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QN
QUAESTIONES NATURALES
VOLUME 5, 2017

UNDERGRADUATE RESEARCH IN SCIENCE

Photo by Don Malcolm

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QUAESTIONES NATURALES

VOLUME 4, 2016

"Quaestiones naturales" is a Latin term referring to investigations into the natural world, or today what we 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.

"The scientist is not a person who gives the right answers, he's one who asks the right questions." – Claude Lévi-Strauss

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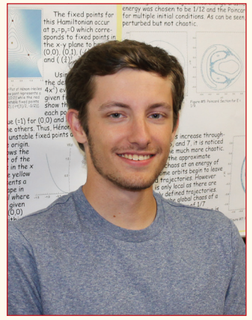
Research in the Classroom

Research projects in the sciences are typically worked on individually under the direct supervision of a research advisor, on a question of mutual interest. On the other hand, some course instructors incorporate research methods and topics as independent studies or group work in a class. One such class is Physics 4113: Classical Mechanics, taught by Physics Professor Hubert de Guise. Students in the course were given a list of current areas of interest in the field and asked to present a poster — a common conference format for presenting research — on their topic. Mark Suffak's topic was the Hénon-Heiles System, which can be used to describe astronomical motion. "I didn't know anything about the topic when I picked it," Mark says. "My partner Ivy and I looked at this mathematical system and learned how it changes over time. We also discovered how certain starting conditions can cause the system to become chaotic, which means the motion becomes random instead of following a defined orbit. The topic was right up my alley because I love the mathematical aspects of physics."



Mark Suffak

Mark is doing a traditional 4th-year research project this year, for which he's better prepared having experienced the research format in PHYS 4113. "I chose Physics because it was challenging enough in high school to be interesting; I chose Lakehead for the small class sizes. In both cases, I've been happy with my choice."

Adèle Jackson, an Environmental Sustainability major, learned her research methods from Associate Professor Thamara Laredo in the course ENSU 4010: Seminar in Environmental Sustainability. In this course, a group of students work together to learn about the process of doing research, choosing a topic, using the scientific literature, and scientific writing; they are responsible for creating a literature review and a research proposal. Then, in the next semester, the students can carry out their proposed research. "I'd taken a water resource science course last year. Between the information I learned in that course, the literature review, and talking to my professors, I found a gap in knowledge that I could fill." she says. This led Adèle to study the absorption of triclosan (found in antibacterial soap and other products) onto biochar. "I got a variety of feedstocks from the landfill," Adèle explains, "and after turning them into biochar, I tested each on its ability to absorb this common pharmaceutical."

Adèle Jackson

Rather than following the traditional thesis route, these ENSU courses allow a more collaborative environment between the students in the class. Adèle says, "My classmates and I didn't know how to go about writing a thesis or picking a topic, so this class allowed us to work together collaboratively, to throw ideas around, to peer review each other. It motivated us all to do our best for each other." ■

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Welcoming Remarks from the Dean

This is the fifth issue of *Quaestiones Naturales*, our annual publication of the research achievements of undergraduate students in the Faculty of Science and Environmental Studies. Student engagement is a top priority in our faculty and involvement of our students in exciting research projects is central to this priority. This year in *QN*, we feature ten students from across Lakehead's two campuses whose research interests cover the spectrum of field- and laboratory-based research done by our professors. Student projects profiled include: Joanna Dowhos' study of the 'trapezium' – a small bone in the wrist; Brant Muir's investigation of water quality in Thunder Bay's McVicker's creek; Andi Tomei's study of the carbon cycle contributions from wetlands in the Lake Simcoe watershed; and a chemical approach formulated by Braedan Prete to assist in the detection and monitoring of the progression of Alzheimer's disease. Several projects demonstrate that many scientific projects are inherently interdisciplinary such as Computer Science student Chris Gibb's use of his coding expertise in helping Dr. Zehbe's research lab in their group's work on the human papillomavirus and its relationship to cervical cancer. These are just a sampling of pure and applied research projects undertaken by students in our 10 academic departments each year. We take pride in being able to offer motivated students meaningful opportunities to work with leading scientists and technology. As you will note in this year's articles, our students clearly value the opportunity to get engaged in the research enterprise, applying their classroom knowledge to scientific questions that are important to them on a personal level or have broader benefits to the wider community. 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.

