Activities report 2018–2019

National Center of Competence in Research Bio-Inspired Materials

FNSNF
SWISS NATIONAL SCIENCE FOUNDATION

BIO-INSPIRED MATERIALS
NATIONAL CENTER OF COMPETENCE IN RESEARCH

Who we are

The National Center of Competence in Research (NCCR) Bio-Inspired Materials was launched in June 2014 with the vision of becoming an internationally recognized interdisciplinary hub for research, education, and innovation in the domain of "smart" bio-inspired materials.

We take inspiration from natural materials to establish design rules and strategies for the creation of macromolecular and nanomaterial-based building blocks and their assembly into complex, hierarchically ordered stimuli-responsive materials with new and interesting properties. We seek to develop a predictive understanding for the interactions of these materials with living cells and use the generated knowledge to develop innovative applications, particularly in the biomedical field.

For the second phase of our activities, our research is organized in four modules that focus on mechanically responsive materials across different length scales, biologically inspired assembly of optical materials, responsive bio-interfaces and surfaces, and dynamics of interacting cell-material systems, respectively. Each of these modules tackles major unsolved problems, provides opportunities for great scientific advances, and requires an interdisciplinary research approach. Our research activities are complemented with many programs that integrate research and education, support structured knowledge and technology transfer, and promote equal opportunities in science.

Table of contents

5

Message from the directors

The NCCR Bio-Inspired Materials enters its second phase, with new members joining, and innovative projects being added.

8

Research

From understanding the true nature of structural color, dealing with skin cancer, and developing tough new materials.

36

Initiatives

Improving equality, understanding the impact of our undergraduate internships, reaching a wider public, and boosting startups are once again at the heart of the Center's initiatives.

Content

Message from the directors

Dear reader

In the last year, the NCCR Bio-Inspired Materials entered its second funding phase under optimal circumstances, as reflected by several key developments presented in this activities report.

Our Center now enjoys a significantly increased funding level compared to the previous phase from its Home Institution, the University of Fribourg, which is an important step towards a future stabilization after our Swiss National Science Foundation funding ends. Our NCCR also saw a large augmentation of SNSF support after the agency endorsed the Center's expansion plan. Our outstanding performance in the first phase was also rewarded with a substantial bonus. These additional funds enabled us to launch a highly interdisciplinary and integrative research module. This program unites the expertise of most of the Center's groups and aims to develop a microfluidic organoid culture platform for the study of tissue and disease biology in combination with innovative delivery systems and detection methods.

Now in its second phase, the Center has grown from 18 to 21 research groups, with over 120 researchers from 35 nations. Collaborative projects increased further, strengthening the positive evolution of our NCCR. Scientific output remained excellent, with 85 papers published in the last business year, 30% of which appeared in journals with an impact factor higher than 10. This impressive figure underlines the quality of our work, and confirms earlier strategic decisions. Besides conducting excellent research, Center members also secured in the last year CHF 1 million in external funding for translational projects, and two additional spinoffs were incorporated.

Our NCCR is committed to supporting the careers of talented non-tenured academics. Recently, its Incentive Program facilitated the appointment of two new professors, whose research topics are aligned with the general goals of our Center, at the University of Fribourg. These incentives were followed up by the integration of Professors Acuna and Salentinig in our NCCR as full PI and associate PI, respectively.

We were again very active in educational and outreach activities, reaching hundreds of students from elementary school to the undergraduate level, as well as high school teachers and the general public. The largest instance was recorded with the exhibition "Inspiration Natur-e" at the Fribourg Museum of Natural History between October 2018 and March 2019. Curated by our Center, it helped over thirty thousand visitors realize the importance of bio-inspiration in a selection of key technologies.

The start of our second phase also marked the launch of the NCCR's Equal Opportunities Envoys Program, which seeks to transfer our Center's most successful EO actions to our research groups' departments at the University of Fribourg, EPFL, and ETHZ. The program's first results can already be seen in the form of gender equality round tables at the EPFL, our involvement in the restructuration of the Home Institution's Equal Opportunities Faculty Commission, and the extension of the Center's activities at the faculty level.

We hope that this activities report conveys our team's passion and enthusiasm for our work, and we look forward to interacting with you in the future.

Christoph Weder & Curzio Rüegg
Directors NCCR Bio-Inspired Materials

Californai poppies are just one example of structural color.

New mechanism

Weevil structure points to more vivid colors

Researchers from the NCCR Bio-Inspired Materials and Yale-NUS College in Singapore have discovered a novel color-generation mechanism in nature that, if it can be translated into artificial materials, has the potential to create cosmetics and paints with purer and more vivid hues, screen displays that project the same true image when viewed from any angle, and even reduce the signal loss in optical fibers.

Using high-energy X-rays, scanning electron microscopy, and optical modelling, NCCR researcher Dr. Bodo Wilts of the Adolphe Merkle Institute and Yale-NUS Assistant Professor Vinodkumar Saranathan examined the rainbow-colored patterns in the elytra (wing casings) of a snout weevil from the Philippines, *Pachyrrhynchus congestus pavonius*. They discovered that to produce its rainbow palette of colors, the weevil shares a color-generation mechanism that has so far only been found in squid, cuttlefish, and octopuses.

The so-called "rainbow" weevil is distinctive for the rainbow-colored spots on its thorax and elytra. These spots are made up of nearly circular scales that are arranged in concentric rings of different hues, ranging from blue in the center to red on the outside, just like a rainbow. While many insects have the ability to produce one or two colors, it is rare that a single insect can exhibit such a vast spectrum of colors. The AMI and Singapore researchers have been investigating the mechanism behind the natural formation of these color-generating structures, as current technology is unable to synthesize structures of this size.

"The ultimate aim of our research in this field is to figure out how the weevil self-assembles these structures, because so far we are unable to do so," explains Wilts. "The ability to produce these structures, which are able to provide a high color fidelity regardless of the angle from which they are viewed, could be useful for applications in any industry where vivid and diverse colors are desired. We could use these structures in cosmetics and other pigmentations to ensure high-fidelity hues, or in digital displays in your phone or tablet, which would allow you to view it from any angle and see the same true image without any color distortion. We could even use them to make reflective cladding for optical fibers to minimize signal loss during transmission."

> "We could use these structures in cosmetics and other pigmentations to ensure high-fidelity hues, or in digital displays in your phone or tablet."
> Bodo Wilts

The "rainbow" weevil is distinctive for the multi-hued spots that cover its body.

Wilts and Saranathan examined these scales and determined that the scales were composed of a three-dimensional crystalline structure made from chitin, the main component of insect exoskeletons. They discovered that the vibrant rainbow colors on this weevil's scales are determined by two factors: the size of the crystal structure that makes up each scale, as well as the volume of chitin used to make up the crystal structure. This means that larger scales with larger crystals and more chitin reflect red light, while the smaller scales with smaller crystals and less chitin reflect blue light.

"The architecture exploited by the weevil is different from the usual strategy employed by nature to produce various different hues on the same animal, where the chitin structures are of fixed size and volume, and different colors are generated by orienting the structure at different angles, which reflects different wavelengths of light," says Saranathan. Having previously examined over 100 species of insects and spiders and catalogued their color-generation mechanisms, he adds that this ability to simultaneously control both size and volume factors to fine-tune the color produced has never before been shown in insects and, given its complexity, is quite remarkable.

Reference

Reference: Wilts, B. D.; Saranathan, V. A Literal elytral rainbow: Tunable structural colors using single diamond biophotonic crystals in Pachyrrhynchus Congestus weevils, Small, 2018, 14, 1802328.

Pollen can serve as inspiration for nanocontainers.

22

Seminars

by NCCR researchers

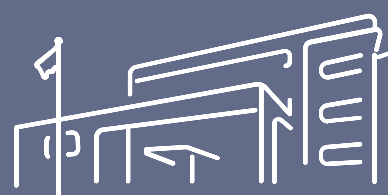
CHF 1 million

of external funding

in translational projects including 3 BRIDGE, 1 Gebert Rüf Foundation, 2 ETHZ Pioneer Fellowships, and 1 Ypsomed Innovation Award

Headquarters

Adolphe Merkle Institute, University of Fribourg



20

Research groups

4

international conferences supported

2

industrial associates

1 journal special issue (Chimia)

highlighting the NCCR's activities through 18 contributions

19

undergraduate students

hosted for the NCCR's Summer Internships

Note: All figures between March 1, 2018 and February 28, 2019

Tougher

Mother of pearl inspires better composites

NCCR Bio-Inspired Materials researchers at the Swiss Federal Institute of Technology in Zurich (ETHZ) are investigating improved composites, using nacre found in mollusk shells as an example of a lightweight material with exceptional strength.

Nacre, commonly called mother of pearl, is a biological composite found in mollusks such as abalone. It displays an exceptional combination of strength and fracture-resistant behavior, despite being constituted of weak mineral building blocks. Viewed under a scanning-electron microscope, the material looks like a miniature brick wall with mortar joints. The bricks are actually nano-scale calcium carbonate plates that are stacked upon one another and connected by mineral bridges, while the spaces in between are filled with an organic "mortar."

NCCR Bio-Inspired Materials Principal Investigator Professor André Studart and his team have been investigating the structure-property correlations in nacre with the goal of establishing guidelines for lightweight composite design. To achieve this, they fabricated tunable nacre-like brick-and-mortar composites from magnetically aligned alumina microplatelets that are interconnected by titanium dioxide mineral bridges, and sealing off the empty spaces with a polymer.

According to Studart and his colleagues, these bridges play an important role in the fracture resistance of nacre-inspired materials, and the researchers established a model that isolates and quantifies the influence of mineral bridge density on the composite's fracture properties. In other words, the model allows them to evaluate how many of these bridges are necessary to maximize the fracture strength of the composite.

The results of this research, published in the influential journal Proceedings of the National Academy of Sciences, allowed the scientists from the ETHZ Complex Materials group to demonstrate that the number of mineral bridges per platelet can be tuned to enhance the composite's ability to carry a mechanical load. Because the model synthetic material is structured from ceramic constituents at the same length scale as biological nacre, it sheds light on the fundamental role of mineral bridges in natural brick-and-mortar structures while also demonstrating outstanding mechanical properties that compete with state-of-the-art composite materials.

"We are able to create composites with an unparalleled combination of strength and fracture resistance, achieving a new record within

The NCCR researchers took their inspiration from abalone shells.

nacre-like composites, while demonstrating the same stiffness as high-performance carbon fiber composite materials," explains Studart.

According to the researchers, these design principles can be directly and easily integrated

"We are able to create composites with an unparalleled combination of strength and fracture resistance."
André Studart

into composites. The proposed technique could be used to tailor regions of a composite for complex mechanical load introduction, such as bolted joints. Other possible applications could include the use of sacrificial surface layers against abrasion in turbine blades, mounting nacre-like architectures to the leading edge of a foil for aircraft for impact resistance, or even on high friction surfaces where protection from wear and abrasion are of paramount importance.

Reference

Grossman, M.; Bouville, F.; Masania, K.; Studart, A. R. Quantifying the role of mineral bridges on the fracture resistance of nacre-like composites, PNAS, 2018, 115, 12698-12703.

Mechanochromic

New approach for self-reporting materials

NCCR Bio-Inspired Materials researchers led by Principal Investigator Professor Christoph Weder (Adolphe Merkle Institute) continue to investigate polymers that change their color as the result of damage or stress, and which can thereby indicate potential damages inflicted upon them.

Polymers that display this so-called mechanochromic behavior could be used to help prevent catastrophic failure in structures where they play a crucial role, as they provide readily perceptible optical cues. Previous research has focused largely on applications that can be detected on the macroscopic scale. However, scientists are now investigating applications to sense microscopic defects, aging, wear, and fatigue in materials. Besides limiting the resistance of structural components, this type of damage can eventually lead to larger defects, and potentially to disaster. Mechanochromic polymers could therefore have a significant impact as self-reporting materials in industries such as aviation, car manufacturing, construction, and healthcare. This built-in monitoring technology could also allow maintenance to be carried out on a as-needed basis, rather than having to adhere to strict schedules.

