

*Third Annual*

## BEE Research Symposium Abstract Book

**Oral Presentations**                      **Riley Robb 125**                      **11:00AM – 1:00PM**

---

11:00 ... **Elliot Friedman** – *Angenent Lab*

Bioelectrochemical systems as biosensors – remote monitoring of bacterial respiration in Arctic peat soils

11:15 ... **Pichamon Kiatwuthinon** – *Luo Lab*

DNA hydrogel for a 3-D cell culture system

11:30 ... **JMR Apollo Arquiza** – *Hunter Lab*

Taking care of garbage in outer space: Drying astronaut trash for stabilization and water recovery in long-duration space missions

11:45 ... **Benjamin Brown-Steiner** – *Hess Lab*

Asian influence on surface ozone in the United States: a comparison of regional chemistry, seasonality, and transport mechanisms

12:00 ... **Todd Anderson** – *Soil & Water Lab*

Denitrification in a northeastern agricultural landscape

12:15 ... **Christine Baver** – *Soil & Water Lab*

Examining the Wetting Front through the Dynamic Contact Angle

12:30 ... **Jiajie Yu** – *March Lab*

Recreating 3D human small intestine villus model in vitro

12:45 ... **Michael Walsh** – *Ahner Lab*

Determination of metal-thiol stability constants using a fluorescent probe

**Poster Session**                      **Riley Robb 400**                      **1:00 – 3:00PM**

---

**Lunch Available**

*Group A presenters will be at their posters from 1:30-2:00; Group B 2:00-2:30*

**Closing Reception**                      **Riley Robb 400**                      **2:45 – 3:00PM**

---

**Refreshments Available**

**March 4<sup>th</sup>, 2011**

---

*Thank you*

**to the BEE Graduate Student Association and all of our 2011 Presenters**

**The 2011 BEE Research Symposium is offered with support from the Cornell Graduate School and the Department of Biological and Environmental Engineering.**

---

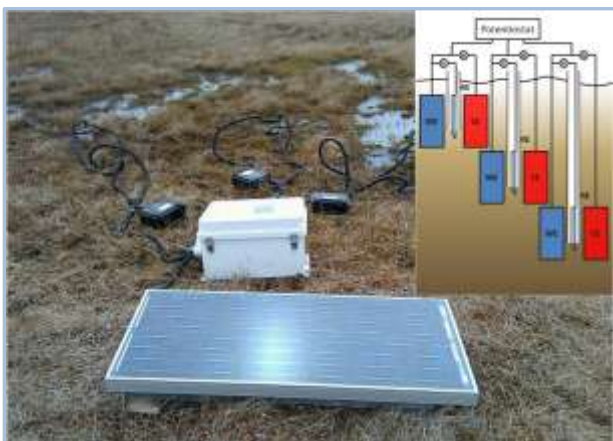
# **Oral Presentation Abstracts**

## 11:00am Bioelectrochemical systems as biosensors – remote monitoring of bacterial respiration in arctic peat soils

Elliot S. Friedman\*, Miriam Rosenbaum, Largus T. Angenent; BEE, Cornell University

\*: Presenter, e-mail [esf59@cornell.edu](mailto:esf59@cornell.edu)

Bacterial anaerobic respiration in Arctic peat soils is not very well studied. The presence of iron and humic substances as terminal electron acceptors for microorganisms (i.e., anaerobic respiration) may have a profound impact on CO<sub>2</sub> and CH<sub>4</sub> fluxes from these organically-rich soils. In addition, it is known that anaerobic respiration processes may vary widely across the topography of Alaska's North Slope, which is dominated by wet depositional environments that are known as drained thaw lake basins (DTLBs). To investigate the extent and significance of microbial respiration with iron and humic acids, a solar-powered potentiostatically-controlled system was designed and built to monitor bacterial respiration in young, medium, and old aged DTLBs around Barrow, Alaska. At each DTLB, three different depths were monitored corresponding to the aerobic, aerobic-to anaerobic-transition, and anaerobic soil zones. Thereby, an electrode mimics iron(III) compounds or humic acids as electron acceptor. A potential of -100 mV<sub>NHE</sub> was applied to the working electrode to stimulate biofilm formation and the current was recorded with respect to time. In addition, cyclic voltammetry was performed on a monthly basis throughout the thaw period to better understand the underlying electrochemical processes. This system incorporates several unique design elements necessary for use in extreme environments, such as we encountered in Alaska. Here, we will present a complete cost-effective, solar-powered, portable, potentiostatically-controlled bioelectrochemical system and demonstrate its application as a biosensor. We will show laboratory test data and first field operation data. Other potential applications of this type of system include watershed monitoring, tracking of pollutant plumes, and water treatment monitoring.



*Experimental setup of a biosensor installed at young DTLB outside Barrow, AK, showing solar panel, solar controller and battery (white box), and three potentiostats (black boxes). Experimental schematic (inset) shows the three electrode BES consisting of working (WE), counter (CE), and reference (RE) electrodes. Each potentiostat controls three BESs at 5, 10, and 15 cm below the surface.*

## 11:15am DNA hydrogel for a 3-D cell culture system

Pichamon Kiatwuthinon\*, Dan Luo; BEE, Cornell University

\*: Presenter, e-mail [pk224@cornell.edu](mailto:pk224@cornell.edu)

DNA has been recognized as a unique generic material building block that can be assembled into different structures such as dendrimer-like and networked. Recently, we demonstrated the X-shaped DNA as a building block for the creation of a hydrogel capable of encapsulating cancer cells in a three dimension fashion. Compared with conventional hydrogels for cell culture, our X- DNA are entirely synthesized with precisely controlled properties whereas conventional hydrogels including collagen, alginate, and fibrinogen are extracts from natural products with inconsistent and difficult-to-control properties. In addition, our DNA hydrogel is biocompatible to cells and biodegradable by cellular nucleases. Moreover, cell encapsulation can be accomplished in situ. Here, we showed a DNA hydrogel, made from an enzyme-catalyzed reaction, as a three-dimensional cell culture system. The proliferation profile of a model cancer cell line HeLa S3 cultured in the DNA hydrogel showed a similar growth curve as that with the conventional culture method. In addition, basic cell functions were preliminarily evaluated with enzyme activity assays. The results showed no differences between cells cultured in our 3D system and in the conventional 2D system. A variety of applications can benefit from this novel cell culture system such as siRNA delivery, cancer ex vivo model study, and stem cell research.

---

## **11:30am Taking care of garbage in outer space: Drying astronaut trash for stabilization and water recovery in long-duration space missions**

**JMR Apollo Arquiza\***, Jean B. Hunter; BEE, Cornell University

\*: Presenter, e-mail [jaa56@cornell.edu](mailto:jaa56@cornell.edu)

During long-term space missions, astronauts generate wet trash, including food residues, moist hygiene wipes and wet paper towels. This waste gives rise to two problems: first, the generation of odors and potential health hazards by microbial growth; second, the diversion of water from the available recovery loops. Drying of wet trash by forced convection with hot air is a viable and simple way of stopping microbial activity by combined pasteurization and desiccation. The water vapor produced can then be recovered by a condenser. Our research group is studying a closed air-loop, forced-convection dryer and condenser system (DRYER) for astronaut cabin waste. The DRYER consists of a blower, air heater, wet material container, a gravity-independent Porous Membrane Condensing Heat Exchanger, thermoelectric heat pump, and waste heat recovery module. Experiments have been done on the system to determine its performance for a range of operating conditions. Computational models of the major processes occurring in the system (drying and condensation) are also being developed for optimization studies. For the drying of wet material, the model uses the conservation equations for energy and moisture applied to the air and solid phases and its formulation includes the unique waste characteristic of having both dry and wet solids. It also incorporates the experimentally measured heat and mass transfer coefficients for the system. The condenser model is based on the conservation equations for momentum, energy, and moisture applied to the air and porous membrane phases together with the thermoelectric heat pump equations. For both models, the resulting systems of differential equations were solved by the finite-volume element method. Good agreement between the simulation and experiment was observed. The model was used to predict the system performance for a range of operating conditions with different values of cold-side plate temperature, initial moisture content of the trash, and air properties (flowrate, humidity, and temperature).

## **11:45am Asian influence on surface ozone in the United States: a comparison of regional chemistry, seasonality, and transport mechanisms**

**Benjamin E. Brown-Steiner\***, Peter Hess; BEE, Cornell University

\*: Presenter, e-mail [beb83@cornell.edu](mailto:beb83@cornell.edu)

Ongoing growth in the transportation and industrial sectors in Asia has resulted in increased emissions of several ozone precursors which are increasingly impacting surface ozone levels in the United States. We use the offline Community Atmospheric Model with Chemistry (CAM-Chem) driven by National Center for Environmental Protection (NCEP) meteorology for 2001 – 2005 and Model for Ozone and related chemical Tracers, version 4 (MOZART-4) chemistry to examine the chemistry, seasonality, and transport of Asian emissions as they are lofted from the Asian boundary layer into the free troposphere over the Pacific Ocean and into the US. We used a methodology in which ozone produced from Asian pollutants is tagged (O3A), which allows us to compare directly with the Hemispheric Transport of Air Pollution (HTAP; [www.htap.org](http://www.htap.org)) project results. We show that springtime O3A enters the US air basin widely dispersed in the free troposphere (2 – 6 km from 30–50° N) with a peak of 10.0 ppbv (30° N at 2 km) and an average of  $7.0 \pm 2.0$  ppbv and that summertime O3A enters the US air basin in the upper free troposphere (6 – 12 km) tightly centered on a higher peak of 12.0 ppbv (40° N at 8 km) but with a lower average of  $6.0 \pm 1.0$  ppbv. However, surface O3A concentrations in the western US (240° E) show a springtime maximum of  $3.5 \pm 1.0$  ppbv (with daily peaks reaching 10.0 ppbv) and a summertime minimum of  $1.0 \pm 0.25$  ppbv. The remainder of the US shows a similar pattern but with lower O3A concentrations. This surface springtime maximum and summertime minimum can be explained by: (i) the O3A plume enters US airspace in the lower free troposphere, while the summertime O3A plume enters in the upper free troposphere; (ii) higher O3A destruction during transport to the surface of the US in the summertime; and (iii) mechanisms that transport free tropospheric air to the surface of the US can “tap” higher O3A concentrations during the springtime. This pattern is in contrast to total O3 concentrations which show a summertime peak. This implies that, while O3A will still exacerbate summertime ozone peaks, the larger Asian impact on surface ozone in the US will be in the off-peak springtime.

