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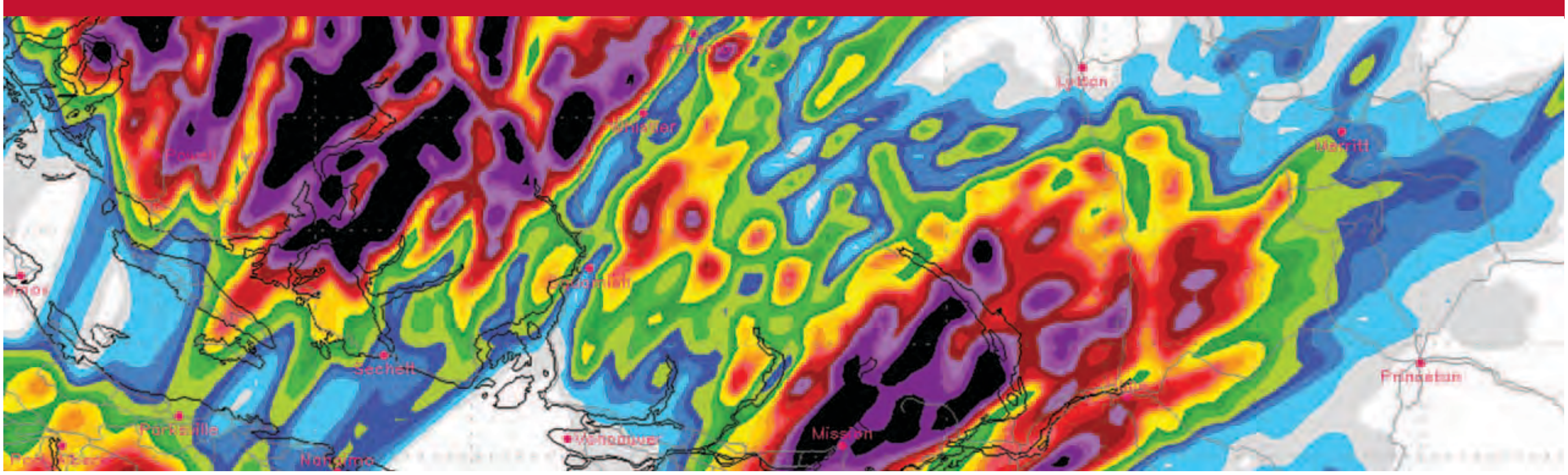


Words from the Editor

Dear Reader,

I am pleased to present our second issue of SYNERGY—Journal of UBC Science. Last spring, we launched a new look and shifted the focus of the publication to give you more in-depth articles on current research and discoveries in the Faculty of Science at UBC. Your considerate feedback has been very encouraging and we have taken your comments to heart. For example, you may notice slight changes to enhance readability.

Again, we are striving to represent the diversity of our researchers and the fields in which they work. They are as diverse as our readership.

In this edition of SYNERGY you will learn about chemist Don Douglas' work in gas phase ions and innovative mass spectrometry instrumentation for analyzing biomolecules; meteorologist Roland Stull's research in computational fluid dynamics to create real-time weather hazard predictions; statistician Will Welch's models for high-throughput screening in drug discovery; and zoologist David Jones' novel method of measuring blood pressure in dead fish.

Our regular features highlight the Faculty of Science's ongoing efforts in research and education. This issue focuses on our Math department, two major infrastructure grants, and the Faculty's recent recruitment success,

as well as research awards won by the faculty members in our nine departments.

We hope you enjoy this edition of SYNERGY—and we always like to hear from you! Please e-mail your comments to: synergy.science@ubc.ca

Carola Hibsch-Jetter

Innovations in Mass Spectrometry

Analyzing Ions from Atoms to Proteins

Chemist Don Douglas and his lab are working on both sides of the research spectrum. They are doing fundamental research on gas phase ions and developing new techniques in mass spectrometry for applications in biotechnology.

Analytical chemists have been using mass spectrometry as a tool for decades. In the past fifteen years, however, there has been a resurgence of interest in this process for the detection and measurement of trace substances, in the analysis of proteins and their binding mechanisms, and in sequencing small amounts of peptides.

"The interest of biotechnology and pharmaceutical industries has generated a dramatic growth in this area of research," says UBC professor and NSERC-Sciex Industrial Research Chair holder, Don Douglas, who is working in the forefront of this burgeoning field.

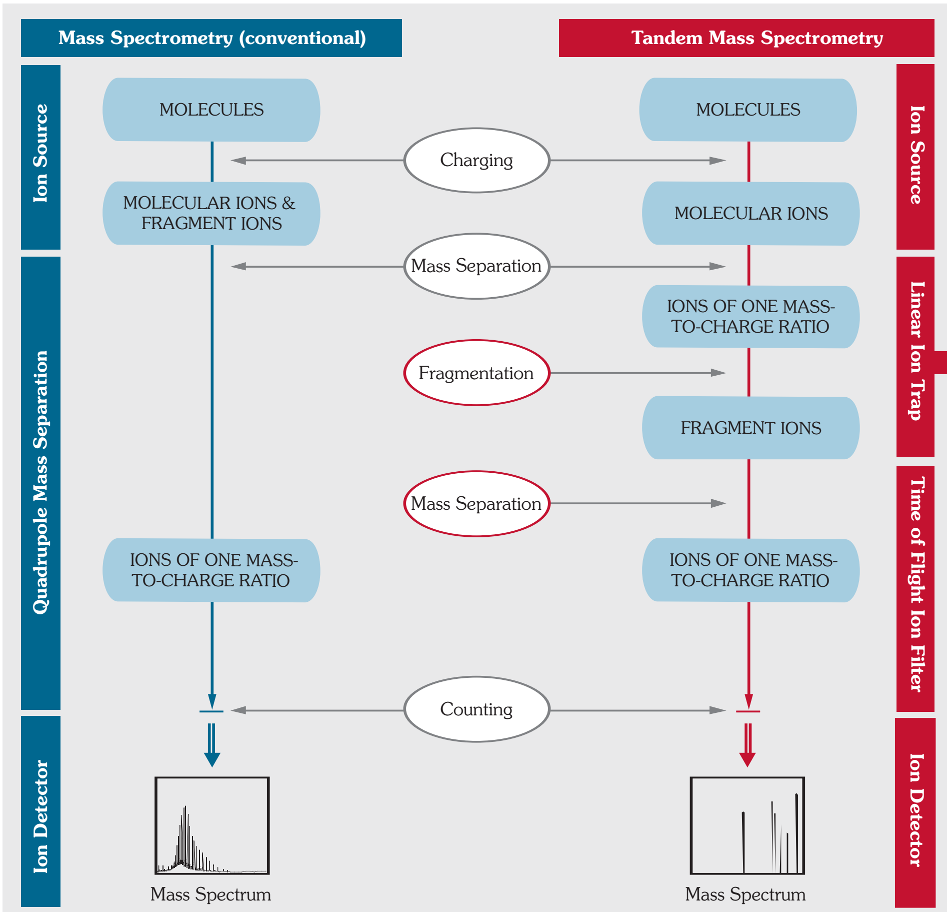
The procedure involves electrically charging neutral molecules to form ions, which are separated by electric or magnetic fields according to their mass and charge. A quadrupole mass filter is widely used for this process. It consists of four parallel rods with alternating positive and negative rods. By applying direct current (dc) and radiofrequency (rf) electric fields between the rods simultaneously, ions with a specific mass-to-charge ratio pass through the analyzer and are collected at the detector, while the rest of the ions collide with the rods. Ions with different masses are collected sequentially by changing the voltages, or field strengths, over time. The output, or mass spectrum, is a graph of the intensity of ions versus their mass-to-charge ratio (m/z).

Detecting Trace Elements with ICP-MS

Mass spectrometry for trace element analysis has become a critical tool in medicine, drug testing and environmental applications. Typical questions it can answer are: How much lead is in a child's blood? How much gold is present in a rock sample? What is the level of mercury in river water?

