QN
QUAESTIONES NATURALES

VOLUME 2, 2014

UNDERGRADUATE RESEARCH IN SCIENCE

Lakehead UNIVERSITY
Faculty of Science and Environmental Studies
lakeheadu.ca

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"Quaestiones naturales" is a Latin term referring to investigations into the natural world, or today what we would call scientific research, especially those studies of a multidisciplinary nature. The term was originally used by the Roman philosopher Seneca the Younger for a series of books on meteorology and other natural processes.

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Welcoming Remarks from the Dean

This is the second issue of Quaestiones Naturales, our annual publication of the research achievements of undergraduate science students at Lakehead University. Student engagement is a top priority of the Faculty of Science and Environmental Studies and involvement of our students in exciting research projects is central to our focus. In Q.N. this year you have nine featured students whose research interests range from the applied to the pure sciences, from field-based to laboratory-based experiments and foundational work in the mathematical sciences. Subjects range from animal behaviour in response to environmental stresses, to novel techniques to remediate pulp biowaste, to identifying microplastics – an emerging contaminant in the Great Lakes, and documenting the industrial land-use history along the Kaministiquia River. We take pride in being able to offer motivated students meaningful opportunities to work with leading scientists on projects that are current and of real interest to the student. In a typical year our faculty's researchers spend close to half a million dollars from individual grants to support students on projects throughout the summer. Research inspires learning and this magazine allows us to showcase just a fraction of the great work being done by some of the future generation of Science Alumni at Lakehead University. Enjoy!

Todd A. Randall, PhD, P.Geo.
Acting Dean of Science and Environmental Studies

Todd A. Randall, PhD, P.Geo.

Featuring research performed by undergraduate students in the Faculty of Science and Environmental Studies at Lakehead University.

Ideally, science is a method by which information is gathered using evidence and physical models. It may then also extend to developing that knowledge for beneficial purposes. Part of the mandate of every university is the creation of new knowledge, and part of the educational experience for science students is the study of new knowledge and how it is gained. As part of this training, many students have the opportunity to take part in research projects under the direct supervision of a professor. As you will see, these projects are truly scientific – the students are creating new knowledge while they learn the skills to become researchers themselves.

In this magazine, we profile nine students and their projects. They performed the research when they were undergraduate students; you will see they made an interesting and significant contributions to their areas of research.

Researcher	Program	Hometown	Supervisor
Andrew Carr	Geography (HBSc)	Thunder Bay ON	Todd Randall todd.randall@lakeheadu.ca
Alea Crupi	Chemistry	Thunder Bay ON	Christopher Phenix phenixc@tbh.net
Daniel Durston	Biology	Thunder Bay ON	Douglas Morris douglas.morris@lakeheadu.ca
Laura Gallagher	Environmental Studies (Geography)	Thunder Bay ON	Robert Stewart rob.stewart@lakeheadu.ca
Niharika Shahi	Biology	Thunder Bay ON	Wensheng Qin wqin@lakeheadu.ca
Cassandra Sinclair	Interdisciplinary Studies (Biology & General Science)	Barrie ON	Nandakumar Kanavillil nkanavil@lakeheadu.ca
Denon Start	Biology	Thunder Bay ON	Douglas Morris douglas.morris@lakeheadu.ca
Dennis Stauffer	Mathematics	Wooster OH	Maria Grazia Viola mviola@lakeheadu.ca
Jennifer Steers	Chemistry	Bradford ON	Craig MacKinnon craig.mackinnon@lakeheadu.ca

We would also like to thank Harikrishnan Nandakumar, Environment Canada Research Intern, for talking with us regarding his project. He was supervised in his internship by Lakehead University professors Florin Pendea (ifpendea@lakeheadu.ca) and Sreekumari Kurissery (skurisse@lakeheadu.ca).

Enzymes to Energy

The search for microorganisms that break down pulp waste

Some students, like Niharika Shahi, catch the research bug early. "I enjoyed my science courses in high school, so my teachers suggested I apply for a research internship," she says. Thus, she became the first high school intern at the Thunder Bay Regional Research Institute (TBRRI), and she has been involved in research projects ever since. "I worked one summer with TBRRI on a cancer project and learned a lot about various techniques common in molecular biology and biochemistry labs," she continues. "A lot of the techniques used in our lab to investigate biomass are the same as the techniques used by the medical researchers at TBRRI."

