THE UNIVERSITY OF BRITISH COLUMBIA

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Words from the Dean

Photo: Martin Dee

I am writing these words on a beautiful sunny Monday, having just heard Premier Gordon Campbell announce that our province will be investing $37.5 million to help UBC build a new Earth Systems Science Building (ESSB). As you may recall from previous issues of *Synergy*, the mineral exploration industry, private benefactors and now our province are partnering to build a new academic building at UBC. ESSB will house the departments of Earth & Ocean Sciences (EOS) and Statistics, the Pacific Institute for the Mathematical Sciences and our dean's office. I and my colleagues are deeply grateful for this tremendous investment in the next generation of students—our future leaders.

On p. 14, you can learn more about how EOS is embracing new teaching techniques to better prepare our students for their future careers. On p. 6, EOS graduate student Janina Micko describes her experience of working with the mineral industry through our Mineral Deposits Research Unit. The next generation of scientists is also benefiting from two new interdisciplinary graduate statistics courses that are being taught jointly and simultaneously across five campuses, on both sides of the US-Canada border (see p. 12).

In 2009, we also celebrate the International Year of Astronomy—an effort initiated by the International Astronomical Union and UNESCO to help citizens around the globe rekindle a sense of wonder and discovery about our place in the universe. In this issue of *Synergy*, we honour the rich heritage of discoveries by our astronomers at UBC by describing research conducted in Douglas Scott's lab, which challenges modern theories that propose the Earth holds a central position in the universe (see p. 4). Astrophysics meets the arts in a CosmoSonnet by science writer and poet Mari-Lou Rowley (see sidebar).

Reaching out to the public, we seek to enrich general science and sustainability knowledge. On p. 16, you will find out about state-of-the-art preparations currently underway for a world-class exhibit at our new Beaty Biodiversity Museum.

I invite you to learn how discoveries are made, knowledge is passed on and new insights are gained every day by our students, instructors and researchers. I hope you enjoy 'exploring' this latest issue of *Synergy*.

Simon M. Peacock
Dean, UBC Faculty of Science

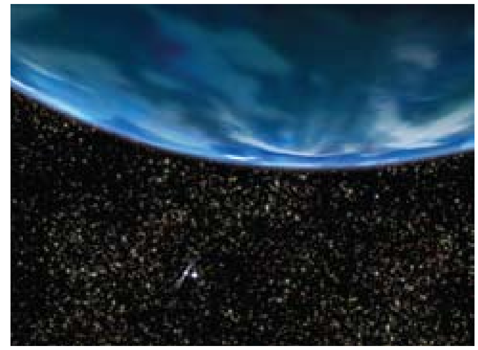

Image: NASA and G. Bacon (STScI)

Supernovae

Everything sprung from a red giant's desire
overblown, burnt out, way beyond prime
he hangs out at the super bowl, watching
the universe recede, a suicidal supernova's
last gasp for greatness, yearning to go down
in time, rival the brightness of galaxies,
be something else. Cosmic demise spews
fragments of matter, solar systems, humans
all begotten by the giant's collapse, final inhale
of space-time until nothing but neutrons
huddle together in the quinzhee of heaven.
Occasionally a pulsar's lonely song
an echo of the giant's last breath, caught
in a black hole's dragnet of gravity.

– Mari-Lou Rowley
From CosmoSonnets, JackPine Press 2006

Cover image: Artist's view of an ancient planet in a globular cluster core

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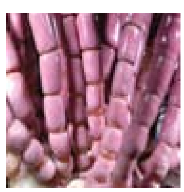
Predicting Climate Change Impact on Salmon Stocks – Oct 2008
An interdisciplinary team led by UBC zoologist Tony Farrell has developed a way to accurately predict the impact of climate change on imperilled Pacific salmon stocks. "Our study has shown that high temperatures push certain sockeye salmon stocks beyond their thermal window, resulting in cardiovascular failure and death," says Farrell.

Humpback Whales' Dining Habits—and Costs – The Vancouver Sun, Nov 2008
"Weighing up to 40 tonnes, humpback whales have relatively short dive times given their large body size," says Jeremy Goldbogen, PhD candidate (Robert Shadwick's lab, UBC Zoology). This has to do with the enormous energy costs of its lunge feeding—a unique foraging behaviour that is related to the overall evolutionary and ecological success of this type of whale (rorquals)."



Billion-Year Revision of Plant Evolution Timeline – Jan 2009
UBC botanist Patrick Martone and colleagues at Stanford University discovered lignin in a marine red alga. "All land plants evolved from aquatic green algae and scientists have long thought that lignin evolved after plants took to land as a mechanical adaptation for stabilizing upright growth and transporting water from the root," says Martone. "Because red and green algae likely diverged more than a billion years ago, our discovery suggests that the basic machinery for producing lignin may have existed long before algae moved to land."

***Inkheart* Monster Powered by UBC Animation Research** – Jan 2009
Algorithms created by UBC computer scientist Robert Bridson played a key role in bringing the monster to life in the adventure film *Inkheart*. By incorporating the laws of physics into computer modules, Bridson's research has helped everything from the mundane (Harry Potter's cape flowing in the wind) to the fantastic (explosions and smoke in *Hellboy II*) follow the rules of nature and look stunningly normal.

Source: UBC media releases 2008/09 or as indicated

UBC Science (in the) News: Discoveries, Innovations, Initiatives

$37.5 Million Investment toward Earth Science Building to Boost Student Experience, Minerals Industry – April 2009

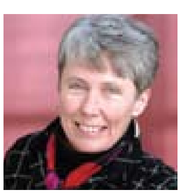
Premier Gordon Campbell (centre) joins (from left to right) UBC president Stephen Toope, Science dean Simon Peacock, EOS master's student Ayesha Ahmed, UBC chancellor Sarah Morgan-Silvester and Minister of Advanced Education and Labour Market Development Murray Coell at the Pacific Museum of the Earth.

Photo: Don Erhardt

The Province of British Columbia (BC) has invested $37.5 million toward UBC Science's future Earth Systems Science Building, a state-of-the-art new home for the Department of Earth & Ocean Sciences. "This investment will help ensure BC's continued leadership in the international mineral exploration industry and strengthen research into sustainable mining practices and climate change," said Premier Gordon Campbell at the announcement ceremony in UBC's Pacific Museum of the Earth on April 6. "EOS has certainly outgrown its 35-year-old facilities," noted dean of Science Simon Peacock. "The new facility will not only benefit the students and researchers who learn and work here, but also help BC's mineral exploration and mining industry meet increasing demand for trained geologists and geoscientists." The Province is providing $37.5 million toward the new $75-million facility, which will feature high-tech research and teaching labs, classrooms, a lecture theatre complex, seminar rooms, quiet study spaces and common areas. The balance of the funding will be provided by unprecedented support from the minerals industry, UBC and other sources. "We're grateful to both the provincial government and to our industry partners for their tremendous vision in supporting our students," added Peacock. "UBC's earth science graduates are already held in high regard and have helped make Vancouver an international hub for mineral exploration. This expanded facility will only enhance that reputation and the department's partnership with industry." The building will meet the growing educational needs of 360 major and honours students, 170 graduate students and more than 6,400 undergraduates enrolled in earth science courses at UBC.

New Canada Research Chair, Three Renewed – Feb 2009

Chemistry professor Stephen Withers is one of four new Canada Research Chairs (CRCs) named to UBC this spring. His lab develops new ways to synthesize carbohydrate-based therapeutics. Jeremy Heyl, CRC in Neutron Stars and Black Holes, Reinhard Jetter, CRC in Plant Natural Products Chemistry, and Dominik Schötzau, CRC in Numerical Analysis of Multiphysics Problems, are among ten CRCs renewed at UBC earlier this year.



Maria Klawe appointed to Microsoft Board – The Seattle and Los Angeles Times, Mar 2009

Harvey Mudd College president Maria Klawe has been appointed to Microsoft's board of directors. Former UBC Computer Science professor Klawe held several administrative positions at UBC, including department head, VP Student & Academic Services, and dean of Science. "Her close connection to university students and the way they shape computing trends will bring an important perspective to the board," said chairman Bill Gates.

Source: UBC media releases 2008/09 or as indicated

Solar Canopy to Send Light Deep into Office Towers – Vancouver Sun, Mar 2009

Physicists at UBC have begun rolling out test versions of a device known as a "solar canopy." The patented Solar Canopy Illumination System, invented by physicist Lorne Whitehead and developed in the UBC Structured Surface Physics Laboratory, collects sunlight on the exterior façade of conventional buildings through a specially designed array of mirrors. It is roughly seven times more efficient than solar panels.

Balloon-borne Telescope Reveals Secrets of Space – The Canadian Press and BBC, Mar 2009

An international team of astronomers—including UBC researchers Ed Chapin, Mark Halpern, Gaelen Marsden, and Douglas Scott—have unveiled the birthplaces of ancient stars using data from the Balloon-borne Large-Aperture Submillimetre Telescope (BLAST). The two-tonne telescope, carried outside of the Earth's atmosphere by a 33-storey-high balloon, recorded new information by capturing submillimetre light that is normally absorbed by the Earth's atmosphere.

