

DEPARTMENT OF CHEMICAL AND LIFE SCIENCE ENGINEERING

B. Frank Gupton, Ph.D.

Research professor and chair

chemical.egr.vcu.edu (<https://egr.vcu.edu/departments/chemical/>)

Chemical and life science engineering represents the formal interaction of chemical engineering with the life sciences. VCU's Department of Chemical and Life Science Engineering is uniquely poised to bring these two premier disciplines together to form a program distinct in the nation. Programs are offered at the undergraduate and graduate levels.

Life science engineering – with interest areas including stem cell and stem cell-derived tissue engineering, biosciences/biotechnology, cellular engineering, biochips and biosensors, bioinformatics and molecular biocomputing, genetic and protein molecular engineering, environmental life science engineering, and molecular- and cellular-based therapeutics – is the fastest growing of all industries that currently employ engineers.

Chemical engineering and life science engineering share a broad range of common foundational knowledge bases, including the principles of mass and energy balances, transport phenomena and thermodynamics, surface and interfacial science, and reaction science and engineering. Strong academic and research programs in chemical and life science engineering will provide a wealth of exciting professional opportunities for successful graduates of the VCU program.

The bachelor's program offers concentrations in chemical engineering and life science engineering, and a chemical and life science engineering concentration is also available in the Master of Science in Engineering program, as well as the Ph.D. in Engineering program. The CLSE concentrations in the graduate-level programs are designed primarily for students who are interested in applying chemical and engineering principles toward important contemporary topics including process design, metabolic engineering, biosensor and biochip development, high-performance polymers in medicine and energy conversion, polymer surface science, and environmentally benign polymer processing technologies. Major emphasis is placed on chemical and life science engineering fundamentals with additional emphasis on applied chemistry and life sciences.

- Chemical and Life Science Engineering, Doctor of Philosophy (Ph.D.) (<http://bulletin.vcu.edu/graduate/school-engineering/chemical-life-science-engineering/clse-phd/>)

CLSE 543. Advanced Reaction Engineering. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Provides the fundamental background needed to effectively design reactors at the macroscale exemplified by batch, pilot and plant operations or at the micro- and nano-scale exemplified by the current trend to miniaturize unit operations. A quantitative analysis is developed to explain why "real" reactor performance departs from ideal batch, CSTR and plug flow reactor performance.

CLSE 544. Applied Transport Phenomena. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Provides the basis for analyzing mass, energy and momentum transport issues in environmental, chemical, biological and industrial processes. Molecular mechanisms of momentum transport, energy transport and mass diffusion are utilized to develop an engineering analysis of a given process. This molecular approach is complemented with macroscopic mass, momentum and mechanical energy balances.

CLSE 549. Process Biotechnology. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Designed to provide a rational basis addressing engineering challenges in the emerging biotechnology area. The course material is broad in scope covering biochemical synthesis, bioreactor design and bioprocess monitoring and control. It also deals with important issues associated with separation and purification techniques used with biomaterials.

CLSE 560. Protein Engineering. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Enrollment restricted to students with senior or graduate standing in the School of Engineering or School of Pharmacy, or by permission of instructor. This course focuses on the structure-function characterization of proteins and the quantification of protein-protein interactions for the design of novel protein and peptide therapeutics. Additional topics include biochemistry of proteins for engineers, large scale, batch production and manufacturing techniques for biologics.

CLSE 561. Stem Cell Engineering. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 218 and CLSE 302. The production and behavior of adult and embryonic stem cells are studied and potential applications for the treatment of disease are surveyed. The importance of the extracellular matrix in cell differentiation and proliferation is established. Stem cell engineering techniques including parthenogenesis, nuclear transfer stem cells and embryonic carcinoma cells are introduced. The use of stem and germ cells for cloning, stem cells and tissue rejection, and ethical considerations in the use of embryonic human stem cells are discussed.

CLSE 562. Advanced Systems Biology Engineering. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 218, CLSE 115, and CLSE 302. The system-level properties of biology will be surveyed to understand how DNA leads to cellular behavior through complex molecular interactions. Theoretical and experimental concepts associated with high-throughput data (genomics, transcriptomics, metabolomics, fluxomics, proteomics), cellular regulation and computational modeling will be introduced. Bioinformatic analysis, integration of data and current challenges are discussed.