One strategy to induce mechanochromic behavior in polymers has been to incorporate motifs known as mechanophores, which usually contain weak bonds that dissociate when activated by mechanical forces, leading to color changes.

Another approach to designing these color-changing polymers is to incorporate microcapsules containing a dye. When they are damaged, the capsules release the dye, which is then activated by a physical or chemical change. This technique has been used, for example, for carbonless copy paper and in pressure-monitoring films. In a recent study, the NCCR researchers used this approach in connection with a “solvatochromic” dye, i.e., a compound whose color changes with the nature of its environment.

> “If you change the polymer matrix, or switch the type of solvent used, you obtain a variety of different color responses.” Céline Calvino

The NCCR researchers incorporated the solvatochromic dye and the solvent in microcapsules, and embedded the latter in several matrix polymers. When these composites are exposed to damage or excessive stress, the dye solution

Solvatochromic polymers could help detect weaknesses in materials before catastrophic failure occurs.

escapes the capsule, the solvent evaporates, and the dye molecules find themselves surrounded by polymer instead of solvent, which triggers a pronounced and permanent color change.

"These systems are extremely versatile," says NCCR alumna Dr. Céline Calvino. "If you change the polymer matrix, or switch the type of solvent used, you obtain a variety of different color responses." In addition, the approach allows for a quantitative evaluation of the damage inflicted upon a polymer matrix. The capsules that escape unscathed can serve as a reference and allow one to determine the level of response and, accordingly, the extent of the damage.

According to Calvino, the next steps would involve the development of fabrication techniques to generate capsules with different dimensions and structures. This would notably lead to new properties, and allow the encapsulation of different core materials. "All of these factors could be tuned depending on the area of application," she adds. "But to achieve this, and improve our capability to rationally design efficient self-reporting materials, further investigations are needed in which the influence of the capsule material, the shell thickness, and the size of the capsules on the deformation behavior in different polymers are studied."

Reference

Calvino, C.; Weder, C. Microcapsule-containing Self-Reporting Polymers, Small, 2018, 14, 1802489.

Melanoma

Hybrid nanoparticles to target cancer cells

NCCR Bio-Inspired Materials researchers from the Adolphe Merkle Institute have developed a method that could help circumvent drug resistance in certain types of cancer. Using ultraviolet light and hybrid stimuli-responsive nanoparticles, the scientists were able to accelerate cell death in melanoma cells.

Nanomedicine is one of the most widely anticipated uses of nanotechnology, especially for the purposes of drug delivery and cancer therapy. Nanoparticles (NPs), with advanced functionalities such as stimuli-responsiveness and targeting moieties on the surface, can in theory be concentrated more easily in diseased cells while generating fewer side effects than traditional drugs. Due to their small size, they can also reach a wide range of cellular and intracellular targets. Because of these various factors, NPs are considered promising candidates to help overcome drug resistance in cancer therapy.

One approach that exploits stimuli-responsive NPs for cancer treatment is hyperthermia, which uses magnetic fields, light, radio waves, or ultrasound to induce a temperature increase inside cells or tissues. At the right temperature, cell death (apoptosis) can be provoked. The NCCR researchers have considered one specific approach that targets melanoma cells, in which NPs then accumulate inside the cells' lysosomal compartments. Lysosomes are sometimes called the "trash bag" of the cell, as they are responsible for degrading molecules and recycling their components. If these organelles leak, the cell will often die as a result. As this approach involves a physical process rather than a chemical one, there is no risk of the cells building up a resistance against it.

For human biomedical applications, however, NPs must be both biocompatible and safe, while demonstrating low persistence in the organism.

> "These results suggest that by delivering NPs to the lysosomes in targeted cancer cells this way, we can effectively kill the melanoma cells by inducing apoptosis." Barbara Rothen-Rutishauser

The AMI scientists chose to investigate polydopamine (PDA), which is derived from melanin, a natural pigment found in human skin. First discovered in mussels, PDA is also found in many other organisms in nature. Besides being an adhesive, the polymer also converts UV radiation energy into heat, making it an interesting candidate for hyperthermia treatments.

Melanomas are a type of skin cancer that frequently appear on the back or legs.

The AMI researchers demonstrated that combining PDA with the protein transferrin, affords hybrid nanoparticles that can latch onto certain types of cancer cells, which express an abundance of the required receptor, before passing through the cell membrane to finally reach the lysosomes. The method was tested in vitro on melanoma cells. After the cells were exposed to the NPs in a cell culture, the researchers were able to induce apoptosis by irradiating them with spatially focused ultraviolet light. They found a local induction of cell apoptosis induces lysosome membrane permeability.

"These results suggest that by delivering NPs to the lysosomes in targeted cancer cells this way, we can effectively kill the melanoma cells by inducing apoptosis," explains NCCR Principal Investigator Professor Barbara Rothen-Rutishauser. "We have succeeded in developing a highly adaptable system to target cancer cells that could eventually be used as a treatment."

Because both PDA and proteins are biocompatible, Rothen-Rutishauser believes that the system is unlikely to cause harm in organisms, although this will have to be validated by in vivo experimentation. "Our inexpensive and straightforward method for combining PDA with protein-based targeting functionality provides a suitable base to pursue investigations into the use of phototherapy, since NPs can be easily tailored to suit specific tasks."

Reference

Hauser, D.; Estermann, M.; Milosevic, A.; Steinmetz, L.; Vanhecke, D.; Septiadi, D.; Drasler, B.; Petri-Fink, A.; Ball, V.; Rothen-Rutishauser, B. Polydopamine/Transferrin hybrid nanoparticles for targeted cell-killing, Nanomaterials 2018, 8(12), 1065.

Biomimetics

Fine-tuning basic in-organic building blocks

Scientists struggle to create even close approximations of the many different structures built from an extremely common mineral building block: calcium carbonate.

NCCR Bio-Inspired Materials researchers at Lausanne's Federal Institute of Technology (EPFL) have demonstrated that the properties of the carbonate are directly influenced by the presence of water, which may be the key to understanding and ultimately imitating this desirable material.

Calcium carbonate ($CaCO_3$) is an extremely widespread compound in nature. It can be found in geological formations where significant amounts of carbon dioxide are present, such as in corals, skeletons, or egg and snail shells. Nature produces $CaCO_3$-based materials that display remarkable mechanical and optical properties. It achieves this by controlling the structure, orientation, shape, and arrangement of these carbonate crystals. Scientists have devoted substantial efforts to trying to produce biomimetic versions of these natural materials, but have failed to achieve the level of control required to create crystals with well-defined structures and morphologies.

The NCCR researchers have chosen to focus on amorphous $CaCO_3$ (ACC), the precursor of both natural and synthetic carbonate crystals. ACC serves as a storage for calcium ions, which are released to build up crystals when needed. Yet, the parameters that lead to the formation of $CaCO_3$ crystals and that influence their structure and properties are not completely understood. Conditions such as the pH, temperature, and drying method can all impact the formation pathways, structure, and stability of the precursor. The stability of ACC was shown to be directly linked to the amount of water it contains. How this amount can be tuned, however, remains a mystery.

> "We should be able to develop new processes that allow us to assemble ceramic-based composites with a tighter control over their structure, and hence, their properties."
> Esther Amstad

The EPFL scientists chose to fabricate ACC particles within small drops that dry quickly, thereby enabling the quenching of particle formation at different times. To avoid using any organic solvents that are traditionally employed to quench

Calcium carbonate is one of the essential building blocks of egg shells.

the formation of ACC, the droplets were produced in a microfluidic sprayer. It was found that the longer ACC particles take to form, the more water they contain. The amount of water in ACC also influences the size of the crystals that form: with more water present, the grains of $CaCO_3$ crystals that form are larger when their particles are subjected to elevated temperatures. This know-how should simplify the processing of ACC into biomimetic materials with tunable structures, and with properties suited to specific applications.

"Our findings are probably not limited to the formation and transformation of calcium carbonate," adds NCCR Principal Investigator Professor Esther Amstad. "They could be applied to the formation of many other materials that form via precursors, such as calcium phosphate, calcium oxalate, or calcium sulfate."

"We should be able to develop new processes that allow us to assemble ceramic-based composites with a tighter control over their structure, and hence, their properties. And we should certainly be able to design materials that have a far stronger filiation with their natural counterparts."

References

Du, H.; Steinacher, M.; Borca, C.; Huthwelker, T.; Murello, A.; Stellacci, F.; Amstad, E. Amorphous $CaCO_3$: Influence of the formation time on its degree of hydration and stability, J. Am. Chem. Soc., 2018, 140, 14289.

Du, H.; Amstad, E. Water: How does it influence the $CaCO_3$ formation?, Angew. Chem. Int. Ed., 2019, 58, 2–21.

Ripe for application

Projects with immediate innovation potential

Within the NCCR Bio-Inspired Materials, research is not just theoretical – in several cases it also spurs practical applications, as some of our recent research papers reveal.

Taste test

The presence of the molecule responsible for cork taint in wine can now be clearly identified without a trained nose, thanks to a new chemical sensor developed by NCCR PI Professor Katharina Fromm at the University of Fribourg. The sensor can detect even the slightest traces of the most common wine fault. Further applications could include the identification of pesticides or even explosives.

When a wine is "corked," it is usually the cork that releases the relevant molecules. These often come from fungicides the cork oak tree has been treated with. With the aid of a porous, sponge-like supramolecular powder, these corked molecules can be "caught." As soon as this type of substance is present and has infiltrated the sensor's pores, an optical marker becomes visible, indicating that the wine has been affected.

The sensor can also detect particular pesticides or herbicides that are authorized in some countries but prohibited in Switzerland. Using the sensor would, for example, enable the detection of traces of these chemical compounds in fruit and vegetables. Moreover, the porous structure also reacts to explosives and could contribute to the detection of explosive substances at airports. When testing, the sensor substance can either be used in solution – in the case of fruit juice or similar liquids – or on a paper test strip. The sensor is able to regenerate, allowing it to be reused for further tests.

Parasite detector

NCCR Bio-Inspired Materials researchers at the University of Fribourg's Adolphe Merkle Institute (AMI) have discovered a novel method to detect the presence of malaria parasites in blood samples. This is now being applied to develop a tool for the detection of asymptomatic infections.

Malaria spread by mosquitoes kills over 400,000 people per year.

No more tasting wine influenced by poor cork quality?

Principal Investigator Professor Nico Bruns and his team at AMI, in collaboration with the Swiss Tropical and Public Health Institute and the University of Fribourg's Department of Medicine, investigated hemozoin, which is generated by the malaria parasite when it digests hemoglobin, a vital oxygen-carrying protein found in red blood cells. To observe the presence of this biomarker, the scientists considered using polymer formation as an indicator.

Hemozoin was used to catalyze a polymerization reaction that leads to precipitation of the polymer at a temperature above 33 °C. The polymer solution passes from a transparent state to a cloudy one, and the speed of the reaction is directly correlated to the concentration of the malarial biomarker. Furthermore, very small amounts of hemozoin are enough to kick-start a reaction producing large numbers of polymer chains, a huge amplification effect that explains the method's sensitivity.

The results of this study have already been implemented as part of an application project at AMI. Led by Dr. Jonas Pollard, the Hemolytics team is currently establishing a diagnostic method for malaria. This new tool could lead to more sensitive parasite detection and help reduce healthcare costs. The test is specifically designed to discover asymptomatic carriers at risk of transmitting the disease, which, undetected, could hinder complete eradication of malaria.

References

Vasylevsky, S.; Bassani, D.; Fromm, K. M. Anion-induced structural diversity of Zn and Cd coordination polymers based on Bis-9,10-(pyridine-4-yl)-anthracene, their luminescent properties, and highly efficient sensing of nitro derivatives and herbicides, Inorg. Chem., 2019, 58, 5646-5653.

