



icord
INTERNATIONAL COLLABORATION ON REPAIR DISCOVERIES

annual report



april 2011 to
march 2012



a place of mind

THE UNIVERSITY OF BRITISH COLUMBIA

Welcome from ICORD's Interim Director



While the search for a new Director of ICORD is underway, I would like to express my sincere thanks, on behalf of all of ICORD, to Dr. Tom Oxland, our Interim Director from March 2010 until June 2012. Tom led and coached ICORD with a great wisdom, sensitivity and respect for everyone which created a wonderful *esprit de corps* among us "ICORDians." This was greatly helped by his strengthening of our relationships with our funding partners: the UBC Faculty of Medicine, the Rick Hansen Institute and the Rick Hansen Foundation, which all generously supported ICORD in the past year. We thank them all!

Their financial support allowed us to venture into novel research areas with our Seed Grant program (see page 25), invest in skilled personnel to support core facilities (see page 7), start programs for monthly seminar speakers, visiting scholars and international trainees (see pages 8-9), and provide funding for

Trainees to not only to travel to conferences but also to grow their own Committee and host an exiting research meeting (see page 12).

I hope you will also take a few minutes to look at ICORD's updated and revamped web site (www.icord.org). Our annual report is coming out a little late this year because our Communications Team spent the summer dedicated to the creation of this new site, which includes in-depth profiles of ICORD researchers and continuously updated PubMed links to their most recent publications.

I'm honoured to be taking over as Interim Director at such an exciting time. The support of UBC Faculty of Medicine, Rick Hansen Institute and Rick Hansen Foundation has stimulated a vibrant research climate and we are all appreciative to be part of it. Please read for yourself in the following pages, and don't hesitate to contact me if you would like to discuss any of our research or initiatives in more detail.

A handwritten signature in black ink, reading "Wolfram Tetzlaff".

Wolfram Tetzlaff
Interim Director, ICORD
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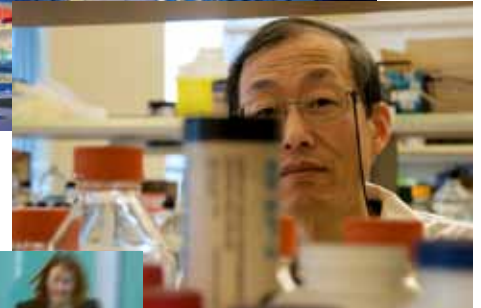
Contents

| | |
|-----------------------------------|----|
| About ICORD | 3 |
| ICORD at a Glance | 3 |
| How ICORD helps researchers | 4 |
| Program highlights | 6 |
| Trainee highlights | 12 |
| Research highlights | 15 |
| Research connections | 18 |
| New researchers | 20 |
| Principal Investigators | 21 |
| Investigators & Associate Members | 24 |
| Seed grants | 25 |
| Spinal Chord gala | 30 |
| Endowed Chair reports | 32 |
| Looking forward | 35 |

About ICORD

ICORD is a world leading health research centre focused on spinal cord injury (SCI). From the lab-based cellular level of understanding injury to rehabilitation and recovery, our researchers are dedicated to the development and translation of more effective strategies to promote prevention, functional recovery, and improved quality of life after spinal cord injury. Located at Vancouver General Hospital in the Blusson Spinal Cord Centre, ICORD is part of the UBC Faculty of Medicine and Vancouver Coastal Health Research Institute.

Visit www.icord.org.



ICORD at a glance

Researchers: 49

Principal Investigators: 31
Investigators: 9
Associate Members: 9

Trainees: 148

Undergrads/other: 31
Grad students: 91
Postdoctoral Fellows: 22
Residents: 4

Staff: 77

Research/Technical: 67
Clerical/Admin: 10

Publications: 376

Peer-reviewed journals
+ book chapters: 176

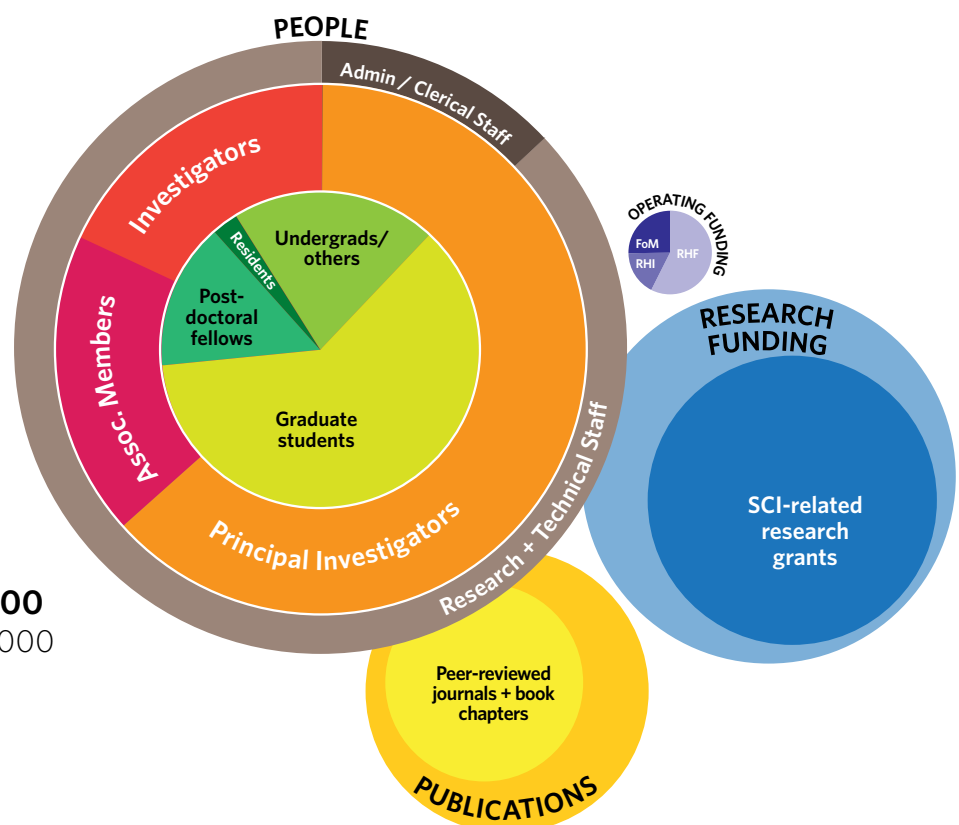
Competitive grant

funding: \$15,437,679

SCI-related: \$8,572,366

Operating funding: \$850,000

Rick Hansen Institute: \$150,000
Rick Hansen Foundation:
\$500,000
UBC Faculty of Medicine:
\$200,000



how does ICORD



"My affiliation with ICORD as a Principal Investigator has very much helped me with at least all of the following: grant applications, interacting with and meeting potential collaborators, attracting potential trainees, and keeping abreast of international activities through the ICORD meetings and talks. The ability to work with Jeswin Jeyasurya has in particular been a boon to my program. Jeswin's skill set and availability for project work in Rehabilitation Engineering is unique in ICORD and beneficial to several ICORD PIs. We have started 2 new projects this past year that would not have been possible without Jeswin's involvement, and I hope to keep working with Jeswin in the future."

- Dr. Jaimie Borisoff

"Being a member of ICORD has been helpful as a networking tool, and useful for overall "context" of my research program."

Dr. E. Paul Zehr

"The collaborations established by being a member of ICORD have allowed our laboratory to conduct innovative and pioneering work and attract the best graduate student trainees. Our laboratory currently publishes 15-25 papers per annum and has received over \$20 million in research funding over the past five years. We are at the forefront of the field."

Dr. Darren Warburton



Dr. Willerth (left) works with a student.

"Having Jocelyn Tomkinson send out grant opportunities has been extremely helpful. She also does a great job of improving my grants. The staff at ICORD is always very helpful which is nice to have as a new professor."

- Dr. Stephanie Willerth

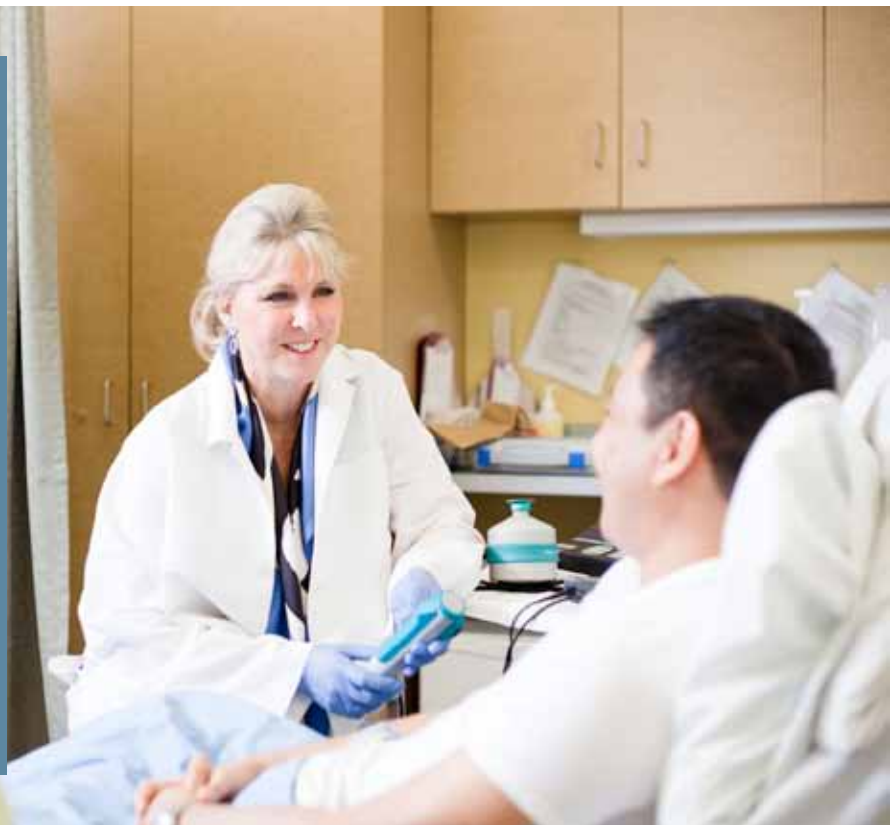
help researchers?

"The biggest impact to my research over the past year has been the ability to get an International Collaboration grant to bring in two researchers, one from Amsterdam and one from Miami. It's been an amazing opportunity to work side by side on something we are all passionate about but come from different perspectives. This opportunity has also opened up further relationship building activities: it's one thing to discuss related work on skype, but seeing the work in other centres within their own contextual setting makes a huge difference."

- Dr. Bonita Sawatzky

"ICORD is one of the rare opportunities for a clinical health care professional (clinician) to feel supported and encouraged in research endeavours. The opportunity to talk in the hall and combine ideas is also a privilege."

- Dr. Stacy Elliott



"ICORD is a unique multi-disciplinary environment that truly brings myself and my trainees in close proximity to preeminent world-class neuroscientists, clinicians, surgeons, statisticians, rehabilitation reserachers, human kinetics reserachers and others. Working in ICORD is THE key factor that enables me to attract top grad students, staff and postdocs to my lab and that allows me to obtain funding for the world-class equipment with which we work and for the studies we perform. I am proud of the state-of-the art research that we perform in a range of injury prevention and neurotrauma and I gratefully acknowledge the key role that the ICORD environment, facilities and people play in our success."

