

# GRADUATE AND POSTDOCTORAL STUDIES

## MCGILL UNIVERSITY



### ***FINAL ORAL EXAMINATION*** **FOR THE DEGREE OF** **DOCTOR OF PHILOSOPHY**

**OF**

### **JACQUELINE GOORDIAL** **NATURAL RESOURCE SCIENCES**

Microbial diversity, activity, and functional ecology of permafrost and cryoendolithic microbial life in a hyper-arid Antarctic dry valley

**November 2, 2015**  
**9:15 am**

Institute of Parasitology, Room P117  
McGill University, Macdonald Campus

#### **COMMITTEE:**

- Dr. J. Bede (Pro-Dean) (Plant Science)
- Dr. J. Whalen (Chair) (Natural Resource Sciences)
- Dr. L. Whyte (Supervisor) (Natural Resource Sciences)
- Dr. C. Greer (Co-Supervisor) (NRC-Biotechnology Research Institute)
- Dr. S. Faucher (Internal Examiner) (Natural Resource Sciences)
- Dr. J. Xia (External Member) (Institute of Parasitology)

Dr. Josephine Nalbantoglu, Dean of Graduate and Postdoctoral Studies  
*Members of the Faculty and Graduate Students*  
*are invited to attend*

## ABSTRACT

A large fraction of Earth's biosphere is permanently cold, and cold-adapted microorganisms capable of growth at temperatures well below freezing have been found in cryoenvironments globally. It is now well established that permafrost—ground that remains at or below 0°C for at least two consecutive years—can host viable and active communities of microorganisms. The permafrost soils of the high elevation McMurdo Dry Valleys are the most cold, desiccating and oligotrophic on Earth; where the continuous aridity and cold results in the formation of dry permafrost overlaying ice-cemented permafrost, a rare condition that likely only occurs in this region. Little is known about the permafrost microbial communities in the high elevation Dry Valleys other than microorganisms are present.

University Valley is a high elevation Dry Valley (1700 MASL), and is one of the coldest and driest locations in Antarctica (mean annual temperature ~ -25°C; no degree days above freezing). The objective of this study was to examine the microbial diversity, activity and functional ecology of microbial communities in two distinct habitats in University Valley: permafrost soils, and the sandstone rock which form the valley walls.

We found total microbial biomass in University Valley permafrost was extremely low ( $10^3$  cells/g), and microbial activity under ambient conditions was undetectable. Only 6 isolates were cultured after 2 years of effort using multiple medias and enrichment strategies. Surprisingly, given the low biomass and undetectable activity, University Valley permafrost soil had high microbial diversity, as determined by 454 pyrosequencing of bacteria, archaea, and fungi. Metagenomic sequencing of University Valley permafrost found there was a low diversity of stress response genes, and instead soils were enriched in genes involved with dormancy and sporulation. Our results contrast with reports on lower elevation Dry Valleys and Arctic permafrost, suggesting that the combination of severe cold, aridity, and oligotrophy is severely constraining microbial survival, and that active microbial life is potentially nonexistent. Intriguingly, genome sequencing of the sole bacterial isolate capable of subzero growth isolated from University Valley soils revealed the presence of genes associated

with adaptation to cold and oligotrophy, as well as genome wide amino acid substitutions thought to confer crucial increased protein flexibility at low temperatures.

In comparison to the soils, the sandstone rock in University Valley contained cryptoendolithic ('hidden within rock') microorganisms with a simple but functional community structure which included photoautotrophic algae, and heterotrophic fungi and bacteria. The cryptoendolithic microorganisms were capable of metabolic activity at *in situ* temperatures, and possessed a diverse suite of stress response and nutrient cycling genes to fix carbon under the fluctuating conditions the sandstone rock would experience during the summer months. Pyrosequencing of two cryptoendolithic communities found that these communities share few OTUs in common with the surface soils in University Valley. The source of the diversity seen in University Valley soils is thus likely a mixture of cryptoendoliths and wind deposited cells.

This thesis outlines a natural setting in the high elevation Antarctic Dry Valleys, which is pushing the boundaries of terrestrial life on Earth. The permafrost soils of University Valley are not sterile, but are uninhabitable, and are selecting for dormancy and sporulation rather than for activity and growth. In contrast, the more clement conditions provided by the porous sandstone rock structure has fostered a thriving cryptoendolithic microbial community living within the same valley. These results are relevant to understanding the limits of life on Earth, as well as the possibility of life on other cold, terrestrial planetary bodies such as Mars.

# CURRICULUM VITAE

## UNIVERSITY EDUCATION

### **Post-doctoral Fellow**, 2015-present

McGill University, Department of Natural Resource Sciences

### **Doctor of Philosophy** 2010- present

McGill University, Department of Natural Resource Sciences

- Research areas: microbial ecology, molecular ecology, cryomicrobiology

### **Master of Science** 2008-2010

University of Toronto, Department of Ecology and Evolutionary Biology

- Research areas: microbial ecology, biodegradation, genomics
- Thesis title: Characterization of a novel chlorobenzoate degrading bacterium: *Burkholderia phytofirmans* OLGA172, isolated from a pristine environment

### **Honors Bachelor of Science (Cell and Molecular Biology)** 2004 - 2008

University of Toronto, Department of Biology

- Study areas: cell biology, molecular biology, microbiology, biochemistry

## PUBLICATIONS

**Goordial, J.**, Raymond-Bouchard, I, Ronholm, J., Shapiro, N., Woyke, T., Whyte, L., Bakermans, C. 2015. Improved-high-quality draft genome sequence of *Rhodococcus* sp. JG-3, a eurypsychrophilic Actinobacteria from Antarctic Dry Valley permafrost. *Standards in Genomic Sciences* 2015;10: 1-6

Perron, G., Whyte, L., Turnbaugh, P., **Goordial, J.**, Hanage, W., Dantas G., Desai, M. 2015. Functional characterization of bacteria isolated from ancient Arctic soil exposes diverse resistance mechanisms to modern antibiotics. *PLoS ONE* 10(3): e0069533. doi: 10.1371/journal.pone.0069533

**Goordial, J.,** and Whyte, L. 2014. Microbial Life in Antarctic Permafrost Environments. *Antarctic Terrestrial Microbiology* (pp 217-232):Springer Berlin Heidelberg.

