UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2025

The National Center of Competence in Research (NCCR) Bio-Inspired Materials offers undergraduate students (from Switzerland and abroad) the opportunity to spend the summer break (8-12 weeks) participating in cutting-edge research within one of the Center's research groups. The undergraduate students have the opportunity to work on a research project and to interact with leading experts in their fields of interest and with fellow students from around the world. The students get a glimpse of advanced research work, gain desirable hands-on work experience, develop their transferable skills, and have the unique opportunity to explore career options and network with professionals. Beyond conducting research in the hosting lab, undergraduates participate in scientific lectures, social and networking events. At the end of the summer, the students present the results of their research projects in a poster session followed by a summer party. The students have the opportunity to learn about Switzerland from an insider perspective, and to take the first steps toward learning or practicing French and/or German language skills.

Requirements

To apply to the program, you need to fulfill the following conditions:

- Be a national of Switzerland, a member state of the European Union, or a country with a Visa exemption agreement with Switzerland for a maximum period of stay of 90 days;
- Be enrolled at a University as a full-time undergraduate student in a relevant field of natural sciences, such as medicine, biology, biochemistry, chemistry, physics or materials science;
- Be an undergraduate student having concluded a minimum of 2 years of a degree program by the start of the internship;
- Certify that you are and will be registered as an undergraduate at your University/College for the upcoming academic year;
- If you are studying in Switzerland, you cannot select a research project at the University where you are studying;
- Have very good (oral and written) English language skills (level B2/C1).

Terms of the research stay

Duration: 8-12 weeks; Only Period between June 15 – September 15

How to apply

Applicants must submit their applications online at www.bioinspired-materials.ch/

Applications are open from December 1, 2024, until January 20, 2025.

Project ID	Project title	Group	Field
P25-01_Acuna	Plasmonic sensing with DNA origami and rhodium nanoparticles	Acuna	Chemistry, Physics
P25-02_Acuna	DNA origami-based nanoantennas for studying light-matter interactions with single emitters	Acuna	Chemistry, Physics
P25-03_Acuna	Synthesis, characterization and application of DNA Origami plasmonic dimers in two-photon excitation	Acuna	Chemistry, Physics
P25-04_Acuna	DNA origami-based nanoantennas applied to the detection of cancer biomarkers	Acuna	Chemistry, Physics
P25-05_Clough	Watching bonds break in polymeric materials	Clough	Chemistry, Materials Science & Engineering
P25-06_Lattuada	Preparation of polymer membranes with aligned cylindrical pores	Lattuada	Chemistry, Materials Science & Engineering
P25-07_Mayer	Single-molecule detection of heterogeneous proteins with biological nanopores	Mayer	Biology, Chemistry, Physics
P25-08_Mayer	Engineering nanopores for single-molecule protein sensing	Mayer	Biology, Chemistry, Physics
P25-09_Steiner	Scale-up of guanine-based white pigment synthesis for industrial applications	Steiner	Chemistry, Physics, Materials Science & Engineering
P25-10_Steiner	Core-shell photonic microparticles for emission control of embedded fluorophores	Steiner	Chemistry, Physics, Materials Science & Engineering
P25-11_Steiner	Backfilling of organic photonic structures with high refractive index materials	Steiner	Chemistry, Physics, Materials Science & Engineering
P25-12_Steiner	Optical colloidal diamond self-assembly	Steiner	Chemistry, Physics, Materials Science & Engineering
P25-13_Steiner	Biomimetic fabrication of structural color from lipidic lyotropic liquid crystals	Steiner	Chemistry, Physics, Materials Science & Engineering
P25-14_Stellacci	Assembly path and structural characterization of lipid rich biocomposites	Stellacci	Chemistry, Biology, Materials Science & Engineering
P25-15_Stellacci	Deciphering the role of small molecules in protein stability	Stellacci	Chemistry, Biology, Materials Science & Engineering
P25-16_Vanni	The molecular basis of protein liquid-liquid phase separation by small molecules and metabolites - insights from molecular dynamics simulations	Vanni	Biology, Biochemistry, Chemistry, Physics
P25-17_Weder	Water-soluble mechanophore for visualizing mechanical force in aqueous systems	Weder	Chemistry, Materials Science & Engineering
P25-18_Weder	Bio-inspired artificial muscles	Weder	Chemistry
P25-19_Weder	Design, synthesis and characterization of new polymeric materials comprising more than one supramolecular motif in a single chain	Weder	Chemistry, Materials Science & Engineering
P25-20_Weder	Electric-fish inspired ion-gradient hydrogel batteries	Weder	Chemistry, Materials Science & Engineering