New Spin on Electrons – Apr 2009

In the first demonstration of its kind, a team of UBC researchers led by physicist Joshua Folk has controlled the spin of electrons using a ballistic technique. The findings could have implications for the development of spintronic circuits—systems that use the directional spin of electrons to store and process data.

PM Urged to Restore Science Funds – The Globe and Mail, Apr 2009

More than 2,000 Canadian researchers, including some of the country's most respected scientists, have signed an open letter to the prime minister decrying budget cuts to basic, curiosity-driven research that history shows leads to discoveries important for society and economy. The budget chopped $147.9 million from the three granting agencies that fund research at Canadian universities. UBC mathematician Nassif Ghoussoub, an organizer of the letter, said Canadian scientists must accept some of the blame because they did not make a stronger case beforehand.

For more news from Science visit us at **science.ubc.ca**

Astronomy: Peering Back in Time

How Galaxies Form in a Flat, Lumpy Universe

Since antiquity, the mysteries of the cosmos have perplexed and inspired poets and scientists alike. In 2009, the International Year of Astronomy celebrates the scientific advances that are allowing astronomers like UBC professor Douglas Scott to probe deep space and shed light on age-old questions.

How did the universe form and how will it end? What shape is it? Where do stars and galaxies come from? These are questions a child might ask, yet they are the fundamental inquiries of physical cosmology—the intricate discipline of an expanding universe, clustering galaxies, dark matter, and dark energy.

As recently as 1998, observations from the Hubble Space Telescope showed that the universe is not only expanding, but accelerating. Before this, astronomers thought the attractive force of gravity would slow expansion as time went on. Today, most scientists acknowledge there is a mysterious repellent force, termed dark energy, which comprises roughly 70 percent of the entire universe. Dark matter—another mystery—comprises about 25 percent. Stars, planets and galaxies make up only five percent of all the matter in the universe.

"These phenomena cover the two parts of my research," says UBC cosmologist and theoretical physicist Douglas Scott. "One is big background cosmology, and the other is trying to understand how galaxies form. These involve entirely different sets of questions, yet they are completely interrelated."

"Illuminating" the Early Universe

To study these phenomena requires measuring and analyzing data from cosmological events and objects over the entire electromagnetic spectrum—from low frequency radio waves to high-frequency gamma rays. Advances in satellite, telescope and computer technology, as well as novel analytic tools, have allowed cosmologists to observe cosmic microwave background (CMB) radiation. This faint glow of the oldest light in the universe is made up of photons left over from the Big Bang, which are getting fainter and less energetic as the universe expands. Studying minute changes in the temperature, or anisotropies, of the microwave background provides information about fluctuations—or lumps—in the early universe, 300,000 years after the Big Bang and before galaxies started to form. The universe is roughly 14 billion years old, and the first galaxies appeared perhaps 13 billion years ago.

CMB radiation shows that the early universe is surprisingly uniform—with nearly the same temperature of 2.73 kelvin in all directions. Scott is interested in studying small temperature fluctuations in the CMB, because they can shed light on the density of the universe—and his two major areas of study.

The density of the universe determines its shape. If the density is greater than the "critical density" (see text box), the universe should be positively curved, like the surface of a closed sphere. If the density of the universe is less than the critical density, the universe should be negatively curved, and open, like a saddle. Recent interpretations of CMB measurements have shown that the density of the universe is very close to critical density, which means the shape of the universe is nearly flat.

Cosmological Primer

Hubble Constant: The rate of expansion of the universe, a correlation between the momentum of expansion and the pull of gravity.

Critical Density: The density at which space is flat as opposed to negatively or positively curved. Without the repellent force of dark energy, the universe would collapse into a "Big Crunch."

General Relativity: Einstein's theory that describes gravity as a property of the geometry of space and time, or space-time.

Confirming Copernicus and Voiding the "Void Theory"

Scientists agree that dark energy is perplexing, but recent "void theories" to explain it away are even less plausible according to findings by Scott and post-doctoral fellows Jim Zibin and Adam Moss.

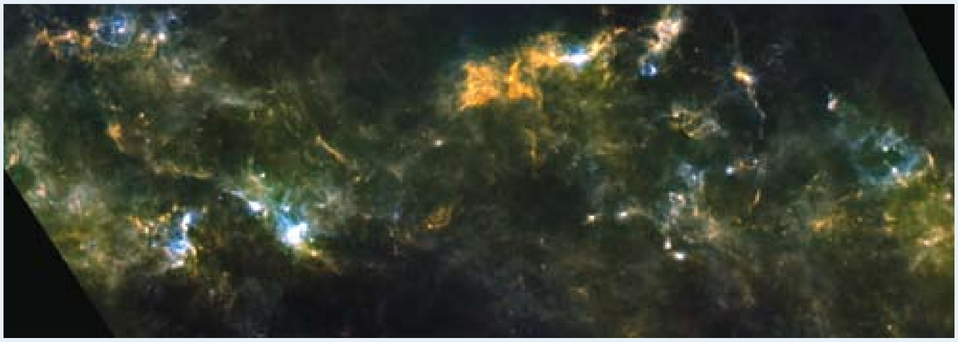
In the 1500s, Copernicus stated that the earth was not the centre of the universe, but merely a planet orbiting the sun. The Copernican Principle—a core tenet of modern cosmology—states that the location of Earth in the universe is completely ordinary and unremarkable. Void theories put the earth right back at the centre, not only of the universe, but in the middle of a giant bubble, or void, nearly empty of matter.

"The idea is very simple," explains Scott. "If you live in a very under-dense region, then relative to the average part of the universe you would be expanding, because in a sense you are being pulled by everything else." However, the void would have to be immensely huge and under-dense. Scott and his team know that the universe is lumpy from observing density fluctuations in galaxies—the older the universe, the lumpier it is. "There simply aren't giant voids like this anywhere else."

While the void theory has been used to explain data from supernova surveys, it needs much tweaking in order to account for other observations of the large-scale universe, such as CMB anisotropies. By comparing the void concept with CMB data, Zibin and Moss showed that void models don't work and are much more contrived than dark energy models, which work very well to explain all the empirical data cosmologists are now able to observe and measure.

"We do not live in the centre of a very special part of the universe," says Scott. On the other hand, we do live just at the time when dark energy started to dominate, so the bigger question is, why do we live at this special time?"

Image: BLAST Collaboration



Star Formation. *Clouds of cold dust mixed with gas in the plane of the Milky Way galaxy as seen by BLAST: blue indicates areas warmed above 20 kelvin by recent or ongoing star formation; orange indicates areas cooled to around 12 kelvin (gas and dust not being warmed by young massive stars). The image is of 50 degrees towards the constellation Vela.*

Inflating a Flat Universe

A flat universe seems completely counterintuitive to Einstein's theory of general relativity (see text box), the curvature of space-time, and the complex Riemannian geometry used to describe these theories. In fact, explains Scott, it seems that the universe has been playing a joke on cosmologists. "As far as we can tell, the universe can be described by Euclidian geometry, with Cartesian coordinates that would behave just as you would expect," says Scott. "It seems too simple."

The reason for the flatness has to do with inflation, the theory that during the first fraction of a second after the Big Bang the universe expanded exponentially. "The idea is that the universe was dominated by massive vacuum energy, which caused inflation," explains Scott. "If you live on the surface of a small sphere, you can easily tell that it is a sphere, but if it balloons out and becomes gigantic, then it appears flat in every direction—and in three dimensions, which is difficult to visualize."

Scott notes that, in a sense, the dark energy that dominates the universe today is similar to the vacuum energy at its formation, but 100 orders of magnitude weaker. Einstein discovered that empty space is not "nothing"; empty space brings about more space. Yet Einstein believed that the universe was positively curved and static, so he balanced the positive gravitational force with his "cosmological constant," a mathematical tweaking that turned out to be his greatest (if perhaps only) blunder.

"The obvious prediction from general relativity is that the universe can't be static, because static is unstable. It must be either expanding or contracting," Scott states. Apparently, even Einstein couldn't think of everything.

Inflation Key to Formation

The inflation theory also provides an answer to how stars, planets and galaxies are formed—and a way to reconcile the macrocosm of cosmology with the microcosm of quantum mechanics. During inflation, quantum fluctuations in the density of matter also expanded exponentially, and over several hundred million years these high-density areas became the seeds of stars and galaxies.

"The really exciting thing about inflation is that a quantum fluctuation becomes a macroscopic fluctuation containing zillions of particles described by everyday physics," says Scott. "And this gives us a very plausible explanation for why the universe contains what it does."

