QN QUAESTIONES NATURALES

VOLUME 1, 2013

UNDERGRADUATE RESEARCH IN SCIENCE

Lakehead UNIVERSITY

Faculty of Science and Environmental Studies

lakeheadu.ca

QN

QUAESTIONES NATURALES

VOLUME 1, 2013

"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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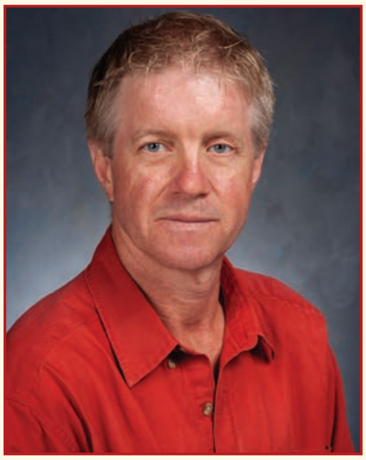
Welcoming Remarks from the Dean

This issue of *Quaestiones Naturales* is the beginning of an 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. you have nine featured students whose research interests range from the applied to the pure sciences. Subjects range from new uses of malt waste in beer production, to cancer treatments, and to the social science aspects of community and home. 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. Last year alone we spent 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!

Andrew P. Dean, PhD
Dean of Science and Environmental Studies
Lakehead University



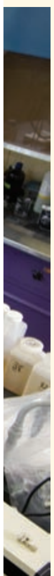
Andrew P. Dean, PhD

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

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 all performed the research described when they were undergraduate students, and you will see that they all made an interesting and significant contribution to their area of research.

Researcher	Program	Hometown	Supervisor
Adrian Arts	Water Resource Science	Victoria BC	Philip Fralick philip.fralick@lakeheadu.ca
Michael Barten	Environmental Studies West (Geography)	Suffield CT	Robert Stewart rob.stewart@lakeheadu.ca
Krista Dowhos	Chemistry	Thunder Bay ON	Mitchell Albert malbert1@lakeheadu.ca
David Frank	Geography	Brampton ON	Todd Randall todd.randall@lakeheadu.ca
Timothy Miao	Mathematics	Thunder Bay ON	D. Li & R. Anisca deli.li@... & razvan.anisca@...
Karl Rom	Physics (with concentration in Biomedical Physics)	Thunder Bay ON	Alla Reznik alla.reznik@lakeheadu.ca
Emily Smyk	Geology	Thunder Bay ON	Peter Hollings peter.hollings@lakeheadu.ca
Joseph Tassone	Chemistry	Thunder Bay ON	Gregory Spivak greg.spivak@lakeheadu.ca
Danielle Thiel	Applied Biomolecular Science	Regina SK	Wensheng Qin wqin@lakeheadu.ca



Sensitive Selenium

Searching for the cause of the photoconductor's instablities

Selenium is not the most familiar element in the periodic table, but it appears in a surprising number of places, including the human body (it is an essential micronutrient), in the production of glass, and as a photoconductor in photocopiers, solar cells, and digital cameras. It is this last use – as a cheap and effective light detector in high-resolution digital photography – that has caught the eye of the medical imaging community. Karl Rom is a fourth-year student studying with Dr. Alla Reznik at the Thunder Bay Regional Research Institute studying the photophysics of the amorphous form of selenium.

"The project is strictly a physics project," says Karl. "We are studying how the interaction between light and amorphous selenium causes the material to degrade. But the application is definitely medical." These two aspects of the project – physics and medicine – neatly encompass the two fields of study in Karl's program of study. His degree is Physics with a Major Concentration in Applied Biomolecular Science, ideal for building a bridge between the physical science and medical communities.

"We need to know the physical basis of the problem before we can fix it."

