List of Projects available in SCELSE

Plant microbiome and metabolome for improving plant immunity and resilience
(Supervisory team: Assoc Prof Sanjay Swarup)
Offered in SCELSE-NUS

Plants and microbes have co-evolved for more than 2,000 million years during which they have developed highly interdependent functions to help in the functioning of each other. This project will extend the current work of plant-associated microbes using two highly related plant models of Arabidopsis and Asian Brassica leafy vegetables. Lab-based experimental models have been developed to achieve enhanced plant growth by highly complex root-associated microbiomes. This project will explore the role of such microbiomes in environmental stresses such as drought or salinity. Additionally, role of plant volatiles would also be investigated. As plants release a bouquet of volatiles, many of them, being bioactive, are likely to have an impact on the composition of the microbiome. The project requires a background in basic biology, love for plants and keenness to work on microbiomes in both laboratory and greenhouse.

For more information, please contact:
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Molecular viability PCR for discriminating viable from dead cells in environments
(Supervisory team: Asst Prof Bae Sung Woo)
Offered in SCELSE-NUS

Assessment of bacterial viability has been based on culture-based methods. Molecular methods targeting nucleic acid have revolutionized microbial diagnosis. DNA-based methods such as PCR and qPCR are rapid, versatile, sensitive, and precise and allow specific detection and/ or quantification for microorganisms of interests in food, environmental, and clinical samples. However, the drawback of molecular assessment, especially for DNA-based methods, is a lack of differentiating viable from nonviable cells in environments because DNA can persist for long periods of time in the environment after cells have lost their viabilities. Recently, our lab developed DNA-intercalating dyes for quantifying viable bacteria using PCR. In this proposal, we further apply the DNA-intercalating dyes for selectively amplifying microbial community in different environments such as soil, drinking water, and wastewater. Therefore, the goal of this project is to apply novel molecular dyes to selectively detect only microbial populations with metabolic activity or ecological contributions. The outcomes of this project will advance our understanding of microbial function in natural and engineered system where microorganisms play important roles for biodegradations of pollutants.

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Development of a mobile microfluidic platform for ballast water quality monitoring
(Supervisory team: Asst Prof Bae Sung Woo)
Offered in SCELSE-NUS

The current methods for detecting microbiological contaminants in a ship ballast treatment system are inconvenient, requiring intensive labor, and expensive. Often, environmental regulation agencies could not receive accurate, reliable and timely information of microbial water quality data from field.
Traditionally, the quality of biological water in marine and ballast water have been examined by enumerating fecal indicator bacteria (FIB) such as E. coli, Enterococcus or waterborne pathogens. The testing process for bacterial water quality is long, as it usually takes more than 24 hours to enrich bacteria in a laboratory. This delay could have dire consequences, as environmental regulation agencies will have to wait to be notified of the biological water quality, even though the pollutants still pose potential threats to the humans

and the marine ecosystem. The goal of the proposed research is to develop a novel microfluidic platform integrated with a smartphone that enables real-time in situ monitoring of microbial contaminations in ballast and marine water. The ideal candidate will have a B.Sc in Environmental Engineering or Microbiology and interest in multidisciplinary research across engineering, chemistry and microbiology.

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Understanding bacterial lipid trafficking and outer membrane biogenesis
(Supervisory team: Assoc Prof Chng Shu Sin)
Offered in SCELSE-NUS

In our laboratory, we use bacterial outer membranes as interesting models for studying the biochemistry of lipid transport and membrane assembly (Figure 1). We focus on both Gram-negative bacteria and mycobacteria, which have separately evolved to assemble a second (outer) membrane in their cellular envelopes. These bacteria have to transport proteins and lipids, and build their outer membranes at a distance away from the cytoplasmic membrane, all in an environment devoid of any apparent energy source. The outer membrane demarcates a second aqueous compartment in these bacteria cells. In addition, it serves as a formidable permeability barrier against toxic substances, in part rendering Gram-negative bacteria and mycobacteria intrinsically resistant to many clinically-relevant antibiotics. Using a combination of chemical, biological, genetics, and structural approaches, we tackle problems in bacterial lipid trafficking and outer membrane assembly. In particular, we deploy major efforts in characterizing transport of phospholipids in Gram-negative bacteria, and mycolic acids in mycobacteria. In each theme, we work towards identifying and characterizing molecular machines in order to gain mechanistic understanding of their functions in lipid transport. Through our studies, we shed light on the fundamental principles of how bacterial cells assemble the outer membrane, maintain homeostasis, and control the function of this very important lipid bilayer. We are always open to new PhD students; interested candidates should have a B.Sc. in Chemistry, Biochemistry, Microbiology or Biology.

