailed concentration dependence to identify best correlates and independent manipulation of several putative signals. Only by understanding the network involved in GSIS can we address the defects that accompany disease.

Coffee Break **10:10-10:40** **Tuesday, 30 July, 2019**

Ruedi Stoop **10:40-11:15** **Tuesday, 30 July, 2019**

Title: ***Critical peripheral neural network physiology explains mammalian pitch perception, frequency dependence of hearing threshold, and harmony vs. disharmony perception of sounds***

Abstract: Since its existence, mankind has wondered about the origins of the power of their brain's cognitive abilities. To explore the human cortex, presently large-scale projects largely focus on the biological building plan of the cortex, in the hope to understand therefrom how thoughts and actions are generated. So far, the gained insight, however, has not kept pace with the efforts spent for this endeavor. To understand the human brain, we propose to follow an alternative, more modest, physics and engineering-motivated approach. By understanding how information arriving through the mammalian sensors is transformed and transduced on its way from the information source towards actions and behavior, many salient properties of the human brain and mind should be understandable.

The mammalian hearing system is particularly suited for such an endeavor. The hearing system can be seen as a very ancient type of nervous system. Therefore, we may expect insight gained from this system to also provide more general guidelines for a coherent view, at a fundamental level, of the nature of biological information processing.

Only very recently, the nature of the most puzzling phenomena of hearing have now been revealed, exhibiting an impressive success story of applied nonlinear dynamical systems. We will show how a nonlinear dynamical systems understanding of the mammalian hearing sensor, the cochlea, provides deep insight into the processes that before were largely believed to be the manifestations of cortical computation. We will see that a whole stunning network of nonlinear sensory nodes is at the origin of mammalian hearing [1], with network properties that can be actively shaped in real-time by "listening". Using present day technical terms, the hearing network has the properties of a critical system in its relaxed state, whereas in the tuned state [2], this property is abandoned [3].

This changes our view of hearing perception from a process occurring primarily at the level of the cortex, to one where the salient phenomena of hearing are established at the level of the sensor itself. Moreover, suggesting

that the hearing system can be taken as a blueprint of sensory systems, this opens the pathway for a modern understanding of sensors based on networks of nonlinear dynamical elements. In the case of hearing, this, for example, leads to an entirely different understanding of the origin of the mammalian hearing threshold [4] and of the human emotion of sound “pleasantness” (unpublished). This will be complemented by results focusing on the properties of standard Hopf systems in this context vs. natural generalizations of Hopf-type systems.
All of this we expect to add a new perspective into the properties, the roles, and the nature of the different computations occurring within the brain, by following the information pathway from outside (the information source) to the inside (the human mind), and to offer, moreover, a huge perspective of novel technological applications for information processing.

Louis M. Pecora **11:15-11:50** **Tuesday, 30 July, 2019**

Title: ***An Introduction to Reservoir Computing***

Abstract: The world of artificial intelligence has generated many versions of neural networks and even more schemes as how to update their parameters or "tune" them to produce specific answers with certain inputs. For example, face recognition or speech transcription or understanding. With the power of large and, even at times small computers, this has become more common in the commercial realm and on our personal devices.
However, one type of "AI" has emerged which has the potential to deliver high computing power with small (nano?) sized, low power systems, which are analog computers, not digital. It is called reservoir computing (RC) and its operation differs very much from the usual neural networks. RC is done with physical systems that are driven with input signals to be analyzed, categorized, or interpreted in some way. As such, it is possible that it also suggests some of the dynamics that may take place in real neuronal systems. Training of RCs consists only of linear fitting to output signals, not to massive and lengthy parameter variations of the network, which remains unchanged in training. Examples of these systems are electronic circuits, laser systems, memristors, mechanical connections, along with respective network connections of wires or wireless transmitters/receivers, fiber optics, nanowires, and mechanical struts. With the introduction of nano-systems (e.g. memristors) the possibility of having a reservoir computer of small size, weight, and cost becomes feasible. For certain cases reservoir computers could do the work that a large, non-portable computer system would do to use a trained neural network to solve the same problem. For example, for speech we might be able to automatically transcribe it, for a dynamical system we might be able to input the signal of one variable and reproduce all the other variables, and for visual object recognition automatically identify things in a photo.
This leads to the conclusion that understanding how reservoir computers function and finding the essential constructs and parameters needed to build such a device are technologically important and inform the physical aspects of neuronal/biological systems. The fact is that at this point no one knows exactly why reservoir computers work so well, why they can be made from a wide range of physical nodes and connections, and how to best design them. A lot of research has been done in the machine learning world, but many of the explanations for reservoir computing are mostly folklore or simply words lifted from the world of dynamics, e.g. operate a reservoir computer at the edge of chaos. The actual understanding of their operation does not currently exist.

Dick Moberg **11:50-12:20** **Tuesday, 30 July, 2019**

Title: ***Developing a Data Collection System for the Injured Brain to Enable Network Physiology Research***

Abstract: The brain is the most complex organ in the body, yet the data to manage the injured brain is not of the quantity or resolution to identify changes for optimal patient management. Our lack of understanding of this complexity has led to decades of unsuccessful clinical trials. The many variables associated with outcome in brain injury have never been adequately taken into consideration. These include genomics, imaging, biomarkers, physiology, psychometric testing, and clinical care in the acute period. Fortunately, two large clinical trials in the U.S. and Europe are addressing this issue and hope to find significant determinants of outcome. Our focus over

the past decade has been on the collection and use of real-time physiology to guide the management of these patients during the acute period of critical care.

In the neurocritical care unit (NCCU) today, commonly-used clinical metrics are outdated and of limited prognostic utility. Monitoring the brain directly often relies on singular metrics (e.g. intracranial pressure) that are inadequately sampled and have questionable benefit. And the emerging use of new brain monitoring metrics has been hindered by technical barriers to real-time data capture, analysis, and integration into existing medical records. However, this is changing, and the capture of high-resolution data in the NCCU from multiple sources is now available in a commercial product. This time-synchronized data, with just visual analysis, is showing relationships in brain systems, never seen before, that can guide more precise management of brain injured patients. Real-time measurements are now available that record activity in multiple brain systems such as oxygenation, blood flow, metabolism, pressure, temperature, and electrical activity, as well as new biomarkers such as spreading depolarizations.

The next step, with a large group of collaborators, is to revise the current medical record for the brain to make it a more useful tool. It is unlikely the univariate metrics now available will provide the answer rather higher-order metrics that can detect events or predict "neuroworsening" are more likely to prove useful. More exciting is the progress in the new field of network physiology. This technology is a likely candidate for understanding the dynamics of brain injury and for the visualization and prediction of significant events. This presentation will provide background in the management of brain injury and the new data available. It will set the stage for discussion as to the role of network physiology in improving the course of brain injured patients.

Lunch Break **12:20-14:00** **Tuesday, 30 July, 2019**

Session Chair: **Louis Pecora**

Brandon Foreman **14:00-14:35** **Tuesday, 30 July, 2019**

Title: ***Multimodality Monitoring after Traumatic Brain Injury***

Abstract: Traumatic brain injuries (TBI) are common and a major cause of death and disability worldwide. After the initial injury, a variety of secondary injury mechanisms create metabolic supply-demand mismatch which precipitates neuronal cell death. The primary role of critical care after TBI is to monitor for these secondary injury patterns. Intracranial pressure monitoring has been a cornerstone of the critical care management of patients with TBI, but recent evidence suggests the measurement of intracranial pressure may not directly lead to improvements in care. Recent advances have suggested that this may be due to complex interactions between intracranial pressure and dynamic autoregulation or brain tissue oxygen delivery. There is increasing adoption of the concept that brain tissue requires more comprehensive monitoring of time-locked physiologic data in order to make inferences about the metabolic status of the tissue, to detect secondary brain injury patterns before they occur, and to make real-time treatment decisions. In this presentation, I will discuss a system developed to capture high-resolution, time-locked physiologic data from the brain and body, and how the interplay between multiple modalities can provide insight into the care of patients with the more severe brain injuries.

