ChBE

CHEMICAL AND
BIOMOLECULAR
ENGINEERING
AT
VANDERBILT
UNIVERSITY

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Vanderbilt University School of Engineering

The School of Engineering is internationally recognized as a leader in engineering research and education. Its faculty expertise and graduate programs are aimed at solving complex societal problems through collaborations among the disciplines, across campus, and beyond the university. That culture of collaboration provides endless opportunities for students and faculty from all disciplines to work in any of our nine core competencies we call intellectual neighborhoods – big data science and engineering; biomedical imaging and biophotonics; cyber-physical systems; energy and natural resources; nanoscience and nanoengineering; regenerative medicine; rehabilitation engineering; risk, reliability and resilience; and surgery and engineering.

The School comprises five main buildings and several satellite facilities. William W. Featheringill Hall houses a three-story atrium designed for student interaction and social events, more than 50 teaching and research labs, and project rooms. The new Engineering and Science building is an eight-story state-of-the-art facility that houses the Wond'ry at the Innovation Pavilion, numerous research labs, interactive classrooms, clean rooms and space for students to work, study and socialize. School administrative offices and several classrooms are located on the ground floor of the Science and Engineering building in Stevenson Center, which also houses the Biomedical Engineering Department on the eighth and ninth floors. Jacobs Hall, adjacent to Featheringill Hall, contains labs, offices and classrooms serving the Civil and Environmental Engineering Department and the Electrical Engineering and Computer Science Department. Olin Hall houses Mechanical Engineering, Chemical and Biomolecular Engineering, and numerous labs.

Satellite facilities include the labs and offices of the Biomedical Photonics Center located in the W. M. Keck Free Electron Laser Center; the Laboratory for Systems Integrity and Reliability (LASIR), an off-campus hangar-style facility dedicated to scaling up experiments to realistic and full size, including a wind tunnel and military aircraft; and on Nashville's famed Music Row, the MuMS facility (multiscale modeling and simulation); the Vanderbilt Institute of Software Integrated Systems; and the Institute for Space and Defense Electronics, providing office space, dry lab and conference space.

COVER, (L-R) Carlos Silvera Batista, Research Professor Julianne Vernon, undergraduate Afi Mohd Sayuti and second-year graduate student Javier Gomez at work in Silvera's lab.

Vanderbilt

Cornelius Vanderbilt had a vision of a place that would "contribute to strengthening the ties that should exist between all sections of our common country" when he gave a million dollars to create a university in 1873. Today, that vision has been realized in Vanderbilt, an internationally recognized research university in Nashville, Tennessee, with strong partnerships among its 10 co-located schools, neighboring institutions and the community.

Vanderbilt offers undergraduate programs in engineering, the liberal arts and sciences, music, education and human development, as well as a full range of graduate and professional degrees. The combination of cutting-edge research, liberal arts education, nationally recognized schools of law, management, divinity, and education, and a distinguished medical center creates an invigorating atmosphere where students tailor their education to meet their goals and researchers collaborate to address the complex questions affecting our health, culture and society.

An independent, privately supported university, Vanderbilt is the largest private employer in Middle Tennessee and the second largest private employer based in the state.

Nashville

Vanderbilt's hometown of Nashville is a vibrant, engaging city known proudly as "Music City, U.S.A." and one of the fastest growing areas in the Mid-South. The university's students, faculty, staff and visitors frequently cite Nashville as one of the perks of Vanderbilt, with its 330-acre campus located a little more than a mile from downtown.

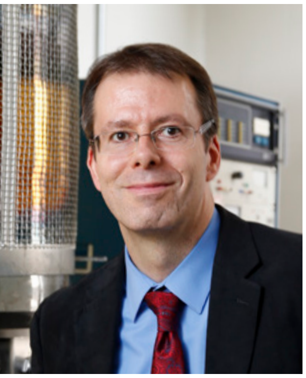
Nashville's downtown features diverse entertainment, dining, cultural and architectural attractions. The Broadway and emerging SoBro areas feature entertainment venues and an assortment of restaurants. North of Broadway lie Nashville's central business district, Legislative Plaza, Capitol Hill and the Tennessee Bicentennial Mall. Cultural and architectural attractions are found throughout the city.

Named America's friendliest city three years in a row, Nashville is a metropolitan place that exudes all the charm and hospitality one expects from a rapidly growing capital in the new south. *Fortune* magazine named Nashville one of the 15 best U.S. cities for work and family. It has ranked as the No. 1 most popular U.S. city for corporate relocations by *Expansion* magazine. *GQ* posted an article dubbing the city "Nowville." *The New York Times* has declared Nashville a new "it" city. CBRE ranked Nashville as the most rapidly growing small market for tech talent in the U.S. and Canada in their 2018 Scoring Tech Talent report.

The city proper is 526 square miles with a population of nearly 667,000. The 13-county metropolitan area population is more than 1.7 million, making it the largest metro statistical area in Tennessee. Major industries include tourism, printing and publishing, technology manufacturing, music production, higher education, finance, insurance, automobile production and health care management.

ChBE

CHEMICAL AND BIOMOLECULAR ENGINEERING AT VANDERBILT UNIVERSITY 2018-2019



The Department of Chemical and Biomolecular Engineering offers a world-class research environment with a distinct personal touch. Throughout its 80-year history, the department has striven to create an interdisciplinary, collegial, and inclusive environment where undergraduates and graduate students work with professors to advance the boundaries between the known and the unknown.

Students don't come to ChBE merely to learn from their professors. Rather, our students collaboratively engage with our faculty to develop creative new ideas to intellectually drive our research mission. Students and faculty relish the scientific proximity of the department, located within a 4-minute walk of Vanderbilt's other engineering and science research departments, and connected to the Vanderbilt Institute for Nanoscale Science and Engineering.

VINSE is the nucleus for nanoscale materials research at Vanderbilt. It is one of numerous interdisciplinary centers and institutes across campus that offers comprehensive and state-of-the-art core facilities. ChBE also is a short walk from the clinical departments of the renowned Vanderbilt University Medical Center, facilitating interdisciplinary engineering research with potential translational medical impact. VUMC is ranked eighth in the nation in NIH funding.

Vanderbilt, consistently ranked nationally in the top 15 universities, has a student body of more than 12,500 undergraduate, graduate and professional students. Of the nearly 7,000 undergraduates, 39 percent are minority students and more than 1,000 international students come from 84 countries.

The School of Engineering currently comprises 100 tenured and tenure-track faculty and serves over 1,400 undergraduate and nearly 500 graduate students. In the most recent rankings of graduate engineering programs by *U.S. News & World Report*, the School ranks in the top three among programs with 100 or fewer faculty (behind Caltech and Harvard) and has risen steadily in the rankings over the past decade.

Today, the ChBE department has achieved its largest size with 15 tenured and tenure-track faculty, three research professors, six affiliated faculty, 10 post-doctoral associates, more than 50 Ph.D. students, and 140 undergraduate students. ChBE has built youthful momentum by hiring four new assistant professors in the past three years. This year, we achieved our highest ever ranking (No. 34) by *U.S. News & World Report*, which places us among the top five chemical engineering graduate programs in the country with 15 or fewer faculty.

Chemical engineering is one of the most far-reaching and rewarding fields of engineering. We invite you to visit Vanderbilt, the School of Engineering, and the Department of Chemical and Biomolecular Engineering.

> "Undergraduates and graduate students work with professors to advance the boundaries between the known and the unknown."

Kane Jennings
Professor and Chair
Department of Chemical and Biomolecular Engineering

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PROGRAMS OF STUDY

UNDERGRADUATE

Chemical engineering is unique among the engineering disciplines in its connections to the molecular sciences. From its early foundation in petrochemical and bulk chemical processing, chemical engineering has expanded to play key roles in the development and production of pharmaceuticals and biological agents, specialty polymers and high-strength composites, semiconductors and microelectronic devices, as well as a wide range of ultrapure fine chemicals. Therefore, chemical engineering is essential for the operation of contemporary society. The solution to many of the problems facing society today, including sustainable energy, healthcare, the environment and development of high-performance materials, involve chemical engineers. Future opportunities in the field are very bright.

The undergraduate program in chemical engineering equips students to investigate solutions for these and many other problems. Most graduates find meaningful careers in industry, while others are attracted to government laboratories, universities and careers as private consultants. Some continue their education through graduate studies in chemical engineering, business, law, or medicine.

Undergraduate students in the Chemical and Biomolecular Engineering Department receive a Bachelor of Engineering degree, which is accredited by the Engineering Accreditation Commission of ABET, www.abet.org. For more information on the degree program, please visit the department website at https://engineering.vanderbilt.edu/chbe/UndergraduateProgram/undergraduate.php.