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Overcoming recalcitrant biofilm infections through nano-delivery systems
(Supervisory team: Assoc Prof Joachim Loo)
Offered in SCELSE-NTU

Bacteria enmeshed in an extracellular matrix, biofilms, exhibit enhanced antibiotic tolerance. Coupled with the rapid emergence of multidrug-resistant strains, the current cohorts of antibiotics are becoming ineffective. Alternative antimicrobial approaches are therefore urgently needed to overcome recalcitrant biofilm infections. In this project, we aim to develop a highly robust and customizable nanoscale carrier that integrates the liposomal and the polymeric systems for the delivery of different classes of antimicrobials to both biofilms and intracellular pathogens. The latest molecular biology and systems biology tools as well as nanoparticle synthesis approaches will be used in this project. Suitable candidates would have interest in multidisciplinary research across Microbiology, Physical Chemistry and Nanoscience.

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Bacterial signalling and the second messenger c-di-GMP to trigger the switch from planktonic to biofilm lifestyle in *Pseudomonas aeruginosa*
(Supervisory team: Professor Alain Filloux, daily supervisor Research Fellow Joey Yam)
Offered in SCELSE-NTU

Pseudomonas aeruginosa is a pathogenic Gram-negative bacterium involves in nosocomial and chronic infections. During chronic infections it can adopt a biofilm lifestyle, which becomes resistant to antibiotic treatment and recalcitrant to eradication by the immune system. The decision-making process to switch to the biofilm lifestyle is tightly controlled and involves complex regulatory networks. In particular, the intracellular concentration of the universal second messenger c-di-GMP is instrumental to the switch, and high c-di-GMP triggers instantaneously biofilm formation. In *P. aeruginosa* the c-di-GMP homeostasis is monitored by an antagonist set enzymes, the makers or diguanylate cyclases (DGC) and breakers or phosphodiesterases (PDE). *P. aeruginosa* PAO1 has 41 DGC/PDE, which is surprisingly high since one of each would suffice to balance the pool of c-di-GMP. This indicates that there is a remarkable level of specificity including transferring c-di-GMP to, or breaking from, proteins which are known as adaptor and that will trigger one of many outputs such as fabrication of adhesins, production of polysaccharides, assembly of fimbriae, which all contribute to biofilm formation but in a different way. This project explores this network by reconstructing distinct c-di-GMP pathways and could use a c-di-GMP zero strain, all *dgc/pde* genes deleted, to use the chassis in a synthetic biology approach where only a subset of those is reintroduced and their role examined. The project requires a background in basic microbiology, molecular biology, bacterial genetics, confocal microscopy and some taste for biochemistry.

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The type VI secretion system in Pseudomonas aeruginosa-an antibacterial weapon to manipulate microbiome structure and composition
(Supervisory team: Professor Alain Filloux, daily supervisor Research Fellow Joey Yam)
Offered in SCELSE-NTU

Pseudomonas aeruginosa is a pathogenic Gram-negative bacterium equipped with 3 distinct Type VI Secretion System (T6SS). The T6SS is a macromolecular nanomachine that is used to deliver toxins into competing bacteria. It is made of different parts of which a contractile tail and a puncturing device resembling those of bacteriophages. The tail is loaded with toxins and upon contraction of the tail the puncturing device pierces target preys to deliver the toxins. The diversity of toxins is remarkable and P. aeruginosa can deliver as many as dozens of those with biochemical activity including peptidoglycan hydrolases, phospholipases, nucleases or NADases. The T6SS is thus a powerful tool to provide P. aeruginosa with a competitive edge so that it prevails in the context of polymicrobial system including in the context of chronic infections. This project will explore the role of the P. aeruginosa T6SS and its associated toxin in killing other organisms within a polymicrobial population. We will also explore the impact of the T6SS on Gram-positive bacteria, such as Enterococcus faecalis or Staphylococcus aureus which has not been explored. The project requires a background in basic microbiology, molecular biology, bacterial genetics, fluorescence microscopy and some taste for omics and metagenomics.

