BBS Track affiliations: BQBS, and MCGD. (Also 3 Micro students joined the lab)
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Best time of year to rotate in your lab: Rotations available any time.

How do bacteria breathe without oxygen or soluble electron acceptors? Structures, functions and electron transfer mechanisms of proteins nanowires.

Deep in the ocean or underground, where there is no oxygen, diverse microbes "breathe" by projecting tiny protein filaments called "nanowires" into the soil, to dispose of excess electrons resulting from the conversion of nutrients to energy. These nanowires enable the bacteria to perform environmentally important functions such as cleaning up radioactive sites, generating electricity or sharing electrons with other bacteria. Although it has been known that *Geobacter* make nanowires, it was not clear what they are actually made of and why they are conductive.

Recent discoveries by our lab resolve two decades of confounding observations in thousands of publications that thought these nanowires as pili filaments (*Current Opinion* 2020). Our studies have revealed a surprise: the protein nanowires have a core of metal-containing molecules called hemes .By "sequencing" with cryo-electron microscopy, we found that hemes line up to create a continuous path along which electrons travel. Using multimodal functional imaging (*Physical Biology* 2020) and a suite of electrical, biochemical and physiological studies, we find that rather than pili, nanowires are composed of cytochromes OmcS and OmcZ that transport electrons via seamless stacking of hemes over micrometers (*Cell* 2019, *Nature Chem.Bio.* 2020, *Nature* 2021).

The students will work on one or more of the following three major research themes of our lab:

1) Mechanism of ultrafast electron transport & storage: We are determining how nanowires move electrons, ions, spins and excitons at ultrafast (~ 100 fs) rates and centimeter distances unprecedented in biology. We have found a novel electron escape route in proteins to avoid oxidative damage (*PNAS* 2021) and how cooling speeds up electrons (*Science Adv.* 2022).

2) Architecture of nanowire electron transport system. We are identifying the nanowire biogenesis and secretion machinery using genetic tools combined with cryo-electron microscopy and tomography and reconstituting the machinery into new species (*Nature Comm.* 2022).

3) Reducing global temperatures by capturing atmospheric methane produced by microbial consortia. How to lower rising global temperatures by capturing methane released to the atmosphere by microbes? We are lowering the nanowire-mediated respiration rate of methane-producing microbes that are producing more CO_2 than that can be used by plants.

Projects could involve structural studies, genetically engineering nanowires using synthetic biology tools, nanoscale electron transfer measurements in nanowires and living biofilms, multiomodal imaging and spectroscopy, electrochemistry as well as building and experimentally testing computational models (with Victor Batista and Gary Brudvig, Yale Chemistry).

We have several interdisciplinary projects embedded in these larger goals that would be great rotation projects as they provide training in a variety of biophysical, molecular biology and biochemical techniques and are likely to yield positive results/publications within the rotation.

Please come chat with me or with one of my laboratory members to match your interests with our training opportunities. Rotation projects are experimentally or computationally oriented with possibilities of combining both and no prior background in a specific discipline is necessary.

Join our lab meetings either in person or via zoom: Tuesdays 4:30 PM (Computation); Friday 2 PM (Experiments). We can adapt our lab meeting schedule to accommodate your class schedule.

Lab's policy on career development: Among lab's foremost goals is the development of the next generation of interdisciplinary scientists who will play vital roles in advancing biological sciences. Our My philosophy is to train students to be self-directed learners by building a core set of discipline-specific expertise first, and then encourage them to expand beyond their core discipline to appreciate and incorporate other disciplines. We encourage all careers, and we have received Blavatnik Innovation Award to bring nanowire-based technologies from lab to market..