The problem with amorphous selenium is that exposure to light or X-rays causes a slow degradation in the material, converting from the desirable photoconductive amorphous form to the inert crystalline form. Therefore any device using the material would also degrade in quality. Previous research in the Reznik group showed that the damage is reversible under certain conditions, such as elevated temperature. Karl's project involves initiating defects in the material and determining exactly what physical effect the defect has on selenium's optical properties. "Setting up the apparatus properly is a big part of the process," Karl explains. "There are two lasers that need to be aligned; the power in each needs to be accurately known so we can correctly measure how much is being absorbed by the darkening effect. We may need to adjust the focus, and so on. It's a lot of trial and error." Getting the data is worth the effort though: Karl and Dr. Reznik have already published some of the work in a scientific journal. If the research sounds esoteric, the use is certainly not. "We need to know what the physical basis of the problem [photoinduced degredation] is before we can find ways to prevent it. Only after that happens will we be able to use the material in medical applications."

Karl Rom

Karl has plans to continue his medical education. "Ever since elementary school I've wanted to become a doctor," he says. While it may seem strange for an aspiring physician to pursue a degree in a Physics Department, in fact Ontario medical schools, such as the Northern Ontario School of Medicine, will accept applications from any degree program. Perhaps by the time Karl finishes medical school, he'll be able to see his research turned into technology. "Potential applications might include flat-panel high-resolution detectors for mammography and X-ray instruments. If we can work out how to prevent this darkening, the resulting detectors could be better than those made with current technology." ■

Bacteria for Better Brewing

Uses for 'waste' malt water created in the beer-making process

Growing up in Regina, Danielle Thiel had no plans to be a scientist. "Both my parents were chartered accountants," she says, "but I took accounting and biology in high school, and I liked the biology class much better." Her interests narrowed after taking her first-year courses to the molecular side of biology, and she is currently in the third year of her Applied Biomolecular Science degree, doing a research internship project with biologist Dr. Wensheng Qin. "He needed someone for a project he was working on with the Canada Malting Company and asked me if I would be interested. The company is located here in Thunder Bay."

"Right now the waste is purely an expense, but could it be used to create useful commodity chemicals?"

In the process of malting, waste water is produced that must be treated before it can be released back into the environment. Danielle explains the problem: "Right now the waste is purely an expense, so they wanted to know if there was something that could be done to make the process cheaper and easier, and maybe even to see if there was something that the water could be used for to create useful commodity chemicals like ethanol, hydrogen, or lactate." Enter Danielle and her bacteria. Because the waste water has a variety of nutrients in it already, it can be used to grow bacteria. These bacteria could then break down the unwanted chemicals in the waste water and use those raw materials to produce useful chemicals instead.

Some of the bacterial strains that Danielle is investigating were already present in the water. "We noticed that the untreated water from the company, when we left it for a while, had clumps of bacteria growing in it," she explains. Danielle isolated and purified eight strains of bacteria from the clump. Along with other naturally occurring strains isolated elsewhere by students in the Qin group, she is in the process of testing their survivability in the malt waste water. The top-surviving strains are then placed in a sample of the waste water and after a period of seven days the water is tested for the presence of useful chemicals. "We used an ethanol kit and it showed positive for ethanol compared to the control, which was the malt water without the bacteria," reports Danielle.

This is a very promising result that bodes well for the project and for the Canada Malt Company.

Danielle Thiel

So why did Danielle choose Lakehead instead of a university in her home province? "I had a friend on the track team here," she says, "and he told me how great it was. I'd never been to Thunder Bay before, so the track recruiter flew me in and I loved the school and the team, so I came here." ■

Making Molecules More Easily

Designing systems to improve chemical synthesis

A catalyst is a chemical species that speeds up a reaction. Perhaps the best known are the enzymes used by living beings, but catalysts are also used in the creation of commodity chemicals, pharmaceuticals, etc. Joseph Tassone is looking at creating new catalysts for use in fine chemical synthesis. "The fine chemical industry creates elaborate new molecules such as those used in medicine," he says. "Many of the catalytic reactions they use are not well developed or understood, so there's lots of room to study and improve upon these reactions." Working with chemistry professor Greg Spivak and his group, Joseph is studying a particular reaction that creates carbon-carbon bonds, the most important type of bond in organic chemistry. The reactions all involve a catalytic step requiring a metal carbyne, which is a molecule with a metal-carbon triple bond. The metals that are currently used are not ideal, explains Joseph. "We want to develop catalysts where ruthenium is the metal, because they may be more stable to environmental conditions and they would certainly be cheaper than the current catalysts being used."