Todd Randall, PhD, P.Geo.

Dean of Science and Environmental Studies

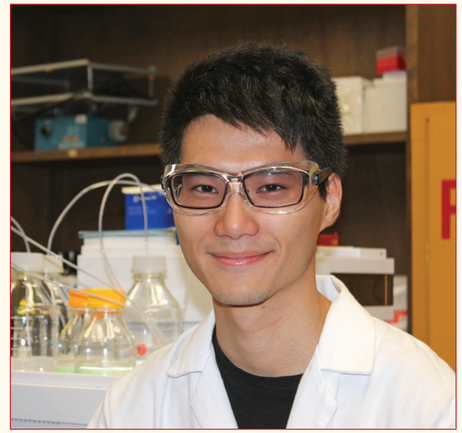
Electrochemical Experimenter

Finding new electrode materials to detect important biomolecules

As with many undergraduate students, Brennan Mao had a career goal in mind when he entered university, but didn't necessarily have his educational plan itemized to the last detail. "My original inspiration was my grandmother's cardiologist, so I knew I wanted to become a doctor," he says. "I knew that a degree in science would help get me there, although I didn't have any specific plans on what I would do for my undergraduate studies." Brennan opted for a degree in chemistry, and he's happy to report that he received an offer of admission to a medical school at the end of his program.

"This project has applications ranging from renewable energy to health care"

At first glance, his research in electrochemistry with Canada Research Chair Dr. Aicheng Chen does not appear to be relevant to his chosen career path. Having already learned multiple electrochemical techniques, Brennan was tasked with creating new electrodes. "My project was designing and testing new electrode materials," he explains. "We start with a common underlying substrate and build nanostructured materials on top of it. The same process can make new electrodes for a variety of purposes." One of Brennan's electrodes, made with cobalt quantum dots, shows promise in low-cost energy conversions for the hydrogen economy. Another electrode, made with bimetallic gold-platinum nanoclusters, was tested for a medical application. Brennan continues, "When coated with glutathione, the electrode can quantitatively detect two important biomolecules – guanine and adenine – under physiological conditions and in the presence of common interferents like glucose, thymine, and vitamin C." The detected molecules are both components of DNA, and their amounts can vary in certain health conditions. "Renal status greatly affects the concentration of these molecules, as do certain types of cancer," he says, "so there's the possibility of using this knowledge to develop a clinical application."



Brennan Mao

Brennan enjoys seeing how theoretical classroom knowledge, in his case in nanoscience and electrochemistry, can be translated into real-life applications. "The great thing about this project is that it has applications from renewable energy to health diagnostics," he says. "It shows that lots of different areas of research are required to solve current problems in health care and other fields." ■

Counting Carbon

Measuring wetland contribution to the carbon cycle

Wetlands are important in the life cycle of carbon in the environment. “They make up only 6% of ground cover but they account for up to 40% of the carbon turnover in the world,” explains Andi Tomei. “In the Lake Simcoe watershed alone there are eleven distinctive types of wetland.” Under the supervision of Sustainability Sciences Professor Florin Pendea, Andi’s project focuses on these wetlands over a span three years, after which she will supply a report to the Lake Simcoe Regional Conservation Authority. “Detailed knowledge of carbon turnover is necessary for communities to properly plan for the regulation of greenhouse gas emissions and for the trading of carbon offsets,” she says.