Niharika's research advisor is Professor Wensheng Qin in the Department of Biology. He and his group are looking at ways to convert biomass waste, for example sludge from pulp mills, into useful products. "The sludge contains large intractable molecules like lignin and hemicellulose that need to be broken down into smaller units before they can be used, for example in generating biofuels," Niharika explains. "My project involved identifying bacteria that would perform this function." The bacteria use the biomass as food, so the way to screen for activity is to find bacteria that grow when fed a diet of these molecules.

"It's good to do a little bit of everything, that way you can find what you like"

Graduate student Amber Jarvinen collected samples from sites in Northwestern Ontario, especially around industrial areas. Niharika then tested the samples; she explains, "The bacteria were grown on petri dishes, and their 'halo' was measured, which demonstrated how well they were growing. We found 10 promising hits out of the original 58 samples." Niharika then set to the work of identifying the species. "We ended up narrowing it down to 5 bacteria samples – in each case the genus is *Aeremonas* or *Bacillus*. I am using PCR [polymerase chain reaction] to amplify the DNA of the samples and performing gel electrophoresis to further determine genetic information. Once we've determined the specific species of these bacteria, we'll look into the enzymatic pathways by which they break down the biomass."

The Department of Biology at Lakehead has a wide range of research interests, and is not subdivided the way many biology and life sciences departments are at other universities. This suits Niharika just fine: "It's good to do a little bit of everything, that way you can find what you like. A field like biology is very broad, so it's best to survey the various topics before specializing in upper years when you know better what suits you." ■

Niharika Shahi

Plastic Pollutant

Determining the extent of an emerging pollutant in Lake Superior

When Laura Gallagher explains her research project, the collaboration between different departments and disciplines that can occur in a small institution becomes obvious. Her primary supervisor was Geography professor Robert Stewart, but she made use of equipment and expertise from three other divisions as well. "I built my own experimental apparatus using flutterboards from the university pool and a plankton net from a prof in Biology. Then I characterized my results using an instrument in Physics," Laura says.

"I want a job that won't keep me stuck behind a desk"

These varied resources were required to tackle an important emerging issue in the environment – that of microplastics. They are defined as any plastic material smaller than 5 mm in diameter, and may be used in applications varying from sand-blasting to body wash. If they are present in the environment, they can have detrimental effects, such as blocking the digestive tract of very small organisms or concentrating toxins.

The extent of contamination in Lake Superior is poorly understood, as is the mechanism by which the microplastics enter the lake. "It's assumed that they are originating from personal care products and coming through the sewage treatment plants, but there's no real evidence to back that up," Laura explains. Therefore, Laura collected samples from sites in Thunder Bay – the bay, not the city! The small size of the microplastics required the use of the plankton net, and the fact that the plastics float required that the collector would have to float, hence the flutterboards. The collected microplastics then needed to be analyzed. Laura continues, "Visually they look the same, but that's not conclusive. So I used data measured on [Physics professor] Dr. Keeler's Raman spectrometer to show that the material we collected was the same as those used in soaps and shampoos. We were able to prove that they are the same material, as opposed to microplastics from other sources, which are made of different polymers."

Laura Gallagher

Laura's educational choice matches her professional outlook and her personal lifestyle. "The Environmental Science degree was a logical choice for me. I want a job that won't keep me stuck behind a desk because I love the outdoors. At the same time, it gives me the opportunity to work at a job that I believe in." ■

PET Project

Targeting tumour-related biomolecules for early cancer detection

The Thunder Bay Regional Research Institute (TBRRI) employs scientists and supports university research in medical imaging, which requires research in chemistry, physics, computer science, biology, and electrical engineering. Alea Crupi is a chemistry student working with Chris Phenix, TBRRI staff scientist and adjunct faculty member in the Department of Chemistry. They are interested in Positron Emission Tomography (PET) Imaging which Alea describes: "Positron emission is a type of nuclear decay, the radiation from which can be pinpointed three-dimensionally in the body. If you can radiolabel a certain site – say a cancerous growth – you can spot a much smaller tumour, and with more accuracy, using PET."

"Research by its nature means you have to forge your own path"

The trick is to label cancer cells specifically. Alea explains her work to label them: "The enzyme Cathepsin B is associated with certain cancers, especially those that metastasize, or spread between sites. I worked to synthesize a molecule that would preferentially bind to Cathepsin B and therefore concentrate at the sites of cancer growth and spreading." Her molecule had three parts that needed to be synthesized separately and then joined together. Alea continues, "It was organic synthesis, using techniques I learned in my undergraduate labs plus new ones. You have to make the molecule, then prove you've made it, then purify it. Purity is important for pharmaceuticals because you don't want side-effects caused by impurities." After finding the right molecule, a radioisotope will be incorporated so that the imaging agent will be visible to the PET scanner. "We're building a cyclotron to supply the radioisotopes," Alea says. "We'll use fluorine-18 in our system."