- Dr. Peter Cripton

program highlights

Connecting researchers with the community

Resource Centre



With funds raised at the *Spinal Chord Galas* in 2010 and 2011, ICORD established a **Community Resource Centre** in the Blusson Spinal Cord Centre (BSCC). The goal of the Community Resource Centre is to connect ICORD researchers and members of the community. Printed material, social media and virtual discussions based on easy-to-understand summaries of recent advances showcase current SCI research and connect members of the community to existing SCI services and information.

Since opening in 2011, the Resource Centre has launched a blog (see www.icord.org), developed a Facebook page and started a Twitter feed. In

addition, Resource Centre staff organized a well-attended community showcase with participation from community partners, including Spinal Cord Injury British Columbia (formerly the BC Paraplegic Association), the Tetra Society, 9Lives Adventures and ICORD's Trainee Committee, and two Lunch-and-Learn workshops at GF Strong Rehabilitation Centre (one for patients and one for staff).

The Resource Centre is staffed primarily by volunteers from 10 a.m. to 2 p.m. daily in the BSCC atrium, with a paid part-time Coordinator (a UBC Work-Study Student), and is overseen by ICORD's Communications and Administration Manager. Volunteers provide information to ICORD's visitors about SCI research and services provided by various community partners. They also assist with way-finding and provide a friendly welcome to visitors to the BSCC, many of whom come to the building for appointments with the VGH Spine Clinic on the second floor.

Café Scientifique

ICORD graduate students Leanne Ramer and Jacqueline Cragg received a grant from the Canadian



Institutes of Health Research to present two **Café Scientifique** evenings at the BSCC. The Café Scientifique program is a federally-funded initiative to provide insight into health-related issues of popular interest to the general public, and in turn provoke questions and provide answers. The events are free of charge and open to everyone. The first Café Scientifique event, *Spinal cord injury research: it's not rocket science, it's harder* was held on the evening of January 19, 2012. More than 90 guests attended in person, and the webcast attracted viewers around the world. ICORD researchers Drs. Brian Kwon, John Steeves, Andrei Krassioukov and Bonita Sawatzky spoke about how

discoveries in the laboratory translate into treatments that affect lives today, as well as the inherent challenges in that process. The event was supported by CIHR • Firefly Fine Wines and Ales • The Lazy Gourmet • Lonsdale Event Rentals

Shared research support staff

In the past year, ICORD hired three full-time and one half-time staff members to directly support researchers: a research assistant/technician to assist with discovery science projects; an engineering technician to assist with rehabilitation projects; a clinical research coordinator based at GF Strong to assist with clinical research projects, and a half-time Research Development Facilitator to assist with major applications for research funding. These shared staff were available to support all ICORD Researchers. Funding for these important new positions was provided by the Rick Hansen Foundation.

Yuan Jiang was hired in April, 2011 as a shared **Discovery Science research assistant**. He assists in research activities for studying regeneration and functional recovery after spinal cord injury in rodent models. His work involves assisting with surgeries, post-operative monitoring and care; performing behavioural testing, cutting and analyzing tissue. Yuan has provided research support to ten different ICORD PIs and their trainees during the past year.

Jeswin Jeyasurya came to ICORD in July 2011 as our shared **Engineering Technician** to support clinical rehabilitation research activities. His position involves overseeing the acquisition, maintenance, and appropriate use of experimental and clinical equipment of the Rehabilitation Research group. Jeswin also helps design and build novel devices and research equipment.

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Foundation



Amber Backwell also started in July, 2011 in her role as **SCI Rehabilitation Research Coordinator**. Based at GF Strong, her job is to coordinate and facilitate the research activities of ICORD rehabilitation researchers. Some of her duties include developing and maintaining a patient database for potential research subject recruitment, tracking all research occurring at GF Strong, assisting with grant applications, performing literature searches, recruiting subjects for research studies and obtaining informed consent and various approvals, coordinating data collection and assisting with preparation of data for publication.

Jocelyn Tomkinson joined both ICORD and the Rick Hansen Institute in November, 2011 as a half-time **Research Development Facilitator** for both organizations. Her goal is to support investigators and trainees in developing research projects and matching them with funding opportunities. The emphasis behind her position is to support funding opportunities that can benefit both ICORD and RHI, such as interdisciplinary partnerships or large team grants. Between November 2011 and March 2012, Jocelyn worked with six ICORD PIs to develop or assist with 16 funding applications, and prepared four applications for ICORD leadership for internal UBC awards and competitions. Jocelyn is proud to have supported six successfully funded applications during this period, and developed a detailed list of funders, competitions and deadlines for matchmaking with the work of ICORD PIs.



Yuan Jiang



Jeswin Jeyasurya



Amber Backwell



Jocelyn Tomkinson

Seminar series

In 2011, ICORD launched a new seminar series, with monthly talks on SCI-related topics by invited speakers from local, national and international institutions. These stimulating seminars were well-attended by ICORD researchers, staff and trainees across all disciplines, sparking new ideas for research directions and potential future collaborations. Funding for this program was generously provided by the Rick Hansen Institute.

Visiting speakers included:

Dr. Richard K. Shields

Professor & Chair, Physical Therapy & Rehabilitation Science, University of Iowa

Capitalizing on tissue plasticity to enhance health in humans with SCI.

Dr. Catherine Pallen

Professor, Division of Hematology and Oncology, Department of Pediatrics, UBC

Multiple roles of protein tyrosine phosphatase alpha in oligodendrocyte development and myelination.

Dr. Cheryl Wellington

Associate Professor, Pathology and Laboratory Medicine, UBC

Apolipoprotein E in Alzheimer's Disease and Traumatic Brain Injury.

Dr. E. Paul Zehr

Professor, Dept of Neuroscience, Div of Medical Sciences, University of Victoria

The quadrupedal nature of human walking: implications for locomotor rehabilitation.

Dr. Samit Chakrabarty

Research Scientist, Sophie Davies Medical School, City College of New York

Promoting motor recovery using FES and corticospinal tract stimulation.

Dr. Karim Fouad

Professor, Rehabilitation Medicine, University of Alberta

Plasticity following spinal cord injury: the good, the bad and the ugly.

Dr. Laurent Bouyer

Professeur Agrégé, Département de Réadaptation, Université Laval.

Providing movement errors to trigger adaptive changes in the neural control of walking: potential for rehabilitation after spinal cord injury.

Dr. Sonja deGroot

Senior Researcher, Reade Centre for Rehabilitation and Rheumatology, Amsterdam

Changes in physical capacity, activities and quality of life during and up to 5 years after SCI rehabilitation.

Dr. Gregory Schultz

Professor, Obstetrics & Gynecology, Institute for Wound Research, University of Florida

Autonomic changes after SCI and possible contributions to secondary tissue damage: Pilot data for a neuroprotective strategy

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International initiatives

With funds provided by the Rick Hansen Institute, ICORD was able to launch two new international initiatives in 2011: the Distinguished Visiting Scholar program and VISIT (Visit ICORD on a Scholarship for International Trainees). Both of these projects provided funding for international scholars to come to Vancouver and collaborate with ICORD researchers on SCI-related projects.

VISIT Scholar | Dr. Christopher West Postdoctoral Research Fellow, Krassioukov Lab

The VISIT program has provided Dr. West, a post-doctoral fellow who had previously studied SCI in humans, the opportunity to learn advanced skills in pre-clinical science. This new training led to Dr. West's pilot analysis into the effect of exercise on cardiovascular function in rodent models of SCI.

Based on the pilot data collected during his time as an ICORD International Awardee, he was able to submit and receive his own two-year Postdoctoral Fellowship from the Craig Neilsen Foundation. This fellowship will allow him to investigate the mechanisms of how exercise improves cardiovascular function in SCI. The same pilot data was also instrumental in his supervisor receiving a \$1.9 million CIHR team grant (see page 17). "On a personal level, this award has allowed me to receive world class mentorship at ICORD, under the supervision of Dr Krassioukov," said Dr. West. "Evidence of this successful mentorship can be seen in the 3 manuscripts that we have co-authored during my first year at ICORD."

Distinguished Visiting Scholars | Dr. Rachel Cowan Post-Doctoral Associate, Miami Project to Cure Paralysis, University of Miami & **Dr. Sonja de Groot** Senior Researcher, Reade Centre for Rehabilitation & Rheumatology, Amsterdam Drs. Cowan and de Groot travelled from Miami and Amsterdam, respectively, to collaborate with Dr. Bonnie Sawatzky on a project to identify the smallest change in manual wheelchair propulsion power output which is clinically meaningful and to determine the smallest change in propulsion kinetics and physiological cost which can be detected in people with SCI. Together, these data will allow researchers to design appropriately powered research protocols to determine what interventions meaningfully decrease or increase the stress of manual wheelchair propulsion. Propulsion power output is determined by performing a drag test on a treadmill, propulsion kinetics by using a SmartWheel, and physiological cost by measuring oxygen uptake. Dr. Sawatzky and her visiting colleagues also began to work on a collaborative systematic literature review exploring all the methods of propulsion measurement, in order to identify all the protocols that are used in the field and then try to create a consensus of what the standards should be so that more of what is published can actually be compared from one study to another. "Overall this grant that we received from ICORD has launched a whole new network that I believe will last as well as make an impact to the field of wheelchair research in SCI," said Dr. Sawatzky.

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Distinguished Visiting Scholar | Dr. Christian Puttlitz Monfort Professor & Associate Professor, Mechanical Engineering, Clinical Sciences & School of Biomedical Engineering, Colorado State University Dr. Puttlitz is a highly accomplished biomechanics researcher with extensive experience and productivity in the areas of spinal column biomechanics and in the viscoelastic characterization of soft tissues. He visited ICORD to collaborate with Dr. Peter Crompton on the use of Dr. Puttlitz's Comprehensive Viscoelastic Characterization (CVC) methods in the characterization of fresh ex vivo and in vivo spinal cord specimens. The spinal cord is a highly viscoelastic, very soft and highly

non-linear structure that experiences large impulses of force during traumatic injury. The visiting scholar award allowed Drs. Crompton and Puttlitz to assemble both pilot data and a publishable data set to allow them to write a journal article on this topic. This data and the journal article will support their future grant applications and allow them to begin a collaboration in this area. The results of this work are expected to influence the design of preventive devices and the understanding and advances in clinical treatment for SCI.



Dr. Puttlitz (right) works with ICORD researchers Jae Lee and Dr. Femke Streijger



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Trainee Travel awards

Funding for ICORD's Trainee Travel Award was made available by the generous support of the Rick Hansen Institute. ICORD Travel Awards are designed to support travel costs to conferences, meetings, courses, or workshops for ICORD trainees and staff. Congratulations to all the successful award recipients in the April and October 2011 competitions:

April 1, 2011 award winners:

Peggy Assinck
Jacquelyn Cragg
Mark Crawford
Antoinette Domingo
Greg Duncan
Ed Giesbrecht
Diana Hunter
Jessica Inskip
Claire Jones
Dorothy Kuk
Megan MacGillivray
Angela Melnyk
Heather Murray
Michelle Ng
Jason Plemel
Leanne Ramer
Rianne Ravensbergen
Brodie Sakakibara
Peter van Stolk
Shirley Wong
Jeanie Zabukovec
Jose Zariffa

October 1, 2011 award winners:

Trevor Barss
Krista Best
Katie Dragert
Brett Hilton
Azadeh Hosseinitabatabaei
Taryn Klarner
Jie Liu
Qian Qian Liu
Samantha Lloyd-Burton
Tao Meng
Nazanin Roshan Moniri
Robyn Newell
Melissa Pak
Audrey Petit
Yun Zhang

Recognition for stellar staff

With funds raised at the *Spinal Chord* Galas in 2010 and 2011, ICORD established the *Spinal Chord Awards* for Excellence in Research and Service to acknowledge and celebrate the outstanding contributions of ICORD research and clerical staff. Recipients were nominated by staff and ICORD researchers, and were adjudicated by an awards committee.