Douglas helped to develop a technique for the analysis of trace elements called inductively coupled plasma mass spectrometry (ICP-MS). It was first commercialized by Sciex, where he was principal research scientist before coming to UBC in 1995. In this method, samples are injected as fine aerosols into argon that has been heated to 5,000 K to form a plasma (a highly ionized gas in which the number of free electrons is approximately equal to the number of positive ions). At this extreme temperature, the material is vaporized and atomized, usually into atomic ions with a single charge. The ions are then extracted into a vacuum and separated according to their mass-to-charge ratios. ICP-MS also can scan for many elements from a single sample.

"In the old days, lengthy chemical separations were required to isolate these elements," says Douglas. "Now the separation part is minimized and the mass spectrometry does the cleanup. It is very fast and requires minimal sample preparation." Of all multi-element techniques commercially available for



Tandem Mass Spectrometry. *Advancing conventional mass spectrometers, Don Douglas and his group analyze complex organic compounds by employing a second mass spectrometer that involves ion trapping and an additional fragmentation step.*

This Linear Ion Trap's rod set *of two disparate pairs of rods (see below) increases the fragmentation efficiency and the overall sensitivity of the mass analysis.*

trace element analysis, ICP-MS has the lowest detection limits; it can detect elements at much lower concentrations than other methods.

In a recent project, Douglas developed a new method of extracting ions from argon plasma, which increased the efficiency by a factor of 100—or 10,000 percent—a critical development for applications that have small samples containing low concentrations of the target element.

Innovative Electrode Geometry

Whereas ICP-MS produces ions of trace elements with a single charge, electrospray ionization is the technique that Douglas' lab uses for macromolecules—producing protein ions with up to ten or twenty charges, depending on the protein.

Linear ion traps use an arrangement similar to a quadrupole mass filter to trap, rather than filter, ions. This is done by placing electrodes on the ends of the device to create high positive potentials to prevent positive ions from escaping. "You can adjust the voltages so ions of a broad range of m/z ratios are stable in the trap," says Douglas. Once all the ions from a sample are trapped, those with a certain mass can be isolated, then fragmented and separated again by m/z. This process is called tandem mass spectrometry.

Douglas and his group are interested in linear ion traps, versus earlier 3-D ion traps, because the injection efficiency into the trap is nearly 100 percent, instead of 1 to 10 percent for 3-D traps. Another advantage is that their volume can be increased to store more ions by simply lengthening the rods.

Using tandem mass spectrometry, ions of peptides and other small organic molecules can be fragmented and analyzed for structural information. "If you understand the fragment spectrum, you can then determine the sequence of amino acids in that peptide," Douglas explains.

The challenge is getting the ion to fragment before it strikes an electrode. With the assistance of Michael Sudakov from the Department of Physics at the University of Ryazan in Russia, Douglas and his UBC lab have devised a linear ion trap that favours ion fragmentation by distorting the geometry and adding a second type of electric field (an octopole field) to the quadrupole field. "Michael decided that the best way to add an octopole field was to make two of the four rods bigger." Early experiments show that the new geometry can be at least five to ten times more efficient at making fragment ions.

"Sciex, our industrial partner, is interested in increasing fragmentation efficiency, but they also want a linear ion trap that can be used as a regular quadrupole mass analyzer," Douglas says. According to accepted science, however, in order to do mass analysis, all the rods have to be exactly the same size—within micron tolerances. Undaunted, Douglas and his research assistant Chuanfan Ding tried a couple of different rod sets until, unexpectedly, one worked.

"We found that these asymmetrical rod sets will do mass analysis as well or in some cases even better, with higher sensitivity, than a normal rod set, but the key is in how you apply the dc voltage to the rods," Douglas says. To mass analyze positive ions, they apply the positive dc voltage to the smaller rods. For negative ions, the dc polarity is reversed. His lab is also testing to see if the new rod sets will be able to do axial ejection—where ions are expelled out of the linear ion trap in order of their mass.

"Other researchers are still writing papers on why 3-D ion traps work better with distorted geometry," says Douglas. "We are trying to figure out why and how our new geometry works on linear ion traps." His group's work in innovative instrumentation design may be motivated by applied science, but it clearly requires the insight and serendipity of basic science as well.

In order to perform the myriad of biological functions required by living organisms, the structures of protein molecules allow them to recognize other molecules in very specific ways, which are critical for binding. But what happens to that protein when you take it out of solution and put it in a vacuum? Does it "remember" its complex folding pattern? Does it bind with other proteins in the same way? Very little is known about the structure of gas phase ions and substrates. The other side of Douglas' research is trying to answer these very fundamental questions.

Studying Gas Phase Biomolecules

Electrospray ionization is used to produce gas phase ions at atmospheric pressure directly from ions in solution. This process is gentle enough that proteins up to a molecular weight of at least 100,000 can be ionized. "Some biologists might say this is a waste of time, because proteins always carry out their cell functions in solution," Douglas says. "But if we can find conditions where gas phase ions undergo the same chemistry as they do in solution, then, in principle, we can use mass spectrometers to do biochemistry and study small amounts of material much more rapidly and with more specificity." The applications for screening new drugs and developing "designer" proteins would be extremely important for Canada's biotechnology industry.

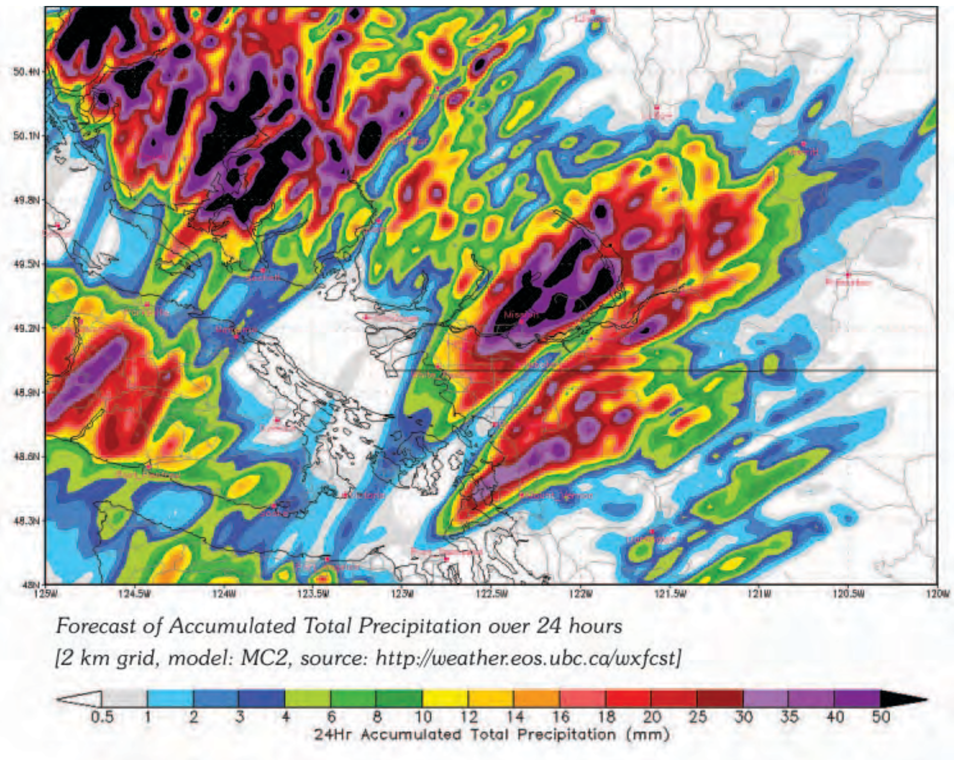
So far, their work is promising. In a collaboration with biochemist Grant Mauk (UBC Faculty of Medicine), they found that myoglobin, a protein that binds a heme group (haemoglobin makes blood red), has a similar folding mechanism in the gas phase as it does in solution. Douglas is also collaborating with UBC chemist Steve Withers to analyze the binding of inhibitors to enzymes that his group has isolated and studied.

