UNIVERSITY OF TORONTO
FACULTY OF ARTS & SCIENCE
Office of the Dean

Project Code: ENV 1

RESEARCH OPPORTUNITY PROGRAM
299Y PROJECT DESCRIPTIONS 2017-2018
FALL/WINTER

Name and Title: Brad Bass, Adjunct Professor, Sarah Finkelstein Associate Professor
Department: School of the Environment

TITLE OF RESEARCH PROJECT: Building Virtual Laboratories: experimentation through simulation models

NUMBER OF STUDENT PLACES AVAILABLE: 6

OBJECTIVES AND METHODOLOGY:

To what degree can a virtual representation of a system complement lab work, field work and meta-analysis, methods that are common to all scientific disciplines. In this ROP, students will be tasked with expanding existing or developing new simulation models that will be used as virtual laboratories. Although the any scientific discipline can be part of this ROP, in the past, students have come from life sciences (including psychology, ecology and chemistry), materials science, geography and environmental science. Students have used their simulation models as virtual laboratories, exploring ecosystem stability, soil phosphorus chemistry, suicide genes, Alzheimer's disease, pre-synaptic and post-synaptic activity, epidemiology, virology and genetics.
Although students are given some opportunity to choose their own system of interest, one objective for the 2017-18 year is to develop a virtual representation of a designer ecosystem. Designer ecosystems are built to mimic some of the characteristics of ecosystems such as wetlands, but they can be broken up into separate components and built in a variety of spaces. The systems can be broken up into different tanks for purposes of observation and to improve our understanding of various ecological processes. Using existing designer systems as models – although some students may have the opportunity to expand upon and existing system – the objective is to build a virtual representation of one such designer ecosystem and assess the degree to which this "virtual lab" can inform research in this area. The ability to design ecosystems is not a new practice, i.e. many stormwater ponds function as wetlands, can enhance the use of green infrastructure to improve water quality an increase habitat as part of a biodiversity strategy.

Not all students will work in this area. In the past four years, students have completed simulations for vector-borne diseases, ecosystem toxicity and bioaccumulation, Alzheimer's disease, soil-phosphorus chemistry and suicide genes. Some students will have the opportunity to continue with work in these areas, either as part of the main project or as a completely separate project. Collaboration between disparate disciplines often occurs in

this ROP, following the philosophical approach of General Systems Theory[1] and Cybernetics[2] where a common set of principles underlie all of the simulation models.

WHY APPLY FOR THIS ROP:

An ROP provides an enhanced research experience, typically not available to second or third-year students, and often not available until graduate school. This ROP provides additional opportunities for cross-disciplinary work, teamwork and team leadership, transferrable software and skills to your specialist/major programs, opportunities for mentoring and opportunities for leading workshops. As mentioned above, this ROP encourages cross-disciplinary collaboration. Students work in teams and there are opportunities to lead teams. As new students come into the lab from other courses, ROP students often provide the training and mentorship. The software used in the ROP is freely available for you to use at any time. We often receive requests to provide workshops for other groups, and ROP students have the opportunity to use these workshops to develop presentation and training skills.

DESCRIPTION OF STUDENT PARTICIPATION:

The students will develop virtual labs with COBWEB (Complexity and Organized Behaviour within Environmental Bounds – a software package, developed by Professor Bass and U of T students. COBWEB is an agent-based simulation model, meaning that the actions of each member of a population can be simulated, each member of the population can learn and populations can evolve novel strategies over time. Experiments are run in a two-dimensional or three-dimensional grid, and the outputs are downloaded into a spreadsheet for display and further analysis. The analyses range from visual description to statistical analysis to mathematical assessment of chaos, depending on the interests and experience of the student. Interested students may contact Brad Bass for a copy of the software.

COBWEB offers opportunities for very sophisticated simulations of many biological processes and chemical reactions. Students have used COBWEB to simulation the growth of plaque in the brain, the transmission of malaria with migration, long-term ecological stability and reversible reactions that occur in the soil. These models are based on choosing several parameters to manipulate and a process of iterative "play" with the model to develop a virtual representation of the system of interest. Although a new model may require the student to start from scratch, there are now several existing models that can be used to start your research.

Students in this ROP will learn how to use COBWEB based on previous year's start-up guides, and will create start-up guides of their own. During the fall semester, each student will also write a literature review. Third-year students will developed a more focused topic and will be expected to utilize more articles. The literature will shape the specifics of the research that students will complete with their simulation models. The model

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[1] Bertlanffy, L. Von. (1968) *General System theory: Foundations*, *Development*, *Applications*, New York: George Braziller, revised edition 1976

[2] Beer, S. (1972) *Brain of the Firm*: Allen Lane, The Penguin Press, London, Herder and Herder, USA. 2nd edition 1995, John Wiley & Sons.

development will begin in the fall semester, but will be completed in January. Experiments with the model will be conducted in January and February. Third year students will be expected to generate multiple outcomes from independent populations and to use basic statistical analysis to evaluate their hypothesis. Students will also participate in the ROP Poster Fair in March, 2018.

This research is intended for students in the biology, ecology, chemistry, physics mathematics and environmental science but is open to students in any discipline with a genuine interest in simulation and/or designer ecosystems.

This ROP is also open to computer science students with programming experience in Java and/or Visual Basic. Computer Science students have the option to expand the capabilities of either the 2D or 3D version of COBWEB. Computer Science students can work on agent behaviour, environmental characteristics, transmission between agents (currently toxins and diseases can be transmitted), visual representation, data collection and display, genetics or mobile applications. This is a process that begins with understanding the capabilities of the program, meeting with the users for to discuss future needs, updating the program, collaboratively testing the new code with the users, debugging the code and retesting it in collaboration with the users. The users are usually the other ROP students, but may include students and faculty who are using COBWEB outside of this course. The difference in participation is that computer science students will begin coding their additions/changes to the software instead of developing simulations of different systems for research. Although, it may be possible to incorporate your modifications into the 2017-18 research program, most likely your changes will take effect in the following year.