UNDERGRADUATE HONORS PROGRAM

The Honors Program in chemical engineering provides an opportunity for students to develop individually through independent study and research. Chemical Engineering requires a minimum overall GPA of 3.5 for the Honors Program, and acceptance into the program is made by petition to the faculty during the junior year. An integral part of the Honor Program is that candidates for honors conduct a multi-semester research project during their junior and/or senior year under the direction of a faculty honors adviser. Requirements are listed on the department website, and the diploma designation is Honors in Chemical Engineering.

GRADUATE

Graduate study in chemical engineering provides a unique opportunity for students and faculty to work together toward advancing knowledge through innovative research. The Vanderbilt ChBE program offers a world-class research environment with the intimacy and faculty contact of a small private university. We provide outstanding research opportunities in the areas of Biotechnology and Biomolecular Engineering, Computational Science and Engineering, Energy and Sustainability, and Materials and Nanotechnology.

Our students collaborate closely with researchers in other departments and institutes on campus, including the Vanderbilt University Medical Center, the Multiscale Modeling and Simulation research facility, and the Vanderbilt Institute for Nanoscale Science and Engineering. Formal coursework for the Ph.D. essentially doubles the exposure to chemical engineering principles that students receive as undergraduates.

Additionally, students are provided numerous professional development opportunities, including attendance at conferences, professional workshops, career services, and teaching programs for those interested in academic careers.

Ph.D. students typically receive full financial support, including a generous stipend and health insurance as well as full tuition and fee waivers. Teaching Assistantships, Research Assistantships, and some special honor scholarships also are available. See more information about financial aid on the inside back cover.

To apply for admission to the graduate program in chemical engineering, you must first meet the general requirements of admission by the Vanderbilt University Graduate School. An application may be made electronically here: www.vanderbilt.edu/gradschool/. The Graduate School Catalog is here: www.vanderbilt.edu/catalogs/

BARDHAN RESEARCH GROUP

Rizia Bardhan
Assistant Professor of Chemical and Biomolecular Engineering
Bardhan Research Group
https://my.vanderbilt.edu/bardhanlab/

My research is focused on multimodal multiplexed immunoimaging combining PET imaging with Raman in mouse models in vivo and ex vivo, in Raman metabolic imaging to examine response to treatment, and in Raman spectroscopy-based, point-of-care diagnostics to analyze serum biomarkers in various diseases.

There are four main research themes in the NBL lab: multimodal multiplexed immunoimaging, metabolic imaging, image–guided therapeutics, and solar energy conversion.

We are combining PET and Raman to enable unparalleled sensitivity, specificity, high resolution, and multiplexing ability to simultaneously track multiple immune markers of cancer in mouse models. This approach will ultimately enable patient selection for immunotherapies improving the objective response rate of therapies which remains low at <25 percent.

We are studying the metabolic effects of cytostatic signal transduction inhibitors on various intracellular pathways with Raman imaging to examine response to treatment of cancer cells in vitro and patient tumors grown in 3D cultures.

We also are designing metal nanostructures to absorb near-infrared light and convert light to heat enabling noninvasive photothermally-triggered drug delivery. These nanostructures are labeled with a Raman tag and can be tracked in vivo, and we are now pursuing image-guided combinatorial chemo-photothermal-immunotherapy in mouse models of cancer.

We are integrating morphology-controlled metal nanostructures in photovoltaics, including dye-sensitized, organic, and perovskite solar cells to improve their performance, stability, and durability. My group has extensively published high impact papers in this area. We are now integrating solar cells with batteries/supercapcitors so a single platform can simultaneously convert solar energy to electricity and then store the energy.

Rizia Bardhan has received a prestigious Congressionally Directed Medical Research Programs (CDMRP) Career Development Award to develop an innovative multi-modal imaging platform for melanoma diagnosis and treatment evaluation.

Rizia Bardhan and Yu-Chan Ou, a fifth-year graduate student, discuss combining surface-enhanced Raman spectroscopy with tagged gold nanostars to improve the ability to target cancer patients who will benefit from immunotherapy.

CUMMINGS RESEARCH GROUP

Peter T. Cummings
John R. Hall Professor of Chemical Engineering
Cummings Research Group
http://huggins.vuse.vanderbilt.edu/ptc/

An enduring problem in science and engineering, and the overriding focus of our research, is, how does complex behavior of a system composed of interacting entities emerge from the simpler dynamics of the individual entities and their interactions with each other and their environment?

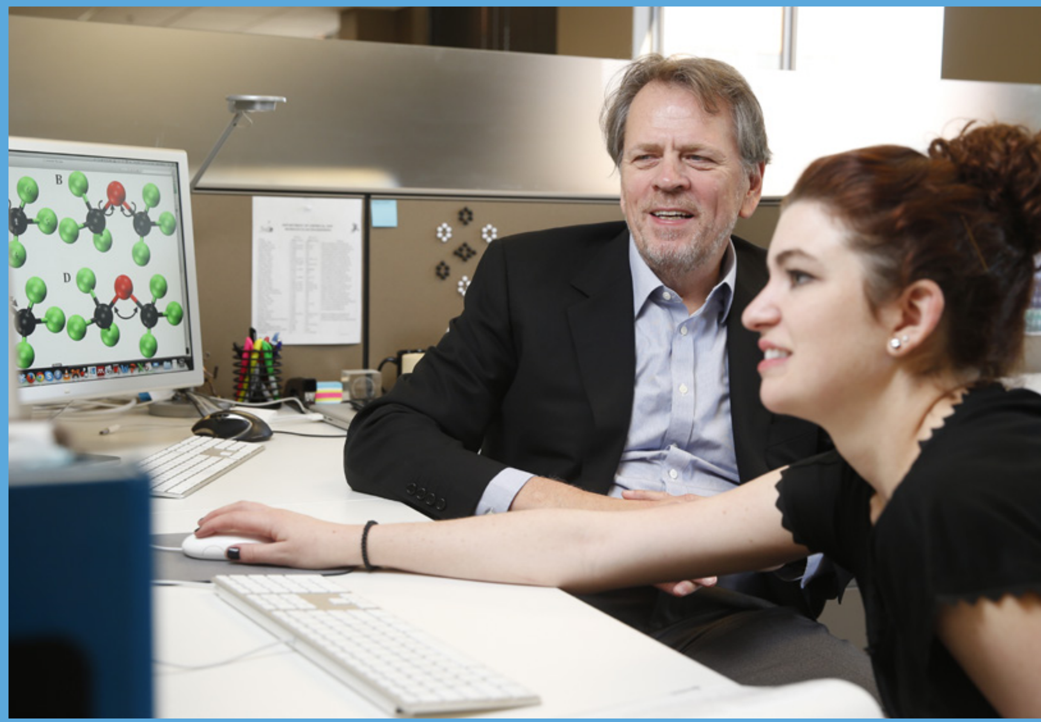
The entities have ranged from molecules to the components of a chemical plant to cells. The tools used in these disparate fields are those of statistical mechanics and large-scale simulation. We currently apply these tools to understanding nanoscale systems – nanoconfined fluids, lubrication at the nanoscale – and to energy-relevant interfaces, for example, in energy storage devices.

Understanding collective phenomena is the ultimate goal of our research group, using a combination of theory and computational tools. We develop and distribute open-source molecular simulation software to enable others to work in this field.

Peter Cummings received the 2018 FOMMS Medal at the seventh triennial Foundations of Molecular Modeling and Simulation conference. He delivered the FOMMS Medal Lecture.

For example, we perform computational simulations of fluids and interfaces by computing the motions of the constituent atoms and molecules. In order to do this, we develop computational tools that we distribute freely, and we make use of a hierarchy of computational resources, from individual workstations, to local and national parallel computing facilities and, in some cases, the largest computers in the world.

