A whole-body

approach to

understanding

# Moving Beyond Isolated Systems

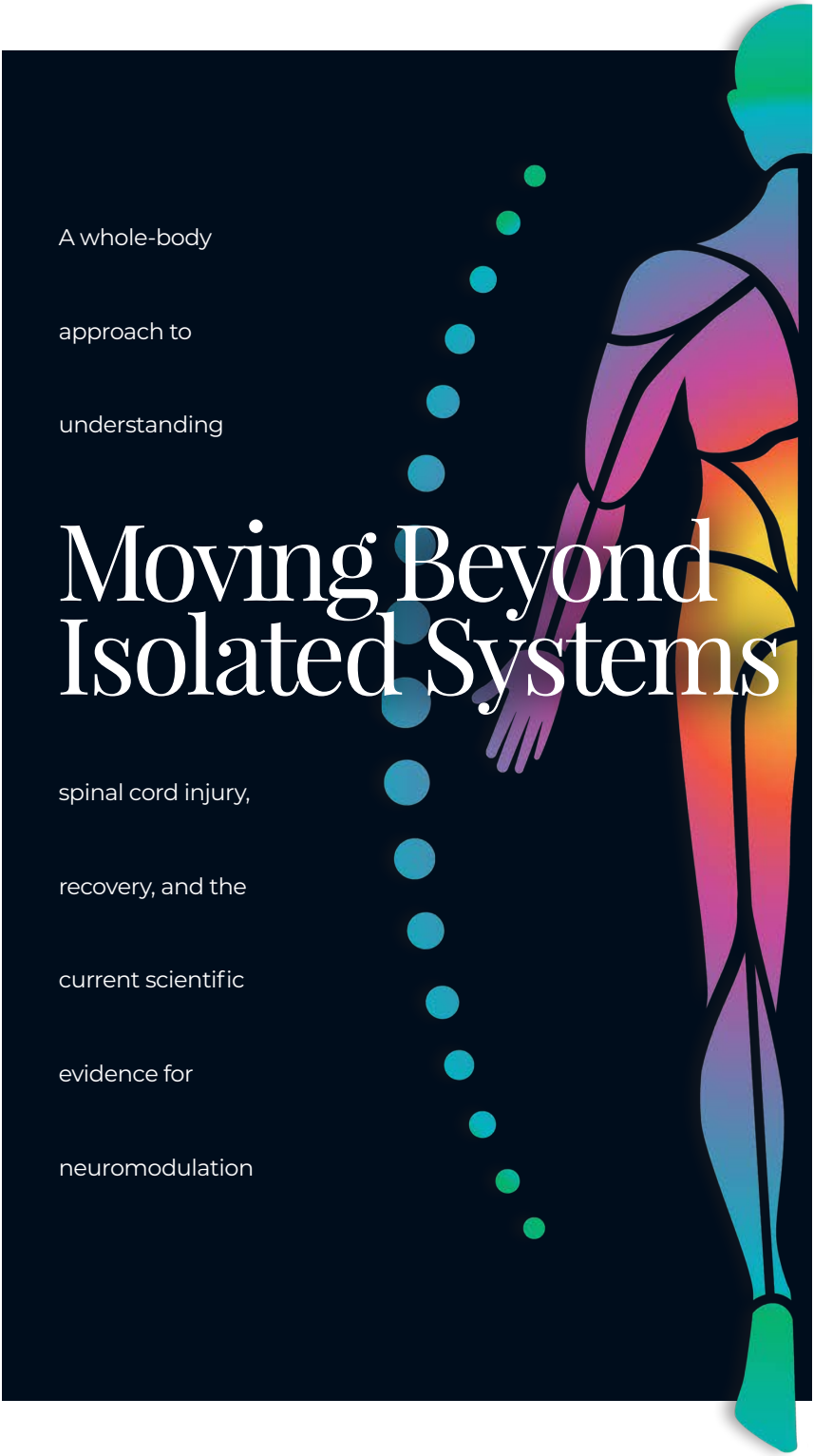
spinal cord injury,

recovery, and the

current scientific

evidence for

neuromodulation



Expand your

knowledge about

SCI treatment

and recovery

# Welcome to Moving Beyond Isolated Systems Symposium

On behalf of the Scientific Organizing Committee, welcome to the inaugural Moving Beyond Isolated Systems Symposium in Louisville, Kentucky. The goal of this meeting is to encourage dialogue that expands the focus of the spinal cord injury (SCI) field from isolated organ-system dysfunction to the study of the multi-system, interrelated consequences of SCI.

The first day will focus on the far-reaching effects of spinal cord injury on the whole body, taking a systems-biology view of the autonomic system, metabolism and muscle function. The second and third days will explore the current state of neuromodulation with a primary focus on epidural stimulation. It has been demonstrated that neuromodulation can enhance restoration of homeostasis across many body systems, and our international group of speakers will discuss the current state of the art and challenges to clinical application. Sessions will open with a personal vignette from one of the meeting's Honorary Chairs and conclude with an interactive Q&A discussion. Finally, a Stakeholders' Roundtable will consider how best to move this promising technology forward, so those who live with SCI have access to the profound improvements neuromodulation can bring to their health and well-being.

Our venue is the wonderful Kentucky International Convention Center, located in the heart of downtown Louisville. It's within walking distance of the Waterfront Park on the banks of the Ohio River and many of the top Louisville destinations including the Frazier History Museum, the Louisville Slugger Museum and Factory and the Muhammad Ali Center. Dinner on the first night of the meeting will be held at Churchill Downs in the heart of the horse racing world and the home of the Kentucky Derby.

Susan Harkema, PhD

UL KENTUCKY SPINAL CORD INJURY RESEARCH CENTER

David Magnuson, PhD

UL KENTUCKY SPINAL CORD INJURY RESEARCH CENTER

A whole-body approach to understanding spinal cord injury, recovery, and the current scientific evidence for neuromodulation

# COVID-19 ANNOUNCEMENT

We are not requiring proof of vaccination
so please act accordingly. Given the surge in infections
and our vulnerable population, we respectfully request
that you wear a mask at all times while indoors, except when
eating or drinking or speaking at the symposium.