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Project ID	**URI P25-01_Acuna**
Project title	**Plasmonic sensing with DNA origami and rhodium nanoparticles**
Research group	Prof. Guillermo Acuna https://www.unifr.ch/phys/en/research/groups/acuna/
Host Institution	Department of Physics, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

While a macroscopic piece of gold is yellow, gold nanoparticles can be all colors from red to purple. The vivid color of gold and other plasmonic nanoparticles is the result of the excitation of the resonance of surface plasmons on their surface. A more useful consequence of this interaction is the amplification of the electric field around them, which is used to enhance the signal in various spectral methods such as fluorescence, SERS, or circular dichroism. To date, scientific interest has focused on the use of nanoparticles with resonances in the VIS-IR region. However, the use of nanoparticles in the UV range can be very beneficial, for example for fluorescence measurements of proteins without labeling them with fluorophores. One of the main candidates for UV detection is rhodium nanoparticles. However, so far relatively few attempts have been made to realize UV detection using these nanoparticles.

The aim of this project is to realize UV plasmonic detection using rhodium nanoparticles. This will be achieved by synthesizing nanoparticle dimers from DNA origami, which can then be used for fluorescence and SERS measurements.

Keywords: Rhodium nanoparticles, DNA origami, sensing.

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Research Projects Summer 2025

Project ID	**URI P25-02_Acuna**
Project title	**DNA origami-based nanoantennas for studying light-matter interactions with single emitters**
Research group	Prof. Guillermo Acuna https://www.unifr.ch/phys/en/research/groups/acuna/
Host Institution	Department of Physics, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

Light and matter can experience significant modifications through the utilization of nanoscale antennas. In particular, properties of fluorescent molecules such as lifetime, fluorescence intensity, or spectrum can be influenced by the presence of antennas. Such effects have been shown to have applications in the fields of biosensing, fluorescence imaging, and wireless communication, among others. However, precise study of these interactions requires accurate positioning and stoichiometry, something challenging to achieve with conventional top-down nanofabrication techniques. In our group, we employ the DNA origami technique to achieve precise positioning of individual fluorophores and nanoparticles within predefined geometries. By tuning various geometrical parameters and utilizing different types of nanoparticles, we aim to examine their influence on emission properties of adjacent fluorophores that have not yet been explored, such as polarization or chirality, and investigate their possible applications for sensing or quantum optics.

Keywords: Fluorescence microscopy, single-molecule emission, nanoantennas, DNA origami.

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Research Projects Summer 2025

Project ID	**URI P25-03_Acuna**
Project title	**Synthesis, characterization and application of DNA Origami plasmonic dimers in two-photon excitation**
Research group	Prof. Guillermo Acuna https://www.unifr.ch/phys/en/research/groups/acuna/
Host Institution	Department of Physics, University of Fribourg
Duration	10 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

The DNA Origami technique is a nanotechnology method based on base pairing of complementary oligonucleotides to synthesize complex and arbitrary 3D nanostructures. The high specificity and programmability of DNA make the technique an attractive tool for the bottom-up assembly of various nanosheets to produce functional nanostructures for a variety of applications. Among these, the most common use is of the plasmonic properties of nanoparticles, which, with the help of DNA origami, can be used to produce nanoantennas that increase signal intensity in spectral methods. A good example of a spectral method in which DNA origami-based nanoantennas can find application is two-photon excitation. Two-photon excitation is the transition of electrons in molecules during the absorption of two photons, usually of near-infrared wavelength. It is a widely used technique in many fields including physiology, neuroscience, and embryology. However, it relies on the measurement of large amounts of fluorophores, which severely limits its use for understanding biological processes at the single-entity level and early detection of disease.