"The hope is that one day we will be able to screen a protein against a huge library of compounds to quickly determine which ones it binds with," says Douglas. "It might only work for certain classes of proteins or small molecules, but we don't know yet; we are still in the early stages."

"With funding from both NSERC (Natural Sciences and Engineering Research Council) and industry, we have the freedom to explore fascinating things that may or may not pay off." – Don Douglas

Modelling Fluid Dynamics

Weather, Fire and Other Disasters



Forecast of Accumulated Total Precipitation over 24 hours
[2 km grid, model: MC2, source: http://weather.eos.ubc.ca/wxfcst]

"In order to model the fluid dynamics of weather, we have to solve for multiple variables in every location, and how they interact with each other at every instant in time, and how this affects the future weather at all points simultaneously." – Roland Stull

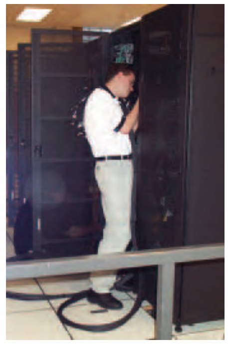
Researchers at UBC's Geophysical Disaster Computational Fluid Dynamics Centre (GDCFD) study the fluid dynamics of weather to create multi-scale, real-time weather hazard predictions, particularly for BC's rugged mountainous terrain.

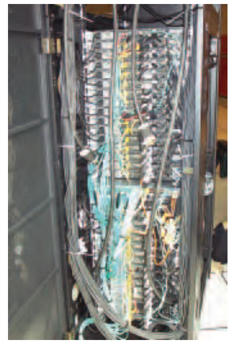
The atmosphere is a dynamic fluid of swirling cyclones, jet streams and turbulent eddies propelled by changes in wind, temperature, moisture, and pressure. The state of weather at any one location (over a weather station, a town or a house) depends on how all of these different variables are interacting and affecting change in different locations at the same time. Obviously, there is more to weather forecasting than "meets the eye," as Roland Stull, professor of Atmospheric Sciences attests.

"Weather forecasters use satellite pictures, radar and surface weather observations, but these tools only tell them what is currently happening," says Stull, who is also director of the GDCFD. "The only tool that can tell us the forecast is numerical weather prediction. If the model is not perfect, then the forecast won't be either."

Given all of the variables of weather, developing a multi-scale, real-time weather forecasting model is extremely complex. To capture the superimposed motion and scales of weather, numerical forecasting breaks the atmosphere into grids and then forecasts the average condition for each grid cell. Smaller grid cells provide a better resolution of data—and more accurate forecasts, particularly for British Columbia's mountainous terrain.

"Whenever you average the terrain height you are going to miss weather over high peaks and in the low-lying valleys," says Stull. "Most towns are in valleys, which have different weather than mountain peaks, so we need to get finer resolution to forecast the weather in steep mountainous terrains." Finer resolution, however, demands much more computing power.





Stull and colleagues use different grid sizes to examine different types of weather events: grids with 108 km cells capture large-scale "synoptic" events such as cyclones; grids with 36 km and 12 km cells capture "mesoscale" events such as fronts and mountain circulations; and 12 km, 4 km and 2 km cells model smaller scale events, such as thunderstorms.

Improving Accuracy with Embedded Grids

"We use these nested grids like a multi-stage rocket," Stull says. "We start with a course resolution forecast and each subsequent grid drives a finer grid."

Stull pulls up the website that shows the centre's daily, real-time numerical weather forecasts (http://weather.eos.ubc.ca/wxfcst). At the 4 km grid, we see a mesoscale cyclone moving east over Ucluelet. We can see the weather pattern is different in Tofino. Stull moves 24 hours ahead in time and we see the cyclone has reached the mainland. "In the mesoscale, we are talking about a circulation that is only a few kilometres long," says Stull. "This mesoscale system would probably be missed by Environment Canada's forecasting system." In fact, Environment Canada is one of the GDCFD's clients.

At the 2 km grid, you can actually forecast different weather in Point Grey, downtown Vancouver and North Vancouver. Unfortunately, this fine resolution model takes so long to run that even with the centre's enormous computing power (see sidebar) they can only afford to make a one-day forecast, versus the two-day forecasts for the coarser grids.

Stull and his colleagues at the GDCFD use the average of four different models of atmospheric fluid dynamics to increase the accuracy of their predictions. They have also collaborated with various government agencies to consolidate the different weather networks into an Emergency Weather Net for BC, which shares data from over 500 locations in the province. "Wherever there is a weather station, we can verify our forecasts every day against observations—and statistically learn from our mistakes," says Stull. The group uses a statistical method called Kalman Filtering to remove bias in the data, in order to determine what corrections should be made. Robust methodology requires verifying daily forecasts over a period of years.

The GDCFD has tailored products for such clients as BC Hydro, BC Rail, BC Ministry of Forests, CN Rail, FluxNet Canada, BC Ministry of Transportation and Highways, Parks Canada, and Whistler–Blackcomb. Smaller private companies—an orchard, winery, road service company, and port terminal operator—are also part of their diverse client base.

The centre has received funding from the Natural Sciences and Engineering Research Council (NSERC), the Canadian Computer Consortium, Environment Canada, the Canadian Foundation for Climate and Atmospheric Science, and the BC Ministry of Water, Land and Air Protection. In addition, le Laboratoire Universitaire sur le Temps Extrême (LUTE) is funding the centre to deploy weather stations around Greater Vancouver in order to improve local forecasts. "We know it is generally rainier in the North Shore than in Tsawwassen, but soon we will be able to forecast exactly when and where," says Stull.

Firestorm Project

Every summer, fires destroy large tracts of Canadian forests. The summer of 2003 was

"Monster" Computer Tackles Six-Dimensional Data

To produce multi-scale, real-time weather forecasts, the GDCFD processes over 100 gigabytes of data—and 5,000 new animations and weather maps—per day! "Our data is six-dimensional," exclaims Stull. "We have the three dimensions in space and the fourth dimension in time. The fifth dimension comprises multiple variables, such as winds, temperatures, and pressures, and the sixth dimension is the multiple realizations we get from the different ensemble models."

To handle the huge amount of data, a high-performance computing Linux super-cluster was built specifically for the centre by IBM. The computer was purchased with funds from the Canada Foundation for Innovation, the BC Knowledge Development Fund and UBC. "This research is too expensive to be purely applied or purely basic," says Stull. "By pooling funds from different funding sources—grants, industry and government clients—we have been able to afford the computers and the people to run them."

This July over 600,000 hectares of forest were burning in the Yukon. British Columbia had 1,000 fires burning over 150,000 hectares. (Source: National Resources Canada, 2004; Photos: Phil Maranda)

one of the most catastrophic fire seasons in British Columbia's—and Canada's—history. The images were terrifying. Walls of flames ravaged through tinder-dry forests at over 7 km per hour (150 square metres in four minutes), leaping several kilometres over highways, waterways and firebreaks, and destroying everything in their path. Nearly 2,500 fires burned more than 265,000 hectares at a cost of $375 million. More than 30,000 people were evacuated from their homes. Ten thousand firefighters and support personnel risked their lives to battle the flames.

These large fires actually alter weather, so forecasting their behaviour is extremely difficult. The Firestorm Project, led by Roland Stull and colleague Terry Clark, was initially funded by Forest Renewal BC in 2001–02, and covered three main aspects of forest fire forecasting. The first involved tailoring real-time weather forecasts to meet the specific needs of fire forecasting. In the second aspect of the project, Clark used ultra-fine resolution numerical simulation of real fires to better understand fire behaviour. "We would use these observations to try and determine how well we were able to predict the unknowns, such as fuel loading, burn rate, and fire front spread," says Clark.

The name "Firestorm" comes from the unpredictability of these huge fires, which have tremendous heat output and updrafts that suck enormous volumes of air back into the fire. "This fans fire even further, and causes the flame front to move in a direction and speed completely different from what forecasters would predict from synoptic-scale, ambient background weather," says Stull. "So the goal is to model the two-way interaction between the fire and the weather itself, including the effects of the steep topography that we have in BC."