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The role of microbial communities in mediating the corrosion of metals in the marine environment
(Supervisory team: Assoc Prof Scott Rice, Assoc Prof Federico Lauro, Asst Prof Matteo Seita)
Offered in SCELSE-NTU

All man-made infrastructure is subject to attack by microorganisms. This is particularly true for metal surfaces in the marine environment, such as oil and gas pipelines and off-shore platforms that corrode in part due to microbial action. Humans are pushing the extreme boundaries of exploration in search of new sources of energy or to deploy critical infrastructure, such as cabling networks, and as a result, there is considerable focus on the deep sea (i.e. 2000 meters and below). These unique environments are characterized by extremes of pressure and nutrient limitation. Due to the challenges of access to these sites, little is known about the organisms that inhabit these depths and even less is known about how they might influence corrosion of expensive and sensitive infrastructure. We are combining the scientific expertise of microbiologists, metallurgists, materials scientists and data modelers to unveil the mysteries of how microorganisms from these unique habitats cause corrosion, with the view to develop strategies to protect sensitive and susceptible infrastructure. Projects are multi-disciplinary with the potential to focus on microbiology, electrochemistry, materials science and sensor development.

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Urban air microbiomes
(Supervisory team: Prof Stephan Schuster)
Offered in SCELSE-NTU

The microorganisms around us in air (including fungi, bacteria, archaea and viruses) remain poorly understood compared to environments such as soil or water, especially in the tropics. To address these gaps, SCELSE's five year MOE Tier 3 urban air microbiomes project aims to: 1) Investigate the identity and function of airborne microorganisms in indoor and outdoor environments in Singapore; and 2) study their sources and sinks, revealing where the airborne microbes come from. The urban air microbiomes project will include establishing protocols for sample collection and processing, capable of collecting enough biological material from the air for sequencing and DNA analysis. High-volume filter-based samplers are used to collect microorganisms for DNA extraction, while high-volume liquid cyclonic samplers are used in parallel for imaging with bright field, fluorescence and scanning electron microscopy. In addition, airborne microorganisms are isolated from air using agar plates and their whole genomes will then be sequenced to build a database, which would be the first comprehensive collection of airborne microorganisms in tropical environment.

Our outdoor air sampling project is now in the final year, we have accomplished sampling on campus every week over a year, 5 consecutive days 24-hour sampling, and monthly sampling at Primary Forest in Nature Reserve. Our findings are that microorganisms have their own daily (diel) cycles and their responses vary according to different conditions, such as temperature, relative humidity, UV, and rainfall. We sample outdoor air at sites distributed temporally and spatially across Singapore and globally to identify microbes locally and globally distributed. Additionally, we also sample indoor air to understand correlation with airborne and human respiratory microbiome.

Suitable candidates would have a B.Sc or M.Sc in Microbiology, Mycology, Molecular Biology, or Biochemistry and interest in multidisciplinary research across medical and atmospheric chemistry, involving plenty of computational analysis (bioinformatics).

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Engineering beneficial biofilms for chemical, energy and environmental applications
(Supervisor: Assoc Prof Cao Bin)
Offered in SCELSE NTU

The objective of this project is to apply insights obtained from the state-of-the-art biofilm biology into developing high performance biofilm-mediated bioprocesses for various applications such as production of high value chemicals, generation of energy, and (waste)water treatment. Various molecular and synthetic biology approaches, omics, and engineering principles will be used in this project. Suitable candidates would have a B.Sc. or B.Eng. in Microbiology/Microbial Biotechnology or Environmental/(Bio)Chemical Engineering and interest in multidisciplinary research across Microbiology and Engineering.

For more information, please contact:
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Biofilm-metal(loid)s interactions
(Supervisor: Assoc Prof Cao Bin)
Offered in SCELSE-NTU

The project focuses on understanding soil/sediment biofilm-mediated redox transformation of metal(loid)s and its influence on the fate and transport of metal(loid)s in natural and engineered ecosystems. Specifically, we are interested in metal(loid)s that are of great importance to South East Asia, for example, arsenic and chromium. Suitable candidates would have a B.Sc. or B.Eng. in Microbiology/Microbial Biotechnology or Environmental/(Bio)Chemical Engineering and interest in multidisciplinary research across Microbiology and Engineering.