Keywords: Two-photon excitation, plasmonic nanoparticles, DNA origami.

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Research Projects Summer 2025

Project ID	**URI P25-04_Acuna**
Project title	**DNA origami-based nanoantennas applied to the detection of cancer biomarkers**
Research group	Prof. Guillermo Acuna https://www.unifr.ch/phys/en/research/groups/acuna/
Host Institution	Department of Physics, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

DNA origami technique is a methodology consisting of folding long, single-stranded DNA molecules into arbitrary three-dimensional nanostructures. This technique enables the development of plasmonic nanostructures with novel optical properties, such as optical nanoantennas (OAs), by accurately arranging metal nanoparticles (MNP) on DNA origami templates. Dimer OAs typically consist of two MNP placed in close vicinity forming a nanometric gap. The fluorescence signal of an individual fluorophore precisely positioned in this gap can be enhanced by several orders of magnitude and this phenomenon holds great potential in the field of biosensing. The optical response of OAs is determined by the size, shape, and material composition of the elements, gap geometry, and optical properties of the surrounding medium.

During the internship, you will learn the synthesis and characterization of OAs based on MNP and DNA origami templates; such particles have a potential application in the development of highly sensitive bioassays for cancer biomarker detection. You will acquire knowledge in optical and electron microscopy by using wide-field microscopy and transmission electron microscopy to characterize the nanostructures.

Keywords: DNA origami, metal nanoparticles, biosensing, electron microscopy, fluorescence microscopy.

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Research Projects Summer 2025

Project ID	**URI P25-05_Clough**
Project title	**Watching bonds break in polymeric materials**
Research group	Prof. Jessica Clough https://www.ami.swiss/mechanoresponsive/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	10 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

Nature is full of incredible examples of how mechanical forces can be used for practical purposes—like how our ears detect sound or how some plants use traps to catch prey. However, in synthetic polymeric materials, mechanical forces cause damage and failure, often by the formation of cracks, cavities, and crazes. Our group works on the development of molecular force sensors, or mechanophores. When incorporated in polymers, these sensors produce an optical signal in response to force, allowing us to detect molecular damage and develop a better understanding of the mechanical failure of these materials. In this project, you will prepare and characterize polymers functionalized with fluorescent coumarin-based mechanophores by, e.g., UV/vis and fluorescence spectroscopy, SEC, NMR, DMA, and tensile testing. You will also learn cutting-edge techniques, such as confocal and single-molecule localization microscopy, to study how small cracks form and propagate—before they lead to permanent damage and mechanical failure of the material. Experience in synthetic chemistry and polymer characterization is helpful but not required. If you have a chemistry or materials science background, we can tailor the focus of the project to suit your skills and goals.

Keywords: Polymers, coumarin, mechanophores, fluorescence microscopy, force transduction.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
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Research Projects Summer 2025

Project ID	**URI P25-06 Lattuada**
Project title	**Preparation of polymer membranes with aligned cylindrical pores**
Research group	Prof. Marco Lattuada https://www.unifr.ch/chem/en/research/groups/lattuada/
Host Institution	Department of Chemistry, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

Polymer membranes are used in various fields, including filtration, separation, energy generation, and biomedical devices. One of their most distinguished features is their porosity. Preparing membranes with well-aligned pores is advantageous, as it increases their performance in reaching a higher permeability, improved selectivity, and reduced fouling. This project aims to improve a method developed in our group to prepare polymer membranes with aligned pores. The technique uses a sol-gel process to create a silica skeleton monolith made of well-aligned strands by incorporating magnetic colloids in the silica sol-precursor in a uniform magnetic field. After gelation, the solvent is removed, and the voids are filled with a monomer solution, which is polymerized. Then, the silica is removed using hydrofluoric acid, leaving long aligned cylindrical pores. The various steps of the process will be optimized to control the pore size and the mechanical properties of the membranes. During the internship, you will learn to synthesize polymer magnetic colloids, characterize particles using scattering methods and materials using electron microscopy, and perform filtration experiments to test the performance of membranes.

Keywords: Membranes, self-assembly, templating, magnetic alignment.