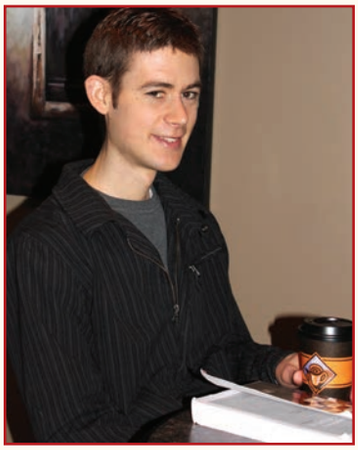
Alea has always wanted to study in a medical field. "I've thought about pharmacy and medicine as career paths," she says. "I participated in the Medical Imaging Summer School, which allowed us to shadow physicians and see the clinical application of the research." In addition to the research skills, Alea's gained valuable life experience. "Real life is never as straightforward or as forgiving as a high school class! There are complications and failures to overcome, which makes you resilient, and research by its nature means you have to forge your own path." She also points out the value of learning how to talk about and defend your ideas. "In a job or medical school interview you have to step it up and sell yourself, just like selling your research ideas." ■

Alea Crupi

Problems in Probability

Free probability is a tool to solve new types of problems

Classical probability is what we think of when we think about statistical chance. However, there are limitations to the theory, such as its inability to be able to deal with matrices and other non-commutive variables. Mathematics researcher Dennis Stauffer explains, "Commutation means that the order doesn't matter – 3 times 5 is the same as 5 times 3. However, with matrices, the order does matter, you get a different answer if you multiply A times B than if you multiplied B times A. As a result, classical probability theory can't be used." He goes on to talk about the theory of free probability, which doesn't have this limitation. "My project with [Mathematical Sciences] Prof. Viola was to understand the theory of free probability and a proof of its free central limit theorem," he says. "This theory is not a traditional probabilistic/ statistical field, so it's not taught in traditional mathematics or statistics courses."



Dennis Stauffer

Although Dennis's problem was theoretical in nature – dealing with the foundations of a theory – the topic is not esoteric and has many practical applications. Thus, it is often used for optimization problems in Engineering. "Models that can be described by a matrix would need to use this method," he says. "A typical example might be a description of traffic flow where you have a matrix consisting of geographical locations in the columns and times of day in the rows; to statistically analyze optimal flow would require the use of free probability. Another example where it's used is in designing wireless networks, for determining optimal positions for the network's nodes."

When asked about his career goals, Dennis points out that he is in the Concurrent Education program, which allows students to work on bachelor's degrees in science and education simultaneously. He credits his educational background for setting him on this career path. "All through high school I had math teachers that were excellent – who challenged me to find my own ways to solve problems," he says. So why choose Lakehead? "I like the outdoors: fishing, hiking, etc. But mainly I've been really interested in education in First Nations, so Lakehead was a natural fit for me." ■

"This theory is not taught in traditional mathematics or statistics courses"

Evolving Ecology

Studying adaptation in a changing climate

The study of animal personality is becoming important in ecological research. Dan Durston and Denon Start worked with Biology professor Douglas Morris on projects in this area. Dan explains, "Behaviour can evolve much more quickly than physical biological traits, so in an era of rapid, human-induced change, it becomes very important to understand how animal personality can change and adapt to environmental changes." Denon expands on the theme, as it relates to his own research, "We looked at the meadow vole, *Microtus pennsylvanicus*, capturing them, determining personality type, and monitoring their foraging behaviour in our Habitron, to see what personality traits led to more or less risky foraging behaviour." One evolutionary conundrum is that traits evolving under one set of conditions may not be adaptive when the environment changes. How do these populations persist? Dr. Morris's Habitron, a unique natural laboratory where small mammal populations live in different controlled habitats, was designed to answer such questions. "When food is scarce, risky behaviour will lead to a higher survival rate because timid individuals will starve," Denon explains. "However, when food is abundant and predation level is high, it's better to be safe and not engage in risky foraging. But in either extreme, the maintenance of greater behavioural diversity confers population stability in a changing environment."