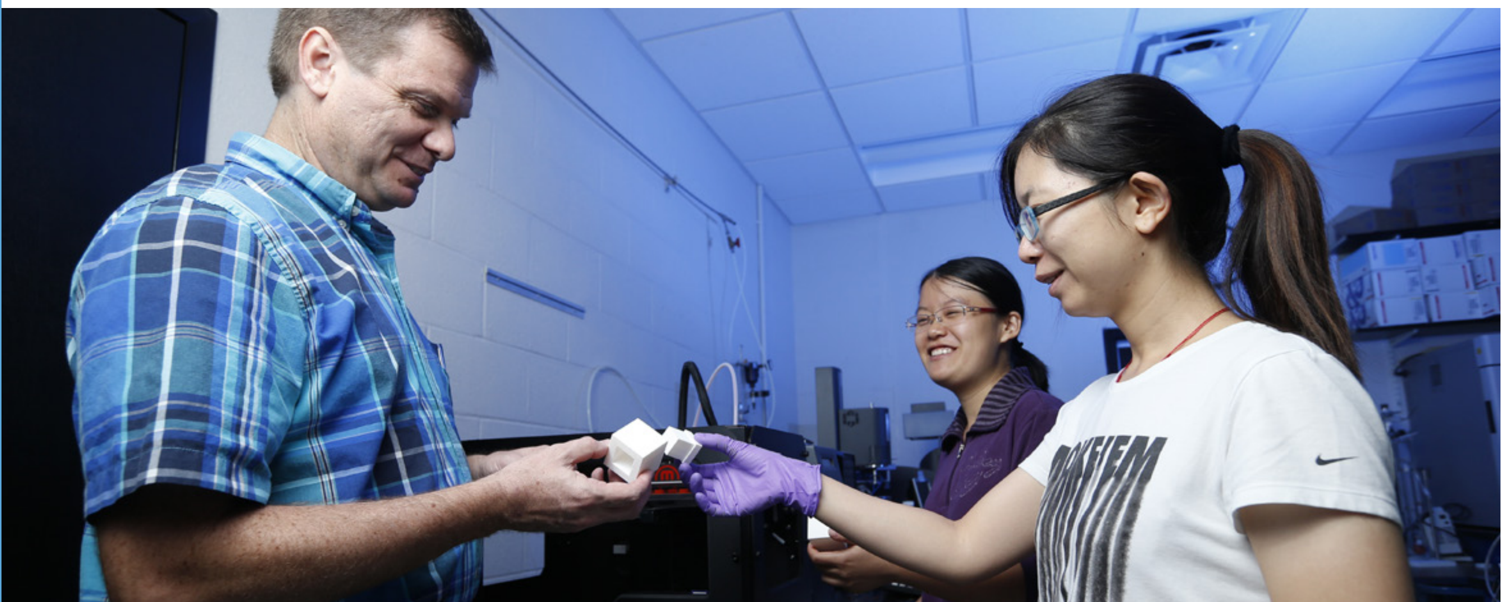
We work closely with experimentalists, particularly those that can perform molecular and atomic level probes of structure and dynamics at the nanoscale, using methods such as X-ray scattering and neutron scattering techniques. The computational tools we develop and apply in our laboratory will evolve into the design tools for new technologies in the future, such as next-generation batteries and energy storage devices. The Cummings Research Group typically consists of a mix of graduate students, postdoctoral researchers, and visiting researchers.



Graduate student Jana Black works with Peter Cummings at the school's Multiscale Modeling and Simulations facility on Music Row in Nashville.

GUELCHER RESEARCH GROUP

Scott Guelcher
Professor of Chemical and Biomolecular Engineering
Guelcher Research Group
https://my.vanderbilt.edu/guelcherlab/



Scott Guelcher works with graduate students Ruijing Guo (front) and Sichang Lu in his laboratory.

The Biomaterials and Tissue Engineering Laboratory explores two main areas of research: scaffolds and drug delivery systems for tissue regeneration and regulation of cell fate by the extracellular matrix.

My research focuses on the design and development of biomaterials and delivery systems that enhance healing of tissue damaged by trauma or disease. I collaborate with biomedical scientists and clinicians to design, develop, and scale-up new materials for tissue regeneration from the bench to the bedside.

Our laboratories in Chemical and Biomolecular Engineering and in the Center for Bone Biology house equipment for polymer synthesis and characterization, cell culture, and histology.

Current projects include design of injectable tissue grafts for healing bone in challenging environments, including weight-bearing skeletal sites, defects contaminated by bacteria, and large tissue voids resulting from extremity and craniofacial trauma. We also study how the bone/tumor microenvironment regulates the progression of tumor-induced bone disease and designs new tumor-targeted therapies to block establishment of tumors in bone. Students participating in this multi-disciplinary research gain experience in materials science, cell culture, and preclinical models of bone regeneration.

Projects are multi-disciplinary and students have extensive opportunities to collaborate with life scientists in the Center for Bone Biology and the U.S. Army Institute of Surgical Research. Translation of new therapies based on laboratory discoveries into the clinic also is an important goal of the laboratory, which is being pursued in collaboration with our corporate partners. Current projects are supported by the National Institutes of Health, Department of Defense, and corporate sources.

Scott Guelcher has been named director of the Vanderbilt Center for Bone Biology housed within the Department of Medicine at Vanderbilt University Medical Center.

JENNINGS RESEARCH GROUP

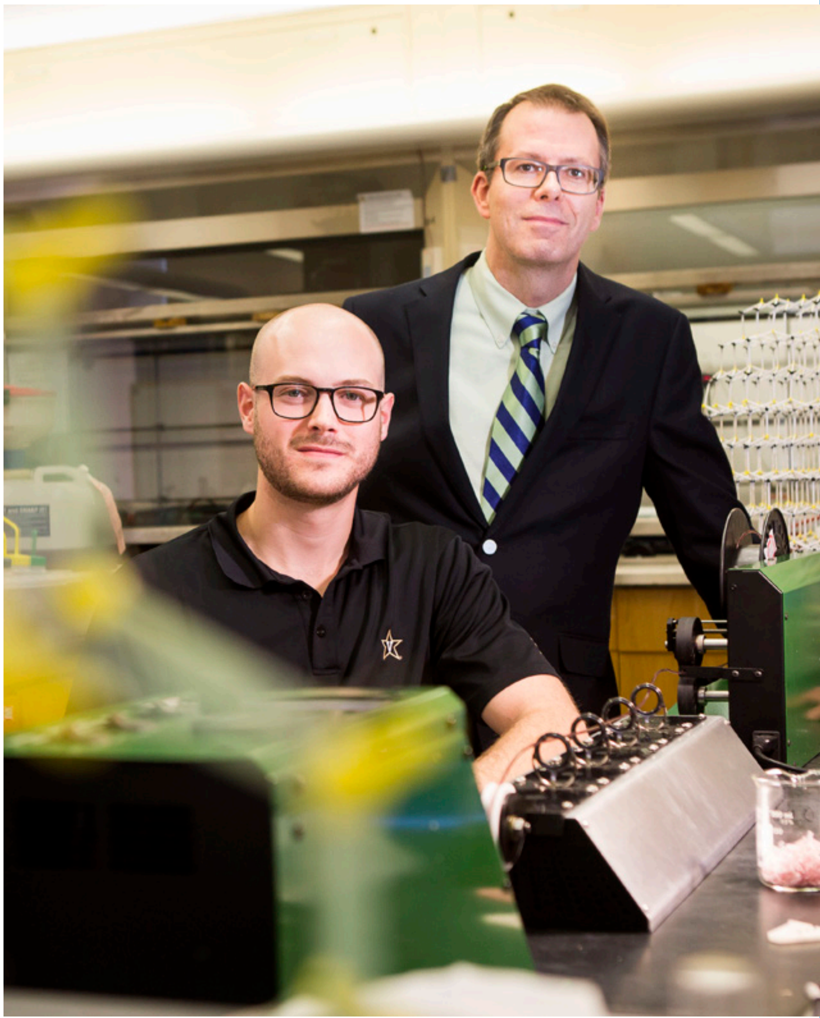
G. Kane Jennings
Professor and Chair of Chemical and Biomolecular Engineering
Jennings Research Group
www.vuse.vanderbilt.edu/Research_Groups/gkjennings/index.html

My research efforts are aimed at the molecular design and fabrication of smart surfaces and materials, many of which mimic, replicate, or employ highly functional biological components. A goal of the Jennings Research Group is to train talented young engineers in the molecular and interfacial aspects of biohybrid, bio-inspired, and bioreplica materials.

We use the methods of self-assembly as well as surface-initiated polymerizations (grafting from) to modify surfaces with molecular or (bio)macromolecular films for applications in solar energy conversion, responsive coatings, superhydrophobic surfaces, lubrication, and metal capture.

Photosystem I (PSI) is a nanoscale protein complex that efficiently converts sunlight to chemical energy to drive photosynthesis in green plants. We are investigating the fundamental issues affecting photo-assisted electron transfer properties of PSI, deposited as thin "biohybrid" films on electrode surfaces. Our recent innovations in this area include interfacing PSI with conducting polymers for more efficient electron transfer and modeling the photoelectrochemical reactions of a PSI multilayer film with redox species.

We are developing smart materials and films for a host of applications. For example, we are investigating nanoscale components that report defects when incorporated into 3D-printed components, as well as coatings that report active corrosion from inside a pipe. We also are designing compositionally tunable thin films that respond dramatically to the pH of the environment by altering their resistance to water and ion transfer.



Cole Brubaker, a civil engineering graduate student, is collaborating with Kane Jennings to create an innovative process using gold nanoparticles for defect detection in 3D printed parts.