**Goordial, J.,** Lamarche-Gagnon, G., Lay, C-Y., and Whyte, L.G. 2013. Left out in the cold: Life in cryoenvironments. *Polyextremophiles: Microorganisms and macroorganisms living under multiple forms of stress* (27: 335-363): Springer

Lacelle, D., Pollard, W., Whyte, L., Davila, A., Andersen, D., DeWitt, R., **Goordial, J.,** Heldmann, J., Marinova, M., Zacny, K., McKay, C. 2012. Origin, Stability and Habitability of Ice-Bearing Permafrost in University Valley, McMurdo Dry Valleys, Antarctica: Analogue for Ground Ice on Mars. *Newsletter for the Canadian Antarctic Research Network* 31:17-22

**Goordial, J.,** Davila, A., Lacelle, D., Pollard, W., Marinova, M., Greer, C., DiRuggiero, J., McKay, C., Whyte, L. 2015. Nearing the cold-arid limits of microbial life in permafrost of an upper Dry Valley, Antarctica (in review).

**Goordial, J.,** Davila, A., Greer, C., DiRuggiero, J., McKay, C., Whyte, L. 2015. Comparative activity and functional ecology of permafrost and cryptoendolithic microbial communities in a hyper-arid upper Dry Valley, Antarctica. (in review).

**Goordial, J.,** Raymond-Bouchard, I., Zolotorov, Y., de Bethencourt, L., Ronholm, J., Shapiro, N., Woyk, T., Stromvik, M., Greer, C., Whyte, L., Bakermans, C., 2015. Cold adaptive traits revealed by comparative genomic analysis of the eurypsychrophile *Rhodococcus* sp. JG3 isolated from high elevation McMurdo Dry Valley permafrost, Antarctica. (in review)

Ronholm, J., **Goordial, J.,** Izawa, M.M.R., Applin, D., Sapers, H., Pontefract, A., Omelon, C.R., Lamarche-Gagnon, G., Ozinski, G., Cloutis, E.A., Whyte, L.G. 2014. Comparison of Prokaryotic and Microbial Eukaryotic Lithic Community Composition Between Serpentine and Felsic Intrusives in Jeffrey (Asbestos) Mine (submitted).

## AWARDS

- Graduate Research Enhancement and Travel (GREAT) award, McGill University, 2014, \$700
- Early Career Scientist Travel Award to attend the 5<sup>th</sup> annual Conference on Polar and Alpine Microbiology (PAM) held in Big Sky, Montana, 2013. \$1,200
- Canadian Astrobiology Training Program (CATP) NSERC CREATE fellowship, McGill University, 2011-2014 \$63,000
- Canadian Institute for Advanced Research (CIFAR) travel award to attend the International Astrobiology summer school, Santander, Spain, 2012. \$1,250
- Graduate Research Enhancement and Travel (GREAT) award, McGill University, 2012, \$500
- Reino S. Freeman Fellowship, University of Toronto, 2010, \$500
- Frederick P. Ide Award in Ecology & Evolutionary Biology, University of Toronto, 2009, \$500
- NSERC Undergraduate Student Research Award (USRA), University of Toronto, 2008, \$5700
- University of Toronto Excellence Award (UTEA), University of Toronto, 2008, \$4,500

## SERVICE AND PUBLIC OUTREACH ACTIVITIES

- A founding member of *Mycollectif(ve)*, at Santropol Roulant, Montreal. A mushroom collective whose mandate is to be a mycology knowledge hub for the Montreal community on cultivation, identification and isolation of mushrooms through holding workshops and educational outreach events regularly. Santropol Roulant is a non-profit organization which focuses on breaking social isolation through food. Feb 2014 - present.
- Volunteer with the science outreach group Let's Talk Science. Activities range from supervising high school students to running workshops and judging student science fairs. 2009-present
- Mycoremediation citizen science project at Champs des Possibles, Montreal. Assisting in a citizen science pilot project to remediate a city lot contaminated with PAHs and heavy metals through mycoremediation. May 2014- present

- Organization of an education and public outreach event "Ask an Astrobiologist" night at McGibbons pub, Montreal where the public was invited to talk with graduate students and members of the Astrobiology community including a researcher from the Canadian Space Agency. June, 2013.
- Organization of an education and public outreach event "Astrobiospeaks!" a public speaking competition. Participants gave 4 minute presentations on an Astrobiology related topic. Redpath museum, Montreal. June, 2013.
- Science outreach from the Antarctic to several schools in the United States and in Canada. Students remotely operated a permafrost drill located in Antarctica. Was covered by multiple media outlets, and included a segment on the Discovery channel:  
<http://watch.discoverychannel.ca/#clip872845>. January-February 2013
- Provided video and still microscopy images for the PBS/NOVA documentary: Finding Life Beyond Earth. Aired October 18, 2011 on PBS.  
<http://www.pbs.org/wgbh/nova/space/finding-life-beyond-earth.html>