Fabrizio Lombardi **14:35-15:10** **Tuesday, 30 July, 2019**

Title: ***Structure and dynamics of the brain-muscle network across the sleep-wake cycle***

Abstract: Physiologic states and functions emerge from the cooperation of several organ systems, and can be therefore fully understood only within an integrative framework taking into account the mutual interactions among different organs across the human body. Network physiology aims to develop a holistic comprehension of physiologic states and functions by associating them with dynamical networks of organ interactions inferred from long-term synchronous recordings of organ activity. In this talk, I will present a novel, integrative approach

to brain and muscle dynamics in the sleep-wake cycle that aims to provide a first map of the interactions between brain waves and frequency components of muscle activity, and extend the current characterization of the sleep stages in terms of dominant brain rhythms and concurrent peripheral muscle tone (e.g. chin and legs). I will first demonstrate that dominant and non-dominant brain waves continuously interact, forming a network across brain areas that undergoes pronounced topological transition during sleep. I will then examine how such dynamical brain network interact with peripheral muscle activity in specific frequency bands, and build a brain-chin-leg network that globally represent the integrated nature of sleep stages.

Coffee Break **15:10-15:40** **Tuesday, 30 July, 2019**

Bela Suki **15:40-16:15** **Tuesday, 30 July, 2019**

Title: ***Cellular shaping of fiber networks: implications for self-healing and pulmonary fibrosis***

Abstract: Biological tissues are composed of fibers and cells. The fibers provide a structural framework to which cells attach. Cells also regulate the composition and structure of the fiber network via homeostatic maintenance. Following injury, tissues have the ability of self-healing via specific cellular processes. However, when the insult is sustained or the amount of injury reaches a critical level, healing is either aberrant or no longer possible. While the biological reasons are not fully understood, mathematical and computational models may help better understand the formal requirements of a self-healing system. We hypothesized that self-healing is a local process that requires interaction of fibroblast cells and the extracellular matrix. To this end, we developed a simple analytic and a computational model that exhibit self-healing and tested their ability to resolve fibrosis in a network model of pulmonary fibrosis. We consider a simple hexagonal network model of the lung tissue to account for its elasticity. The members of the network are linear elastic springs with the border of the network fixed in space. We only consider a single cell type, the lung fibroblast, which is modeled as an agent capable of moving around, responding to stimulus and remodeling the tissue. Initially, agents are placed at a small percent of the network nodes and they are allowed to move around. When the agents are stimulated by some exposure such as toxic material or non-physiological stiffness, they become activated. In the absence of additional stimulus, the activation decreases exponentially to a constant level. Agent activity and local stiffness also interact, which we model by allowing the baseline activation level to be a saturation-like function of the stiffness. Furthermore, the stiffness of each network element is increased according to agent activation while exponentially decaying to accounting for the effects of digestive enzymes. The stiffness of a typical network member is a function of how often the member is visited by agents and their average activation. We show that the governing differential equations have a stable fixed point. For any initial conditions such as high stiffness corresponding to mild fibrosis, the differential equations are evaluated many times as agents repeatedly migrate over the region. Eventually the network approaches the stable fixed point predicted at each location, which homogenizes the network. Thus, the time-averaged interactions of agents with the network members exhibit the property of self-healing. We tested the ability of this mechanism to resolve pulmonary fibrosis. Simulations show that for a network model of pulmonary fibrosis to develop its typical honeycomb structure, mechanical failure must be included. This failure results from the high mechanical stresses at the interface between normal and fibrotic regions. We compare the network model to CT images obtained in patients with pulmonary fibrosis. Both the high and low attenuation area clusters follow a power law distribution which the network model can quantitatively mimic. Our model thus serves as a basis for investigating possible mechanisms by which homeostasis might fail in a way that results in progressive pulmonary fibrosis.

Françoise Argoul **16:15-16:50** **Tuesday, 30 July, 2019**

Title: ***Disentangling cardiogenic and respiratory rhythms from physiological noise in dynamic infrared thermograms: A computer-aided time-frequency method to assist in early breast cancer diagnosis***

Abstract: Using a wavelet-based time-frequency (1D) method, we demonstrate that temperature temporal fluctuations (measured in real time with an IR-camera) superimposed on cardiogenic and perfusion rhythms are different from instrumental noise, but contain physiological information that can be exploited to anticipate the transition to malignancy. The observed drastic simplification from multifractal to homogeneous monofractal skin temperature fluctuations in malignant tumor foci is interpreted as the signature of breast vascular network alteration, as confirmed by a wavelet-based (2D) multifractal analysis of X-ray mammograms that reveals some lost of correlations in roughness (spatial) fluctuations in the tumor environment. In this talk, we investigate the interplay of these temperature fluctuations with cardiogenic and respiratory rhythms, by using complex wavelets to disentangle oscillatory from noisy components in temperature time series. Comparing cancer and healthy breasts from a set of 30 patients and 15 volunteers, we show that the cardiac rhythms (fundamental and higher harmonics) loose drastically their temporal phase synchronization in the presence of a malignant tumor. These vascular network dynamics changes are further related to the detection of intermittent synchronization of cardiac and respiratory rhythms. These results open new perspectives in the understanding of interaction mechanisms between cardiovascular and respiratory network systems in homeostatic (healthy) and pathological (cancer) situations.

Poster Session II **17:00-18:30** **Tuesday, 30 July, 2019**

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Session Chair: **Alain Arneodo**

B. Taylor Thompson **9:00-9:35** **Wednesday, 31 July, 2019**

Title: ***Sepsis and Multiple System Organ Failure***

Abstract: Sepsis, initially defined by the Greeks as decomposition or rot, is now defined as life-threatening organ dysfunction caused by a dysregulated host response to infection. Sepsis is a major public health concern and while the true incidence is unknown, conservative estimates indicate that sepsis is a leading cause of mortality and critical illness worldwide and the incidence is increasing. Survivors often have long-term physical, psychological, and cognitive disabilities compounding health care and social impacts. The dysregulated response to infection is heterogenous with contributions from the pathogen (e.g. inoculum, virulence, toxin production) and host factors (e.g. age, comorbidities, genetics) combined with the adequacy of treatment (availability, timing and appropriateness of antibiotics and resuscitation of failing organs). Host responses varies from an exaggerated innate inflammatory response to innate immune suppression, all within hours of developing sepsis. Most patients die of multiorgan failure even though the triggering infection may involve a single organ. There is no specific treatment for this dysregulated host response and a better real-time read out of the individual's immune and organ system responses are badly needed. This presentation will review the challenges of clinical phenotyping patients with sepsis and organ failures. We will discuss the factors thought to contribute to vascular collapse (shock), myocardial depression and coma, dysregulated coagulation, and kidney failure. While most of our understanding has derived from reductionist approaches (studying each organ independently) more holistic approaches are emerging. For example, oxygen delivery appears to be adequate to failing organs but oxygen utilization is impaired. Are we hibernating to survive? Is mitochondrial dysfunction in every organ to blame? Recent data suggests the brain is monitoring regional organ specific inflammation through neural afferents but to what end? Is the brain key to restoring balance? The field of Network Physiology is well suited to advance our understanding of this complex cascade of events.

J. Randall Moorman **9:35-10:10** **Wednesday, 31 July, 2019**

Title: ***Network Physiology in the neonatal ICU***

Abstract: The distressed fetus and the septic premature infant share the same pathophysiological phenotype. Recordings of heart rate in both show that heart rate variability, the product of regulation of the sinus node by the autonomic nervous system, falls, and that there are short-lived heart rate decelerations, the mechanism of which are not completely known. In the fetus, this phenomenon has been exploited to detect distress and to proceed to surgical delivery through continuous monitoring of the fetal heart rate during labor. In the premature infant, this phenomenon has been exploited to fashion continuous monitoring for the early detection of sepsis, an approach that save infants' lives. Moreover, the more complete cardiorespiratory monitoring that is possible in the premature infant shows that some of the decelerations occur in concert with slowing and cessation of breathing (apnea) and decreases in O2 saturation. Thus, the pathological phenotype of the septic premature infants encompasses the network of at least the heart, the lungs and the autonomic nervous system. Interestingly, this pathophysiological phenotype is the same for most acute illnesses in the neonatal Intensive Care Unit. We will review the state of the art of the clinical, physiological and mathematical knowledge of this network and propose areas for future study.