Vanderbilt researchers have developed a technique for gold nanoparticles to 'shine' inside 3D printed parts to highlight defects. Kane Jennings is co-author on a paper published in the *American Chemical Society Applied Nano Materials Journal*. The U.S. Office of Naval Research funded the research. Patents are pending on the technology.

KIDAMBI RESEARCH GROUP

Piran Kidambi
Assistant Professor of Chemical and Biomolecular Engineering
Kidambi Research Group
https://pirankidambi.wixsite.com/kidambiresearchgroup

The Kidambi Research Group aims to advance the science and technology for scalable nanomaterial synthesis. Our multidisciplinary work is collaborative with academic and industrial partners and we are affiliated with the Vanderbilt Institute of Nanoscale Science and Engineering and the Interdisciplinary Materials Science Program.

Our research leverages the intersections of in-situ metrology, process engineering and material synthesis to enable bottom-up novel materials design and synthesis for energy, membranes, electronics, catalysis, metrology, environmental protection and health care applications.

In nanomaterials, the material structure determines functionality. However, most nanomaterial characterization happens post synthesis. The post synthesis characterization is typically used as feedback to tailor material structure. This process leads to speculations on what actually transpires during material synthesis and limits effective control over structure/functionality at the atomic scale. Nanomaterial synthesis, thereby, remains in the realms of trial and error optimization.

Our laboratory works on developing routes to directly characterize materials during formation across length scales from atomic resolution to macroscopic scales (via in-situ ETEM, ESEM, XPS, and XRD). Our work is highly multidisciplinary and our team is a mix of graduate students, post-doctoral researchers, undergraduate students, high school students and visiting researchers. We collaborate extensively with researchers in the United States, internationally and specifically at user facilities in national labs.

Masturina Sukri, senior chemical engineering student, conducts research in Piran Kidambi's lab.

Piran Kidambi is one of 35 junior faculty nationwide to win a 2018 Ralph E. Powe Junior Faculty Enhancement Award, which provides funds to enrich the research and professional growth of young faculty at Oak Ridge Associated Universities member institutions.

LAIBINIS RESEARCH GROUP

Paul Laibinis
Professor and Associate Department Chair of Chemical and Biomolecular Engineering
Director, Undergraduate Studies
Laibinis Research Group

Our work focuses on the assembly of systems whose performance is a direct result of surface effects. These systems include chemical sensors, antifouling coatings, responsive interfaces, and nanoparticle dispersions. Our systems range in complexity from single-atom coatings useful in chemical sensing to polymeric films to retard biomolecule adsorption to arrays of immobilized DNA molecules for genetic analyses or programmed multi-particle assembly.

Using both molecular and polymeric approaches, we prepare surfaces that are able to avoid non-specific adsorption processes that often lead to losses when materials are introduced into biological media. We develop strategies for enhancing the biological activity of species when tethered to a surface as employed in biological sensing applications.

Nanoparticles offer a range of useful properties by virtue of their high surface areas and short interparticle separation distances. By chemically tailoring their surfaces, these particles can be prepared to have desired adsorptive (or non-adsorptive) properties. Their utility for performing separations and mixing in microfluidic systems are under investigation.

Automated DNA synthesis provides an ability to tailor surfaces with DNA strands of readily selectable sequence and at controlled densities. Our efforts with these systems are directed toward providing enhanced methods for performing genetic analyses.

We collaborate with researchers in the Vanderbilt Medical Center to develop techniques useful in obtaining histological information from tissue sections. Here, imaging mass spectrometry is used to measure the spatial distributions for multiple molecular signals across a biological sample. Surface engineering provides opportunities for improving this process, where our efforts are focused on the fabrication of surface coatings and microstructures that can improve imaging resolution, increase signal generation, and shorten sample processing times.

Brad Baker, fourth-year graduate student, and Paul Laibinis collaborate on a research project.

LANG RESEARCH GROUP

Matthew Lang
Professor of Chemical and Biomolecular Engineering
Lang Research Group
https://www.vanderbilt.edu/langlab/

The general goal of our research program is to probe the inner-workings of nature's molecular and cellular machinery, the mechanome.

At the molecular level, we study a number of biological motors, including the ClpXP motor protease that destroys proteins tagged for degradation for removal from the cell, kinesins, which are integral to cell division spindle architecture, and cellulose-based motors relevant to health and energy (biofuels) applications. The ClpXP research is supported by a National Science Foundation grant; Professor Lang is the Principal Investigator. The biofuels research also is supported by a NSF grant; Lang is the co-PI.

We also are investigating the molecular and cellular underpinnings of T cell activation that has relevance to cancer, vaccine development and personalized medicine. We collaborate with a number of groups with expertise in such systems – the Vanderbilt Institute for Infection, Immunology and Inflammation at the Vanderbilt University Medical Center and Molecular Physiology and Biophysics in the Vanderbilt School of Medicine, among others.

We employ a measure-make-model approach including single molecule biophysics measurements with optical tweezers, single molecule fluorescence spectroscopy, functional mutations and simulations.

The Lang Laboratory also is involved with advancing microscopies and related technologies especially relevant to single molecule, single cell systems, automation and advanced assay development.

Matt Lang, graduate student Yinnian Feng and their Harvard University collaborators' have produced groundbreaking work on disease recognition underpinning adaptive immunity. The paper published recently in the *Proceedings of the National Academy of Sciences* is "rewriting the textbooks on how T cells sense antigen." For this paper, Feng recently won the school's Outstanding Graduate Student Research Paper Award.

From left, Matt Lang, senior Richard Stroder and graduate student Juan Carlos Cordova in the Lang Lab in Olin Hall

LIPPMANN RESEARCH GROUP

Ethan S. Lippmann
Assistant Professor of Chemical and Biomolecular Engineering
Lippmann Research Group
www.lippmannlab.com

My research program is focused on understanding and treating neurovascular disease. We use human induced pluripotent stem cells (iPSCs) and engineering techniques to build representative in vitro models of the vascularized brain for drug screening and disease modeling applications. We also use targeted and high throughput techniques to interrogate blood-brain barrier (BBB) function and determine how loss of cerebrovascular integrity may influence neurodegeneration. And, we investigate unique ways to develop more selective drugs and deliver them specifically to sites of injury in the brain.

Neurovascular dysfunction is increasingly recognized as a key contributor to neurodegenerative diseases such as Alzheimer's Disease and stroke. In addition, loss of blood-brain barrier integrity causes or exacerbates a variety of neurological disorders, whereas an intact BBB can hinder drug delivery to the brain.

We blend hypothesis-driven research, discovery-driven investigations and technology development to achieve these goals. Our efforts are highly collaborative as we seek to translate our benchtop discoveries into in vivo tests and preclinical assays.

Our research takes iPSCs, differentiates them to a spectrum of neurovascular cell types – BBB endothelial cells, pericytes, astrocytes, and neurons – and assembles them into coordinated 3D models that resemble native brain architecture. These models are intended to bridge the large experimental gap between studies on isolated cell types and in vivo investigations.

Ethan Lippmann has won a NARSAD Young Investigator Grant from the Brain and Behavior Research Foundation. He seeks to improve drug screening processes by creating three-dimensional tissue models of the vascularized human brain. The NARSAD grant provides support for the most promising young scientists conducting neurobiological research

We further use our BBB endothelial cells and a variety of cutting-edge profiling techniques (CRISPR genome engineering, transcriptomics, metabolomics, etc) to provide clues into how its function is lost in disease. Last, we are developing improved methods to target biomolecules with high specificity, such that if we identify a prospective therapeutic target, we have the ability to inhibit its function or track its location to determine its role in disease progression.

(L-R) Ethan Lippmann, Jonah Rosch, fourth-year graduate student, and Nicholas Marinelli, second-year quantitative chemical biology graduate student at work in Lippmann's lab.