CLSE 563. Metabolic Engineering. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 218, CLSE 115, and CLSE 302. The principles and methods used in metabolic engineering of microbes will be covered. Theoretical and experimental concepts associated with metabolite production, strain design, strain construction and strain characterization will be introduced. Design principles, metabolic engineering challenges, metabolic engineering applications and ethical considerations of genomic alterations are discussed.

CLSE 570. Molecular Physiology and Microanatomy for Chemical and Life Science Engineering. 4 Hours.

Semester course; 3 lecture and 2 laboratory hours. 4 credits.

Prerequisites: BIOL 218 and CLSE 302. Understanding physiology from the molecular perspective of cellular biochemical mass action kinetics, molecular diffusion and transport, biomolecular separation processes, and dynamic biochemical control theory is key to the engineering and design strategies for medical intervention in disease and human health. This course explores these biomolecular dynamic events in human physiology with an emphasis on the application of the fundamental biochemical transport phenomena, kinetics and separation processes, and dynamic control theory. Laboratory component emphasizes living, single-cell manipulation and analysis methods, such as patch clamp devices, and the microanatomy of internal organs.

CLSE 575. Nanotechnology in Life Science and Engineering. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Enrollment restricted to students with senior or graduate standing in the School of Engineering or Department of Chemistry, or with permission of instructor. Nanobiotechnology is the application of nano- and micro-fabrication methods to build tools for exploring the world of biological systems. This course will introduce the principles and practice of microfabrication techniques and perspectives in the field of nanobiotechnology. Lectures will cover interdisciplinary topics such as biomolecules at interfaces, biosensors, micro- and nano-fabrication strategies, self-assembly, nanoparticles, micro- and nano-devices and microfluidics.

CLSE 580. Sustainable Chemical Engineering. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Prerequisite: CLSE 202 or permission of instructor. The course offers a survey of sustainability, green chemistry and green engineering considerations in chemical processing. Topics include quantitative analysis of green chemistry metrics, process intensification, renewable resources and waste valorization. Science communication and science policy will be discussed.

CLSE 585. Interfacial Phenomena. 3 Hours.

Semester course; 3 lecture hours. 3 credits. The course offers an introduction to interfacial phenomena and colloid physical chemistry. Students will develop the ability to apply basic concepts from interface and colloid chemistry and physics to describe engineering applications. The course will also introduce modern experimental techniques and current literature in colloidal and interfacial phenomena.

CLSE 645. Biosensors and Bioelectronic Devices. 3 Hours.

Semester course; 3 lecture hours. 3 credits. This course develops the methodologies used in the design, fabrication and application of biosensors and bioelectronic devices to monitoring problems in the environmental, medical and chemicals industries. Fundamentals of measurement science will be applied to optical, electrochemical, mass and thermal means of signal transduction. Fundamentals of surface science will be used to interpret bio-immobilization, biofouling and non-specific interactions of enzymes, antibodies and DNA at surfaces.

CLSE 650. Quantitative Analysis in Chemical and Life Science Engineering. 3 Hours.

Semester course; 3 lecture hours (delivered online, face-to-face or hybrid). 3 credits. Prerequisite: MATH 301. An understanding of the quantitative descriptions of chemical and biological processes is required for engineering analysis, including prediction and design. Analytical approaches are necessary to simplify and provide limits of complex behavior. These approaches include perturbation theory and scaling, density functional formulations, control theory, and stability theory. This course represents the applied mathematical foundations on equilibrium and nonequilibrium analysis of chemical and biological systems.

CLSE 654. Equilibrium Analysis in Chemical and Biological Systems. 3 Hours.

Semester course; 3 lecture hours (delivered online, face-to-face or hybrid). 3 credits. Prerequisite: CLSE 305. Provides a molecular-based, thermodynamic framework for the quantitative equilibrium analysis of a broad range of biological and chemical processes. Contemporary equations of state, liquid solution models and elementary statistical mechanics are used to predict the behavior of molecules. Important issues addressed include the estimation of solvation and partitioning of molecules between phases or media, the calculation of free energy changes associated with cellular events and prediction of order/disorder phenomena.

