Welcome to the Undergraduate Research Program at Trinity University’s Department of Chemistry! The Chemistry and Biochemistry faculty takes great pride in being one of the top undergraduate programs in the country. This informational packet serves as a brief introduction to the undergraduate research opportunities available in our department. The general information is directed towards current Trinity students, high school students looking at potential colleges, and local high school students interested in research opportunities. Any faculty member would be glad to discuss the program and individual research topics. Please do not hesitate to contact us by email; contact information can be found at:

http://new.trinity.edu/academics/departments/chemistry/faculty-staff
Program Scope

The chemistry department has seven research-active faculty members representing all of the major disciplines of chemistry (Analytical, Biochemistry, Inorganic, Organic and Physical). These professors supervise externally funded research programs that provide undergraduate chemistry and biochemistry students opportunities to work closely with professors on cutting-edge projects using state-of-the-art research equipment, to publish their research in the top journals in our fields, and to present their research at major conferences. Faculty members have laboratory space in the new Center for the Sciences and Engineering in which their research groups operate, and many faculty members collaborate with groups at major research institutions and national laboratories. Departmental instructional facilities (see list of major equipment on our website) are also utilized by faculty research groups, particularly during the summer research program. Increasingly, chemistry and biochemistry projects are at the interface of traditional research disciplines, particularly with biology, applied physics, and engineering. We have developed a number of collaborations between various research groups at Trinity, and there are numerous non-chemistry majors in our research program.

The strength of our program is evidenced by the external funding that the faculty has successfully attracted. Currently, the chemistry faculty manages ~$2.1 Million in active, externally funded grants from the Beckman Foundation, the National Science Foundation, National Institutes of Health, the Robert A. Welch Foundation, Research Corporation, the American Chemical Society and the San Antonio Area Foundation. These funds help to support summer stipends for undergraduate and high school students, major research equipment, research supplies, instructional equipment, and salaries for postdoctoral research associates. The Department also currently participates in several inter-departmental initiatives, which have provided millions of dollars in equipment and student stipends over the last several years. This research generates scientific publications with student co-authors, far more per faculty member than the national average for undergraduate institutions.

Summer Research Program

Instead of teaching courses during the summer term, the Chemistry department is focused entirely on research with students using all laboratories, facilities, and equipment. In 2016, faculty and departmental grants allowed us to support 34 undergraduate students for the 10-week summer program. This makes our program one of the largest chemistry summer undergraduate research programs in the country. All summer research students receive a summer stipend (approx. $4000). Trinity University also covers the dormitory costs for summer research students.

One of the hallmarks of our program is that it is highly accessible to students early on in college. About half of the students have just completed their first or second years, and the other half started in their first or second years and are continuing. The application process starts in January, and the program generally runs from mid-May to the end of July.

Research During the Semester

Research opportunities are also available for course credit or on a volunteer basis during the semester. Professors generally expect about 6 hours of work in and out of the lab per week for one hour of credit. Students are asked to talk with at least 3 faculty members to discuss research opportunities before being admitted into a research group.

Research Areas

The following pages give brief summaries of the areas of research under active investigation by our faculty. If you have questions about the opportunities in specific research groups, please do not hesitate to contact any of our faculty. We would enjoy the opportunity to share with you more information about our programs and our department. For questions about the summer research program, please contact our Summer Research Program Coordinators, Drs. Corina Maeder (cmaeder@trinity.edu) and Bert Chandler (bert.chandler@trinity.edu).
Research in the Hunsicker-Wang laboratory will focus on studying enzymes that utilize or bind metal ions, called metalloproteins. There are two major areas of interest: iron-sulfur cluster enzymes and cytochrome oxidase proteins.

Iron-sulfur proteins make up ~30% of all metalloproteins. These proteins utilize iron and sulfur atoms that are organized into clusters. These proteins are often involved in electron transfer reactions. Specifically, the Rieske protein, which is part of Complex III in the respiratory chain, contains a [2Fe-2S] cluster, which is ligated to the protein via 2 cysteine and 2 histidine residues. The reduction potential of this protein depends on the organism and the type of system that it was derived from. Previous studies have shown that the number of hydrogen bonds to the cluster, the solvent accessibility, and the type of charge residues near the cluster all affect the reduction potential. Research on this protein involves making site-specific mutations, purifying, crystallizing and solving the structure of the mutant enzymes. The reduction potentials of these mutants are also evaluated. This protein is also be chemically modified with reagents that alter the properties of specific amino acids. This approach allows a greater variety of chemical properties to explore. Chemical modification also allows study of how individual amino acids contribute to the electron transport function within the protein.

Reactive oxygen species (ROS) are destructive and form from the reduction of molecular oxygen. One hypothesis is that a mismatch in the potential of the Rieske protein with its partners within Complex III leads to the production of ROS and may lead to neurodegenerative diseases. This hypothesis is starting to be explored in the Hunsicker-Wang lab.