McCABE RESEARCH GROUP

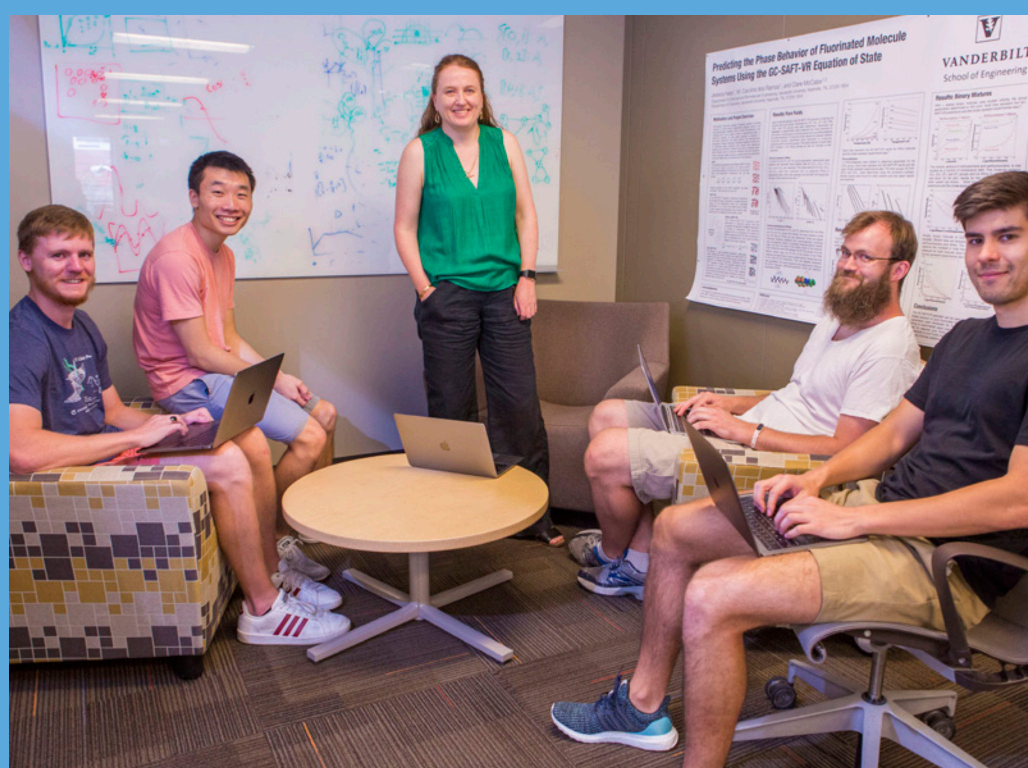
Clare McCabe
Cornelius Vanderbilt Professor of Engineering, Professor of Chemical and Biomolecular Engineering, Director of Graduate Studies for Chemical and Biomolecular Engineering and Associate Dean for Postdoctoral Affairs, The Graduate School
McCabe Research Group
http://huggins.vuse.vanderbilt.edu/clare/

With today's advances in computational power the future of computational research has never been brighter! The complexity, in both size and detail, of the systems we can now study, compared to even 10 years ago, means computational studies can make a real impact and drive experimental research.

In particular, in my group we are using molecular simulation to elucidate the structure of assemblies of skin lipids in order to understand the barrier function of skin and to develop enhanced coatings for the lubrication of nanoscale devices. We also work in the area of molecular theory to develop accurate tools to predict the thermodynamics of separation processes relevant to the chemical industry, with particular emphasis on green solvents and carbon capture. Some of the agencies that support this work include the National Science Foundation's Division of Chemical Transport Systems and Division of Materials Research, the American Chemical Society Petroleum Research Fund, the National Renewable Energy Laboratory, and the U.S. Department of Energy's Office Basic Energy Sciences.

The common thread in our approach to tackling problems that have broad societal impact is the use of molecular-based computational methods, which include molecular simulation, both Monte Carlo and molecular dynamics, and molecular-based theory, to elucidate the atomic level behavior responsible for observed macroscopic properties. Through a molecular-level understanding, we can provide a rational basis for the prediction, design, and optimization of new physical and biological systems.

Clare McCabe received a 2018 Chancellor's Award for Research for her paper on simulating skin assembly – A Coarse-Grained Model of Stratum Corneum Lipids: Free Fatty Acids and Ceramide NS – that appeared in the *Journal of Physical Chemistry B.*



Clare McCabe with student researchers (L-R) Andrew Summers, Alexander Yang, Matt Thompson and Ray Matsumoto.

PINTAURO RESEARCH GROUP

Peter Pintauro
H. Eugene McBrayer Professor of Chemical Engineering
Pintauro Research Group

My research activities are focused on the use of electrospinning as a robust and scalable method to fabricate new composite membranes and porous electrodes for electrochemical devices.

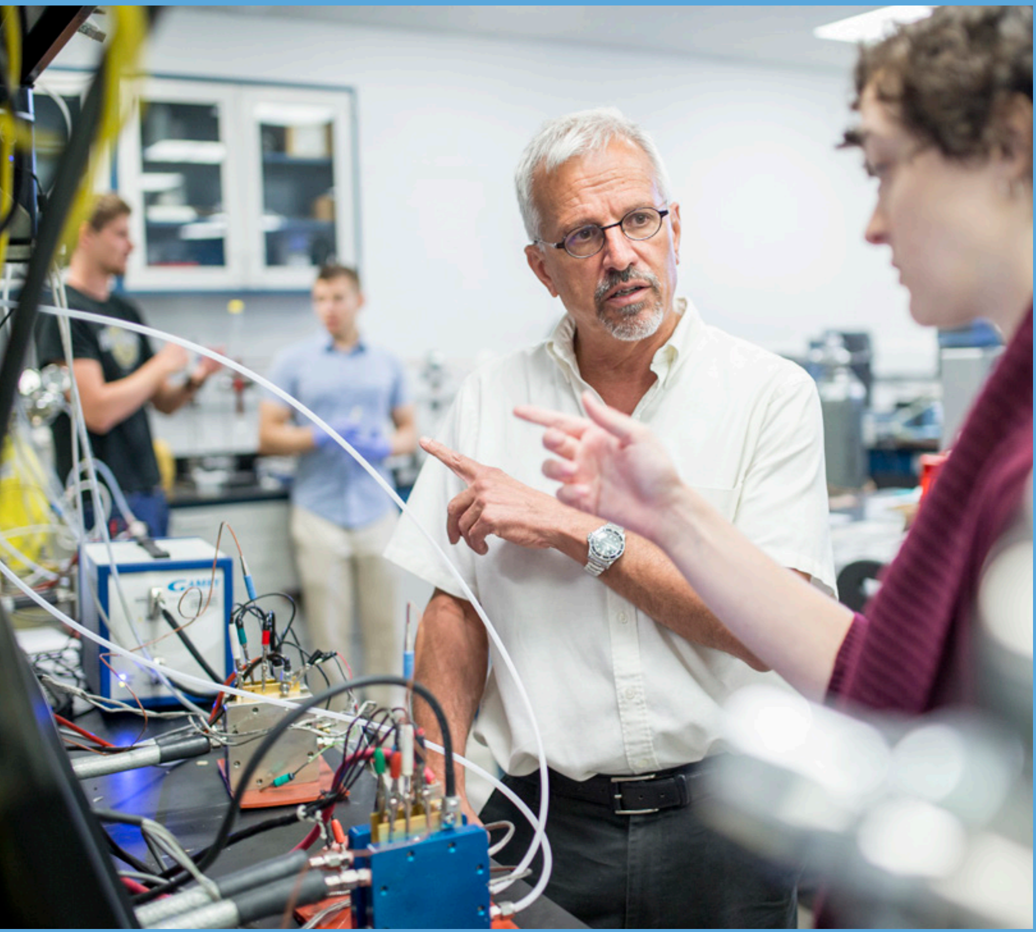
A dual fiber electrospinning approach is being used to create high performance and dimensionally stable nanocomposite anion-exchange, cation-exchange, and bipolar membranes with optimized properties for use in electrodialysis separations, redox flow batteries, and fuel cells.

Novel particle/polymer nanofiber mat electrodes with Pt and Pt-alloy catalysts are being electrospun, characterized, and incorporated into H_2/air fuel cells and Li-ion batteries. Fiber electrodes in fuel cells produce more power and exhibit better long-term durability than conventional electrode designs. Similarly, the morphology of nanofiber mats anodes and cathodes is ideally suited for high capacity and fast charging Li-ion batteries.

Existing projects are collaborative efforts with industry and national laboratories. Work is continuing to exploit the structure and properties of nanofiber materials in energy conversion and storage devices, water electrolyzers, and electrochemical reactors.

Research projects are experimental in nature and highly interdisciplinary, where graduate students receive training in the fields of polymer chemistry, membrane science, electrochemistry, chemical engineering, and polymer fiber electrospinning. Mathematical modeling is used to support and explain experimental data and to generate useful structure/function correlations.

Peter Pintauro is co-author on a paper – High performance electrospun bipolar membrane with a 3D junction – published recently by the *Royal Society of Chemistry Journal.*



Peter Pintauro and graduate student Krysta Waldrop discuss their research project.

RAFAT RESEARCH GROUP

Marjan Rafat
Assistant Professor of Chemical and Biomolecular Engineering
Rafat Research Group
https://my.vanderbilt.edu/rafatlab/

(L-R) Graduate students Steven Alves and Benjamin Hacker work with Marjan Rafat in her laboratory.

The rate of local recurrence remains high for triple-negative breast cancer patients despite surgical, radiation, and chemotherapeutic treatment. Recent studies have found that tumor re-seeding by circulating tumor cells may contribute to recurrence. The role of the microenvironment in cancer relapse after treatment, however, is not well understood.