Coffee Break **10:10-10:40** **Wednesday, 31 July, 2019**

Franca Tecchio **10:40-11:15** **Wednesday, 31 July, 2019**

Title: ***Complexity of the language the 'Body and Brain' system uses to communicate with the environment***

Abstract: The neurological or psychiatric diseases distort the communication in the brain's connected networks. In a sense, a person with a brain disorder can become unreachable due to dysfunctional integration within and across brain networks as well as impaired processing and integration of incoming sensory signals. The brain's ability to adapt depends on feedback signaled through the five sensory channels, which produce neuronal synchrony, which drives neuronal plasticity. I'll present some examples in physiological and pathological (carpal tunnel syndrome, otosclerosis, stroke) conditions showing how the change in the sensory income does reflect in the central representation, making our body & brain in continuous connection with the environment.

Deficiencies in communication via the senses requires alternative ways to engage adaptation in a diseased brain— one potent way is via transcranial neuromodulation, bypassing the afferents sensory channels.

Even in our personal experience, sometimes the 'magic' understanding with a dear person can get sick, we do not understand each other anymore. And, which is the wisest advice in this case? TO LISTEN!

Aiming at developing proper neuromodulation interventions, I listen to and interpret the activity of the brain affected by a disease via proper electrophysiological neuroimaging techniques. Listening aims at identifying the networks whose neuronal electric activity alters more as the symptom to be cured increases. Consistent efficacy of a personalized neuromodulation in independent groups of patients supports the idea that proper personalization of neuromodulation will enhance efficacy of electroceuticals interventions.

Overall, we can conceive that by listening to the brain via proper neuroimaging techniques, analysis tools and measures of the neuronal electrical activity state, we will open a new line of adapting the neuromodulation interventions, of transcranial electric stimulations in particular. We aim at obtaining curative effects by rebalancing those alterations of the brain's activity and connectivity, which subtend psycho-physical ailments.

Marina de Tommaso **11:15-11:50** **Wednesday, 31 July, 2019**

Title: ***Brain Networks Interaction in Migraine***

Abstract: Migraine is a complex disorder, with fluctuating neuronal dysfunction leading to the phenomenon of cortical spreading depression and trigeminovascular system activation. Neuronal excitability shows fluctuating abnormalities in the course of migraine cycle. In the inter-critical phase, a thalamo-cortical dysrhythmia might induce an altered response to multimodal stimuli, represented by reduced habituation to repetitive sensory inputs. As a consequence of altered thalamic-cortical interaction, migraine brain resembles a model of oscillopathy, with fluctuating synchronized and desynchronized connections across brain regions. The

bioelectrical and biomagnetic signals seem adequate to reveal this dysfunction, for their high time resolution. In the intercritical phase, migraine without aura presents with hyper-synchronized EEG response under visual stimuli, while migraine with aura patients display a different pattern of synchronization and functional connectivity across scalp regions. The cortical network interactions related to painful stimulation, seem also different in migraine patients compared to not migraine subjects, with hyper-active causal connections and reduced synchronization. How these complex patterns could be referred to migraine generation, clinical phenotype and response to treatment, is the challenge of the next future research direction.

Hagen Malberg **11:50-12:20** **Wednesday, 31 July, 2019**

Title: ***From Single Biosignal measurement to contactless multimodal physiological measurement technologies***

Abstract: Usually, the clinical diagnosis consists of a sequence of individual measurements of biosignals carried out one after the other. Although there are some examples of synchronized measurements known, such as in cardiorespiratory polysomnography (sleep medicine) or intensive care monitoring, the routine analysis of signal couplings is not the clinical standard. Another major disadvantage is the large number of electrodes and sensors fixed on the body surface. In the lecture, metrological alternatives will be shown how several biosignals can be acquired synchronously and even contactlessly. This could be the basis for a clinically routine characterization of physiological networks.

Lunch Break **12:20-14:00** **Wednesday, 31 July, 2019**

Session Chair: **Sebastiano Stramaglia**

Arkady Pikovsky **14:00-14:35** **Wednesday, 31 July, 2019**

Title: ***Synchronization of noisy systems and its characterisation***

Abstract: In this lecture I will discuss effects of noisy environment on synchronization properties of oscillatory systems. I will show that usual notions of phase locking and frequency entrainment may be contradictory here. Methods of extracting phase from noisy observations, and their usage in characterising synchrony will be presented.

Michael Rosenblum **14:35-15:10** **Wednesday, 31 July, 2019**

Title: ***Inferring network properties via phase dynamics modeling with application to Network Physiology***

Abstract: Physiological systems can be often considered as networks of interacting self-sustained oscillators. Reconstructing properties of the nodes and connections within such a network from observations is highly relevant for fundamental and applied biomedical research in the field of Network Physiology. Here we discuss an approach based on reconstruction of the phase dynamics model of the system. We start by an overview of the phase reduction theory, briefly introducing the phase dynamics equations written either via so-called coupling functions or via phase response curves. We demonstrate that although these equations can be derived only in the first-order approximation with respect to the coupling strength, validity of this approach goes far beyond this approximation and is preserved for quite strong coupling. Then we show how phase equations allow one to reveal directed links in the network. First, we briefly mention the frequently treated case of continuous-time signals, suitable for phase estimation and demonstrate how direction and strength of interaction can be determined from scalar signals. Next, we concentrate on the case of pulse-coupled units and point-process data and show how the phase response curves of all elements of the network and their connections can be inferred. We discuss applications to studies of the cardiovascular and respiratory systems as well as to neuroscience.

Coffee Break **15:10-15:40** **Wednesday, 31 July, 2019**

Olga Sosnovtseva **15:40-16:15** **Wednesday, 31 July, 2019**

Title: ***Network Physiology aspects of kidney-brain-heart interactions and function***

Abstract: The kidney links cardiovascular, nervous and metabolic systems providing regulation of blood pressure and release of hormones. The brain and the kidney are fundamental for maintaining the homeostatic milieu of the body by regulating body fluid though adjusting sodium and water balance and volume. The vasopressin hormone is secreted from the brain and acts on the kidney to regulate water balance and osmolality. The kidneys and the heart have a very intriguing and close relationship. The kidney regulates blood pressure through the renin-angiotensin system while the heart provides the kidney with oxygen. It is now well established that kidney disease can trigger or aggravate heart disease; and conversely, heart disease has the ability to ravage the kidneys. Can the kidney function and measures of dynamic network interactions between the kidneys, the cardiac system and the brain be a better predictor of heart attacks and strokes than standard cholesterol and blood pressure tests? Can kidney be a new target for new therapeutic strategies? The utility of novel network physiology approaches will be discussed.

Andreas Voss **16:15-16:50** **Wednesday, 31 July, 2019**

Title: ***Causal Linear and Non-linear Assessment of Central-Cardiorespiratory Network Pathways in Healthy Subjects in Comparison to a Neurological Disorder under Resting Conditions***

Abstract: The analysis of couplings within and between dynamic systems has become more and more a topic of great interest in different fields of science. Especially in the medical field, the understanding of driver-response relationships between regulatory systems and within sub-systems is of growing interest. In particular, the focus has moved towards the multivariate assessment of the strength and the direction of such couplings for a better understanding of physiological regulatory mechanisms. Especially, the new interdisciplinary field of Network Physiology is getting more and more into the focus of interest in medicine. Network Physiology aims to define healthy and diseased physiological network states by analyzing structural, dynamical and regulatory alterations in the interaction of physiological systems and sub-systems.

We investigated the central-cardiorespiratory network (CCRN) applying linear and non-linear causal coupling approaches (Normalized Short Time Partial Directed Coherence and Multivariate Transfer Entropy). The focal point of interest was to figure out how different regulatory mechanisms of the central nervous system (CNS) and autonomic nervous system (ANS) influence or respectively compose the CCRN.

In this respect, we applied the methods In several extensive studies with age-gender matched healthy subjects (CON) under resting conditions compared to patients suffering from a neuropathological disease (paranoid schizophrenia - SZO). From all participants, continuous heart rate (successive beat-to-beat intervals, BBI), synchronized calibrated respiratory inductive plethysmography signal (respiratory frequency, RESP), and the mean power EEG from a 64-channel EEG (in relation to RR-intervals) were recorded for 15 min under resting conditions.