Joseph Tassone

So how does one design a catalyst? The metal has more than just the metal-carbon triple bond. There are other molecules attached to the metal called ligands. By changing the properties of the attached ligands, the overall properties of metal centre are also changed, and therefore the catalytic properties. "A lot of what we do is ligand design," Joseph says. "We make a ligand, try it in a variety of different situations, evaluate its effectiveness in mediating the reactions we want, then alter the ligand to make improvements." This iterative approach seeks to improve the properties from one catalyst to the next.

"They may be more stable and would certainly be cheaper than the catalysts currently being used."

One challenging part of this chemistry is that the reactions are often oxygen and/or moisture sensitive. "We need to remove the air and replace it with an inert atmosphere. So we get to use interesting glassware, vacuum pumps, and liquid nitrogen, which is always fun," Joseph says. "We also use a lot of the techniques that we learn in our classes, so it reinforces those concepts and helps you see how they are used in a broader context."

Research is also a social endeavour. Joseph continues, "Doing research means you get to know the profs better. You meet people with similar interests, who you wouldn't have met otherwise, and you learn lots of other things." Even the wide variety of music that's always playing in the Spivak lab is a positive part of the experience. "My other passion is music, I've played piano for years." ■

Understanding the Canadian Shield

A 'gold mine' of information about the geological past

Since Thunder Bay sits right on the Canadian Shield, there is no better place to do a geology degree. "People come from all over the world to look at our rocks," says Emily Smyk, a student studying for her geology degree. "They are incredibly varied, they are easy to access; they are some of the oldest rocks in Canada." You might say that Emily was born a geologist. "Even as young as age two I wanted to be a paleontologist so I could dig up dinosaur fossils."

There are few fields where the academic and economic aspects are so closely intertwined as they are in geology. Emily spent two summers working for the Ontario Geological Survey before starting her research project co-sponsored by geology professor Peter Hollings and GoldCorp Inc. at Musselwhite mine. "We're studying a very old felsic volcanic unit, that's a certain type of volcanic rock. It's three billion years old," explains Emily. Although the Shield is considered inert now, it was not always so. Different parts were formed in different ways, which all fused together later. Emily's rocks stand out from the surrounding rocks, and her research is to classify them and create a model on how they were created. "I have to hike through the bush for a couple of kilometres," she says as she describes her typical day. "You usually make enough noise that it scares off the wildlife, although I have run into a moose, and I did have to use a bear banger once to scare off a bear."

"They are incredibly varied, and some of the oldest rocks in the Canada."

Emily Smyk

Once at her site, she maps the area and takes rock samples, making note of the samples' GPS coordinates. "The company wants to know the extent of the formation to get an overall 'big picture' of their property." She then takes the samples back to the lab to analyse them to determine the exact composition of the rock. "Certain trace elements are concetrated by certain types of tectonic activity – rock from a spreading ridge from the mid-Atlantic would be different than rock formed by a plume like the Hawaiian Islands."

Emily has already learned lots of skills through her research projects that wouldn't be possible in a classroom setting. "Half of geology you learn in the field," she says. "I've also done training to use boats, ATVs, trucks, and animal awareness." It's little wonder that Emily is so enthusiastic about her work, and that she plans to continue in a geological career. "I love the exploration aspect – you get to work outside and with exploration I'll get the chance to keep discovering new things." ■

Accreting Arsenic

Concentration of trace elements in lakebed formations

When Adrian Arts was looking at programs in which to do his degree, Lakehead's Water Resource Science stood out. "I looked at other programs in Canada and even a couple in Europe, and Lakehead just felt like the right fit," he explains. Having already attended a couple of other post-secondary institutions in his native British Columbia, he immediately saw the value in the smaller class sizes and the hands-on opportunities that Lakehead offers. "I went to a university in B.C. for a couple years," he says. "I was in a geology class with a thousand other students, learning out of a textbook. I can't learn anything that way. I need to be in the lab, to actually do it myself. That's why doing research is so much fun too."

"The arsenic content is 1700 ppm, which basically makes them poisonous!"