Cytochrome oxidase is complex IV in the respiratory system. Within this protein, there are 4 metal sites, 2 heme-iron sites and 2 copper binding sites. One of the copper sites is the CuA center, found in subunit II of cytochrome oxidase. This center may also be involved in H⁺ translocation within cytochrome oxiase. Subunit II can be expressed as an isolated protein. The Hunsicker-Wang lab is exploring how the histidines in this protein may function to pump H⁺ using chemical modification and site-directed mutagenesis. Additionally, the lab is also studying how the copper ions are incorporated into CuA when cytochrome oxidase is assembled. The protein, Sco, is thought to be involved in the process but its exact role is not well-defined. Thus, studies are aimed at understanding what role(s) that Sco plays in the assembly of the CuA site.
Research in the Maeder Lab centers on understanding the mechanisms involved in gene expression, specifically that of pre-messenger RNA splicing. In eukaryotes, initially, RNA transcribed from DNA may have intervening non-protein coding sequences, or introns. These sequences must be removed for accurate protein translation. The removal of these introns must be precisely coordinated to avoid inaccuracies that can result in many diseases, including cancer and retinitis pigmentosa. This process is known as pre-messenger RNA splicing.

A large macromolecular complex of RNA and proteins called the spliceosome facilitates splicing. The mechanism of pre-mRNA splicing involves large-scale rearrangements of protein-RNA complexes, which must be regulated to ensure both splicing timing and accuracy. Our research focuses on understanding these large-scale rearrangements within the spliceosome. The spliceosome is composed of five small nuclear ribonucleoprotein complexes (snRNPs). Dynamic rearrangements occur both within and between the snRNPs during the splicing cycle. These rearrangements are indicators that splicing is proceeding accurately. Our research aims to dissect the molecular interactions that stimulate spliceosome assembly and activation. Specifically, we are currently focused on the role of the Dib1 protein and its interactions in regulating these rearrangements. Dib1 is essential for cell viability and splicing and is conserved from yeast to humans. Dib1 (Figure 1) is a small protein with a thioredoxin-like fold and little is known about its function. Using site-directed mutagenesis and yeast growth assays, we have identified amino acids that are important for splicing. We are now trying to characterize the protein using biochemical and molecular biology techniques in order to understand the importance of these amino acids in splicing. For example, a change to an amino acid in the core of protein may cause the protein to be less stable overall, while a change to a amino acid in an external loop may be important for interactions with binding partners. Our works aims to determine the function of Dib1 through this characterization and whether it might be involved in the regulation of spliceosome assembly directly or indirectly.

Our studies on the spliceosome are quite interdisciplinary. In our lab, we use a variety of biochemical, molecular biological, and genetics techniques to dissect the importance of protein-nucleic acid and protein-protein interactions in the spliceosome. Students have opportunity to perform: 1) biochemistry assays, including gel based kinetic unwinding assays, binding assays for protein-RNA and protein-protein interactions, and structural studies using circular dichroism, 2) molecular biology, including protein purifications, DNA cloning, and RNA transcription and purification and 3) genetic assays using Saccharomyces cerevisiae (Baker’s yeast) including gene deletion, tetrad analysis and growth assays.

Figure 1. Crystal Structure of human Dim1 (Dib1 homolog) with amino acids that affect cell growth highlighted. (PDB 1QVC)
Catalysis is the enabling discipline in energy supply and conversion, in the synthesis of fuels and chemicals, and in our thoughtful care for the environment; it remains an essential contributor to quality of life and to sustainable growth in the world at large.” Prof. Enrique Iglesia, UC Berkeley

You probably know that a catalyst speeds up a reaction but is not consumed like a reactant is. Heterogeneous catalysts are solid materials that perform chemical reactions. Essentially, liquid and/or gas phase molecules adsorb (or stick) onto the catalyst surface. Heterogeneous catalysts are used extensively in petroleum refining, emissions abatement, and the production of bulk and fine chemicals. They are also key components to many developing technologies, including solar energy conversion and fuel cells. This makes catalysis one of the most important technologies in industrial chemistry, and means that future catalytic chemistries will be important parts of solutions to our most urgent societal and environmental needs for decades to come. One of the most common classes of heterogeneous catalysts are supported metal catalysts, which typically consist of a high surface area oxide that has metal nanoparticles (NPs, typically 1-10 nm or roughly 100 to 100,000 atoms) spread across the surface.

The Chandler group studies the art and science of these supported NP catalysts. Some of the art comes in learning to prepare metal NPs in solution. We try to control how metal atoms assemble in solution so that we can control the structure and properties of the catalyst. In the picture to the right, we would like to control the number and types of atoms (pink vs. gray) balls on the surface of the metal particle. These particles can then be deposited onto a metal oxide support and the stabilizing molecules (which are added to control the synthesis) can be removed.