Andi Tomei

In her project, Andi will be sampling for carbon three different ways. “We’ll take surface samples by collecting litter in sample bags and measuring how it

“With this program at Lakehead, I really found my place”

decays over time,” she describes. “We’ll also lay out ground feldspar, which is like white sand, to capture organic matter out of flood water.” Below-ground turnover will be measured from core samples. “We will core up to 50 cm deep, and use caesium-137 and lead-210 isotopic dating to determine the age of sediments.” Because the presence of these isotopes are related to human activity, the amount in the atmosphere is well known. “The caesium isotope started getting into the air from the first nuclear arms tests, and the lead isotope started with the industrial revolution, so the timing for each is very well known.” Finally, the cores are replaced by peat and the rate of new root growth into it measured.

For someone who has long enjoyed the outdoors, Andi is right at home getting her hands dirty (literally!) for science. “Sometimes I’ll come back with mud all over my face,” she says, “but it’s really great to be able to do a project that gets me outside.” Having taken environmental courses in high school and being involved in recycling programs and gardening clubs, Andi was immediately attracted to Lakehead’s Environmental Sustainability program at the Orillia campus. She loves the small class sizes, the ability to do a co-op degree, and the fact that her professors treat her has a colleague rather than as a student. “With this program, I really found my place,” she says, “and with this project, it’s validated my interest and verified that this is what I want to do with my life.” ■

Quaestiones Naturales

Undergraduate Research in Science

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 ten students and their projects. They performed the research when they were undergraduate students; you will see they made interesting and significant contributions to their areas of research.

Researcher	Program	Hometown	Supervisor
Amy Cleaver	Geology	Grimsby ON	Shannon Zurevinski shannon.zurevinski@lakeheadu.ca
Joanna Dowhos	Anthropology	Winnipeg MB	Matthew Tocheri mtocheri@lakeheadu.ca
Christopher Gibb	Computer Science	Thunder Bay ON	Ingeborg Zehbe izehbe@lakeheadu.ca
Adèle Jackson	Environmental Sustainability	Barrie ON	Thamara Laredo tlaredo1@lakeheadu.ca
Brennan Mao	Chemistry	Hong Kong	Aicheng Chen aicheng.chen@lakeheadu.ca
Brant Muir	Geography	Thunder Bay ON	Rob Stewart rob.stewart@lakeheadu.ca
Braedan Prete	Chemistry	Thunder Bay ON	Mitchell Albert malbert1@lakeheadu.ca
Leah Shaw	Interdisciplinary Studies	Orillia ON	Sreekumari Kurissery skurisse@lakeheadu.ca
Mark Suffak	Physics	Thunder Bay ON	Hubert de Guise hubert.deguise@lakeheadu.ca
Andi Tomei	Environmental Sustainability	Angus ON	Florin Pendea ifpendea@lakeheadu.ca

Runoff Research

The effect of precipitation on water quality in urban areas

McVicar Creek starts outside the city of Thunder Bay, runs through urbanized areas, then empties into Lake Superior. Brant Muir's research project is an investigation on the change in water quality in the creek as the water moves through the city. By measuring things like dissolved oxygen and dissolved solids, he can assign a water-quality index rating. "In the rural sampling site, the water is consistently over 80 in score, which is excellent," Brant says. The high-quality score is maintained through the urbanized areas if there is no runoff entering the stream on dry days. Unfortunately, as Brant explains, "On dry days contaminants are deposited in areas of urban cover that washes into the stream on wet days, so the overall quality can quickly drop to poor."

"With this kind of project, you get the freedom to do your own research."

Brant makes the conclusion that the creek suffers periodic "shocks" of poor water quality when precipitation events wash the material deposited during the dry times from the urban landscape into the creek. This kind of conclusion requires a lot of tests at different sites under different conditions over the course of several weeks. He used a multi-meter to measure certain parameters *in situ* (directly in the stream), and also collected water samples to analyse nutrient concentrations in the lab. "October was really dry this year, but that helped establish the baseline of what the water is like under dry conditions," he says. "When it finally started to rain in November, I would rush out to get samples to capture and test the runoff."