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Research Projects Summer 2025

Project ID	**URI P25-07_Mayer**
Project title	**Single-molecule detection of heterogeneous proteins with biological nanopores**
Research group	Prof. Michael Mayer https://www.ami.swiss/biophysics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

Biological nanopores are emerging as powerful tools for single-molecule sensing in both fundamental science and industry. Currently, the characterization of natively folded proteins in complex, heterogeneous samples remains a significant challenge.

Recently, we developed a large-diameter biological nanopore—poly(C9) nanopore—with a diameter approaching 10 nm. This innovation enables the characterization of a wide range of natively folded proteins with unprecedented sensitivity.

In this project, we will utilize poly(C9) nanopores to profile human serum samples. This work offers students the opportunity to learn about modern methods for single-molecule detection and gain hands-on experience with techniques such as biological nanopores, mass photometry, protein gel electrophoresis, and size-exclusion chromatography. The project will take place within a dynamic and collaborative team of postdocs and PhD students. Participants will gain insights into single-molecule protein characterization while making meaningful contributions to an active research project.

Keywords: Proteins, single-molecule detection, biomolecule sensings.

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Research Projects Summer 2025

Project ID	**URI P25-08_Mayer**
Project title	**Engineering nanopores for single-molecule protein sensing**
Research group	Prof. Michael Mayer https://www.ami.swiss/biophysics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

Measurement of ionic current through nanopores permits the single-molecule level characterization of analytes in a label-free manner in solution. Biological nanopores have emerged as powerful tools to detect unfolded proteins, DNA, and polymers. Recently, we developed large-diameter biological nanopores to facilitate the entry of large, globular molecules. However, a long-standing challenge is implementing specific interfaces for detecting proteins. We wish to explore the possibility of engineering the biological nanopore by chemical modifications to accommodate specific full-length folded proteins. The student will help us in our efforts to develop protocols for bioanalytical protein sensing at a single molecule level using biological nanopores.

Keywords: Proteins, single-channel measurements, biosensors.

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Research Projects Summer 2025

Project ID	**URI P25-09 Steiner**
Project title	**Scale-up of guanine-based white pigment synthesis for industrial applications**
Research group	Prof. Ullrich Steiner https://www.ami.swiss/physics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

Titanium dioxide is widely used in industry as a white pigment due to its excellent optical properties but has been banned as a food additive in the EU due to health concerns. This project seeks to develop a sustainable, edible alternative based on guanine crystals, inspired by marine organisms that use these crystals to produce bright structural colors.

To achieve this, we will scale up the synthesis of guanine-based white pigments using two methods:

(1) One-Step Recrystallization—dissolving guanine in a basic solution with an analog, then mixing it with a non-miscible solvent and copolymer at 40°C;

(2) Inverse Emulsion Method—creating spherical guanine particles through an inverse emulsion.

Optical characterizations will measure the whiteness and brightness of the pigments, comparing them to titanium dioxide to assess their industrial viability.

Keywords: Guanine, white pigments, crystallization control, light-scattering.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
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Research Projects Summer 2025

Project ID	**URI P25-10_Steiner**
Project title	**Core-shell photonic microparticles for emission control of embedded fluorophores**
Research group	Prof. Ullrich Steiner https://www.ami.swiss/physics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

The goal of this project is to create polymeric microspheres that can control and change the light-emitting properties of fluorophores. To do this, we will fabricate "photonic particles" made of block copolymer concentric layers. The first step is to study how these structures can be formed using a self-assembly process, where the used materials naturally arrange themselves in the desired arrangement. Once we understand and can reliably produce the process, we will encapsulate a light-emitting core inside each microparticle. Then, we will evaluate how factors such as particle size and shape, layer spacing, and type of embedded fluorophore affect the light emitted by the core.

The fabricated core-shell structures will be characterized by using microscopy and spectroscopic techniques.