Rifaie-Graham, O.; Pollard, J.; Raccio, S.; Balog, S.; Rusch, S.; Hernández-Castañeda, M. A.; Mantel, P.-Y.; Beck, H.-P.; Bruns, N. Hemozoin-catalyzed precipitation polymerization as an assay for malaria diagnosis, Nat. Commun., 2019, 10, 1369.

Extension

New module focuses on tissue and disease biology

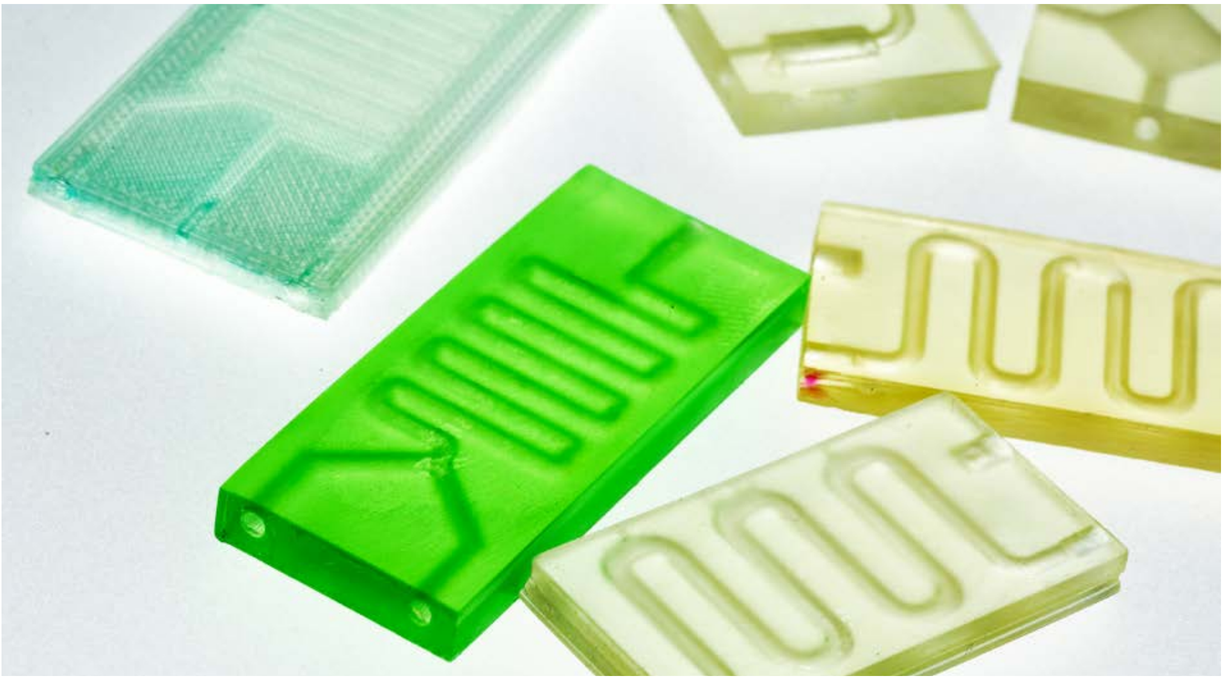
The NCCR Bio-Inspired Materials has been able to increase the number of its research modules from three to four, thanks to additional funding from the Swiss National Science Foundation. The new research module will draw on the Center's interdisciplinary strengths to develop a platform to study tissue and cancer biology.

In today's medicine, cell-based bioassays are essential for drug discovery and diagnostic developments, as they enable the screening of candidate drug molecules, detection of molecular markers associated with diseases, and fundamental studies in cell and molecular biology. Conventional assays of this type are typically static and not specifically representative of the complex and dynamic biochemical environment in living tissues. Lab-on-a-chip microfluidic devices are one suggested solution to this issue, because they enable dynamic changes of the culture medium chemistry through the flow of aqueous solutions around immobilized cells. These devices, however, which commonly integrate one or multiple laboratory functions on a single small integrated circuit, still require tools to monitor cellular response remotely, as well as to trigger environmental changes on demand, even in the absence of flow.

The NCCR's new Module 4 aims to establish a versatile microfluidic organoid culture platform for the in vitro study of tissue and disease biology. Organoids, grown from stem cells, are small, self-organizing three-dimensional structures – tiny versions of normal organs. They can be used to study complex physiological processes such as tissue development and repair, various diseases, or the response of drugs in these model systems. The platform, calling on the Center's interdisciplinary strengths, will be used to tackle biological and clinical problems that have so far defied conventional in vitro and in vivo approaches due mainly to their complex and dynamic nature as well as tissue inaccessibility.

In a first approach focusing on intestinal organoids as a model system, the researchers will study the cellular and molecular mechanisms by which stem cells self-organize into a patterned epithelial tissue composed of stem cells and domains of differentiated cell types. They will notably be investigating what triggers the event that precedes patterning, and which molecular events lead to symmetry breaking and subsequent patterning. These two elements should provide scientists with a roadmap to engineering tissues with improved precision and function.

Module leader and NCCR Principal Investigator Professor Matthias Lütolf and his team at the Federal Institute of Technology in Lausanne (EPFL) have already provided some first results on an-



Lab-on-a-chip microfluidic devices are designed to be more representative of the biochemical environment found in living tissues.

other self-organizing multicellular system. Using a microfluidic device, they simulated aspects of embryo formation in vitro starting from embryonic stem cells. Engineering an artificial signaling center enabled the researchers to steer the self-organization of a stem cell population towards a desired outcome. This could have obvious advantages for future tissue and organ engineering, reckons Lütolf, as understanding how cells build tissues and organs in the embryo could be key to growing functional organs.

For the other major research angle tackled by the Module 4 researchers, breast cancer organoids will be used to study the role of inflammation in cancer initiation – the first phase of tumor development – and progression. Previous research has shown that inflammation may be an inducer of the initiation phase. NCCR scientists aim to discover the role of cancer-immune cell crosstalk in cancer initiation and progression, as well as to define the molecular mechanisms involved. Researchers believe that providing the answers to these key questions will allow them to provide prognostic information on a patient's responsiveness to anti-cancer treatments.

Funding

ERC grants demonstrate strengths of NCCR researchers

Two NCCR Bio-Inspired Materials Principal Investigators have recently been awarded prestigious European Research Council (ERC) grants, allowing them to investigate underlying order among apparent chaos and how cells carry out their housekeeping duties.

Structural colors

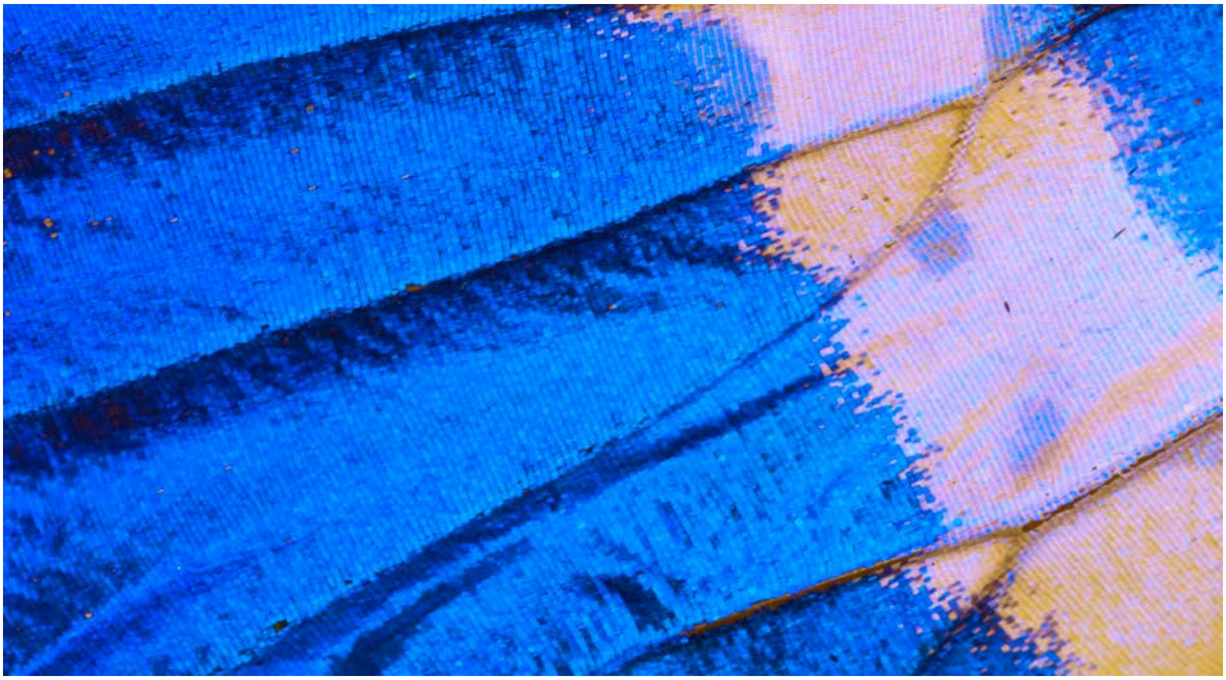
Professor Ullrich Steiner, who heads the Soft Matter Physics group at the Adolphe Merkle Institute, was awarded a prestigious ERC Advanced Grant by the European Research Council in 2019. Worth €2.5 million over five years, the grant will fund research into furthering our understanding of structural color found in nature.

Dazzling color effects, such as those exhibited by some butterfly and beetle species, are sometimes created by complex nanostructures that cause certain wavelengths of white light to be superimposed and eliminated; the resulting colors arise from this interference. In theory, these effects should only be produced by an ordered structure, but in reality, they often appear to stem from apparent disorder instead. Professor Steiner's project will focus on determining if there is, in fact, some underlying order in these seemingly random morphologies that would help explain the presence of structural colors. It will also attempt to establish design rules for simple manufacturing processes.

Structural colors have several advantages. Unlike pigments, structural colors do not fade with time and sunlight, and display iridescence, or color variation, with respect to the angle at which they are viewed. These features can be especially useful for security features in banknotes, packaging, or labels, and could even be used to create pigment-free colors in food.