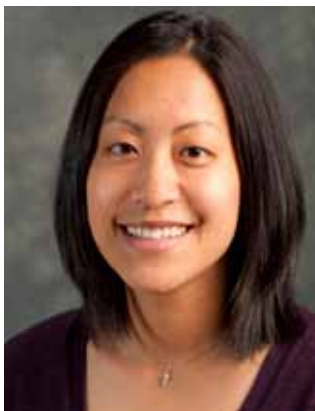
In 2011-12, the following individuals received \$250 awards:



Clarrie Lam, Manager, Tetzlaff Lab, received an award for her patience and skill at teaching new techniques to lab members, for directing the work of volunteers, students and technicians, and for her efficiency in lab management, mastery of multitasking and excellent interpersonal abilities.



Peter van Stolk, Research Assistant/Technician, Krassioukov and Ramer Labs, was recognized for the excellent quality of his lab work, his foresight and enthusiastic participation in research events (journal club, meetings, safety committee), and his supportive and collegial attitude in the lab.



Melissa Pak, Research Coordinator, Krassioukov Lab, was nominated for her excellent contributions to a successful \$1.9 million Canadian Institutes of Health Research (CIHR) Team Grant in Cardiovascular Health for people with SCI, which was awarded to her supervisor.



Allan Aludino, Research Manager, Orthopaedics-Spine Research Group, was nominated by several spine surgeons and colleagues who noted his diligence, excellent organizational skills and calm demeanor under pressure.



Mario Cruz, Manager, Ramer Lab, was nominated for his unwavering positive attitude, efficiency, accuracy and enthusiasm for his work.

trainee highlights

Mark Crawford, Masters student in Dr. Matt Ramer's lab and ICORD Trainee committee communications rep, reports on trainee highlights from 2011-12:

The past year for the ICORD Trainee Committee (ITC) was very busy and exciting. The committee kicked-off the academic year with a fun-filled Orientation Social, bringing together trainees from many different labs throughout ICORD to test our skills at wheelchair ramp racing and scavenger hunting in the building. ITC members regularly volunteered around the Blusson Spinal Cord Centre, facilitating tours for visiting dignitaries, and providing refreshments and conversation during the Vancouver Cantata Singers' spring concert held in the Atrium. Trainees also facilitated the first CIHR Café Scientifique evening in January. Throughout the year, the ITC continued to organize monthly ICORD-wide trainee seminars, giving trainees from all disciplines a chance to see and hear about research going on in many different labs within ICORD.

ICORD Trainees were also very literally active this year! A group of trainees represented ICORD at the annual BC Wheelchair Basketball Association's Hoopfest, to raise money for BC wheelchair basketball; the team came 5th out of 8 teams! This year also saw the inception of the ICORD Running Group (led by trainees), and an ICORD Trainee Ultimate Frisbee team (Team Xtreme!)

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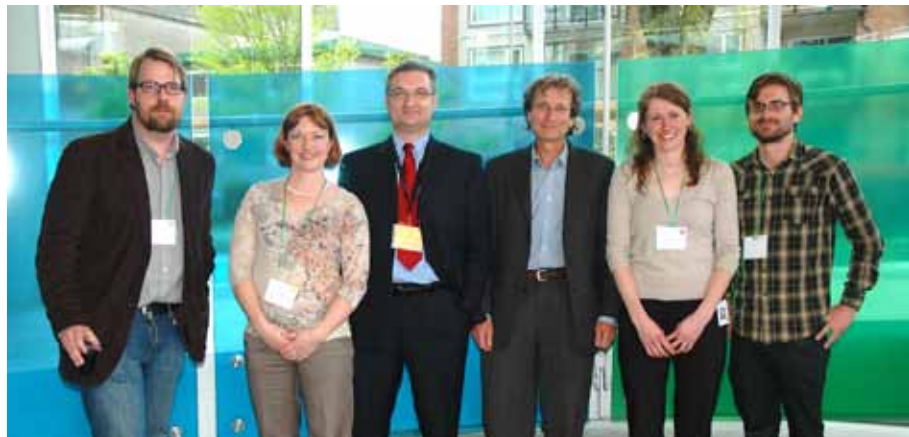


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The inaugural **ICORD Trainee Research Day** took place on May 6, 2011. Organized by trainees, this meeting was initiated by Dr. Tania Lam (Associate Director of Education and Training), who proposed that ICORD trainees have the opportunity to host visiting guest speakers. Through discussions with Dr. Lam, the Trainee Committee drafted a budget for a trainee-centered research day. The budget was approved by the ICORD

Executive, and the Trainee Committee worked throughout the 2010-11 academic year to organize an event that highlighted the work of ICORD trainees. The principal organizers were John Kramer (Steeves Lab), Jessica Inskip (Claydon Lab), Jason Plemel (Tetzlaff Lab), Leanne Ramer (Krassioukov Lab), and Adina Houldin (Lam Lab); however, at least 20 other trainees participated in meeting planning and volunteered on the day.

The result, by all accounts, was an excellent meeting. Seventy people attended (46 trainees, 11 staff members, and 13 faculty); the majority of these (55) worked in the BSCC, but members of ICORD from SFU (5), UBC Point Grey



L-R: J. Plemel, L. Ramer, M. Popovic, M. Tuszynski, J. Inskip, K. Kramer

(4), and Jack Bell (6) also attended. Participants enjoyed excellent talks by two prestigious plenary speakers, Dr. Mark Tuszynski (University of San Diego) and Dr. Milos Popovic (University of Toronto). Importantly, 22 trainees gave short (5 minute) presentations highlighting their research. Trainee talks were judged the by Drs. Tuszynski and Popovic, along with Drs. Victoria Claydon, Wolfram Tetzlaff, and Tom Oxland. The Trainee Committee was very impressed with the quality of the presentations; award winners were:

Masters-level category

1st: Angela Melnyk, Oxland Lab
2nd: Master's: Heather Murray, Oxland Lab
Honourable mention: Greg Duncan, Tetzlaff Lab

PhD/Postdoc-level category

1st: Peggy Assinck, Tetzlaff Lab
2nd: Dr. Femke Streijger, Tetzlaff Lab

As a final component of the Meeting, two teams of ICORD trainees debated the question of obtaining ethical consent for entry into a clinical trial testing cell transplantation in acute SCI. The debate was initiated and moderated by Jacquelyn Cragg (Ramer Lab). The debate led into a lively reception in the atrium (including door prizes provided by our sponsors, Original Joes, Café d'Artigiano, the Vancouver Cantata Singers, and Duke's on Broadway). The meeting was supported by the Rick Hansen Institute. Jeanie Zabukovec (Lam Lab) won an award for the best time on the wheelchair obstacle course, while Megan MacGillivray (Sawatzky Lab) had the best time in the wheelchair race up the ramp. The Trainee Committee is thrilled with the success of the meeting and the positive feedback, and hopes that this event will set the stage for ICORD trainee-organized endeavours for years to come.

★ **TRAINEE AWARD WINNERS**

ICORD Trainees were also very successful in **award competitions** this past year. Congratulatory to the following award winners (their supervisors are shown in brackets):

Peggy Assinck (Tetzlaff): CIHR Transplant Training Award; UBC Paetzold Doctoral Award

Ryan Brodie (Hundza): NSERC Scholarship

Samantha Lloyd Burton (Roskams): MS Society of Canada Postdoctoral Fellowship

Matthew Carr (Ghahary): Frederick Banting & Charles Best Canada Graduate Scholarship Masters Award (CIHR); CIHR SRTC Scholarship

Athena Chou (Roskams): Frederick Banting & Charles Best Canada Graduate Scholarship Doctoral Award (CIHR); Alzheimer Society of Canada Doctoral Studentship

Jacquelyn Cragg (Borisoff): Alexander Graham Bell Canada Graduate Scholarship (NSERC); PhD Studentship, MS Society of Canada; Killam Doctoral Award

Terry-Ann Curran (Ghahary): Worksafe BC Research Secretariat Training award; CIHR Transplant Training Award

Greg Duncan (Tetzlaff): PhD Studentship, MS Society of Canada; CIHR Transplant Training Award

Mischa Harris (Warburton): CIHR Masters Award

Brett Hilton (Tetzlaff): CIHR Transplant Training Award

Jessica Inskip (Claydon): Frederick Banting & Charles Best Canada Graduate Scholarship Doctoral Award (CIHR)

Claire Jones (Crompton): Medtronic Spinal Research Award, Annual Scientific Meeting of the Australia Spine Society

Mark Lam (DeLongis): Meritorious award for research presented at the Society for Behavioral Medicine

Katie Lee (Forwell): Rehabilitation Graduate Scholarship (UBC Rehab Sciences)

Christie McShane (Roskams): Frederick Banting & Charles Best Canada Graduate Scholarship Doctoral Award (CIHR)

Aaron Phillips (Warburton): MITACs Accelerate Internship

Jane Wacker (Townson): Winner, Canadian Association of PM&R Medical Student Essay Contest

Shirley Wong (Krassioukov/Warburton): Frederick Banting & Charles Best Canada Graduate Scholarship Doctoral Award (CIHR)

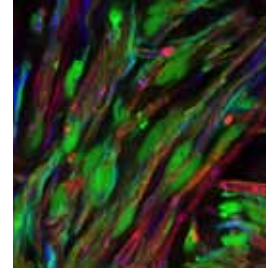
SPOTLIGHT ON TRAINEE RESEARCH PROJECTS



Peggy Assinck | PhD Candidate, Tetzlaff Lab

The motor, sensory and autonomic dysfunctions associated with SCI result primarily from the loss of projecting axons (which carry electrical signals) and the loss of glial cells (that insulate axons with myelin to maintain the speed of those electrical signals). Replacing those lost cells is one potential strategy to treat SCI. My research aims to determine the potential benefits of treating SCI by transplanting insulating myelinating glial cells known as Schwann cells into the injured rat spinal cord. These particular Schwann cells (known as SKP-SCs) are of great interest because they can be generated from cells found in adult

human skin (SKPs) rather than being harvested from peripheral nerve—the traditional source of Schwann cells. SKP-SCs would be advantageous for use in clinical settings because they can be transplanted into the same person who donated the skin to produce the cells; eliminating the need for harmful immunosuppressive drugs normally required to prevent cell rejection. SKP-SCs have been shown to myelinate and enhance the growth of axons after sub-acute and chronic SCI. My research involves examining the histological and behavioural outcome of transplanting SKP-SCs in a rodent model of SCI to further establish their potential for clinical translation.



Malihe Pourmasjedi | PhD Candidate, Ghahary Lab



When skin experiences trauma, thermal injury, or surgical incisions, it frequently develops raised, firm, itchy, bulky, and inelastic scars (known as fibrosis). This is caused by excessive production of extracellular matrix (ECM) or abnormalities in ECM remodelling. They can limit the mobility of joints, are potentially devastating, and no satisfactory treatments are presently available.