Planck and Herschel Slated to Soar

A major event in the International Year of Astronomy was the launch of two new research satellites—named after physicists Max Planck and William Herschel—on April 29, 2009. The Planck satellite, launched by the European Space Agency, uses two very sensitive low-temperature radio receivers capable of distinguishing much smaller temperature variations (around one microkelvin) in the CMB, with greater resolution. Together, the two instruments, unimaginatively named (for physicists) the low-temperature instrument and the high-temperature instrument, will produce the best maps to date of anisotropies in the CMB radiation field.

The Planck instrument covers the full range of electromagnetic wavelengths, where predecessor satellites WMAP and COBE only record low-frequency waves. With the full range of frequencies, the Planck satellite will also allow researchers

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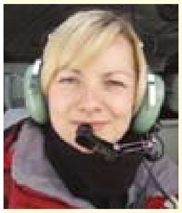
UBC's Stellar Astronomers

Several astronomers in UBC's Department of Physics & Astronomy have received international acclaim for their research. Along with Douglas Scott, Mark Halpern is part of the Balloon-borne Large-Aperture Submillimetre Telescope (BLAST) project, which recently concluded an eleven-day deep-space observation over Antarctica. As member of the WMAP satellite team, Halpern also investigates CMB. Ingrid Stairs is an expert on rotating neutron stars, or pulsars (*Synergy* 1 | 2007). Paul Hickson developed liquid mirror telescopes that combine Newtonian physics and high-tech optics to allow astronomers on Earth to peer back to the beginning of time (*Synergy* 1 | 2004). Jaymie Matthews is leading the Microvariability & Oscillations of STars (MOST) mission (*Synergy* 2003). This summer marks the sixth year of Canada's 'humble' (suitcase-sized) space telescope in orbit, discovering and exploring planets within and beyond the solar system. Brett Gladman, Canada Research Chair in Planetary Astronomy, is part of a team that discovered several irregular satellites (or moons) around Jupiter and three around Neptune. Harvey Richer leads an international team of scientists who are using the Hubble Space Telescope to measure the brightness and temperature of white dwarfs—remnants of the oldest stars in our galaxy (*Synergy* 2003). Ludovic Van Waerbeke was one of the first astronomers to use the gravitational bending of light to study the distribution of dark matter. More recent additions to the UBC Astronomy team include Jeremy Heyl, an expert on the complex physics of neutron stars, and Kris Sigurdson, who studies the universe's past, evolution and future.

Bright Young Minds – 'Rock' Star Janina Micko



Logging 750-metre-long core samples in the remote BC wilderness might not be your typical summer job, but for Janina Micko, the rocky terrain of Galore Creek warranted two trips. Micko—an award-winning PhD candidate with UBC's Mineral Deposit Research Unit (MDRU)—has spent two summers in remote northwestern British Columbia (BC) working with research collaborators and industry partners to explore the area's major precious mineral deposits. "Overall it's been a fantastic experience," says Micko, now back at UBC and reviewing the data resulting from the field work. "Taking part in the project has exposed me to real-world exploration, and in particular, to all the economic and feasibility considerations that go in to work on the ground." Discovered in the mid-1950s, the Galore Creek Valley site is one of the world's best examples of a particular type of alkalic porphyry deposit: deposits that promise high yields of copper, silver and gold, and may produce less acid run-off when mined. Due to its high acid-buffering potential and low total sulphide content, mining this deposit is expected to be more environmentally friendly than other types of ore deposits. However, the deposit model isn't well understood yet, something this project—a collaboration between the MDRU and the University of Tasmania's Centre for Ore Deposit Research—is trying to rectify.

Award-winning PhD candidate Janina Micko worked with industry geoscientists to explore one of North America's largest undeveloped porphyry copper-gold-silver deposits.

Micko is linking the results of the geochemical analysis of the core samples with deposit-scale geological features on the surface, trying to paint a clearer picture of the deposit. "It's a project that could increase our understanding of how these deposits form, and also have implications for how we explore similar deposits in BC and around the world," says Micko's co-supervisor, Greg Dipple, a professor with the Department of Earth & Ocean Sciences and MDRU. Micko is now wrapping up her PhD thesis and weighing her options. "A post-doc has its appeal, but now having some exposure and understanding of industry processes has also opened my eyes to some of those possibilities." Richard Tosdal, former director of the MDRU and Micko's other co-supervisor on the project, notes: "MDRU students work closely with industry geoscientists, and many go on to employment with the sponsoring company. At the same time, students are able to take a longer-term look at some of the data and produce results that are useful for their scientific research, as well as for the company." In addition to her experience in the field, Micko has also benefited from a variety of academic awards, including recognition from Geoscience BC, the Society of Economic Geologists Canada, Shell, and the Universitas 21 network. The MDRU-CODES Alkalic Mineral Deposit project is supported by Geoscience BC and industry partners, including NovaGold Resources Incorporated and Teck Resources Limited.

www.mdru.ubc.ca

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to see through the cosmic dust that envelopes galaxies like our Milky Way. Scott is a co-investigator on the low-frequency instrument. As a Canadian member of the elite international team of scientists, he will be working with the data that are sent back to Earth from the Planck satellite over the next couple of years.

"We hope to understand the properties of the universe in more detail, to learn about the process of inflation and to discover completely unexpected things that are missing from our current cosmological picture."

Scott is also part of the Herschel mission team, which will study how stars form in the Milky Way and how the earliest galaxies formed in the distant universe. "When stars form, they are typically buried in dust clouds, so they are invisible at optical wavelengths," explains Scott.

Herschel carries a 3.5-metre-diameter telescope, the largest astronomical telescope ever put into space. Its three instruments are designed to carry out imaging and spectroscopy in the 60–700 μm wavelength range.

"The Herschel satellite is an observatory, so it will be able to point at specific places and do detailed studies, whereas Planck is designed to make a map of the entire cosmos," says Scott. At submillimetre wavelengths (between far-infrared and microwaves), it will allow astronomers to examine molecular clouds and dark cloud cores, which are the birthplace of stars.

"Just like the Milky Way, submillimetre galaxies are very bright and dusty. Although unlike our galaxy, they are undergoing the most violent phase of star formation," says Scott. "If you want to study where the biggest galaxies form early on, you need to go to these wavelengths, because they are invisible in the optical spectrum, even in the deepest Hubble images." ■

Molecular Mechanics

Fine Tuning Proteins for Optimal Performance

Elastomeric proteins enable our bodies to jump, run, breathe, and pump blood through our veins. UBC biophysical chemist Hongbin Li's research into their unique properties has led to the development of novel artificial proteins that can act as both spring and shock absorber at the flick of a molecular switch.

Think of the biophysical chemist as a molecular mechanic, fine tuning the properties of molecules in order to tweak their behaviour in the way a car mechanic might tune an engine to get better mileage or faster acceleration. Canada Research Chair in Molecular Nanoscience and Protein Engineering Hongbin Li is working to understand the mechanical properties and folding dynamics of elastomeric proteins in order to develop novel synthetic molecules that could ultimately be used in the fabrication of smart materials for engineering and biomedical applications.

Elastomeric proteins drive various biological activities and function as molecular springs to provide tissues with the elasticity, extensibility and strength that propel champion athletes, migrating birds and jumping insects. "Mechanical stability is partially defined as the force needed to unfold proteins at a given velocity, or loading rate," Li explains. "By tuning these mechanical properties, the body is able to regulate various biological processes and activities." Understanding the innate tuning mechanisms is key to engineering artificial elastomeric proteins.

Engineering Super Proteins

In a 2007 letter in *Nature Materials*, Li and graduate student Yi Cao described the creation of an artificial elastomeric protein by fusing eight non-mechanical GB1 proteins into one chain, or polyprotein. Li and his lab used atomic force microscopy (AFM, see below) to demonstrate that $(GB1)_8$ is one of the first artificial proteins with elastomeric properties that are comparable and even superior to known natural elastomeric proteins. In fact, they found that $(GB1)_8$ has faster folding kinetics, high folding conformity, low mechanical fatigue, and the ability to fold against the pull of residual force (see left image on p. 8). "This was a bit unexpected because the GB1 protein does not have any mechanical function in living systems," says Li. "We realized that it would be a good candidate for an artificial elastomeric protein because it combined all of these neat features."

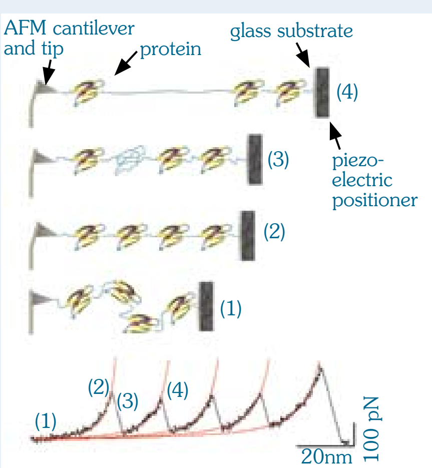
Their super protein also survived 276 cycles of extension before it detached from the AFM tip—a protein pulling record set by a student in Li's lab. "It is not easy to do, because the protein has to cooperate so it doesn't break or detach," he admits. A usual number of extension cycles would be fewer than 30 in a good experiment. "Overall, $(GB1)_8$ is an ideal artificial molecular spring, which eventually could be used in engineering novel nanomaterials."