Brant Muir

With a long-standing interest in environmental science, Brant is glad to get the chance to do research in the area. "I really liked my Environmental Science course in high school, and the teacher I had," he explains. As his interest focused on water quality, he approached Professor Rob Stewart in the Department of Geography and the Environment to see about research opportunities. "The research project really complements the course work – in classes you learn the necessary material but with the project you use that information and you get the freedom to do your own research." ■

HPV Detective

Determining how a virus genetically integrates in cervical cancer

As a computer science major, Chris Gibb often has to explain why he is employed by a biology professor. "Genetic information is enormous, even for simple life forms," he explains. "Then there's the complication that there is no standardized format, so every group uses whatever freeware format they find or write for themselves in the lab." For Dr. Ingeborg Zehbe, a Thunder Bay Regional Health Research Chair in the Department of Biology, this is a big problem. She and her group are investigating how human papillomavirus (HPV) causes cervical cancer. "We want to see where in the genome the HPV genetic material is inserting itself into the cancer cells' genetic information," Chris continues. "Thus we need to compare

"We want to see where the HPV genetic material is inserting itself into the cancer cells"

human genetic sequences to viral ones." The comparison algorithms are well understood, although not trivial because no one knows which parts of the viral genome are inserted, nor where in the human genome they might be found. Thus, a computerized search system must be set up to scan for any part of the viral DNA within any part of the cancer cell's DNA.

This is the point at which the computer scientist is needed. "Computers aren't able to intuitively recognize the same type of information in different formats," Chris says. "Therefore, you need to transform

Christopher Gibb

between formats so all the data is in the same format." Transforming formats automatically and without errors requires a precise algorithm that will be different for each format, which the investigating scientist will need to code into a computer language. Not until the data is consistently formatted can the biological study commence.

Chris was always interested in computer programming from the earliest years of high school. "I had good mentors in my high school, and I already considered programming to be a hobby, ever since learning C++ one summer just for something to do," he says. His unconventional research path into a biology lab has been intellectually stimulating, even if unexpected. "I've been the 'programming guy' in the lab," he continues, "and I've even been able to mentor other computer science students in self-directed study projects. That's given me some teaching experience as well, which has been very rewarding." ■

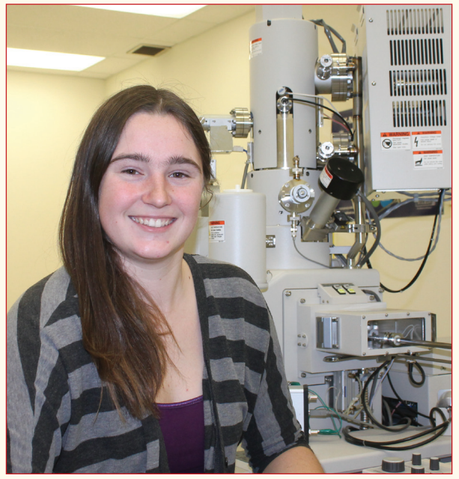
Mineral Hunter

Finding strategic resources in the minerals of Northwestern Ontario

A two-month canoe trip is not the typical introduction to science research, but that is exactly how Amy Cleaver started. “That’s the great part of doing a Geology degree,” Amy says, “you get to spend time outdoors. At the same time, you get to apply the basic chemistry and physics knowledge you’ve learned to a practical situation, which is very appealing.” Amy’s degree path started years earlier in high school. “It’s not until high school science that you start to be able to answer the question of ‘why?’” she says. As she got deeper into her studies, she realized (as all university science students do) that there are very real and easily-reached limits to what is known. “Research makes you think and question instead of just accepting what other people have said.”

“You start to appreciate why you were forced to learn all that stuff in your classes.”