Keywords: Photonic microparticles, block copolymers, emitting materials, self-assembly.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS

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Research Projects Summer 20254

Project ID	**URI P25-11_Steiner**
Project title	**Backfilling of organic photonic structures with high refractive index materials**
Research group	Prof. Ullrich Steiner https://www.ami.swiss/physics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

The project aims to fabricate photonic structures with a controlled degree of order/disorder. To achieve such an objective, organic photonic structures will be first prepared and subsequently backfilled with high-refractive-index inorganic materials, such as titanium dioxide. The candidate will be responsible for exploring and optimizing the backfilling strategies to achieve a uniform infiltration of the initial organic structures, which will then be removed by high-temperature treatment. Therefore, key tasks will include sample preparation and characterizing the resulting optical and structural properties using advanced microscopy and spectroscopic techniques. This hands-on project will not only deepen the student's understanding of material deposition processes, but also provide valuable insights into creating photonic devices with applications in sensing, imaging, and optical signal processing.

Keywords: Photonics, high-refractive-index materials, backfilling, sol-gel chemistry.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
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Research Projects Summer 2025

Project ID	**URI P25-12_Steiner**
Project title	**Optical colloidal diamond self-assembly**
Research group	Prof. Ullrich Steiner https://www.ami.swiss/physics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

Nature displays the beautiful structural color in the scales of insects, where bright colors often emerge from periodic diamond or disordered diamond-like morphologies. This aims to artificially reproduce these natural structures and their optical properties, thus establishing a toolbox system to investigate the unique properties of diamond-like structures.

The fabrication exploits the self-assembly of patchy particles, which consist of tetrameric colloids created through the coordination of solid polymer nanoparticles and liquid oil nanodroplets mediated by DNA strands. These nanosized building blocks determine the final self-assembled morphologies solely due to their shape and number of binding sites.

This project focuses on the control and investigation of the self-assembly process to gain control over the degree of order/disorder in the system. We use a combination of state-of-the-art microscopy techniques to analyze the resulting structure and its optical response (fluorescence, SEM, FIB-SEM).

Keywords: Soft matter physics, colloidal diamond, DNA self-assembly, microscopy.

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Research Projects Summer 2025

Project ID	**URI P25-13_Steiner**
Project title	**Biomimetic fabrication of structural color from lipidic lyotropic liquid crystals**
Research group	Prof. Ullrich Steiner https://www.ami.swiss/physics/en/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

The most striking colors in nature, such as those in peacocks, morpho butterflies, abalone shells, and Pollia fruits, arise from structural color. This phenomenon results from transparent materials with nanoscale structures. Our goal is to fabricate such vibrant colors using only biomolecules to create sustainable photonic pigments, while also gaining insight into the natural process of photonic crystal formation.

In this project, the student will address the following challenges: (i) scaling the lipid vesicles to photonic dimensions, and (ii) developing a method to preserve the nanostructure geometry after dehydration, as in the sclerotization of butterfly wings.

The student will learn nanostructure fabrication of lipidic lyotropic liquid crystals from oleic acid and monoolein through extrusion and apply characterization methods such as dynamic light scattering, fluorescence microscopy, microphotospectrometry, and electron microscopy. Additional techniques like lyophilization and solvent temperature annealing will also be explored.

Keywords: Biomimetic, nanofabrication, structural color, lipidic lyotropic liquid crystals.

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Research Projects Summer 2025

Project ID	**URI P25-14_Stellacci**
Project title	**Assembly path and structural characterization of lipid rich biocomposites**
Research group	Prof. Francesco Stellacci https://www.epfl.ch/labs/sunmil/
Host Institution	Supramolecular NanoMaterials and Interfaces Laboratory, EPF Lausanne
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

Traditionally, lipid bilayers in matrix vesicles are known to initiate mineralization. However, recent findings indicate the presence of lipids within mineralized structures, bound to minerals and proteins, which may influence material properties—a largely uninvestigated area warranting further study. The research focus of this proposed study is the manipulation of inorganic phases by organic macromolecules to create lipid-rich, biocomposite-based constructs and study their structural and mechanical properties. This study will encourage the design and synthesis of biocomposites which are materials composed of biologically sourced components and are being increasingly studied for their suitability in biomedical applications due to their biocompatibility, biodegradability, and low toxicity. An example of such a naturally occurring material is mineralized bone, a biocomposite of hydroxyapatite, collagen, proteins, and lipids and although extensive research on bone mineralization exists, most studies emphasize biological mechanisms rather than material properties, particularly overlooking the role of lipids. The participants of this study will be able to gain hands-on experience in material characterization both from thermodynamic and instrumental perspectives. To understand the complex interfacial chemistry, we will use appropriate microscopic (TEM, AFM, SEM etc.), spectroscopic, and diffraction (FTIR, Raman, XRD, SAXS etc.) techniques. Theoretical calculations and models will be developed to understand the energetics of assembly and interaction.