Our goal is to develop a new generation of anti-scarring wound care products, including wound dressing for open wounds, and strips for closed wounds.

A safe, recently discovered anti-scarring molecule will be encapsulated in nanofibres to produce slow-release drug delivery systems; the research will evaluate the effect of these drug delivery systems on functionality, ECM production, and the viability of skin cells. These nanofibres will be used to develop biofunctional wound dressing and strips, and animal models will be used to evaluate their efficacy in reducing or preventing scarring.

Through the controlled release of the anti-scarring drug, these new products will improve healing outcomes and quality of life in the millions of patients who develop scarring after burn injuries, surgeries, or non-healing wounds (such as pressure ulcers) that are often a secondary complication of SCI. This novel anti-scarring system has the potential to ease the pain and difficulties associated with wound contractures that affect physical activity; improve or prevent disfiguring conditions in patients, which are otherwise likely to have long-term psychological implications; reduce the cost of long-term treatment, rehabilitation, and post-reconstructive surgeries; and provide valuable knowledge for the fields of drug delivery and wound healing, while producing results and information that can be easily translated to the clinic.

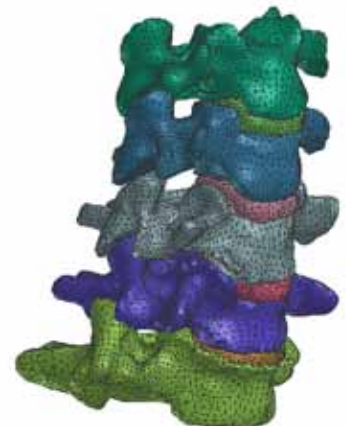
Hannah Gustafson | PhD Candidate, Oxland Lab



When studying injury to the cervical spine, computational models can be a valuable tool for predicting the locations or types of failure. However, before a model can be used to make predictions, it must be compared to experimental data to ensure the response of the modelled spine is realistic. This process is called *validation of the model*. The goal of this work is to perform experiments and derive data for validating and improving computational modelling of the cervical spine under head-first loading, such as might occur in a rollover car accident, or in a head-first landing over the handlebars of a mountain bike.

The first step for improving the modelling of head-first loading is to investigate the response of the bone in experiments, particularly under dynamic loading conditions. The research uses digital image correlation

to measure the deformation on the entire surface of the cervical vertebrae, during compressive loading in the laboratory. This deformation on the surface of the bones can be compared to computational models, which helps improve the models. Better computational models of the spine will assist in designing environments and protective devices for reducing cervical spine injuries.



research highlights

Dr. Jaimie Borisoff awarded Canada Research Chair

ICORD PI Dr Jaimie Borisoff was named a Canada Research Chair in November, 2011, for his work in Rehabilitation Engineering Design at BCIT. Started in 2000 by the Federal Government, the awards



are given to exceptional emerging researchers, acknowledged by their peers as having the potential to lead in their field. The award of \$100,000 annually for five years will support Dr Borisoff's research into the development of assistive technology for people with disabilities.

Dr Borisoff and his team focus on technology that allows for inclusiveness and access for anyone with mobility impairments. Borisoff created the Elevation™ wheelchair, which allows the user to adjust the chair and backrest in real-time throughout the day. His current projects include working with Occupational Therapists at ICORD to implement a wheelchair activity monitor that will log how people use the Elevation wheelchair throughout the day in order to make any refinements and to demonstrate changes to the user's quality of life. His team is also focusing on improving home access for people with mobility challenges

and are creating a prototype of a new lift.

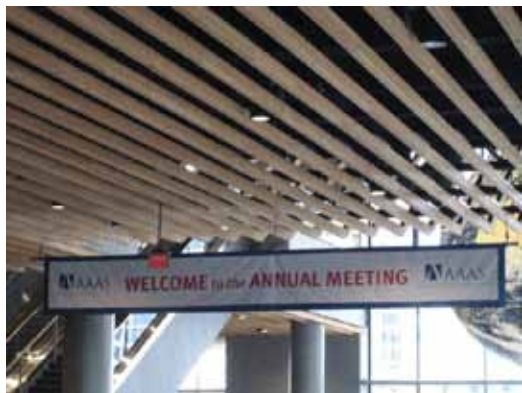
As a Canada Research Chair, Dr. Borisoff will maintain two labs, one at ICORD, and a new lab at BCIT in Rehabilitation Engineering Design. Dr. Borisoff and his team will draw on a wide range of experts that include human factor engineers, product developers, technicians, neuroscientists, and occupational therapists to develop innovative rehabilitation tools.

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ICORD @ AAAS

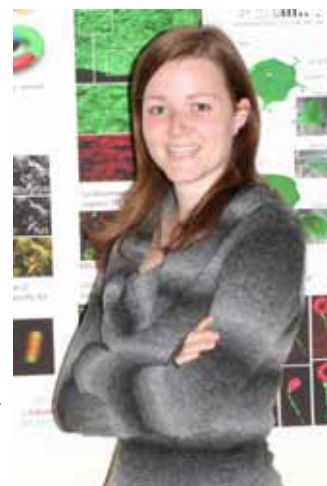
ICORD researchers joined with other eminent faculty from within Canada and the US to present **Curing Spinal Cord Injury: The Need for Global Collaboration** at the American Association for the Advancement of Science Annual Meeting in Vancouver. This meeting, held in February, 2012, brought together approximately 8,000 scientists from around the globe.



The symposium addressed the need for global collaboration to further improve the condition of people living with SCI and eventually develop cures. Symposium Co-organizers Dr. Thomas Oxland, ICORD Interim Director, and Dr. Michael Fehlings from the University of Toronto assembled a panel of experts to speak at the symposium. Mr. Rick Hansen started the symposium by introducing his vision for a cure for spinal cord injury. Dr. Charles Tator (University of Toronto) spoke about the critical role of basic science research to solve these complex problems, and Dr. Wolfram Tetzlaff (ICORD) discussed the potential for stem cells in the treatment of SCI. Dr. Marcel Dvorak (ICORD) addressed the challenges in the clinical

application of basic science discoveries and presented an exciting new spinal cord injury registry that promises to be a key research platform for the future. Dr. Judy Illes (UBC Centre for Applied Ethics) discussed the ethic issues presented by the application of novel therapies in the field, and Dr. Naomi

Kleitman (US National Institutes of Health) discussed ethical issues amidst the presentation of possible solutions for global collaboration. A number of ICORD trainees presented posters at the Student Poster Competition of the AAAS Annual Meeting. Congratulations to Diana Hunter (pictured, right), PhD student in Dr. Matt Ramer's research group. Her entry, *A Very Large Organelle in Sympathetic Neurons*, was the co-winning poster in the Cellular and Molecular Biology category. Diana's achievement will be recognized in a forthcoming issue of the prestigious journal, *Science*.



2012 Annual Research Meeting

ICORD's Annual Research Meeting for 2012 took place at the Blusson Spinal Cord Centre on February 21st and 22nd, immediately following the AAAS meeting. The two-day event included plenary talks by world-renowned SCI experts Drs. Charles Tator, Michael Fehlings and Naomi Kleitman, and was attended by more than a hundred ICORD faculty, staff

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and trainees. ICORD researchers Drs. Darren Warburton, Aziz Ghahary, Lynn Stothers, Tim O'Connor, John Street, Jane Roskams, and Sue Forwell gave short talks on their research.

Undergraduate, graduate and postdoctoral trainees presented their research at a lively poster session on February 21st, and competed for one of three travel and research prizes. Poster awards are an important and valued part of ICORD's Annual Research Meetings. Through the support of generous donors, the poster awards are presented annually to ICORD trainees. Congratulations to the 2012 poster winners:

The Gordon Hiebert Award for the best poster presented by an ICORD trainee at the Postdoctoral Fellow level

Winner: Dr. Reza Jalili

Honourable Mention: Dr. Chris West

The Aaron Moser Award for the best poster presented by an ICORD trainee at the Doctoral Student level

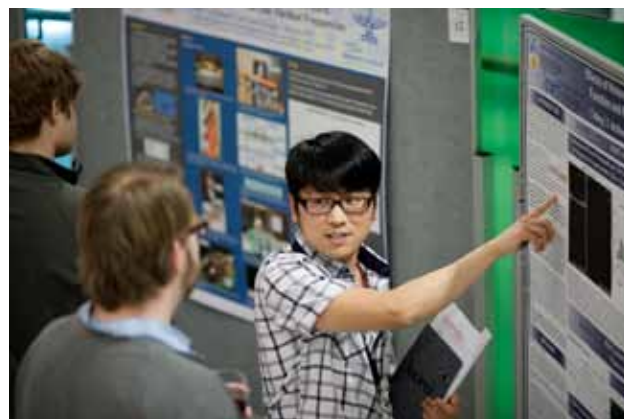
Winner: Robyn Newell

Honourable Mention: Peggy Assinck

The ICORD Award for the best poster presented by an ICORD trainee at the Masters Student level:

Winner: Brett Hilton

Honourable Mention: Mark Crawford



The 2013 Annual Research Meeting is scheduled for March 5 and 6th. Registration will open in December, 2012.

Improving cardiovascular health for people with SCI

Cardiovascular disease is the main cause of death in people with SCI, who develop the chronic disease at younger ages and greater rates than the able-bodied population. This is a surprising fact—both for people who suffer a spinal cord injury, as well as their health caregivers, but a \$1.9 million team research grant awarded to ICORD PI Dr. Andrei Krassioukov in the fall of 2011 promises to increase understanding and create healthier outcomes in this area. This Canadian Institutes of Health Research grant funds a research network of Canadian Scientists. The team research project is entitled *Improving cardiovascular health for Canadians living with spinal cord injury: Effects of exercise and targeted education*. The Canada-wide team, which includes ICORD PIs Drs. Janice Eng, Tania Lam and Matthew Ramer, will study the cardiovascular risks and effects of exercise training in people with SCI, as they respond differently to exercise. Another aspect of the study will involve educating health care providers on specific cardiovascular problems associated with SCI to help reduce the financial burden of care, and improve treatment, for people with SCI. The Honourable Leona Aglukkaq, Federal Health Minister, was at the Blusson Spinal Cord Centre on Friday February 24th to announce the CIHR Team Grant. The Minister and Dr. Krassioukov were joined at the announcement by Dr. Rob McMaster, Executive Director, VCHRI, Dr. Howard Feldman, Associate Dean of Research for the UBC Faculty of Medicine, and Ms. Marni Abbott-Peter, a three-time Paralympic gold medalist in wheelchair basketball.