Dual Elasticity in Chameleon Proteins

In more recent work, Li and his lab engineered an artificial polyprotein that can switch properties—from acting as a mechanical spring to a mechanical shock absorber. "In naturally occurring elastomeric proteins in animals or humans, these properties are generally found in two distinct classes," explains Li. Elastin in lung tissue, for example, behaves like an elastic spring. In contrast, the giant muscle protein—appropriately named titin—acts as a shock absorber by unfolding under mechanical stress, thereby relaxing the force to prevent tissue damage.

Based on molecular dynamics simulations of the GB1 protein conducted by Dmitri Makarov of the University of Texas at Austin, Li predicted that the hydrogen bonds

Measuring the Force of Single Molecules



Atomic force microscopy (AFM) is the method Hongbin Li and his lab use to mechanically manipulate individual polymer chains in order to measure force-extension relationships at the single-molecule level, with pico-Newton resolution in force and nanometre precision in extension. A protein molecule is deposited onto a glass cover slip, then picked up by the AFM tip and stretched between the tip and the solid substrate, which is mounted onto a piezo-electric positioner. AFM has two modes of operation: force-extension mode, where two ends of a protein are stretched apart at a constant velocity, and force-ramp mode, where the stretch force increases linearly as a function of time.

Li notes that the force-extension mode is the most commonly used method in single-molecule AFM because it is easy to implement. However, it does have limitations. When you look at the force extension curve for $(GB1)_8$, for example, it has a sawtooth-like pattern. The force change as a function of extension is very complicated and that makes it very difficult to obtain an analytical solution to describe the distribution of the unfolding forces.

In AFM force-ramp mode, where the force as a function of time increases linearly, it is much easier to use an analytical solution to determine the distance between the native folding state and the extended state of the protein.

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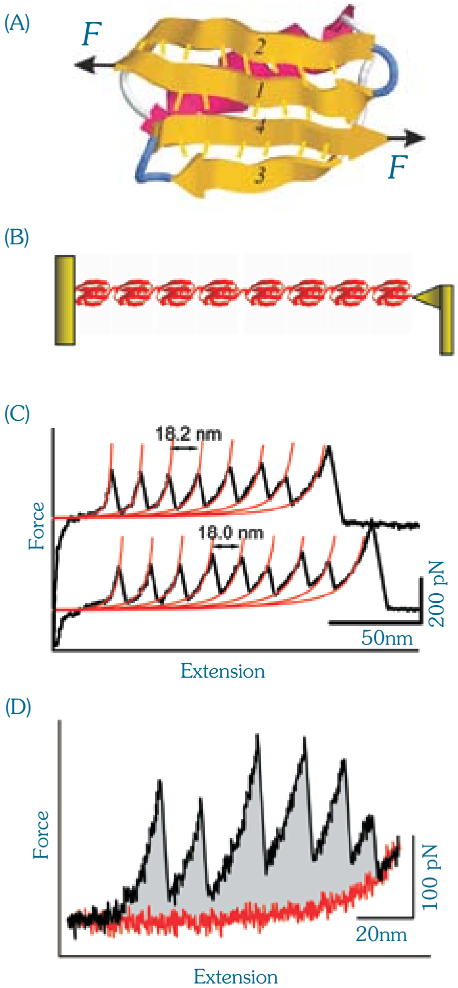
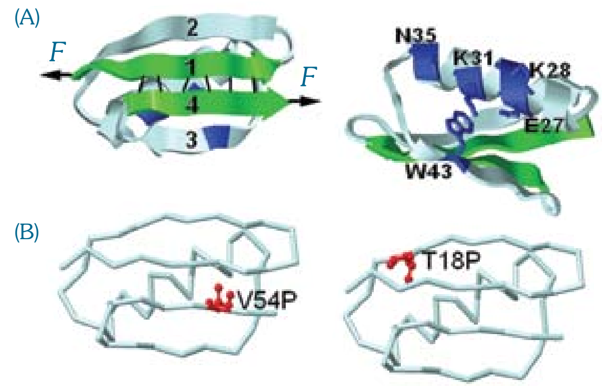


Mechanical Stability of Polyprotein (GB1)$_8$. *(A) Three-dimensional structure of the non-mechanical protein GB1. (B) A schematic diagram of polyprotein (GB1)$_8$: eight identical GB1 monomers are joined in tandem. (C) Typical force–extension curves of (GB1)$_8$: the last peak of each curve corresponds to the detachment of the protein from either the AFM tip or substrate. The curves can have up to eight unfolding force peaks and can be described by the worm-like-chain model of polymer elasticity (red lines). (D) A pair of typical stretching (black line) and relaxation (red line) curves of the polyprotein.*



Designing Elastomeric Chameleon Proteins Using Proline Mutagenesis. *(A) The binding site for Fc (indicated in dark blue) on the GB1 protein is distant from the mechano-active site (green). (B) Valine on position 54 and threonine on position 18 in GB1 are substituted with a proline (V54P, T18P).*

connecting β-strands 1 and 4 are the key barrier to mechanically unfolding the protein. (This area on the protein is the mechano-active site.) By breaking these hydrogen bonds, the protein is converted from a rigid spring to a softer spring. But if they could make GB1 less like a spring and more like a shock absorber, was the reverse possible? Could they switch it back to rigid spring-like properties? The key to accomplishing such a transformation was in a fragment of a common human antibody IgG, called hFc. Li and his lab knew that this molecule could bind to GB1and that the addition of hFc could significantly enhance mechanical stability of GB1. However, the hFc binding site on GB1 is far—in molecular terms—from the mechano-active site.

To design their chameleon proteins, Li used the technique of protein mutagenesis (see image above): the amino acid valine on position 54 of β-strand 4 of GB1 was substituted with proline, creating the mutant protein GB54P, which has reduced spring activity. (Proline mutations—in this case a valine-to-proline mutation—are known to disrupt the beta-sheet structure.) The researchers then added hFc to enhance the mechanical stability lost by the proline mutation. Using these molecular tuning mechanics, and measuring the protein's properties with AFM, they showed that GB54P exhibited two distinct properties of spring-like and shock absorbing behaviour. "Because the mechano-active site and the hFc binding site are different, we could design the protein to have these chameleon properties," says Li. "What is really interesting for us is to make a protein that responds to controllable exterior stimuli, and this is one example."

Using a similar process, they made another mutant of GB1, where the amino acid threonine on position 18 of β-strand 2 was mutated to proline. They then made eight identical repeats of the protein into the chain (GT18P)$_8$. "We found that this protein turns out to be even better," says Li. "The GB54P mutation still had some residual mechanical stability, where a small fraction unfolds at a lower force. In comparison, (GT18P)$_8$ behaves like an ideal entropic spring, so the mechanical stability is completely knocked out."

Li's lab is collaborating with UBC zoologist John Gosline, an expert in spider silk, to try to make biomaterials using these novel elastomeric proteins. "We have a lot of knowledge about how to design proteins at a single-molecule level, but how to translate those processes into a biomaterial is a completely new and very exciting area that we are now exploring." ■

Medical Ramifications of Protein Mechanics

Mechanical transduction of signals is a main biological pathway in cells, where force is the trigger of important biological responses. For example, the cells that line blood vessels are subject to mechanical forces due to the blood flow. Medical researchers have found that forces on the outside of the cell can lead to changes in the chemistry inside the cell. As a Career Investigator of the Michael Smith Foundation for Health Research (MSFHR) and with funding from the Canadian Institutes for Health Research and MSFHR, Hongbin Li is studying the extracellular matrix protein tenascin. The extracellular matrix (ECM) is the part of animal tissue that provides structural support to cells, a main feature of connective tissue. Two mutations of this protein have been found to cause connective tissue disorders. "This protein is subject to stretch or force in the body, so we are looking at the mechanical architecture and design to see whether we can establish any direct connection between the protein mechanics and connective tissue disorder," says Li.

Viral Attack Strategies

Multiple Pathways to Pandemic Preparedness

Molecular virologist François Jean is developing multiple approaches to stop the spread of life-threatening human viruses. His research focuses on enzymes that control both viral and host-cell pathways essential for infection, and he is developing inhibitors to interrupt these enzymatic pathways—and stop viruses in their tracks.

The potential threat of a viral pandemic has researchers and governments around the world working hard to keep one step ahead of new viruses and the latest mutations of existing ones. "Avian flu, HIV, hepatitis C, and West Nile viruses are emerging or re-emerging human-enveloped viruses associated with the world's most serious diseases," says François Jean, associate professor in Microbiology & Immunology at UBC.

In 1997, a strain of highly pathogenic (HP) avian flu, influenza A H5N1, made the genetic leap from chickens to humans in Hong Kong. Since that first H5N1 outbreak, H5 infA viruses have been reported in over 60 countries around the world, including Canada, where the first cases of avian H5 infA occurred in January 2009.

