Research Projects in the SMART DiSTAP IRG
(August 29, 2019)

1. **Development of nanosensor technology for in planta monitoring of plant hormones**
Plant hormones play a vital role in the control of the growth and development of plants. In this project, the aim is to develop new tools for the continuous measurement of important plant metabolites and hormones for novel discovery, deeper understanding and control of plant biosynthetic pathways in ways not yet possible, especially in the context of green leafy vegetables. Utilizing the novel technology Corona Phase Molecular Recognition as the platform for nanosensor development, the project will involve the rational design, synthesis and application of polymer-single walled carbon nanotube composites as the near-infrared fluorescent sensor for *in planta* monitoring of plant hormones with temporal-spatial resolution. These new techniques would be leveraged to engineer plants with highly desirable properties for global food security, including high yield density production, drought and pathogen resistance and biosynthesis of high-value commercial products.

    MIT Principal Investigator(s):
    Michael STRANO (Chemical Engineering)

    Singapore Co-Investigator(s):
    Mary CHAN (NTU, School of Chemical and Biomedical Engineering)

2. **Volatile organic compounds (VOCs) signalling in plants**
VOCs play a crucial role in biotic and abiotic stress responses in plants. Specific VOCs could serve as diagnostic markers for stress responses in plants. When a VOC-emitting plant is grown adjacent to a receiver plant, the receiver plant upon VOC perception can respond by priming its own defence responses and inducing reactive oxygen species (ROS) signalling. This results in increased H2O2 levels, which triggers further downstream generation of plant hormones such as jasmonic acid, salicylic acid and auxins. The student will join an interdisciplinary team of chemists, engineers and plant biologists in the development of nano-sensors, which can monitor changes in ROS levels in plants in response to intercropping with VOC-emitter aromatic plants, as well as deliberate exposure or treatment with VOCs. The student will be introduced to single-walled carbon nanotube (SWNT) suspension and characterization techniques. The student will also be trained in agro-infiltration techniques and near-infrared fluorescence imaging of plants with standoff setup to monitor changes in SWNT fluorescence due to the plants' defence priming induced by VOCs from neighbouring emitter plants. Finally, bio-pesticides can be developed with the optimal mix of VOCs used as active ingredient.

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    Singapore Co-Investigator(s):
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3. **Development of nano-carriers for gene delivery in plants**
   The student will join an interdisciplinary team of chemists, engineers and plant biologists in the development of nano-carriers for delivery of plasmids into different compartments of the cell. The nano-carriers are based on polymer-wrapped single-walled carbon nanotubes or other nanoparticles and are found to localize at different sub-cellular organelles based on their particle size and charge. This model is known as lipid exchange envelope penetration. After binding with plasmid DNA, the nano-carriers should selectively deliver the transgene to the desired organelles such as nucleus and chloroplast, and release the plasmid DNA for gene expression, without any external biolistic or chemical aid. The student will be introduced to polymerization techniques, single-walled carbon nanotube suspension and covalent functionalization methods, as well as characterization techniques such as nanoparticle tracking analysis and surface charge zeta potential measurements. Finally, nano-carriers developed will be used as a transformation method for mature plants.

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   Michael STRANO (Chemical Engineering)

   Singapore Co-Investigator(s):
   Mary CHAN (NTU, School of Chemical and Biomedical Engineering)

4. **Novel nano-sensors for plant hormones**
   The student will join an interdisciplinary team of chemists, engineers and plant biologists in the development of novel nano-sensors for real-time measurement of plant metabolites. These novel tools enable optimal crop production and rapid development of plants suitable for high-density farming and revolutionalizes urban farming strategies. This project focuses on the synthesis and characterization of polymer-wrapped single-walled carbon nanotube (SWNT) suspensions which are intended as nanosensors for plant hormones such as auxins, jasmonates, salicylic acid etc. The student will be introduced to amphiphilic co-polymerization techniques, as well as SWNT suspension methodologies and characterization and in vitro screening with plant hormone analytes. Finally, sensors developed will be validated in a variety of wild-type and engineered mutant plant species to demonstrate their effectiveness and generality, and hence are suitable for understanding important plant biological processes.

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   Michael STRANO (Chemical Engineering)

   Singapore Co-Investigator(s):
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5. **Develop cell factory to produce biopesticides for urban farming**
   Natural pest-repelling molecules are promising next generation pesticides because they are safer and more targeted against pests instead of beneficial insects. One challenge faced by commercializing these molecules is their high cost. They are conventionally produced by extracting from plant materials. In this project, we will take the genes from plants and use them to transform fast-growing microbes into cell factories that can produce such biopesticides much faster and more efficiently than using plants.

   MIT Principal Investigator(s):
   Kristala PRATHER (Chemical Engineering)
   Anthony SINSKEY (Biology)
   Gregory STEPHANOPOULOS (Chemical Engineering)

   Singapore Co-Investigator(s):
   Kang ZHOU (NUS, Department of Chemical and Biomolecular Engineering)

6. **In-Field optical sensing of plant stress**
   This project builds on the recent results at SMART DiSTAP demonstrating the ability of Raman spectroscopy to monitor several different stress responses in plants - from shade stress to nutrient stress to infection. This project will seek to explore the translation of this work to field applications. It will involve the evaluation of several portable Raman instruments developed within SMART, the development of protocols for analysis in an urban farm environment, and the application of machine learning algorithms to diagnose the plant conditions and to suggest remediation in a farm environment where plants may be experiencing multiple stresses.

   MIT Principal Investigator(s):
   Rajeev RAM (Electrical Engineering and Computer Science)

   Singapore Co-Investigator(s):
   Incheol JANG (NUS, Department of Biological Sciences and Temasek Life Sciences Laboratories, TLL)

7. **Optical spectroscopy for forensic analysis**
   This project is a collaborative project between Professor Stella Tan at NUS - a leader in forensic biology - and the Ram group within SMART DiSTAP. The project will explore both hardware and data sciences aspects of Raman spectroscopy as tool to support law enforcement efforts in Singapore. This project will focus primarily on the detection of counterfeit products from medicine to food where in-field chemical analysis via Raman spectroscopy may support prosecutors. We will explore portable Raman instruments developed within SMART and the development of decision support tools for law enforcement.

   MIT Principal Investigator(s):
   Rajeev RAM (Electrical Engineering and Computer Science)

   Singapore Co-Investigator(s):
   Stella TAN (NUS, Department of Biological Sciences)