## 12:00pm Denitrification in a northeastern agricultural landscape

Todd R. Anderson\*<sup>1</sup>, Peter Groffman<sup>2</sup>, Sujay Kaushal<sup>3</sup>, M. Todd Walter<sup>1</sup>

<sup>1</sup>BEE, Cornell University

<sup>2</sup>Cary Institute of Ecosystem Studies, Millbrook, NY

<sup>3</sup>Chesapeake Biological Lab, UMD, Solomon, MD

\*: Presenter, e-mail [tra8@cornell.edu](mailto:tra8@cornell.edu)

Denitrification may be an important sink of anthropogenic nitrogen (N) in eastern US watersheds. Denitrification occurs primarily under anaerobic conditions by heterotrophic microbes, and is therefore expected to be vigorous in wet soils containing high amounts of organic carbon. Actual rates of denitrification, however, have been difficult to quantify, and remain one of the critical unresolved N processes at the landscape scale. We measured denitrification rates in situ along hydrologic flow paths and across gradients of hydroperiodicities, i.e., frequencies and durations of saturated conditions, at Cornell University's Teaching & Research Center in Harford, NY (an active dairy farm). Denitrification rates were measured monthly using the  $-15\text{N}$  push-pull method from 14 mini-piezometers arrayed along a gradient of hydroperiodicity as indicated by a soil topographic index (STI). Measured rates of denitrification were spatially variable across sites and ranged from undetectable to over  $3500 \mu\text{g N/kg soil/day}$  with a mean of  $418.3 \pm 122.2 \mu\text{g N/kg soil/day}$ . Mean rates of denitrification increased with STI, which ranged from 8.7 to 23.0 across our mini-piezometer sites. This relationship was used to estimate denitrification rates across the landscape and resolve a missing piece of the N budget for the farm. Only 14% of the farm fell into areas of STI greater than 8.7; however, denitrification in these areas account for more than 60% of the missing N balance for the entire landscape. Improved understanding of the distribution and magnitudes of denitrification in agricultural landscapes has good potential to facilitate new, novel, and better management practices for controlling nitrogen loading to streams and rivers. Indeed, the very areas that appear to have a propensity to harbor denitrification, i.e., areas prone to be wet, are often artificially drained as part of standard agricultural practices which effectively increase N loading to rivers and contributes to downstream eutrophication.

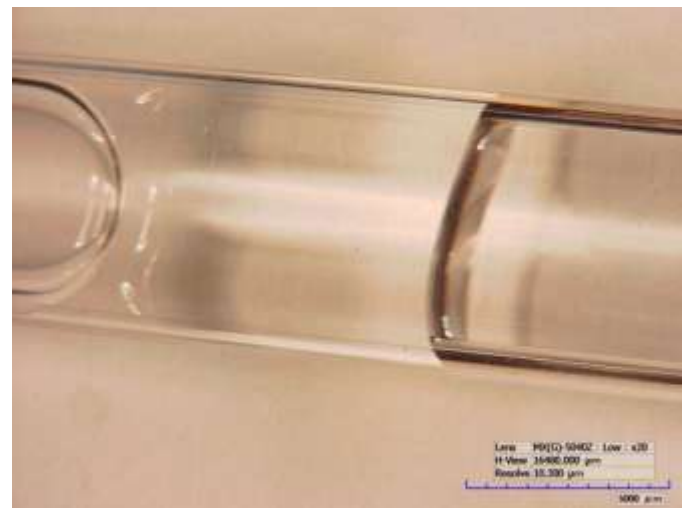


## 12:15pm Examining the wetting front through the dynamic contact angle

Christine E. Baver\*, Yuniati Azziano, J.-Yves Parlange, Tammo S. Steenhuis; BEE, Cornell University

\*: Presenter, e-mail [ceb282@cornell.edu](mailto:ceb282@cornell.edu)

Preferential flow – the non-uniform and often fast movement of water and solutes through soils can greatly accelerate the transport of contaminants to groundwater, significantly reduce the soil's water retention capacity, and decrease crop yields due to root-zone water bypass (Doerr et al. 2007). While the transport mechanism can be induced or enhanced by soil macropores, soil layering, and soil water repellency, preferential flow has been observed in widely ranging soil types and land uses indicating that it is more the rule rather than the exception. The purpose of this presentation is to examine the stable and unstable (i.e. preferential flow) wetting fronts using the Hirox Bright Field Microscope. More specifically, we observed the moving contact line at the air-liquid-solid interface at the wetting front (referred to as dynamic contact angle) understand the interacting capillary, viscous and gravitational forces. Results were then compared to Hoffman who measured the change in contact angle with respect to flow velocity.



**Advancing and receding contact angle shown for a slug of silicon in a capillary tube.**

## 12:30pm Recreating 3D human small intestine villus model *in vitro*

Jiajie Yu\*, John C. March; BEE, Cornell University

\*: Presenter, e-mail [jy298@cornell.edu](mailto:jy298@cornell.edu)

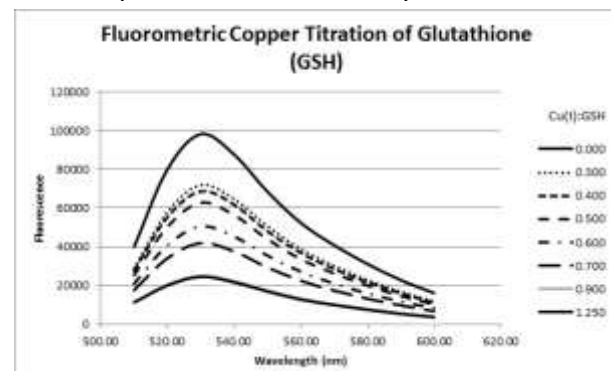
A much more realistic *in vitro* model is needed to achieve a deeper understanding of human intestine microenvironment and its function. The 3-D structure of intestinal villi, which is ignored in conventional models, was re-created by microfabrication. Intestine epithelia cells were seeded on villous scaffolds to mediate the 3-D model. To further improve the model, a fabrication process was developed to make permeable 3-D artificial villi possible. The 3-D structures exhibited high aspect ratios and curvature which could have wide-ranging applications in medicine and technology.

## 12:45pm Determination of metal-thiol stability constants using a fluorescent probe

Michael J. Walsh\*, Beth A. Ahner; BEE, Cornell University

\*: Presenter, e-mail [ans62@cornell.edu](mailto:ans62@cornell.edu)

Cysteine containing molecules play a substantial role in regulating metal metabolism in biological systems. Metallic cofactors such as Zinc and Copper are often found in cysteine rich domains of proteins. Small peptides such as glutathione have been shown to be involved in the transport of zinc, copper, cadmium and other metals. In the ocean, a pool of organic ligands, including thiols, significantly affect the speciation and bioavailability of metals. Determination of the chemical strength of thiol-metal complexes is essential to understanding the role of these compounds in metal regulation. Traditional methods of determining metal-ligand stability constants are problematic for the study of these complexes due to the redox activity of copper and thiols. In this approach, indirect metal-ligand titrations were performed at several biologically relevant pH's under anaerobic conditions. Free metal concentrations were measured using a metal specific fluorescent probe. Stability constants were subsequently calculated by fitting the fluorescent titration curve to an equilibrium model using least squares error minimization by the Solver add-in of Microsoft Excel. Confirmation of well documented stability constants of Zn<sup>2+</sup>, Cd<sup>2+</sup> with glutathione demonstrated the viability of this method. Stability constants of Zn<sup>2+</sup>, Cd<sup>2+</sup> and Cu<sup>+</sup> with several ubiquitous and novel thiols are presented and their implications in marine systems are discussed.





# Poster Presentation Abstracts

## **POSTER SESSION**

1:00 – 3:00pm in Riley Robb 400

A: Presenters will be at their posters from 1:30-2:00pm

B: Presenters will be at their posters from 2:00-2:30pm

## [1A] Feasibility of home biogas generation from kitchen waste

Robert J. Frost\*, Joseph G. Usack, Largus T. Angenent;  
BEE, Cornell University

\*Presenter, e-mail [rjf44@cornell.edu](mailto:rjf44@cornell.edu)

The purpose of this study is to investigate the production of useful biogas (methane) and system stability of anaerobic digesters for use in residential homes. Economic analysis and theoretical methane yield calculations were used to determine a hydraulic retention time (HRT) and volatile solids (VS) loading rate of 16 days and 4 g/L-day, respectively, for two 9L plug flow reactors using kitchen waste from a North campus dining hall. Although operating the reactors at these conditions led to high biogas production (greater than 15L/day), volatile fatty acid (VFA) accumulation after only one HRT rose to levels unfavorable to methanogens. The reactors were allowed to return to safe VFA levels by halting VS loading, and then more conservative conditions were used. An HRT of 27 days and a loading rate of 2.5g VS/L-day led to steady biogas production of 12L/day, but again led to high VFA levels and visible fat and oil accumulation after slightly more than one HRT. Our research shows that fats, oils, and greases must be separated from kitchen waste to sustain stable operating conditions for mesophilic digestion in residential homes.

## [2B] Biosensor with integrated pre-concentration module for the detection of enteric viruses

John T. Connelly\*, Antje J. Baeumner; BEE, Cornell University

\*: Presenter, e-mail [jtc25@cornell.edu](mailto:jtc25@cornell.edu)

Electrochemical biosensors are being investigated for their application in nucleic acid and immunoassays using liposomes for signal generation and amplification. They have been shown previously to provide simplicity of design and operation and yet very low limits of detection when utilizing interdigitated ultramicroelectrode arrays (IDUA) within a microfluidic channel system (1). Here, we investigate the optimization of the electrochemical reaction by varying channel and electrode dimensions. We predict that the detection of a few molecules will be feasible in this design eliminating the need for PCR-like reactions in the case of DNA and RNA analysis, and lowering the limits of detection in immunoassays beyond current possibilities. For sensors that rely on liposome lysis for signal generation, the limit of detection for any analyte can be decreased by decreasing the overall channel volume into which the liposomes are lysed. Since the liposomes contain a set concentration of the redox couple, lysing the same number of them in a smaller volume will produce a higher overall concentration of the electroactive species. Previous work determined that the lowest detectable concentration of potassium ferri/ferrohexacyanide for the IDUA used is 0.5  $\mu\text{M}$ (1). Also based on previous data, liposomes extruded through 0.4 $\mu\text{m}$  pore polycarbonate filters have been shown to be unilamellar and have a diameter of approximately 275 nm(2). Assuming spherical geometry and that the combined concentration of the encapsulated redox couple is the same as the initial concentration added, 200 mM, one can predict that 230 liposomes/nL will be needed to reach the limit of detection of 0.5  $\mu\text{M}$ . Simply by reducing the width and depth of the channel to 10  $\mu\text{m}$ , the detectable number of liposomes needed drops to only 2 liposomes.

Based on these calculations, channels 500, 300, 100, 50 and 10  $\mu\text{m}$  in width and 50  $\mu\text{m}$  high were tested using a nucleic acid hybridization assay for protozoan *Cryptosporidium parvum* and the limit of detection and dynamic range for each channel width was assessed. Additionally, the optimal channel width was tested with decreasing channel depths, including 50, 30, 20 and 10  $\mu\text{m}$ .