My laboratory emphasizes using in vivo and biomimetic in vitro tumor models that recapitulate the microenvironment to better understand the mechanisms that drive tumor recurrence. We are interested in examining the biological, chemical, and physical cues that influence cancer metastasis and recurrence. We study how the tumor and tissue microenvironments facilitate breast cancer recurrence and metastasis. This research is supported by multiple grants from the National Institute of Health, National Cancer Institute.

Our current studies focus on the effect of radiation and surgery on tumor and immune cell migration, the molecular profiles of tissues wounded from therapy, and the biomechanical properties of tissues following therapy. We use pre-clinical breast cancer models, multiple non-invasive imaging modalities, and biomaterials to probe the reasons behind tumor cell recruitment to specific tissues. To advance this research, we have assembled a team of talented graduate and undergraduate students.

Marjan Rafat received a NIH Pathway to Independence Award (K99/R00) from the National Cancer Institute. She is interested in determining the microenvironmental factors that are responsible for breast cancer recurrence. This grant provides support for promising new investigators to launch a successful research career.

ROGERS RESEARCH GROUP

Bridget R. Rogers
Associate Professor of Chemical and Biomolecular Engineering
Rogers Research Group

Our research focuses on using surfaces, interfaces, films and powders to engineer materials and microstructures for technically important applications such as microelectronics, catalysis, ultra-high temperature environments, radiation detection, and energy.

The Rogers Group creates materials and structures using thin film processing techniques as well as combustion synthesis. We characterize our materials using a myriad of techniques including spectroscopic ellipsometry, ion beam backscattering spectrometry, electron spectroscopy, and x-ray diffraction.

We use the characterization results as feedback into process optimization. Having a complete knowledge of a material's chemical and physical properties also helps us to understand why certain materials work well in a particular application, but not in others. This understanding enables us to engineer materials with desired properties for optimal performance in the targeted application.

The theme of our research is "From Atoms to Applications." Our research includes making the materials, characterizing their properties, and testing them in the targeted applications. Our laboratory facilities include processing and characterization equipment. We have a chemical vapor deposition (CVD) reactor to form thin solid films on substrates. We have the ability to characterize our materials using electron, ion, x-ray, and optical probes.

We support the research projects of many investigators across the Vanderbilt campus through our x-ray photoelectron spectroscopy (XPS) analyses. Our group also leverages the processing capabilities in the Vanderbilt Institute of Nanoscale Science and Engineering (VINSE) core facilities and characterization instruments found in labs across Vanderbilt and Oak Ridge National Labs' user facilities.

Bridget Rogers and graduate student Courtney A. Mitchell in Rogers' lab.

SILVERA BATISTA RESEARCH GROUP

Carlos A. Silvera Batista
Assistant Professor of Chemical and Biomolecular Engineering
Silvera Batista Research Group
https://my.vanderbilt.edu/silvera/

Our research program aims to improve control over the structure of soft materials through the manipulation of the shape and chemistry of colloidal building blocks as well as interparticle forces.

We use a multiscale approach that examines the factors determining the forces at the molecular level, while also employing direct observation of microcolloids to study flows and forces as well as paths and kinetics of assembly. A topic of interest is solvation forces in nanoscale systems where we investigate how solvation shell structure and dynamics mediate forces between nanoparticles. A second topic of interest is the electrokinetics and directed assembly of anisotropic colloids where we investigate the transport and forces under low frequency electric fields and the formation of reconfigurable 3D colloidal phases.

We rely on a variety of techniques such as analytical ultracentrifugation, neutron and light scattering, Raman and fluorescence spectroscopy as well as confocal microscopy. Our research is relevant to dispersion of nanoparticles in high salinity media (oil recovery), protein corona of nanoparticles (nanomedicine and nanotoxicity), colloidal crystals (structural colors and camouflage) and active motion (reconfigurable materials).

Carlos Silvera Batista and second-year graduate student Javier Gomez collaborate on a research project.

WILSON RESEARCH GROUP

John Tanner Wilson
Assistant Professor of Chemical and Biomolecular Engineering
Wilson Research Group
http://www.wilsonlabvanderbilt.com/

From infectious disease, to cancer, to autoimmunity and chronic inflammation, the immune system underlies the pathophysiology of an increasing number of important diseases. Our group works at the interface of engineering and immunology to improve human health.

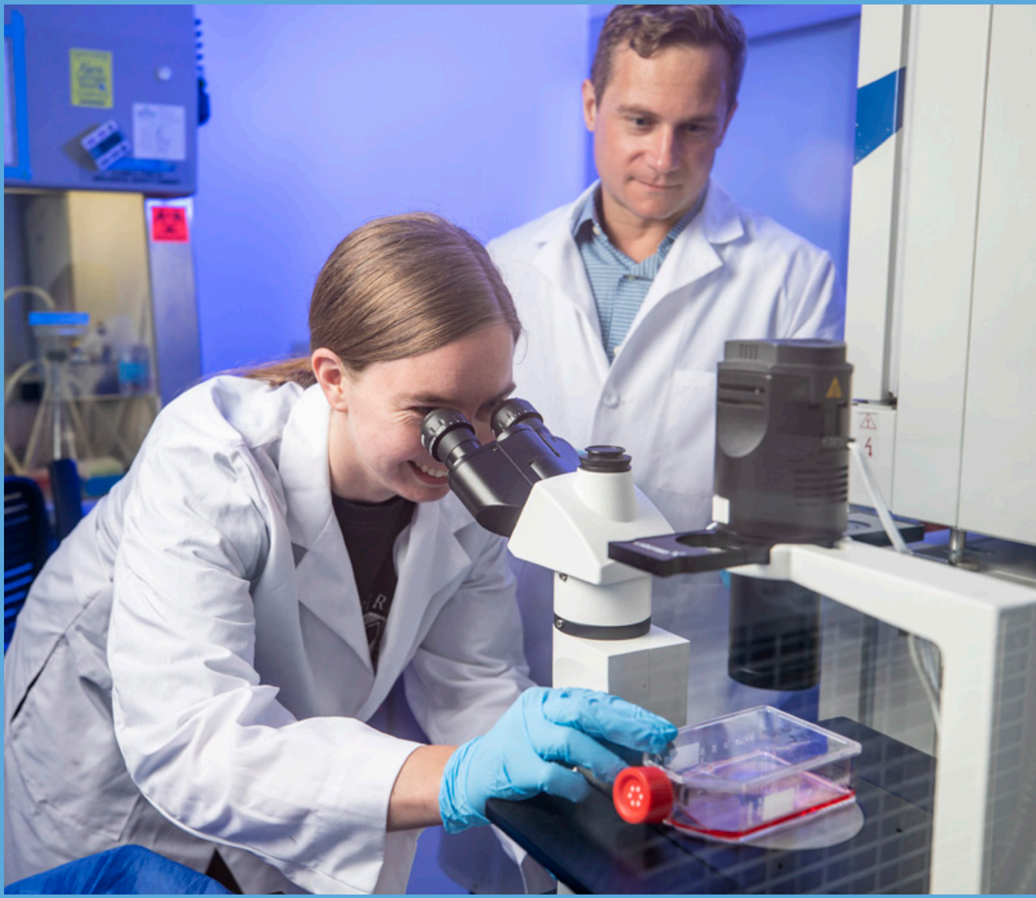
By combining expertise in polymer science, nanotechnology and immunobiology while fostering cross-disciplinary and translational collaborations, we are innovating biomaterials and drug delivery strategies to drive the next generation of vaccines and immunotherapeutics.

The goal of our laboratory is to innovate molecularly engineered materials to harness the immense power of the immune system. Polymeric materials are at the core of our research. The ability to engineer diverse materials with tailored and well-defined properties is critical to controlling immunological phenomena.

John T. Wilson has received a National Science Foundation Faculty Early Career Development award to support development of new synthetic materials for "encoding" immunological messages and tightly regulating their delivery to organs, cells, and pathways of the immune system.

We specialize in the design of novel bio- and nanomaterials using cutting edge approaches, including controlled free radical polymerization (e.g. RAFT), self-assembling polymer thin films and colloids, and smart materials that respond to environmental stimuli.

Currently, we are focused primarily on applications in cancer immunotherapy and vaccine design, with a particular emphasis on developing polymeric nanoparticles to regulate innate immune responses. Our work is highly multidisciplinary, ranging from organic and polymer synthesis, to design and fabrication of novel self-assembled colloids, to mechanistic studies of material-cell interactions, to in vivo evaluation of novel therapies in a variety of pre-clinical animal models.



Jessalyn Baljon, second-year biomedical engineering graduate student, is working on research with John Wilson.