Adrian is working with geology professor Philip Fralick, trying to determine how a certain geological formation called a ferromanganese nodule is formed. He describes them as, "disc-shaped, thin but up to 40 cm in diameter and very porous. There is a lot of debate over how they form, so we wanted to use modern instrumental techniques to see if we could figure out their origins." They form in lakes and oceans, but the chemistry is very different. Adrian's freshwater nodules contained a variery of elements in concentrations many times higher than the surrounding water. "The arsenic content is 1700 ppm, which basically makes them poisonous! So the arsenic in the ground water enters the lake, the water chemistry changes to oxidizing conditions, and the arsenic gets absorbed and incorporated into the nodule. Also lots of other elements: zinc, lead, cobalt, barium."

Adrian Arts

The technique that Adrian uses most is scanning-electron microscopy (SEM), which magnifies the samples 100,000 times. With it, he's been able to see structures that no-one else has ever identified in these nodules. "It was thought that the structures were mainly amorphous, which is what X-ray diffraction [another instrumental technique] would suggest. But with the SEM, we've been able to find different crystalline domains. Getting good images and identifying them is all about manipulating the different SEM instrumental parameters – it's like a video game," Adrian says. He's also discovered clusters of iron-covered bacteria, which likely account for the origins of the nodules. He explains, "We find these things growing on pipes and plastic bottles. There's no way something can grow that quickly through purely geological means, there had to be a biological origin, which appears to be these iron-fixing bacteria."

This is exactly the sort of skill set required to determine whether life has ever existed on planets other than Earth. Adrian is ready to take up the challenge: "If they ever ask for volunteers to go to Mars, I'm going to be first in line!" In the meantime, there's lots of terrestrial potential: "The way these nodules collect arsenic, we hope to be able to make use of their formation mechanisms for water purification." ■

Finding Cancer

Making new molecules to help detect tumors early

It is a truism in cancer treatment that the earlier the cancer is detected, the more treatable it will be. Therefore, increasing the ability of medical scanners to identify small features would automatically increase the rate of diagnosis as smaller tumors could be identified. Krista Dowhos is doing research at the Thunder Bay Regional Research Institute with chemistry professor Mitchell Albert. Her goal is to assemble a biosensor capable of finding cancers and marking them so that a magnetic resonance imaging (MRI) scanner can detect them more easily.

Krista explains the design of the sensor she hopes to create: "It has three parts. The first is a ligand, a molecule that will attach to a biomolecule associated with a type of cancer, which causes the sensor to collect at the site of the tumor. Attached to that is a cage-like piece called a cryptophane. Inside the cage is something called hyperpolarized xenon." The xenon is the key ingredient for the imaging properties, specifically its exchange between its dissolved and biosensor-encaged forms. Krista continues, "While in the cage, application of radio waves will destroy the xenon MR signal. Then when the xenon leaves the cage and moves into the dissolved state, this 'destroyed' signal follows. This process takes place at the site of the cancer because that's where the biosensor has taken the cage, so imaging xenon in the scanner will show a dark spot where the signal was destroyed, which corresponds to the location of the tumor."

"Doing research as an undergraduate gives you additional incentive to learn the material."

Doing medical research in oncology fits right into Krista's career path. "One week into Grade 11 chemistry I knew I'd like to study that in university, and the more I looked into career paths, the more I realized that a chemistry degree opens endless career opportunities. By the end of Grade 11, I'd settled on medicine." She was also inspired in her career choice by a family member: "My grandfather was a surgeon, and I always thought I'd like to be a doctor too," she says. She has now gravitated to cancer medicine because of its potential for research. Work on the causes of cancers and on improving treatments are going to keep continuing, so there's lots of room to combine research with clinical practice in oncology. "That also comes from my grandfather," Krista explains. "He was a life-long learner, always reading and learning as much as he could, not just about medicine but everything. As kids, he was always the family member we went to if we needed information or wanted to know how something worked."