Cell housekeeping

Professor Stefano Vanni, who investigates the molecular biophysics of cellular membranes at the University of Fribourg's Department of Biology, was awarded an ERC Starting Grant in 2018, worth €1.5 million over five years. Vanni's project, launched at the beginning of 2019, involves studying the inner workings of living cells thanks to computer simulations at the molecular level. Biologists can study cells working in living organisms – in vivo – and in their lab tubes – in vitro – but many features are too complex and too small to understand in this way. "In silico" biology, the study of life via computer simulations, aims to



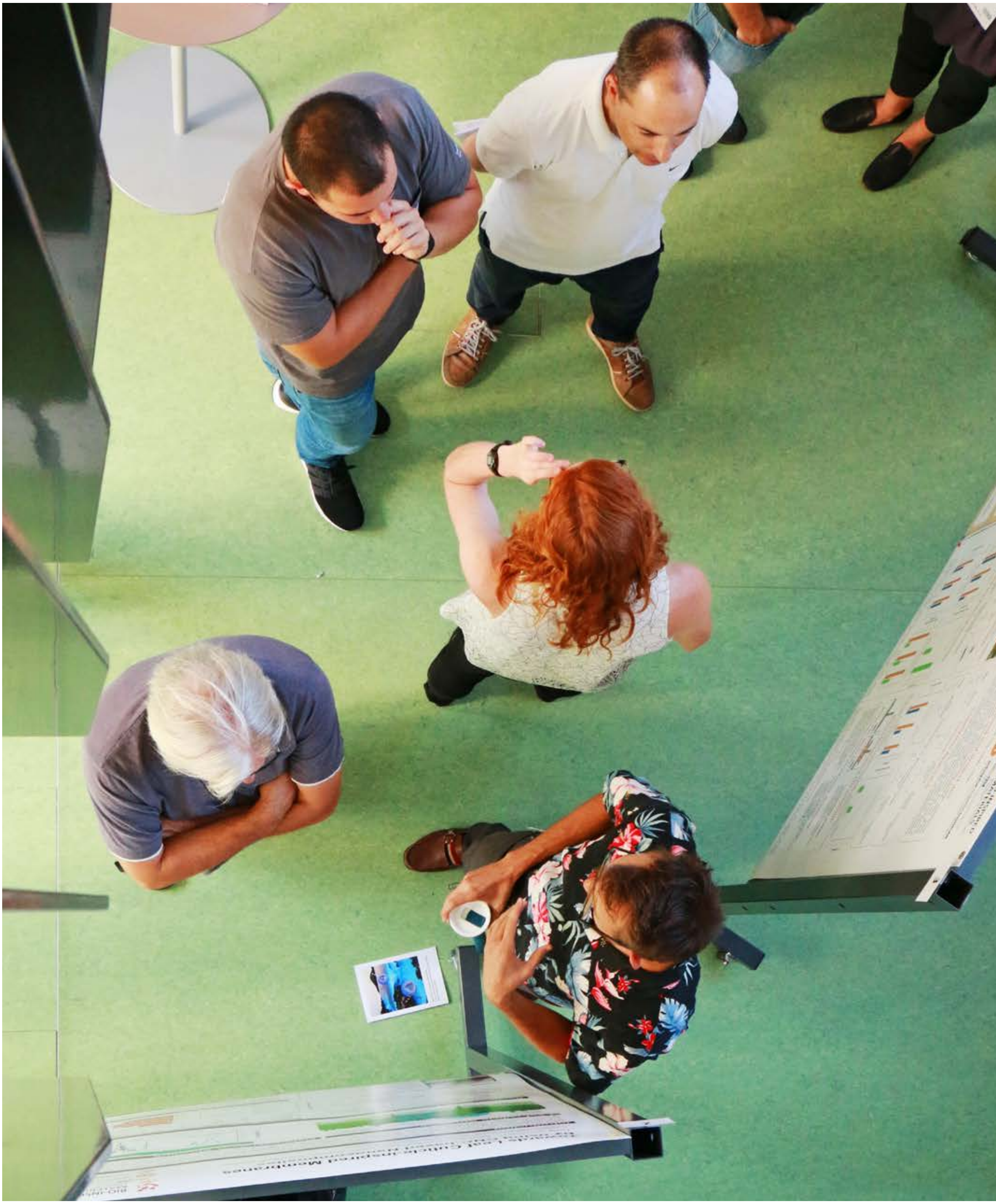
Ullrich Steiner's ERC project will investigate the underlying order of seemingly random structures.

overcome these limitations. Vanni's own work uses the laws of physics and millions of simulated molecules to follow what actually happens in cellular processes.

His ERC project focuses on discovering more about what cells have to do in order to stay alive: cells spend a substantial proportion of their energy on "housekeeping duties." This entails making sure things do not fall apart, putting molecules back in their right place, regularly cleaning up and throwing away the rubbish – perhaps even recycling it. Within a living cell, it is a constant struggle to contain the natural rise of disorder and entropy. Molecules keep diffusing towards the wrong places, and without this housekeeping, our cells would dissolve into a mass of unsorted molecules and die.

> "Cancer cell membranes are 'unkempt' and full of lipids that would have been cleaned away by healthy cells. This feature could be used to identify and eliminate them."
> Stefano Vanni

The way cells carry out this molecular housekeeping is still poorly known, and a better knowledge can have profound implications. "For instance," says Vanni, "cancer cells look very different from the housekeeping point of view. Their membranes are 'unkempt' and full of lipids that would have been cleaned away by healthy cells. This feature could be used to identify and eliminate them."



Undergraduate research program poster session.

127

Researchers

including 56 supported by the SNSF grant

CHF 7.7 million

of funding including CHF 4 million from the SNSF

35 Nationalities

represented by NCCR Bio-Inspired Materials staff: Switzerland, Australia, Argentina, Belgium, Brazil, Canada, China, Costa Rica, Croatia, France, Germany, Greece, Hungary, India, Indonesia, Iran, Ireland, Italy, Lithuania, Luxembourg, Morocco, Netherlands, New Zealand, Nigeria, Portugal, Romania, Russia, Slovenia, South Africa, Spain, Turkey, United Kingdom, Ukraine, USA, Vietnam

42 high school students

carried out small research projects supported by the NCCR

25

Publications

in journals with an impact factor of over 10, (including Nature Chemistry, Nature Communications, the Proceedings of the National Academy of Sciences, Advanced Materials, the Journal of the American Chemical Society, and Angewandte Chemie)

Note: All figures between March 1, 2018 and February 28, 2019

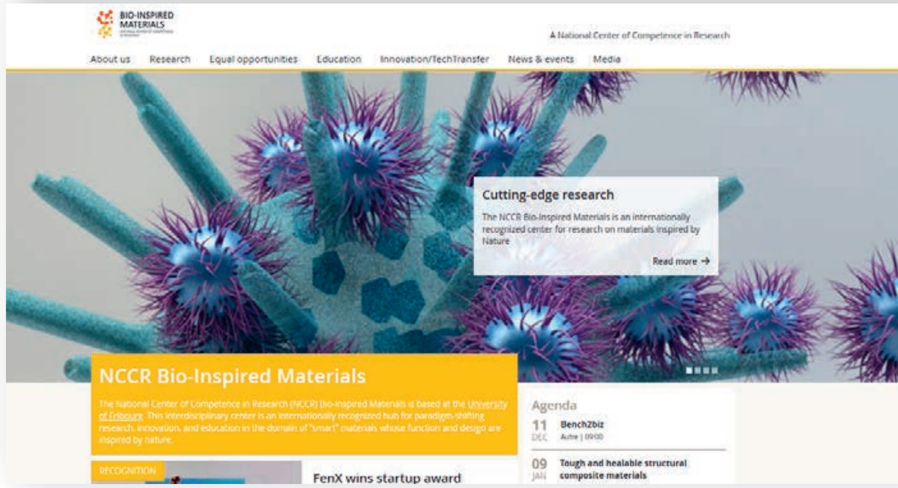
In brief

Student entrepreneurship conference

In May 2019, the Adolphe Merkle Institute in Fribourg hosted the second-ever National Conference for Student Innovation.

Organized by the Association for Student Innovation, which is co-presided by the NCCR Bio-Inspired Materials Knowledge Transfer & Innovation Manager, Dr. Eliav Haskal, the conference compared and contrasted Swiss experiences and ecosystems around innovation support and entrepreneurship for cantonal universities and universities of applied sciences. It also provided insights into methods for encouraging an innovation culture for students interested in intra- and entrepreneurship, and sought to help build a network of innovation experts interested in developing best practices for student support. The keynote speaker this year was Tine Van Lommel, Innovation Manager at KU Leuven.

Tine van Lommel of KU Leuven was the conference's keynote speaker.



The new website now automatically adapts to all viewing formats.

New website

A new website was launched for the NCCR Bio-Inspired Materials at the end of 2018, replacing the old site with a more user-friendly platform that provides more information about the Center's research and activities.

Navigation on the website is now improved. Project data is more accessible, with information drawn in real time from an innovative bespoke database that links staff, programs and publications. The Center's initiatives in education, equal opportunities, and innovation also benefit from heightened visibility on the platform. In response to larger numbers of users turning to mobile technology to browse on the internet, the website now also conforms to recent standards such as responsive design.

Moving up the career ladder

The NCCR Bio-Inspired Materials first recipient of the Women in Science Fellowship, Dr. Khay Fong, has returned to Australia after securing a lecturer position at the University of Newcastle, which she took up at the beginning of 2019.

Dr. Fong worked on projects investigating the biological fate of nanostructured lipidic nanoparticles when exposed to complex media, and the positioning of phosphate surfactants in a lipid bilayer depending on headgroup size and pH.

Before joining the NCCR, Khay Fong had worked at Monash University in Melbourne and at ETHZ.

Reaching out

The NCCR Bio-Inspired Materials was implicated in a wide variety of education and outreach activities in 2018 and 2019.

At the elementary and high school levels (5–18 years old), Center members participated in the University of Fribourg's Goûters Scientifiques, KidsUni, Women in Science and Technology, and Future en tous genres/Zukunftstag programs. The center also organized workshops for the Passeport Vacances Fribourg and FriTime Schmitten, and hosted four school classes that were given the chance to perform experiments in the lab. The Center was also present at the SATW TecDays, where NCCR Principal Investigator Professor Barbara Rothen-Rutishauser explained nanoscience to students of the Kantonsschule Olten with the help of mobile phone-coupled microscopes. Overall, these activities allowed the NCCR to reach over 300 children and high school students. The Center also participated in outreach activities addressed to the general public such as the Museum Night in Fribourg, in which the Center presented its research activities, organized experiments for children at the Adolphe Merkle Institute, and participated in "Going Wild," a weekend exhibition at Zurich Zoo in the summer of 2018.

PhDs

Sarah-Luise Abram (University of Fribourg, Department of Chemistry): Nanoencapsulation of silver

Matthias Bott (University of Fribourg, Department of Physics): Phase transitions in confined geometry

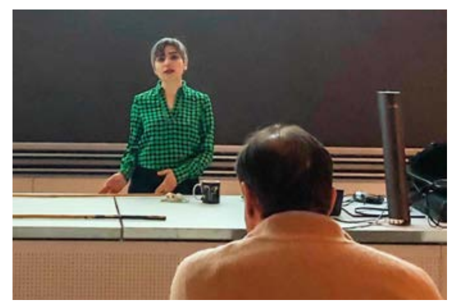
Celine Calvino-Carneiro (University of Fribourg, Adolphe Merkle Institute): Functional Polymers through Mechanochemistry

Michela Di Giannantonio (University of Fribourg, Department of Chemistry): Asymmetric synthesis of a new type of biosensor

Golnaz Isapourlaskookalayeh (University of Fribourg, Department of Chemistry): Responsive hydrogels

Marc Karman (University of Fribourg, Adolphe Merkle Institute): Mechanically Responsive Materials

Omar Rifaie Graham (University of Fribourg, Adolphe Merkle Institute): Force-responsive polymersomes as gated nanoreactors and drug delivery systems



Golnaz Isapourlaskookalayeh was one of seven PhD graduates.

Special issue

The Swiss Chemical Society handed over the reins for the first 2019 issue of its bimonthly journal Chimia to the NCCR Bio-Inspired Materials to mark the beginning of the Center's second phase. The issue presented a selection of original contributions and reviews illustrating the NCCR's activities since its launch, along with future perspectives. Besides the more traditional science-oriented content, other elements highlighted included the NCCR's education, equal opportunities, and innovation initiatives.

The special issue of Chimia highlighted the NCCR's research activities and initiatives.

Early publication

An alumnus of the NCCR's summer Undergraduate Research Intern program has seen his work published in the highly-rated journal Nanoscale.

Seth Price of Durham University (United Kingdom) worked at the Adolphe Merkle Institute with Center instrument platform specialist, Dr. Sandor Balog in 2017. Their paper, published in March 2019, focuses on computational particokinetics models used in the design and interpretation of in vitro nanoparticle toxicology assays involving submerged adherent cell cultures. Together with Dr. Calum Kinnear of the University of Melbourne (Australia), they developed a method to estimate the delivered dose of high-aspect ratio nanoparticles, including nanorods, nanotubes, and nanofibers. Knowing the delivered dose becomes essential when deciphering interactions between cells and particles, particularly for these high-aspect nanoparticles.

Seth Price is one of the many undergraduates who has benefited from the NCCR's summer research program.