For SZO in comparison to CON we found that the central-cardiorespiratory coupling was a bidirectional one, with stronger central driving mechanisms towards BBI (EEG→BBI) than vice versa, and stronger respiratory driving towards EEG (RESP→EEG) than vice versa. The central-cardiac (EEG-BBI) and central-respiratory couplings (EEG-RESP) seem to be more clearly indicated by the linear method than the nonlinear one. Particularly the CNS stronger controls the cardiac and less the respiratory system. This suggests that in SZO the reduced non-linear coupling expresses a more rigid coupling that leads to a maladaptation in brain heart interactions. Moreover, it seems to be, that the central-cardiorespiratory process (closed-loop) is mainly focusing on adapting the heart rate rather via the ANS than via the central influence on the respiratory system. On the other side, the

feedback-loop from ANS to CNS is strongly dominated by the respiratory activity. This behaviour may be interpreted as a stronger information flow from RESP to central regulatory processes acting as a feedback-loop to central activity for more inputs (information flow) toward ANS.
We could demonstrate a considerably significantly different central-cardiorespiratory network behaviour in schizophrenia with strong central influence on the cardiac system and a strong respiratory influence on the central nervous system. Moreover, this study provides a more in-depth understanding of the interplay of the central and autonomic regulatory network in healthy subjects and schizophrenia.

Round Table Discussion **17:00-18:30** **Wednesday, 31 July, 2019**

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Session Chair: **Marina de Tommaso**

J. Randall Moorman **9:00-9:35** **Thursday, 1 August, 2019**
Title: ***Network physiology in the adult Intensive Care Unit***
Abstract: Unlike infants, adults have a large repertoire of physiological responses to illness. Recordings from the ICU show illness-specific signatures that can be used to develop continuous cardiorespiratory monitoring for early detection. Thus, a decrease in blood pressure and an increase in heart rate indicate cardiovascular instability, while an increase in breathing rate and fall in O2 saturation indicate respiratory instability. Clearly, better understanding of the complex physiology of human illnesses such as inflammation will lead to better monitoring, earlier detection, and better patient outcomes. The current art is crude, and relies on statistical pattern recognition by Machine Learning techniques. While these approaches are not without success, better determination of the network physiology of the heart, lungs, central and autonomic nervous systems in illness will improve them. We will discuss the future pathways for study.

Jürgen Kurths **9:35-10:10** **Thursday, 1 August, 2019**
Title: ***Brain oscillations via rhythmic stimulation – synchronization or superposition?***
Abstract: In extension of the concept of phase synchronization introduced in my first talk, I will also explain some phenomena of superposition, in particular concerning event related responses in the brain activity. Techniques to identify both regimes will be presented. This methodology will then be applied to experiments with visual rhythmic stimulation measured by EEG. Based on a critical comparison of these methods, we identify the underlying mechanism of brain activity.

Coffee Break **10:10-10:40** **Thursday, 1 August, 2019**

György Buzsáki **10:40-11:15** **Thursday, 1 August, 2019**
Title: ***Preexisting dynamics in the brain networks – constraints and advantages***
Abstract: Performance in sensory perception, time and space perception, decision-making, short-term memory and motor control obeys the Weber (log-scale) law. What neuronal mechanisms can support such a wide dynamic range yet in a well-controlled manner? I will demonstrate that skewed (typically lognormal) distributions are fundamental to both structural and functional brain organization, including synaptic weights, firing rates, bursting, population cooperativity, microscopic and macroscopic connectivity, axon diameter and many derived measures such as place field number, size, information per spike, etc. In all brain states, a small minority of neurons and connections may be responsible for 'good enough' brain performance. This 'backbone', consisting of the fast-firing minority of neurons in a postulated strongly connected network provides the brain's 'best guess'

for ‘good enough’ performance but deployment of the weakly active majority is needed for precision performance. The two ends of a continuous log-distribution of physiological parameters may also explain the perceptual contiguity between ‘similar’ and ‘different’. A minority of strongly intercorrected neurons may generalize across situations and afford the brain the capacity to regard no situation as completely unknown. In contrast, the mobilization of the reservoir majority of weakly active neurons is needed to reliably distinguish one situation from another. These observations bridge anatomical structure with physiological function and the rules are used to establish how learning results in changing the synaptic matrix via plasticity.

Ronny P. Bartsch **11:15-11:50** **Thursday, 1 August, 2019**

Title: ***Coexisting forms of physiological coupling and networks of organ systems interactions***

Abstract: We investigate how diverse physiological systems in the human organism interact and collectively behave to produce distinct physiologic states and functions. This is a fundamental question in the new interdisciplinary field of Network Physiology, and has not been previously explored. We demonstrate that physiological systems can exhibit multiple forms of coupling that are independent of each other, respond differently to changes in autonomic regulation, and act on different time scales. We also find that physiologic systems interaction is of transient nature, and that different forms of coupling can simultaneously coexist representing different aspects of physiologic regulation. We identify a network of physiologic interactions between the brain and other organ systems for different sleep stages, well-defined physiologic states with distinct neuro-autonomic regulation, and we show how the network undergoes transitions with changes in physiological state, demonstrating a robust interplay between network structure and function. These empirical investigations shed new light on the mechanisms of organ interactions, and establish a first association between patterns of physiological network interactions and specific physiologic states.

Daniele Marinazzo **11:50-12:20** **Thursday, 1 August, 2019**

Title: ***Synergy and Redundancy in the Granger Causality Framework: an application to muscle networks***

Abstract: Synergy and Redundancy are ubiquitous yet elusive concepts. I will describe a framework in which they can be operationally defined starting from the widely known Granger Causality.

As an application of this framework in the context of Network Physiology, we aimed to elucidate the neuro-motor mechanisms involved in the muscular activity at rest and during the execution of motor tasks, performing an exhaustive assessment of Granger causality (GC) and related measures in functional networks of muscle activity probed by multichannel electromyography (EMG).

In 14 healthy subjects, we analyzed bipolar EMG signals (multiple 30 s windows, 6 trials per subject) acquired from 36 muscles distributed across the body during three stability conditions (quiet standing, anterior-posterior instability, and medial-lateral instability) and three coordination conditions (resting, pointing to a target with the right arm, pointing with two arms). We undertake a fully multivariate approach to the description of the EMG dynamics, fitting a vector autoregressive (VAR) model to the 36 EMG signals. The state-space representation of the VAR parameters is then used to derive measures of the overall GC influences directed towards any EMG sensor, as well as of the multivariate GC between each pair of sensors and of the redundant and synergistic GC effects.

We find that the strongest directed links of the muscular network assessed by multivariate GC are located mostly at the level of the chest muscles during quiet standing, and extend to the leg muscles during lateral and especially during antero-posterior instability; GC influences emerge also within the subnetworks involving shoulder and upper arm in the pointing conditions. As documented by the overall GC, these directed functional connections convey significantly higher amounts of information to the leg muscles in the instability conditions, while the information transfer toward the chest muscles is blunted by pointing. Redundant GC interactions are prevalent in the upper body at rest, while synergistic interactions emerge in both chest and legs during postural instability. These results document that the GC framework is able to elicit peculiar patterns of information transfer which

reveal the motor strategies adopted during postural control.

Lunch Break **12:20-14:00** **Thursday, 1 August, 2019**

Session Chair: **Arkady Pikovsky**

Robert Thomas **14:00-14:35** **Thursday, 1 August, 2019**

Title: ***Pathological sleep as a network disorder***

Abstract: Sleep disorders result in the breakdown of the sleep state network. Individual components of the network may show the primary dysfunction, or multiple components may be simultaneously abnormal. A fragmenting network results in the downstream symptoms typical of sleep disorders, such as insomnia, fatigue and sleepiness. Thus, the pattern of network breakdown determines the clinical syndrome. Resilience of the network to breakdown results in individual differences in expression of pathology. Examples of a single component abnormality include sleep hypoxia and sleep hypoventilation, which may occur in isolation, epileptic discharges during sleep, or REM without atonia and REM behavior disorder, which results in aggressive dream enactment. Examples of multi-component breakdown include sleep apnea, and periodic limb movement disorder. In most instances, linked networks at multiple levels show coupled dysfunction. For example, in sleep apnea, there is cyclical and synchronized disruption of cortical, subcortical, and brainstem networks, manifesting as arousals, cyclical tidal volume variation, blood pressure surges and cyclic variation in heart rate. All sleep disorders are overlaid and entrain the natural kinetics and network dynamics of stable and unstable REM and NREM sleep. Thus, most sleep pathologies will amplify unstable-pattern network interactions, and sleep enhancing therapies will amplify stable-pattern network interactions.