Dan Durston

Another type of human impact on animal behaviour occurs when animals exhibit maladaptive responses to anthropogenic changes, for example, mistaking a human-made item for a natural one. These are called ecological traps. Dan's research involved such traps; he gives some examples: "There are certain beetles that mate with beer bottles because they are shiny and the right colour as an ideal beetle mate. Mayflies may mistake the reflectivity of a window for the surface of water. Obviously, behaviours such as mating with a beer bottle are not conducive to successful reproduction!" In order to study these traps, and how organisms might evolve in order to escape falling into such traps, Dan needed a laboratory model. "There is an invertebrate species *Folsomia candida*, which is unpigmented and the young die very quickly if exposed to light. We discovered that by making changes within the visible light spectrum, adults fail to avoid egg-laying in illuminated habitats when given a choice, leading to increased infant mortality." Thus light versus dark conditions in the laboratory create an ecological trap that Dan and his fellow researchers can now use to explore the effect of changed environments on habitat use and its downstream effects on population size.

Denon Start

As one would expect from their research interests, both Dan and Denon are outdoors types with an interest in the

natural world. Denon says, "I've always liked the outdoors – hiking and white-water kayaking are two of my hobbies. A career in conservation is my goal, and this project gives me the kinds of analytical and

"In an era of rapid, human-induced change, it is important to understand how animal personality can adapt to environmental changes"

practical tools that I'm going to need." Dan expands on the sentiments of his lab mate, saying, "I had a couple of jobs after high school, but they were just jobs. I discovered I really had a passion for ecology – it sounds like a cliché but it really is a field where you have the potential to 'save the world' so it's easy to motivate yourself. That's what's important in choosing an educational program and a career: you need to do something that you're passionate about."

{{Post-script: Dan and Denon used their research experiences at Lakehead to help earn prestigious NSERC Graduate Scholarships. Denon received the President's Award at the May 2014 convocation.}} ■

OUTSIDE OPPORTUNITIES

Project-specific funding for undergraduate researchers

Research programs are funded through various sources, from government to NGOs to industry. Some agencies also fund salaries for specific undergraduate projects. One example is Environment Canada's Science Horizon Youth Internship. Harikrishnan Nandakumar took advantage of this program to study wetland sediments with professors Sree Kurissery and Florin Pendea in the Department of Sustainability Sciences. He explains, "The program is designed to help students obtain technical skills. My home is in Barrie so I was interested in this opportunity to do research of local importance."

The project involved taking core samples from wetland sediment around Lake Simcoe. "Nitrogen and phosphorus are more abundant near human activity, for example, from water treatment plants and fertilizer run-off." Hari says. "We found a strong positive correlation between levels of these nutrients and bacterial count." In addition, the natural ratios changed. "We had one remote site, which we used to determine 'natural' bacterial levels. Our results show that the nutrients arising from human activity had increased the ratio of anaerobic to aerobic bacteria," he says.

Hari considers his various research projects to have been an integral part of his undergraduate experience. "You learn a lot in the classroom, but performing original research in a lab group is another complementary set of skills that adds so much to the university experience."

Investigating Invasives

Determining resource requirements for zebra mussels

As she progressed through school, Cassandra Sinclair realized she was good at the sciences. Cassandra credits her mother: "She worked in the health sciences, so it was natural for me to gravitate toward the life sciences when it came time to choose a university program." Thus, she took specializations in general science and biology when enrolling in the Interdisciplinary Studies program at Lakehead's Orillia campus. As she progressed, she gravitated toward ecology as a career goal, influenced by her instructors and her longstanding interest in outdoor activities like camping and biking. These interests brought her to the laboratory of Dr. Nandakumar Kanavillil, a professor in the Departments of Biology and Sustainability Sciences.

"I get to use modern equipment and I'm gaining invaluable field experience"

Invasive species is the subject of a lot of ecological research, and one of the most damaging of these species is the zebra mussel. They are not native to North America, but are now ubiquitous in the Great Lakes region. "Even the small lakes in Simcoe County have zebra mussels in them," Cassandra says. Understanding their resource use and life cycle is therefore of interest if attempts to control their populations are to succeed.