The Soft Matter, Bioinspiration & Photonics Symposium in Messkirch, Germany, was one the events sponsored by the NCCR.

Sponsoring

The NCCR Bio-Inspired Materials actively organized, supported, contributed to, and/or sponsored numerous scientific events and conferences in 2018 and 2019.

These included the Gordon Research Conference (GRC) on Bio-Inspired Materials in Les Diablerets (Switzerland) in May 2018, the Bioinorganic Chemistry Gordon Research Seminar (GRS) in Ventura (USA) in January 2019, the International Society for Aerosols in Medicine Montreux in February 2019, the Soft Matter, Bioinspiration & Photonics Symposium in Messkirch (Germany) in May 2019, and the 'Going Wild' exhibit at the Zurich Zoo in August 2018.

Alumni prize

NCCR Bio-Inspired Materials Principal Investigator Professor Katharina Fromm (Department of Chemistry, University of Fribourg) was awarded the University of Geneva's Prix Jaubert 2018 for her 'significant contributions and works for the betterment of humankind'.

This is the highest recognition given to former alumni of the University of Geneva. Her award lecture was entitled "How bacteria cope with anti-microbial silver: molecular insights." The prize, endowed with CHF 5,000, was allocated for research and the organization of seminars.

PI Katharina Fromm was recognized for contributions and works for the betterment of humanity.

Selected high impact publications (IF >10)

Di Giannantonio, M.; Ayer, M. A.; Verde-Sesto, E.; Lattuada, M.; Weder, C.; Fromm, K. M. Triggered metal ion release and oxidation: Ferrocene as a mechanophore in polymers, Angew. Chem. Int. Ed., 2018, 57, 11445–11450.

Sagara, Y.; Karman, M.; Seki, A.; Pannipara, M.; Tamaoki, N.; Weder, C. Rotaxane-based mechanophores enable polymers with mechanically switchable white photoluminescence, ACS Central Sci., 2019, 5, 874–881.

Rifaie-Graham, O.; Ulrich, S.; Galensowske, N.F.B.; Balog, S.; Chami, M.; Rentsch, D.; Hemmer, J.R.; Read de Alaniz, J.; Boesel, L.F.; Bruns, N. Wavelength-selective light-responsive DASA functionalized polymersome nanoreactors, J. Am. Chem. Soc., 2018, 140, 8027–8036.

Ofner, A.; Mattich, I.; Hagander, M.; Dutto, A.; Seybold, H.; Rühs, P.A.; Studart A.R. Controlled massive encapsulation via tandem step emulsification in glass, Adv. Funct. Mater., 2018, 29, 1806821.

Yasir, M.; Liu, P.; Tennie, I. K.; Kilbinger, A. F. M. Catalytic living ring-opening metathesis polymerization with Grubbs' second- and third-generation catalysts, Nat. Chem., 2019, 11, 488–494.

Dolan, J.A.; Dehmel, R.; Demetriadou, A.; Gu, Y.; Wiesner, U.; Wilkinson, T.D.; Gunkel, I.; Hess, O.; Baumberg, J.J.; Steiner, U.; Saba, M.; Wilts, B.D. Metasurfaces atop metamaterials: Surface morphology induces linear dichroism in gyroid optical metamaterials, Adv. Mater., 2019, 31, 1803478.

Kim, H.S.; Şenbil, N.; Zhang, C.; Scheffold, F.; Mason, T.G. Diffusing wave microrheology of highly scattering concentrated monodisperse emulsions, PNAS, 2019, 116, 7766–7771.

Rima, S.; Lattuada, M. Protein amyloid fibrils as template for the synthesis of silica nanofibers, and their use to prepare superhydrophobic, lotus-like surfaces, Small, 2019, 14, 1802854.

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Archetti, A.; Glushkov, E.; Sieben, C.; Stroganov, A.; Radenovic A.; Manley, S. Waveguide-PAINT offers an open platform for large field-of-view super-resolution imaging, Nat. Commun., 2019, 10, 1267.

Hočevar, S.; Milošević, A.; Rodriguez-Lorenzo, L.; Ackermann-Hirschi, L.; Mottas, I.; Petri-Fink, A.; Rothen-Rutishauser, B.; Bourquin, C.; Clift, M.J.D. Polymer-coated gold nanospheres do not impair the innate immune function of human B lymphocytes in vitro, ACS Nano, 2019, 13, 6790–6800.

Mottas, I.; Bekdemir, A.; Cereghetti, A.; Spagnuolo, L.; Sabrina-Yang, Y.-S.; Müller, M.; Irvin, D. J.; Stellacci, F.; Bourquin, C. Amphiphilic nanoparticle delivery enhances the anticancer efficacy of a TLR7 ligand via local immune activation, Biomaterials, 2018, 190-191, 111–120.

New groups

Two new professors appointed by the University of Fribourg have been integrated into the Center.

Professor Guillermo Acuna (Department of Physics) joined the NCCR as a Principal Investigator on January 1, 2019. His project is "Bioinspired DNA self-assembly of nanophotonic devices." Professor Stefan Salentinig (Department of Chemistry) joined the NCCR later in 2019, with his associated project "The design and characterization of digestion inspired functional food nano-biointerfaces." Both professors benefitted from the NCCR's Incentive Program, which provides startup funds for new professors at the Home Institution whose work aligns with that of the Center and who would like to contribute to the Center's activities.

New horizon

NCCR Bio-Inspired Materials Principal Investigator Professor Nico Bruns completed a successful move to the University of Strathclyde (United Kingdom) in October 2018, where he was named full Professor of Macromolecular Chemistry. Bruns previously held a Swiss National Science Foundation professorship at the Adolphe Merkle Institute (AMI). He remains affiliated with the AMI and the NCCR.

Equal opportunities

Academic equality still a work in progress

Since its launch in 2014, the NCCR Bio-Inspired Materials has devoted considerable energy, thought, and resources to its Equal Opportunities (EO) program. The related activities and measures have grown from a few roundtables for students to the creation of fellowships and workshops. NCCR Principal Investigator Professor Barbara Rothen-Rutishauser has led EO at the NCCR since its beginning, developing a program whose quality has been recognized by the Swiss National Science Foundation.

Five years after its launch, has the NCCR Bio-Inspired Materials made a real impact in terms of equal opportunities?

Professor Barbara Rothen-Rutishauser: When our NCCR was launched and I began my duties as Equal Opportunities Delegate, I thought that there would not be much need for this type of activity, as much had already been done to promote equal opportunities. One of the reasons for setting up these activities within NCCRs, though, was because there was a recognition by the Swiss National Science Foundation that universities lacked proper EO programs. I have since realized that there are several shortcomings in academia that require some form of intervention. Indeed, there has been huge interest in our EO activities, and our staff, both female and male, find them useful. We started with the organization of roundtables, as well as the identification of female role models, and more recently, in collaboration with other EO representatives from the home institution's Faculty of Science and Medicine, a heightened web presence of the university's EO program was launched. This reflects the NCCR's impact. One of our strengths is also that female professors have taken charge of the EO activities. One remaining challenge is to quantify the impact of our EO activities, which we do by tracking careers, carrying out surveys, or through personnel feedback, but it is difficult to put precise numbers on our achievements.

A number of programs were set up: the WINS (Women in Science) fellowship, STEM (science, technology, engineering and mathematics) activities, roundtables. Which ones have been clear winners, according to you?

Roundtables have clearly been popular with our NCCR staff, and designed to answer their queries as well as initiate important conversations. They have also been opportunities for me to learn. Our WINS program in favor of female postdoctoral researchers is also a success, in my view. The daycare subsidies we provide answer a need for additional support for families. STEM activities for

NCCR-supported STEM programs help increase teenagers' interest in chemistry.

young girls at the University of Fribourg are co-ordinated by NCCR outreach, and have benefited from heightened visibility with the support of our NCCR. Finally, a recent workshop for female staff only, "Done being nice," was hailed by the participants. It was important to organize an activity for only women, where they could express themselves more freely. That said, it remains important to have activities that involve male and female staff.

You described the roundtables as a success. What is their appeal to NCCR staff?

Our roundtables, for example, often draw on our own and our guests' personal experiences and allow a direct, unfiltered exchange with our students. It helps our NCCR staff understand the difficulties and pitfalls of academic life, and provides them with other perspectives. Not everyone who completes a PhD is destined for an academic career. Our roundtables are also dynamic in the sense that the themes that are discussed, such as career advice, are often suggested by staff members themselves.

In June 2019, women all across Switzerland went on strike for a day to demand more equality with men. Do you believe this was necessary?

Equal rights are certainly an issue that Switzerland as a whole still needs to deal with. The national strike was an important event to flag up the many hurdles Swiss women still face to be treated on an equal footing with men. Imposing equality through quotas, as some campaigners suggest, is not necessarily a one-size-fits-all solution, though. Personally, I would rather mentor young female researchers and encourage women to pursue an academic career. Women must be more confident in their talents and qualities to truly succeed.

In your view, does the academic sector suffer from an equality problem?

Yes, it does, and the problem is in the pipeline of researchers, where numbers of women fall the higher the rung of the academic ladder. Women also seem to lack the confidence needed to impose themselves further up the pecking order, perhaps because of a fear of failure. I believe confidence is a vital ingredient that can take you a long way.

The WINS grant for postdocs is a program only in favor of women. Is this financial and career boost still a necessity in this day and age?

I feel that we still need this kind of program because many women drop out of the academic system between their PhD and the group leader level. The program doesn't just provide funding, either, but also mentoring and support. I say that if this type of fellowship exists, a female researcher should not hesitate to apply simply because it only targets women. All fellowships are competitive, the WINS no less than others. Men applying for a fellowship would never question whether they would succeed because as men, they have better chances.

At the end of the day, some of the NCCR programs can apply equally to men and women – childcare, career advice. Does this show that, in some cases, men need just as much support as women during their academic careers?

I think this is one of the biggest changes that I have observed in academia in recent years. Men are now far more involved in family life, meaning that, in many cases, they are facing the same issues as women – finding affordable daycare, moving on to the next job or contract, getting the right work-life balance. So mentoring is just as important for men as it is for women. They have the same questions, and they appreciate the advice we can give them just as much as women, without feeling judged.

So how do you see progress in terms of equality in academia? Do you see the glass as being half full, or half empty?

For me, the answer is obvious – when I see the incredible willingness of all NCCR members, the National Science Foundation and the Home Institution to implement change, then the glass is obviously half full. The success stories of the past years show that there is a desire to reconsider past positions and to change people's mindsets. Even if further steps must be taken to fill the glass, we have clearly shown that the situation can be improved.

Outreach

Museum highlights potential of bio-inspired technology

The NCCR Bio-Inspired Materials successfully curated its first exhibition, "Inspiration Natur-e," at Fribourg's Natural History Museum, attracting over 30,000 visitors between October 2018 and March 2019. Plans are now afoot to send the exhibit elsewhere in Switzerland and abroad.

Geckos provided a gripping demonstration of physics.

The exhibition was the NCCR's first major outreach activity to target the general public. Other activities, such as KidsUni or the women in science program for young girls, have generally been aimed at very specific groups. "We realized that our NCCR does great research, and has excellent outreach programs, but we also understood that our work deserved to be presented to a wider public in a more accessible way," explains Dr. Eliav Haskal, the Center's Knowledge Transfer and Innovation Manager. "The idea of collaborating with the museum seemed an obvious way of making a stronger impact on the local population."

The museum responded enthusiastically to the proposal for an exhibition focusing on bio-inspired materials, kicking off an 18-month partnership. "Collaborating on exhibitions with university-level institutions such as the NCCR allows us to access knowledge where it is produced," explains Dr. Peter Wandeler, director of the Natural History Museum of Fribourg. "We are convinced that this type of collaboration leads to a more authentic and relevant experience. And it allows scientists to present their work and results to a wide public."