Over the last decade, new deadly strains of avian flu have been observed around the world. In February 2004, a low-pathogenic (LP) H7 avian infA strain (H7N3) was found in Canada in poultry on a commercial breeding farm east of Vancouver. Then the virus rapidly became highly pathogenic and spread to 42 farms and eleven backyards. The Government of Canada made a decision to destroy the poultry from the entire control area—an estimated 19 million birds—to keep the disease from spreading. Thus, a pandemic was averted—for the time being.

In his work, Jean leads an inter-institutional and multidisciplinary team that recently received $1.5 million from the Pandemic Preparedness Strategic Research Initiative of the Canadian Institutes of Health Research (CIHR). The largest award of its kind in Canada, it supports international collaborative research in influenza virus biology associated with human and avian flu. The team of world-class researchers from Canada, the US and China will study the genetics of H5/H7 infA viruses to understand how the disease manifests both in birds and humans, as well as the animal–human interface. This research includes co-supervision and inter-institutional training of graduate students and post-doctoral fellows in the HP H5/H7 infA virus field. "The results of our proposed study on the HP influenza A virus biology and pathogenesis will help to define new models for risk assessment, disease surveillance and pandemic preparedness," Jean says.

FINDER Functional Infectomics

François Jean is the scientific director of UBC's Facility for Infectious Disease and Epidemic Research (FINDER). Jean leads a major research initiative on the biology of risk group 3 (RG3) viruses of concern in Canada and around the world (e.g., influenza A H5N1 virus, West Nile virus, HIV-1, and SARS-CoV) in order to catalyze the discovery of novel classes of antiviral drugs. FINDER, funded by CFI and BCKDF infrastructure grants (Centre for Disease Modeling, $19.3 million, 2004), is equipping Canadian and international researchers with the resources to apply cutting-edge genomics, proteomics and imaging or "infectomics" tools to the research of RG3 pathogens.

Combating Re-emerging Viruses

West Nile virus (WNV), a member of the *Flaviviridae* family first discovered in 1937 in Africa, is now considered endemic in North America. Since its first appearance in New York in 1999, WNV has undergone a dramatic expansion of its ecological niche across Canada and the US, with several thousands of human cases across North America. While no cases have been seen in BC as yet, WNV has changed its genetic makeup over the last ten years of co-evolution in the Western hemisphere. The virus has evolved to spread into the brain (neuroinvasive) of the human host, causing encephalitis, which can be lethal.

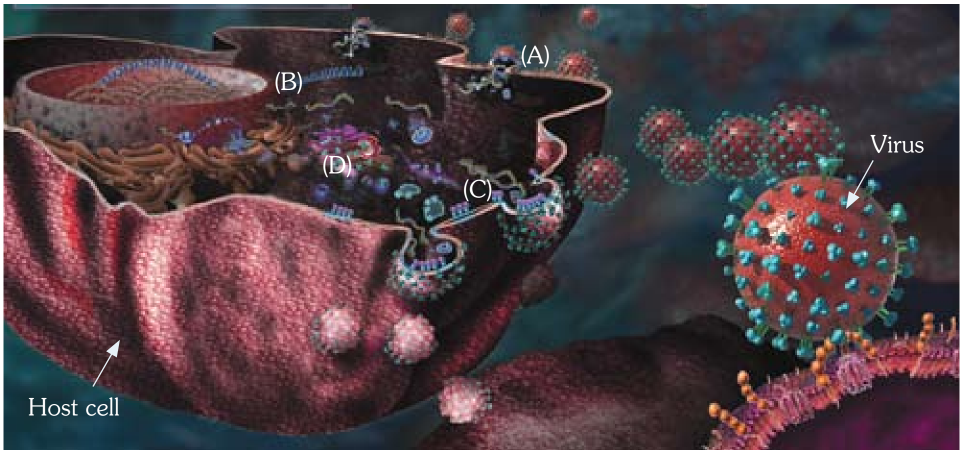
Another member of the *Flaviviridae* family, hepatitis C (HCV), identified 20 years ago, is continuously spreading around the world and has reached epidemic proportions. An estimated three percent of the world population is infected and around 170 million people are chronic carriers, including approximately 240,000 Canadians. HCV is referred to as the silent killer, since both acute and chronic HCV have no symptoms. However, persistent infection can result in liver disease and liver cancer.

"Despite the increased threat of these viruses around the world, our arsenal of treatment against *Flaviviridae* (HCV, WNV), *Orthomyxoviridae* (infA), and *Retroviridae* (HIV-1) is very limited," Jean says. "In the case of anti-*Flaviviridae* drugs, the current multi-drug regimen for HCV is not very effective against the most predominant HCV genotype circulating in North America, Japan and Western Europe. Anti-WNV drugs are just not available yet. And although anti-infA and anti-HIV drugs were initially successful, their therapeutic application is now seriously compromised by the rise of resistant viral strains around the world."

Jean and his staff are working on several lines of attack simultaneously: investigating inhibitors of both viral enzymes and host cell enzymes, and identifying both small-molecule and protein-based antiviral agents. "We are testing all of these approaches side by side and trying to find connections and synergies," he says. With multiple strategies for both viral and host-cell-directed targets, they hope to discover new antiviral agents and combination therapies that are more effective, less toxic and less susceptible to viral resistance than the current regimens.

Marine Compounds Stymie Viral Attack

During 2003, severe acute respiratory syndrome (SARS) spread quickly in 29 countries, including Canada, causing over 8,000 probable cases worldwide and more



Artwork: Sayo-Art

Discovery of Novel Antiviral Targets and Class of Antiviral Drugs. *On this HIV life cycle representation, (A) to (D) indicate Jean's research into various viral and host cell pathways and his strategy goals for developing inhibitors that eventually stop infection. (A) Virus adsorption, virus-cell fusion. Goal: co-receptor antagonists, fusion inhibitors. (B) Reverse transcription (RT), integration, transcription. Goal: RT inhibitors, integrate inhibitors. (C) Translation, proteolytic cleavage, assembly, budding. Goal: novel class of viral protease inhibitors. (D) Cell protease. Goal: novel class of cellular protease inhibitors. Outcome: new combination therapy (C, D).*

than 700 deaths. "At this point, it appears that the SARS coronavirus (SARS-CoV) is in remission, but it continues to exist in animals and could well re-emerge in the human population again," Jean says.

In 2004, Jean's research group initiated a pilot project with Raymond Andersen at UBC to discover new anti-SARS small molecules derived from natural marine extracts. "Nature has been generating all sorts of metabolites over millions of years, and the biodiversity is phenomenal. We just cannot reproduce that with synthetic chemistry," says Jean. Funded by CIHR and NCE/PENCE, the studies resulted in the development of a new high-throughput (HT) fluorescence-based assay, which is now used to identify small-molecule anti-SARS agents from marine organisms. Using the HT screening assay platform, the team identified a new inhibitor, marine compound 8 (MC8) in the marine sponge *Axinella corrugata*. Studies performed with Richard Kao at the biocontainment level-3 laboratory at the University of Hong Kong have confirmed the existence of MC8 anti-SARS activity in the cell-based system of SARS-CoV infection. "Our results have triggered considerable research in the potential of marine-based compounds to work as viral protease inhibitors with good inhibitory activity and low toxicity in human cells," Jean says.

"We have since tested a wide range of marine-based compounds against other important viral proteases and recently discovered two nanomolar inhibitors¸ compound 11 (C11) and compound 21 (C21), that are selective against the *Flaviviridae* HCV NS3 protease," Jean notes. HCV NS3 protease as an effective target for anti-HCV therapy was recently validated in a clinical setting by three research teams using competitive small-molecule protease inhibitors (PIs). "Given the limited number of such inhibitors in clinical trials, as well as the likelihood of eventual resistance to monotherapy, there is an important need to identify and develop a new class of small-molecule HCV NS3 PIs," Jean says.

His lab's C11/C21 analogs were recently patented with UBC's University-Industry Liaison Office. Their work on HCV NS3 PIs is supported by a Proof of Principle phase I CIHR grant. The goal is to scale up synthesis of C11/C21 to demonstrate their anti-HCV properties using cell-based systems of HCV replication and infection. This project also aims to identify C11/C21 analogs through a virtual screening strategy, using a powerful *in silico* chemical library screening approach.

Innovative Targeting of Host Enzymes

Worldwide nearly half of all antiviral drugs available are small-molecule inhibitors that target virally encoded enzymes (e.g., protease, helicase, polymerase, reverse transcriptase). Yet drug-resistant viruses continue to evade treatment, leaving few or no alternative therapeutic agents available. Although combination therapies have reduced the number of emerging resistant variants over the last decade, new global antiviral strategies are required to aid in the creation of therapeutics with novel mechanisms of action. Jean's team is proposing to shift the current paradigm on global antiviral strategies towards the exploration of host-directed drug targets to create a new class of therapeutic agents.