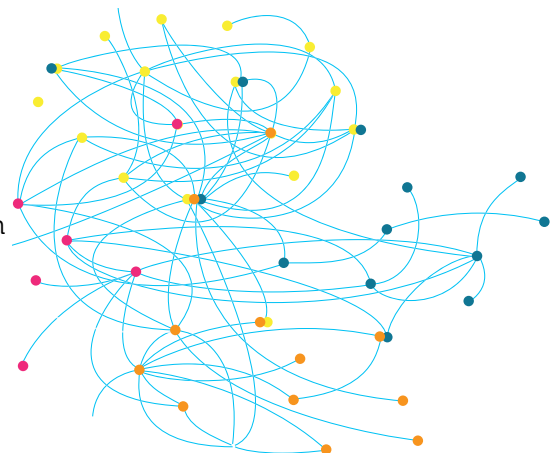


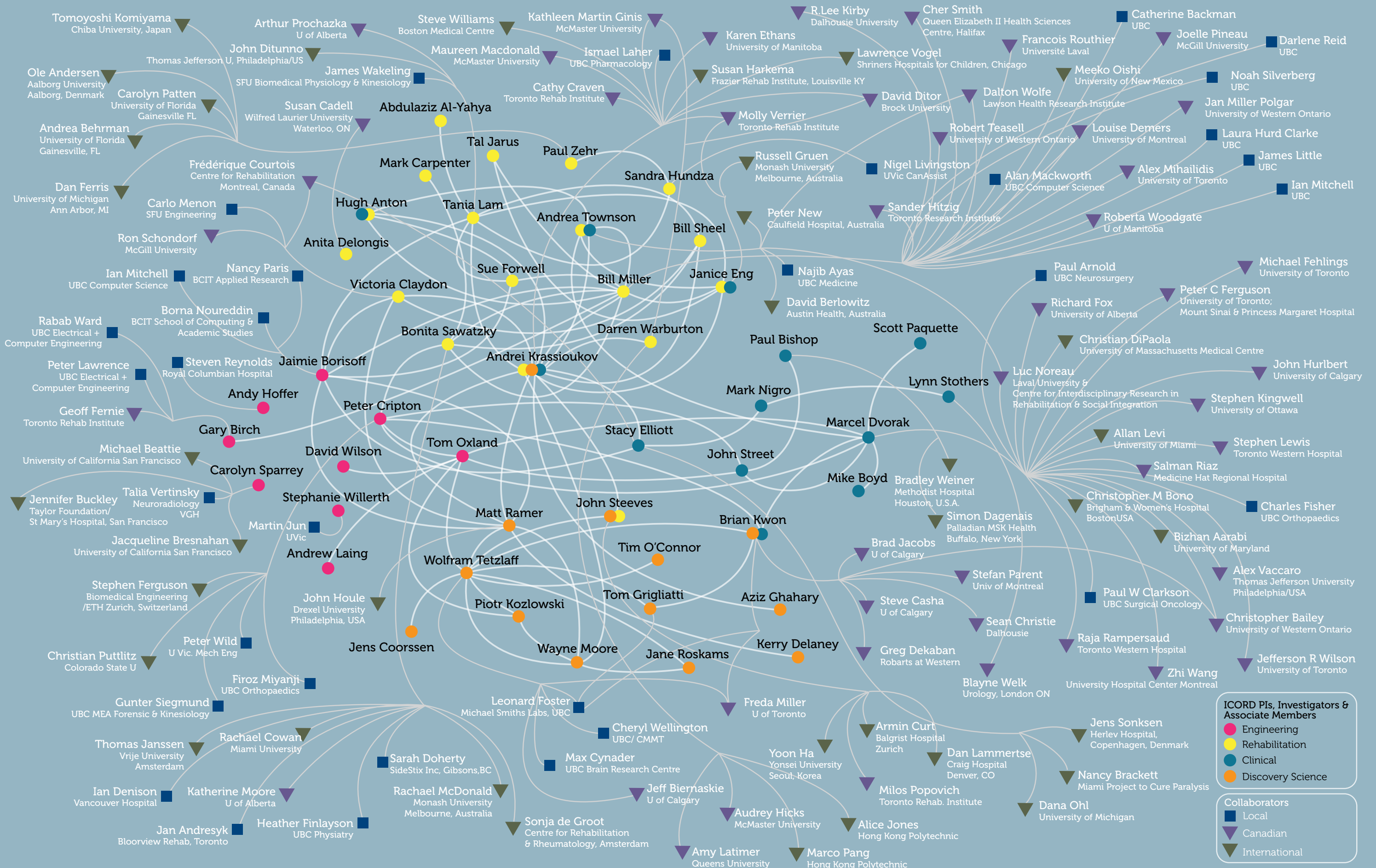
L-R: Dr. Krassioukov, Dr. McMaster, Ms. Abbott-Peter, Dr. Feldman, Minister Aglukkaq

Interconnectedness inspires new research

ICORD has always been an interdisciplinary research group, but before the completion of the Blusson Spinal Cord Centre, our researchers were based in labs spread out around university campuses. So while researchers were all looking at different solutions for spinal cord injury, it was somewhat challenging for them to work together on projects. And while not all of our Principal Investigators and Investigators are currently based at the BSCC, its existence and the programs that have been made possible because of it, have led to new working relationships and encouraged an interconnectedness that is fostering new approaches to SCI research.

The illustration on the following page shows how ICORD researchers are working together, as well as their SCI-related collaborations within local institutions (UBC, SFU, U.Vic, BCIT), other Canadian institutions. This interconnectedness is inspiring promising new research directions in the development and translation of more effective strategies to promote prevention, functional recovery, and improved quality of life after SCI.





icord's researchers

Three new Principal Investigators have joined ICORD within the past year.

Dr. Aziz Ghahary, a world-renowned leader in the field of wound healing, joined ICORD and moved with his research team into the Blusson Spinal Cord Centre in the summer of 2011. Dr. Ghahary is a Professor in the UBC Department of Surgery and Director of the BC Professional Firefighter's Burn and Wound Healing Research Group at VCHRI. He has an extensive publication record and has presented



his findings at more than 170 different conferences, seminars and scientific meetings all over the world. He and his team have developed and used a non-rejectable skin substitute as wound coverage in an in vivo model, and are investigating the use of a liquid, non-rejectable skin composite to treat non-healing wounds such as pressure ulcers and diabetic wounds. Dr. Ghahary received his Ph.D in Medical Physiology from the University of Manitoba in 1988, and after 2 years postdoctoral training with Dr. Henry Friesen (former president of CIHR), he accepted a faculty position in the Department of Surgery at the University of Alberta in 1990. He moved to Vancouver in 2005 to head up the Burn and Wound Healing Group and currently supervises seven Ph.D students, four Masters students, two post-doctoral fellows, a Research Associate and two visiting scientists.



Dr. John Street joined ICORD in early 2012. He is an Assistant Professor within the Department of Orthopedics at UBC, in addition to being co-Medical Director of the Complex Spine Program at VGH, Clinical Lead for the Integrated Ambulatory Spine Program and coordinator of the undergraduate and postgraduate education program. Dr. Street's research interests include minimizing and accurately recording adverse events in the spinal cord injured population. His clinical practice involves the surgical and non-surgical management of adult patients with spinal disorders, across the entire breadth of degenerative and traumatic conditions of the spine. He is specifically interested in spinal trauma, complex degenerative lumbar spine pathologies and quality of life outcomes of patients with spinal disability.



New ICORD PI **Dr. Lynn Stothers** is the Director of Research for the Bladder Care Centre at UBC and a member of the active staff at VGH. Dr. Stothers is a Professor in the UBC Department of Urologic Sciences, with co-appointments to the Department of Healthcare and Epidemiology and the Department of Anesthesiology, Pharmacology & Therapeutics. In addition to her surgical and urological training, Dr. Stothers also holds a masters degree in epidemiology and has specialized training in neurology. She has received numerous awards for her work on near-infrared spectroscopy of the bladder, and has two patents pending. Bladder function is a major issue for many people living with SCI, and Dr. Stothers has conducted a number of research projects in this area.

ICORD also welcomed Drs. Andrew Laing, Jens Coorsen and Abdulaziz Al-Yahya as Associate Members. They collaborate with Drs. Tom Oxland, Wolfram Tetzlaff and Tania Lam, respectively.

ICORD'S PRINCIPAL INVESTIGATORS

Dr. Gary Birch

Executive Director, Neil Squire Society; Adjunct Professor, Electrical and Computer Engineering, UBC

- researches accessible technology & brain-computer interfaces

★ awarded *Queen Elizabeth II Diamond Jubilee Medal*, March 2012.

Dr. Paul Bishop

Research Professorship in Non-Operative Spine Care, ICORD; Clinical Associate Professor, Orthopaedics, UBC; Staff Physician, Outpatient Clinic, Combined Neurosurgical and Orthopaedic Spine Program, VGH

- researches biochemical causes and clinical management of acute spinal nerve root injury

Dr. Jaimie Borisoff

Canadian Research Chair, Rehabilitation Engineering Design, British Columbia Institute of Technology; Research Director, BCIT; Adjunct Professor, Occupational Science and Occupational Therapy, UBC

- researches improved accessibility & mobility for people with SCI

★ awarded CRC, Nov. 2011

Dr. Victoria Claydon

Assistant Professor, Biomedical Physiology and Kinesiology, SFU

- researches cardiovascular dysfunction after SCI & cardiovascular adaptation in high altitudes

Dr. Peter Cripton

Co-Director, UBC Orthopaedic and Injury Biomechanics Group; Associate Professor, Mechanical Engineering, UBC; Associate Member, Orthopaedics, UBC

- researches injury prevention and minimization

Dr. Marcel Dvorak

Head, Div. Spine, Orthopaedics, UBC; Cordula and Günter Paetzold Chair in Clinical Spinal Cord Injury Research and Associate Director of Clinical Research, ICORD; Scientific Director, Rick Hansen Institute; Medical Director, Combined Neurosurgical and Orthopaedic Spine Program, VGH; Co-Chair, Spine Trauma Study Group

- researches spine trauma, arthritis, and spine deformity.

Dr. Stacy Elliott

Clinical Professor, Psychiatry and Urologic Sciences, UBC; Medical Director, BC Centre for Sexual Medicine; Co-Director, Vancouver Sperm Retrieval Clinic; Medical Director, Men's Sexual Assessment and Rehabilitation Service, Prostate Centre Physician Consultant, GF Strong Sexual Health Rehabilitation Service

- researches community sexual health, outpatient sexual rehabilitation, and fertility following SCI

Dr. Janice Eng

Professor, Physical Therapy, UBC

- researches physical rehabilitation to improve recovery for people with SCI and stroke.

Dr. Susan Forwell

Associate Professor, Occupational Sciences and Occupational Therapy, UBC

- researches chronic neurological conditions and their impact on chosen occupations

Dr. Aziz Ghahary

Director, BC Professional Fire Fighters' Burn and Wound Healing Research Group; Professor, Div. of Plastic Surgery, Surgery, UBC; Associate Member, Dermatology and Skin Sciences, UBC; Active Staff Member, VGH

- researches biology of wound healing, including burns and other non-healing wounds

Dr. Tom Grigliatti

Professor, Life Sciences Institute, Zoology, UBC; Associate Member, Medical Genetics, UBC

- researches cell and developmental biology.

★ Peter Wall Distinguished Scholar, 2012

Dr. Andy Hoffer

Professor, Kinesiology, SFU; Associate Member, School of Engineering Science, SFU

- researches minimally invasive approach for pacing the diaphragm.