Krista Dowhos

Krista also points to more immediate benefits to doing research as an undergraduate student. "It really helps you understand a context for the classroom skills and information you've learned, and that gives you an additional incentive to really learn the material," she says. "It also helps your overall confidence because you always need to throw ideas out there, and it helps you develop the initiative – if you don't do the work, no one will and we'll all miss out on that new discovery." ■

Back to the Natural State

Determining the effect of a man-made stream diversion

You might say that Michael Barten was genetically predisposed to a career in science. "My parents were both scientists, which can make for some interesting dinner table conversations," he says. Michael comes to Lakehead from Connecticut. "I wanted to see other parts of the world, and so I looked around at a few places and decided I loved the Thunder Bay area." He is taking a degree in Environmental Science (Geography major), which he enjoys due to its interdisciplinarity, i.e., he gets to take courses in many departments and meet lots of people with different scientific backgrounds. His research reflects this as well, he is working with Dr. Rob Stewart in the Department of Geography on a project that includes the Department of Fisheries and Oceans, the North Shore Steelhead Association, and the Lake Superior Remedial Action Plan group.

Michael's project was to provide a water quality analysis of a small stream in a local park. It has been targeted for remediation to a natural state. Michael explains, "There's two parts to the stream, the source is a groundwater seep and then the stream meanders naturally for about half of it's length. Then suddenly, it's completely straight right down to the Current River. My bet is someone didn't want to have to navigate a lawn mower or something around this stream bed, so they just created this drainage ditch, basically, and diverted the stream into it." In spite of its small size, there is a local population of sexually mature brook trout trapped in the stream. "They can get up there at times of high flow and then they get trapped."

Using portable instruments, Michael measured various parameters such as pH (a measure of acidity), temperature, and total dissolved solids along the length of the stream, over the course of a month. He then analyzed the data and discovered a significant statistical difference between the data in the two regions of the stream. "The groundwater seep had very little fluctuation in temperature, even though it was October and the ambient weather changed a lot. On the other hand, the remainder of the creek fluctuated significantly." He goes on to explain that temperature stability is one of the important uses of small tributaries. "Brook trout are very sensitive to temperature. They seek thermal refuge when the river is too warm, but as the stream is now, they can't navigate up to the thermally ideal part."

Michael Barten

In consultation with Dr. Stewart, Michael has put together a report containing his water quality findings (perfect conditions for brook trout in the upper stream) along with recommendations for how to proceed when the DFO and NSSA go ahead with the remediation project. "I have influence on a real-world natural resources project, which is one of the coolest parts of doing research here. The engineers are using my data as the basis for a water diversion permit." Michael would encourage everyone to take advantage of research project courses, even if it isn't required by their degree program. "It's such a great capstone to the undergraduate experience," he says. "It brings together concepts you might not have really understood and forces you to learn them properly, in order to use them for a real-world application." ■

> **"Brook trout are very sensitive to temperature, but as the stream is now, they can't navigate up to the thermally ideal part."**

What is Community?

Determining what makes a neighborhood a home

There were plenty of urban landscapes for David Frank to observe when he was growing up in southern Ontario. “Brampton only had one French immersion school, and it was on the other side of town from where I lived. So I had to bus across the whole city every day,” he says. The physical separation of his home and school also got David thinking about community, “I had two communities – my school group and my home group, and they were essentially independent of each other.” Thus, David had a head start when organizing his research project with Dr. Todd Randall in the Department of Geography. David explains the project: “My research addresses sense of place, which is a measurement that refers to an attachment people feel to a physical environment, and then relating that attachment to a sense of community, which is an attachment to social processes that exist in that place.”

David Frank

The New Urbanism movement supports a change from the typical separation of residential and service locations – typified by the stereotypical suburban subdivision – to mixed zoning where people’s homes, schools, and shopping areas are all located in a small geographical area. “Obviously the shorter distances would lead to greater opportunities to walk or bike,” David says, “The literature shows that people have a greater sense of place in these kinds of neighbourhoods. I wanted to see how this scenario applied to neighbourhoods in Thunder Bay.”