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Bioprospecting of magnetic bacteria for environmental and biotechnological applications
(Supervisor: Assoc Prof Cao Bin)
Offered in SCELSE-NTU

This project focuses on exploring biodiversity and bioprospecting of magnetotactic bacteria in the tropical marine environment around Singapore. Multidisciplinary tools including experimental biofilm systems, optical and molecular imaging, microbiology, analytical chemistry, and biochemical engineering will be used in this project. Suitable candidates would have a B.Sc. or B.Eng. in Microbiology/Microbial Biotechnology or Environmental/(Bio)Chemical Engineering and interest in multidisciplinary research across Microbiology and Engineering.

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Fortification of microbial membranes
(Supervisor: Prof Staffan Kjelleberg)
Offered in SCELSE-NTU

Microbes draw on several natural strategies to fortify their membranes against environmental chemical assaults. For example, they can change the fatty acid profile of membrane phospholipids or they can express hopanoids. A vacancy for a bright, enthusiastic, and independently driven PhD student is available on an exciting project to develop chemical interventions to fortify membranes beyond the natural range of microbes. The intended utility of such an effort is to improve the performance of industrial bioprocesses. The successful candidate will work in a team of multidisciplinary scientists representing skills in computational modelling, biochemical engineering, microbiology, synthetic chemistry, analytical chemistry, and environmental engineering. Flexible and intellectually curious candidates who are strong in any of the disciplines listed above and with a proven interest in any of the others should apply immediately.

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High Pressure Microbial Electron Transfer
(Supervisor: Prof Stefan Wuertz)
Offered in SCELSE-NTU

Microbes deploy remarkable strategies to gain an energetic advantage in the environment. Over the last few decades, electrogenic bacteria, those which are able to 'breathe' solid minerals, have received much attention particularly in the context of electricity generation in microbial fuel cells. This focus on energy production has ignored many of the natural environmental conditions where electricigens thrive; namely deep sea benthic environments. In this project you will study the energetics of microbial electron transfer in model organisms like Shewanella spp. and Geobater spp. at high hydrostatic pressure to describe these processes in representative environmental conditions. The successful candidate will work in a multidisciplinary setting on a project that will combine microbiology, bioelectrochemistry and environmental engineering. Flexible and intellectually curious candidates who are strong in any of the disciplines listed above should apply immediately.

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Biologically-enhanced geological carbon sequestration
(Supervisory team: Assoc Prof Janelle Thompson)
Offered in SCELSE-NTU

Many geological formations targeted for Geologic Carbon Sequestration (GCS) are compromised by drilled exploration and production wells that are potential sites for injected CO_2 leakage. Biofilm barriers are identified as a promising technology to protect well bore cement and to "heal breaches" by microbially-induced carbonate precipitation (MICP) which can occur via several routes: 1) Bioweathering of native minerals to enhance cation release for fixation of CO_2 into new carbonate minerals, 2) cells serving as nucleation sites for growth of carbonate minerals, and 3) cells catalyzing alkalinity-promoting reactions that create more favorable conditions for growth of carbonate minerals. Use of biofilm barriers to overcome well-leakage concerns has been highlighted as a mechanism to make additional space for 675 Gt of CO_2 in depleted oil and gas reservoirs in the US alone. To better understand the potential application of biofilm barriers in GCS, PhD research will carry out experiments that examine properties of biofilms in rock cores (i.e. growth, permeability reduction, geochemical activity, durability) under the $scCO_2$ conditions associated with GCS, leveraging $scCO_2$ tolerant microbial strains and native bacteria. Students should be intellectually curious with a strong background in Geology, Microbiology and/or Biotechnology.

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Investigation of microbial water quality in the tropics
(Supervisory team: Assoc Prof Janelle Thompson)
Offered in SCELSE-NTU

Bacterial, algal and viral populations interact as a complex system to control emergent properties relevant to water quality such as total biomass (e.g. algal blooms), biosynthesis of compounds that are toxins or nuisances in finished water, and the occurrence of human pathogens. In countries with temperate climates such as the USA and Australia, water quality is assessed by measuring levels of Fecal Indicator Bacteria (FIB) that are a proxy for risks from sewage-borne human pathogens. However, in the tropics many FIB occur naturally and may grow in the warm conditions. Thus, methods for tracking human sewage contamination must be developed and/or validated for tropical application. Since Bacteroidales are obligate anaerobes, they are not expected to survive in oxygenated surface waters and thus we hypothesized these would be more reliable than traditional FIB to identify impaired surface waters in the tropics. We have previously identified assays targeting Bacteroidales bacteria that are appropriate for use in tropical climates and have used identification of pathogen-like sequences (PLS) to explore whether FIB and Bacteroidales markers were predictive for increased exposure to potential agents of human risk. In further work, we will develop and validate improved methods for quantitative detection of microbial populations and their functions relevant to water quality leveraging state of the art molecular tools and computational methods. Students interested in this area of PhD research should be intellectually curious, with a strong background in Microbiology, Molecular Biology or Biotechnology.