# Symposium at a Glance

## Tuesday, July 26th

KENTUCKY INTERNATIONAL CONFERENCE CENTER
BALLROOMS D & E

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|---|---|
| 7:00 – 7:45 am | Registration |
| 7:45 – 8:00 am | Opening Remarks<br>Susan Harkema and David Magnuson<br>Kentucky Spinal Cord Injury Research Center<br>Kevin H. Gardner • Executive Vice President for Research and Innovation, University of Louisville |
| 8:00 – 8:45 am | Keynote Speech<br>Steven Kirshblum • Kessler Institute for Rehabilitation<br>*Spinal Cord Injury as a Whole Body System: Biology and the Hope of Neuromodulation*<br>Honorary Chair: Natalie Barrett |
| SESSION ONE | METABOLIC DISEASES |
| 8:45 – 8:55 am | Chair: Dana McTigue • Ohio State University College of Medicine<br>Honorary Chair: Marissa Kirkling |
| 8:55 – 9:15 am | David Gater, Jr. • The Miami Project to Cure Paralysis<br>*Neurogenic Obesity after Spinal Cord Injury: Metabolic Melee* |
| 9:15 – 9:25 am | Q&A with David Gater, Jr. |
| 9:25 – 9:45 am | Phillip Popovich • Ohio State University College of Medicine<br>*Dysautonomia as a Unifying Neurogenic Feature of Multi-organ Pathology After Spinal Cord Injury* |
| 9:45 – 9:55 am | Q&A with Phillip Popovich |
| 9:55 – 10:10 am | Break and Posters Review |
| 10:10 – 11:00 am | Panel Discussion |
| SESSION TWO | MUSCLE AS AN ENDOCRINE ORGAN |
| 11:00 – 11:10 am | Chair: David Magnuson • Kentucky Spinal Cord Injury Research Center<br>Honorary Chair: Paul Erway |
| 11:10 – 11:30 am | David Ditor • Brock University Department of Kinesiology<br>*High Quality Weight Loss After Spinal Cord Injury: Can Lean Mass Be Preserved While Fighting Obesity?* |
| 11:30 – 11:40 am | Q&A with David Ditor |
| 11:40 am – 12:40 pm | Lunch |
| 12:40 – 1:00 pm | Karyn Esser • University of Florida Health Department of Physiology and Functional Genomics<br>*The Muscle Circadian Clock and Glucose Metabolism; A New Role For Exercise* |
| 1:00 – 1:10 pm | Q&A with Karyn Esser |
| 1:10 – 1:30 pm | Christopher Cardozo • Icahn School of Medicine at Mount Sinai<br>*Exercise Corrects Perturbation of the Hepatokine-adipokine Axis of Spinal Cord Injury Mice* |
| 1:30 – 1:40 pm | Q&A with Christopher Cardozo |
| 1:40 – 2:00 pm | Panel Discussion |
| 2:00 – 2:15 pm | Break and Posters Review |
| SESSION THREE | AUTONOMIC CARDIOVASCULAR DYSFUNCTION IN SCI: PRESENTATION, CONSEQUENCES, TREATMENTS |
| 2:15 – 2:25 pm | Chair: Andrei Krassioukov • University of British Columbia Division of Physical Medicine and Rehabilitation<br>Honorary Chair: Rob Wudlick |
| 2:25 – 2:45 pm | David Goldstein • NINDS Autonomic Medicine Section<br>*The Extended Autonomic System, Homeostasis, and Biocybernetics* |
| 2:45 – 2:55 pm | Q&A with David Goldstein |
| 2:55 – 3:15 pm | Andrei Krassioukov • University of British Columbia Division of Physical Medicine and Rehabilitation<br>*Neuromodulation for Restoration of Autonomic Functions After Spinal Cord Injury* |
| 3:15 – 3:25 pm | Q&A with Andrei Krassioukov |
| 3:25 – 3:45 pm | Jill Wecht • James J Peters VAMC and Icahn School of Medicine, Mount Sinai<br>*Autonomic Cardiovascular Dysfunction in Spinal Cord Injury: Presentation, Consequences, Treatments* |
| 3:45 – 3:55 pm | Q&A with Jill Wecht |
| 3:55 – 4:15 pm | Panel Discussion |
| 4:15 – 4:30 pm | Break and Posters Review |
| 4:30 – 5:30 pm | Keynote Speech<br>Sten Grillner • Karolinska Institute Department of Neuroscience, Stockholm<br>*The Intrinsic Capacity of the Spinal Cord to Coordinate Movements, and its Control From Brainstem and Forebrain*<br>Honorary Chair: Rob Summers |
| 5:30 – 5:45 pm | Q&A with Sten Grillner |
| 5:45 – 6:15 pm | Transportation to Dinner |
| 6:30 pm | Symposium Dinner • Churchill Downs |

# Symposium at a Glance

## Wednesday, July 27th

KENTUCKY INTERNATIONAL CONFERENCE CENTER
BALLROOMS D & E

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| 7:00 – 7:45 am | Registration |
| 7:45 – 8:00 am | Opening Remarks |
| 8:00 – 8:45 am | Keynote Speech<br>Karen Minassian • Medical University of Vienna<br>*History and Overview of Epidural and Transcutaneous Spinal Cord Stimulation Strategies for Motor Recovery*<br>Honorary Chair: Henry G. Stifel, III |
| SESSION FOUR<br>8:45 – 8:55 am | TRANSCUTANEOUS STIMULATION: MOTOR SYSTEMS<br>Chair: Karen Minassian<br>Honorary Chair: Mike Nichols |
| 8:55 – 9:25 am | Yury Gerasimenko • Kentucky Spinal Cord Injury Research Center and Pavlov Institute<br>*Multi-modal Stimulation for the Recovery of Posture and Locomotion* |
| 9:25 – 9:45 am | Ursula Hofstötter • Medical University of Vienna<br>*Transcutaneous Spinal Cord Stimulation for Enhancing Locomotor Activity and Controlling Spasticity* |
| 9:45 – 9:55 am | Q&A with Ursula Hofstötter |
| 9:55 – 10:45 am | Break and Posters Review |
| 10:45 – 11:05 am | V. Reggie Edgerton • University of California, Los Angeles<br>*It is What We Think We Know Already That Often Prevents Us From Learning* |
| 11:05 – 11:15 am | Q&A with V. Reggie Edgerton |
| 11:15 – 11:45 am | Panel Discussion |
| 11:45 am – 12:30 pm | Plenary Lecture<br>Grégoire Courtine • Swiss Federal Institute of Technology<br>*Mechanism-driven Technologies and Therapies for Spinal Cord Injury*<br>Honorary Chair: Trisha Taylor |
| 12:30– 1:30 pm | Sponsored Lunch • Dave Marver<br>ONWARD<br>*Delivering Breakthrough SCI Therapies for Research and Clinical Practice* |
| SESSION FIVE<br>1:30 – 1:40 pm | EPIDURAL STIMULATION: MOTOR SYSTEMS<br>Chair: Kristin Zhao • Mayo Clinic Department of Physical Medicine and Rehabilitation<br>Honorary Chair: Devina Robles |
| 1:40 – 2:10 pm | Marco Capogrosso • University of Pittsburgh Department of Neurological Surgery<br>*Computer Models in the Understanding of Electrical Epidural Stimulation for the Recovery of Motor Control* |
| 2:10 – 2:20 pm | Q&A with Marco Capogrosso |
| 2:20 – 2:40 pm | Igor Lavrov • Mayo Clinic Departments of Neurology and Biomedical Engineering<br>*Merging Neuromodulation and Neuroregeneration Therapy for Spinal Cord Injury* |
| 2:40 – 2:50 pm | Q&A with Igor Lavrov |
| 2:50 – 3:05 pm | Break and Posters Review |
| 3:05 – 3:25 pm | Enrico Rejc • Kentucky Spinal Cord Injury Research Center<br>*Spinal Cord Epidural Stimulation to Promote Standing Motor Function Recovery After Motor Complete Spinal Cord Injury* |
| 3:25 – 3:35 pm | Q&A with Enrico Rejc |
| 3:35 – 3:55 pm | Claudia Angeli • Kentucky Spinal Cord Injury Research Center<br>*From Modulation to Recovery: Crossing the Threshold* |
| 3:55 – 4:05 pm | Q&A with Claudia Angeli |
| 4:05 – 4:25 pm | Panel Discussion |
| 4:25 – 5:25 pm | Panel Discussion:<br>*Performance Focused Neuromodulation*<br>Megan Gill • Mayo Clinic<br>Claudia Angeli · Kentucky Spinal Cord Injury Research Center |
| 5:25 – 7:00 pm | Cocktail Reception and Posters Review |
| 7:00 pm | *"Rise Up: Discovering Hope"*<br>Feature-length Documentary Premiere |