To understand this two-way interaction, Clark's model examines the heat exchange between the fire and the atmosphere. This means working with flamelets and combustion at the molecular level, which requires much smaller grid cells, in the range of one to three metres. "In a moving wall of flames, probably only 10 percent is actual hot flame; the rest is air," notes Clark. "We want to know how the atmosphere arranges itself to exchange oxygen with the fuel."

The third aspect of their research involved flying over forest fires to study the flame-front dynamics. "Larry Radke was the airborne mission scientist who directed the pilot to fly us over the fires, and Jenn Rosberg was the student who was strapped in the back of the plane with an infrared camera and laptop computer," notes Stull. "Circling the fires in these steep mountains with all of the smoke, cold air and turbulence was very exciting."

Last year's fierce forest fire season impelled Forestry Innovation Investment Ltd.—the BC government's investment mechanism for promoting sustainable forest management—to extend Firestorm funding for 2003. However, the focus was on real-time weather forecasting rather than fire-behaviour simulation. Even with the GDCFD's enormous computing power, these models are still too large to run in real time. Stull is optimistic that with increases in computing power in the next five years—and crucial new funding—they will be able to use this basic research to better predict and fight forest fires, and help save lives, communities and industries across Canada.

"What makes the Firestorm Project unique is that this model also allows the fire to alter the weather, not just the weather to alter the fire."
– Roland Stull

Beating the Odds

Statistical Models Aid Drug Discovery

New Department Head of Statistics, Will Welch, uses statistical models to increase the efficiency and reduce the cost of high-throughput screening in drug discovery.

Most pharmaceutical research companies have corporate libraries of hundreds of thousands to millions of chemical compounds—huge data sets that potentially contain biologically effective substances useful for creating new drugs. With the advent of high-throughput screening (HTS) in pharmaceutical research, many compounds can be quickly tested for activity against a biological target. Although the cost per bioassay is relatively low, approximately 50 cents to five dollars per compound, screening every compound against every target is expensive and unfeasible, says Will Welch, new department head and professor of Statistics at UBC.

While HTS allows scientists to assay a million compounds in a couple of weeks, without statistical tools the error rate can be as high as 10 to 40 percent, with a "hit rate" as low as two percent for finding active compounds. "Even if you screen everything, the assays are not accurate," Welch states. "The molecules that are assayed to be positive will in many cases turn out to be negative and vice versa."

One of the reasons for the high error rate is in the methodology. In current high-throughput methods, speed is attained at the expense of accuracy. A typical testing plate used in HTS (roughly 3" x 4") contains 1,584 wells, each about the size of the head of a pin. One target compound and one chemical compound are mixed in solution in each well and the amount of activity, such as binding, is measured. With samples this small, it is easy for errors to occur.

Streamlining High-Throughput Screening with Sequential Screening

Instead of attempting to test millions of compounds, Welch approaches the problem by building a statistical model to predict biological activity based on a small subset of the entire compound library. With funding from the Natural Sciences and Engineering Research Council (NSERC), the Mathematics of Information Technology and Complex Systems (MITACS), and industry partner GlaxoSmithKlein, Welch and his group are honing statistical methods for sequential screening, which rank unassayed compounds in the order of their probability of activity—from most active to least active. By bioassaying only the most promising compounds, the "hit rate" for finding active compounds is increased. Moreover, doing fewer assays means testing can be more carefully conducted, reducing the error rate. It is an iterative process; whenever additional compounds are selected for screening and new bioassay results added to the initial data set, the model is improved. In one example, screening less than 20 percent of a collection yielded nearly 75 percent of the active compounds.

Welch uses an analogy of credit card offers in direct mail. Most people throw the mailing away, thereby falling into the inactive category. Those who apply would be actives. "The credit card company builds a model of who is likely to respond and only mails to those people," he says. "It's exactly the same problem."

Tackling Descriptor Variables, Systematic Errors and Psychological Hurdles

To build the statistical model, the three-dimensional structure and electrostatic activity of a chemical compound must be translated into quantitative variables. The problem is that there are no standard definitions—different chemists have completely different sets of descriptor variables. These might consist of a large number of simple variables, such as how many times a carbon is connected to another carbon a certain number of atoms away. Or they might attempt a mathematical description of the properties of a whole molecule.

"Trying to benchmark the different descriptors against each other is ongoing work," says Welch. "We really don't know which descriptor set is the best, or which statistical method is the best. The question may not be as simple as what is best, because it may depend on the type of assay you are doing."

Systematic errors in the bioassays pose a challenge as well, such as calibration and higher evaporation at the edge of the plate. When measurements are replicated to check for errors, the robotic equipment is often set up to put the same compound in the same well on every plate. "This makes it difficult to tell if a measurement is a result of a well effect or a compound effect," says Welch.

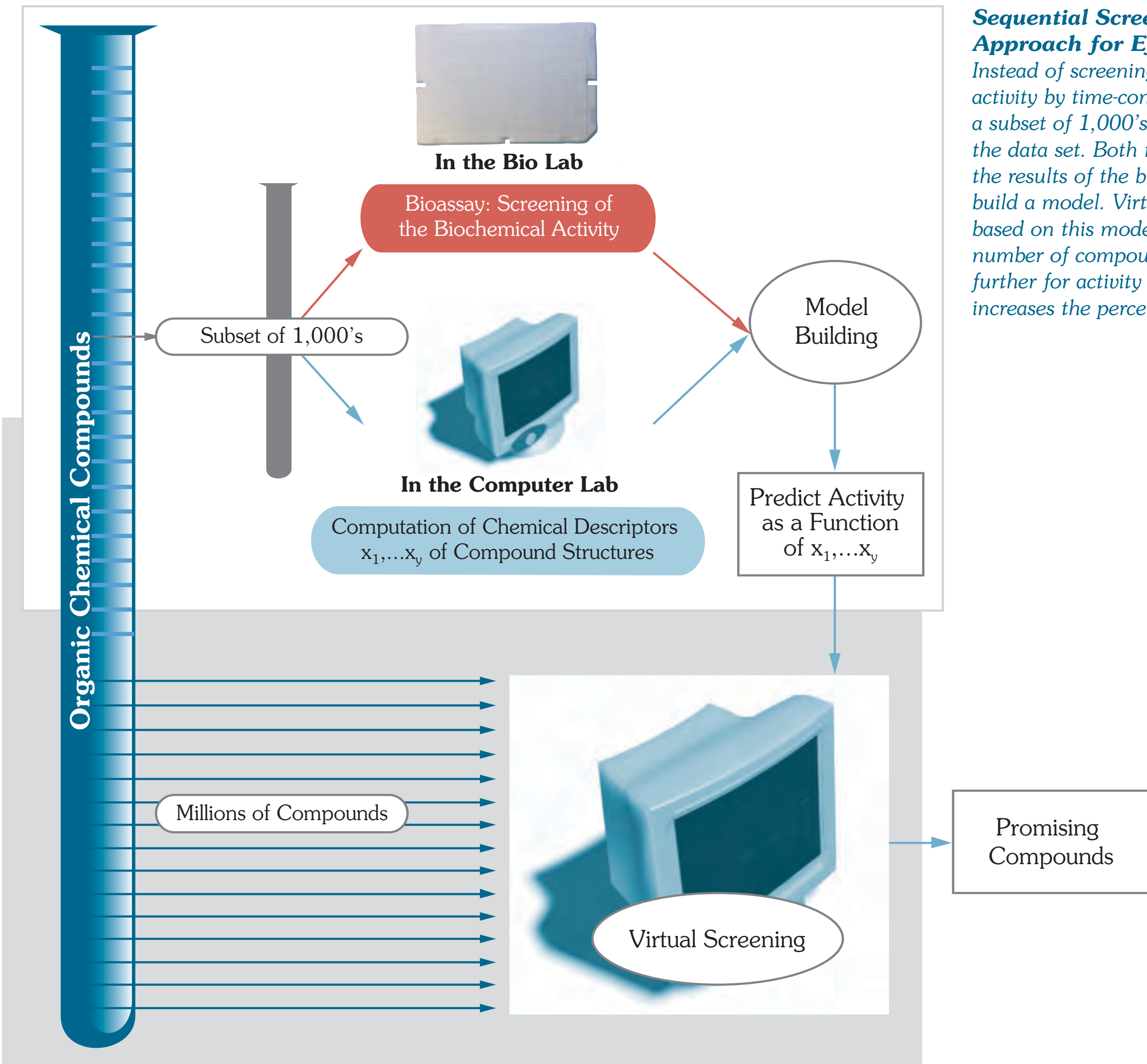
There is also a psychological bias favouring diversity over replication in choosing active compounds. Given a choice between screening a large, diverse number of compounds versus assaying a smaller number twice, most researchers favour diversity. "There is a psychological barrier that we don't totally understand," Welch notes. People believe that they are less likely to miss something if they assay a larger number of compounds against a target, even in the presence of considerable error."