Dr. Sandra Hundza

Assistant Professor, Exercise Science, University of Victoria; Adjunct Professor, Island Medical Program, UVic

- researches neural control of human movement

Dr. Piotr Kozlowski

Associate Director, Magnetic Resonance Imaging Research Centre, UBC; Associate Professor, Radiology and Urologic Sciences, UBC; Associate Member, Physics and Astronomy, UBC; Research Scientist, Vancouver Prostate Centre

- uses MRI-based techniques to study SCI

Dr. Andrei Krassioukov

Professor, Physical Medicine and Rehabilitation, UBC; Associate Director, Rehabilitation Research, and Director, ICORD Autonomic Research Unit; Staff physician, Spinal Cord Program, GF Strong Rehabilitation Centre; Adjunct Professor, Physical Medicine and Rehabilitation, University of Western Ontario

- researches cardiovascular health; autonomic dysreflexia in SCI

Dr. Brian Kwon

Associate Professor, Orthopaedics, UBC; Attending Spine Surgeon, Vancouver Spine Program, VGH; Assoc. Scientific Director, Rick Hansen Institute; Operations Director, Vancouver Spine Research Program

- does bi-directional ("bench to bedside" and "bedside back to bench") translation
- ★ received VCH Award of Excellence & ABC Travelling Fellowship from Canadian Orthopaedic Assn.

Dr. Tania Lam

Associate Professor, Kinesiology, UBC

- researches neural control of human walking gait

Dr. William Miller

Professor, Occupational Science and Occupational Therapy, UBC; Joint Appointment, Rehabilitation Sciences, UBC

- researches wheelchair mobility; wheelchair skills

Dr. Wayne Moore

Clinical Professor, Pathology and Laboratory Medicine, UBC

- researches pathology of multiple sclerosis

Dr. Mark Nigro

Active Staff, VGH; Consultant Staff, Children's & Women's Health Centre of British Columbia, St. Paul's Hospital, GF Strong Centre, Pearson Hospital; Director, Provincial Organ Retrieval Program; Surgical Director of Renal Transplant, VGH; Co-Director, Vancouver Ejaculatory Dysfunction Clinic; Clinical Professor, Urologic Sciences, UBC

- researches infertility and urologic prosthetics

Dr. Thomas Oxland

Canada Research Chair, Spine Biomechanics; Professor and Associate Head of Research, Orthopaedic Engineering Research Division, Orthopaedics, UBC; Joint Appointment, Mechanical Engineering, UBC; Associate Member, Rehabilitation Sciences, UBC

- researches biomechanics of orthopaedic injury
- ★ inducted as a Fellow of the CAE, July 2011

Dr. Scott Paquette

Clinical Assistant Professor, Surgery, UBC; Active Staff, VGH

- researches surgical treatment of spinal pain and spasticity.

Dr. Matt Ramer

BC Neurotrauma Professor; Associate Professor, Zoology, UBC

- researches sensory neurons; signal processing

Dr. Bonita Sawatzky

Associate Professor, Orthopaedics, UBC

- researches mobility for people with SCI and related injuries

Dr. Carolyn Sparrey

Assistant Professor, Mechatronics System Engineering, Engineering Science, SFU

- researches biomechanics and biomaterials

Dr. John Steeves

Professor, ICORD, UBC; Chair, SCOPE

- researches arm and hand rehabilitation after SCI

★ Peter Wall Distinguished Scholar 2011

Dr. Lynn Stothers

Director of Research, Bladder Care Centre, UBC; Professor, Urologic Sciences, UBC; Active Staff, Vancouver General Hospital; Co-Appointments, Healthcare and Epidemiology, Anesthesiology, Pharmacology & Therapeutics, UBC

- researches bladder function in SCI

Dr. John Street

Assistant Professor, Orthopedics, UBC; co-Medical Director, Complex Spine Program, VGH; Clinical Lead, Integrated Ambulatory Spine Program

- researches adult spine disorders

Dr. Wolfram Tetzlaff

Rick Hansen Man In Motion Chair in Spinal Cord Research, ICORD; Professor, Zoology and Surgery, UBC

- researches neuroprotection & repair of the injured spinal cord

Darren Warburton

Chair, Strategic Initiatives Committee, CSEP Health & Fitness Program; Co-Director, Physical Activity Promotion and Chronic Disease Prevention Unit, UBC; Associate Professor, Kinesiology, UBC

- researches clinical exercise rehabilitation

Dr. Stephanie Willerth

Assistant Professor, Biomedical Engineering, UVic; Member, Centre for Advanced Materials & Related Technology










- researches tissue engineering; 3D biomaterial scaffolds; stem cells

Dr. E. Paul Zehr

Professor, Neuroscience, UVic; Chair, Michael Smith Foundation for Health Research

- researches neural control of movement

ICORD'S INVESTIGATORS

-  **Dr. Hugh Anton** | *Clinical Professor, Physical Medicine and Rehabilitation, UBC; Clinical Research Coordinator, GF Strong Rehabilitation Centre*
neurological and neuromuscular disorders
-  **Dr. Mark Carpenter** | *Assistant Professor, Kinesiology, UBC*
balance and falls
-  **Dr. Anita Delongis** | *Associate Professor, Psychology, UBC*
effects of stress on health
-  **Dr. Tal Jarus** | *Professor, Occupational Science and Occupational Therapy, UBC*
motor learning; relationship between occupational performance and health
-  **Dr. Tim O'Connor** | *Professor, Cellular and Physiological Sciences, UBC; Associate Member, Zoology, UBC*
neural development and regeneration.
-  **Dr. Jane Roskams** | *Professor, Zoology, UBC*
development and regeneration of the nervous system
-  **Dr. William Sheel** | *Associate Professor, Kinesiology, UBC*
exercise science
-  **Dr. Andrea Townson** | *Clinical Associate Professor and Head, Physical Medicine and Rehabilitation, UBC; Medical Site Lead, GF Strong Rehab Centre; Attending Physician, SCI Rehabilitation Program, GF Strong Rehab Centre*
high cervical SCI; ventilator dependency
-  **Dr. David Wilson** | *Associate Professor, Orthopaedics, UBC; Associate Member, Mechanical Engineering, UBC*
links between joint mechanics, clinical symptoms, and the success of treatment procedures

ICORD'S ASSOCIATE MEMBERS

-  **Dr. Abdulaziz Al-Yayha** | *Associate Professor, Pharmacology Department, School of Pharmacy, King Saud University*
oxidative stress; histopathological evaluations
-  **Dr. Mike Boyd** | *Clinical Associate Professor, Orthopaedic Surgery, UBC; Active Staff, VGH*
reconstruction of the injured spine
-  **Dr. Romeo Chua** | *Professor, Kinesiology, UBC*
effect of perceptions and sensations on goal-directed movement
-  **Dr. Jens Coorsen** | *Professor and Department Head, Molecular Physiology, University of Western Sydney; Head, U. Western Sydney Molecular Medicine Research Group; Adjunct Professor, Physiology and Pharmacology, University of Calgary*
proteomics and lipidomics
-  **Dr. Kerry Delaney** | *Chair and Professor, Biology, UVic*
physiology of cells
-  **Dr. Tim Inglis** | *Professor, Kinesiology, UBC*
human neurophysiology
-  **Dr. Andrew Laing** | *Assistant Professor, Kinesiology, University of Waterloo*
effect of age on biomechanics, human health, and injury prevention
-  **Dr. Michael Negraeff** | *Chair, Board of Directors, Pain BC; Clinical Associate Professor, Anesthesiology, Pharmacology & Therapeutics, UBC*
neuropathic pain and pain following SCI
-  **Dr. Rhonda Willms** | *Clinical Instructor, Physical Medicine and Rehabilitation, UBC*
Research interests?

For an in-depth profile of each ICORD researcher, see www.icord.org/our-researchers/



Seed grants

With support from the Rick Hansen Foundation, ICORD launched a grant competition to provide seed funding for novel research projects proposed by Principal Investigators and Investigators within ICORD. A total of \$200,000 was available to be awarded over competitions in August 2011 and February 2012. Grants were adjudicated based on alignment with ICORD's mission and research platform and the likelihood that successful proposals could lead to sustainable research programs.

Seed Grants awarded in September 2011:

Dr. Matt Ramer

Signals from noise: reflex variability as a diagnostic tool in SCI

Our actions are guided by our senses. This notion is probably best exemplified by walking, during which muscle stretch dictates how those same muscles flex—a greater muscle stretch produces a larger flexion. This stretch reflex can be induced by tapping on a tendon (the 'knee-jerk' reflex we are familiar with from visits to the doctor),

or, in more specialized tests, by giving a mild shock to a muscle nerve and electrically recording the resulting twitch. Even though the nerve cells involved are not affected directly by spinal cord injury (SCI), the stretch reflex is profoundly altered in individuals with SCI in a number of ways. For one, it is much larger than normal. It is also much less variable: in uninjured individuals but not in those with SCI, the size of the reflex varies a great deal from shock to shock even though shock intensity stays the same. The normal variability of the stretch reflex depends on moment-to-moment 'tuning' of the reflex by pathways descending from the brain (severed by SCI), and by other nearby nerve cells in the spinal cord (which themselves lose contact with the brain and may undergo changes in activity). Since the usual way to measure stretch reflexes is to average a number of responses, the information contained within reflex variability is lost. Variability data may provide a powerful way to reveal important information such as the extent of the injury, how it improves or deteriorates over time, or the effect of potential treatments. We will perform experiments that will allow us to understand how reflex variability relates to the functional outcome of SCI, both in pre-clinical studies using animals and in the clinic, where such an analysis will better track spontaneous changes over time and/or measure the effects of treatments.

Dr. Brian Kwon

Human SCI proteomics

The two overall objectives of this proposal are to increase our understanding of the pathophysiology of human SCI by conducting an extensive analysis

of cerebrospinal fluid (CSF) and blood derived from acute SCI patients; and establish a series of biomarkers of injury severity that can be used to accelerate the pace of clinical trials by correlating the levels of specific proteins within the CSF and serum with baseline neurologic impairment. While much scientific SCI research is done in rodent models, we know comparatively little about the biologic events that occur within the human spinal cord after injury. We conducted a clinical trial in which CSF and blood samples were collected from acute SCI patients. By measuring the concentrations of a variety of proteins related to neuronal damage, we provided the first description of important biological changes occurring within the

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first 3 to 5 days after human SCI. This analysis also revealed specific proteins within the CSF that could predict injury severity after neurologic recovery. In this proposed study, we will initiate the use of state-of-the-art technology in "proteomics" and "bio-informatics" to greatly expand upon our previous work. While we were previously able to measure 10 proteins in the CSF using standard biochemical methods, we propose to now use advanced mass spectrometry techniques to analyze up to 500 proteins. This will eventually provide a much more expansive description of the biology of human SCI, and will identify many more potential treatment targets. Additionally, by correlating these proteins with the clinical severity of paralysis, we

will expand upon the series of potential biomarkers of injury severity that we have previously described. These insights will help scientific researchers in the development of clinically applicable therapies for human patients, and provide clinical researchers with tools that will facilitate the testing of novel therapies.

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Dr. Tim O'Connor

Characterization of novel bioactive compounds that stimulate neurite outgrowth on inhibitory substrates

Neurons of the central nervous system (CNS) typically do not regrow, or regenerate, axons after they have been cut or damaged. There are number of reasons why neurons don't regenerate, however one of the major contributing factors is the molecular nature of the CNS environment as there are a number of molecules present that actively inhibit neuronal outgrowth. One strategy proposed to overcome this inhibition is to directly stimulate the intracellular mechanisms that are responsible for neuronal outgrowth such that the neurons effectively ignore the surrounding inhibitory environment and regenerate their axons. To this end, we have previously developed a screening method to test thousands of novel compounds to examine whether they will directly stimulate neuronal growth and regeneration. From our initial screen we identified a number of potential compounds and tested one purified molecule (called a diketopiperazine) in an animal model of CNS lesion and although it was not entirely successful in stimulating regeneration, it was shown to stimulate neuronal branching of intact neurons in the spinal cord. This pioneering work has provided us with a basis to identify additional therapeutic candidates for further testing in animal models. The goal then of this proposal is to obtain preliminary data on additional potential candidates in order to secure additional funding for a larger multi-team regeneration grant.