YOUNG RESEARCH GROUP

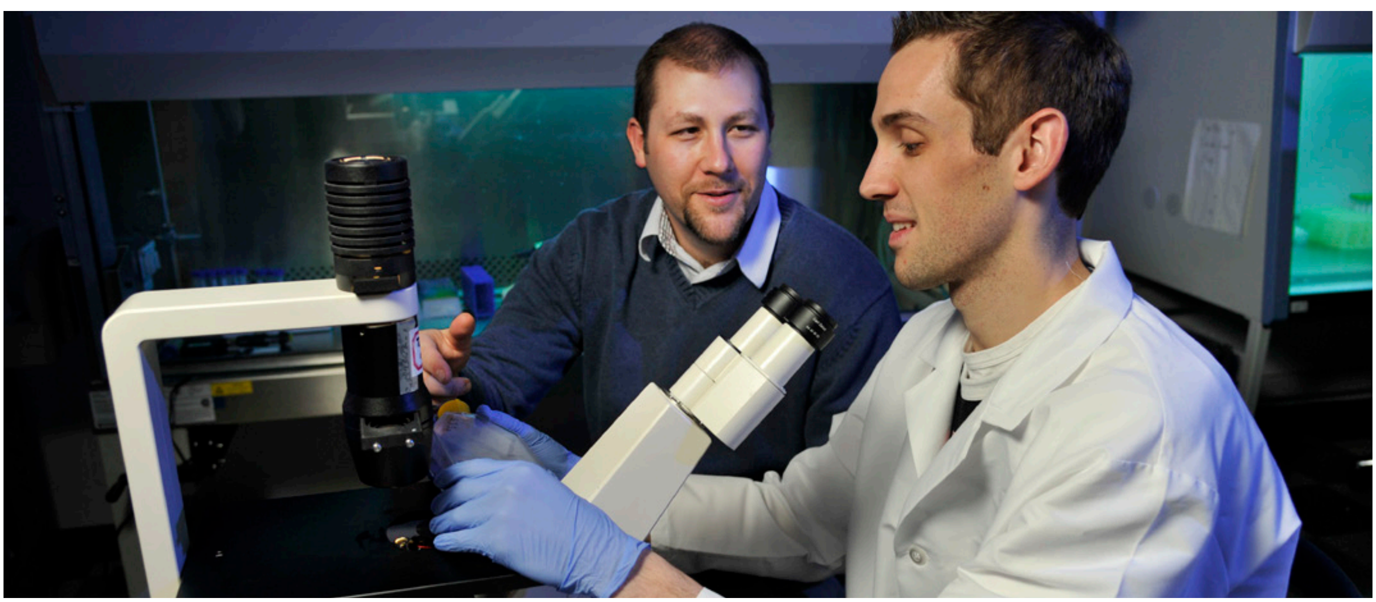
Jamey D. Young
Associate Professor of Chemical and Biomolecular Engineering
Associate Professor of Molecular Physiology and Biophysics
Young Research Group
http://www.vanderbilt.edu/younglab

Living cells rely on metabolic reactions to break down nutrients and synthesize complex biomolecules. The overall goal of my lab is to develop novel approaches to measure, understand, and control cellular metabolism.

These approaches are being applied to a variety of research questions of relevance to medicine and biomanufacturing. It is expected that this work will lead to new discoveries that uncover fundamental disease mechanisms and can be targeted for clinical diagnosis or treatment or to innovative metabolic engineering strategies that can be implemented to enhance production of biochemicals, biofuels, recombinant proteins, or other bioproducts.

Although diverse in biological scope, all projects rely on my lab's core expertise to quantify rates of intracellular biochemical processes using mathematical modeling and flux analysis, with the ultimate goal of deciphering how metabolic networks are natively regulated and how they can be engineered to achieve a desired outcome.

My group developed the first publicly available software package (INCA) capable of both isotopic steady-state and nonsteady-state flux analysis. We have successfully applied INCA to achieve several breakthroughs, including the first comprehensive 13C flux studies of photosynthetic bacteria and plant leaves. In addition to research, I teach courses in Metabolic Engineering, Bioprocess Engineering, Modeling and Simulation in Chemical Engineering, and Chemical Process Control.



Graduate student Taylor Murphy at work in Jamey Young's lab.

Jamey Young is part of a team led by the J. Craig Venter Institute that received a five-year, $10.7 million grant from the U.S. Department of Energy to optimize metabolic networks in photosynthetic microalgae. Young recently was selected as a Chancellor Faculty Fellow at Vanderbilt.

STUDENT ORGANIZATIONS

The 2018 senior class.

Last year's Founder's Medalist Duncan Morgan and Banner Bearer Claire Lafferty, representing the School of Engineering, were both chemical engineering majors.

L-R, 2018 chemical engineering Ph.D. students Sichang Lu, Yinnian Feng, Maxwell Robinson and Ian Njoroge.

American Institute of Chemical Engineers (AIChE) is the world's leading organization for chemical engineering professionals, with more than 60,000 members from more than 110 countries. The undergraduate student chapter of AIChE provides professional mentorship and social programming for the chemical engineers at Vanderbilt. The organization hosts company information sessions, internship and graduate school panels, and even sponsors student researchers to present at the national AIChE conference. In addition to this, AIChE hosts faculty-student mixers, ice cream socials, and plant tours to build community among all chemical engineering students.

"AIChE has provided me with a chance to receive mentorship from upperclassmen who I otherwise would not have been able to meet. Besides this, I have also greatly benefitted from AIChE bringing more chemical engineering companies to the career fair and to private information session to increase opportunities for jobs in my field." **–Mitesh Bhalani**

The Chemical Engineering Graduate Student Association (ChEGSA) serves to enhance the experience of graduate students within the Chemical Engineering department by engendering camaraderie among graduate students and increasing student involvement in the department through student and faculty interactions. Students have organized department picnics and potlucks, sponsored brewery tours, and organized optional group outings to sporting events throughout Nashville. Interested students are encouraged to participate in intramural teams each semester. ChEGSA also sponsors a regular seminar series where students in the program present their research and has coordinated a cross-departmental career workshop.

"The camaraderie that ChEGSA fosters has yielded many productive, academic collaborations as well as life-long friendships." **–Kyle Garland, ChEGSA President (2017-2018)**

The Engineering Ambassadors Network (EAN) is a service-based organization for graduate and undergraduate students. EAN members work with Nashville-based middle and high schools to inspire them to pursue a STEM education. EAN's annual event introduces about 100 Rose Park Middle School eighth graders to Vanderbilt University when students come to campus for a STEM showcase.

"By having in-class interactive discussions and hands-on activities at schools around the Nashville area, we educate the students on the importance of STEM careers and the broad impact they have on society." **–Dustin Groff**

Other organizations of interest

– Society of Women Engineers
– National Society of Black Engineers
– Society of Hispanic Engineers
– Engineers Without Borders

3 Questions for Miles Barr, Ubiquitous Energy co-founder and CEO

Leah Fastnen

Anyone who's stared helplessly at a dead smartphone, its charger sitting at home on a bedside table, can appreciate the mind of Miles Barr.

The Vanderbilt chemical engineering alumnus and founder of Redwood City-based Ubiquitous Energy developed a transparent film that can power phones. Placed over enough windows, it can power an entire house or office building. Indoors, it converts overhead lights into electricity for devices.

Barr (BE'06) also majored in math and music at Vanderbilt and went on to earn his Ph.D. at MIT. He's been listed in MIT Technology Review as one of the world's top innovators under 35 and in Forbes 30 Under 30 for Energy.

How did a Vanderbilt education prepare you to launch Ubiquitous Energy?

At Vanderbilt, I was a chemical engineering major and I also majored in math and music, so I was fortunate to receive a multidisciplinary education with coursework from very different professors. That set a really good foundation in terms of problem solving, critical thinking and getting excited about fields that could become a professional career. I had exposure to research, working in Professor Kane Jennings's lab, and that got me inspired to go into a Ph.D. program. The research I did at MIT ended up evolving into the technology we're developing at Ubiquitous Energy.

What's the biggest challenge you've faced as an entrepreneur?

There are a lot of challenges, so it's hard to pick one. One of the challenges is the number of different things you have to juggle. We're simultaneously developing a new technology, fund-raising with investors and working with commercial partners – figuring out where this technology will find a home. You have to effectively navigate those different priorities, and having a great team that can help you with that.

An MIT Technology Review article about you said, "Barr pairs his inventiveness with a flair for salesmanship." What's the key to a great pitch?

It's really about storytelling. You've got to make what you're doing accessible to the person you're describing it to, explaining what it means for your audience. We're inventing a brand-new product. It doesn't exist today. The key is finding a simple story that's able to connect the dots on what value our technology can bring to the investor.