Averaging Nearest Neighbours and Regression Trees

Determining how to select a smaller representative set of molecules for sequential screening is a major aspect of Welch's work. The task is relatively simple if some active compounds have already been identified, if there is a crystal structure of the target, or if a structure–activity relationship (SAR), is known. However, when a target is not yet identified—as in many protein–protein interactions—the task is much more problematic. How do you choose a diverse subset in a descriptor space of several hundred dimensions in the absence of target information? How do you build a model with highly proprietary corporate databases, where you are working with disguised compounds?

Using public-domain data from the National Cancer Institute, Welch and colleagues have adapted the "K-Nearest Neighbour" statistical model, which predicts the activity of an unassayed compound relative to the activity of its "nearest neighbours" in chemical descriptor space. "Basically it is guilt by association," says Welch. "If the compound of unknown activity is in a neighbourhood with many actives, then I predict it to be active. For example, if it is near two compounds that are active and five that are not, then we estimate it has a probability of two out of seven to be active."

Large molecular data sets contain many weak or "junk" variables. For drug discovery,



Sequential Screening—Statistical "Filter" Approach for Efficient Drug Discovery
Instead of screening millions of compounds for activity by time-consuming and costly bioassays, a subset of 1,000's of compounds is used from the data set. Both the chemical descriptors and the results of the bioassay are incorporated to build a model. Virtual (computational) screening based on this model immensely reduces the number of compounds that need to be tested further for activity and at the same time increases the percentage of active compounds.

often only a subset of descriptor variables is relevant to biological activity. A technique called subset averaging is used to filter the plethora of data and screen out junk variables.

Welch's group also applied this method to classification trees, another statistical method they are working on. The average of regression trees based on various subsets of variables detected 37 percent more active compounds than a single tree based on all variables. "It turns out that if we average across all of these models, where some might be good and others not so good, the performance is close to that of the good models," notes Welch. "This is a relatively new finding that I am working on with collaborator Professor Hugh Chipman at Acadia University and graduate student Marcia Wang." Welch's other principal collaborators in drug discovery are Raymond Lam and Stan Young at GlaxoSmithKline and Ruben Zamar, Statistics professor at UBC.

Sequential screening for drug discovery can be used to rank virtual compounds as well. "The compounds being ranked could be the rest of your corporate sample, or they could be molecules that have never been synthesized," notes Welch. "Now we can assay compounds that only exist on the computer." He and other statisticians are showing that life *in silico* can be multi-dimensional indeed.

"We believe that not much is learned by making a million measurements versus ten thousand carefully chosen measurements."
– Will Welch

Physiology under Pressure
UBC Zoologist Walks on the Wild Side

Celebrated zoologist and Order of Canada member David Jones has pioneered the study of diving response and circulatory systems of a variety of animals. Now, after 35 years, his research path has taken a surprising new twist.

The animal care facility where David Jones conducts his research is hidden away in a remote area of UBC's campus. It is populated with rare and common species from all over the globe: birds, fishes, giant sea turtles, crocodiles, Australian emus. As we walk past the turtle tanks, an enormous 130-pound turtle comes to the edge and swats the water. "They take great delight in splashing you," Jones laughs—something he does heartily and readily.

Delving into Diving Response

Jones' basic curiosity and passion for research has made him a world leader in his field. In his work on comparative physiology of diving animals, he and former student Russ Andrews pioneered the use of telemetric data logging devices to monitor dive depths and times, swimming speed, heart rate, body temperature, and feeding in free-ranging elephant seals and leatherback turtles—work that garnered the Flavelle Medal from the Royal Society of Canada.

"What you find in really accomplished divers is small lungs, which seems counterintuitive, but in fact they are not using their lungs at all," he says. It takes 5 to 10 minutes for a seal to get down to a depth of between 300 to 500 metres, while their lungs have collapsed 30 seconds into the dive. Seals use oxygen that is stored in the blood, and when they dive, their heart rate drops to about one-fifth of the normal rate, he explains.

Studying Circulatory Structure and Function

The second major area of Jones' research is the functional morphology of circulatory systems in both vertebrates and invertebrates. His study of extra cardiac chambers in fishes and frogs, and multiple hearts in invertebrates led to seminal research in the cardiac dynamics of crocodilians. Unlike all other reptiles, crocodiles have a completely divided ventricle, which recirculates venous blood to the body while bypassing the lungs. The crocodiles' unique circulatory system is in part what makes them such deadly predators, because it allows them to swim silently underwater for hours at a time without surfacing.

One of Jones' ongoing interests has been the bulbus arteriosus in teleosts, or bony fish. It is an elastic chamber that sits between the ventricle and ventral aorta. Two basic questions he has been studying over the past twenty years are: What is the function of the bulbus in regulating the blood pressure of fish, and does morphology affect function? "The interesting thing is that the bulbus comes in all shapes and sizes," says Jones. "For example, the bulbus of a marlin is long and thin, and that of a tuna is conical, but they all do the same job."

In one study, he and colleagues recorded arterial blood pressure and simultaneous changes in the volume of the bulbus of anaesthetized yellowfin tuna. When the bulbus was nearly empty, a small change in blood volume resulted in a large increase in blood pressure. Once systolic pressure was reached (the pressure when the heart contracts) large changes in volume resulted in very small changes in pressure, indicating that the bulbus is responsible for maintaining ventral aortic pressures over a large range of volumes pumped by the heart.

Necrophysiology—Studying the Hearts of Dead Fish

After twenty years of research in bulbar morphology and function, Jones discovered that the hearts of dead fish can reveal blood pressure as accurately as testing live, anaesthetized fish. It was an unexpected breakthrough. "There are over 25,000 species of bony fishes, so this allows us to record the blood pressure of a fair number in a way that is quick, infallible and cheap," he says. Setting up to measure blood pressure of live fish can cost in the range of $200 to $300 per fish. Tiny fish such as zebrafish, which weigh less than a gram, cost nearly $20,000 because of the specialized equipment required.

The crocodiles' unique circulatory system allows them to swim silently underwater for hours at a time without surfacing. (Photo: Manuela Gardner)

The beauty of the procedure is in its simplicity. With saline, a syringe and some tubing, it can be done almost anywhere. A small amount of saline is injected into one end of the bulbus and then rises up a vertical tube tied into the other end. The height of the fluid in the tube is a measure of the pressure in the bulbus. "If you plot the pressure versus the volume you are putting in, there is a large pressure increase with the first injection of saline," says Jones. After it reaches normal blood pressure, the plot is absolutely flat. Additional injections further inflate the bulbus, but do not change the pressure. This method works for any fish above 100 grams but with more sophisticated (and expensive) technology Jones has measured pressure in fish as small as one-third of a gram! To test the method, he plotted the relationship between blood pressures measured in both living and dead fish. The regression coefficient was a near-perfect .96. "It was the best R^2 I've ever had in my life," he exclaims.