Her current project with Geology Associate Professor Shannon Zurevinski is on a rock called carbonatite. “The rock itself is interesting because the mechanism of formation isn’t fully understood,” Amy says. “I was focused more on the mineralogy, especially the presence of the rare metal niobium.” Ease of processing in a mining operation depends on the mineral composition and crystal phase of the metal. Amy continues, “After collecting samples of drill core from a local deposit, we determined by SEM [scanning electron microscopy] that there was lots of niobium, in the



Amy Cleaver

form of the mineral “pyrochlore”. We also found that there’s not much thorium or uranium present, which is good because those metals are costly to remove. Most importantly, the niobium was mostly in one phase, so it can be extracted using a simple method.” The deposit is located near Marathon, Ontario, which is of interest because the world’s supply of niobium comes mostly from three mines in Brazil. “It’s very much a strategic resource, so it’s important to find new sources.”

Research projects often serve as capstones to a degree program. As Amy says, “Once you get to doing your own research, you can then start to appreciate why you were being ‘forced’ to learn all this other stuff in your classes. You can see why the professors are teaching what they’re teaching.” ■

Tool Time

Tracing the evolution of anatomy related to tool-use in the genus Homo

Joanna Dowhos loves the learning environment at Lakehead University: its small class sizes, location in a smaller urban centre, etc. “In a big city, you leave extra time to account for traffic; even now I’m always early,” she says. “I talk to friends at other universities and tell them how small my second-year classes are and their jaws just drop.” At the end of one such course, Joanna got recruited into the research lab of Canada Research Chair in Human Origins and Anthropology Assistant Professor Matt Tocheri.

Joanna Dowhos

In Dr. Tocheri’s lab Joanna has been studying how the shape of the trapezium — a small wrist bone at the base of the thumb — has changed over the course of evolution in humans and great apes. She explains, “These species use their hands (and thumbs) in a variety of different ways. Understanding how the anatomy influences these different behaviours is crucial for answering big questions like why do humans make and use tools and most other animals do not.” Joanna’s results using 3-D models of the trapezium show how the shapes of this bone vary among these different species such as *Homo habilis* and Neandertals. She continues, “My analyses can clearly differentiate gorillas from chimpanzees, bonobos and humans. The bone in fossil humans has a shape falling between the shape clusters for humans and chimps, our species’ closest living relatives.” This gives anthropologists a tool to objectively assess new fossil finds to determine how modern human-like they were in terms of thumb anatomy and function. This information is important for increasing our understanding of the evolution of behaviours involving stone tools in hominins. The bad news is that Joanna’s work is on one particular hand bone, which hasn’t been recovered for every fossil species, like *Homo erectus* for instance. “Now that we have a clearer understanding of the evolutionary changes that have occurred for this bone, we’ll move on to other ones in the wrist to see if there are similar changes through time.”

“Research makes you learn to digest information differently”

Since she’s been actively involved in research from early in her university education, Joanna has noticed it has enhanced her learning experience. “In a university course you’re mostly learning information, which isn’t what science is necessarily about. In research, you have to constantly question your information: ‘What do these results truly mean?’ You learn to digest information differently,” she says. Students get another important learning tool, which Joanna has found useful throughout her academic career. “Research forces you to problem-solve and think critically, and the more you learn those skills, the easier everything becomes.” ■

What's Old is New

Looking for modern medicines in traditional remedies

The Interdisciplinary Studies program at Lakehead's Orillia campus allows students to study a variety of topics in both the arts and science, which appealed to Leah Shaw. "This program allowed me to study sciences like Biology and Geography, which were two specializations in my program, while also exploring the social sciences and humanities as well. The combination was very appealing to me," she says. For a research project, she worked with Biology and Sustainability Sciences Professor Sree Kurissery, investigating traditional medicines. "Oral tradition from the native peoples of the area describe medicinal attributes in local plants," Leah continues, "so they are great places to look for new anti-bacterial compounds, for example."