The team's primary goal, funded by CIHR, is to develop new drug leads that target recently discovered host enzymes from the proprotein convertase (PC) family. These host enzymes are essential to viral infection for a number of serious human viruses such as HIV-1, HP H5/H7 infA and WNV. "Our hypothesis is that because the therapeutic targets are cellular enzymes, resistance by mutation of the virus is highly unlikely," Jean says. "By developing selective and potent cellular enzyme inhibitors as antiviral drugs, my lab is pioneering a new global antiviral strategy directed at inhibiting the host-mediated activation of viral glycoproteins in the secretory pathway of the cells, an essential processing event for virus infectivity."

The results of a series of recent studies performed with a protein-based inhibitor of PCs discovered in the Jean lab, Spn4A, demonstrate that developing novel host-directed broad-spectrum biopharmaceuticals is achievable. Team member Vesna Posarac, in collaboration with Peter Cheung at the BC Centre of Excellence in HIV/AIDS at UBC, recently demonstrated the anti-HIV properties of Spn4A in cultured cells.

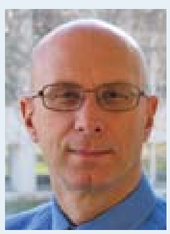
Team Members and Research Funding
The Jean lab team (2008/09) includes graduate students Heather Braybrook, Stephanie Condotta, Christine Lai, Emma-Kate Loveday, Andrea Olmstead, and Meera Raj; post-doctoral fellow Julius John; lab technicians Martine Boutin and Ingrid Hao; Co-op students Pamela Lincez and Vanessa Silva; and research assistant Steven McArthur. Morgan Martin and Vesna Posarac graduated in 2008. Research in the Jean lab is currently supported by three CIHR operating grants (F. Jean, PI). The trainees are supported by UBC, CIHR, CIHR-TRID, and MSFHR.

New Appointments

Professor Doug Bonn was appointed head of the Department of Physics & Astronomy January 1, 2009. His administrative background includes serving as chair of the university's Senior Appointments Committee. Bonn's research into the electromagnetic properties of high-temperature superconductors has helped make UBC a world leader in the area. His main focus involves unravelling the origin of high-temperature superconductivity—a major unsolved problem in condensed matter physics. Bonn was awarded a Killam Research Prize in 1999 and, in 2005, shared the NSERC Brockhouse Canada Prize with colleagues Walter Hardy and Ruixing Liang. "Since joining UBC in 1989, Bonn has made many valuable contributions to the department, the Faculty of Science and the university," notes dean Simon Peacock. Bonn succeeds physics professor Jeff Young, who provided five years of excellent leadership. www.physics.ubc.ca

Craig Hart was appointed director of UBC's Mineral Deposit Research Unit (MDRU) and grant-tenured associate professor in the Department of Earth & Ocean Sciences January 1, 2009. UBC alumnus Hart returned to UBC from the University of Western Australia (Perth), where he was a senior research fellow at the Centre for Exploration Targeting. He completed his PhD at the University of Western Australia (2004) working on the Tintina Gold Belt in the Yukon and Alaska, research he began as a geologist for the Yukon Geological Survey. "On behalf of the board, I welcome Craig back to Canada," notes Ian Graham, chair of the MDRU board of directors. "We look forward to working with him to continue the research and training excellence that has been established at MDRU through the previous directors." Hart succeeds Richard Tosdal, who spent nine years at the helm of MDRU. www.mdru.ubc.ca

Tara Ivanochko was appointed an instructor in the Department of Earth & Ocean Sciences January 1, 2009. Ivanochko, who teaches environmental science, provides a direct connection between the curriculum content and events that are timely or significant in our daily lives. She motivates her students to understand the science underlying current world issues. Ivanochko's research looks into the mechanisms by which the tropical oceans exert influence on high-latitude climate change and vice versa. She reconstructs paleoenvironments and investigates climate change on decadal to millennial time scales. Ivanochko graduated with a BSc in Biology and Oceanography and an MSc in Marine Geochemistry from UBC, and earned her PhD in Paleoclimatology from the University of Edinburgh, UK. She was a research associate at UBC 2006 to 2008. www.eos.ubc.ca/about/faculty/T.Ivanochko.html



Allan Berezny was appointed assistant dean of Development for the UBC Faculty of Science February 1, 2009. He attended McGill University (BA and MA) and Queen's University (MPA) and has worked in the field of university development at McGill, the University of Victoria, Cardiff University (Wales), and the University of Northern BC. Throughout his career, Berezny has been active in securing funding for large initiatives. These include scientific and medical research projects involving agencies and donors in North America, Europe and Asia. Berezny looks forward to helping advance the work of researchers in UBC Science. For further information on how he and his team can be of assistance, contact him at 604-822-8686 or at allan.berezny@ubc.ca. science.ubc.ca/support/giving

Quentin Cronk joined the department of Botany as full professor in December 2008. He came to Canada from his position as Reader in Vascular Plant Systematics at the University of Edinburgh, UK, in 2002, when he was appointed professor and director of UBC's Botanical Garden and Centre for Plant Research. After six very successful years at the helm of the Botanical Garden, he stepped down from the position in order to devote more time to research. Cronk graduated with a BA Natural Sciences (Botany) and earned his PhD Botany from Cambridge University, UK. His appreciation for the vast diversity in plants and the impact it has on our lives and the lives of other organisms on the planet motivates Cronk's research into how this variation evolved at all levels—from the molecular to the ecosystem. www.botany.ubc.ca/people/faculty.html

Nigel Lockyer, director of TRIUMF (since May 2007), joined the Department of Physics & Astronomy as full professor July 1, 2008 (BSc Physics, York University, Toronto, ON; PhD Physics, Ohio State University, Columbus, USA). Lockyer came to Canada from the University of Pennsylvania (Philadelphia, USA), where he focused on high energy particle research, reaching into neighbouring areas such as accelerator science and medical physics. Owned by seven Canadian universities and located on the UBC Vancouver campus, TRIUMF is Canada's National Laboratory for Particle and Nuclear Physics. With 55 partner institutions and an international user community of nearly 1,000 scientists, it is one of the world's leading subatomic physics laboratories. www.triumf.ca

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Another team member, Heather Braybrook, is testing the efficacy of these PC inhibitors against HP H5 infA viruses, and the preliminary results are very promising.

The key to developing host enzyme inhibitors, they have found, is to knock down the target enzyme rather than knock it out, or eliminate it completely. "Just a reduction in the actual activity levels of the cellular enzyme can trigger the effect you are looking for while still allowing it to perform its natural biological function, and this reduces the risk of side effects," says Jean.

For Jean, developing effective, non-toxic antiviral drugs requires the best of multiple approaches. "The most effective line of defence might be a combination of small molecules and protein-based inhibitors, or a combination of inhibitors that target both viral and cellular enzymes," he says.

"What makes this research so exciting and challenging is that there are always surprises." ■

Environmetrics without Borders

Multi-Institution Courses Increase Options for Students

Technology is revolutionizing the way universities are delivering programs. UBC's Department of Statistics is at the forefront, with two new distributed graduate-level courses offered to students at four universities across the Pacific Northwest.

The Next Wave of Teaching and Learning. *Graduate student Luke Bornn, professor Jim Zidek and government scientist Nathaniel Newlands (from left to right) are in the middle of an interdisciplinary online conference on climate change management.*

Distributed programs, video conferencing and off-site or online classes have become buzzwords of educational institutions that are embracing the potential of technology to transform teaching and learning. But collaborative, interdisciplinary, inter-institutional—and international—courses that use this technology are as yet few and far between.

The idea to offer distributed graduate-level statistics courses was spearheaded by Jim Zidek, University of British Columbia (UBC), Peter Guttorp, University of Washington (UW), Charmaine Dean, Simon Fraser University (SFU), and Sylvia Esterby, UBC Okanagan (UBCO)—all members of the Pacific Institute for the Mathematical Sciences, or PIMS (see text box). With support from PIMS, the group established a collaborative research group (CRG) in the area of environmental statistics, or environmetrics.

"The Pacific Northwest has a number of very strong people in environmetrics, and we realized that we could offer a much richer program if we could bring together experts from across the region," says Zidek, professor emeritus and former head of Statistics at UBC. "One of the goals of the PIMS group is to develop an educational program to complement the research."

"The greatest benefit for students and the institutions involved is the ability to provide specialized graduate courses that we would not be able to do otherwise because of limited enrolment," says Sylvia Esterby, UBCO statistics professor and head of Mathematics, Statistics and Physics. "These courses also help to create an awareness of environmetrics as a career option."

To date, a number of students from the four institutions have taken the two course offerings. Their areas of study include quantitative ecology, urban planning, agriculture, and statistics. "This technology also facilitates international collaborations while cutting down on travel," says UW statistics professor Peter Guttorp, who teaches the first-semester course in spatial statistics.