Dr. Victoria Claydon

Cardiovascular autonomic control in acute SCI

Many people with SCI have abnormal control of the heart and blood vessels. This can lead to episodes of very high (autonomic dysreflexia; AD) and low (orthostatic hypotension; OH) blood pressures. AD can cause seizures, cardiac arrest and stroke. OH can cause fainting and disabling fatigue, and complicates rehabilitation after SCI. People with SCI can also experience irregular heartbeats, particularly during AD, that can be life-threatening. We think damage to cardiovascular nerves after SCI might underlie these debilitating problems. However, it is hard to test how badly these nerves have been injured. Another concern is that cardiovascular problems after SCI change with time, making them hard to treat. We aim to measure the severity of injury to spinal cardiovascular nerves in people who have recently had a SCI using a test that quantifies spontaneous changes in blood pressure and heart rate. These fluctuations are due to changes in the nervous control of the heart and blood vessels, allowing us to measure how well the nerves are working. We will also measure features of the normal heartbeat after a SCI, and test whether they are related to the development of irregular heartbeats. Finally, we will measure any changes in spinal

cardiovascular nerve function, and in the heartbeat, over time after injury. We will perform these tests five times on people with SCI, from within a few days of their injury until one year later. These measures will be correlated with symptoms and signs of cardiovascular disease at each time point. This will allow us to track how the cardiovascular system changes with time after SCI, and how this impacts cardiovascular disease. This will aid understanding of the mechanisms underlying cardiovascular problems after SCI, and ultimately aid in their treatment, improving quality of life for those with SCI.

Dr. Wolfram Tetzlaff

Ketogenic diet for SCI: gene expression analysis

Other than stabilizing the patient's vital functions, fixating the bones of the spine, and providing rehabilitation training, there is no effective treatment for the acutely injured spinal cord itself. Recently we discovered that a diet high in fat and very low in carbohydrates promotes recovery from SCI in rodent models. This so-called Ketogenic Diet (KD) is an established and validated non-pharmacological treatment

for drug-resistant epilepsy in children. Starting the KD in rodents after SCI tripled the usage of their otherwise paralysed paw and improved twofold the ability to successfully reach for food pellets. Importantly, after returning to a standard diet after 12 weeks of KD treatment, these beneficial effects on forelimb function remained stable for at least 6 weeks. Since KD improved functional recovery even when initiated hours after injury, this diet could become a treatment for humans with acute spinal cord injury. To date, we do not know how KD works in the context of SCI. The goal of the proposed research is to gain an understanding of the mechanisms by which ketogenic diet exerts its beneficial effects. To achieve this goal we will perform a screen of the expression of all genes in the organism to identify which are affected by this diet. The information will be highly valuable when trying to administer this diet in humans with SCI, as it will indicate possible interactions with other treatments. This approach may also identify novel targets for even more specific and effective interventions to promote recovery from this devastating injury. The broad database generated on the molecular changes after spinal cord injury (with and without diet) will also be of broad interest to the spinal cord discovery scientists as these can be used as "seeds" for novel research directions.

Seed Grants awarded in February 2012:

Dr. Jaimie Borisoff

Arch support for the hand: evolving wheelchair handrim designs

The manual wheelchair has been in existence in its "modern" form since the 1930's; however little progress has been made on the impact that wheeling has on a person's body. Round tube metal handrims are still the standard equipment issued with the 10,000's of wheelchairs sold every year in North America. These wheelchair handrims are prone to poor grip and ergonomics, and cause long-term impact on a user's body. The aim of this pilot study is to design and fabricate a new handrim concept and to evaluate it in people with spinal cord injury with respect to their perspective on the

quality and effectiveness of the design for pushing their wheelchairs. We will design several new profiles of an ergonomic wheelchair handrim and fabricate them using rapid prototyping techniques. The new handrim designs will feature an improved friction surface to promote grip and ergonomic comfort support for the thumb and hand for injury prevention. Several designs have been recently created and assessed by our design team. We will prototype other designs and show them to potential users in a focus group. The preferred design will be installed on a set of wheels and wheelchair users will push with them in a wheeling evaluation in comparison

to their own handrims. We will assess subjects' perception of the designs in order to gather early validation of the design approach. Later stage research and development will assess other measures such as muscle activation, push force, and joint kinematics. The significance of this work comes from both healthcare and commercialization opportunities. The wheelchair handrim is an obvious candidate for innovation due to its simple integration with existing products and its direct impact on health and participation. Success here will lead to larger funding opportunities and further the path towards commercialization of a potential product with positive benefits to people with spinal cord injury and other wheelchair users.

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Dr. Peter Crompton

Development of a Pro-Neck-Tor prototype for mountain biking

The objective of this project is to design, build, and test a prototype Pro-Neck-Tor mountain biking helmet. The PNT is a helmet that was invented by researchers in the Orthopaedic and Injury Biomechanics Group at ICORD to prevent spinal cord injuries in head-first impact. The most common mechanism of cervical spine fracture while mountain biking is the "over the bars" mechanism where the bicycle's front wheel contacts an obstruction and the rider's momentum then carries them over the handlebars. The rider subsequently

contacts the ground head-first and this is the classic mechanism for cervical spine fracture. Mountain biking is gaining in popularity especially in the North Shore mountains of Vancouver and the Whistler-Squamish corridor. This sport has become more popular since its inclusion in the Olympics in 2000 and riders have engaged in ever more technical and faster riding. The incidence of mountain bike-related cervical spine and spinal cord injuries rose steadily in BC in the early 2000s. Anecdotal reports suggest that mountain biking may be overtaking skiing and other sports as one of the most common sports-related causes of cervical spine and spinal cord injury in BC. 3.7% of all spinal cord injuries treated at Vancouver General Hospital between the years 1995 and 2007 occurred due to mountain biking. In this time period there were 79 cervical spine injuries and 43 spinal cord injuries. For comparison, in the United States, 7.4% of spinal cord injuries are caused by all sports. We have previously build and characterized prototype PNT helmets for football. Due to the high incidence of these catastrophic injuries in mountain biking we would now like to develop a version of the helmet for this sport and we feel that this would significantly help us in our ongoing efforts to commercialize the PNT helmet; this research would lead to a Mountain-Biking version of the helmet being commercially available as soon as possible

Dr. Janice Eng

Brain activation during motor tasks after SCI

Significant functional recovery occurs after incomplete SCI and one potentially important mechanism is the reorganization processes in the brain. Few brain imaging studies have involved human SCI patients, and the majority of these studies were severely limited by small patient numbers (2-5 subjects). This study is innovative in that no studies have attempted to assess the relationship of daily hand activity to

brain activation after an SCI. This study will compare the brain activation of individuals with incomplete SCI to age- and sex-matched controls during a hand motor task and determine the relationship between the amount of daily hand activity (i.e. daily use) and brain activation during a hand motor task. This study will help to increase our understanding of brain reorganization after SCI as related to hand use and function. These findings will determine whether future therapeutic strategies aimed at restoring spinal cord function can build on preserved brain control in individuals with SCI. We will be able to determine whether daily arm use influences the brain re-organization after an SCI, while controlling for the severity of the injury. This study

will help us formulate the best treatment strategies to enhance brain recovery (and in turn, motor function) after SCI.

Dr. Tania Lam

Sensory tongue stimulation & rehab therapy for balance & gait function

Many people who have a spinal cord injury (SCI) have the potential to improve their ability to stand and walk. In people who have partial paralysis as a result of their injury, there may be pathways in the nervous system that could be adapted and strengthened in order to improve function. We know that providing people with rehabilitation therapy that allows them to practice a desired movement (e.g. walking) in a safe way can be beneficial. We also have evidence that combining this kind of task-specific training with sensory stimulation (e.g. using electrical stimulators) can strengthen the effects of training. The tongue has a very high density of sensory receptors, whose connections directly reach the brainstem. The brainstem is an important area of the nervous system for the control of balance and it is intricately linked with other areas of the nervous system for walking. Therefore, the goal of this study is to test the idea that sensory tongue stimulation combined with intensive physical therapy is feasible and will improve mobility and quality of life in people with incomplete SCI. Our participants will undergo daily training for 12 weeks focusing on balance and walking skills. Half of the participants will receive tongue stimulation at the same time through a small electrode array (causing a tingling sensation on the tongue). We anticipate that the combination of training and tongue stimulation will result in greater improvements in balance and walking function as well as self-reported life satisfaction and community participation.

Dr. John Steeves

Mechanisms of accelerated aging following spinal cord injury

People living with a chronic SCI often suffer more illness and die earlier than predicted by data from the general population. Treatment of SCI has improved to the point where people typically do not die as a direct result from the injury itself. Overall, the causes of death among people living with SCI are the same as those in the general population and include heart disease and cancer. In other words, people with SCI die for the same reasons as everyone else, but they develop these life-threatening conditions at an earlier age and more frequently.

Even a person with a relatively minor injury, who regains the ability to walk with a cane, can expect to lose about one decade of life due to their SCI. One possible explanation is that sustaining an SCI results in the acceleration of the aging process. There is some evidence for this: people with SCI exhibit hallmark characteristics of advanced aging, including changes in the immune system and increased risk for heart disease. The objective of this project is to use animal models to determine how this accelerated aging occurs after SCI. Considering aging involves all of the systems in the body, this project involves ICORD scientists working in many fields, including engineers, neurobiologists, molecular biologists and physiologists. We are also partnering with an international expert on aging from the BC Cancer Agency, Dr. Peter Lansdorp, to determine whether there is accelerated aging at the level of the DNA after SCI. This work has wide-spread implications for future SCI research, as it investigates how the trauma of SCI affects a number of organs in the body, as well as overall longevity after SCI. Identifying aspects of accelerated aging is the first step to developing treatments and lifestyle changes to limit accelerated aging after SCI, and extend the lifespan of people living with SCI.

Spinal Chord gala



The *Spinal Chord* gala is co-hosted annually by ICORD and Vancouver Cantata Singers. This unique partnership between ICORD and VCS celebrates interdisciplinary collaboration between art and science in the community while raising awareness and funding for ICORD's leading-edge SCI research and education.

Spinal Chord 2011 was the most successful gala to-date. Attendance at the event, hosted by CTV's Coleen Christie, reached more than 275, helping *Spinal Chord* 2011 raise \$56,268, a significant increase over attendance and total funds raised in previous years. At ICORD, funds raised from *Spinal Chord* 2011 were used to support the Community Resource Centre—an educational hub located in the Blusson Spinal Cord Centre, established to increase awareness, provide education and offer community resources on SCI to ICORD's visitors. Funds were also used to acknowledge excellence in research and service among staff through the *Spinal Chord* Awards for Excellence in Research and Service, and to create a new granting initiative for community-focused research projects led by ICORD faculty members.

We are sincerely grateful for all the support provided for the 2011 event from the sponsors listed on the next page.