### [3A] Improving specificity and yield of the carboxylate platform with continuous and product-specific pertraction

**Matthew T. Agler\***, Arjan Dekker, Nebiyu Merdekios, Jeffrey J. Werner, Largus T. Angenent; BEE, Cornell University  
\*: Presenter, e-mail [mta42@cornell.edu](mailto:mta42@cornell.edu)

We use undefined mixed cultures of microbes to convert lignocellulosic biomass into medium-chain carboxylates, which are important platform chemicals for bio-energy production. We derive our cultures from natural sources, and then evolve them via applied environmental conditions to produce C4 (n-butyrate), C6 (n-caproate), and C8 (n-caprylate) carboxylates. Medium-chain carboxylates are preferred because their hydrophobic nature allows relatively easy *in-situ* separation from fermentation broth; this into stark contrast with, for example, short-chain carboxylates or ethanol that are almost or completely miscible, respectively. Anaerobic digestion does not require any separation technology because the gaseous product – methane - freely bubbles out, but methane is currently not economically valuable enough to warrant digester investments. Here, we hypothesized that product-specific removal (i.e., *in-situ* separation) would improve the selection of medium-chain carboxylates by increasing hydrolysis and thermodynamically “pulling” electrons toward our preferred product. We operated two 5-L thermophilic anaerobic bioreactors treating acid-pretreated corn fiber (i.e., a waste product from corn wet milling plants) for over 450 days (15-day HRT, and pH of 5.5). After identical operating conditions for a period of 230 days, we initiated liquid-liquid-membrane-based pertraction. Both the control (R1) and experimental (R2) reactors were exposed to the extraction solvent (mineral oil with 3% tri-n-octylphosphine oxide), while only the solvent from R2 was subsequently stripped of carboxylates into an alkaline stripping solution. Indeed, stripping of carboxylates improved the process. In addition, after continuous exposure to extraction solvent (over 200 days), we maintained the microbial functionality of the undefined mixed culture, and thus we found no inhibition. Product concentrations in the alkaline stripping solution were concentrated up to 25x compared to the level in the control reactor. However, carboxylate yields were comparable to the control reactor because pertraction

was not efficient enough to improve solids hydrolysis. On day 350 of the operating period, we began adding ethanol to further “push” electrons toward medium-chain carboxylates via microbial chain elongation. Combining the chain elongation process and pertraction (R2), increased production rates of n-butyrate, n-caproate, and n-caprylate 2x, 4x, and 8x, respectively, compared to R1. To our knowledge, this is the first time continuous pertraction has been performed with an undefined mixed culture fermentation. Finally, we showed that product-specific pertraction, under the right conditions, can improve the metabolic activity and specificity of undefined mixed cultures.

### [4B] Climate change impacts on nitrogen dynamics in hydrologically active areas

**Josephine A. Archibald\***, M. Todd Walter; BEE, Cornell University  
\*: Presenter, e-mail [jaa78@cornell.edu](mailto:jaa78@cornell.edu)

Nitrogen loading from agriculture can cause major damage to coastal areas by triggering excessive algal growth, creating “dead zones” such as those seen seasonally in the Chesapeake Bay and the Gulf of Mexico. Riparian buffers are often used to minimize nutrient pollution, slowing runoff from agriculture, and consequently allowing denitrification to occur before water reaches streams and rivers. However, it is unclear how a changing climate will impact the rates of nitrogen fixation, nitrification and denitrification, which could impact the effectiveness of mitigation strategies to prevent excessive nitrogen loading. I will be examining the changes that we are already seeing in the hydrologic cycle that have implications for the nitrogen cycle. Eventually, we hope to develop a model that can accurately predict the rates of nitrogen loss under different climate scenarios.

## [5A] Mapping 3D Cellular Traction in Real Time using a Fluorescent Microscope

Matthew S. Hall<sup>1\*</sup>, Rong Long<sup>1,2</sup>, Chris Roh<sup>1</sup>, Beum Jun Kim<sup>1</sup>, Chung-Yuen Hui<sup>2</sup>, Mingming Wu<sup>1</sup>; Cornell University

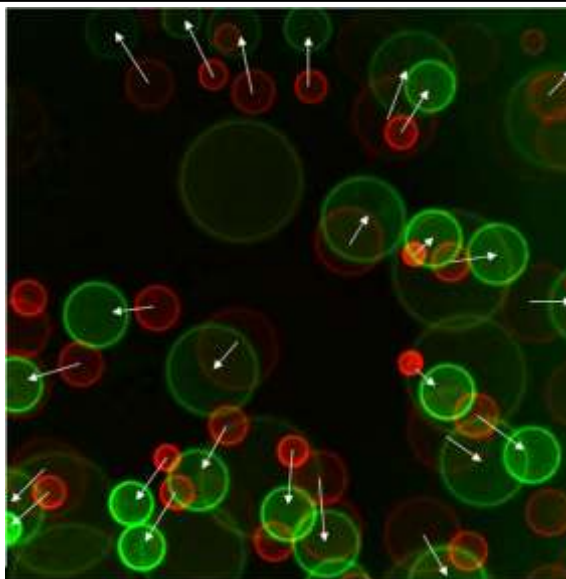
<sup>1</sup>Department of Biological and Environmental Engineering

<sup>2</sup>Field of Theoretical and Applied Mechanics, Sibley School of Mechanical and Aerospace Engineering

\*: Presenter, e-mail [msh56@cornell.edu](mailto:msh56@cornell.edu)

Mechanical environment plays important roles in cellular behaviors including adhesion, differentiation, and migration. It is known that cellular traction generated within a biomatrix changes with time during pathological dysfunctions such as tumor progression, chronic inflammation and cardiovascular disease. To our knowledge, there is no existing technology that is able to measure cellular traction in a physiologically relevant 3D state. Here, we present our efforts in developing a 4D cellular traction microscope that is able to map cellular traction in three spatial dimension and time using an epifluorescent microscope.

In the 4D cellular traction microscope, micrometer size fluorescent beads are embedded in cell seeded collagen gels. Traction exerted by the cells deforms the collagen matrix and thus displaces the fluorescent beads. A defocused ring method is used to track the 3D displacement of fluorescent beads. The measured displacement field is used to evaluate cellular traction based on a force dipole model. To demonstrate the ability of the 4D traction microscope, we first measured the displacement field within a thin layer of polyacrylamide or collagen gel generated by the indentation of a steel or glass ball. The displacement field is then translated into the stresses within the gel using the known mechanical properties of the gel.



**Figure 1 : Illustration of a 4D traction microscope**

The red (green) circles are images of fluorescent beads with (without) indenter. The arrow indicates the displacement of the beads due to the removal of the indenter. The ring size change is used to calculate the indentation displacement.

## [6B] Microfluidic nucleic acid amplification system for a lab-on-a-chip

Cassandra R. Greene and Arne Behrent<sup>\*1</sup>, Peter J. Asiello<sup>1</sup>, Chunhui Xiang<sup>2</sup>, Margaret W. Frey<sup>2</sup>, Antje J. Baumner<sup>1</sup>; Cornell University

<sup>1</sup>Department of Biological and Environmental Engineering

<sup>2</sup>Department of Fiber Science and Apparel Design

\*: Presenters, e-mails [crg84@cornell.edu](mailto:crg84@cornell.edu) and

[ab977@cornell.edu](mailto:ab977@cornell.edu)

Novel ways of functionalizing microfluidic systems for bioanalysis are being investigated by integrating electrospun nanofibers within polymer-based microfluidic channels and with biological recognition molecules. Electrospun poly(lactic acid) (PLA) nanofibers are patterned using gold microelectrodes on poly(methyl methacrylate) (PMMA) surfaces and are then incorporated into PMMA microfluidic channels. The nanofibers are arranged across the microchannels, along the microchannels, and as nanofiber tufts within the microchannels in order to create distinct immobilization strings within channels or to function as guiding structures for cell movement within the PMMA channels.

The fundamental issues relating to entrapment of biologically active molecules within nanofibers are being explored along with physical and chemical characterization of the nanofiber surfaces. Functional investigations will provide preliminary studies of nanofiber applicability as biofunctional guiding structures in microchannels, as biological separators in sample clean up and analyte concentration steps, and also for enhanced immobilization of biorecognition elements. This research will have impact on the advancement of sensing fiber technology for advanced materials; on the immobilization of the biological molecules without additional chemical reactions; and will further progress the development of coordinated biosensing in which 3D biosensing structures have enhanced capability due to simulation of the 3D structure of the original biological system.

## [7A] Improving photobioreactors using advanced photonics

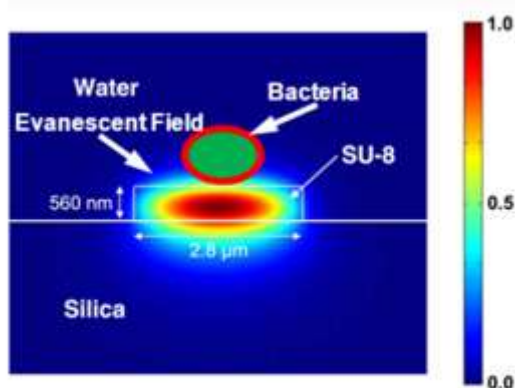
Devin F. Doud<sup>1\*</sup>, Michael Kalontarov<sup>2</sup>, Bernardo Cordovez<sup>2</sup>, E. Jung<sup>2</sup>, David Sinton<sup>2</sup>, Largus T. Angenent<sup>1</sup>; Cornell University

<sup>1</sup>Department of Biological and Environmental Engineering

<sup>2</sup>Sibley School of Mechanical and Aerospace Engineering

\*: Presenter, e-mail [dfd53@cornell.edu](mailto:dfd53@cornell.edu)

The production of energy carriers from algal growth in photobioreactors (PBRs) shows great potential as one of the most important solutions to the current energy crisis. PBRs circumvent many problems associated with crop-based biofuels because they can be operated on non-agricultural land using non-potable water sources, while providing a higher energy yield per surface area of land. It is widely agreed that current limitations of PBR technology centralize around the inefficient delivery and utilization of light in the working volume of the reactor - high light intensity on the surface of the reactor that exponentially drops off to a low intensity in the interior volume. This results in inefficient operating conditions in the bulk portion of the reactor where most of the algal biomass is located. Evanescent waves are composed of light energy that escapes and rapidly decays from the surface of waveguides. Due to the attenuation property of these waves, the majority of the emitted energy is within a 200-nm radius from the waveguide boundary. Thus, evanescent waves are capable of efficiently coupling with the photosynthetic centers of algae adjacent to the waveguide. By optimizing a PBR with a reactor wide waveguide array that is capable of delivering evanescent light, a standardized amount of light can efficiently and directly provide photosynthetic growth throughout all regions of the reactor. We anticipate that homogenization of the light regime in the PBR can considerably improve volumetric efficiencies in PBRs.



Use of the evanescent field allows for precise control of the light distribution in a reactor.

## [8B] Exploring interactions between meteorological and hydrological characteristics of flash flood events in the Northeast United States

Rebecca D. Marjerison<sup>1\*</sup>, Stephen M. Jessup<sup>2</sup>, M. Todd Walter<sup>1</sup>, Stephen J. Colucci<sup>2</sup>; Cornell University

<sup>1</sup>Department of Biological and Environmental Engineering

<sup>2</sup>Department of Earth and Atmospheric Sciences

\*: Presenter, e-mail [rdm95@cornell.edu](mailto:rdm95@cornell.edu)

The tipping point between landscape hydrological and meteorological conditions that result in a flash flood is difficult to quantify. Specifically, if the rainfall volume exceeds the storage capacity or the rainfall intensity exceeds the infiltration capacity of a critical fraction of a watershed, the result is a flood. The details of these conditions and their interactions are not currently well understood, especially for the Northeast United States. Our analyses show some of the relationships between storm characteristics and watershed characteristics that have been observed for reported flash floods. Storm types, precipitation profiles, and contributing watersheds were determined for 187 flash flood events around the Northeast. Frequency analysis of precipitation intensity established the likely return period of the flash-flood-causing storms. Soil properties within the watersheds were used in a very simple model to determine the amount of infiltration excess runoff for each flood. Stream flow records for streams that have operating USGS gages in a flood-event watershed were used to compare the probabilities of the flood event to the precipitation event. Preliminary results show that for about 70% of the storms the maximum 5-minute rainfall rate did not exceed the predicted 5-minute, 1-year rainfall rate. Runoff calculations suggest both infiltration excess and saturation excess are present in most of the events. Understanding more about the conditions leading to flash floods in the Northeast will help improve prediction and preparation for these events.