Keywords: Biomineralization, biocomposites, lipid-rich biocomposites, mineralization mechanism.

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Research Projects Summer 2025

Project ID	**URI P25-15_Stellacci**
Project title	**Deciphering the role of small molecules in protein stability**
Research group	Prof. Francesco Stellacci https://www.epfl.ch/labs/sunmil/
Host Institution	Supramolecular NanoMaterials and Interfaces Laboratory, EPF Lausanne
Duration	12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

The stabilization and destabilization of protein solutions by small molecules (SMs) like proline and urea are well-documented phenomena with wide implications in both biology and industry. However, understanding the mechanisms underlying these effects remains elusive. For example, the literature suggests that proline stabilizes and urea destabilizes proteins, yet explanations vary, attributing effects to either direct protein interactions or alterations in water structure that influence protein folding and aggregation. This proposed study investigates whether such effects are universal across different proteins and conditions and explores the biochemical mechanisms by which SMs modulate protein stability. Despite advances, the field lacks a unifying theory that accurately predicts SM effects on protein stability and dispersions, especially considering the influence of factors like salt concentration and pH. The participants of this study will be able to gain hands-on experience in material characterization both from thermodynamic and instrumental perspectives. To understand the complex interfacial chemistry, we will use appropriate microscopic (TEM, AFM, SEM etc.), spectroscopic, and diffraction (FTIR, Raman, XRD, SAXS etc.) techniques. Theoretical calculations and models will be developed to understand the energetics of assembly and interaction.

Keywords: Protein stability, protein interactions, protein stabilization mechanism.

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Research Projects Summer 2025

Project ID	**URI P25-16_Vanni**
Project title	**The molecular basis of protein liquid-liquid phase separation by small molecules and metabolites - insights from molecular dynamics simulations**
Research group	Prof. Stefano Vanni https://www.unifr.ch/bio/en/research/bioinformatics/vanni.html
Host Institution	Department of Biology, University of Fribourg
Duration	8 to 12 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

Intrinsically disordered proteins (IDPs) represent a unique class of biomolecules lacking a well-defined three-dimensional structure. Many IDPs commonly undergo liquid-liquid phase separation (LLPS) to form membrane-less organelles in the cell, contributing to the regulation of intracellular biochemical reactions. Dysregulation of these liquid droplets/condensates can also lead to the formation of neurotoxic oligomers/fibrils, causing several disorders. The aggregation propensity of IDPs is influenced by various factors, and characterization of interaction dynamics is a challenging task.

In this project, we aim to leverage simulation techniques, such as molecular dynamics, to investigate the underlying driving forces behind the LLPS of various IDPs and their regulation by small molecules and metabolites. These simulations will enable us to explore the multi-chain association processes of these proteins at different lengths and time scales and in diverse environmental conditions.

Keywords: Intrinsically disordered proteins, molecular dynamics simulation, liquid-liquid phase separation (LLPS).

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National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2025

Project ID	**URI P25-17_Weder**
Project title	**Water-soluble mechanophore for visualizing mechanical force in aqueous systems**
Research group	Prof. Christoph Weder https://www.ami.swiss/en/groups/polymer-chemistry-and-materials/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	10 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

Mechanical forces, such as tension and compression, are widespread in nature and play a role in the growth and development of living organisms. Materials exposed to mechanical forces, including grinding, shearing, and tensile stress, can undergo deformation that may lead to damage or even failure. To probe force-induced deformation or damage, molecular force sensors known as mechanophores have been developed. These motifs transduce mechanical into optical signals, enabling direct visible detection. However, due to the hydrophobic properties of many mechanophores, their application has largely been limited to organic systems, with few applications in aqueous environments. In this project, we aim to develop new water-soluble mechanophores to facilitate the probing of mechanical effects in aqueous systems. The mechanophore will be functionalized with hydrophilic groups and integrated into different polymer networks for mechanical testing. This project can be tailored to the applicant's interests, with a focus on mechanophore synthesis, material characterization, or mechanical testing.