## Thursday, July 28th

KENTUCKY INTERNATIONAL CONFERENCE CENTER
BALLROOMS D & E

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| 7:00 – 7:45 am | Registration |
| 7:45 – 8:55 am | SPECIAL PRESENTATION<br>*How to Stimulate:*<br>*Tonic-integrated Network Focused?*<br>*Spatial Temporal Dorsal Root Focused?*<br>Presenters: Claudia Angeli; Grégoire Courtine; V. Reggie Edgerton; Susan Harkema; Igor Lavrov |
| SESSION SIX | NEUROSURGICAL APPROACHES AND THE CLINICAL FUTURE OF NEUROMODULATION |
| 8:55 – 9:05 am | Chair: James Guest • University of Miami Miller School of Medicine<br>Honorary Chair: Jerod Nieder |
| 9:05 – 9:25 am | James Guest • The Miami Project to Cure Paralysis<br>*Combined Neuromodulatory Approaches to Amplify Recovery After Spinal Cord Injury* |
| 9:25 – 9:35 am | Q&A with James Guest |
| 9:35 – 9:55 am | Maxwell Boakye • Kentucky Spinal Cord Injury Research Center<br>*Patient Selection, Risk Mitigation and Optimization of Surgical Technique and Implant Position* |
| 9:55 – 10:05 am | Q&A with Maxwell Boakye |
| 10:05 – 10:25 am | David Darrow • University of Minnesota Medical School<br>*Patient-in-the-loop Optimization of Spinal Cord Stimulation for Spinal Cord Injury* |
| 10:25 – 10:35 am | Q&A with David Darrow |
| 10:35 – 11:05 am | Panel Discussion |
| 11:05 – 11:25 am | Break and Posters Review |
| SESSION SEVEN | INTERSYSTEMS, HEALTH, AND COMMUNITY INTEGRATION OF NEUROMODULATION |
| 11:25 – 11:35 am | Chair: Susan Harkema<br>Honorary Chair: Denna Laing |
| 11:35 – 11:55 am | Aaron Phillips • University of Calgary, Cumming School of Medicine<br>*A Mechanism-guided Cardiovascular Stabilizing System For Spinal Cord Injury* |
| 11:55 am – 12:05 pm | Q&A with Aaron Phillips |
| 12:05 – 1:00 pm | Lunch |
| *12:05 – 1:00 pm*<br>*Room L006* | *Sponsored Lunch with Scott Chesney of ONWARD*<br>*Bringing the Symposium HOME to Our SCI Community*<br>*By Invitation Only for SCI Community and Caregivers Room*<br>*scott.chesney@onwd.com* |
| 1:00 – 1:20 pm | Charles Hubscher • Kentucky Spinal Cord Injury Research Center<br>*Cardiovascular and Bladder Integrated* |
| 1:20 – 1:30 pm | Q&A with Charles Hubscher |
| 1:30 – 1:50 pm | Ona Bloom • Feinstein Institutes for Medical Research, Northwell Health<br>*Immune System* |
| 1:50 – 2:00 pm | Q&A with Ona Bloom |
| 2:00 – 2:20 pm | Susan Harkema • Kentucky Spinal Cord Injury Research Center<br>*Neuromodulation for Whole Body Systems* |
| 2:20 – 2:30 pm | Q&A with Susan Harkema |
| 2:30 – 3:00 pm | Panel Discussion |
| 3:00 – 3:15 pm | Break and Posters Review |
| SESSION EIGHT | INTEGRATION OF COMMUNITY, INDUSTRY, SCIENCE, AND FUNDERS |
| 3:15 – 5:00 pm | Stakeholders' Roundtable<br>PANELISTS<br>Linda Bambrick • NINDS<br>*Roundtable Moderator*<br>Camilo Castillo • UofL Health<br>Naomi Kleitman • Craig H. Neilsen Foundation<br>Denna Laing • Honorary Chair<br>Dave Marver • ONWARD<br>Mary Schmidt Read • Magee Rehabilitation Hospital<br>Nate Torgerson • Medtronic |

Steven Kirshblum, MD

*Chief Medical Officer, Kessler Foundation, Reynolds Center for Spinal Stimulation, Centers for Spinal Cord Injury Research*

## Spinal Cord Injury as a Whole Body System: Biology and the Hope of Neuromodulation

**Abstract Synopsis** Spinal cord injury causes multi-organ system dysfunction that significantly affects quality of life. These complications along with the potential adverse effects of some treatments will be highlighted. Neuromodulation techniques, most specifically spinal stimulation, have facilitated enhancements of multiple issues. Recommendations to overcome hurdles and hope for the future will be proposed.

**About The Speaker** Steven Kirshblum, MD is a nationally recognized expert in spinal cord injury rehabilitation and research who also co-directs the Foundation's Reynolds Center for Spinal Stimulation and the Centers for Spinal Cord Injury Research. Dr. Kirshblum is board-certified in physical medicine and rehabilitation and spinal cord medicine. At Kessler Institute for Rehabilitation, part of Select Medical Corporation, he serves as chief medical officer and director of Spinal Cord Injury Services. He is also the chief academic officer for Select Medical's rehabilitation hospital division.





David Gater, Jr., MD, PhD, MS

*Professor and Chair, Spinal Cord Injury Fellowship; Director, Department of Physical Medicine & Rehabilitation; Medical Director, Rehabilitation, Jackson Memorial Hospital; Co-Director, NIDILRR South Florida Spinal Cord Injury Model System University of Miami | Leonard M. Miller School of Medicine*

## Neurogenic Obesity after Spinal Cord Injury: Metabolic Melee

**Abstract Synopsis** Neurogenic obesity is the result of neurogenic sarcopenia, neurogenic osteoporosis, neurogenic anabolic deficiency, sympathetic dysfunction, and blunted satiety after spinal cord injury (SCI). Adipose tissue and its associated macrophages after SCI accumulates in much greater quantities than in the non-SCI population and secretes a large number of proinflammatory cytokines and non-esterified free-fatty acids that mediate the metabolic syndrome including insulin resistance, dyslipidemia, hypertension and systemic vascular inflammation. Although the comorbidities (insulin resistance, dyslipidemia and hypertension) of neurogenic obesity can and should be managed pharmacologically, systemic vascular inflammation will persist so long as excess adipose tissue remains to secrete proinflammatory cytokines.

**About The Speaker** Dr. Gater obtained a BS in General Biology (1982), MS in Exercise and Sports Sciences (1985), PhD in Physiology (1990), and MD (1992) from the University of Arizona in Tucson, Arizona. Dr. Gater completed an Internal Medicine internship at the University of Arizona and Affiliated Hospitals (1993), and PM&R residency training (1996) at the UC Davis Medical Center in Sacramento, California. Dr. Gater has board-certifications in PM&R, Electrodiagnostic Medicine and the subspecialty of Spinal Cord Injury Medicine. Dr. Gater has completed Research Career Development Awards with both VHA and NIH, and has mentored many undergraduate, graduate and medical students, resident physicians, fellows and junior faculty. He has received several teaching, research and clinical awards, and is a passionate lecturer. He is currently President of the American Paraplegia Society, President-Elect of the Academy of Spinal Cord Injury Professionals and has published more than 100 manuscripts in peer-reviewed journals. His research emphasizes the effects of diet and exercise training on energy metabolism, glucose and lipid metabolism, obesity/body composition, cardiovascular fitness, neuroplasticity and functional outcomes in Spinal Cord Injury, and he has been funded by NIH, NIDRR, AHA, PVA SCRF, CH Neilsen Foundation and the VHA.

Phillip Popovich, PhD

*Director, Ohio State University Center for Brain and Spinal Cord Repair; Professor, Neuroscience and Neurosurgery, The Ohio State University; Visiting Professor, Deutsches Zentrum fur Neurodegenerative Erkrankungen, Bonn, Germany; Chair, Department of Neuroscience, The Ohio State University College of Medicine; Executive Director, Belford Center for Spinal Cord Injury*

## Dysautonomia as a Unifying Neurogenic Feature of Multi-organ Pathology After Spinal Cord Injury

**Abstract Synopsis** Severe, high-level spinal cord injury (SCI) causes excessive or exaggerated activity in spinal sympathetic autonomic circuits. This SCI-induced dysautonomia causes pathological changes in all organ systems. Dysautonomia is caused by protracted structural remodeling of spinal autonomic circuitry. Excitatory spinal interneurons are critical cellular determinants of remodeled spinal autonomic circuitry; excessive activation of these interneurons after SCI causes or contributes to multi-organ pathology. This presentation will highlight effects of SCI-induced dysautonomia on immune organs, heart and adrenal gland.