Several specific disorders have predictable effects on the network state. In Alzheimer's disease, progressive loss of the cortical synaptic network will result in fragmentation of normal large-scale network synchrony into subnets with reduced information flow, which in turn results in loss of the < 1 Hz slow oscillation and can be seen on the surface EEG as sleep fragmentation. Parkinson's disease is a primarily subcortical disorder with well-defined network dysfunction and fragmented sleep from abnormal interaction and bidirectional information flow in cortical-subcortical connected loops. Widespread injury to the subcortical while matter will also disrupt connectivity and result in sleep fragmentation, as seen in multiple sclerosis. Sleep apnea can entrain all levels of the network from the repetitive arousals and cyclical respiratory abnormality. Periodic limb movement disorder has invariant cortical, autonomic and hemodynamic associations consistent with motor system driving of multiple network components.

The typical approach to treat sleep disorders/pathology is to target the primary driver (e.g., apnea, pain, epilepsy). However, in the multi-component multi-layered network model of sleep, strengthening normal network behaviors to increase resilience can have widespread effects. For example, drugs that increase cortical network strength (e.g., sodium oxybate) or thalamic mechanisms (e.g., benzodiazepines) can reduce sleep apnea in NREM sleep by inducing stable-type NREM network behavior. Thus, utilizing network physiology principles can increase sophistication of diagnosis and therapy of a wide range of sleep disorders, and enable multimodal therapies with target distinct driver and/or network components to optimize sleep.

Andrei Ruckenstein **14:35-14:55** **Thursday, 1 August, 2019**

Title: ***The NASA Human Research Program and potential impacts of Network Physiology***

Abstract: A new science, like Network Physiology, needs examples that clarify both to funding agencies and to researchers the scientific benefit of the new intellectual endeavor. Often interdisciplinary efforts built on common themes flounder because, while the common themes seem very promising, different disciplines ascribe different

meanings to the same term. The only way to move interdisciplinary conversations forward is to define an explicit problem that researchers from different areas decide to address together as a community. As member of the Board of the National Laboratory on the International Space Station. I would like to see the NASA Human Research Program study the effects of microgravity on astronauts by developing an integrative approach to data collection, data curation and analysis. I will use the example of the ISS to suggest a path for accelerating the development of approaches and tools needed to realize the potential of this exciting new direction of science for improving human health.

Murad Taqqu **14:55-15:15** **Thursday, 1 August, 2019**

Title: ***Levy driven Ornstein-Uhlenbeck type processes and intermittency***

Abstract: We study Ornstein-Uhlenbeck-type random processes. They provide a rich class of random models whose marginal distribution and dependence structure may be modeled independently. We show that superpositions of stationary Ornstein-Uhlenbeck processes can display intermittency, which is expressed as a change-point in the asymptotic behavior of the absolute moments.

Coffee Break **15:15-15:40** **Thursday, 1 August, 2019**

Ulrich Parlitz **15:40-16:15** **Thursday, 1 August, 2019**

Title: ***The Nonlinear dynamics of the Heart: chaos and synchronization in networks of cardiac cells***

Abstract: The heart muscle is an excitable medium exhibiting complex dynamics including spatio-temporal chaos associated with (lethal) cardiac arrhythmias. On small scales cardiac tissue is composed of a network of myocardial cells embedded in an extracellular matrix. The beating cardiomyocytes constitute a dynamical network of electro-mechanically coupled oscillators exhibiting synchronized motion and supporting the propagation of excitation waves. These waves may turn into spiral or scroll waves resulting in tachycardia with impaired pumping capacity. A further loss of stability of the excitation waves may even result in spatio-temporal chaotic dynamics and a complete loss of pumping functionality, which, in the case of ventricular fibrillation, immediately leads to death if not treated by electrical defibrillation shocks. In the talk we shall present novel measurement modalities and numerical simulations addressing various aspects of cardiac dynamics like the synchronization of networks of cardiac cells, features of (transient) chaos in cardiac arrhythmias, and novel concepts for controlling and terminating arrhythmias.

Bela Suki **16:15-16:50** **Thursday, 1 August, 2019**

Title: ***Mitochondrial network structure, bioenergetics and blood pressure variability***

Abstract: Mitochondria are the power house of the cell capable of storing chemical energy in ATP. Mitochondria also form an extensive dynamic network that continuously undergoes fission and fusion. Interestingly, the larger and more complex this network is the more ATP is produced by the cell. We have shown that mitochondrial network formation is sensitive to mechanical factors such as those during cyclic stretch due for example to blood pressure waveforms. However, cells in the vascular wall are not only exposed to cyclic stretch within a heart cycle but also beat-to-beat blood pressure variability (BPV) which can vary considerably with pathological conditions. For example, BPV is elevated in patients with hypertension but reduced in subjects under anesthesia and completely eliminated in standard laboratory conditions. The question is whether BPV influences mitochondrial network structure and hence bioenergetics via ATP production. We hypothesized that the extent of BPV-induced fluctuations in mechanical forces applied to vascular smooth muscle cells (VSMCs) regulates mitochondrial network structure. Additionally, we also hypothesized that the mechanically regulated ATP production may affect other cellular processes such as reactive oxygen species (ROS) production. To test our hypotheses, we stretched VSMCs in culture with a mean area strain amplitude of 10% and gradually superimposed an increasing level of

cycle-by-cycle variability in strain ranging from no variability (0%), as in standard laboratory conditions, through small (6%) and physiological (25%) to pathologically high variability of 50%, resulting in strain amplitudes uniformly distributed between 5% to 15% to mimic hypertension. To shed light on how oxidative stress and ATP-dependent processes interact with the ability of mechanical fluctuations to organize mitochondrial network structure, the experiments were repeated in the presence of hydrogen peroxide and AMP-PNP, an ATP analog and competitive inhibitor of ATPases. Our results showed that mechanical fluctuations corresponding to normal BPV at 25% strain variability maintained mitochondrial structure near the critical percolation threshold characterized by a power law distribution of mitochondrial cluster sizes that maximized ATP and minimized ROS production via selective control of key regulatory proteins of mitochondrial fission and fusion. Furthermore, pathologically low or high BPV moved mitochondria away from criticality which reduced the effectiveness of the electron transport chain by lowering ATP and increasing ROS production. We conclude that normal BPV is likely an evolutionarily conserved dynamic phenomenon which helps maintain an optimal mitochondrial structure and bioenergetics in VSMCs.

Social Event
Classical Music Concert
Como Opera Theater - Teatro Sociale di Como **19:00-20:00** **Thursday, 1 August, 2019**

Social Event
Dinner
Osteria l'Angolo del Silenzio **20:30-22:30** **Thursday, 1 August, 2019**

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Session Chair: **Klaus Lehnertz**

Hagen Malberg **9:00-9:35** **Friday, 2 August, 2019**
Title: ***Approaches to integrated medical technology development***
Abstract: Currently, there is a trend to shift the place of medical treatment more and more to the domestic environment. This trend covers almost all phases of life: from early childhood risk monitoring to healthy ageing at home. Besides the so-called Life-style technology, medically validated technologies have to be developed which can be used sensibly for medical treatment. It can be assumed that the signal quality in domestic medical technology is significantly lower compared to the clinically established silver/silver chloride electrode, for example. Therefore, environmental information must be collected and brought to a medically usable data quality by means of sensor data fusion. In this lecture the results of the research projects "FAST Care" (Fast Sensor and actuators Technology) and "Domestic Health Station" accompanied by our own institute will be presented and discussed. In it, cardiopulmonary and movement parameters are recorded and clinically analyzed by multimodal recording with various sensors (inertial sensors, contactless sensors, sensor network). In general, data pre-processing is much more complex than clinically recorded signals because the data quality is poorer. Especially here the approach of physiological networks is very helpful.