> "Collaborating on exhibitions with university-level institutions such as the NCCR allows us to access knowledge where it is produced."
> Peter Wandeler

Initial work focused on selecting which technologies to present to the public. Ultimately, a first list of 15 proposals was whittled down to

six: stimuli-responsive materials that mimic pine cones; hydrophobic surfaces inspired by plants; mussel-inspired adhesives used in fetal cardiac surgery; stickers based on gecko grip; fibers drawing on the strengths of spider silk; and artificial iridescent surfaces similar to the shimmering colors of some butterflies and beetles. Each section was designed to present the natural inspiration for the material, the science behind it such as physics or chemistry, and the technological application.

"Classic exhibits in a natural history museum usually put an object and its story front and center. For Inspiration Natur-e, natural phenomena were the centerpiece, so this was more akin to what a science center would present than what we would normally do," adds Wandeler.

> "I particularly appreciated the juxtaposition of living organisms and current research. It was possible for the wider public to understand the science and its possible applications."
> Peter Wandeler

While an external design company pieced together the concept for the exhibit, NCCR staff provided the explanatory texts and visuals for each section, the challenge being to condense the science into bite-sized chunks for the public. Additional elements included live animals – geckos, spiders, and mussels – floating ferns, and multimedia with NCCR researchers explaining in their respective native languages why they chose a career in science. Corporate partners also provided products that showcased applications of the science being presented.

"I particularly appreciated the juxtaposition of living organisms and current research," says Wandeler. "I think that because of people's fascination with those living organisms, it was possible for the wider public to understand the science and its possible applications."

The exhibition was officially inaugurated on October 12, 2018, in the presence of the Canton of Fribourg's education minister, launching its six-month run at the museum. During this time, the NCCR outreach manager coordinated with the museum to organize a series of events, including company and school visits, hands-on science evenings, and after-work guided visits.

Given the substantial number of visitors despite the relatively modest size of the museum, plans are now in preparation for sharing the exhibit with other NCCR partners, as well as with partners of the Bio-inspired PIRE program and the swissnex network in the United States.

An art installation demonstrated how pinecones change shape depending on ambient humidity.

Startup culture

Technology moves out of the lab

Since the NCCR's launch in 2014, five startups have been created by our participating laboratories with the support of the Center's Knowledge Transfer and Innovation Manager, along with proof-of-concept grants in some cases. Of the five spin-offs, four were recently incorporated: NanoLockin GmbH, Spectroplast AG, FenX AG, and Microcaps AG.

NanoLockin

NanoLockin is an early-stage startup company that was launched in 2018 and develops instruments for the detection and analysis of nanoparticles in all kinds of products. The NanoLockin system developed at the Adolphe Merkle Institute is designed to detect metallic nanoparticles containing gold, silver or copper, carbon-based materials such as carbon nanotubes, and selected metal-oxides such as titania in complex environments. These include biological and physiological fluids, cells, body tissue, consumer products, and composite materials. NanoLockin won the canton of Fribourg's Innovation Prize for startups in November 2018.

Spectroplast

As the world's first high-resolution silicone 3D-printing service provider, Spectroplast fabricates ready-to-use products that are functional and perform like injection-molded parts. Its breakthrough innovation comes from the development of a unique additive manufacturing technology, the result of research undertaken at the Complex Materials laboratory at Zurich's Federal Institute of Technology (ETHZ). It enables the direct fabrication of elastomeric components made of silicone without molding, notably suitable for industrial and medical applications. The company just completed a €1.38 million seed funding round. It has also received a number of awards, most recently the CES (Consumer Electronics Show) Asia Innovation Award.

Microcaps

Microcaps, also launched out of the Complex Materials laboratory at ETHZ, offers a novel technology for the production of microparticles and microcapsules that are used to protect pharmaceutical agents in drugs or fragrances in cosmetic products. Clear advantages of this technology include the high throughput and precise size control of the microcapsule production step. For example, Microcaps devices can fabricate monodisperse capsules and emulsions of various sizes down to 10 µm at throughputs that are 1,000 times faster than other competitive technologies. The company finished second in 2019 in the Health & Nutrition category of the national Venture competition.

Spectroplast provides high-resolution 3D printing of silicone parts.

FenX

FenX, the third NCCR-supported spinoff of the Complex Materials laboratory at ETHZ, creates fully recyclable insulation materials from mineral waste to be used in building construction. The insulation materials are highly porous and very light, meet all the safety regulations for building materials and are not flammable. At the end-of-life, the insulation materials can also be reprocessed and re-employed in the production of new foams. FenX's founder, Etienne Jeoffroy, has been featured in Forbes magazine's "30 under 30" list and was awarded the SEIF award for social innovation for his project in 2019.

Hemolytics

Hemolytics has developed a patented assay with the potential to serve as a mass diagnostic tool for malaria eradication campaigns. Based on the amplification of a pan-malarial biomarker, the tool showed a sensitivity comparable to the most sophisticated method in use to diagnose malaria, while being inexpensive and based on stable chemicals. The ongoing development of the project, launched at the Adolphe Merkle Institute, has been financed, among others, by a Bridge grant from Innosuisse and the Swiss National Science Foundation, as well as another grant from the Gebert Rüf Foundation. Hemolytics was also the third prize winner at the Ypsomed Innovation Fund's Innovation Award for research, development and technology transfer in January 2019.

A measure of success

These startups are only one part of the NCCR's efforts to boost knowledge and technology transfer, as multiple innovative research projects are progressing towards becoming startups themselves while benefiting from the Center's support. These projects are concrete key performance indicators of the Center's excellent research, motivated staff and students, and support for innovation.

"This is also a reflection of the project's success in leveraging that scientific research, sensitizing staff and students to innovation, and training and supporting students and postdocs in achieving the application potential of their work," adds Dr. Eliav Haskal, the Center's Knowledge Transfer and Innovation Manager.

Undergraduate internships

A first research experience to help guide careers

Every summer, the NCCR Bio-Inspired Materials welcomes a select group of undergraduates from abroad as part of a unique internship program. Besides gaining valuable skills and experience, the program also allows many of these students to decide what the next steps will be for their future careers.

The NCCR hosts up to 20 Undergraduate Research Interns (URIs), who spend their time in Switzerland working on a project in one of the Center's laboratories. When they apply to the program early in the year, the students from North America and Europe can choose from a wide variety of projects defined by the Principal Investigators. On average, there are twice as many applicants as available places in the program.

Successful applicants participate in cutting-edge research projects within one of the Center's research groups, spending eight to twelve weeks in Switzerland. The URIs get a glimpse of advanced research work, gain hands-on work experience, develop transferable skills, interact with leading experts in their fields of interest as well as with their fellow students, and have a unique opportunity to explore career options and network with an interdisciplinary team of professionals. All of these factors, along with the fact that many of the costs inherent to their stay are covered by the NCCR, help attract talented students.

"When my research supervisor revealed an opportunity to conduct summer research in Switzerland, I realized that this wasn't just a chance to branch into materials science or live abroad for the first time," explains summer intern Molly Sun, who studies at the University of Chicago. "It was also an opportunity to join a new scientific community with an international perspective."

Personal recommendations play a role in convincing students to sign up. "Two other students from my university completed the program in the past and really enjoyed it," says Nicole Mortensen of the University of Utah. "Furthermore, I have a huge passion for polymers and biomaterials and wanted to challenge myself by gaining experience outside of the country."

Learning new skills is also a powerful factor for some of the students, as Minji Han of University College London explains. "My motivation to apply was that I could gain hand-on experience, as my degree, chemical engineering, doesn't provide enough opportunities to develop practical skills in the lab," she points out.

Aside from doing research in their host labs, students in the program come together for scientific lectures as well as social and networking events. They also have the opportunity to learn about Switzerland from an insider perspective and to maybe even take some first steps towards learning or practicing French or German language skills. One of the more interesting outcomes for the students, however, is that it helps them clarify which career path they would like to pursue. "This program solidified my desire to complete

Up to 20 undergraduates join the program each summer.

a Master's degree, and has made me consider a PhD," says Mortensen. "Conducting research for 40 hours a week was something I enjoyed a lot more than I thought I would."

Sun also believes the internship has helped her decide what her future direction should be. "Although I'm a chemist by training, I'm also fascinated by materials and wanted to learn more about polymers and their behavior," she explains. "This summer internship was the perfect experience to learn about materials science, and I definitely know that I want to pursue a PhD that links chemistry and materials science together as a result of this program."

For others, it was a confirmation of earlier choices that clarified exactly which field they wished to work in. "I'm now considering my career path related to the project I joined, lithium-ion batteries," says Han. "I had already decided to pursue a Master's degree and PhD before I joined in this internship. And now I've narrowed down the field I want to choose as my future career."

The undergraduates are more often than not the best ambassadors of the summer program when they return home.

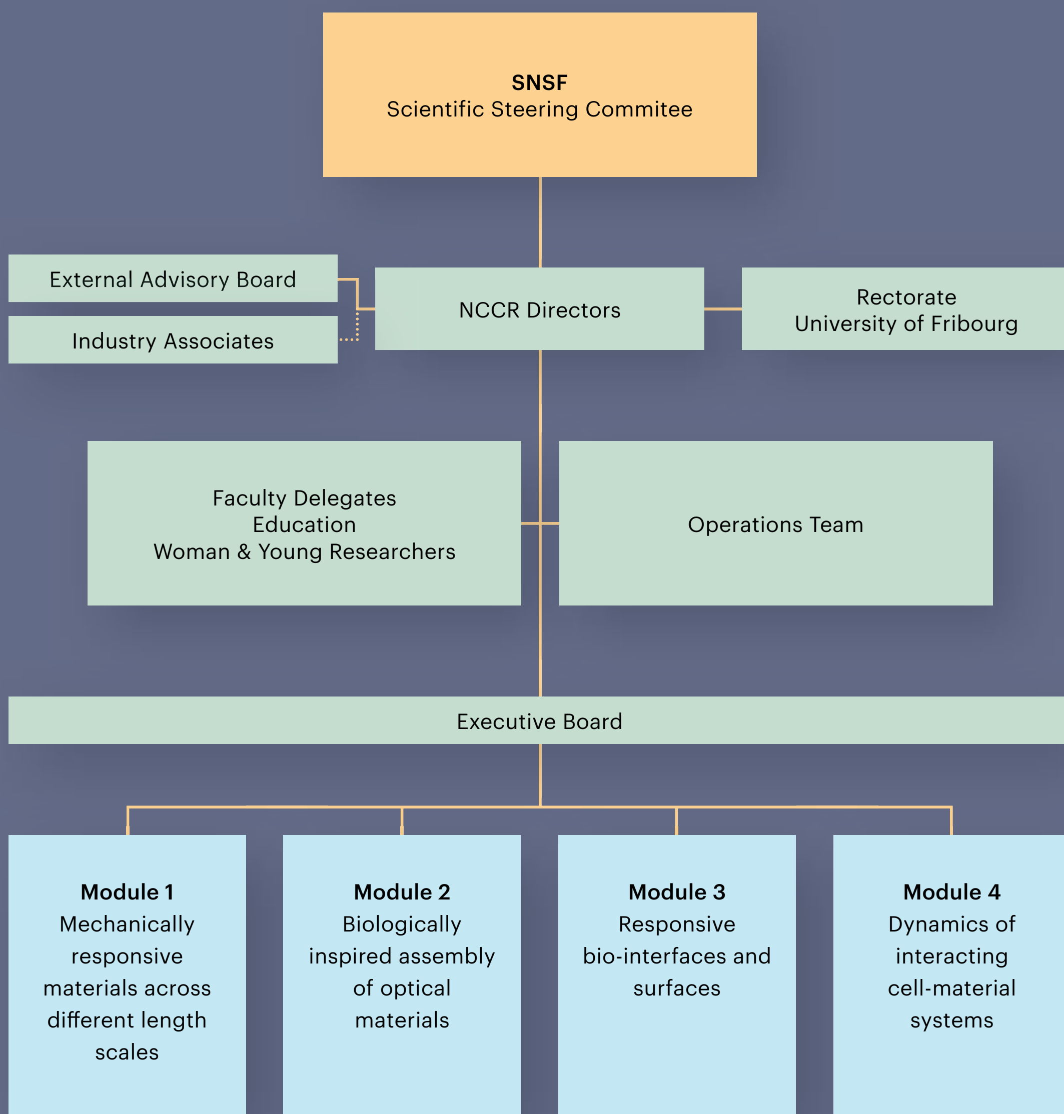
"I would definitely recommend this program to my peers – this program surpassed my expectations and gave me a far more well-rounded experience than I would otherwise receive in my home country," points out Sun. "There is a special opportunity to connect with researchers from around the world and learn about different perspectives on science."