David’s project involved surveying three neighborhoods, all of which were built about the same time and which contain the same demographic mix. “The literature is very clear that it is very important to control for demographics, because they can have a huge effect on these topics,” he says. The three neighbourhoods each had different ammenities: one had a small shopping centre on its border, another had a small school located within it, while the third had no amenities at all. He then distributed surveys asking respondents to rank how important certain amenities were to them (schools, shopping, recreation, parks). He then went on to assess people’s attachment to these physical features and to test the level of community within each neighborhood, in order to determine if there was a correlation between the two. “In this context, community is the combination of the social processes in the neighborhood,” David explains. “It can be tested by assessing statements like, ‘I am on a first-name basis with my neighbors,’ or ‘Children play safely and responsibly in my neighborhood.’ You rank each statement on a scale of one to five, strongly disagree to strongly agree.”

> **“Community is the combination of the social processes in the neighbourhood; it can be tested by assessing statements like, ‘I am on a first-name basis with my neighbors.”**

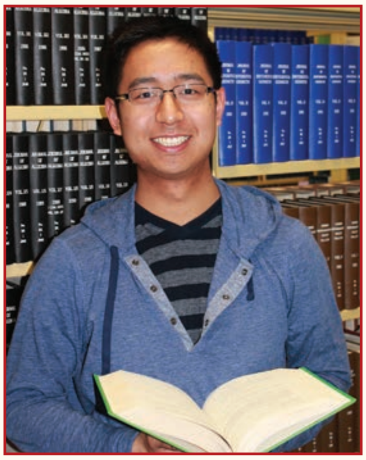
Ultimately, David’s ideal career would be in urban planning, for example planning subdivisions for a real estate developer, or a transportation grid for a city. “This research project was not a requirement of my program, but I’ve benefited greatly from it. It’s given me additional skills that are going to be of great use to me as I move on from university.” ■

Prove Everything

Making assumptions is never an option in mathematics research

Making the most of the university experience means taking advantage of extracurricular academic activities. Tim Miao learned this early on. He explains, "In my first year at Lakehead, I was talking to an upper-year student who was a Student Ambassador, and he was telling me about summer work opportunities. Of course these were research jobs, so I started asking around and was lucky enough to find someone willing to take me on."

For two summers, Tim did probability research with Professor Deli Li. Tim describes mathematical research this way: "You need to use rigorous definitions and prove every step along the way. You can't make assumptions based on intuition, because often the intuitive answer is incorrect." Specifically, his research involved trying to find general solution methods for recurrence relations. "These are equations that recursively define a sequence, meaning the solution to an equation is used in a subsequent equation in the sequence," Tim says. Traditionally these kinds of equations are hard to solve, but he was able to use the Master Theorem to solve certain classes of these relations. A second project with Dr. Li involved discrete time Markov chain studies. "These systems experience the Markov property, where the variables are random and change over time," he says. "Practical applications include weather prediction, economic analysis, or modelling the motion of particles moving in a fluid."



Tim Miao

Tim was therefore well-experienced when it came time to enroll in a 4th-year project course for credit. Working with Prof. Razvan Anisca, he studied pathological functions. "The word pathological, in a mathematical sense, means that the function behaves in a non-intuitive way," Tim says. "This type of research definitely involved creativity, but also taught me to clear my work of assumptions, because by definition these functions don't do what you think they should." Tim worked on two types of strange functions: continuous yet non-differentiable, and increasing functions that have 0 (instead of positive) derivatives at most points. He then drives home his point about mathematical rigour: "100 years ago it was thought that such functions couldn't possibly exist. But they never bothered to prove it, so it was quite a shock when they were discovered."

"100 years ago it was thought that such functions couldn't possibly exist. But they never bothered to prove it, so it was quite a shock when they were discovered."

Tim sums up his experience this way, "I like how I was able to use what I learned in my classes and apply them to current areas of research." He also likes to point out that the university experience doesn't just involve academic work. "I've spent time with Superior Science, which is a science camp for elementary school kids. I've hosted celebrity scientists like Jay Ingram as part of the Science Speaker Series. I also wanted to do something completely different than academic schoolwork, so in the last few years I've trained and competed in weightlifting competitions, which I've really enjoyed. My experiences at Lakehead have offered me a lot and have definitely set me on a positive direction for my future." ■

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