Ruedi Stoop **9:35-10:10** **Friday, 2 August, 2019**
Title: ***Novel experimental and theoretical insights into role and modalities of criticality, reveal for small-size neural networks unanticipated complexity bound by universality.***
Abstract: In biological neural systems, activity patterns that can be related to the properties of critical states of statistical mechanics have obtained wide attention, mostly as fingerprints of computational optimality. Commonly, in a given system, a single critical state with well-defined critical exponents that correspond to well-known universality

classes of statistical physics is expected to occur. We first demonstrate that this expectation is unjustified [1]. Moreover, we present first experimental evidence of transitions between different critical regimes during the development of in vitro neuronal cultures, and show how a model based on fundamental biological arguments only, reproduces these transitions, at maintained interaction topology.
Finally, we present evidence that small size neural networks of the size of a cortical (micro)column follow in their development process a universal behavior, i.e., their development is essentially independent of the specifics of the neuronal dynamics and of the underlying network topology.
These results not only question some more dogmas of the current understanding of neuronal systems, they also offer, more generally, a novel perspective towards understanding the behavior of complex interacting many-body systems - like cortical neural networks - via suitably generalized notions of statistical physics. Our results finally suggest that for understanding biological neural networks, the microscopic focus in the description of biological computational units may be dismissed, for a better-suited mesoscopic approach focusing on interacting networks of higher-level physiological modules.

Coffee Break **10:10-10:40** **Friday, 2 August, 2019**

Marina de Tommaso **10:40-11:15** **Friday, 2 August, 2019**
Title: ***Default Mode Network and Functional Connectivity in Chronic Pain Syndromes***
Abstract: Chronic pain includes numerous disabling diseases of different origin, sharing common mechanisms of central sensitization. The modern vision about central modulation of pain, attributes to a cortical network, named "salience network", the role of activation of subcortical substructure in the brainstem, specifically devoted to descending control. Patients experiencing chronic pain, in absence of neuropathic diseases or active inflammation, represent an example of central generation of subjective sufferance, due to disrupted connections within the pain-related cortical network. Bioelectrical and magnetic signals and functional neuroimaging methods, have efficaciously shown that in the resting state condition, the default mode network is different between chronic pain patients and controls, and that the salience network is activated in a dysfunctional way during acute and tonic pain stimulation. The interactions between motor, cognitive and emotional networks and neuronal circuits devoted to pain processing is profoundly altered in chronic pain, leading to plastic and volumetric modifications with permanent alterations within the brain. Early pharmacological and not pharmacological treatment, including neurostimulation procedures, should avoid the negative evolution toward this chronic maladaptive brain condition.

Ulrich Parlitz **11:15-11:50** **Friday, 2 August, 2019**
Title: ***Time Series Analysis, Data Assimilation, and Machine Learning in Network Physiology***
Abstract: Understanding the interplay of different dynamical components in Network Physiology requires novel and efficient concepts for analyzing the interrelation of different types of measurement data and methods for establishing links between observations and mathematical models enabling a better understanding of underlying mechanisms and causalities. In the talk we shall discuss methods for time series analysis and classification, parameter estimation, and network identification. Furthermore, we shall address the task of incorporating measured data into mathematical models where efficient data assimilation methods are required (e.g., ensemble Kalman filters, particle filters). With the growing interest in mathematical modeling these techniques, previously developed for weather forecasting, become more and more important in Network Physiology and many other Life Sciences. Very often, however, no model is available (yet) for the physiological process of interest and the measured data. In this case novel machine learning methods like deep learning or reservoir computing can be used to estimate variables which are difficult or expensive to measure, to predict the future evolution of the system, or to classify observations. We shall present and discuss such possible applications and tasks for machine learning in Network Physiology and their potential impact on research, diagnostics, and therapy.

Luca Faes **11:50-12:20** **Friday, 2 August, 2019**

Title: ***An information-theoretic framework to dissect multivariate and multiscale physiological interactions***

Abstract: Although it is widely accepted that complex systems exhibit dynamics spanning several temporal scales, research on data-driven inference of the multiscale structure of coupled systems is still largely undeveloped. This issue is particularly relevant in the field of Network Physiology where it is known that several different organ systems dynamically interact across multiple time scales to generate physiological states and pathological conditions. While these multivariate multiscale interactions must be assessed from short and noisy realization of the underlying biological processes, the traditional empirical approaches for the multiscale analysis of dynamical interactions are seriously limited by estimation issues related to the rescaling of observational data.

This presentation introduces a novel time series analysis framework for the multiscale analysis of multivariate dynamics measured from networks of multiple interacting physiological systems. The framework constitutes the first formal extension of Granger causality and Information Decomposition, two related very popular tools for the evaluation of directed interactions between coupled dynamical systems, to the study of multivariate time series observed at multiple temporal scales. Our approach exploits the state space representation of vector autoregressive processes to yield, at arbitrarily large time scales, computationally reliable estimates of Granger causality and of several information decomposition measures, including information storage and redundant/synergistic information transfer within dynamical networks.

After illustrating the theoretical formulation of the framework, ongoing advancements will be discussed which include the time-varying definition of multivariate multiscale measures and their extension to the analysis of long-range correlated processes. Then, a number of practical applications relevant to Network Physiology will be presented, including the multiscale assessment of cardiovascular, cardiorespiratory and brain-heart interactions during the transitions which occur during physiological stress, across different sleep states, or in critical care conditions, as well as the analysis of muscle networks probed during postural control and of brain epileptic networks.

Lunch Break **12:20-14:00** **Friday, 2 August, 2019**

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Session Chair: **Ruedi Stoop**

Arkady Pikovsky **14:00-14:35** **Friday, 2 August, 2019**

Title: ***Synchronization on networks: direct and inverse problems***

Abstract: Different methods of inferring dynamics of oscillatory networks, applicable for synchronous and asynchronous regimes, will be discussed. We will show how the errors in the reconstruction of directed networks are related to the network structure. Examples include both oscillatory and chaotic networks.

Michael Rosenblum **14:35-15:10** **Friday, 2 August, 2019**

Title: ***Dynamical disentanglement in analysis of oscillatory systems***

Abstract: A typical problem in data analysis is to eliminate a particular component of a given time series, e.g. to remove noise, trend, oscillation in a certain frequency band, etc. A whole variety of techniques have been designed to tackle this task by means of filtering in the frequency domain, smoothing in a running window, subtracting a fitted polynomial, and soon. Furthermore, a number of modern methods - principal mode decomposition, independent mode decomposition, empirical mode decomposition - represent a signal of interest as a sum of modes such that (at least) dominating modes are assumed to represent certain dynamical

processes. Correspondingly, some of these modes can be analyzed separately or, on the contrary, if they are considered as irrelevant, they can be subtracted from the original data, so that the cleansed signal is processed. Here we elaborate on a technique, designed for analysis of signals, generated by coupled oscillatory systems. The technique is based on reconstruction of phase dynamics of the analyzed unit. The obtained equation is then used for generation of new, cleansed, data by excluding one, or, generally, several inputs to the system. For example, if only the deterministic part of the model is used, i.e. the noise term is omitted, then the simulated data represents the dynamics of noise-free system. This disentanglement procedure is neither the standard filtering (because the preserved and eliminated components can overlap in frequency domain) nor the mode decomposition (because the sum of preserved and eliminated components does not yield the original signal). Here we consider application of this approach to analysis of cardio-respiratory interaction in humans.

Coffee Break **15:10-15:40** **Friday, 2 August, 2019**

Kathryn A. Hibbert **15:40-16:15** **Friday, 2 August, 2019**

Title: ***Heterogeneity in Critical Illness: Challenges and Opportunities***

Abstract: The Acute Respiratory Distress Syndrome (ARDS) and sepsis are among the most common causes of death and account for a significant portion of admissions to intensive care and to the hospital – nearly a quarter million patients in the US develop ARDS annually, and over one and half million patients are diagnosed with sepsis in the US annually. Each condition carries significant morbidity and mortality with estimated mortality rates of 30-40% in ARDS and approximately 50% in those patients with septic shock. However, despite this burden of disease, both sepsis and ARDS remain both difficult to identify and treat with both broad definitions and limited specific therapies. Diagnosis is made with inclusive clinical criteria, resulting in heterogeneous syndromes with widely varied underlying pathophysiology. These definitions attempt to strike an important balance between early recognition – early intervention with appropriate therapy significantly improves mortality for both sepsis and ARDS – and specificity – an important parameter when offering prognosis or specific therapy. For example, many therapies have been tested and failed for ARDS and sepsis, often failing to show benefit – this is likely due at least in part to heterogeneity of treatment effect, in which some patients benefit and others are harmed resulting in a negative clinical trial result. This talk will outline the limitations of current diagnostic and monitoring strategies in critical illness using sepsis and ARDS as examples, and will address the following questions: How can we better identify patients with life-threatening critical illness? How can we identify groups within these diagnoses – endophenotypes – that will benefit from specific therapies? How can we better identify response to early intervention to tailor therapy to individual patients? Network physiology is a novel and exciting potential tool to tackle these ongoing challenges in caring for our sickest patients.