CLSE 655. Nonequilibrium Analysis in Chemical and Life Science Engineering. 3 Hours.

Semester course; 3 lecture hours (delivered online, face-to-face or hybrid). 3 credits. Prerequisites: CLSE 301, CLSE 302 and MATH 301. An understanding of the spatial and temporal dynamics of biological systems is key to many cellular events including cell signaling processes, second messenger systems, positive and negative feedback control, transcription, translation, and many more. This course introduces nonequilibrium (dynamic) analysis as applied to biological and chemical systems.

CLSE 656. Advanced Chemical Reaction Engineering. 3 Hours.

Semester course; 3 lecture hours (delivered online, face-to-face or hybrid). 3 credits. Prerequisites: MATH 301 and CLSE 312. This course builds upon fundamental principles of chemical reaction engineering including integration of mass balances, reactor design equations and chemical rate laws. Emphasis is given to development of mathematical models and computational simulation of chemical reaction systems with multiple reactions. Additional topics include analysis of systems with unknown reaction parameters and mechanisms and bioprocess/biochemical approaches to chemical production.

CLSE 660. Biomolecular and Computational Engineering. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Prerequisite: CLSE 650. Dynamic analysis of interacting cellular events, including cell signal pathways, clock reactions, etc., often requires large-scale computational approaches. Furthermore, these techniques are necessarily time dependent requiring unique methodologies, such as multi-time scale methods. This course introduces the subject of real-time biomolecular simulations.

CLSE 675. Polymers in Medicine. 3 Hours.

Semester course; 3 lecture hours. 3 credits. This course is based on the need for integration of engineering and materials science of polymers with applications in life science engineering. Basic principles of polymer science including structural concepts at the molecular-, nano-, micro- and macro-scales are emphasized so that the student can understand structure/function correlation. The course treats polymer synthesis, molecular weight, morphology and surface science at an introductory level, but quantitative correlations are emphasized. Surface science is emphasized, as medical applications are often dependent on the interaction of a solid polymer with an in vivo environment (tissue, blood, membrane). The polymers chosen for emphasis include polyethylene (hip, knee replacement), poly(vinylchloride) (blood bags, catheters), polyurethanes (artificial heart, wound care) and silicones (implants, catheters). The use of polymers in drug delivery applications is explored, including osmotic-pressure-driven drug delivery. Concepts surrounding polymeric surface modifiers are developed, including applications such as enhanced biodegradability and biocidal function.

CLSE 690. Research Seminar in Chemical and Life Science Engineering. 1 Hour.

Semester course; 1 lecture hour. 1 credit. May be repeated up to eight times. Presentations and discussions of current problems and developments in life science engineering by faculty and visiting lecturers.

CLSE 691. Special Topics in Chemical and Life Science Engineering. 1-4 Hours.

Semester course; 1-4 lecture hours (delivered online, face-to-face or hybrid). 1-4 credits. Enrollment is restricted to students who have completed at least one graduate-level engineering course and with permission of the instructor. Lectures, tutorial studies, library assignments in selected areas of advanced study or specialized laboratory procedures not available in other course offerings or as part of research training.

CLSE 692. Independent Study in Chemical and Life Science Engineering. 1-5 Hours.

Semester course; 1-3 lecture and/or 0-4 laboratory hours. 1-5 credits. Prerequisites: graduate standing or permission of instructor. The student must submit a prospectus to the graduate committee for approval and identify a faculty member willing to supervise the course. Investigation of specialized engineering problems through literature search, mathematical analysis, computer simulation and/or experimentation. Written and oral reports, final report and examination required.

CLSE 697. Directed Research in Chemical and Life Science Engineering. 1-15 Hours.

Semester course; 1-15 research hours. 1-15 credits. Enrollment is restricted to graduate students or by permission of instructor. Research directed toward completion of the requirements for the M.S. or Ph.D. in engineering with concentration in chemical and life science engineering under the direction of an engineering faculty member and advisory committee. Graded S/U/F.