## [9A] Sucrose Uptake in Developing Embryos of Canola

David W. Keifer\*<sup>1</sup>, Michael A. Rutzke<sup>2</sup>, Roger M. Spanswick<sup>1</sup>

<sup>1</sup>*Department of Biological and Environmental Engineering, Cornell University*

<sup>2</sup>*Department of Food Science at Robert W. Holley Center for Agriculture and Health, USDA-ARS*

\*: Presenter, e-mail [dwk34@cornell.edu](mailto:dwk34@cornell.edu)

Canola is a potential biodiesel crop as both the seed oil content and oil yield per acre exceeds that of soybeans and most all other crops. This project is focused on determining the nature and kinetic characteristics of the transport systems for sugars in the developing cotyledons of canola. The developing cotyledons of the embryo accumulate sugars and then convert them to oil, making the examination of sugar uptake into the embryo the first step in understanding this process.

We worked with embryos isolated from developing seeds of canola at 14 to 21 days after flowering. The developing embryo and its cotyledons are bathed in a fluid called embryo sac liquid (ESL). Using appropriate methods, we determined the pH and osmolarity of the embryo sac liquid, together with the concentration of minerals, sugars and amino acids, so as to make solutions of artificial embryo sac liquid (AESL) to use in other studies.

Membrane potential depolarization induced by adding sucrose to the AESL bathing the excised canola embryo was measured with a microelectrode inserted into a cell of the embryo. This depolarization suggests that sucrose transport is coupled to charge transfer. The magnitude of this transient was dependent on the sucrose concentration. An Edie-Hofstee transformation of this data yielded a  $K_m$  value of 6.3 mM and  $V_{max}$  value of 15.7 mV.  $K_m$  is inversely proportional to the affinity of the transport system for sucrose; a low value indicates a transporter efficient at binding sucrose.

In canola embryos, the influx of radiolabeled sucrose was essentially a linear function of external sucrose concentration. This is unique in that with most other uptake systems the response can be separated into a saturating component and a linear component. Uptake is inhibited by higher concentrations of  $K^+$ , consistent with a charge dependent co-transport system and the known depolarization of the membrane caused by increased  $K^+$  concentrations. Inhibitors of known membrane transport processes are being evaluated for their effect on sucrose uptake so as to define the linear transport mechanism.

The path to increasing oil yield in canola for use as a biofuel will be defined by consideration of the transport process in relation to the metabolic steps in evaluating the limitations to oil production.

## [10B] Optimal Integration of Wind and Hydropower in African States

Maureen W. Murage\*, C. Lindsay Anderson; BEE, Cornell University

\*: Presenter, e-mail [mwm88@cornell.edu](mailto:mwm88@cornell.edu)

Over the past five years, higher-than-anticipated economic growth in African states has led to a rapid increase in electricity demand and renewed interest in alternative forms of power generation [1]. Some African countries (e.g South Africa, Kenya, Tanzania, Nigeria) are looking to wind energy to meet the increasing demand as well as supplement their current power sources. Hydropower is another source of power that is readily available in most of Africa and by 2020 hydropower is expected to account for 79 and 52 per cent of East and West Africa's total new generation capacity, respectively [2]. While wind may be a "clean" source of power, its production is subject to high variability and limited predictability. Hence, the integration of wind power has impacts on the operation of electric power systems [3]. A storage system can be used to control the variability of wind energy, and one example of a storage system that would be readily available in Africa is pumped hydro. This is because hydropower has the ability to respond quickly to the fluctuations of wind power. This study looks to develop a model that optimally integrates wind, using hydro as a storage system, into the local electricity system within output constraints, while ensuring that the grid perceives a relatively predictable combined power output. Using Kenya as a case study, all wind forecast data as well as hydro data, will be obtained from the country and used to set up the model and develop optimal control strategies for wind/hydro system.

## [11A] Measuring soft gel modulus using a microscope

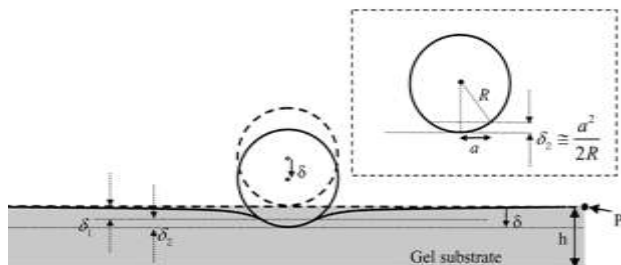
Rong Long<sup>\*1,2</sup>, Matthew S. Hall<sup>1</sup>, Chung-Yuen Hui<sup>2</sup>, Mingming Wu<sup>1</sup>; Cornell University

<sup>1</sup>Department of Biological and Environmental Engineering

<sup>2</sup>Sibley School of Mechanical and Aerospace Engineering

\*: Presenter, e-mail [rl267@cornell.edu](mailto:rl267@cornell.edu)

In vitro, animal cells are mostly cultured on a gel substrate. It has been shown recently that substrate stiffness impacts cellular behavior in a significant way, including adhesion, differentiation, and migration. These experiments require an accurate method to characterize mechanical properties of the biomaterial. Current in situ microscopic measurements of the gel substrate modulus are made using a spherical indenter, where the Young's modulus is calculated from the known indentation force and the measured displacements based on Hertz contact mechanics. In Hertz theory, the substrate is modeled as a linear elastic half space with an infinite depth whereas in practice the thickness of the substrate,  $h$ , can be comparable to the contact radius and other relevant dimensions such as the radius of the indenter,  $R$ . As a result, measurements based on Hertz theory overestimate the Young's modulus. We modify Hertz theory using a finite element method and present our results in a simple correction factor  $\beta$ , the ratio of the corrected Young's modulus and the Hertz modulus. This correction factor agrees with experimental observations using polyacrylamide gel. This work extends the capability of the existing indentation method for modulus measurements of thin gel layers.



**Illustration of indentation method.** A steel ball of known weight is placed on soft gel. The indentation displacement is used for calculation of gel modulus based on Hertz theory.

## [12B] Bacteria-based AND logic gate: a decision-making and self-powered biosensor

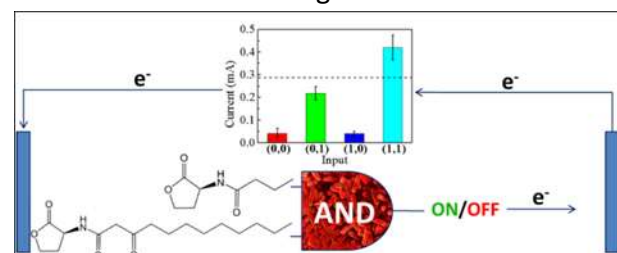
Zhongjian Li<sup>\*1</sup>, Miriam A. Rosenbaum<sup>1</sup>, Arvind Venkataraman<sup>1</sup>, Tsz Kin Tam<sup>2</sup>, Evgeny Katz<sup>2</sup>, Largus T. Angenent<sup>1</sup>

<sup>1</sup>Department of Biological and Environmental Engineering, Cornell University

<sup>2</sup>Department of Chemistry and Biomolecular Science, Clarkson University, Potsdam, NY 13699

\*: Presenter, e-mail [zl258@cornell.edu](mailto:zl258@cornell.edu)

Here, we use a bioelectrochemical system (BES) in which microorganism are donating electrons to an anode to build a Boolean logic gate - a computational component for decision-making (i.e., biocomputing). A *Pseudomonas aeruginosa* PA 14 double mutant, which can generate electric current through the production of phenazines, was the processing unit of our Boolean logic gate. Thereby, the concentration of phenazines is directly related to current production in BESs with *P. aeruginosa*. Phenazine production is regulated by the quorum sensing (QS) system, which is defined as a cell-density-dependent regulation system with secreted signaling factors. Two quorum sensing signals, 3-oxo-dodecanoyl homoserine lactone and N-butanoyl-L-homoserine lactone, which can trigger the phenazine production through the QS cascade, were used as input signals for an AND logic gate. That means that both signals had to be present to activate the AND logic gate and make a distinct decision. This AND logic gate was built in two different types of BESs, i) a three electrode potentiostatically controlled system, and ii) a microbial fuel cell (MFC). Through integration with a MFC, the AND logic gate can be further developed into a self-powered biosensor. *P. aeruginosa* is an opportunistic pathogen. Our work demonstrates the feasibility of developing an onsite biosensor for the detection or long-term monitoring of *P. aeruginosa* infections via homoserine lactone sensing.



## [13A] Hydrologic impact of roadside ditch networks in an agricultural watershed: Implications for non-point source pollutant transport

Brian P. Buchanan<sup>1\*</sup>, Kimberly Falbo<sup>2</sup>, Rebecca L. Schneider<sup>2</sup>, M. Todd Walter<sup>1</sup>; Cornell University

<sup>1</sup>Department of Biological and Environmental Engineering

<sup>2</sup>Department of Natural Resources

\*: Presenter, e-mail [bb386@cornell.edu](mailto:bb386@cornell.edu)

Nonpoint source pollution and hydromodification are the leading causes of impairment to our Nation's rivers and streams. Recent studies have indicated that roadside ditch networks, ubiquitous in both rural and urban landscapes, intercept and shunt significant quantities of overland runoff and shallow groundwater to stream systems. By altering natural flowpaths, road ditches are contributing not only to hydromodification but also potentially to nonpoint-source pollution by acting as hydrologic links between agricultural fields and natural streams. Unfortunately, the impact of these alterations to natural flow regimes, watershed hydrology, and water quality are not well understood in agricultural landscapes. This study examines the effect of road ditch networks on basin morphometry, field- and watershed-scale hydrology, and pollutant transport dynamics/efficiencies in a 38 km<sup>2</sup> agricultural watershed in south-central NY. Salient findings include:

- (i) 94% of road ditches were hydrologically connected to the natural stream network, which resulted in a doubling of the drainage density,
- (ii) on average, road ditches increased peak and total event flows in their receiving streams by 78% and 57%, respectively,
- (iii) ditches are intercepting large quantities of surface and subsurface runoff from agricultural fields and therefore represent efficient conduits for the transport of agricultural NPS pollutants to sensitive receiving waterbodies.

Our results provide useful information for hydrologists who wish to further understand how artificial drainage may be affecting watershed hydrology and for managers and engineers tasked with designing appropriate flood and NPS pollution control measures.