**About The Speaker** Dr. Popovich completed his PhD training in physiology and spinal cord injury (SCI) at Ohio State University (OSU). As a post-doctoral fellow, also at OSU, he was awarded a Sandoz Research Fellowship that supported his formal training in immunology and CNS autoimmune disease. His research program is focused on understanding how SCI disrupts communication between the nervous and immune systems leading to a state of chronic immune dysfunction, including immune suppression and “metainflammation”.



David Ditor, PhD

*Professor, Department of Kinesiologist; Professor Kinesiology, Brock University; Adjunct Professor, Department of Kinesiology, McMaster University; Adjunct Professor, Department of Kinesiology and Health Science, York University*

## High Quality Weight Loss After Spinal Cord Injury: Can Lean Mass Be Preserved While Fighting Obesity?

**Abstract Synopsis** Dietary interventions have been shown to reduce inflammation and manage secondary health complications after spinal cord injury (SCI), however, unwanted reductions in lean mass often accompany losses in fat mass. High quality weight loss refers to the preservation of lean mass during diet-induced losses in fat mass, and although challenging to achieve, various approaches have shown promise. This presentation will discuss strategies that may allow high quality weight loss in those with SCI, as well as the benefits to multi-system health and function.

**About The Speaker** David Ditor's research program focuses on the secondary health complications that accompany spinal cord injury (SCI). More specifically, Dr. Ditor’s research interests involve, chronic inflammation after SCI and the associated range of negative effects, cardiovascular disease and dysfunction after SCI, and sexual dysfunction after SCI. As some of these health complications are modifiable, Dr. Ditor is also interested in the role of exercise and diet in managing and reversing them. In addition to his teaching and research responsibilities at Brock University, Dr. Ditor is also the Founder and Director of POWER CORD; an accessible facility that provides specialized and supervised exercise for individuals with SCI, MS, and lower limb amputations. POWER CORD is both a community-based exercise center and a research facility, offering unique experiential learning opportunities to the Brock University students who implement the exercise programs.

Karyn Esser, PhD

*Preeminence Professor, Department of Physiology and Functional Genomics, University of Florida; Associate Director, Basic Muscle Biology, Institute of Myology, University of Florida*

## The Muscle Circadian Clock and Glucose Metabolism; A New Role For Exercise

**About The Speaker** Karyn Esser's lab has been working in the area of skeletal muscle adaptation for over 25 years. During the first part of her career, her lab studied the molecular mechanisms that underly adult skeletal muscle adaptation to both endurance training (e.g. fiber type) and resistance training (e.g. hypertrophy). Following a discover from an early generation microarray study in 2002, Dr. Esser's research direction has transitioned to focus on circadian rhythms, the molecular clock and skeletal muscle. Her lab has pioneered research on the role of circadian rhythms in skeletal muscle health. Use of genetic mouse models of circadian disruption were used to demonstrate that skeletal muscle exhibits profound weakness, and disrupted mitochondria. Her lab's recent work has found that targeted disruption of the molecular clock only in adult skeletal muscle is sufficient to induce muscle weakness and insulin resistance. In addition, they found that there were systemic changes that including the heart, brain and bone. The lab is currently pursuing the role of the circadian clock in muscle weakness, how exercise can work with the circadian systems and the links between skeletal muscle and other organ systems.



Muscle As An Endocrine Organ
SESSION TWO

Christopher Cardozo, MD

*Professor of Medicine and Rehabilitation Medicine at Icahn School of Medicine, Mount Sinai; Director, Molecular Program, Center for the Medical Consequences of Spinal Cord Injury, James J. Peters VA*

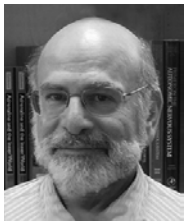
## Exercise Corrects Perturbation of the Hepatokine-adipokine Axis of Spinal Cord Injury Mice

**Abstract Synopsis** Insulin action and fat metabolism are regulated by hormones that include the hepatokine FGF21, which acts largely by stimulating release from adipocytes of adiponectin. Research on effects of SCI on the FGF21/adiponectin axis will be summarized. Studies demonstrating effects of physical rehabilitation or drugs to mitigate effects of SCI on FGF21/adiponectin levels will be presented.

**About The Speaker** Dr. Cardozo is a physician scientist with an undergraduate degree in mechanical engineering who practices pulmonary medicine. Since 2001, his research has sought to understand mechanisms of impaired muscle function after spinal cord injury (SCI) and to evaluate the potential of new drug candidates to improve muscle performance after SCI. More recently, he has contributed to projects evaluating mechanisms for and treatment of sublesional bone loss after SCI, and to cell culture and small animal studies of organ and tissue interactions through release of exosomes, myokines, adipokines and hepatokines, particularly as they relate to dysregulation of body composition and metabolism.

David Goldstein, MD, PhD





*Director, Autonomic Medicine Section, Clinical Neurosciences Program, Division of Intramural Research, National Institute of Neurological Disorders and Stroke, National Institutes of Health, Bethesda, Maryland*

## The Extended Autonomic System, Homeostasis, and Biocybernetics

**Abstract Synopsis** This lecture updates integrative physiological concepts that provide a background for biocybernetic therapies in a variety of multi-system disorders of regulation.

The "extended autonomic system" includes Langley's tripartite autonomic nervous system (ANS) as well as neuroendocrine systems, immune/inflammatory systems, and the central autonomic network, all of which were discovered during the century after Langley promulgated his definition of the ANS.

The homeostatic theory incorporates stress, allostasis, and allostatic load and principles of homeostatic systems operation such as multiple effectors and effector sharing that are amenable to computer modeling and enhance comprehension of an expanding repertoire of biocybernetic treatments.

**About The Speaker** Dr. Goldstein graduated in 1970 from Yale College, completed an MD/PhD at Johns Hopkins in 1976, and came to the NIH in Bethesda, Maryland, in 1978. He has been a supported continuously as a tenured Senior Investigator at the NIH since 1984. An internationally recognized authority on catecholamines and autonomic disorders, he has more than 600 publications, more than 100 articles cited at least 100 times, and more than 135 first-authored original research reports. Among his honors are the Society for Clinical and Translational Science's Distinguished Investigator Award, the American Academy of Neurology's Irwin Schatz Award in Autonomic Disorders, and the NIH's Distinguished Clinical Teacher Award. He has made several fundamental discoveries, including cardiac sympathetic denervation, buildup of the autotoxic dopamine metabolite DOPAL, and the "sick-but-not-dead" phenomenon in Parkinson's and related diseases. These discoveries continue to inspire his research on biomarkers, mechanisms, and disease-modifying treatments for catecholamine-related disorders. He is an author of an e-textbook: *Principles of Autonomic Medicine*.

Autonomic Cardiovascular Dysfunction in SCI: Presentation, Consequences, Treatments

Andrei Krassioukov, MD, PhD

SESSION THREE

*Professor, Department of Medicine, Division of Physical Medicine and Rehabilitation, University of British Columbia (UBC) Vancouver; Associate Director, Rehabilitation, International Collaboration on Repair Discoveries (ICORD), UBC, Vancouver; Staff Physician, Spinal Cord Injury Program, Physical Medicine and Rehabilitation, Vancouver Acute, Department of Medicine, Division of Physical Medicine and Rehabilitation, Vancouver*

## Neuromodulation for Restoration of Autonomic Functions After Spinal Cord Injury

**About The Speaker** Dr. Krassioukov is a co-chair of the International Autonomic Standards Committee for the American Spinal Injury Association and International Spinal Cord Society (ASIA/ISCoS). Prof. Krassioukov's research is focused on autonomic dysfunctions following spinal cord injury and his laboratory is supported by grants from the Canadian Institute for Health Research, Heart and Stroke Foundation, Canadian Foundation for Innovation, Rick Hansen Institute/ Foundation, Craig Neilsen Foundation, Department of Defense, Wings for Life, and many others. He has published more than 300 peer-reviewed manuscripts, books, book chapters and reviews. He is a member of numerous advisory boards for the international agencies involved in research in the area of spinal cord injury and disability. Prof. Krassioukov's work in the area of spinal cord injury has been recognized through numerous national and international awards including the inaugural Alan Brown Award from American Spinal Injury Association. Prof. Krassioukov was inducted as a fellow of the Canadian Academy of Health Sciences. Presently, Dr. Krassioukov is a President of the American Spinal Injury Association.