To get accurate measurements, the testing must take place within 24 hours after the fish has died—preferably within 12 hours for large predators. However, Jones' lab discovered that putting the fish hearts in 30-percent alcohol could prolong the study period by several days. Most recently, he and student Kevina Perbhoo have managed to make recordings from rainbow trout that had been preserved in the Zoology Fish Museum for 55 years! They were still able to obtain accurate measurements of that species' blood pressure. "It really is an amazing organ," he says with characteristic enthusiasm.

Protecting Brains and Brawn

Jones also discovered a correlation between species activity level and blood pressure. Top predators like tuna and marlin have the highest blood pressures: 100 millimetres of mercury (133 hectopascal), close to that of mammals. Lazier species such as perch and seahorses have blood pressures in the range of 10 millimetres of mercury (13 hectopascal), and the not-so-ace predators such as trout and salmon have middling blood pressures.

Studying diving animals under water: Since their lungs have collapsed after half a minute into a 500-metre dive, seals use oxygen that is stored in the blood.

Jones is anxious to study the bonito because it is closely related to tuna and marlin. If the bonito also has a high blood pressure, then this would be characteristic of the group, he explains. However, if the bonito has a low blood pressure, then high blood pressure correlates with heating parts of the body. "Tuna keep their muscles warm and marlin keep their brains and eyes warm because they both go down to really cold water," notes Jones. "This would indicate that you need a high blood pressure to develop these regions of heating."

This research can provide insight into the evolution of blood pressure in fish, the long-term effects of non-lethal cardiac mutations in zebrafish, and blood pressure as a factor in the population distribution or health of a group. It also presents a new opportunity to study the effects of size on blood pressure. "In rats for example, an adult is only about 20 times the size of a baby. Whereas a 100-kilogram fish hatches from a tiny egg—so you can get a million times the size range."

For Jones, it all comes down to asking the right questions. "If, as a zoologist, you orient your research to questions of a medical nature, often they are not very interesting because they don't really address the issue of what the animals are designed to do."

"Many people collect a great amount of data and then decide what to do with it. What you really need to do is to start with an interesting question." – David Jones

Portrait: The Department of Mathematics

The Department of Mathematics is known throughout the world as a leading centre of mathematical research. In the past five years, our faculty have won half of the major Canadian Mathematical Society research prizes. Recently, Math faculty have received many other prestigious awards, including several Sloan Fellowships and research prizes in Probability and Number Theory.

The department has played a critical role in the development of vibrant institutes. The Pacific Institute for the Mathematical Sciences (PIMS), centred at UBC, has been a major force in the mathematics of North America and beyond. Under leadership from PIMS, the Banff International Research Station (BIRS), which hosts weekly workshops in mathematics, was created last year. Mathematics of Information Technology and Complex Systems (MITACS) provides exceptional opportunities for collaboration with industry.

Currently, the department has roughly 60 full-time faculty, 85 graduate students and 25 postdoctoral fellows. Research interests cover a broad array of areas, pure and applied. In the past four years, the department has undergone a remarkable period of renewal with the recruitment of many new faculty members, including several Canada Research Chairs.

The department offers a lively program of courses, seminars, workshops, and informal activities that encourages the study of mathematics on all levels. This includes many innovations to serve the changing needs of math students and those in other departments, as well as advanced graduate-level courses taught in the summer in conjunction with special programs sponsored by PIMS and other institutes.

Through the Institute for Applied Mathematics (IAM) and several joint appointments, the department enjoys strong connections with other UBC departments. Each week, the department, IAM and PIMS host a large number of specialized seminars and colloquia, featuring talks by leaders in pure and applied mathematics from UBC and around the world.

The Math Club provides many study and social opportunities for undergraduates in Math and related fields. The department offers weekly training sessions (with pizza!) for the challenging Putnam Exam; our Putnam team regularly finishes within the top twenty in North America and often within the top ten.

Students from all around the world choose to undertake graduate study in Mathematics at UBC, leading to MSc and PhD degrees. Math graduates have won many distinguished awards and have obtained high quality jobs in universities and industry.
For more information, please take some time to browse through the department website: www.math.ubc.ca

Projects and Initiatives: Two Grand Micro-Spectroscopy Facilities

This year Faculty of Science researchers have earned two significant infrastructure grants in federal funding—more than $8 million for groundbreaking laser and X-ray spectroscopy research from the Canada Foundation for Innovation (CFI). "Our researchers are to be congratulated for their determination to strengthen UBC research through cutting-edge equipment and facilities," said Indira Samarasekera, UBC's vice-president, Research.

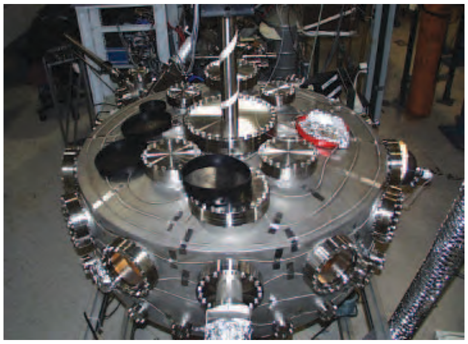
Laboratory of Advanced Spectroscopy and Imaging Research

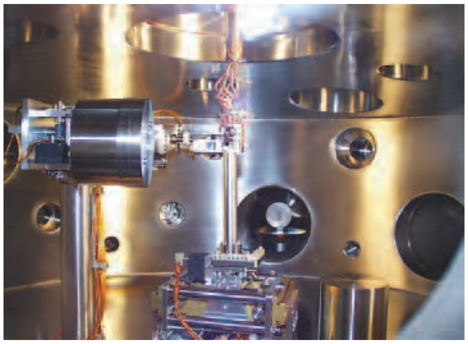
Project leader John Hepburn, professor in the departments of Chemistry and Physics & Astronomy, and dean of the Faculty of Science, got good news for his collaborators at UBC and Simon Fraser University (SFU): Their joint application for a new Laboratory of Advanced Spectroscopy and Imaging Research (LASIR) has been granted $5 million by the CFI. The principal researchers involved at UBC are the chemistry professors Allan Bertram, Michael Blades, Michael Fryzuk, Mark MacLachlan, Moshe Shapiro, and Michael Wolf.

LASIR will encompass two hubs with a total of 5,000 square feet of laboratory and clean rooms within renovated space in the chemistry building at UBC and in newly constructed space at SFU. Together they will be equipped with seventeen end stations, which will be linked to a core of seven state-of-the-art laser systems. The lasers will span a range of wavelengths from X-ray to infrared, a variety of power intensities, and time scales from nanosecond to femtosecond.

This research facility will help explore new frontiers in laser–matter interaction. The key areas of LASIR are laser chemistry and spectroscopy, new materials and catalysis research, and environmental science. The wide array of various lasers and their innovatively flexible laser system to end-station configuration will facilitate a photolithography centre and spur new approaches to materials characterization and atmospheric aerosol research.

The great and still growing consequences of aerosol pollutants have long been neglected. Now environmental scientists will be able to scrutinize the chemistry of such airborne particles in order to quantify their secondary health effects. Materials scientists will develop new functional materials and processes for molecular-scale semiconductor circuitry and nano-scale devices, and will be able to characterize a variety of optical properties of new materials. Catalysis researchers will see first-hand the photo-physics of catalytic reactions and enzyme activity with the time resolution and wavelength tunability required to unravel the intricate molecular motions driving these complex systems. Laser chemists and spectroscopists will have the tools needed to develop and apply new, high-order nonlinear optical spectroscopies and microscopies. Using the quantum properties of matter, methods of controlling chemical processes can be developed. These techniques will help to





Soft X-ray Scattering Beamline and End Station. *This experimental station is 'just' a prototype of what George Sawatzky and collaborators are going to build at UBC—a new state-of-the-art facility that then will be stationed at the CLS where a new beamline is being built according to their specifications. The new facility will be an immense improvement and will be much more flexible due to a complete control of the polarization and high-energy resolution.*

better understand surface processes that are important in industry, atmospheric science and cell biochemistry.