For the science, we are interested in studying what factors influence the reactivity of metal nanoparticles, how we can control them, and how we can use that knowledge to develop new reactions. We spend a lot of time trying to understand reaction mechanisms on catalysts and developing tools for using kinetics (especially biochemical kinetic tools) to probe catalyst properties. Mechanistic studies require a lot of kinetics studies, so there are always projects for students who are interested in learning about how molecules react and how we figure that out. We investigate many different types of reactions, including hydrogenations and oxidations, and are especially interested in the role that water can play as a co-catalyst. It turns out that, just like in organic chemistry, in heterogeneous catalysis, proton transfers can play important roles in reaction mechanisms. These studies have led to some exciting advances over the past several years, and we are looking to employ our new understanding of the role of water to new reactions.

Catalysis is an inherently multi-disciplinary field, which means that there is something for everyone: chemical synthesis, Inorganic chemistry, Organic chemistry, Physical chemistry, and some Engineering. We do a lot of nanoparticle synthesis, and study the individual synthetic steps. We are also doing a good bit of organic chemistry, studying organic reactions to help understand how our nanoparticles change under different conditions. We are developing ways to employ enzyme reaction terminology to help understand nanoparticle catalysts. And, of course, we do a number of basic physical and inorganic chemistry measurements to quantify and understand the differences between catalysts.
Chemical Synthesis, Bioorganic Chemistry and Chemical Biology

Research in the Cooley lab spans the interface of chemistry and biology. I believe strongly in the power of synthetic organic chemistry to access new approaches to solve problems. Students in my lab will have the opportunity to design and synthesize new molecules and then test them in relevant biological systems. This summer students will have the opportunity to work on one of two interdisciplinary projects to detect and treat human disease.

The first project describes a new strategy for antigen detection by polymerization amplification as a low-cost, robust platform to detect and diagnose disease in the developing world. Sensitive and economic diagnostic assays could have immediate impact in low-resource environments, for example in the early detection of HIV infection, which is still a widespread problem in Sub-Saharan Africa. We are developing a sensitive and quantifiable fluorescence-based polymerization amplification detection assay by synthesizing antibody-initiator conjugates and monomers that are fluorogenic upon polymerization for atom transfer radical polymerization (ATRP, see Figure). We will then immobilize a selected antigen, such as p24 for the early detection of HIV, and evaluate the sensitivity and specificity of the fluorescent ATRP polymerization to detect the antigen of interest. The specific fluorescent polymer was chosen to be excited in the UV range (for example by a hand-held UV lamp) and emit in the visible spectrum for naked eye detection, which would be especially desirable for resource-limited applications.

The second project combines the fields of drug delivery and stress-responsive signaling. Stress-responsive signaling pathways regulate the protein homeostasis (proteostasis) network, whose activity significantly declines upon aging and has been linked to a range of human protein-misfolding disorders such as Alzheimer’s and Parkinson’s disease. We will design and develop prodrugs for modulators of stress-responsive signaling pathways, that are selectively uncaged by the presence of reactive oxygen species (ROS) associated with cells undergoing degenerative pathology. Students will synthesize the ROS-activatable prodrug conjugates, examine their stability and release kinetics to free drug in the presence of ROS such as hydrogen peroxide, and explore their release and activity in mammalian cells.
Amber is the fossilized end product of resinous materials exuded by plants millions of years ago (Figure 1). It is found on every continent except Antarctica. There are at least five chemically distinct types of amber, depending on the botanical material from which the original exudate came from. Nuclear magnetic resonance (NMR) spectroscopy can distinguish these different botanical sources and provide a means of determining authenticity of amber and learning about its geographical sources.

More generally, exudates are complex mixtures of organic compounds produced by plants, usually as the result of injury or disease. Secreted as liquids, exudates may harden to solids in hours to months (Figure 2) on the surface of the plant. These materials have found numerous practical applications throughout human history, and they provide a molecular window to the classification of plants (taxonomy). We have found that exudates are remarkably robust and consistent in their molecular constitution within a single plant and from plant to plant within a given species. There are several, distinct chemical constitutions of exudates. Resins, which can form amber through fossilization, are composed of terpenoid compounds. Gums are made of polysaccharides. Gum resins like frankincense and myrrh contain both materials. Kinos contain phenols. Although these four chemical groups are the largest, there are several other smaller but distinct chemical groups,

We are carrying out a worldwide survey of plant exudates from all plant families, and of amber, necessitating field acquisition of materials and analysis by NMR in the lab. We also are examining the effect of heat on the molecular structure of amber and its slightly younger colleague, copal. Heat has been used to alter the properties of amber prior to carving. Spectroscopic examination of artificially heated samples may clarify how structure change with heating.
We are fascinated by the ways in which molecules stick together. In living systems there are many thousands of different types of molecules, each with its own shape and charge, and yet each molecule knows where to go--it "recognizes" its partner and sticks to it selectively; this molecular recognition is a central function of biochemistry. We study the recognition of proteins by non-natural organic molecules to help us better understand natural systems and to develop biomedical technologies. Students are involved in every aspect of the project, including designing and implementing the experiments, analyzing the data, and communicating the work through publications and presentations.