*Typical VSA - agricultural field – roadditch interaction observed within the study region. Road ditch flow eventually discharges to a natural stream.*

## [14B] Improving estimates of wetland methane emissions from the tropics and the globe

Lei Meng<sup>1\*</sup>, Peter G.M. Hess<sup>1</sup>, Natalie M. Mahowald<sup>2</sup>, Joseph B. Yavitt<sup>3</sup>, William R. Riley<sup>4</sup>, Zack Subin<sup>4</sup>, David M. Lawrence<sup>4</sup>, Sean Swanson<sup>4</sup>, Jyrki Jauhiainen<sup>4</sup>, Daniel R. Fuka<sup>1</sup>,

<sup>1</sup>: Department of Biological and Environmental Engineering, Cornell University, Ithaca, NY 14850

<sup>2</sup>: Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY 14850

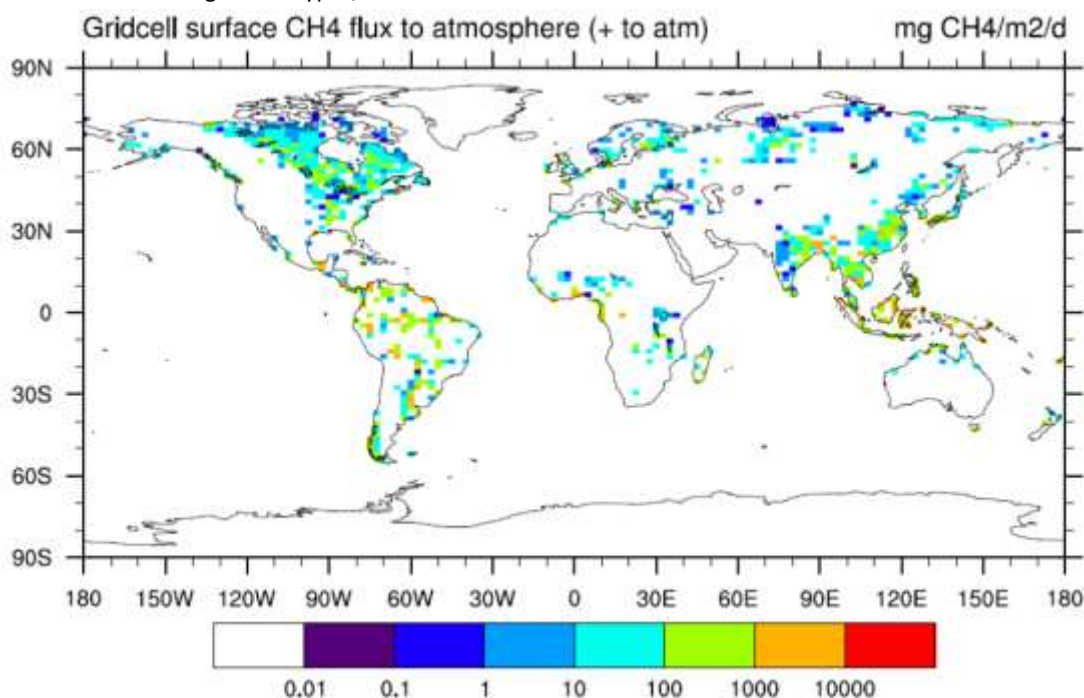
<sup>3</sup>: Department of Natural Resources, Cornell University, Ithaca, NY 14850

<sup>4</sup>: Climate and Carbon Sciences, Earth Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720

\*: Presenter, e-mail [lm494@cornell.edu](mailto:lm494@cornell.edu)

Methane emissions from natural wetlands and rice paddies constitute a large proportion of atmospheric methane and its magnitude is still uncertain. A process-based methane biogeochemical model has been developed in the Community Land Model 4.0 (CLM4-CN) to help constrain the global methane budget (Riley et al., submitted). We discuss here new processes that have been added to this model to improve estimation of current global methane flux. A new soil pH function and redox potential function have been incorporated into the model that reduce methane production and allow a better match to available observations. A plant growth cycle has been introduced to constrain O<sub>2</sub> diffusive transport into the rhizosphere in order to improve and enhance seasonal variation of plant-mediated methane oxidation. We also limit aerenchyma to plants in mostly inundated areas, in order to better simulate wetland vegetation types, without an

explicit representation within the model. Further, satellite inundated fraction and rice growth fraction are explicitly forced into the model to improve estimates of the current methane budget due to the large differences between model simulated fractional inundation and satellite observation. A rice paddy module is also incorporated into the model. The model is evaluated at the site level with available site level information such as vegetation covers and water table measurements. Evaluation of the model suggests that site level comparisons are quite different from grid-cell level using grid-level averaged information. Our model estimated average global wetland emission for the period 1993-2004 to be 263 Tg CH<sub>4</sub>/yr and rice paddy emission in the year 2000 to be 74 Tg/yr by using a set of mean parameter values. Tropical wetlands contributed to 204 Tg/yr (77%) of global wetland flux. Northern latitude (>50N) released 12.7 Tg CH<sub>4</sub>/yr due to low inundated area captured by satellites. Sensitivity analysis showed a large range (151-373 Tg/yr) of global methane flux. On the global scale, approximately 41% of methane transported through aerenchyma was oxidized before released to the atmosphere. Inclusion of soil pH in methane production helped reduce methane emission by more than 100 Tg/yr in this model. Redox potential reduced methane flux by 45.6 Tg/yr. Dependence of O<sub>2</sub> diffusive transports into the rhizosphere on the annual growth cycle increased methane emission by 116 Tg/yr. This study suggests that different parameterization of processes has substantial influence on global methane fluxes and further research on the methane related biogeochemical processes is necessary to constrain wetland methane emissions.



**Global distribution of the mean methane emission rates during the period 1993-2004 from natural wetlands.**

---

**[15A] Modeling the impact of landscape variability and placement of best management practices on hillslope-scale contaminant transport**

Sheila M. Saia<sup>1\*</sup>, Zachary M. Easton<sup>1</sup>, Jan Boll<sup>2</sup>, Erin Brooks<sup>2</sup>, Tammo Steenhuis<sup>1</sup>

<sup>1</sup>*Department of Biological and Environmental Engineering, Cornell University, Ithaca, NY 14850*

<sup>2</sup>*Department of Biological and Agricultural Engineering, University of Idaho, Moscow, ID 83844*

\*: Presenter, e-mail [sms493@cornell.edu](mailto:sms493@cornell.edu)

The effectiveness of agricultural best management practices (BMPs) for reducing soil, nutrient, and pesticide transport depends on the hillslope topography (i.e. slope) as well as the placement of the practice along the length of the hillslope. For instance, a riparian buffer at the bottom of a steep hillslope may reduce phosphorous loading to a Northeastern stream but fail to have the same impact in the Midwest where hillslopes are more gradual. Because areas generating overland flow are more prone to nutrient and pesticide transport, new management tools must accurately predict surface and subsurface flows. We propose a nutrient and pesticides transport model to be used in conjunction with the process-based Water Erosion Prediction Project (WEPP) model. WEPP was first developed by the USDA as a replacement to the Universal Soil Loss Equation (USLE) and the version used here can adequately estimates surface and subsurface flows as well as sediment, nutrient, and pesticide transport from saturated and unsaturated hillslopes. Besides topography, the model runs presented here also consider variables such as: soil type, crop rotation, and tillage practice for hillslopes in Idaho, Iowa, and Pennsylvania. Once available online, this modified WEPP model will be a valuable tool for policymakers and water resource managers to make scientifically informed decisions concerning the impact of agricultural practices on stream water quality.

**[16A] Investigation of *Thermobifida fusca* cellulases binding mechanism on BMCC and supercritical CO<sub>2</sub> pretreated biomass**

Dong Yang\*, Stephane C. Corgié, Larry P. Walker; BEE, Cornell University

\*: Presenter, e-mail [dy226@cornell.edu](mailto:dy226@cornell.edu)

Enzymatic hydrolysis of lignocellulosic biomass to produce reducing sugars is considered the key step in renewable biofuel production. This research aims to investigate the enzyme binding behaviors involved in the enzymatic hydrolysis of pretreated biomass. Research was conducted to investigate different methods to determine binding curves of *Thermobifida fusca* Cel5A, Cel6B and Cel9A on bacteria microcrystalline cellulose (BMCC) and supercritical CO<sub>2</sub> pretreated biomass.

## [17A] Long-term conversion of butyrate to n-butanol with *Clostridium saccharoperbutylacetonicum* using a two-stage continuous culture and online product removal

Hanno Richter<sup>1\*</sup>, Nasib Qureshi<sup>2</sup>, Bruce Dien<sup>2</sup>, Michael A. Cotta<sup>2</sup>, Largus T. Angenent<sup>1</sup>;

<sup>1</sup>Department of Biological and Environmental Engineering, Cornell University, Ithaca, NY 14853

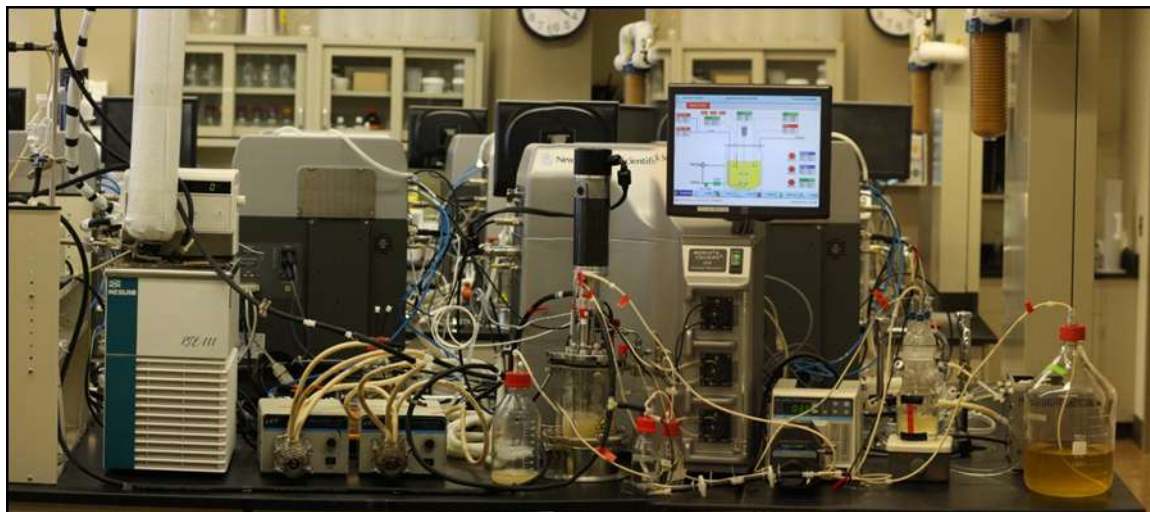
<sup>2</sup>USDA, Peoria, IL 61604

\*: Presenter, e-mail: [hr95@cornell.edu](mailto:hr95@cornell.edu)

In the Angenent lab, we are operating anaerobic bioreactors with undefined mixed cultures to convert waste lignocellulosic biomass into useful products. A traditional product of anaerobic bioreactors (i.e., anaerobic digesters) is methane, which is an energy carrier. Recently, we modified bioreactor conditions to produce a range of carboxylates, such as n-butyrate, instead of methane. The objective of the present study was to convert n-butyrate into the liquid biofuel n-butanol via fermentation, using pure cultures of solventogenic *Clostridia*.