Keywords: Mechanophore, mechanochromic polymer, polymer networks.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2025

Project ID	**URI P25-18_Weder**
Project title	**Bio-inspired artificial muscles**
Research group	Prof. Christoph Weder https://www.ami.swiss/en/groups/polymer-chemistry-and-materials/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	10 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

Living organisms' ability to convert energy into motion has inspired artificial muscle development. However, replicating the nuanced actuation of mammalian muscles is still a major challenge. Powerful artificial muscles often rely on rigid materials that lack compatibility with soft tissues, while softer versions fall short of strength.

This project aims to bring us closer to nature's engineering by creating bio-inspired artificial muscles using composite materials. Our design combines the strength of rigid nanoparticles with the ductility and biological relevance of hydrogels. To enable actuation, we will use stimuli-responsive polymers that react to external inputs, and to mimic the directional motion of muscles, the colloidal particles will be oriented and locked within the composite hydrogels.

The material will be evaluated for its ability to mimic muscle-like movement, advancing synthetic muscles for soft robotics and biomedicine applications.

Keywords: Stimuli-responsive polymers, artificial muscles, hydrogels, actuation.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2025

Project ID	**URI P25-19_Weder**
Project title	**Design, synthesis and characterization of new polymeric materials comprising more than one supramolecular motif in a single chain**
Research group	Prof. Christoph Weder https://www.ami.swiss/en/groups/polymer-chemistry-and-materials/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	10 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

Supramolecular interactions are ubiquitous in Nature and exist at the base of Life as we know it. DNA strands, for example, are held together primarily by hydrogen bonds, whereas metal-ligand interactions govern oxygen transport in blood via hemoglobin. As materials chemists, we often look at naturally occurring structures, operating principles, and phenomena for inspiration to develop novel materials with interesting properties. Supramolecular interactions are introduced into polymeric materials to endow them with new functions, including stimuli responsiveness. In this project, we will explore new polymeric materials that comprise different types of supramolecular motifs in each polymer molecule. We will study the mechanical characteristics of these polymers and explore how they differ from polymers with one single supramolecular motif. We expect to see orthogonality in their responsiveness to different stimuli, which could lead to new functions such as shape memory and increased toughness. The project will comprise all aspects of polymer engineering, including monomer and macromolecular synthesis, as well as polymer physicochemical and thermomechanical characterization.

Keywords: Polymer synthesis, mechanical characterization, stimuli-responsive.

UNDERGRADUATE SUMMER RESEARCH INTERNSHIPS
National Center of Competence in Research for Bio-Inspired Materials

Research Projects Summer 2025

Project ID	**URI P25-20_Weder**
Project title	**Electric-fish inspired ion-gradient hydrogel batteries**
Research group	Prof. Christoph Weder https://www.ami.swiss/en/groups/polymer-chemistry-and-materials/
Host Institution	Adolphe Merkle Institute, University of Fribourg
Duration	10 weeks
Possible period	**Period 15 June - 15 September including 21.08.2025**

Project summary

Currently available battery systems have limitations that complicate or prevent their use under extreme environmental conditions such as posed by aerospace

applications or biomedical devices. In recent years, the electric organs of several electric fish have inspired the development of novel hydrogel-based power sources. These batteries consist of ion-containing reservoirs with different ion concentrations that are separated by anion- and cation-selective membranes.

The gradient in ion concentration generates an electric potential difference that can be harvested. This new concept for the design of soft batteries opens the door for future technologies but their performance must be considerably increased before they approach the functionality of the biological models. In this project, new ion-selective polymeric membranes and ion-containing gels will be developed and their electrical, thermal, and mechanical properties will be characterized. Complete batteries will be constructed and measured with the aim of exploring how the variation of the various components affects the device's performance.

Keywords: Bio-inspired polymers, membranes, ion-gradient batteries, hydrogels.