Johann Rapp, a student from the University of Florida, concurs. "The program brought me a wide variety of knowledge in the field as well as broadened my scope on where I would like to study in the future," he says. "Spending time on a different continent with people you have just briefly met also fostered some long-lasting friendships."

Mortensen, who made the journey to Europe after recommendations from program alumni, gives the program an emphatic thumbs-up. "I would recommend this program to my colleagues because one gains valuable experiences and skills, both on an educational and a personal level," she adds. "Not everyone gets to pursue ground-breaking biomaterial research in a beautiful country like Switzerland."

A golden orb weaver spider featured in the NCCR curated exhibition Inspiration Natur-e.

Organization Phase II



The National Centers of Competence in Research (NCCR) are a research instrument of the Swiss National Science Foundation

Who is who

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- Prof. Curzio Rüegg (UniFR)
  Deputy director
- Prof. André Studart (ETHZ)
  Leader Module 1
- Prof. Frank Scheffold (UniFR)
  Leader Module 2
- Prof. Alke Fink (AMI/UniFR)
  Co-leader Module 3
- Prof. Barbara Rothen-Rutishauser (AMI)
  Faculty Delegate for Women and Young Researchers, co-leader Module 3
- Prof. Matthias Lütolf (EPFL)
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- Prof. Andreas Kilbinger (UniFR)
  Faculty Delegate for Education
- Dr. Lucas Montero
  Scientific coordinator
- Dr. Eliav Haskal
  Knowledge Transfer and Innovation manager

Principal investigators

- Prof. Guillermo Acuña
  (Department of Physics, UniFR)
- Prof. Esther Amstad
  (Institute of Materials, EPFL)
- Prof. Nico Bruns
  (Adolphe Merkle Institute, UniFR/University of Strathclyde)
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- Prof. Michael Mayer
  (Adolphe Merkle Institute, UniFR)
- Prof. Aleksandra Radenovic
  (Institute of Bioengineering, EPFL)
- Prof. Barbara Rothen-Rutishauser
  (Adolphe Merkle Institute, UniFR)
- Prof. Curzio Rüegg
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- Prof. Frank Scheffold
  (Department of Physics, UniFR)
- Prof. Ullrich Steiner
  (Adolphe Merkle Institute, UniFR)
- Prof. Francesco Stellacci
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- Prof. André Studart
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- Prof. Stefano Vanni
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- Prof. Christoph Weder
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Management

- Dr. Lucas Montero, Scientific coordinator
- Danielle Canepa, Finance
- Scott Capper, Communications manager
- Dr. Eliav Haskal, Knowledge Transfer and Innovation manager
- Myriam Marano, Administrative assistant
- Dr. Sofía Martín, Master and outreach coordinator

Research groups

Acuña group (UniFR)

- Prof. Guillermo Acuna
- Dr. Mauricio Pilo-Pais, Postdoctoral researcher

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- Huachuan Du, Doctoral student
- Matteo Hirsch, Doctoral student
- Amin Hodaei, Doctoral student
- Yanchen Song, Doctoral student
- Mathias Steinacher, Doctoral student

Bruns group (AMI/Strathclyde)

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- Livia Bast, Doctoral student
- Micael Gouveia, Doctoral student
- Samuel Raccio, Doctoral student
- Omar Rifaie Graham, Doctoral student
- Justus Wesseler, Doctoral student

Dufresne group (ETHZ)

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- Alexandre Torzynski, Doctoral student
- Tianqi Sai, Doctoral student
- Dr. Guido Panzarasa, Postdoctoral researcher

Fink/Rothen group (AMI)

- Prof. Alke Fink
- Prof. Barbara Rothen-Rutishauser
- Liliane Ackermann Hirschi, Laboratory technician
- Mauro Almeida, Doctoral student
- David Burnand, Doctoral student
- Jernej Cebela, Other staff
- Dr. Yendry Corrales, Senior researcher
- Federica Crippa, Doctoral student
- Dr. Barbara Drasler, Postdoctoral researcher
- Dr. Khay Fong, Senior researcher
- Dr. Christoph Geers, Senior researcher
- Daniel Hauser, Doctoral student
- Aaron Lee, Doctoral student
- Dr. Thomas Moore, Postdoctoral researcher
- Dr. Dedy Septiady, Postdoctoral researcher
- Dr. Miguel Spuch-Calvar, Senior researcher
- Dr. Patricia Taladriz, Senior researcher
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Fromm group (UniFR)

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- Anja Holzheu, Doctoral student
- Emilie Jean-Pierre, Doctoral student
- Serhii Vasylevskyi, Doctoral student
- Noémie Voutier, Doctoral student
- Philippe Yep, Doctoral student

Kilbinger group (UniFR)

- Prof. Andreas Kilbinger
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- Phally Kong, Doctoral student
- Dr.Iris Kramberger-Tennie, Postdoctoral researcher
- Angélique Molliet, Doctoral student
- Subhajit Pal, Doctoral student
- Md Atiur Rahman, Doctoral student
- Manvendra Singh, Doctoral student

Klok group (EPFL)

- Prof. Harm-Anton Klok
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- Friederike Metze, Doctoral student
- Sabrina Sant, Doctoral student
- Dr. Corey Stevens, Postdoctoral researcher

Lütolf group (EPFL)

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- Dr. Nicolas Broguière, Postdoctoral researcher
- Dr. Andrea Manfrin, Postdoctoral researcher
- Stefanie Boy-Röttger, Other staff
- Stefano Vianello, Doctoral student

Lattuada group (UniFR)

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- Golnaz Isapour Laskookalayeh, Doctoral student
- Joelle Medinger, Doctoral student
- Jansie Smart, Doctoral student
- Lorenzo Turetta, Doctoral student

Mayer group (AMI)

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- Jessica Dupasquier, Other staff
- Dr. Aziz Fennouri, Postdoctoral researcher
- Dr. Jonathan List, Postdoctoral researcher

Radenovic group (EPFL)

- Prof. Aleksandra Radenovic
- Evgenii Glushkov, Doctoral student
- Michael Graf, Doctoral student
- Vytautas Navika, Doctoral student

Rüegg group (UniFR)

- Prof. Curzio Rüegg
- Grégory Bieler, Senior researcher
- Sarah Djahanbakhsh Rafiee, Doctoral student
- Ivana Domljanovic, Doctoral student
- Corine Dos Santos Reis, Doctoral student
- Dr. Samet Kocabey, Postdoctoral researcher
- Dr. Sanam Peyvandi, Postdoctoral researcher

Salentinig group (UniFR)

- Prof. Stefan Salentinig

Scheffold group (UniFR)

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- Dr. Luis Salvador Froufe Pérez, Postdoctoral researcher
- Nathan Fuchs, Doctoral student
- Emmanuel Gendre, Other staff
- Oswald Raetzo, Other staff
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- Dr. Pavel Yazhgur, Postdoctoral researcher

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- Dr. Mohammadreza Ghanbari, Senior researcher
- Dr. Ilja Gunkel, Senior researcher
- Mirela Malekovic, Doctoral student
- Dr. Bodo Wilts, Senior researcher

Stellacci group (EPFL)

- Prof. Francesco Stellacci
- Matteo Gasbarri, Doctoral student
- Simone Gavieri, Doctoral student
- Dr. Emma-Rose Janecek, Postdoctoral researcher
- Dr. Quy Ong, Senior reseacher

Studart group (ETHZ)

- Prof. André Studart
- Dr. Ahmet Demirörs, Senior researcher
- Dr. Etienne Jeoffroy, Postdoctoral researcher
- Iacoppo Mattich, Doctoral student
- Alessandro Ofner, Doctoral student
- Dr. Elena Tervoort, Postdoctoral researcher

Vanni group (UniFR)

- Prof. Stefano Vanni
- Dr. Pablo Campomanes, Senior researcher
- Emanuele Petretto, Doctoral student

Weder group (AMI)

- Prof. Christoph Weder
- Mathieu Ayer, Doctoral student
- Céline Calvino-Carneiro, Doctoral student
- Aristotelis Kamtsikakis, Doctoral student
- Marc Karman, Doctoral student
- Derek Kiebala, Doctoral student
- Laura Neumann, Doctoral student
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Support staff

- Dr. Sandor Balog, Senior researcher (AMI)
- Véronique Buclin, Laboratory technician (AMI)
- Dr. Aurélien Crochet, Senior researcher (UniFR)
- Laetitia Häni, Laboratory technician (AMI)
- Dr. Dimitri Vanhecke, Senior researcher (AMI)

Alumni

- Sarah-Luise Abram (Doctoral student, Fromm group) 2014–2018
- Stefan Aeby (Doctoral student, Scheffold group) 2017–2018
- Mahshid Alizadeh (Doctoral student, Kilbinger group) 2015–2018
- Edward Apebende (Doctoral student, Bruns group) 2014–2018
- Delphine Blondel (Doctoral student, Lütolf group) 2018–2019
- Prof. Michal Borkovec (Professor) 2014–2018
- Matthias Bott (Doctoral student, Brader group) 2014–2018
- Prof. Carole Bourquin (Professor) 2014–2018
- Prof. Joseph Brader (Professor) 2014–2018
- David Burnand (Doctoral student, Fink group) 2014–2018
- Céline Calvino (Doctoral student, Weder group) 2014–2018
- Jernej Cebela (Other staff, Rothen-Rutishauser group) 2019–2019
- Dr. Marc Conley (Postdoctoral researcher, Scheffold group) 2014–2018
- Federica Crippa (Doctoral student, Fink group) 2014–2018
- Michela Di Giannantonio (Doctoral student, Fromm group) 2014–2018
- Sarah Djahanbakhsh Rafiee (Doctoral student, Rüegg group) 2014–2018
- Huachuan Du (Doctoral student, Amstad group) 2018–2018
- Dr. Khay Fong (Senior researcher, Rothen-Rutishauser group) 2017–2018
- Dr. Barbara Fraygola (Master coordinator, Management) 2016–2018
- Nathan Fuchs (Doctoral student, Scheffold group) 2015–2018
- Dr. Christoph Geers (Postdoctoral researcher, Fink group) 2017–2018
- Dr. Florian Guignard (Postdoctoral researcher, Lattuada group) 2018–2018
- Daniel Hauser (Doctoral student, Rothen-Rutishauser group) 2015–2019
- Amin Hodaei (Doctoral student, Amstad group) 2018–2019
- Anja Holzheu (Doctoral student, Fromm group) 2015–2019
- Golnaz Isapourlaskookalayeh (Doctoral student, Lattuada group) 2014–2019
- Dr. Emma-Rose Janecek (Postdoctoral researcher, Stellacci group) 2016–2018
- Marc Karman (Doctoral student, Weder group) 2014–2018
- Svilen Kozhuharov (Doctoral student, Borkovec group) 2014–2018
- Phally Kong (Doctoral student, Kilbinger group) 2014–2018
- Dr. Jonathan List (Postdoctoral researcher, Mayer group) 2017–2019
- Anne-Marie Loup (Other staff, Borkovec group) 2014–2018
- Dr. Plinio Maroni (Postdoctoral researcher, Borkovec group) 2014–2018
- Aristea Massaras (Other staff, Bourquin group) 2016–2018