The Challenges of Cross-Border Teaching

Guttorp notes that environmental issues are global issues, and having courses jointly offered in neighbouring countries like Canada and the US helps to address shared concerns and to develop more comprehensive management strategies. "Jim and I started working on acid rain a couple of decades ago, when there were very different approaches in the US, Canada and Europe. Yet, we all had the same problems, which required the same processes to model," he notes.

Zidek and Guttorp are international leaders in environmetrics research. Zidek is a member of the Clean Air Science Advisory Committee for Ozone of the US Environmental Protection Agency (EPA). Guttorp contributed to the Intergovernmental Panel on Climate Change. They are concerned about leaving as small an environmental footprint as possible while sharing their expertise with students from the broad range of disciplines in the field of environmental science. Part of their goal in offering these courses is to develop a diploma or certificate program for those who already have graduate degrees and who want to gain advanced credentials to further their careers.

Trials of Long-Distance Teaching

Offering distributed courses is not without challenges, however. First, there is the matter of scheduling courses in different institutions with different timetables. UBC is on the semester system, while UW is on the quarter system. Second, students need to be able to receive credits from a course offered by another institution. For UBC, UBCO and SFU, arrangements are already in place through the Western Deans' Agreement. In order for Canadian students to receive credits from Guttorp's course, taught out of UW, Zidek, Dean and Esterby, with Paramjit Gill, are co-instructors at their respective institutions. "Peter does the teaching and reviews the assignments first, then we review them for UBC and SFU students and assign final grades," says Zidek.

Perhaps the biggest challenge is the technology itself. However, the students seemed to take it in stride although there were initial glitches with sound and video. Some even expanded on the theme, using Skype online video conferencing to discuss their projects.

"The technology was a bit of a challenge at first, but it improved over the course of the semester," notes UBC PhD student Luke Bornn. "We were able to see, hear and interact with students from the other institutions, and we even worked directly on

PIMS' Cumulative Collaborations

The Pacific Institute for the Mathematical Sciences (PIMS) was created in 1996 and funded by NSERC to establish a mathematical research community in the Pacific Northwest. Today, PIMS connects researchers in eight universities in BC, Alberta, Saskatchewan, and Washington State. PIMS' mandate is to promote research in the mathematical sciences and their applications, to enrich public awareness, and to develop collaborative research groups and educational programs.

Pacific Institute *for the* Mathematical Sciences

"We have a wealth of talented mathematicians in Western Canada and Washington State, and the whole structure of PIMS is designed to bring people together and create a critical mass for research and education," says PIMS director Alejandro Adem. To facilitate their mandate, equipment and facilities upgrades are planned. PIMS is also assuming the WestGrid node for video conferencing at UBC. WestGrid operates high-performance computing, collaboration and visualization infrastructure across western Canada. www.pims.math.ca

one of the labs with someone from UBC Okanagan."

"Mathematicians come from a culture of blackboard and chalk. To write formulae on PowerPoint slides is cumbersome, so we want to provide facilities that people feel more comfortable using," says Alejandro Adem, director of PIMS. "We are planning to upgrade equipment, which will include a SMART board so that instructors will not have to prepare slides."

Tackling Uncertainty and Data Gaps

Inherent in all environmental and natural phenomena is complexity and uncertainty. One of the biggest challenges for statisticians is developing mathematical models that take this complexity and uncertainty into account in order to make inferences—or fill in the gaps—when data are absent or unreliable.

Spatial statistics, the topic of Guttorp's course STAT 546, was first developed for the gold mining industry in South Africa to predict the amount of gold in locations under the ground based on core samples. Now, the subdiscipline is critical to studies in population dynamics, epidemiology, ecology, and climate change.

Zidek cites an example he has confronted while serving on the ozone panel for the US EPA. "One of the factors we had to consider was the effect of ozone on crop yields," he explains. "The trouble is, ozone is not well monitored in rural areas of the US where crops are grown." Spatial statistics methods were used to impute unobserved levels of ozone in those rural areas, which then were used to develop new air quality standards for ozone, proclaimed in March 2008.

Applying Statistics to Agriculture and Ecosystems

The second distributed course (STAT 547) is offered by UBC and taught by Nathaniel Newlands, a research scientist with Agriculture and Agri-food Canada out of the University of Lethbridge. "The motivation was to expand on mainstream curriculum and to showcase actual examples so that students can apply the theory to real-world problems," he says.

Newlands notes that the complex behaviour of ecosystems is cumulative, multi-scale, interactive, and adaptive. Finding new ways to describe this complex cascade is critical, not only to students, but to the public as well. "Our department and the government in general are interested in developing suites of models so we can package our research and deliver it to different decision makers, whether they are farmers, managers or people involved in crop insurance."

Newlands' perspective as a government scientist benefits students who want to graduate with practical skills. The six-week course summarizes various statistical methods, including a spatial analysis method developed by Zidek. Students are then presented with a problem and must determine what approach works best. "The idea is that students work collaboratively to synthesize the methods and then adapt and improve them," says Newlands.

Rossella Onorati, PhD student, UW Statistics: "My interest has always been in environmental problems, so key benefits of this course are being able to study real-world examples and compare several statistical techniques, many of which are recent developments. The technology is a good way to interact over a large distance, but I will wait for my final presentation to test it!"

Luke Bornn, PhD student, UBC Statistics: "I took these courses because it was an opportunity to work with some renowned experts in specialized fields and to be exposed to subjects that I wouldn't have had a chance to study. I started in computational methods in statistics, but moved to environmetrics because it is a field that has a lot of possibility. It involves many open problems that need to be solved—problems that will exist for years to come, and I may have the chance to be part of the solution."

Managing Climate Change in Canada

While wine may not be a necessity of life, it is certainly an elixir—and an important agri-food industry in Canada. One student of STAT 547 is working with Newlands and principal investigator Denise Neilsen on a project to predict how grape vines in the area around Summerland, BC, are going to react under climate change. "We foresee the growing region of grapes will be shifting further north, so we want to look at soil types and water needs for what would be a northward expansion," says Newlands. His class is also working on a project with Environment Canada and the BC Agricultural Research and Development Corporation to map the historical climate of southern BC. Hopes are to expand this work over the entire province. "One of the most difficult phenomena to model spatially is climate—in other words, temperature and precipitation," he notes. The group is expanding work done in the BC Okanagan to the surrounding mountainous zone and

Active Engagement Enriches the Learning Experience

Earth & Ocean Sciences Clicks in the Classroom

The Carl Wieman Science Education Initiative and a curriculum review in the Department of Earth & Ocean Sciences affect the learning experience of thousands of students through interactive tools and innovative teaching approaches.

When Sara Harris and Roger Francois, two oceanographers in the Department of Earth & Ocean Sciences (EOS), co-taught a first-year course for non-science students last term, it was the first time Francois used "clickers" in the classroom. A research scientist, he only began teaching large survey courses when he joined UBC four years ago.

Clickers are remote control-like devices that allow students in the classroom to anonymously answer multiple-choice questions at the click of a button. The results can be tallied and shown to the students immediately.

"The obvious and basic use of the clickers is as a quiz tool," says Harris, who has used this personal response system since 2006. "But when you pose thoughtful questions, they become a powerful facilitator of discussions." Harris, who says using the device was a learning experience for her too, has been working with the Carl Wieman Science Education Initiative (CWSEI) to incorporate clickers and other innovative teaching methods into EOS courses.

Recent surveys show that students are finding the clicker exercises challenging—they provoke students to discuss material both before and after they register an answer. Francois, a professor and the Canada Research Chair in Marine Geochemistry, notes, "There is definitely more interaction among the students and with me compared to before. Essentially, you see students becoming more interested and more involved." In fact, he says, he often gets bombarded with questions after class by students invigorated by the discussions. "You feel that you're doing a better job. It's gratifying."

"I think it's very inspiring when students collectively have this 'ah-ha' moment," says Harris. "As an instructor, I often work with individual students who come to my office confused. We'll go through a concept together and when they get it, it's great. But that's one student—when it happens with most students in the class, it's so much more satisfying." This infectious sense of satisfaction may be why 62 percent of tenure-track EOS faculty members are currently engaged in some form of pedagogical reform, according to recent statistics compiled by Brett Gilley and Francis Jones, two of the four CWSEI Science Teaching and Learning Fellows (STLFs) working in EOS.

"Faculty members are involved either as lead instructors in one of 12 currently targeted courses, as members of corresponding workgroups or by receiving specific support from the STLFs," says Jones. "We estimate that out of the more than 6,200 students who enrolled in EOS courses last year, 70 percent were affected by these efforts." STLF Erin Lane, for instance, has been providing support to Francois's class by carefully measuring the degree to which students are paying attention and participating and by documenting what types of teaching activities achieve the most engagement. Her feedback has allowed Francois to fine-tune his teaching approach.