# Autonomic Cardiovascular Dysfunction in SCI: Presentation, Consequences, Treatments

Jill Wecht, Ed D

SESSION THREE

*Professor, Human Performance and Rehabilitation Medicine, Icahn School of Medicine, Mount Sinai; Program Director, Cardiovascular Autonomic Program, National Center for the Medical Consequences of SCI, James J Peters VA Medical Center; Chair, Autonomic Standards Committee of ASIA and ISCoS; Planning Committee Member, Moving Beyond Isolated Systems Symposium*

## Autonomic Cardiovascular Dysfunction in Spinal Cord Injury: Presentation, Consequences, Treatments

**Abstract Synopsis** Impaired descending autonomic cardiovascular control has an adverse impact on blood pressure regulation, which may lead to cognitive dysfunction and diminished quality of life in persons with chronic spinal cord injury. Potential options to restore autonomic cardiovascular regulation will be discussed.

**About The Speaker** Dr. Jill Wecht investigates the impact of autonomic cardiovascular impairment on blood pressure regulation and the secondary consequences of hypotension and orthostatic hypotension on cognitive function and quality of life in persons with chronic spinal cord injury (SCI). She and her team have established associations between systemic and cerebral hemodynamics and cognitive test performance and suggest premature cognitive aging in the SCI population may be the result of impaired decentralized autonomic cardiovascular control following injury. Recent findings, which describe the use of lumbosacral epidural stimulation to safely and effectively increase and maintain seated blood pressure in persons with chronic SCI are exciting and offer a viable clinical option to target autonomic cardiovascular regulation and restore blood pressure regulation, cerebral blood flow, cognitive function and quality of life.





Sten Grillner, PhD

*Director and Professor, Karolinska Institute's Nobel Institute for Neurophysiology, Stockholm*

## The Intrinsic Capacity of the Spinal Cord to Coordinate Movements, and its Control From Brainstem and Forebrain

**Abstract Synopsis** Sten Grillner will present an overview of the capacity of the spinal cord to coordinate movement based on its intrinsic circuitry and the sensory control of the different phases of the step cycle. Moreover, he will summarize the many different modes whereby the brainstem and the forebrain can control the spinal cord. These are the systems that have partially or entirely been damaged after an injury to the spinal cord.

**About The Speaker** Dr. Grillner is a neurophysiologist and distinguished professor at the Karolinska Institute's Nobel Institute for Neurophysiology in Stockholm where he is the director of that institute. He is considered one of the world's foremost experts in the cellular bases of motor behavior.

Karen Minassian

*Ap. Professor, Center for Medical Physics and Biomedical Engineering, Medical University of Vienna, Austria; Planning Committee Member, Moving Beyond Isolated Systems Symposium*

## History and Overview of Epidural and Transcutaneous Spinal Cord Stimulation Strategies for Motor Recovery Treatments

**Abstract Synopsis** Recent studies combining spinal cord stimulation (SCS) with intense neurorehabilitation training have demonstrated unprecedented improvements of motor function in individuals with chronic, severe spinal cord injury (SCI). Different invasive and non-invasive methods for SCS have emerged, all with the goal to augment functional activity of spared spinal circuits. In this presentation, I will discuss the historical background of SCS and its evolution towards current applications in individuals with SCI, as well as the concepts of the various stimulation strategies for motor recovery.

**About The Speaker** Karen Minassian is a pioneer of the recent advances in epidural spinal cord stimulation (SCS) in individuals with spinal cord injury. His main interest is the understanding of the neural control of movement with a focus on human spinal cord locomotor circuits. With a background in physics and mathematics, he first used computer simulations to identify the neuronal structures that are electrically activated by epidural SCS. He then extended his approach by using neurophysiological methods and unraveled some of the mechanism underlying the generation of movement in otherwise paralyzed legs under epidural stimulation. His research has paved the way for the recent high profile studies of epidural stimulation. In parallel, he developed transcutaneous SCS, a non-invasive method that can be used as a neuromodulation tool as well as for human neurophysiological studies, a method that has been meanwhile adopted by several groups internationally. From 2016 to 2018 he supervised the research team of Prof. Grégoire Courtine at the Swiss Federal Institute of Technology, employing next-generation implantable SCS technologies in spinal cord injured individuals. At the Medical University of Vienna, he is currently planning novel approaches to delineate the intrinsic anatomical and physiological properties of the human locomotor networks.





Yury Gerasimenko, PhD, D Sci

*Professor and Head, Laboratory of Movement Physiology, Pavlov Institute of Physiology, St.Petersburg, Russia; Planning Committee Member, Moving Beyond Isolated Systems Symposium*

## Multi-modal Stimulation for the Recovery of Posture and Locomotion Injury

**Abstract Synopsis** A novel strategy of noninvasive multi-segmental spinal cord transcutaneous stimulation was developed to provide multi-functional enabling of the locomotor-related neuronal networks for facilitation of stepping recovery after motor complete paraplegia. We show evidence that non-invasive neuromodulation through multi-site spinal cord transcutaneous stimulation can transform complete paraplegia to independent stepping.

**About The Speaker** Yury Gerasimenko received his PhD and later doctor's degree (D Sci) in the Pavlov Institute of Physiology, Russian Academy of Sciences, St. Petersburg, Russia. While at the Pavlov Institute of Physiology, he worked as a researcher and later as a director at the Movement Physiology Laboratory. He then moved to Los Angeles, taking a position at UCLA as a researcher with the Department of Integrative Biology and Physiology. He is now Professor of Pavlov Institute of Physiology and Corresponding Member of Russian Academy of Sciences.

Dr. Gerasimenko is an expert in the area of regulation of locomotor behavior in decerebrated and spinal animals, as well as in human subjects with spinal cord injuries. He has performed extensive studies that have led to the development of effective rehabilitative strategies for recovery of the injured spinal cord using a combination of therapies, including epidural and transcutaneous spinal cord stimulation, pharmacological intervention and locomotor training.

Ursula Hofstötter, MSc, PhD

*Ap. Professor, Center for Medical Physics and Biomedical Engineering, Medical University of Vienna, Austria*

## Transcutaneous Spinal Cord Stimulation for Enhancing Locomotor Activity And Controlling Spasticity

**Abstract Synopsis** Recent studies of epidural electrical spinal cord stimulation have marked the dawn of a new era in neurorehabilitation, in which unprecedented levels of improvements have become attainable even in the chronic stage of spinal cord injury. With the development of transcutaneous spinal cord stimulation, a clinically accessible technique has complemented the current landscape of state-of-the-art neuromodulative therapeutic options. This presentation gives an overview of my recent studies of transcutaneous spinal cord stimulation as a non-invasive method to control diffuse forms of lower-limb spasticity and to enhance residual locomotor capacity and delineates some of the mechanisms underlying its therapeutic effects.

**About The Speaker** Dr. Hofstöetter is affiliated with the Center for Medical Physics and Biomedical Engineering at the Medical University of Vienna, Austria. Her scientific approach is inspired by her background in technical mathematics and her longstanding collaborations with the leading neurorehabilitation centers and clinical research units in Austria, Germany, Switzerland, and the United States. Her research focuses on human spinal sensorimotor circuits, their functional alterations after upper motoneuron injury or disease, and their neuromodulation by electrical spinal cord stimulation. Her research in epidural spinal cord stimulation has contributed to unraveling the directly recruited neural structures and the transsynaptically activated spinal circuits. Ursula Hofstöetter has co-developed the method of transcutaneous spinal cord stimulation in Vienna as a tool for human neurophysiological studies and for innovative neurorehabilitation strategies. She is internationally recognized for her leading role in implementing clinical studies using transcutaneous spinal cord stimulation to augment residual locomotor function and to control spinal spasticity in individuals with spinal cord injury and multiple sclerosis.