Here, we describe a two-stage continuous fermentation system with *Clostridium saccharoperbutylacetonicum* strain N1-4 designed for conversion of n-butyrate into n-butanol. In the first stage, glucose was added as a source of energy and reducing equivalents to promote growth, while in the second stage, undissociated butyrate was maintained at a concentration of 0.3 g/L with a pH-

auxostat to induce a high solventogenic activity (i.e., production of n-butanol). We integrated gas-stripping in the second stage as a strategy for online product removal. The two-stage fermentation successfully minimized metabolic oscillations that are common to n-butanol fermentation carried out by *Clostridia*. In addition, culture degeneration was avoided by periodical heat shocking and reinoculating stage 1. The average n-butyrate consumption was 0.251 g/(L\*h), the conversion efficiency for n-butyrate to n-butanol was 93 %, the overall n-butanol production was 0.39 g/(L\*h), the molar ratio of butyrate:glucose consumed was 0.358, the ratio of n-butanol produced per n-butyrate consumed was 2.0, the yield  $Y_{\text{butanol/carbon}}$  was 0.386, and the molar yield  $Y_{\text{butanol/glucose}}$  was 0.718. This is the first report of a continuous fermentation system specifically designed and optimized for the conversion of n-butyrate into n-butanol.



## [18B] Applying reconstructed metabolic networks to model microbial conversion of mixed sugars to biofuels

Hnin W. Aung\*, Larry P. Walker; BEE, Cornell University  
\*: Presenter, e-mail [hwa22@cornell.edu](mailto:hwa22@cornell.edu)

A challenge to biological conversion of cellulosic biomass is achieving complete and rapid fermentation of the diverse sugars of biomass. Fermentation of both glucose and xylose, the dominant sugar monomers of cellulosic biomass, has been demonstrated by pure cultures of engineered strains. However, these single strains preferentially ferment glucose and xylose consumption occurs only after most of the glucose has been consumed. Therefore, it may be more effective to co-culture a strain specialized for efficient glucose fermentation with another strain specialized for efficient xylose fermentation. This poster describes our efforts to apply genome-scale metabolic models to simulate fermentation profiles of glucose-xylose mixtures using co-cultures. Such an approach may provide insights for genetic engineering schemes to increase the conversion efficiency of mixed-sugar fermentations.

***Variation of the non-dimensional effective tracer diffusivity with the non-dimensional bacterial concentration. Presence of the bacteria enhances the transport of the tracer.***

## [19A] Tracer diffusion in bacterial suspensions

T. V. Kasyap<sup>1\*</sup>, Donald L. Koch<sup>1</sup>, Mingming Wu<sup>2</sup>; Cornell University

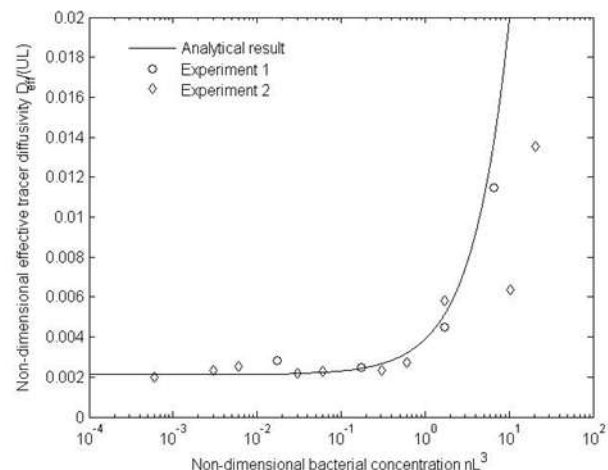
<sup>1</sup>Department of Chemical and Biomolecular Engineering

<sup>2</sup>Department of Biological and Environmental Engineering

\*: Presenter, e-mail: [kt358@cornell.edu](mailto:kt358@cornell.edu)

Passive tracer particles undergo random motion in bacterial suspension due to the hydrodynamic disturbance created by swimming bacteria and at long length and time scales, the tracer undergoes 'hydrodynamic' diffusion. For a Brownian tracer particle, the effective diffusivity is then the sum of this 'hydrodynamic' diffusivity and its Brownian diffusivity. Here we seek to find out the effective diffusivity of the tracer particle using experiments and theory. Experiments are carried out in a three-channel microfluidic device molded out of agarose gel with the middle channel being filled with a suspension of known bacterial concentration and fluorescent polystyrene beads. Time resolved images of the fluorescent beads are taken and the images are subsequently analyzed to obtain the bead tracks. The effective diffusivity of the beads is calculated from the slope of the mean squared displacement versus time curve. We then formulate a theory for the hydrodynamic diffusion in dilute and isotropic bacterial suspensions based on averaged transport and momentum equations. We find that effective diffusivity of the beads is enhanced by the swimming bacteria, and increases with bacterial concentration. The enhanced transport of the passive tracer may be advantageous to bacteria as it helps to facilitate the transport of nutrients and other chemicals in a high bacteria concentration suspension. We find reasonable agreement between the theoretical and experimental results.

This work is supported by the National Science Foundation (CBET) and the Lehman Scholar fund at Cornell University.



## [20B] Modeling fixed-bed alcohol production from pyrolysis gas

Alexander C. Esche\*, Largus T. Angenent; BEE, Cornell University

\*: Presenter, e-mail [ace46@cornell.edu](mailto:ace46@cornell.edu)

Pyrolysis of lignocellulosic biomass generates chars that can be used for fuels, filters, or soil additives. Char production emits CO and CO<sub>2</sub>, both greenhouse gases. If captured, pyrolysis gases can be converted into valuable products by microbial catalysts. Several species of *Clostridium* have been shown to produce ethanol from CO or CO<sub>2</sub> and H<sub>2</sub> in stirred reactors with high agitation rates, but these reactors cannot be operated economically at the industrial scale. Packed columns can increase gas-liquid mixing as well as provide support for biofilm formation. We aim to create bioreactors capable of economical alcohol production from gases derived from pyrolysis gas.

We have designed four 3L packed column reactors for trickle bed or flooded operation. We will compare ethanol concentration, production (mg ethanol/g cell-day) and pressure drop over the column with parallel or opposite gas flow. The reactors will be operated isobarically with 80% H<sub>2</sub> 20% CO<sub>2</sub> microbubbles fed through sintered glass filters. Porcelain berl saddles were chosen as packing to provide high surface area:volume ratio (900m<sup>2</sup>/m<sup>3</sup>) and support biofilm growth. Recirculation of the gas phase will increase the atom efficiency of ethanol production. Gas chromatography/mass spectrometry will be used to measure liquid and gas composition.

## [21A] Biomatrix stiffness modulates tumor cell proliferation in 3D cell culture

Shuting Zhao<sup>1\*</sup>, Beum Jun Kim<sup>2</sup>, Mingming Wu<sup>2</sup>; Cornell University

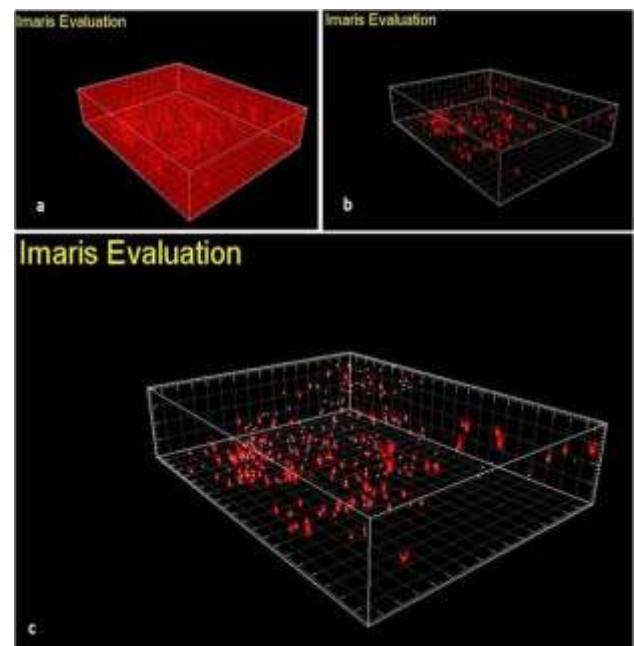
<sup>1</sup>Department of Biomedical Engineering

<sup>2</sup>Department of Biological and Environmental Engineering

<sup>‡</sup>Authors with equal contribution

\*: Presenter, e-mail [sz325@cornell.edu](mailto:sz325@cornell.edu)

It is now increasingly clear that cellular mechanical environment play important roles in cell proliferation, differentiation and migration. However, little is known about the roles of mechanical environment on cellular phenotypic behavior at a quantitative level, in part due to the lack of 3D cell culture model; and in part due to the lack of quantitative measurement tools. Here, we present our experimental results on how the stiffness of the extracellular matrix (ECM affects the proliferation of a breast cancer cell line (MDA-MB-231) using a 3D cell culture model. In parallel to this, we developed an advanced 3D cell tracking technique in conjunction with bright field microscopy to quantify cell density. We found that (1) the growth rate of a 2D cell culture (cells cultured on a 2D substrate) is higher than those in 3D; (2) Cells proliferate at a faster rate in a soft biomatrix (0.15% collagen) than they do in a stiffer biomatrix (0.25% collagen). We conjecture that stiffer environment suppresses cell growth from these experimental results.



---

**[22B] Anaerobic co-digestion with inhibitory organic wastes: microbial community response and dynamics**

**Joseph G. Usack\***, Jeffrey J. Werner, Largus T. Angenent; BEE, Cornell University

\*: Presenter, e-mail [jgu3@cornell.edu](mailto:jgu3@cornell.edu)

Anaerobic digestion of dairy waste is a mature technology with many benefits to farmers, including bioenergy production (as methane), low operating costs, greater than 50% solids reduction, nutrient conservation, and odor reduction. However, co-digestion of dairy manure with other organic wastes is necessary to raise additional income by “tipping fees” to make this economically attractive for a Northeast farmer. The stability and performance of anaerobic digestion depend largely on the substrate(s) used and the operating conditions employed because these parameters influence the structure of the mixed microbial community. Therefore, it is important to understand how changes in the substrate mix can affect microbial community robustness as it relates to system stability and performance in an anaerobic co-digestion. Our research will provide insights into the microbial ecology of anaerobic communities subjected to perturbations induced through energy-rich but potentially inhibitory co-digestion substrates: alkaline hydrolysate, fat/oil-rich food waste, and glycerol. We will determine the strategies and limitations of microbial communities to maintain methane production following the addition of these substrates.

**[23] Curating yeastnet: the iterative process of validating reconstructed metabolic networks**

**Ben D. Heavner\***, Larry P. Walker; BEE, Cornell University

\*: Presenter, e-mail [bdh32@cornell.com](mailto:bdh32@cornell.com)

A community effort led by the Manchester Centre for Integrative Systems Biology and the Yeast Systems Biology Network in 2007 resulted in a consensus network representation of yeast metabolism. This consensus representation was published in 2008 as Yeastnet. Incorporating community contributions and review, Yeastnet has since expanded through four major revisions to the most recent version, Yeastnet 4.32, released on January 19, 2010. This poster describes the process of working with Yeastnet to find its limitations and troubleshooting problems revealed through flux balance analysis. It also documents recent contributions to the Yeastnet reconstruction.