In addition to activities supported by CWSEI, EOS was the first of the nine Science departments to receive funding for a five-year transformative plan. The department is also undergoing a curriculum review to ensure that its eleven bachelor degree streams are made up of courses that progress logically and meet the needs of the students. "At the best of times, curriculum reform is like pushing water uphill with a garden rake," says EOS department head

Source: Adapted from an article by Brian Lin, published in UBC Reports, Vol. 55, Mar 2009

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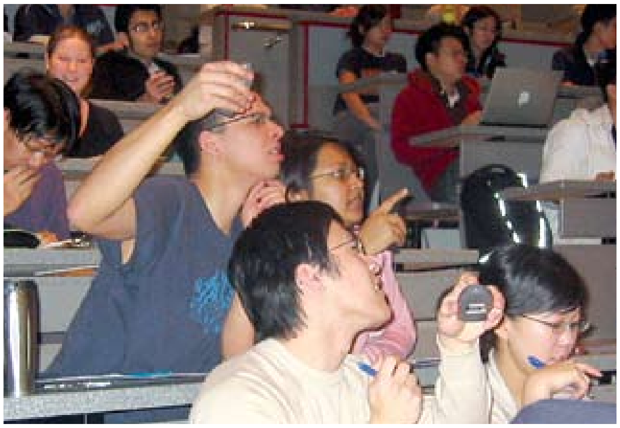
looking at historical data on a daily scale from 1916 to 2006. The goal is to produce spatial maps of climate variables that can be used to analyze climate extremes and be input into a variety of different models—such as water budget and crop models. Students have to deal with variability of weather, rainfall and elevation, as well as integrating various scales. Some models require daily information, while some require hourly or broader, monthly information. In addition, there are fewer weather stations at higher elevations.

The students' task is to apply spatial kriging—a method of interpolation for geographical information—to model data uncertainty, particularly with respect to elevation. As if their task wasn't tricky enough, Newlands added another twist. "What I didn't tell students is there is a temperature elevation inversion that establishes itself seasonally within this region." Newlands is pleased with the progress to date. "The students already had broad and advanced understanding of geostatistics after taking Peter's course, and combined with more information on applications and methods for conducting sensitivity and validation analysis, the students had the range of informed questions and tools to immediately test approaches."

Plans are underway to include other projects in future courses, such as modelling of hydrology, climatic extremes, greenhouse gases, and issues around biofuels. The ultimate goal—and one that is already being achieved as part of this course—is enabling young researchers to contribute in creative and innovative ways that ultimately help to shape policies and make a difference for society as a whole. "The younger generation wants to help solve environmental problems, but there is a gap between jobs that allow that and their expertise," Newlands says.

"We want to train students to think both laterally and in depth so that when they encounter these problems in the employment setting, they can adapt approaches based on the specific needs of stakeholders and other interest groups." ■

Photos: Daryl Smith (left), Martin Dee (right)



Active Engagement in the Classroom. *Clickers are remote control-like devices that allow students in the classroom to anonymously answer multiple-choice questions.*

Paul Smith. "This is because it takes considerable time and energy, both of which are in short supply in the busy lives of faculty. The combined efforts of CWSEI and the universal curriculum review, however, have contributed to a high level of enthusiasm within the department."

Professor and air pollution meteorologist Douw Steyn teaches second- and third-year courses in the environmental science program and uses a variety of activities to keep his students deeply engaged. "As instructors, our role is to facilitate student learning rather than capturing them by way of lecturing or making them read a particular set of texts for a course," says Steyn. "And we've got to instill in them a sense of responsibility for their own learning."

One deeply engaging activity Steyn employs is having his students conduct a mock town hall meeting on topical environmental issues, such as fish farming. Students explore different perspectives on the issue through role playing: as scientists they present findings on the environmental impact; as government officials they promote economic growth; or as journalists they cover the meetings. "The students have to research not only the technical side of fish farming, but all of the opposing and proposing views," says Steyn. "Then they have to communicate it."

What the CWSEI has added to this teaching style, says Steyn, is the scientific investigation of the impact different approaches have on student learning. With the help of STLFs, the department is evaluating student understanding of key concepts, participation in class and overall attitude towards their field of study. Evaluations are done before and after specific courses or modules within a course.

Science Teaching and Learning Fellows

Many Science departments have hired Science Teaching and Learning Fellows (STLFs) who work closely with the CWSEI. Combining an expertise in a specific discipline with knowledge of relevant science education methodology, the STLFs assist the departments to implement sustainable educational improvements. They help faculty members with introducing new teaching tools and assess the effect of new approaches on the students' learning. STLFs are also establishing and maintaining a web-based resource of the educational materials developed and tested in courses, along with assessment results. Currently, the Faculty of Science has eleven STLFs supporting department efforts to advance our students' learning experience. The most recent appointment is Joshua Caulkins in the Department of Earth & Ocean Sciences.

The CWSEI is a $12 million initiative headed by Nobel Laureate and physics professor Carl Wieman and aimed at systematically advancing and scientifically measuring the effectiveness of undergraduate science education at UBC. www.cwsei.ubc.ca

As for Francois, he is now co-teaching the course he shared with Harris with another instructor who, in turn, is using clickers for the first time.

For more information on the EOS education initiatives, visit www.eos.ubc.ca/research/cwsei. ■

Photo: Martin Dee

Physics Nobel Laureate Bases New Teaching and Learning Approaches on Scientific Research

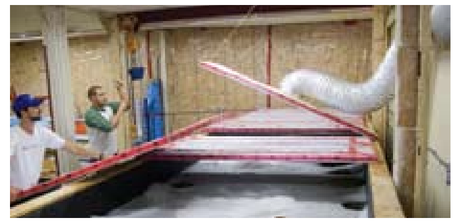
"Research on learning shows that students learn more effectively when they construct their own understanding of scientific ideas within the framework of their existing knowledge," says Carl Wieman, physics Nobel Laureate and director of UBC's Science Education Initiative.

Research on his Physics Education Technology (PhET) project shows that interactive computer simulations motivate students to actively engage with the content taught, which in turn helps them to learn effectively through that engagement. The PhET project has developed more than 80 interactive simulations. These cover various topics in physics and real-world applications, such as the greenhouse effect and lasers. Research on the design and use of these interactive simulations in a variety of educational settings found students showing higher mastery of the concepts than students in parallel courses using traditional instruction. Feedback from the students reveals that the simulations—through their dynamic visual environment, the challenges posed and the visual complexity—are found to be fun and intellectually engaging.

Another approach to increasing student engagement—leading to improved student performance—involves the use of clickers that trigger peer discussions on in-class concept questions. Recent research indicates that peer discussions enhance understanding, even when none of the students in a discussion group originally knows the correct answer.

Results of this research co-authored by Carl Wieman have been published in *Science*, Vol. 322, Oct 2008, and Vol. 323, Jan 2009. More references on science education research can be found at www.cwsei.ubc.ca/resources/papers.htm.

Enzymes Clean Whale Bones
Nature Helps Create a World-Class Exhibit



Photos: Andrew Trites

Last spring, the bones of a blue whale buried on the coast of Prince Edward Island 22 years ago travelled across the continent to British Columbia. The skeleton was destined to become the core attraction at UBC's Beaty Biodiversity Museum (see *Synergy* 1 | 2008), which is scheduled to open in early 2010. Imagine 6,000 kilograms of gigantic, stinking whale bones. Now picture the enormous cleaning task that lay ahead. While the flesh had been stripped off at the burial site, the bones were still drenched with a rancid oil that amounted to a third of the skeleton's total weight. The solution? In May 2008, the bones were moved to Victoria, BC, where they were put in large, custom-designed tanks in a studio space generously donated by Ellice Recycle Ltd. Master articulator Mike deRoos and his team—responsible for cleaning and reassembling the skeleton—immersed the bones in 10,000 litres of water containing pure enzymes and bacterial microbes. This blend, provided by Novozymes A/S, facilitates organic degreasing of the bones, thus also controlling the odour. Enzymes such as proteases and lipases—similar to those we have in our stomach—catalyze the breakdown of fats, or whale oils, into water-soluble fatty acids. These, in turn, are consumed by the microbes. "The cleaning phase has proven to be one of the most challenging aspects of the project," says deRoos. It was expected that the bones would soak in the aerated solution at about 40° Celsius for several months before the oil removal would be complete. Since this method had never been applied on such a huge scale before, exact time predictions could not be made. By November 2008, however, substantial amounts of oil still remained in the bones. A group of UBC researchers—including the Michael Smith Laboratories' Gary Lesnicki, and microbiologists Doug Kilburn and Tony Warren—were asked to assess the degreasing method. Based on their recommendations, the process was adjusted. Increasing the temperature of the solution, for instance, boosted the rate of oil extraction significantly. "Once the bones have lost their oil content, the team will assemble and install the complete skeleton in the museum's specially built glass atrium," says Wayne Maddison, director of the Beaty Biodiversity Museum and Canada Research Chair in Biodiversity and Systematics. "Blue whales are the biggest animals that have ever lived on earth. This magnificent skeleton will inspire Canadian citizens' imagination about biodiversity and about how we can further discover and sustain an essential level of biodiversity in Canada and around the globe."

www.beatymuseum.ubc.ca

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