Transcutaneous Stimulation:
Motor Systems
SESSION FOUR

V. Reggie Edgerton, PhD

*Distinguished Professor, UCLA, Department of Neurobiology; Director, Neuromuscular Research Laboratory*

## It is What We Think We Know Already That Often Prevents Us From Learning

**Abstract Synopsis** The recent quote by Claude Bernard that was noted by the American physiological society reflects perfectly the scenario that has negatively impacted progress in understanding the biology of spinal cord injury and the efforts to develop strategies to recover functions from spinal trauma. The quote states, “It is what we think we know already that often prevents us from learning”. What we think we know, routinely becomes embedded in the assumptions that we “unknowingly” make in designing or even performing a given experiment and/or in interpreting the data derived from experiments. The results from a series of experiments with a focus on spinal cord injury will be discussed, demonstrating that what we thought we knew, was clearly wrong.

**About The Speaker** Professor Edgerton received his PhD in Exercise Physiology from Michigan State University and is a member of the Brain Research Institute at University of California, Los Angeles. He has moved his more mechanistic work and his clinical studies to the highly supportive environments of the University of Southern California Neurorestoration Center, Keck School of Medicine and the Rancho Research Center at the Rancho Los Amigos National Rehabilitation Center in Downy, CA. His research is focused on how the neural networks in the lumbar spinal cord of mammals, including humans, regain control of standing, stepping and voluntary fine movements after paralysis and how these motor functions can be modified by imposing activity-dependent interventions after spinal cord injury (SCI). He and his team have demonstrated three effective ways to neuromodulate the spinal cord to improve and regain function: Stimulation of the spinal circuitry using both invasive and non-invasive electrical current; administration of pharmacological agents; and repetitive training of motor tasks. They have reported that epidural stimulation, combined with activity-dependent mechanisms, can enable human subjects with chronic, complete paralysis to regain the ability to stand independently and recover significant levels of voluntary control of movement of the legs. More recently, they have begun to test different methods for neuromodulation of spinal circuitry to determine efficacy improving arm, hand and ventilatory function after SCI and promoting a more normal gait pattern after stroke and improved motor function in individuals with Parkinson’s Disease. They are also pursuing strategies to restore bladder function after spinal cord injury.

# Transcutaneous Stimulation: Motor Systems

Grégoire Courtine

SESSION FOUR

*Full Professor, Neuroscience and Neurotechnology EPFL | Ecole Polytechnique Lausanne CHUV | Hopital Universitaire Lausanne, Genève; Planning Committee Member, Moving Beyond Isolated Systems Symposium*

## Mechanism-driven Technologies and Therapies for Spinal Cord Injury

**Abstract Synopsis** Two decades of preclinical discoveries, clinical innovations and industrial developments enabled the design and validation of various mechanism-based neuroprosthetic systems to improve motor and autonomic functions in people with spinal cord injury. Dr. Courtine will summarise this journey, while mapping the next steps to turn these technologies into widely available treatments.

**About The Speaker** Grégoire Courtine was trained in Physics and Neurosciences. His passion for translational neurosciences has fueled his research in the development of neurotechnologies to improve recovery from neurological disorders. After obtaining the Chancellor Award during his post-doc at the University of California, Los Angeles, he established his own laboratory at the University of Zurich in 2008 before joining the Swiss Federal Institute of Technology Lausanne (EPFL) in 2012. He is also Chief Scientific Officer of GTX medical, a start-up he founded in 2014 to translate the neurotechnologies developed in his laboratory into clinical treatments.

# Epidural Stimulation: Motor Systems

Marco Capogrosso, PhD

SESSION FIVE

*Assistant Professor, Department of Neurological Surgery, University of Pittsburgh*

## Computer Models in the Understanding of Electrical Epidural Stimulation for the Recovery of Motor Control Learning

**Abstract Synopsis** Spinal cord stimulation is gaining momentum as a potential new therapy for leg motor paralysis. In this talk we will discuss the neural mechanisms that enable the restoration of voluntary motor control. By leveraging this unique feature we then show how we are adapting this technology to the cervical spinal circuits to enable recovery of arm and hand movements in humans after paralysis. Finally, we will discuss the hypothesis that the observed motor effects are an emergent property of the integration of electrical stimulation in complex circuit processing.

**About The Speaker** Marco Capogrosso, PhD, completed his doctoral studies in Biomedical Engineering and Robotics at the Scuola Superiore Sant'Anna in Pisa, Italy. His PhD work focused on computer models of electrical stimulation to support the design of neural interfaces for sensory and motor applications.

After the PhD, Dr. Capogrosso completed his post-doctoral training at the Ecole Polytechnique Fédérale de Lausanne, Switzerland where he worked on the development of brain spinal interfaces for the restoration of voluntary motor control in animal models of spinal cord injury. Before joining the University of Pittsburgh, he was SNSF Ambizione Fellow, research faculty and member of the managing board of the primate center at the University of Fribourg, Switzerland.

Dr. Capogrosso research interests broadly involve the study of voluntary motor control. Specifically, he is interested in the design of neurotechnologies to restore sensorimotor function after neural damage or disease. For his work he parallels human clinical trials with experiments in non-human primates and physics simulations.

Igor Lavrov, MD, PhD

*Assistant Professor, Mayo Clinic, Department of Neurology; Assistant Professor, Mayo Clinic, Department of Biomedical Engineering*

## Merging Neuromodulation and Neuroregeneration Therapy for Spinal Cord Injury

**Abstract Synopsis** This talk will cover up-to-date results that highlight the interplay between neuromodulation and neuroregenerative therapies in enhancing functional recovery following spinal cord injury. We will show new evidence of the contribution of newly regenerated axons in the reorganization of the spinal circuitry and restoration of motor functions with and without neuromodulation and will discuss potential mechanisms of reestablishing functional levels of excitability and enabling sensorimotor signaling via residual or newly regenerated connectivity.

**About The Speaker** Igor Lavrov, MD, PhD, was trained in medicine (neurology) and neuroscience. After completing Postdoctoral Research Fellowships at the University of Louisville and at the University of California Los Angeles, he was working as a researcher at UCLA and later as an Assistant Professor at the Mayo Clinic. He also completed clinical fellowship in Deep Brain Stimulation and Clinical Neuromodulation at the Department Neurology and Neurosurgery, Mayo Clinic.

Over the course of twenty years career, he participated and directed multiple research projects. He studied spinal cord neuromodulation on several animal models and in clinical trials. His current research interests are focused on neuronal circuits, their modulation, reorganization, and repair after traumatic injury, with particular focus on spinal cord stimulation and regenerative therapies. The ongoing success of these studies currently is leading to establishment of a new perspective for restoration after spinal cord injury and also covers multiple aspects of neuromodulation for movement disorders and chronic pain.





Epidural Stimulation:
Motor Systems
SESSION FIVE

Enrico Rejc, PhD

*Assistant Professor, Kentucky Spinal Cord Injury Research Center, University of Louisville, KY; Scientific Director, Neuromuscular and Skeletal Research Core, Kentucky Spinal Cord Injury Research Center, University of Louisville, KY*

## Spinal Cord Epidural Stimulation to Promote Standing Motor Function Recovery After Motor Complete Spinal Cord Injury

**Abstract Synopsis** Activity-based training with spinal cord epidural stimulation can promote the recovery of standing ability and upright postural control in individuals with chronic, motor complete spinal cord injury.

Sensory information, residual supraspinal inputs and training-induced neural plasticity are the important contributors of standing motor recovery that will be discussed in this presentation.

The implications of using (i) upper limbs for self-balance assistance during standing and (ii) a cable-driven robotic device for postural training will be also discussed in the context of upright postural control regulation.