Casandra Sinclair

Cassandra collected samples from Lake Couchiching. She describes her sample collection, "I collected water samples, algae from the rocks to be used as a food source, and mussels. I kept them in mason jars, some with algae, others without." Specifically, Cassandra was measuring their oxygen consumption. She continues, "Each day I monitored various levels of pH, dissolved oxygen, etc. in the jars. We were not replenishing the oxygen content so the drop had to have been through consumption by the mussels. In the case of jars that also contained algae, they could also have been consuming/producing oxygen, so we corrected for that." Not surprisingly, the well-fed mussels consumed more oxygen. "The O2 was depleted much faster in the jars that contained the fed mussels," Cassandra says. Through research like that done by Cassandra and the Kanavillil group, a greater understanding of these invasive species is achieved, which will aid in dealing with them without further harming the ecosystems into which they have been introduced. As a more practical matter, her ecological research is giving Cassandra skills that she can take into the workforce. She says, "I get to use modern equipment and I'm gaining invaluable field experience." ■

The Lay of the Land

Compiling land use information along the Kaministiquia River

Geographic information systems (GIS) are meant to manage data by location. In the case of urban planning and development, information on past land use is important. It is the subject of Andrew Carr's project, working with Geography professor Todd Randall. "The City of Thunder Bay has a long-term development plan for the banks of the Kaministiquia River," he says. "It's a beautiful river but it has traditionally been zoned for industrial use. Now that most of the industry is gone, the plan is to redevelop the land." Andrew explains that this is not simple: "You can't just re-zone the land from industrial to mixed-use and hope that it's safe. There will be environmental damage and contamination at old industrial sites, which will need to be cleaned up first."

"You can't just re-zone the land and hope that it's safe"

Therefore, the first step in a redevelopment project is to understand the land-use history. Andrew collated data from land survey maps of his area – the north bank of the river from Lake Superior to Highway 61. He used maps from 1913, 1935, 1950, and 1961 to get his information, determining what each property and building was used for, and entering the information into a database. "A GIS map is a series of polygons representing a parcel of land or a building, and each polygon is linked to a database that contains information about it. I entered data for 1500 polygons," he says. Once assembled, the data can then be visually displayed to demonstrate information.

Andrew Carr

Andrew gives the example of coal use: "There were 5 or 6 coal docks, which would be sites of high coal contamination. Sites that used coal to generate power would be considered secondary use sites, and areas of probable contamination." With Andrew's land-use history maps and the attached database, the City will be better able to plan for development, and to have an idea of potential remediation costs when a site comes up for sale. In fact, his maps have already been shared with the City's Planning Division.

Andrew's project fits well with his long-term goal of a career in urban planning. However, he points out that he didn't know what he wanted to do at university until he'd taken some electives in geography. "I wasn't strong in the traditional sciences, and I switched my major a couple of times," he says. "Then I took an elective in this area and really liked it. I think the key to success is to try things until you find something you like." ■

Sustainable Synthesis

Finding ways to make molecules in a more environmentally friendly way

Green chemistry is the study of making chemical transformations in environmentally friendly ways. Jennifer Steers is looking at one such transformation – that of putting a bromine atom onto an organic ring system – in the laboratory of chemistry professor Craig MacKinnon. "Bromine atoms can act as directing groups in organic transformations and brominated compounds themselves have many useful properties, so they abound in the chemical literature" Jen explains. "Unfortunately, the most common ways of putting on the bromine have waste by-products and they use organic solvents that are environmentally harmful." Therefore, her investigation has two complementary goals: finding an alternate source of the bromine atom and finding a green solvent.

Jennifer Steers

Since pure bromine is itself corrosive and dangerous to handle, Jen looked at ways to generate it from easy-to-handle bromide salts. For solvents she looked at those that are ubiquitous in nature – water, ethanol (drinking alcohol), and acetic acid (vinegar). Jen describes her lab work: "I did a lot of reactions, changing the various parameters of solvent, brominating agent, concentrations, and so on. After that I'd have to analyse the products to see what effect the different variables had. My goal was to find the optimal conditions to maximize a single pure product and minimize any waste by-products." Analysis of the products was done instrumentally and required identifying the product and determining its purity (seeing if there were any secondary products or leftover starting material). "You learn to use the instruments yourself, because there are so many samples, it's the most efficient use of instrument time," Jen says.

"The goal is to maximize product and minimize waste"

As an aspiring teacher in a concurrent education program, Jen didn't initially consider doing a research project. "I enjoyed teaching when I was in Air Cadets, and I liked my science courses in high school, so teaching chemistry was an ideal career path for me," she says. "But I had a lot of fun doing the research, so now I'm considering doing an MSc degree after my BEd." Either way, she says the experience has been useful. "It builds confidence in your presentation and organizational skills, which you also need as a teacher." ■

“Education is not the filling of a pail, but the lighting of a fire”

- William Butler Yeats

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