Klaus Lehnertz **16:45-15:25** **Friday, 2 August, 2019**

Title: ***Estimating resilience of evolving epileptic brain networks***

Abstract: The concept of resilience captures the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, and feedbacks. In this lecture, I will provide an overview of the various methods for measuring resilience of multistable complex networked dynamical systems that have emerged across disciplines, largely extending the classical linear stability analysis. At the example of epileptic seizures, I will discuss how a time-resolved estimation of brain resilience can contribute to the development of novel therapies, e.g. based on seizure-prediction.

Closing **17:30-17:50** **Friday, 2 August, 2019**

Plamen Ch. Ivanov

Round Table Discussion

17:00-18:30 **Wednesday, 31 July, 2019**

Panel participants:

(In progress)

Poster Session I

17:00-18:30 Monday, 29 July, 2019

1. From tissue to Tumor. Towards a Unifying Theory of Cancer
Consuelo San Gabriel[1], Pere Gascón1 Natàlia Balàguè[2], Robert Hristovski[3]
1 Laboratory of Molecular and Translational Oncology, Hospital Clínic, Barcelona, Spain
2 Health and Applied Sciences Department. INEFC, Universitat de Barcelona (UB), Spain
3 Ss. Cyril and Methodius University, Skopje, Macedonia

2. Simulation Study of Direct Causality Measures and Lag Estimations in Multivariate Time Series
Jolan Heyse[1], Pieter Van Mierlo[1]
1 MEDISIP, Ghent University, Ghent, Belgium

3. Changes in cardiac circadian rhythm induced by 60-days Head-Down Bed Rest
Solbiati S[1], Turcato M[1], Martin-Yebra A[2], Costantini L[3], Vaida P[4], Landreani F[1], Caiani Eg[1]
1 Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milano, Italy
2 BSICoS Group, Instituto de Investigación en Ingeniería de Aragón (I3A), IIS Aragón, Universidad de Zaragoza, Zaragoza, Spain
3 Azienda Sanitaria Locale Lecce - P.O. Santa Caterina Novella - U.O. di Cardiologia e UTIC, Lecce, Italy
4 University of Bordeaux, Bordeaux, France

4. Large Scale Cardiovascular Model Personalisation for Mechanistic Analysis of Heart & Brain Interactions
Jaume Banus[1], Marco Lorenzi[1], Oscar Camara[2], and Maxime Sermesant[1]
1 Inria, Epione team, Universite Cote d'Azur, Sophia Antipolis, France
2 PhySense, Department of Information and Communication Technologies, Universitat Pompeu Fabra, Barcelona, Spain

5. Foetalskeletal muscle programmingthrough gestational obesity: an epigenome-wide study
Anna Prats-Puig[1,2], Miquel Puig-Parnau[1], Silvia Xargay-Torrent[2] and Abel López-Bermejo[2]
1 Department of Physical Therapy, EUSES University School, Salt, 17190, Spain.
2 Pediatric Endocrinology Group, [Girona Biomedical Research Institute] IDIBGI, Salt, 17190, Spain

6. Identifying important edges in complex networks
Timo Broehl and Klaus Lehnertz
1 Department of Epileptology, University Bonn, Bonn, 53105, Germany

7. The central-cardiovascular network in schizophrenia
Schulz S.[1], Haueisen J.[2], Bär K.J.[3], Voss A.[1]
1 University of Applied Sciences, Institute of Innovative Health Technologies IGHT, Jena, Germany
2 Ilmenau University of Technology, Institute of Biomedical Engineering and Informatics, Ilmenau, Germany
3 University Hospital, Department of Psychiatry and Psychotherapy, Jena, Germany

8. Dynamical Networks of Brain - Muscle Interactions and Transitions across Physiological States
Rossella Rizzo[1,2], Xiyun Zhang[1], Jilin WJL Wang[1], Fabrizio Lombardi[1], and Plamen Ch. Ivanov[1,3]
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9. Predictability and resistance of pre-seizure states
Thorsten Rings, Amin Akshi, Mahmood Mazarei, Christian Geier, M. Reza Rahimi Tabar, and Klaus Lehnertz
1 Department of Epileptology, University Bonn, Bonn, 53105, Germany

10. Multifractal analysis of perioperative cerebrocortical hemodynamics among patients undergoing open heart surgery
Peter Mukli[1,2], Endre Nemeth[3], Zoltan Nagy[2], Frigyes Samuel Racz[1], Anita Darago[2], Katalin Orban[2], Istvan Portoro[2], Klara Ronkay[3], Edina Wappler[3,4], Janos Gal[3] and Andras Eke[1,2]
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2 Semmelweis University, Institute of Clinical Experimental Research
3 Semmelweis University, Faculty of Medicine, Department of Anesthesiology and Intensive Therapy

4 Neurosciences Intensive Care Unit, Wessex Neurological Center, University Hospital Southampton, NHS Foundation Trust, UK

11. Data Adaptive Threshold (DAT): A method to separate genuine and spurious correlations in correlation matrices applied to electroencephalography (EEG).

Octavio A. Lecona[1,2], Wady A. Ríos Herrera [2], Martha Yoko Takane[4], Francisco F. De-Miguel[2,3], and Ruben Fossion[2,5]
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5 Instituto de Ciencias Nucleares, UNAM, México D.F.

12. Analysis of fast recovery after cycling until exhaustion: challenges and limitations in studies of short physiological data.

M. Petelczyc[1,3], M. Żebrowska[1], M. Weippert[2]
1 Faculty of Physics Warsaw University of Technology, Koszykowa 75, 00-662
2 Institute of Sport Science, University of Rostock, Ulmenstr. 69, Rostock 18057, Germany
3 Institute of Geophysics Polish Academy of Sciences, Ks. Janusza 64, 01-452 Warsaw, Poland

13. Multilayer network approaches as the next frontier in multicellular systems research

Marko Šterk[1,2,3], Lidija K. Bombek[2], Jurij Dolenšek[2], Marko Marhl[1,2,3], Marjan S. Rupnik[2,4], Andraž Stožer[2] and Marko Gosak[1,2]
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2 University of Maribor, Faculty of Medicine, Maribor, Slovenia
3 University of Maribor, Faculty of Education, Maribor, Slovenia
4 Medical University of Vienna, Institute of Physiology and Pharmacology, Vienna, Austria

14. Heterogeneity and delayed activations are promotors of self-organization and scale-invariant behavior in excitable tissue

Andraž Stožer[1], Rene Markovič[2,3,4], Jurij Dolenšek[1,2], Matjaž Perc[2,5,6], Marko Marhl[1,2,3], Marjan Slak Rupnik[1,7,8], and Marko Gosak[1,2]
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15. Perinatal stress quantification in premature infants

M Lavanga[1], O De Wel1, A Caicedo[1], M Deviaene[1], J. Moeyersons1, C Varon[1], B Bollen[2], K Jansen[2], E Ortibus [2], G Naulaers[2], S Van Huffel[1]
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2 Dpt. of Development and Regeneration, UZ Leuven, Belgium

16. Gait dynamics of frail and non-frail elderly people during a 160m walk at self-selected speed

Lesli Álvarez[1,2], Daniel Castillo[3], Argelia Pérez[3] Rosa Quispe[3], Maia Angelova[4,5], Jesús Rivera[3], and Ruben Fossion[2, 6]
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17 Dynamic connectivity in the musculoskeletal system reveals changes in motor control between different modes of coordination during walking.