**About The Speaker** Enrico Rejc, PhD is presently Assistant Professor and Director of the Metabolic, Neuromuscular and Skeletal Research Core at the Kentucky Spinal Cord Injury Research Center, Department of Neurosurgery, University of Louisville, USA. Prior to taking this position, he was involved in research activities at the University of Udine, University of California Los Angeles, and Manchester Metropolitan University. In the last 10 years, his research has been primarily focused on investigating the effects of spinal cord epidural stimulation parameters, peripheral sensory information, and activity-based training paradigms on the recovery of lower limb motor function in individuals with motor complete spinal cord injury. He is also interested in the effects of disuse, aging and physical exercise on the human neuromuscular system.

Claudia Angeli, PhD

*Assistant Professor, University of Louisville; Director, Epidural Stimulation Program Core, Kentucky Spinal Cord Injury Research Center; Senior Researcher, Human Locomotion Research Center, Frazier Rehab Institute, University of Louisville, Louisville, KY*

## From Modulation to Recovery: Crossing the Threshold

**About The Speaker** Dr. Claudia Angeli's research background and interests are focused in understanding mechanisms of control of human locomotion following neurologic injury. She has over ten years of experience utilizing a combination of epidural stimulation and activity based training for the restoration of function following motor complete spinal cord injury. Her publications have generated a pivotal paradigm shift providing evidence for the potential of functional recovery following motor complete spinal cord injuries.





Megan Gill, PT, DPT

*Research Physical Therapist, Assistive and Restorative Technology Laboratory, Physical Medicine and Rehabilitation, Mayo Clinic*

## Panel Discussion:
## Performance Focused Neuromodulation

**About The Speaker** Megan Gill in a licensed physical therapist who received her Master's in Physical Therapy in 2004 from Mayo Clinic's School of Health Science Physical Therapy program and later received her Doctorate in Physical Therapy from the College of St. Scholastica in 2011. She has held multiple clinical roles, all at Mayo Clinic in Rochester, MN including staff PT and later as the Clinical Lead for the Spinal Cord Injury program. As the clinical lead, she was integral in developing internal clinical pathways, facilitated relationships with industry partners for advanced technology, and gained a growing interest for recovery principles following spinal cord injury. She was able to participate in 0.5-time research and 0.5-time clinical between the years of 2015-2017 and then transitioned full-time into research within the Rehabilitation Medicine Research Center at Mayo Clinic in 2018. Megan's involvement and interests in research include spinal stimulation for motor recovery after a spinal cord injury.

*Clinical Professor, Department of Neurological Surgery, The Miami Project to Cure Paralysis, Miami, FL; Planning Committee Member, Moving Beyond Isolated Systems Symposium*

## Combined Neuromodulatory Approaches to Amplify Recovery After Spinal Cord Injury

**About The Speaker** Dr. James Guest obtained his MD degree from the University of Alberta in 1988 and completed neurosurgical residency training in Vancouver in 1998. He was certified by the Royal College of Surgeons of Canada and the American Board of Neurological Surgeons. During residency, he obtained a PhD in Neuroscience at the University of Miami studying cell transplantation after spinal cord injury (SCI). In Vancouver, during the last years of residency, he collaborated with the nascent ICORD. He then moved to the Barrow Neurological Institute in Phoenix, Arizona for fellowship training in spinal surgery and research training in the primate motor system. He then returned to the University of Miami.

Dr. Guest has a strong interest in translational research and clinical trials in SCI. He has received funding from Spinal Research, the DOD, the NIH, and the Craig Nielsen foundation. Together with colleagues, he translated autologous Schwann cell transplantation for SCI into human subjects through two sequential clinical trials. For these trials, his team also conducted neurophysiological studies to identify recovery of neural circuits. He is the PI in Miami for the North American Clinical Trials Network (NACTN) Registry, the RISCIS study, and co-chairs NACTN. He is an AO Spine knowledge forum member and has served on the California Institute for Regenerative Medicine grants working group for the past 6 years. He has conducted therapeutics studies in large animal models including cell transplantation, the use of biomaterials and pioneered delivery methods that have been patented. Current work includes neuromodulation using deep brain stimulation (DBS) of the mesencephalic locomotor region (MLR) tested in in combination with epidural stimulation after SCI. He is a co-investigator in a small clinical trial testing MLR DBS for freezing-of-gait. His neuromodulation group recently participated in the Up-LIFT transcutaneous study for upper extremity recovery. He is collaborating with researchers from the Bronx VA, Kessler Rehabilitation, and the University of Louisville to assess the mechanisms by which epidural stimulation normalizes blood pressure in cervical injury subjects during epidural stimulation.

Neurosurgical Approaches and the Clinical Future of Neuromodulation
Maxwell Boakye, MD, MPH, MBA


*Ole A., Mabel Wise and Wilma Wise Nelson Endowed Research Chair; Professor, Chief Spinal Neurosurgery, and Director, Outcomes Research Clinical Director, Kentucky Spinal Cord Injury Center, Department of Neurosurgery, University of Louisville Louisville, KY*

## Patient Selection, Risk Mitigation and Optimization of Surgical Technique and Implant Position

**About The Speaker** Maxwell Boakye, MD, MPH, MBA, FAANS, FACS is a clinician-scientist, who devotes about half of his time to outcomes and comparative effectiveness research, and spinal cord injury research. He also directs the University of Louisville spine fellowship. His spinal cord injury research focuses on discovering innovative treatments for paralysis. He is director of the Brain and spinal cord injury lab and is the lead neurosurgeon for the University of Louisville epidural stimulation research program. Dr. Boakye has published over 200 peer-reviewed scientific manuscripts, book chapters, and abstracts and coedited one spinal cord injury textbook.

# Neurosurgical Approaches and the Clinical Future of Neuromodulation

David Darrow, MD, MPH

SESSION SIX

*Assistant Professor, Department of Neurosurgery, University of Minnesota*

## Patient-in-the-loop Optimization of Spinal Cord Stimulation for Spinal Cord Injury

**About The Speaker** Dr. David Darrow is the Rockswold-Kaplan Endowed Chair for Traumatic Brain Injury at Hennepin County Medical Center, specializing in functional and pain neurosurgery. Dr. Darrow treats diseases of the central nervous system with neuromodulation including epilepsy, movement disorders, trigeminal neuralgia/facial pain, chronic pain, and psychiatric diseases.

Dr. Darrow is co-PI of the Herman-Darrow Human Neuroscience Lab with a mission of understanding and treating disorders of the nervous system with neuromodulation. The Herman-Darrow Lab links together circuit-level electrophysiology with behavior. By pairing neuromodulation with a quantitative understanding of the pathological circuits of the brain, the lab hopes to help patients improve symptoms and quality of life.

Dr. Darrow is also the PI of the Traumatic Brain and Spinal Cord Research Center at HCMC where electrophysiology and neuromodulation and used to better understand and treat traumatic injuries of the central nervous system. He is the PI for the E-STAND trial, where neuromodulation is used to restore function after Spinal Cord Injury. In collaboration with many other investigators, the team is testing neuromodulation to restore volitional movement and autonomic function using algorithmic, personalized approaches through remote data collection.

# Intersystems, Health, and Community Integration of Neuromodulation

Aaron Phillips, PhD

SESSION SEVEN

*Assistant Professor, University of Calgary*

## A Mechanism-guided Cardiovascular Stabilizing System For Spinal Cord Injury

**Abstract Synopsis** We established a preclinical model that enabled us to dissect the topology and dynamics of the sympathetic circuits, and to understand how epidural stimulation can engage these circuits. We incorporated these spatial and temporal features into stimulation protocols to conceive a clinical-grade biomimetic haemodynamic regulator that operates in a closed loop. This 'neuroprosthetic baroreflex' controlled haemodynamics for extended periods of time in rodents, non-human primates and humans, after both acute and chronic spinal cord injury.