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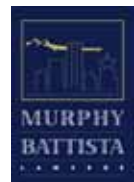
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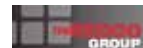


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Endowed chair reports

ICORD is fortunate to have four endowed chairs and an endowed professorship. The **BC Neurotrauma Professorship** is held by Dr. Matthew Ramer and the **Rick Hansen Man In Motion Chair in Spinal Cord Injury Research** is held by Dr. Wolfram Tetzlaff. These two endowments were created and funded by the Rick Hansen Foundation. The Foundation partnered with other donors to create and fund the **Cordula and Gunther Paetzold Chair in SCI Clinical Research**, held by Dr. Marcel Dvorak, as well as the **John & Penny Ryan BC Leadership Chair in Spinal Cord Injury** and the **Spinal Cord Injury Rehabilitation Research Chair** (both currently vacant, pending the appointment of a new Director).

Cordula and Gunther Paetzold Chair in Clinical Spinal Cord Injury Research: Dr. Marcel Dvorak



Dr. Marcel Dvorak, a spine surgeon in the Vancouver General Hospital Acute Spinal Cord Injury Unit, and Associate Director of Clinical Research for ICORD, holds the **Cordula and Gunther Paetzold Chair in Clinical Spinal Cord Injury Research**. His focus is on improving treatment based on research evidence for better care of patients with traumatic SCI.

Funds from this endowed chair have enabled Dr. Dvorak to support clinical research staff within his group to assist with his research: describing the population of acquired SCI in BC, supporting international collaborations with other SCI researchers, and developing our understanding of how to improve research with SCI patients.

Dr. Dvorak has pioneered the largest descriptive study of patients with SCI in Canada: the Rick Hansen Spinal Cord Injury Registry (RHSCIR) is an invaluable source of information on more than 2,500 patients from across Canada, collecting essential information that will help researchers better understand the actual progression of SCI and the care these patients receive. Dr. Dvorak also tracked almost 1000 patients to describe their SCI-related

complications, which often have a life-long impact on their quality of life and costs to the healthcare system. Studies like these help physicians and researchers better understand the significance of the health challenges people with SCI are dealing with, and where care can be improved to address these challenges.

Continuing his leadership in improving the care available to patients early after a spinal cord injury, Dr. Dvorak collaborated on an international multi-hospital study on the safety and effectiveness of early surgical treatment for patients with serious neck injuries. This study showed that surgeons can intervene very soon after a neck injury is sustained – even earlier than originally thought - to remove pressure on the spinal cord, preserving vital functions that may have been lost otherwise.

Surgical treatment of SCI has changed greatly over the years, improving patients' chances at recovery of sensation and function. Dr. Dvorak continues to push for research on better care and treatments for patients with SCI so that more people can survive and recover from this traumatic injury than ever before.

BC Neurotrauma Professor: Dr. Matthew Ramer

Associate Professor Dr. Matt Ramer a principal investigator at ICORD, and is the **BC Neurotrauma Professor in Spinal Cord Injury**. His research focus is on the interactions between the peripheral nervous system (nerves connecting the spinal cord and the body), and the spinal cord, and how this changes with injury. This year, the Ramer lab has continued its focus on nerve regeneration and the relationship between nerve cell changes after SCI and its most common complications.

Dr. Ramer's group has recently discovered that unlike pain-sensing nerve cells, those that sense body position tend to shrink in size after SCI. These cells connect to spinal nerve cells driving muscle reflexes, which after SCI, can cause involuntary muscle spasms. Passive exercise causes these nerve cells to shrink even further, but what changes in spinal nerve connections might underlie this intriguing relationship? Dr. Ramer is examining how this knowledge can be applied to reduce these involuntary muscle spasms common to SCI.

This past year, the International Spinal Research Trust (UK) granted Dr. Ramer new funding to examine how changes in the bladder and bowel after SCI affects their connection to the nervous system. This multi-year project has already shown that abnormal connections between the sensory and involuntary nervous systems develop over time following injury lead to short-circuits which increase pain and cardiovascular dysfunction.

Dr. Ramer's work has also received considerable recognition this year, including three research publications. An upcoming article in a special issue of *Frontiers in Physiology* (in collaboration with ICORD PI Dr. Andrei Krassioukov) describes how pain-detecting sensory nerve cells grow after SCI, which are known to contribute to debilitating consequences of SCI such as pain and disruptions in cardiovascular function. By selectively eliminating the fibres of these larger nerve cells in the spinal cord, Dr. Ramer was able to show a reduction in the severity of dangerous fluctuations in blood pressure which can occur with SCI. Animal models have also indicated that exercise such as passive cycling may help to prevent or even reverse this change in size of nerve cells resulting in less severe blood pressure swings. Dr. Ramer is also building on his pioneering work using neurotrophins, a class of growth-promoting proteins, in regeneration of injured sensory nerve fibres. In collaboration with ICORD's Dr. Wolfram Tetzlaff, Dr. Ramer is examining how neurotrophins affect the formation of myelin, the insulating layer required for nerve signal transmission, around regrowing nerve fibres. Drs. Ramer and Tetzlaff anticipate this project will reveal how encouragement of myelin formation will improve patient recovery and ability after SCI.



Rick Hansen Man in Motion Chair in Spinal Cord Injury Research: Dr. Wolfram Tetzlaff

Dr. Wolfram Tetzlaff, Interim Director of ICORD, is the **Rick Hansen Man in Motion Chair in Spinal Cord Injury Research**. Dr. Tetzlaff runs an internationally-known research lab working in the area of nerve cell physiology and is a leader in animal models of SCI.



Dr. Tetzlaff and his lab have focused over the past year on the completion of a study of the effects of a high-fat, low-carbohydrate diet on recovery after neck SCI in an animal model. The Tetzlaff lab is pioneering this exciting new area in SCI research, which came after previous research indicated that fasting after SCI showed benefits for recovery. The current study emphasizes the original results, showing that specific changes in diet after SCI have significant benefits on the recovery of movement and ability. This study shows the enormous potential for diet change as an inexpensive, non-invasive treatment to promote recovery after SCI. Dr. Tetzlaff is now collaborating with colleagues in China to investigate the feasibility of testing this therapy in humans.

Recently, Dr. Tetzlaff and his lab completed a large study in animals on transplantation of skin-derived cells for the treatment of long-term

SCI. This study demonstrated an improvement in repair of the injured spinal cord, and recovery of functional ability. This study looked at skin-derived cells implanted at 8 weeks, representing the expected time it will take to prepare the patient's own cells for transplant. The extreme cost of clinical trials is a frequent obstacle to getting new treatments to patients, so Dr. Tetzlaff's work maintains a practical perspective: by incorporating a delay into the treatment, physicians testing this therapy are able to compare recovery before and after treatment in each individual, requiring fewer individuals and reducing costs. This work is supported by the Canadian Institutes of Health Research, the Craig H. Neilsen Foundation (an American SCI research charity) and the Canadian Stem Cell Network of Excellence.

This year, the Tetzlaff lab has also initiated projects involving a combination of cell transplants with other therapies designed to promote recovery after SCI. One project is aimed at stimulation of the nerve cells to redevelop their "processes" across the site of the spinal cord injury. The other project examines what relationship might exist for the replacement of myelin, a material that insulates and aids in communicating nerve cell signals, in spinal cord repair. These projects generated funding from the Red Bull-sponsored European SCI charity *Wings For Life*, and the Multiple Sclerosis Society of Canada.

Meet the ICORDians

The photographs on the front cover of this report were created as part of a project to showcase the work that goes on every day in the Blusson Spinal Cord Centre. Staff from ICORD, the Brenda & David McLean Integrated Spine Clinic and Rick Hansen Institute were photographed as they explained the work they do and its importance to people with SCI. We plan to display these posters in the Blusson Spinal Cord Centre atrium later this year.



Dr. Femke Streijger is a Preclinical Discovery Scientist working with Drs. Brian Kwon and Wolfram Tetzlaff at ICORD. She studies the effects of a high-fat, low-carbohydrate diet on functional recovery after SCI. Dietary treatments may provide a low-risk, low-cost alternative therapy for SCI.



Drs. Antoinette Domingo and Zhen Chen belong to Dr. Tania Lam's Human Locomotion Laboratory at ICORD. They study how the nervous system uses sensory information to control walking, and also how people with SCI respond to exercise. They use this information to develop and improve gait rehabilitation strategies for people with SCI.



Shirley Wong, Melissa Pak and Dr. Chris West are members of Dr. Andrei Krassioukov's Autonomic Research Lab at ICORD. They study the effects of SCI on cardiovascular health. Cardiovascular disease is currently the leading cause of death in people with SCI. They are investigating ways to help people with SCI live longer and healthier lives.



Jeswin Jeyasurya is a Rehabilitation Research Engineer at ICORD. He maintains specialized equipment, develops customized modifications, writes software programs and provides training to researchers. His support allows ICORD researchers to focus on their projects, and his engineering expertise is a valuable resource.



Malihe Pourmasjedi and Azadeh Hosseinitabatabaei study with Dr. Aziz Ghahry in the BC Professional Fire Fighters' Burn and Wound Healing Research Lab at ICORD. They research management of non-healing wounds and scars. They also study treatments for type 1 diabetes and its secondary complications. Non-healing wounds and related infections are among the main causes of death in patients with SCI. Their research aims to improve health outcomes.



Dan Dressler and Seth Gilchrist work with Dr. Peter Crompton in the Orthopaedic Injury and Biomechanics Lab at ICORD. They do research on traumatic injuries like head-first impacts in sporting activities and hip fractures due to falls. Their work is focused on preventing injuries through development of novel injury prevention devices. Most injuries are not accidents; they can be prevented through education, regulation or engineered safety devices.

looking forward

Challenges & opportunities

ICORD is fortunate to have the support of the UBC Faculty of Medicine, Vancouver Coastal Health Research Institute, the Rick Hansen Foundation and the Rick Hansen Institute. It is only thanks to this generosity that we have had the capacity to initiate new programs such as the seed grant competition, international exchanges, and the Trainee Research Day, as well as continuing to provide trainee travel support and run our annual research meeting. The shared research and technical staff have been invaluable in advancing research for a significant number of ICORD researchers, and ICORD's small but efficient administrative team has managed all of the administrative, communications and financial support for the researchers in the BSCC, as well as providing support for research infrastructure, overseeing the operation of BSCC common areas, and organizing both internal and public events to connect ICORD researchers with each other and with the greater community.

The Blusson Spinal Cord Centre, owned and maintained by Vancouver Coastal Health, is a hub of SCI research, care, and teaching in western Canada. Located here, ICORD is uniquely positioned to foster the collaboration between clinicians, researchers and patients that will bring us closer to cures for SCI. Our challenge in the coming year is to secure ongoing, sustainable operating funding, which will allow us to support our researchers as they move closer to that goal, and help them, in turn, train a new generation of researchers which will build capacity in SCI research worldwide.



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Thank you for reading our 2011-12 Annual Report. It was written by Cheryl Niamath, Lowell McPhail and Jocelyn Tomkinson, with photography by Lowell McPhail, J. Evan Kreider, Mehdi Eshraghi and Michelle Ng. Design and layout were done by Cheryl Niamath, and printing was done by EastVan Graphics. For additional copies of this report or any other ICORD publication, please call 604-675-8844 or email admin@icord.org.

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