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Establishing a microbial observatory at a geothermal system
(Supervisory team: Assoc Prof Janelle Thompson)
Offered in SCELSE-NTU

Hot springs around the world are colonized by communities of thermophilic (i.e. heat-loving) microorganisms that thrive under temperatures as high as 122˚C. Such microbes include photo-autotrophs like cyanobacteria that form brightly colored microbial mats, litho-autotrophic bacteria that “eat” dissolved spring-borne minerals such as reduced sulfur and iron compounds, and heterotrophic bacteria that consume organic-derived matter such as terrestrial and anthropogenic material introduced into the spring system. The Sembawang Hot Spring in Singapore is a well-known and well-loved locality with a history that includes development by the food and beverage, and hospitality industries, maintenance as an off-limits reserve, and public-use as a tap point for geothermal water. Significant green biofilms have previously been observed suggesting the presence of thermophilic photosynthetic microorganisms, as has been commonly noted in hot springs from around the world. Launching of the new NParks facility at Sembawang creates a unique opportunity to observe, in real-time, the establishment and development of a new hot spring microbial community along a temperature gradient, allowing exploration of key ecological questions. PhD research will establish a microbial observatory at this local hydrothermal system to address fundamental scientific questions about the assembly of hot spring microbial communities, and their function, and to provide information for water quality management. Students should be intellectually curious with a strong background in Environmental Science, Microbiology and/or Biotechnology.

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Microbiology under supercritical CO_2 and high pCO_2
(Supervisory team: Assoc Prof Janelle Thompson)
Offered in SCELSE-NTU

Natural deposits of supercritical (sc) CO_2 represent unique and uncommon environments. We have shown that microorganisms exposed to $scCO_2$ exist naturally in several deep subsurface deposits around the world where pressures exceed 71 atm and temperatures exceed 31.1˚C. In our prior work funded by the US Department of Energy, we explored biotechnological applications of $scCO_2$ tolerance in bacterial isolates and used genetic engineering and synthetic biology to bioproduce compounds with hydrophobic character that partition into a $scCO_2$ solvent phase. This approach is attractive because it addresses problems with growth-inhibitory accumulation of toxic end products while minimizing the need for costly dehydration due to a single step extraction into "dry" $scCO_2$. We have conducted proof of concept studies demonstrating bioreactor integrated supercritical fluid extraction (BI-SFE) using supercritical CO_2-tolerant strain Bm_SR7. However, several major challenges limit titer and yield for currently-targeted biofuel compounds (i.e. isobutanol and isopentanol) and other planned targets (e.g. pharmaceuticals). To address this, PhD research to further develop BI-SFE will include: Metabolic flux analysis (MFA) of wild-type and genetically modified Bm_SR7 under $scCO_2$ and ambient conditions to identify metabolic factor imbalances that may lead to improved growth and biofuel titers under $scCO_2$, directed evolution to select for best performing strains by continuous passage under $scCO_2$, development of tools for chromosomal insertion for improved stability of multi-gene pathways, (in collaboration with MIT), and coupling BI-SFE to waste streams as feedstock e.g. sewage. These efforts are poised to bring the technology for low-energy in situ extraction of advanced biofuels closer to proof-of-value by achieving competitive biofuel titers and extraction of high-value non-fuel chemicals. Students should be intellectually curious with a strong background in Chemical Engineering, Microbiology and/or Biotechnology.

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Genomic determinants of marine virulence
(Supervisory team: Assoc Prof Janelle Thompson)
Offered in SCELSE-NTU

Improved understanding of the factors mediating virulence in the marine environment will enable more informed management of the triggers that initiate disease outbreaks. Students interested in applying genetics and genomics tools to understand the behavior of marine pathogens in natural and mariculture systems may discuss ideas for PhD research with PI Thompson. Students must be willing to carry out significant experimental work at the Marine Aquarium facility at St. John Island National Marine Laboratory. Students should be intellectually curious, with a strong background in Microbiology, Marine Science, and/or Biotechnology.

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