## [24B] A 3D microfluidic *in vitro* model for studies of cancer cell migration and invasion

Beum Jun Kim<sup>1\*</sup>, Pimkhuan Hannanta-anan<sup>1</sup>, Melody A. Swartz<sup>2</sup>, Mingming Wu<sup>1</sup>

<sup>1</sup>*Department of Biological and Environmental Engineering, Cornell University, Ithaca, NY 14853*

<sup>2</sup>*Institute of Bioengineering, Ecole Polytechnique Federal de Lausanne, 1015 Lausanne, Switzerland*

\*: Presenter, e-mail [bk37@cornell.edu](mailto:bk37@cornell.edu)

Cancer metastasis is a complex and dynamic process that involves cancer cells leaving the primary tumor and establishing secondary tumors in foreign sites. Current *in vitro* models (e. g. the Boyden chamber assay) for cancer cell motility and invasion have limitations, providing population-based and end-point results. In addition, animal models do not always apply to humans. As a result, drugs developed are either nonspecific or not effective. We present a 3D microfluidic *in vitro* model that allows us to quantify cellular behavior (cell morphology and speed) in both space and time, and at single cell resolution under well-defined chemical gradients. Using this model, we investigated a breast cancer cell line (MDA-MB-231) responding to epidermal growth factor (EGF) and chemokine (SDF-1 $\alpha$ ) gradients. Our experimental results demonstrate (1) EGF and SDF-1 $\alpha$  promote cancer cell motility, both individually and synergistically; (2) Breast cancer cells exhibit plasticity when exposed to SDF-1 $\alpha$ , showing three different types of cell motility; (3) Breast cancer cells are chemotactic towards high concentrations of SDF-1 $\alpha$ . These findings will eventually shed light on the physical and chemical drivers in cancer cell migration.

The work described was supported by the Cornell Center on the Microenvironment & Metastasis through Award Number U54CA143876 from the National Cancer Institute, and the Cornell Nanobiotechnology Center.

## [25A] Multi-channel microfluidic biosensor for nucleic acid detection

Peng He, Nongnoot Wongkaew\*, Vanessa Kurth, Antje J. Baeumner; BEE, Cornell University

\*: Presenter, e-mail [nw253@cornell.edu](mailto:nw253@cornell.edu)

The development of a multi-channel poly (methyl methacrylate) (PMMA) microfluidic biosensor coupled with an interdigitated ultramicroelectrode array (IDUA) for electrochemical detection is presented here. The multi-channel biosensor was successfully designed and fabricated and enables the simultaneous detection of five analytes. Here, we focus on the optimization of the electrochemical detection of mRNA from pathogenic organisms. *Cryptosporidium parvum* mRNA is recognized via sandwich hybridization of the target sequence with capture probes conjugated to superparamagnetic beads and reporter probes labeled with liposome. The liposomes entrap the redox couple potassium ferro/ferri hexacyanide. The current signal generated via liposome lysis using a non-ionic detergent correlates thus directly to the concentration of mRNA in the sample. For the electrochemical detection, the redox couple is flown over the IDUA in detection zone. Optimizing the electrochemical detection it was determined that peak area recording provided highly reliable signals and when normalized to the background signals provided relative standard deviations below 10% between different biosensor chips. Further, the detergent flow rate was optimized and it was determined that a flow rate of 2  $\mu\text{L}/\text{min}$  provided the best signal-to-noise-ratios. The investigated device offers a great opportunity for application in clinical diagnostics, food-borne pathogen detection or environmental protection that require multi-analyte detection and high-throughput assays.

---

**[26B] Metabolic bioengineering of purple algae with clostridial solventogenesis genes to produce n-butanol via photoreduction of n-butyrate**

Wendy A. Hoose<sup>1\*</sup>, Hanno Richter<sup>1</sup>, Largus T. Angenent<sup>1</sup>, Georg Jander<sup>2</sup>; Cornell University

<sup>1</sup>Department of Biological and Environmental Engineering

<sup>2</sup>Department of Plant Biology

\*: Presenter, e-mail [wah2@cornell.edu](mailto:wah2@cornell.edu)

To meet current global energy needs there is an increasing need to produce more renewable energy. In particular the reliance on petroleum based products for transportation cannot be sustained and can partially be met with biofuels, such as ethanol and butanol. n-Butanol, unlike ethanol, does not attract water and is, therefore, not corrosive to preexisting vehicle ignition systems and is closer in its chemical properties to gasoline than ethanol (Lee et al. 2008). n-Butyrate, an intermediate of n-butanol fermentation, can be produced from agricultural lignocellulosic waste in a fermentor. *Clostridium acetobutylicum*, which is an anaerobic bacterium, is used in the fermentation of n-butyrate to produce n-butanol. Currently the clostridial conversion of n-butyrate to n-butanol is not an economically viable option due to the need for sugar as carbon source and concurrent fermentation pathways with multiple end products, such as ethanol, acetone, and acetate (Lee et al., 2008). An approach to overcome these issues is to bioengineer a homobutanol metabolic pathway in a host that is naïve to n-butanol production and can produce its own energy from sunlight, a renewable energy source.

**[27A] Branched DNA nanostructures for pathogen detection**

Mark R. Hartman<sup>1\*</sup>, Young Hoon Roh<sup>1</sup>, Krishna Jayant<sup>2</sup>, Edwin C. Kan<sup>2</sup>, Dayong Yang<sup>1</sup>, Dan Luo<sup>1</sup>; Cornell University

<sup>1</sup>Department of Biological and Environmental Engineering

<sup>2</sup>Department of Electrical and Computer Engineering

\*: Presenter, e-mail [mrh39@cornell.edu](mailto:mrh39@cornell.edu)

Diagnosis of infectious diseases often relies on DNA-based detection methods, but popular methods such as PCR or DNA microarrays typically require specially-trained personnel, expensive equipment, and fussy enzymes. We present a “self-amplifying DNA-polymer” technology that preserves the advantages of conventional nucleic acid amplification tests, but uses a rapid and robust light-driven amplification step instead of a traditional enzyme-based approach. Our assay is based on novel “DNA photo-monomers” that can recognize and bind to specific pathogen biomarkers. Upon exposure to light, the signals from these DNA photo-monomers are amplified by several orders of magnitude through the formation of DNA-polymer aggregates. This amplification step will only occur in the presence of specific pathogen biomarkers. The resulting aggregates can then be easily detected by fluorescence, turbidity measurements, or electrochemical sensing. Since this approach is based on nucleic acids, it can be easily extended to any infectious pathogen with only minor modifications to the system -- and since the system is enzyme-free, it is relatively user-friendly and potentially suitable for point-of-care applications.

## [28A] Parameter optimization of bioelectrochemical systems using a microsystems engineering approach

Davina A. Widjaja<sup>1\*</sup>, Lindsey B. Sidrane<sup>2</sup>, Arvind Venkataraman<sup>1</sup>, Largus T. Angenent<sup>1</sup>, Mingming Wu<sup>1</sup>; Cornell University

<sup>1</sup>Department of Biological and Environmental Engineering

<sup>2</sup>Department of Chemical and Biomolecular Engineering

\*: Presenter, e-mail [lbs66@cornell.edu](mailto:lbs66@cornell.edu)

There is a growing interest in exploiting bioelectrochemical systems (BESs), such as microbial fuel cells, as an alternative energy source for sustainable living. Certain species of microorganisms such as *Pseudomonas aeruginosa* Wild Type 14 (PA14) produce electrons or electron carriers that can be a digital output signal. The electric current generation of BESs is influenced by many biophysical and biochemical parameters in the system, such as glucose level, cell culture community, cell density, PH, and oxygen level. The existing MFCs are at macro scale and are not suitable for parameter optimization. Here, we present preliminary experimental results on our efforts in parameter optimization of BESs; and in particular, on the roles of carbon sources in *P. aeruginosa* motility. We will discuss the relation between PA14 motility and biofilm formation, and subsequently electric current generation.

This work is supported by a Lehman Scholarship award from the Cornell University to M.W. and a NSF CAREER grant with no. 0939882 to L.T.A.

## [29B] Nanofiber-Enhanced Microfluidic Biosensors for Pathogen Detection

Marissa A. Agustin<sup>1</sup>, Christian Willrodt<sup>1</sup>, Marion Schelling<sup>1\*</sup>, Christine L. Pitner<sup>1\*</sup>, Lauren E. Matlock-Colangelo<sup>1</sup>, Daehwon Cho<sup>2</sup>, Margaret W. Frey<sup>2</sup>, Antje J. Baeumner<sup>1</sup>; Cornell University

<sup>1</sup>Department of Biological and Environmental Engineering

<sup>2</sup>Department of Fiber Science and Apparel Design

\*: Presenters, e-mail [marionschelling@gmail.com](mailto:marionschelling@gmail.com) and [clp65@cornell.edu](mailto:clp65@cornell.edu)

This project aims to develop a microfluidic biosensor for the detection of *E. coli* cells in apple juice in a short timeframe. This study specifically focuses on the capability of functionalized polyvinyl alcohol nanofibers incorporated onto microchips to isolate, purify and detect *E. coli* cells. The nanofibers were electrospun onto polymethyl methacrylate (PMMA) substrates patterned with conducting gold surfaces and subsequently bonded to microfluidic channels embossed into a second PMMA plate. This resulted in fiber mats with pore sizes between 0.2 and 8  $\mu\text{m}$ . Quantitative experiments involving the counting of colonies on agar plates were performed in addition to qualitative measurements using syto9 as fluorescent dye marker. The methods investigated here include on- and off-chip experiments.

The net surface cell charge of *E. coli* is negative at neutral pH. We were able to demonstrate under these conditions that positively charged fibers retained 98% of all *E. coli* cells. Negative nanofibers retained only 35%, which is attributed mainly to non-specific loss of cells in tubing, as no bacteria were detectable on the fibers using fluorescence microscopy. Experiments involving neutral fibers were also carried out in order to study the mechanical property of bacteria retention. Additional investigations are targeting the possibility of influencing cell-capture and cell-release from the fibers by varying pH conditions, and detecting captured cells specifically via antibodies.

## [30B] *Pseudomonas aeruginosa* – A model organism for understanding ecological networks in bioelectrochemical systems

Arvind Venkataraman\*, Zhongjian Li, Miriam A. Rosenbaum, Largus T. Angenent; BEE, Cornell University

\*: Presenter, e-mail [av299@cornell.edu](mailto:av299@cornell.edu)

The microbial ecology of bioelectrochemical systems (BESs) is of fundamental interest to increase the power output and/or product yield after reactor configuration problems have been resolved. *P. aeruginosa* is a model organism for BESs due to the production of electrochemically-active phenazines to mediate current production of *P. aeruginosa* itself and/or other community members. Phenazines also act as antibiotics, and therefore have an influence on the microbial ecology of BES. In addition, *P. aeruginosa* exhibits coordinated communal behaviour via quorum sensing (QS) – bacterial communication - via secreted signalling factors (acyl homoserine lactones in this case). Thus, we propose that this unique combination of electrochemical activity and a “social” nature makes *P. aeruginosa* an important organism for studying the ecological networks in BESs.