Carl Haney, The Estée Lauder Companies

Carl P. Haney graduated cum laude with a degree in chemical engineering in 1984. He is Executive Vice President of Global Research & Development, Corporate Product Innovation and Package Development at The Estée Lauder Companies Inc. He joined Estée Lauder following a more than 20-year career at The Procter & Gamble Company, where he started his career. Haney is known for growing businesses and brands, innovating organizations, and creating strong external partnerships.

Sandra Cochran, Cracker Barrel Old Country Store

Chemical engineering alumna Sandra Cochran, BE'80, president and CEO of Cracker Barrel Old Country Store, Inc. since 2011, attended Vanderbilt on an Army ROTC scholarship and was commissioned in the U.S. Army upon graduation. She served in the Army until 1985, attaining the rank of captain. Her awards and decorations include the Meritorious Service Medal, the Army Commendation Medal with oak leaf cluster, Army Parachute Wings, and several service ribbons. She was previously CEO at the nation's third-largest book retailer, Books-A-Million, Inc. Cochran received the Vanderbilt School of Engineering's Distinguished Alumnus Award and was inducted into its Academy of Distinguished Alumni in 2008.

FACULTY

Rizia Bardhan
Assistant Professor of Chemical and Biomolecular Engineering

Peter Cummings
John R. Hall Professor of Chemical Engineering
Professor of Chemical and Biomolecular Engineering
Associate Dean for Research

Russell Dunn
Professor of the Practice of Chemical and Biomolecular Engineering

Scott Guelcher
Professor of Chemical and Biomolecular Engineering

Kane Jennings
Professor of Chemical and Biomolecular Engineering

Piran Kidambi
Assistant Professor of Chemical and Biomolecular Engineering

Paul Laibinis
Professor of Chemical and Biomolecular Engineering

Matthew Lang
Professor of Chemical and Biomolecular Engineering

Ethan Lippmann
Assistant Professor of Chemical and Biomolecular Engineering

Clare McCabe
Cornelius Vanderbilt Professor
Professor of Chemical and Biomolecular Engineering

Peter Pintauro
H. Eugene McBrayer Professor of Chemical Engineering
Professor of Chemical and Biomolecular Engineering

Marjan Rafat
Assistant Professor of Chemical and Biomolecular Engineering

Bridget Rogers
Associate Professor of Chemical and Biomolecular Engineering

Julie Sharp
Professor of the Practice of Technical Communications

Carlos Silvera Batista
Assistant Professor of Chemical and Biomolecular Engineering

John Wilson
Assistant Professor of Chemical and Biomolecular Engineering

Jamey Young
Associate Professor of Chemical and Biomolecular Engineering

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Todd Giorgio
Professor of Biomedical Engineering
Professor of Chemical and Biomolecular Engineering

Kelsey Hatzell
Assistant Professor of Mechanical Engineering
Assistant Professor of Chemical and Biomolecular Engineering

David Kosson
Cornelius Vanderbilt Professor
Professor of Civil and Environmental Engineering
Professor of Chemical and Biomolecular Engineering

Shihong Lin
Assistant Professor of Civil and Environmental Engineering
Assistant Professor of Chemical and Biomolecular Engineering

Sandra Rosenthal
Jack and Pamela Egan Professor of Chemistry
Professor of Chemical and Biomolecular Engineering

Florence Sanchez
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Associate Professor of Chemical & Biomolecular Engineering

Marija Zanic
Assistant Professor of Cell and Developmental Biology
Assistant Professor of Chemical and Biomolecular Engineering

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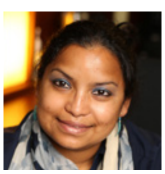
Research Assistant Professor of Chemical and Biomolecular Engineering

Julianne Vernon
Research Assistant Professor of Chemical and Biomolecular Engineering
Assistant Dean for Academic Programs

Ryszard Wycisk
Research Associate Professor of Chemical and Biomolecular Engineering

ADJUNCT/ADJOINT FACULTY

Bryan Beyer
Adjunct Instructor in Chemical and Biomolecular Engineering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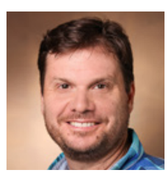
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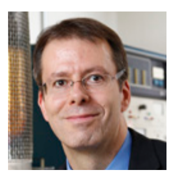
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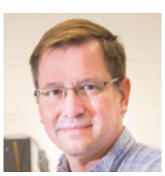
Kidambi


Lang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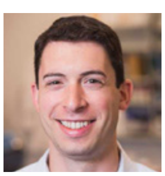
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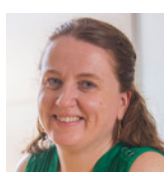
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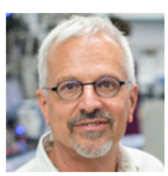
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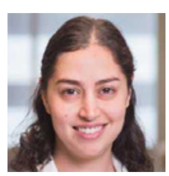
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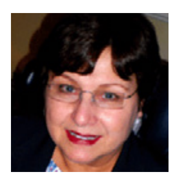
Rogers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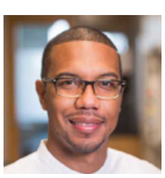
Silvera Batista


Wilson


Young

ADMISSIONS

UNDERGRADUATE

The Vanderbilt Office of Undergraduate Admissions manages admission to this program. Admissions staff can answer questions, arrange campus tours, provide additional information about degree programs and more.

Office of Undergraduate Admissions
Vanderbilt University
2305 West End Avenue
Nashville, TN 37203-1727
Phone: (615) 322-2561 or (800) 288-0432
Website: *admissions.vanderbilt.edu*

Prof. Paul Laibinis
Department of Chemical and Biomolecular Engineering
Office: 308B Olin Hall
Email: paul.e.laibinis@vanderbilt.edu
Phone: (615) 936-8431

GRADUATE

To apply for admission to the graduate program in chemical engineering, you must first meet the general requirements of admission by the Vanderbilt University Graduate School. Application for admission may be made electronically here: www.vanderbilt.edu/gradschool/. The Graduate School Catalog may be viewed at www.vanderbilt.edu/catalogs/

Vanderbilt University Graduate School
117 Alumni Hall
2205 West End Avenue
Nashville, TN 37240 USA
ATTENTION: Chemical Engineering
Phone: (615) 343-2727

Prof. Jamey Young
Department of Chemical and Biomolecular Engineering
Office: 212B Olin Hall
Email: j.d.young@vanderbilt.edu
Phone: (615) 343-4253

IMPORTANT DATES

January 1: Fall application deadline
March-April: Fall admission offers
April 15: Deadline to accept admission

FINANCIAL AID

UNDERGRADUATE

Vanderbilt is committed to enrolling talented, motivated students from diverse backgrounds. About 65 percent of Vanderbilt students receive some type of aid. Our admissions process is need-blind for U.S. citizens and eligible non-citizens, which means the ability to pay for a Vanderbilt education is not a factor in the admissions process. All need-based aid packages now include scholarships, grants (gift assistance), and employment opportunities in place of need-based loans. This initiative does not involve income bands of income cutoffs that limit eligibility. More information can be found at *vanderbilt.edu/financialaid*.

GRADUATE

Students wishing to be considered for financial awards administered by the Graduate School should check the appropriate box under "Financial Information" on the online application and make certain that a complete application is received by January 1. Prospective applicants are urged to apply for fellowships or grants from national, international, industrial, or foundation sources. More information can be found at *vanderbilt.edu/gradschool*.

Graduate students in the Department of Chemical and Biomolecular Engineering seeking the Ph.D. degree receive a competitive stipend, tuition waiver, health insurance and reimbursement for some incidental fees. This financial aid can be in the form of a Teaching Assistantship or a Research Assistantship. Assistantships may be supplemented by a departmental, service-free scholarship or fellowship.

- **Graduate Teaching Assistantships:** Financial aid for the academic year to students who assist in supervised teaching of undergraduates
- **Graduate Research Assistantships:** Financial aid for the calendar year to students carrying out thesis or dissertation research with support from a research grant

Teaching or Research Assistantships may be supplemented by a scholarship or fellowship through a competitive process supported by exceptional applicant qualifications. In order to be considered for these service-free awards, an applicant's file must be complete by January 1. The honor fellowships listed below are in addition to a Teaching or Research Assistantship.

- **Harold Stirling Vanderbilt Graduate scholarships:** $6,000/year for up to five years
- **University Graduate Fellowships:** $5,000/year for up to two years
- **Provost's Graduate Fellowships:** $5,000/year for up to two years
- **School of Engineering Fellowships:** $4,000/year for up to four years plus an award of $1,000 for professional development

VANDERBILT School of Engineering

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Department of Chemical and Biomolecular Engineering
2301 Vanderbilt Place
PMB 351604
Nashville, TN 37240-1592

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