The overarching goal is to understand the structure and chemical reactivity of biological molecules, and to create new compounds that can selectively recognize them, giving us a way to control their activity. Drugs do this—they recognize a specific protein, bind tightly to it, and inhibit its normal activity. The ultimate challenge is to be able to design a drug that can selectively bind to any protein we want. Another important goal is to make “sensors” that bind to and reveal the presence and quantity of a target molecule, either by changing color or by producing light or electricity. Sensors are key components of medical diagnostics, such as a device that can measure the amount of a hormone in a patient’s blood (a blood test). We have recently developed the first synthetic receptor for insulin, and we are working to develop a method for measuring insulin concentration continually, which would improve the treatment of type 1 diabetes.

Students in the Urbach research group become proficient with a variety of techniques, even in their first year. These can include: 1) organic synthesis to make peptides and other small molecules; 2) protein expression and purification using molecular biology techniques; 3) protein semisynthesis; 3) NMR spectroscopy, mass spectrometry, and X-ray crystallography to characterize molecular structure; 3) microcalorimetry, stopped-flow spectroscopy, and gel electrophoresis to measure the thermodynamics and kinetics of binding; and 4) UV-visible, fluorescence, and circular dichroism spectroscopy to study electronic and structural properties. This combination of methods and approaches offers students a breadth of technique and depth of study that is an excellent foundation for further study in organic chemistry, biophysical chemistry, medicinal chemistry, biochemistry, bioengineering, and biotechnology.

The image at left shows an experimentally determined, high-resolution structure of our receptor, Q7 (the cyclic molecule that looks like a cage), binding to human insulin. This is the first synthetic receptor for insulin, and it is extraordinarily selective for insulin versus other proteins. This structure confirms our hypothesis that binding occurs at a specific amino acid residue, the terminal phenylalanine (Phe^B1, which fits inside the cage). A Trinity student in his first year of college grew the crystal of the complex shown at left, which was crucial for determining its structure. (Journal of the American Chemical Society, 2011, 133, 8810-8813).
Catalytic Adsorption Studies; Fuel Film Evaporation Studies

1. Adsorption Studies on Catalysts - Supported gold nanoparticles display unique and uncharacteristic catalytic activity as compared to bulk metallic gold. While bulk gold is well known for being chemically inert, highly dispersed gold nanoparticles exhibit exceptional catalytic activity for several reactions. Probably the most extensively studied reaction concerns the oxidation of CO. While the reaction appears to be simple and straightforward, a detailed understanding of the mechanism has been surprisingly difficult to achieve. Not only has this reaction been thoroughly studied as a model system, but what is believed to be the first step in the mechanism, namely the adsorption of CO on the gold nanoparticles, has also become a model interaction to investigate. In collaboration with Dr. Chandler (also in Chemistry), we have been examining the adsorption of gas phase CO to gold supported nanoparticle catalysts. Most recently we have also been examining the adsorption of H₂ on Au/TiO₂ catalysts. Using a special pressure/vacuum/temperature apparatus, along with infrared transmission spectroscopy, we are able to quantify the amount of CO or H₂ adsorbed.

![Figure 1: Infrared transmission spectra of CO adsorbed on Au/Al₂O₃ catalyst.](image)

![Figure 2: Thermodynamic plot for Au/TiO₂ and Au/Al₂O₃ catalysts.](image)

2. Fuel Film Evaporation Studies - This is a joint project with Dr. Kelly-Zion in the Engineering Science department. Thin films of fuel can be deposited in the interior of an automobile engine, especially under cold, initial operation. These fuel films lead to reduced performance and increased pollution. We are studying the evaporation process of model films (or droplets) that represent these automobile fuel films. The general goal of this research is to elucidate the complex coupling between the mass transport processes during the evaporation of multi-component films. As a film evaporates, its overall composition can change due to the preferential evaporation of the more volatile components. Both temperature and composition gradients are induced in the film and the physical properties may vary in both time and space. Fundamental studies, involving small hydrocarbons like hexane, include (1) gravimetric measurements to determine evaporation rates, (2) infrared spectroscopy to observe and quantify both the liquid and vapor concentrations during evaporation, and (3) use of an optical technique to capture the image of the vapor cloud above an evaporating thin film. The results of these studies are allowing us to better understand the transport mechanisms involved in the evaporation of thin liquid films.