**About The Speaker** Aaron Phillips was trained in Experimental Medicine, Biosciences and Mathematics. His appreciation of the interactions between the nervous and cardiovascular systems, and understanding how these systems are disrupted in the presence of clinical conditions, has driven his research into the development of novel therapies for people with neurological health issues. After obtaining the Banting, CIHR, NSERC, Heart & Stroke Foundation, and Craig Neilsen Fellowships as well as the Killam Research Award during his post-doc at the University of British Columba (UBC), he established his laboratory at the University of Calgary in 2017. He is now an Associate Professor of Physiology and Pharmacology, Clinical Neurosciences, and Cardiac Sciences. Within the Foothills Medical Centre, he is Director of RESTORE.net, which is a platform dedicated to developing translational technology for neurological injury. He has received the Brain Canada Leader Award, The Arthur Guyton Award in Excellence in Physiology from the American Physiological Society, and the Top 40 Under 40 from Avenue Magazine. He has funding from several organizations including CIHR, NSERC, PRAXIS, Wings for Life, and the US Military through DARPA.

*Interim Deputy Director, Kentucky Spinal Cord Injury Research Center; Professor and Vice Chair, Department Anatomical Sciences and Neurobiology; Coordinator, Undergraduate Neuroscience Program University of Louisville School of Medicine*

## Cardiovascular and Bladder Integrated

**Abstract Synopsis** Bladder distention is a primary trigger of autonomic dysreflexia (AD) in individuals with spinal cord injury (SCI) at cervical and upper thoracic levels (majority of population), with systolic blood pressure (SBP) rising more than 20 mmHg and remaining elevated with intolerable symptoms (pounding headache and/or chills, for example). In the current presentation, data is first presented on the frequency of impairments related to bladder storage (low volume and high pressure), as well as the frequency of AD when bladder capacity is reached. Data is then presented on how spinal cord epidural stimulation (scES) can be used to maintain a low bladder pressure below 10 cmH2O during filling and normative SBP (110-120 mmHg), resulting in increased storage. These data highlight a major advantage of scES; i.e., the versatility of the multi-electrode array, and the ability to activate multiple spinal cord regions and associated functions with a single electrode placement and device using numerous cohorts simultaneously.

**About The Speaker** Dr. Charles Hubscher received his Bachelor of Science degrees in Biochemistry (1986) from Concordia University and in Psychology (1988) from McGill University in Montreal, Canada. He earned his Master of Science degree (1990) and Doctor of Philosophy degree (1994) in Neuroscience from the Psychology Department at Florida State University in Tallahassee. He held an Assistant Scientist position at the University of Florida in Gainesville in the Department of Physiological Sciences before coming to the University of Louisville as a faculty member in the Department of Anatomical Sciences and Neurobiology in 2001. Dr. Hubscher has an Associate appointment in the Department of Neurological Surgery. His research on spinal cord injury is funded by grants from agencies that include the National Institutes of Health, the Department of Defense, the Craig H. Neilsen Foundation, and the Kentucky Spinal Cord and Head Injury Research Trust. Specific research includes functions related to the upper and lower urinary tract, anorectum, and male and female reproductive organs.





*Professor, The Feinstein Institute for Medical Research; Director of Research, Dept. of Molecular Medicine, Dept. of Physical Medicine and Rehabilitation, Zucker School of Medicine, Hofstra Northwell, East Garden City, NY*

## Immune System

**Abstract Synopsis** Autonomic dysfunction in people with spinal cord injury (SCI) rostral to thoracic level 6 (T6) drives clinically significant impairments in both the cardiovascular and immune systems. Immune consequences of SCI are clinically significant: historically (pre-COVID-19 pandemic), infections are the leading cause of death and rehospitalization for people with SCI. Also, most people with SCI have persistent systemic inflammation that promotes risk of cardiovascular disease and stroke. This presentation will review aspects of immune dysfunction in persons with SCI and describe how novel interventional strategies may promote immune function after SCI in order to improve life expectancy, recovery and quality of life.

**About The Speaker** Dr. Bloom's translational research program investigates changes in the immune system after spinal cord injury (SCI). Her goal is to identify mechanisms of heightened risk of infection and inflammation in people with SCI, to promote life expectancy, recovery, and quality of life. Her research program has received support from private foundation, state and federal funding agencies.

Dr. Bloom is the Director of the International Symposium for Neural Regeneration. She has served as a peer reviewer for the Veterans Administration Rehabilitation Research and Development Panels, the Paralyzed Veterans of America Foundation, NIH, NSF, Program Committee of the Society for Neuroscience and is a member of the SCIRTS study section of the Craig H. Neilsen Foundation. She is a member of the VA's National Center for the Medical Consequences of Spinal Cord Injury at the James J. Peters VA Medical Center (Bronx, NY).

# Intersystems, Health, and Community Integration of Neuromodulation

Susan Harkema, PhD

SESSION SEVEN

*Professor, Department of Neurological Surgery; Associate Scientific Director, UofL Kentucky Spinal Cord Injury Research Center; Director, Research, Frazier Rehab Institute; Director, Christopher & Dana Reeve Foundation's Neurorecovery Network; Rehabilitation Research Director, Kentucky Spinal Cord Injury Research Center*

## Neuromodulation for Whole Body Systems

**Abstract Synopsis** Neuromodulation of the lumbosacral spinal cord emerged focused on locomotion by targeting central pattern generation. As knowledge expanded we realized that the complex circuitry of the human spinal cord also mediated autonomic function. Serendipitously after a decade of exploration motor and autonomic recovery has been shown simultaneously with tonic-integrated stimulation with the same placement of the epidural electrode using interleaved and targeted stimulation fields. This approach allows a whole body systems approach to recovery for chronic spinal cord injury.

**About The Speaker** Dr. Harkema's research has explored the neural plasticity of spinal networks and recovery of function after spinal cord injury (SCI). She initially focused on locomotion in a model of clinically diagnosed motor complete injury. Over the years, serendipitous discoveries allowed her to unravel mechanisms of the human spinal circuitry that modulate the autonomic nervous system, and her translational research program expanded to include technology development to improve implantable epidural stimulators.

Dr. Harkema leads the KSCIRC translational faculty within the Pediatric NeuroRecovery, Adult NeuroRecovery, and Epidural Stimulation Programs. Over the past decade, these programs have collectively been awarded over $72 million to improve motor, cardiovascular and bladder function and the health, and quality of life of adults and children living with paralysis. She also led six rehabilitation centers and nine community fitness and wellness centers in the translation of scientific knowledge into clinical practice as the Director of the Christopher & Dana Reeve Foundation NeuroRecovery Network.

Dr. Harkema has published more than 110 scholarly manuscripts and book chapters, delivered over 100 worldwide lectures and keynotes and co-authored seven United States patents. Among her honors and awards, she was the 2008 co-recipient of the Reeve-Irvine Research Medal, awarded to individuals who made critical contributions to promoting repair of the damaged spinal cord and recovery of function. In 2011, she received the Difference Maker Award from the Rick Hansen Foundation, and the Breakthrough Award from Popular Mechanics. In 2014 and 2019 she was named the Innovator of the Year by Business First. She earned both her BS and PhD from Michigan State University and conducted her postdoctoral fellowship in neurophysiology at the University of California, Los Angeles.



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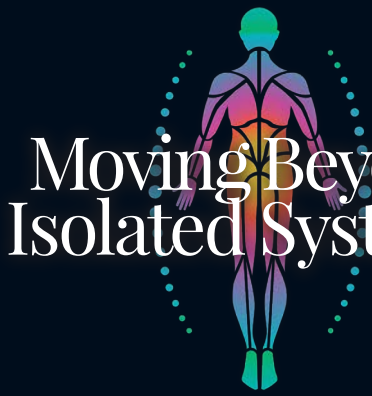

# Moving Beyond Isolated Systems

A whole-body approach to understanding
spinal cord injury, recovery, and the current scientific evidence
for neuromodulation

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