LASIR will allow researchers—for the first time—to tackle fundamental scientific questions beyond the reach of previously available instrumentation. Further benefits anticipated from LASIR include new technologies and processes to control chemical reactions with light and to produce nanowires that use light to carry data.

LASIR will be accessible for specialists and non-specialists alike. Experts from a variety of disciplines, such as physics, engineering, biology, medicine, microbiology and chemistry, will work side by side, creating an environment of enriched training for graduate students and an enhanced exchange of knowledge. Synergies generated between academia and the private sector will stimulate growth in advanced technology.

Resonant Elastic and Inelastic Soft X-ray Scattering Beamline

Project leader George Sawatzky, professor in the departments of Physics & Astronomy and Chemistry, and his UBC colleagues, physics professors Douglas Bonn, Andrea Damascelli, and Thomas Tiedje, also got their share from the CFI Innovation Fund this year—more than $3 million to create a unique experimental facility involving a novel soft X-ray scattering beamline and end station. This multi-university resource will enable the researchers to apply spectroscopic techniques that have been developed for visible light at soft X-ray wavelengths. The ensuing high resolution and extremely high sensitivity spectroscopy will make it possible to analyze chemical elements and magnetic phenomena to view ultra-small structures of materials.

Part of the facility will be built at UBC and then installed at the Canadian Light Source (CLS, University of Saskatchewan). Wavelengths matching the size of nanostructures will facilitate high-precision spectroscopy in dilute systems such as single magnetic atoms in large macromolecules. For the first time, phases in materials that differ only by their electronic or magnetic structure on a nanometre scale will be made visible without electron damage. Atomic site-specific studies of complex organic systems like polymers, biological macromolecules, and cells in aqueous environments will be possible. Researchers will be able to determine spatial distribution of elements or particular molecular groups and their changes with time and chemical environment. They will also be able to study important aspects of the electronic structures in high temperature super-conductors, monolayers of molecules on surfaces, and artificial structures.

This project will exceed the international state of the art of soft X-ray based research when added to the current end station and complementary beamline at CLS. The facility will be used not only for pioneering research but also for studies into applicable technologies. For instance, the proposed investigation of magnetism in thin films has the potential of evolving a new type of memory electronics in computers. The unique analytical capabilities of the X-ray spectroscopy and scattering techniques are also expected to be exploited by collaborators in the environmental consulting industry.

New Masterminds: Brain Gains at Science

Avilés

Barth

Carenini

Cytrynbaum

Eberhardt

Ekeland

Graham

Whether Canadian Research Chair (CRC), cross appointment, junior or senior position—the Faculty of Science welcomes the new faculty members in the nine Science departments.

Leticia Avilés, Assoc. Prof., Dept. of Zoology; Licenciate Biological Sciences, Pontificia Universidad Católica del Ecuador, Quito; MSc and PhD Organismic and Evolutionary Biology, Harvard University, Cambridge, MA, USA. *Research:* Evolutionary ecology. Using both empirical and theoretical approaches, I am currently investigating the role of multi-level selection on the evolution of sociality and of life history traits and local population dynamics in metapopulations. Empirical studies, primarily in Ecuador, focus on spiders and other arthropods.
www.zoology.ubc.ca/zoology/z/aviles

Johannes V. Barth, Assoc. Prof., Depts. of Chemistry and Physics & Astronomy; CRC; Diploma (MSc) Physics, LMU München, Germany; Dr. rer. nat. (PhD) Physical Chemistry, Freie Universität Berlin, Germany. *Research:* My research contributes to the advancement of supramolecular science and methodologies for nanoscale control of matter. Notably, we focus on functionality and atomistic understanding of low-dimensional molecular nanosystems engineered at surfaces, using devised assembly protocols.
www.chem.ubc.ca/personnel/faculty/barth

Giuseppe Carenini, Assist. Prof., Dept. of Computer Science; BSc and MSc Computer Science, U of Milan, Italy; PhD Intelligent Systems, U of Pittsburgh, PA, USA. *Research:* Within the fields of artificial intelligence and human–computer interaction, I integrate natural language processing and information visualization to ultimately generate highly efficient interactive computer systems. I study preference elicitation, information summarization and the generation of interactive multimedia arguments.
www.cs.ubc.ca/people/profiles/carenini.html

Eric Cytrynbaum, Assist. Prof., Dept. of Mathematics; BSc Mathematics, McGill University, Montreal, Canada; MS and PhD Mathematics, U of Utah, Salt Lake City, USA. *Research:* I apply mathematical and computational techniques to problems both in cell biology and electrophysiology, focussing on the role of the cytoskeleton and molecular motors in mitosis and on the dynamics of cardiac tissue, particularly in the context of cardiac arrhythmias.
www.math.ubc.ca/~cytryn

Erik Eberhardt, Assist. Prof., Dept. of Earth & Ocean Sciences; BEng Geological Engineering, MSc and PhD Geotechnical/Rock Engineering, U of Saskatchewan, Saskatoon, Canada. *Research:* I am interested in geotechnical rock engineering problems. Specifically, I apply advanced numerical methods combined with geotechnical instrumentation to investigate rock slope stability and underground excavation problems.
www.eos.ubc.ca/public/people/faculty/E.Eberhardt.html

Ivar Ekeland, Prof., Depts. of Mathematics and Economics; CRC; BSc and MSc Mathematics, Université Paris-Sorbonne, France; PhD Mathematics, Université Paris-6, France. *Research:* My present field of interest is the mathematical modelling of human behaviour. My earlier work was in geometry and the calculus of variations.

James J. Feng, Assoc. Prof., Depts. of Mathematics and Chemical & Biological Engineering; CRC; BSc and MSc Mechanics, Peking University, Beijing, China; PhD Fluid Mechanics, U of Minnesota, Minneapolis, USA. *Research:* I study the flow of complex fluids, a group of microstructured materials with wide applications. I use mathematical and numerical modelling to explore how interfaces between immiscible fluids evolve during flow and processing.
www.math.ubc.ca/~jfeng

Sean W. Graham, Assist. Prof., Dept. of Botany and UBC Centre for Plant Research; BSc Genetics, U of St. Andrews, Scotland; PhD Botany, U of Toronto, Canada. *Research:* The reconstruction of the Tree of Life is a central goal of modern biology. My research focuses on making robust inferences of the major details of land–plant phylogeny, applying these to studies of morphological and molecular evolution, and investigating the biodiversity of understudied plant lineages. www.botany.ubc.ca/graham.htm

David J. Jones, Assist. Prof., Dept. of Physics & Astronomy; BA Physics and BS Engineering, Swarthmore College, PA, USA; MPhil Engineering, U of Cambridge, UK; PhD Electrical Engineering, MIT, Cambridge, MA, USA. *Research:* I pursue the development and application of phase-stable ultrafast lasers and related technology. Present projects include time and frequency distribution with 1 part in 10^{15} precision and coherent control with phase-stable femtosecond lasers.
www.physics.ubc.ca/php/directory/research/fac-1p.phtml?entnum=278

Pakhomov

Rasmussen

Ridgwell

Salibian-Barrera

Schötzau

Thompson

Wasteneys

Kevin Leyton-Brown, Assist. Prof., Dept. of Computer Science; BSc Computer Science, McMaster University, Hamilton, ON, Canada; MSc and PhD Computer Science, Stanford University, CA, USA. *Research:* I work at the intersection of computer science and microeconomics, studying computational problems in economic contexts and incentive issues in multi-agent systems. Research communities in which I participate include artificial intelligence, game theory, empirical algorithmics, and electronic commerce.
www.cs.ubc.ca/~kevinlb

Evgeny A. Pakhomov, Assist. Prof., Dept. of Earth & Ocean Sciences; Adj. Prof., U of Fort Hare, South Africa; MSc Hydrobiology, Kazan State University, Russia; PhD Biological Oceanography, P. P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow. *Research:* I am a biological oceanographer covering topics from species ecology to ecosystem structure as well as physical–biological and biochemical coupling. My current research focusses on changes in the Antarctic ecosystem functioning due to global climate change.
www.eos.ubc.ca/public/people/faculty/E.Pakhomov.html

Paul W. Rasmussen, Sr. Instructor, Dept. of Chemistry; BSc Chemistry, Acadia University, Wolfville, NS, Canada; PhD Organic Chemistry, McMaster University, Hamilton, ON, Canada. *Research:* I am interested in practical applications of instrumental methods of analysis, automated data acquisition and analysis, student assessment in the undergraduate laboratory, and spectroscopic data storage and retrieval.