Jennifer N. Kerkman, Annike Bekius, Andreas Daffertshofer, Nadia Dominici
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Poster Session II

17:00-18:30 Tuesday, 30 July, 2019

1. Analysing the collective activity of tissues: fusing time series analysis and network science to understand the pancreatic islets of Langerhans

Jan Zmazek[1], Andraž Stožer[2], Rene Markovič[1,3,4], Jurij Dolenšek[2], Marko Marhl[1,2,3] and Marko Gosak[1,2]
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2 University of Maribor, Faculty of Medicine, Maribor, Slovenia
3 University of Maribor, Faculty of Education, Maribor, Slovenia
4 University of Maribor, Faculty of Energy Technology, Maribor, Slovenia

2. Information flow between heart rhythm and polarization of the ventricles in the Long QT Syndrome

Mateusz Ozimek, Jan J. Żebrowski
1 Cardiovascular Physics, Complex Systems Physics Division, Faculty of Physics, Warsaw University of Technology, Warszawa, Poland

3. Interaction between single neurons in different brain regions: influence of sleep

Irene Malvestio[1], Johannes Niediek[2], Florian Mormann[3], Ralph G. Andrzejak[1,4]
1 Dept. of Information and Communication Tech., Univ. Pompeu Fabra, Barcelona, Spain
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3 Dept. of Epileptology, Univ. of Bonn, Bonn, Germany
4 Inst. for Bioengin. of Catalonia (IBEC), The Barcelona Inst. of Sci. and Tech., Barcelona, Spain

4. Multifractal and entropy analyses of resting-state electroencephalograpy reveals spatial organization in local dynamic functional connectivity

Frigyes Samuel Racz, Orestis Stylianou, Peter Mukli and Andras Eke
1 Department of Physiology, Semmelweis University, Budapest, Hungary

5. Phase reconstruction with iterative Hilbert transform embeddings

Erik Gengel[1], Arkady Pikovsky[1, 2]
1 Institute for Physics and Astronomy, University of Potsdam, Karl-Liebknecht Str. 24/25, 14476 Potsdam, Germany
2 Department of Control Theory, Institute of Information Technologies, Mathematics and Mechanics, Lobachevsky UniversityNizhny Novgorod, Russia

6. EEG network synchronization increases with Parkinsons disease stage

Eitan E. Asher[1], Shlomo Havlin[1], and Ronny P. Bartsch[1]
1 Department of Physics, Bar-Ilan University, Ramat Gan, Israel

7. Warning sign of transitions in the IsingModel on the Human Connectome: the role of Synergy

Davide Nuzzi[1], DanieleMarinazzo[3], Sebastiano Stramaglia[1,2]
1 Dipartimento Interateneo di Fisica, Universit`a degli Studi Aldo Moro, Bari and INFN, Sezione di Bari, Italy
2Center of Innovative Technologies for Signal Detection and Processing (TIRES), Universit`a degli Studi Aldo Moro, Bari, Italy
3Department of Data Analysis,Ghent University, Ghent, Belgium

8. Double Power-Law Behavior in the Mechanical Response of Living Cells

J. S. de Sousa[1], R. S. Freire[2], F. D. Sousa[1], A. F. B. Silva[3], A. C. O. Monteiro-Moreira[4], R. Montenegro[5], M. Radmacher[6], and C. L. N. Oliveira[1]
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6 Institut f ̈ur Biophysik, Universit ̈at Bremen, Postfach 330440, D-28334 Bremen, Germany

9. Quantification of Linear and Nonlinear Cardiorespiratory Interactions by means of Least-Squares Support Vector Machines

Carolina Varon[1], Dries Hendrikx[1], Juan Bolea[2,3], Pablo Laguna[2,3], Raquel Bailon[2,3]

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2 BSICoS Group, I3A, IIS Aragon, University of Zaragoza, Zaragoza, Spain
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10. Network analysis for recovering the electrical dynamics of the heart
Baltasar Rüchardt[1], Ulrich Parlitz[1,2]
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2 Institut für Dynamik komplexer Systeme, Georg-August-Universität Göttingen, Göttingen
3 DZHK (German Centre for Cardiovascular Research), Partner Site Göttingen, Göttingen, Germany

11. Untangling metabolic syndrome using physiological networks
Antonio Barajas-Martínez, Jonathan F. Easton, Ricardo Martínez-Tapia, Alejandro, Hernández-Chávez, Lizbeth de la Cruz, Christopher R. Stephens.
1 Antonio Barajas Martínez, M.D. Department of Physiology, Faculty of Medicine, National Autonomous University of Mexico, Mexico

12. Are observable links between brain nodes due to geometric proximity?
Alessio Perinelli[1], Davide Tabarelli[2], and Leonardo Ricci[1,2]
1 Department of Physics, University of Trento, I-38123 Trento, Italy
2 CIMeC, Center for Mind/Brain Sciences, University of Trento, I-38068 Rovereto, Italy

13. Quantifying the Cardiorespiratory Coupling in a Mobile Setup
John F. Morales, Jonathan Moeyersons, Sabine van Huffel, Carolina Varon
1 Department of Electrical Engineering, KU Leuven, Belgium

14. Heart Rate Variability of healthy individuals depends on sex and age: a complex approach
Ana Leonor Rivera[1,2], Juan Antonio López-Rivera[1,3], Bruno Estañol[1,4], Juan Claudio Toledo-Roy[1,2], Ruben Fossion[1,2], Alejandro Frank[1,2,5]
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4 Laboratorio de Neurofisiología Clínica, Departamento de Neurología, Instituto Nacional de Ciencias Médicas y Nutrición "Salvador Zubirán", Mexico.
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15. Neurocardiovascular interactions before, during and after open surgery for congenital diaphragmatic hernia
D. Hendrikx[1], S. Costerus, A. Caicedo, D. Tibboel[1], J. de Graaff, G. Naulaers and S. Van Huffel[1]
1Department of Electrical Engineering (ESAT), STADIUS, KU Leuven, Leuven, Belgium

16. Homeostasis from a time-series' perspective
Ruben Fossion[1,2], Ana Leonor Rivera[1,2] and Bruno Estañol[2,3]
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17. Cardiorespiratory coordination. A novel variable for testing training and fatigue effects
Sergi Garcia-Retortillo[1,2], Jordi Martínez[2], Casimiro Javierre[3], Josep Lluís Ventura[3], Robert Hristovski[4], Natàlia Balagué[2]
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3 Dep. Physiological Sciences, University of Barcelona (UB), L'Hospitalet de Llobregat, Spain
4 Faculty of Physical Education, Sport and Health, Ss Cyril and Methodius University of Skopje, Skopje, Rep. Macedonia

18. Network Physiology Approach to Liver Cirrhosis
Yen Yi Tan[1], Alireza Mani[1], Sara Montagnese[2]
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Announcements

Special Issue in the journal Physiological Measurement

In parallel with the ISINP meeting, we organize a special issue in the journal ***Physiological Measurement***, published by IOP Science, entitled: "*The new field of Network Physiology: redefining health and disease through networks of physiological interactions*".

Despite the vast progress and achievements in systems biology and integrative physiology in the last decades, we do not know the basic principles and mechanisms through which diverse physiological systems and organs dynamically interact as a network and integrate their functions to generate a variety of physiologic states and pathological conditions at the organism level.

This special issue will focus on both empirical and theoretical interdisciplinary work with contributions ranging from applied math, statistical physics, nonlinear dynamics and complex networks to biomedical engineering, neuroscience, physiology and clinical medicine, and is now open for manuscript submissions.

More information is available on the journal website:

http://iopscience.iop.org/journal/0967-3334/page/Focus-issue-on-the-new-field-of-Network-Physiology

Several manuscripts have already been submitted, and we invite all ISINP attendees and speakers to contribute work related to *Network Physiology*.

Social Event

Classical Music Concert		
Como Opera Theater - Teatro Sociale di Como	19:00-20:00	Thursday, 1 August, 2019
Dinner		
Osteria l'Angolo del Silenzio	20:30-22:30	Thursday, 1 August, 2019

Thank you for joining this second international event on Network Physiology, and for being part of a growing society of scholars, clinicians and biomedical engineers working in this new field.

We look forward to meeting you again in 2021!