- Dr. Thomas Moore (Postdoctoral researcher, Fink group) 2018 – 2018
- Vytautas Navika (Doctoral student, Radenovic group) 2018 – 2019
- Frederik Neuhaus (Doctoral student, Zumbühl group) 2015 – 2018
- Laura Neumann (Doctoral student, Weder group) 2015 – 2019
- Alessandro Ofner (Doctoral student, Studart group) 2015 – 2018
- Corine Reis dos Santos (Doctoral student, Rüegg group) 2014 – 2018
- Omar Rifaie Graham (Doctoral student, Bruns group) 2014 – 2018
- Isabelle Segarini (Master coordinator, Management) 2017 – 2018
- Dr. Alexander Smith (Postdoctoral researcher, Borkovec group) 2017 – 2018
- Yanchen Song (Doctoral student, Amstad group) 2018 – 2018
- Lorenzo Turetta (Doctoral student, Lattuada group) 2018 – 2019
- Yuki Umehara (Laboratory technician, Rothen-Rutishauser group) 2015 – 2019
- Olivier Vassali (Other staff, Borkovec group) 2014 – 2018
- Noémie Voutier (Doctoral student, Fromm group) 2014 – 2018
- Julia Wagner (Doctoral student, Bourquin group) 2016 – 2018
- Prof. Andreas Zumbühl (Professor) 2015 – 2018

Summer students 2018

- Sylvain Adamowicz (Imperial College London)
- Jeremy Ben-Nathan (Durham University)
- Sarah Benware (University of New Hampshire)
- Frederick Bertani (Durham University)
- Alicia Dibble (University of Utah)
- Madeline Eiken (Santa Clara University)
- Ander Gonzalez de Txabarri (University of the Basque Country EHU-UPV)
- Allison Kaczmarek (Clemson University)
- Jessica LaLonde (Case Western Reserve University)
- Ben Lancaster (Durham University)
- Ava LaRocca (Massachusetts Institute of Technology)
- Tessa Loman (University of Technology Eindhoven)
- Max Mowbray (University of Birmingham)
- Sandra Rodriguez (University of the Basque Country EHU-UPV)
- Cole Sorensen (Virginia Polytechnic Institute and State University)
- Christina Stebbins (University of Chicago)
- Alessandra Stevens (Durham University)
- Loren Temple (Durham University)
- Jessica Zhou (Case Western Reserve University)

External advisory board

- Prof. Helmut Coelfen, Department of Chemistry, University Konstanz, Germany
- Prof. Ursula Graf-Hausner, graf 3dcellculture, Switzerland
- Prof. Takashi Kato, Department of Chemistry and Biotechnology, University of Tokyo, Japan
- Prof. LaShanda Korley, Department of Macromolecular Science and Engineering, Case Western Reserve University, USA
- Dr. Christiane Löwe, Director Equal Opportunities Office, University of Zurich, Switzerland
- Dr. Martin Michel, Food Science and Technology Department, Nestlé Research Center, Switzerland
- Prof. Marcus Textor, Emeritus Professor, Department of Materials, ETH Zurich, Switzerland
- Prof. Marek Urban, Department of Materials Science and Engineering, Clemson University, USA

Abbreviations:

AMI: Adolphe Merkle Institute;
UniFR: University of Fribourg;
UniGE: University of Geneva;
EPFL: Federal Institute of Technology Lausanne;
ETHZ: Federal Institute of Technology Zurich


Inspiration Nature
L'évolution a développé les structures et processus de la nature depuis des millions d'années. Le concept de bio-inspiration implique l'observation de ces structures et phénomènes naturels pour stimuler la recherche scientifique. Il permet aux scientifiques d'acquérir de nouvelles connaissances fondamentales et d'inventer de nouvelles technologies destinées à servir la société.
L'Institut Adolphe Merkle de l'Université de Fribourg, siège du Pôle de Recherche National Matériaux bio-inspirés, explore la bio-inspiration en associant la formation académique, la recherche fondamentale et une exploration du développement technologique au profit de la société.
Die Evolution gestaltet seit Millionen von Jahren Strukturen und Prozesse in der Natur. Bio-Inspiration beinhaltet die Beobachtung dieser natürlichen Strukturen und Phänomene zur Förderung der wissenschaftlichen Forschung. Bio-Inspiration ermöglicht es der Wissenschaft, neue, grundlegende Einsichten zu gewinnen und neue Technologien zu entwickeln, die der Gesellschaft dienen.
Das Adolphe Merkle Institut der Universität Freiburg, Sitz des Nationalen Forschungsschwerpunkts Bioinspirierte Materialien, erforscht die Bio-Inspiration durch die Kombination von akademischer Ausbildung, Grundlagenforschung und einer Erforschung der Technologiemöglichkeiten zum Vorteil der Gesellschaft.
Evolution has shaped structures and processes in nature for millions of years. The concept of bio-inspiration involves the observation of these natural structures and phenomena to stimulate scientific research. It enables scientists to form new fundamental insights and to invent new technology aimed at serving society.
The Adolphe Merkle Institute of the University of Fribourg, home of the National Competence Center for Research in Bio-Inspired Materials, is exploring bio-inspiration by combining academic training, fundamental research and an exploration of technology development for the benefit of society.

Projects

Module 1: Mechanically responsive materials across different length scales

1. Mechanically responsive and mechanically adapting polymers
2. Mechanically responsive block copolymer nanoreactors inspired by the marine bioluminescence of dinoflagellates
3. Auxetic polymer networks
4. Mechanoresponsive materials enabled by 3D printing and high-throughput microfluidics
5. Adaptive functional polymers and nanocontainers
6. Mechano-responsive $CaCO_3$-based coatings
7. Biomechanically-responsive nanoparticles

Module 2: Biologically inspired assembly of optical materials

8. Design of novel optical materials through self-assembly of patchy particles
9. Interplay of order and disorder in biophotonic materials
10. Structurally colored micron scale pigments for inkjet printing
11. Physical mechanisms underlying the self-assembly of living optical materials
12. Disguising the core: Photonic core-shell particles
13. Bioinspired DNA self-assembly of nano-photonic devices

Module 3: Responsive bio-interfaces and surfaces

14. Novel antiviral supramolecular materials
15. NanoRoomba®: Cellular uptake and durotaxis on ''soft and rigid'' nanoparticles carpet
16. Stimulation of cellular endocytosis for sensing and enhancing nanoparticle uptake
17. Self-assembly of DNA- or RNA-triggered ion channels for targeted cell killing and nanopore sensing
18. Trapping cancer cells with self-assembling biomolecules (DNA)
19. Fluorescent nanodiamonds as quantum bio-molecular probes for live cell imaging and sensing
20. Characterizing nanoparticle-membrane interactions via molecular dynamics simulations
21. Steering tissue morphogenesis via programmable microgel assemblies

AP1. Design of digestion-inspired functional food nano-biointerfaces

Module 4: Dynamics of interacting cell-material systems

23. Development of a microfluidic platform
24. Development of cargo carriers
25. Development of controlled delivery systems for organ-on-chip devices
26. Development of a tumor/immune cell organoid model

Publications

NCCR

Capper, S.; Haskal, E.; Kilbinger, A.; Montero de Espinosa, L.; Rothen-Rutishauser, B.; Rüegg, C.; Weder, C. Not just fundamental research: Education, equal opportunities, knowledge and technology transfer, and communication at the NCCR Bio-Inspired Materials, Chimia, 2019, 73, 86-89.

Module 1

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Rifaie-Graham, O.; Hua, X.; Bruns, N.; Balog, B. The kinetics of hematin crystallization measured by depolarized light scattering, Small, 2018, 14, 1802295.

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C.; Fromm, K. M.; Lattuada, M.; Weder, C. Functional polymers through mechanochemistry, Chimia, 2019, 73, 7 – 11.

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Module 2

Böbel, A.; Bott, M. C.; Modest, H.; Brader, J. M.; Räth, C. Fluid demixing kinetics on spherical geometry: power spectrum and Minkowski functional analysis, New. J. Phys., 2019, 21, 013031.

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Dolan, J. A.; Dehmel, R.; Demetriadou, A.; Gu, Y.; Wiesner, U.; Wilkinson, T. D.; Gunkel, I.; Hess, O.; Baumberg, J. J.; Steiner, U.; Saba, M.; Wilts, B. D. Metasurfaces atop metamaterials: Surface morphology induces linear dichroism in gyroid optical metamaterials, Adv. Mater., 2019, 31, 1803478.

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200
14
13
12
11
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6

round tables

on topics related to equal opportunities

Gender balance

41% of the NCCR PhD students were women

38% of the NCCR members were women in Phase I. 7 out of 16 NCCR seminars were delivered by women.

85 papers

incl. 66 original contributions and 15 reviews

1 WINS symposium

organized during the 9th NanoTox Conference in Neuss (DE)

76 oral presentations at conferences

including 50 keynote and plenary lectures at international conferences

150

children

participated in NCCR outreach activities

18

cooperation projects

with external partners (two with industry, 14 with research institutions, two other)

Note: All figures between March 1, 2018 and February 28, 2019

Seminars

The NCCR organizes seminars on a regular basis throughout the academic year. These seminars are both an excellent opportunity to learn about recent scientific advances from prominent researchers as well as a meeting point for NCCR participants to network and exchange ideas.

Speaker	Talk	Home Institution	Date
Prof. Jochen Feldmann	Metal halide perovskite nanocrystals: 2D materials and supercrystals	Ludwig-Maximilians-Universität München, Munich, Germany	5 June 2018
Prof. Herbert Waite	Long-term mussel adhesion depends on intricate extracellular redox controls	University of California Santa Barbara, Santa Barbara, US	29 June 2018
Prof. Christoph Weder	Stimuli-responsive supramolecular polymers	Adolphe Merkle Institute, Switzerland	24 September 2018
Prof. Claudia Bagni	Gender equality in academia – Myth and reality	University of Lausanne, Switzerland	23 October 2018
Prof. Paolo Arosio	Protein phase transition: from biology towards new protein materials	ETHZ, Switzerland	5 November 2018
Prof. Stephen Mann	Proto-living materials?	Bristol University, Bristol, UK	12 November 2018
Prof. Marleen Kamperman	Bioinspired complex coacervate-based adhesives	Groningen University, Groningen, Netherlands	19 November 2018
Prof. Giulia Rossi	Nanoparticle-protein and nanoparticle-lipid interactions	University of Genoa, Genoa, Italy	29 November 2018
Prof. Kaori Sugihara	Can antimicrobial peptides be an antibiotic alternative? – fundamental studies and tool development	University of Geneva, Switzerland	13 December 2018
Prof. Craig Broderson	The role of surface tension in the formation, spread, and removal of gas bubbles in the xylem of plants	Yale University, New Haven, USA	11 March 2019
Prof. Craig Broderson	A multi-method approach for studying leaf optics and the effect of diffuse vs. direct light on photosynthesis	Yale University, New Haven, USA	18 March 2019
Prof. Pupa Gilbert	Nanoscale amorphous precursors and their phase transitions in diverse biominerals	University of Wisconsin-Madison, Madison, USA	18 March 2019
Prof. Helmut Cölfen	Nanocrystals as chemical building blocks	University of Konstanz, Konstanz, Germany	15 April 2019
Dr. Judit Horvath	Chemical and chemomechanical morphogenesis in far-from-equilibrium systems	University of Sheffield, Sheffield, UK	25 April 2019
Prof. Li-Zhu Wu	Artificial photosynthesis for chemical transformation	Chinese Academy of Sciences, Beijin, China	29 April 2019
Prof. Helmut Schlaad	Functional polymers from amino acids and sugar	University of Potsdam, Potsdam, Germany	16 May 2019

Impressum

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