MARKING SCHEME (assignments with weight and due date**):**

2-page quick-start guide to COBWEB	Oct. 31, 2017	10%
Journal	Apr. 08, 2018	20%
Literature Review	Dec. 15, 2017	20%
Poster	Mar. 02, 2018	5%
Final Report	Apr. 04, 2018	40%
Participation	Ongoing	5%

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Project Code: ENV 2

RESEARCH OPPORTUNITY PROGRAM
299Y PROJECT DESCRIPTIONS 2017-2018
FALL/WINTER

Name and Title: Brad Bass, Adjunct Professor, Sarah Finkelstein Associate Professor
Department: School of the Environment

TITLE OF RESEARCH PROJECT: Incentivizing Behavioural Change: exploring options through simulation models

NUMBER OF STUDENT PLACES AVAILABLE: 6

OBJECTIVES AND METHODOLOGY:

New environmental policies often rely on regulations, guidelines or programs to achieve the intended outcomes. Economic incentives are another option. Incentives involve subsidies, costs or trading permits to pollute. The objectives of this ROP are to study the degree to which incentives can change environmental outcomes. Students will develop simulation models using the COBWEB simulation software. COBWEB will allow students to develop economic models based on marginal utility functions, the Prisoner's Dilemma – a game used to analyze socio-economic interactions and group dynamics – the emergence of central places/retail clusters or the trade-offs between housing and transportation costs within urban land use models.

WHY APPLY FOR THIS ROP:

An ROP provides an enhanced research experience, typically not available to second or third-year students, and often not available until graduate school. This ROP provides additional opportunities for cross-disciplinary work, teamwork and team leadership, transferrable software and skills to your specialist/major programs, opportunities for mentoring and opportunities for leading workshops. Collaboration between disparate disciplines often occurs in this ROP, following the philosophical approach of General Systems Theory[1] and Cybernetics[2] where a common set of principles underlie all of the simulation models. Students work in teams and there are opportunities to lead teams. As new students come into the lab from other courses, ROP students often provide the training and mentorship. The software used in the ROP is freely available for you to use at any time. We often receive requests to provide workshops for other groups, and ROP students have the opportunity to use these workshops to develop presentation and training skills.

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[1] Bertlanffy, L. Von. (1968) *General System theory: Foundations*, *Development*, *Applications*, New York: George Braziller, revised edition 1976

[2] Beer, S. (1972) *Brain of the Firm*: Allen Lane, The Penguin Press, London, Herder and Herder, USA. 2nd edition 1995, John Wiley & Sons.

DESCRIPTION OF STUDENT PARTICIPATION:

The impact of incentives will be studied with COBWEB (Complexity and Organized Behaviour within Environmental Bounds – a software package, developed by Professor Bass and U of T students. COBWEB is an agent-based simulation model, meaning that the actions of each member of a population can be simulated, each member of the population can learn and populations can evolve novel strategies over time. Experiments are run in a two-dimensional grid, and the outputs are downloaded into a spreadsheet for display and further analysis. The analyses range from visual description to statistical analysis to mathematical assessment of chaos, depending on the interests and experience of the student. Interested students may contact Brad Bass for a copy of the software.

COBWEB offers opportunities for a very sophisticated simulation of the Prisoner's Dilemma involving multiple agents, flexible rewards, multiple strategies, marginal utilities and the ability to restrict one-on-one interactions. COBWEB also has a module to study the emergence of retail clusters/central places with both producers and consumers. Although the central place model is based on l Krugman's work on spatial economics[3], it has been enhanced with the emergence of a market and the impact of urbanization on food production. COBWEB 3D allows students to work with specific functions for controlling production and consumption, all within an agent-based framework.

Students in this ROP will learn how to use COBWEB based on previous year's start-up guides, and will create start-up guides of their own. During the fall semester, each student will also write a literature review. Third-year students will developed a more focused topic and will be expected to utilize more articles. The literature will shape the specifics of the research that students will complete with their simulation models. The model development will being in the fall semester, but will be completed in January. Experiments with the model will be conducted in January and February. Third year students will be expected to generate multiple outcomes from independent populations and to use basic statistical analysis to evaluate their hypothesis. Students will also participate in the ROP Poster Fair in March, 2018.

This research is intended for students in the economics, political science, geography, social psychology, sociology, mathematics and environmental studies but is open to students in any discipline with a genuine interest in the issue.

This ROP is also open to computer science students with programming experience in Java and/or Visual Basic. Computer Science students have the option to expand the capabilities of either the 2D or 3D version of COBWEB. Computer Science students can work on agent behaviour, environmental characteristics, transmission between agents (currently toxins and diseases can be transmitted), visual representation, data collection and display, genetics or mobile applications. This is a process that begins with understanding the capabilities of the program, meeting with the users for to discuss future needs, updating the program, collaboratively testing the new code with the users, debugging the code and retesting it in collaboration with the users. The users are usually the other ROP students, but may include students and faculty who are using COBWEB outside of this

[3] Krugman P. (1996) *The Self-Organizing Economy*: Cambridge, MA. Wiley-Blackwell

course. The difference in participation is that computer science students will begin coding their additions/changes to the software instead of developing simulations of different systems for research. Although, it may be possible to incorporate your modifications into the 2017-18 research program, most likely your changes will take effect in the following year.

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