We investigated the electrochemical behavior of *P. aeruginosa* PA14 in potentiostatically-controlled BESs with respect to both intraspecies (quorum sensing) and interspecies interactions (between *P. aeruginosa* and a fermenter):

**i) intraspecies interaction:** First, we showed that QS modulates the current production by *P. aeruginosa* in

BESs by controlling phenazine production. The current and phenazine production by a wildtype strain (WT) and a mutant were investigated under different conditions that are important for QS, such as the addition of the signaling lactone molecule. As hypothesized, anaerobic current production by the WT was 29-fold higher with extraneously supplied lactones than without lactones. Second, since we directly correlated current production to QS in *P. aeruginosa*, we used BESs to develop a bacteria-based AND logic gate (i.e., biocomputer) using a *P. aeruginosa lasI/rhlI* double mutant with two quorum-sensing signaling molecules as the input signals and a distinct digital electrical current as the output signal. Therefore, we have found a new niche for BESs – bio-computing.

**ii) interspecies interaction:** We studied *P. aeruginosa* in association with a fermenter (*Enterobacter aerogenes*) and found that the current generation by this co-culture was 18-fold higher than the current production by either of these two bacteria alone. This synergism was due to metabolite-based mutualism in which a fermentation product of *E. aerogenes* stimulated enhanced and specific phenazine production by *P. aeruginosa*. The presence of the specific phenazine triggered a switch from fermentation to electrode respiration for *E. aerogenes* under these conditions. Our work shows that *P. aeruginosa* plays an important ecological role in BESs. In addition, BESs are valuable tools for real-time monitoring/sensing of QS activity in *P. aeruginosa* and for bio-computing.

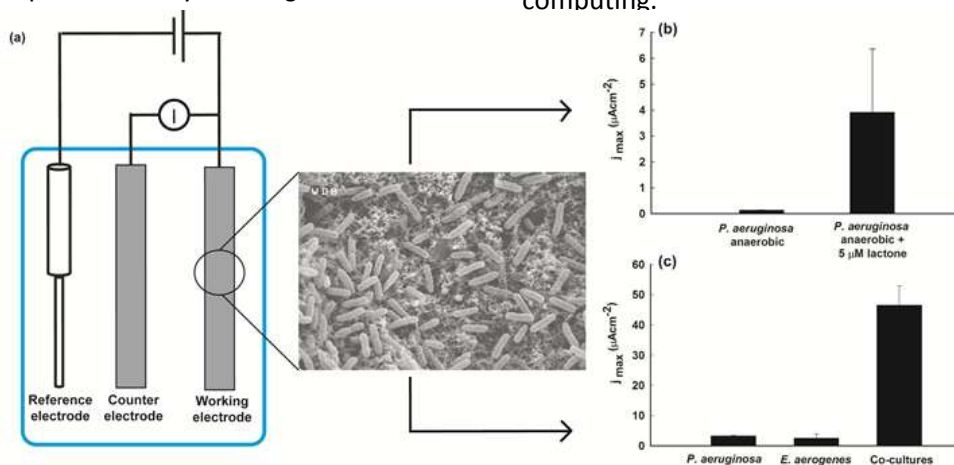


Figure 1. (a) Schematic of potentiostatically controlled 3-electrode system with inset showing SEM image of *P. aeruginosa* on the electrode (b) Maximum current densities of *P. aeruginosa* with and without the quorum sensing lactone molecule (c) Maximum current densities with pure cultures of *P. aeruginosa*, *E. aerogenes*, and a co-culture of both microorganisms.

## [31A] Recession slope analysis coefficients, low flows, groundwater and precipitation responses for climate change studies

Asha N. Sharma<sup>1\*</sup>, Vania Pereira<sup>1,2</sup>, M. Todd Walter<sup>1</sup>

<sup>1</sup>Department of Biological and Environmental Engineering, Cornell University

<sup>2</sup>Departamento de Geografia, Universidade Estadual de Campinas, Campinas, Sao Paulo, Brazil

\*: Presenter, e-mail [ans62@cornell.edu](mailto:ans62@cornell.edu)

Recession slope analysis has often been used to estimate aquifer thickness, i.e. groundwater depth. Here we look at long term trends in the coefficients of this analysis for several large watersheds in areas potentially free of human influences in Pennsylvania, and compare them with trends in groundwater depths and low flows. We also look at long term precipitation trends in these areas, making the effort to compare the trends according to different hydrological units such as individual watersheds and Atlantic/non-Atlantic drainage areas. Intriguingly, the trends in the various analyses do not consistently match each other. These comparisons show that the choice of analysis may have important implications on the conclusions drawn from studies that attempt to assess the effects of climate change on the hydrological cycle.

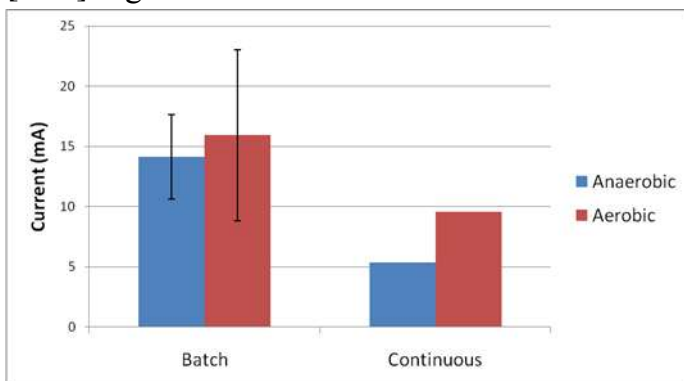
## [32B] Characterizing the effect of micro-aerobic conditions on *Shewanella oneidensis* in bioelectrochemical systems

Michaela A. TerAvest<sup>\*</sup>, Miriam A. Rosenbaum, Largus T. Angenent

\*: Presenter, e-mail [mat273@cornell.edu](mailto:mat273@cornell.edu)

In bioelectrochemical systems, microorganisms can use an anode electrode as a terminal electron acceptor for respiration, while generating an electric current. Competing electron acceptors, such as oxygen, are considered detrimental to system performance because they redirect electrons that could be transferred to the electrode, and therefore decrease current production. Oxygen is the most common competing electron acceptor, but recent studies have shown that in some circumstances oxygen can enhance current production by improving the growth rate of facultative anaerobes in the system. We are studying this effect on the facultative anaerobe, *Shewanella oneidensis* MR-1, which is a model organism for electron transfer processes in bioelectrochemical systems. *S. oneidensis* is capable of direct electron transfer and mediated electron transfer through self-produced, soluble redox shuttles (e.g., flavins). Here, we investigate the effect of oxygen on a potentiostatically-controlled anode with *S. oneidensis* MR-1 under both batch- and continuously-fed regimes. We measured electric current generation and other variables including planktonic cell density, biofilm density, and the flavin concentrations in the planktonic phase and in the biofilm. Preliminary results show that the presence of oxygen increases growth and current production under our operating conditions, although the coulombic efficiency (i.e., how much of the substrate is used to generate the electric current) is lower because more substrate is required to maintain the higher growth rate. We also found more pronounced effects of oxygen in continuously fed systems than in batch fed systems (Figure 1). This may be due to a greater basal metabolic energy requirement under continuous flow conditions induced by constant cell and flavin loss to the effluent. Oxygen may help cells overcome this disadvantage because it improves the growth rate of this organism. This could be useful for BES applications in which efficiency is less important than high current production and substrate degradation.

[32B] Figure → →



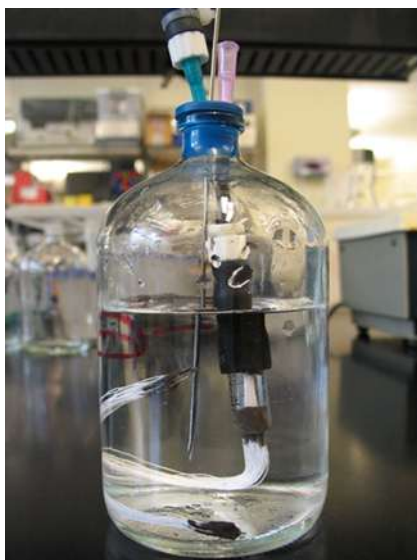
**Oxygen increases the current production in continuously-fed systems but has little effect on the batch-fed systems.**

### [33A] Production of n-butanol from syngas using *Clostridium ljungdahlii*

Jose M. Perez\*, Hanno Richter, Largus T. Angenent; BEE, Cornell University

\*: Presenter, e-mail [jmp426@cornell.edu](mailto:jmp426@cornell.edu)

Pyrolysis of biomass results in synthesis gas (syngas), a blend of gases composed mainly of carbon monoxide, hydrogen, and carbon dioxide. Syngas fermenting organisms, which are able to produce alcohols (primarily ethanol), have been isolated in the past. Converting biomass into syngas and subsequent fermentation into alcohols has several potential advantages over conventional fermentation of sugars because of the availability of cheaper and more abundant substrates, higher rate of utilization of the carbon and energy contained in the substrate, and no interference with human food production. Any kind of biomass can be converted in syngas by pyrolysis and the specificity of microbial catalyst help to avoid unwanted by-products. Our work focuses on the conversion of syngas into alcohols using biological catalysts. The specific objective is to convert n-butyrate into n-butanol with *Clostridium ljungdahlii* using syngas as a source of energy and reducing equivalents. The bio-fuel n-Butanol is considered superior compared to ethanol because of its higher energy density, lower affinity to water, and lower corrosivity. We used 250-ml serum bottles for planktonic microbial growth and the syngas was injected into the medium using hollow fiber membranes to produce micro bubbles to increase the mass transfer rate. The bottles were incubated at 37°C in a shaking water bath at an initial pH of 6.5. n-Butanol concentrations up to 8.4 mM were detected and n-butyrate consumption of up to 10.5 mM was measured. Future work aims to determine the tolerance of *C. ljungdahlii* to increasing concentrations of n-butyrate, and to test the effect of different parameters, such as pH and yeast extract concentration, on n-butanol production.



**Serum bottle with hollow fiber membranes**

### [34B] Rapid detection of rotavirus in whole feces

Katie A. Edwards\*, Monica L. Jackman, Heike Menne, Christine L. Pitner, Barbara L. Leonard, Yinan Tang, Antje J. Baumner; BEE, Cornell University

\*: Presenter, e-mail [kae24@cornell.edu](mailto:kae24@cornell.edu)

Rotavirus infection leading to severe watery diarrhea is highly prevalent in children. In fact, it is estimated that nearly every child will have contracted a rotavirus infection by the age of 5. Between 20-60 deaths occur in the U.S. and over 600,000 deaths occur worldwide annually due to rotavirus infection, with 82% of deaths occurring in the most underdeveloped nations. The costs in the U.S. alone stemming from rotavirus are ~\$1 billion annually. A rapid, simple assay is needed in non-clinical settings to diagnose rotavirus infection in cases of diarrhea, versus other causes, early thus allowing caretakers to seek rehydration treatment sooner. Towards this end, we are developing a rapid test for rotavirus in whole fecal samples. This tests does not require any separate sample processing steps and can detect low concentrations of virus directly in fecal samples. We present the design and preliminary optimization of the test which focused on the development of a highly sensitive antibody-recognition system, visual detection using gold nanoparticles and nitrocellulose membranes. Special sample pads were being identified for the partial separation of rotavirus from fecal matter automatically within the test system.