"Traditional medicines are great places to look for new anti-bacterial compounds"

Specifically, Leah is looking at endophytes living in the interior of the leaves and roots of the medicinal plant. "These fungi and bacteria produce secondary metabolites, some of which may protect the plant from harmful organisms like bad bacteria," Leah explains. In order to isolate them and test the metabolites, she takes aseptic, surface-sterilized leaves and roots, cuts them up and adds them to growth media. "The endophytes come out of the plant matter and grow in the medium. We then take a colony and insert it onto another plate containing a pathogen bacterium

Leah Shaw

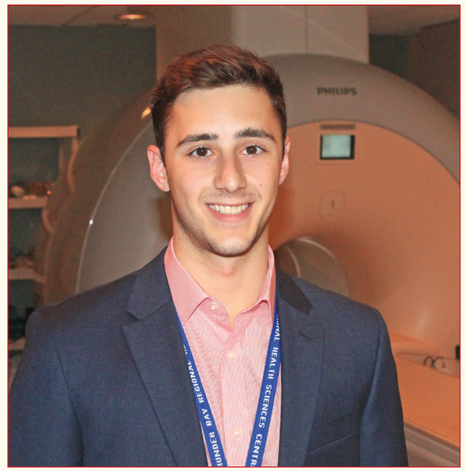
like *E. coli* or a *Staphylococcus*." As the endophyte grows and produces metabolites, they leach into the surrounding pathogen. "If the metabolite has antibacterial properties, a halo will form, which shows that it is killing the pathogen bacteria," she says. Leah has collected several hits, *i.e.*, endophytes that are cytotoxic. She continues, "The next step will be to analyse the best hits to determine the effective species, probably by DNA analysis, and then the chemical identity of the metabolite."

Leah is continuing her education by volunteering at an animal refuge in Rosseau, Ontario. "I've always loved animals, and I want to try different things so I can find what I like and what I will do for a living." A multidisciplinary degree like Lakehead's HBASc is designed for just such a purpose. ■

Biosensor Breakthrough

Creating new molecular imaging agents to improve detection of Alzheimer's disease

Chemistry bills itself as the "central science", which is why Braedan Prete chose it as his major. "I like to understand the underlying function of how things work, so I've always been drawn to science, especially chemistry," he explains. Now that he is well into his university degree, he has grown to find the combination of theoretical coursework and practical research appealing.



Braedan Prete

Braedan is currently working with Chemistry Professor and Research Chair Mitchell Albert in a pre-clinical setting at the Thunder Bay Regional Health Research Institute to find improved methods of detecting and monitoring Alzheimer's disease using magnetic resonance imaging (MRI). He has a personal connection to the project, which he claims as his original inspiration: "My grandfather suffers from Alzheimer's and his condition inspired me to engage in this project." Specifically, Braedan's research focuses on finding improved ways of imaging the fibril components of β-amyloid plaques in the brain, which are known precursors to Alzheimer's disease.

A contrast agent that can detect these fibrils using a clinical MRI scanner would be an ideal solution. Braedan's chemical approach utilizes a molecular system of three components: "The first is a supramolecular cage, which is basically a doughnut-shaped molecule capable of interacting with the second component, hyperpolarized xenon gas. The third is an antibody, which is attached to the cage,

"Now that we've demonstrated 'proof of concept' we can begin working on a targeted system"

allowing for the imaging agent to bind to the desired site." Via his approach, a particular disease biomarker, such as β-amyloid, can be identified using MRI. "We have successfully highlighted various organs in a living mammalian model using a non-specific, prototype system," explains Braedan. "Now that we've demonstrated 'proof of concept' we can begin working on developing a targeted molecular imaging system to specifically locate fibrils of β-amyloid plaques before they progress into Alzheimer's disease." Being able to apply fundamental concepts learned in his coursework helps Braedan to understand his research, along with its potential for clinical use. "It's exciting to be able to apply these concepts to real-life situations," he says. "You can see how this research may lead to unmet clinical solutions that will benefit actual people, which is a great way to stay motivated." ■