Andrew J. Ridgwell, Assist. Prof., Dept. of Earth & Ocean Sciences; CRC; BA Natural Sciences, U of Cambridge, UK; MSc Environmental Sciences, U of Nottingham, UK; PhD Earth System Modelling, U of East Anglia, Norwich, UK. *Research:* My research involves the development and use of computer models in understanding how the concentration of carbon dioxide in the atmosphere is controlled, its relationship to past and future changes in climate, and the role played by the evolution of life on Earth.
www.eos.ubc.ca/public/people/faculty/A.Ridgwell.html

Matias O. Salibian-Barrera, Assist. Prof., Dept. of Statistics; BSc Mathematics, U of Buenos Aires, Argentina; PhD Statistics, UBC, Vancouver, Canada. *Research:* I develop statistical methods that can extract meaningful information from large data sets when the quality of the data is doubtful. I also work at the intersection of statistics and computer science.

Dominik M. Schötzau, Assist. Prof., Dept. of Mathematics; CRC; BSc, MSc and PhD Mathematics, ETH Zürich, Switzerland. *Research:* My main research interest is the design of computer methods for the simulation of complex phenomena in fluid mechanics and electromagnetics. Current projects include the development of new finite element methods for such simulations.
www.math.ubc.ca/~schoetzau

Charles J. Thompson, Prof. and Head, Dept. of Microbiology & Immunology; BSc Washington and Lee University, Lexington, Virginia, USA; MSc and PhD Pennsylvania State University, USA. *Research:* We carry out molecular genetic studies of mycobacteria, pathogenic microbes that cause tuberculosis and streptomyces, a related group of multicellular filamentous procaryotes that undergo a program of colonial differentiation coordinated with biosynthesis of antibiotics and pharmaceutically important natural compounds.
www.microbiology.ubc.ca

Geoffrey O. Wasteneys, Assoc. Prof., Dept. of Botany; CRC; BSc Biology, Carleton University, Ottawa, ON, Canada; PhD Plant Cell Biology, Australian National University, Canberra. *Research:* Plant shape depends on the cell wall, whose mechanical properties are modulated by cytoskeletal protein networks. My team combines molecular genetics and microscopy to unravel the mysteries about how these networks function.
www.botany.ubc.ca/wasteneys.htm

Recent appointments also include:
Keith Adams, Assist. Prof., Dept. of Botany and Faculty of Agricultural Sciences – Neil Balmforth, Prof., Depts. of Mathematics and Earth & Ocean Sciences – Jin-Gui Chen, Assist. Prof., Dept. of Botany – Keng Chang Chou, Assist. Prof., Dept. of Chemistry – Marco Ciufolini, Prof., Dept. of Chemistry – Kurt Eiselt, Sr. Instructor, Dept. of Computer Science – Michael Paul Friedlander, Assist. Prof., Dept. of Computer Science – Darren I. Irwin, Assist. Prof., Dept. of Zoology – Richard Kenyon, Prof., Dept. of Mathematics – Kevin Murphy, Assist. Prof., Depts. of Computer Science and Statistics – Rachel Pottinger, Assist. Prof., Dept. of Computer Science – Jeffery Richards, Assist. Prof., Dept. of Zoology – Ozgur Yilmaz, Assist. Prof., Dept. of Mathematics – Eric Wohlstadter, Assist. Prof., Dept. of Computer Science – Steve Wolfman, Instructor, Dept. of Computer Science

(Photos [Ekeland/Ridgwell/Schötzau/Wasteneys]: Bayne Stanley)

Faculty of Science: Kudos and News

In 2003/2004 Science faculty members won the following prestigious academic awards.

Anita Borg Early Career Award, Computing Research Association
- Joanna McGrenere, Assist. Prof., Computer Science

Killam Research Fellowship, Canada Council for the Arts
- Tony Sinclair, Prof., Zoology

Steacie Fellowship, NSERC
- Patrick Keeling, Assist. Prof., Botany

Fellow of the Mineralogical Society of America
- Lee Groat, Prof., Earth & Ocean Sciences (EOS)

Fellow of the American Physical Society
- Mona Berciu, Assist. Prof., Physics & Astronomy
- Ian Affleck, Prof., Physics & Astronomy

Foreign Honorary Fellow of the American Academy of Arts and Science
- Walter Hardy, Prof., Physics & Astronomy

Honorary Doctorate, University of Guelph
- Julian Davies, Prof. Em., Microbiology & Immunology

Academic Gold Medal for Students, Governor General
- Mirela Andronescu, Computer Science

Andre-Aisenstadt Prize, Centre de Recherches Mathématiques (CRM)
- Nike Vatsal, Prof., Mathematics

Prix de l'IHP, Institut Henri Poincaré
- Gordon Slade (co-winner), Prof., Mathematics

Ribenboim Prize, Canadian Number Theory Association
- Michael Bennett, Assoc. Prof., Mathematics

CAP-CRM Prize in Theoretical Physics, Canadian Association of Physicists & CRM
- Matthew Choptuik, Prof., Physics & Astronomy
- Jeremy Heyl, Assist. Prof., Physics & Astronomy

Best Paper Award, Association for Computing Machinery (ACM-SIGMOD)
- Raymond Ng & Yuhan Cai, Computer Science

Coxeter-James Prize, Canadian Mathematical Society
- Izabella Laba, Assoc. Prof., Mathematics

Rollo Davidson Prize, Cambridge
- Alexander Holroyd (co-winner), Assist. Prof., Mathematics

Award for Pure or Applied Inorganic Chemistry, Chemical Institute of Canada
- Michael Wolf, Assoc. Prof., Chemistry

Catalysis Award, Chemical Institute of Canada
- Colin Fyfe, Prof., Chemistry

Distinguished Academics of the Year Award, Confederation of University Faculty Associations of BC (CUFA)
- David H. Dolphin, Prof., Chemistry

Glenn T. Seaborg Award, American Chemical Society (ACS-NCD)
- Donald G. Fleming, Prof., Chemistry

Lecture Award, Merck Frosst Centre for Therapeutic Research
- Martin Tanner, Prof., Chemistry

Distinguished Achievement Award, American Statistical Association (ASA-ENVR), and Hunter Lecture, International Environmetrics Society
- James V. Zidek, Prof., Statistics

Dobzhansky Prize, International Society for the Study of Evolution, and Howard Alper Postdoctoral Prize, NSERC
- Aniel Agrawal, PDF Zoology

Murray Newman Award, Vancouver Aquarium
- David R. Jones, Prof., Zoology

Top 50 Contributors to Science and Technology (2003), Scientific American
- Daniel Pauly, Prof., Zoology

Service Award, Geological Association of Canada
- Greg Dipple, Prof., EOS
- Catherine Hickson, Adj. Prof., EOS
- Steve Rowins, Assist. Prof., EOS

Sproule Annual Achievement Award, Canadian Society of Unconventional Gas
- Marc Bustin, Prof., EOS

W. H. Weston Award, Mycological Society of America
- Mary Berbee, Assoc. Prof., Botany

Lorne Whitehead UBC's new Vice President, Academic and Provost

Dr. Whitehead was appointed Vice President, Academic and Provost July 1, 2004. He joined the UBC Dept. of Physics & Astronomy in 1994, was appointed professor in 1999 and has served as associate dean and dean *pro tem* in the Faculty of Science.

Science Department Heads News

Charles Thompson assumed the headship of the Dept. of Microbiology & Immunology in May, 2004. Robert J. Woodham stepped down at the end of 2003 after eight years at the helm of the Dept. of Computer Science.

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