Activities report 2019–2020

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. Each of these modules tackles major unsolved problems, provides opportunities for great scientific advances on its own, 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.

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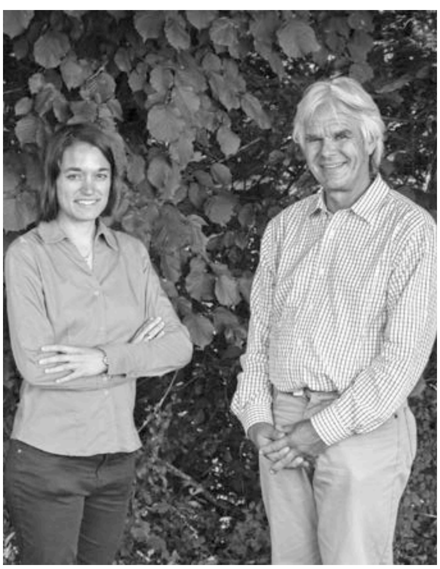
The NCCR Bio-Inspired Materials completes a leadership transition.



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Printing glass, boosting solar power, or fighting viruses are just some of our research projects.

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Initiatives

Leveling the playing field for women, or helping young researchers develop an independent project are just a few of the Center's initiatives, along with award-winning application projects.

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Message from the directors

Dear reader

The NCCR Bio-Inspired Materials just reached the halfway point of the SNSF funding period after six successful years filled with exciting science and important developments in the educational, equal opportunities, and technology transfer domains.

The impact of the Center on its Home Institution, the University of Fribourg, is already visible with direct outcomes such as new professorships, research infrastructure and educational programs, and through indirect indicators such as the ranking of the University of Fribourg by Nature Index as the 3rd fastest rising institution in Materials Science in Europe. The six-year landmark was also an ideal moment for the initial Directors to step down and pass the torch to a new team that will introduce fresh energy and visions to our NCCR, a change which has been part of the strategic plan of the Center since its inception, and which was endorsed by the SNSF's Research Council in mid-2020.

It was an absolute privilege for the outgoing Directors, Christoph Weder and Curzio Rüegg, to lead this NCCR and to be able to work with a fantastic team of researchers, PIs, Executive Board members, Management Team members, Advisory Board members, Industrial Associate representatives, and many other partners. This NCCR has created a unique sense of community and catalyzed collaborative research across disciplines and institutions, both nationally and internationally. The support received from the leadership of the NCCR's Home Institution has been outstanding and key to sustain this venture, and the interactions with the members of SNSF's NCCR team, the representatives of the Research Council, and the review panel have been excellent and very constructive. Thanks to all of you for your valuable contributions to our Center and helping to make this venture such a success.

The new Directors, Ulli Steiner and Esther Amstad, are thrilled to take the lead of this NCCR, and look forward to six years in which the main objectives will be to maintain the high standards of the Center, explore new scientific questions and start shaping the legacy of the NCCR in close collaboration with the Home Institution. In the immediate future, the new Directors will focus on the pre-proposal for the third and final funding phase of the NCCR, a critical phase-out period in which the Center will focus its priorities to maximize its overall impact, and, define the future of the NCCR and its legacy beyond Phase 3. These are no small challenges, but the new Directors are confident that the NCCR will as always face themsuccessfully.

Last year was not only marked by the changes in the NCCR Directorship. In this activities report, you will find a selection of research highlights, an overview of the activities in the strategic areas and some general figures of our Center during the last year. We wish you a pleasant reading and look forward to our future interaction.

Christoph Weder & Curzio Rüegg
Ullrich Steiner & Esther Amstad
Directors NCCR Bio-Inspired Materials

The structure of bluebird feathers could hold the key to biomimetic nanostructures

Research

What we do

The overarching research theme of the NCCR Bio-Inspired Materials is to use inspiration from nature for the design of artificial materials that can change their properties on command, so to speak, or, in other words, in response to an external stimulus. These materials, sometimes referred to as “smart” or “intelligent”, are of fundamental scientific interest and potentially useful in countless applications that range from climate control for buildings to drug delivery systems in the body.

In the recent past, scientists have begun to consider nature’s principles as inspiration for the design of artificial materials with intriguing stimuli-responsive properties. Previous examples of materials studied by individual research groups that belong to the Center include mechanically adaptive nanocomposites inspired by sea cucumbers, drug-delivery nanoparticles that mimic the structure and stealth behavior of viruses, and optical elements that emulate the nanoscale patterns found in butterfly wings.

With the aim of carrying out paradigm-changing scientific breakthroughs and harnessing the enormous innovation potential in this domain, the Center has developed into a large-scale interdisciplinary effort that merges competences in chemistry, physics, materials science, biology, and medicine.

Our research is organized in four modules: mechanically responsive materials across different length scales; biologically inspired assembly of optical materials; responsive bio-interfaces and surfaces; and the dynamics of interacting cell-materials systems. As hoped and expected, however, the boundaries between projects and modules have started to blur, and several new research endeavors were launched that take full advantage of the Center’s interdisciplinary environment.

Three dimensional

A novel printing technique for glass structures

NCCR Bio-Inspired Materials researchers at ETH Zurich have developed a novel stereolithographic approach to print transparent glass structures in three dimensions using available hardware technology, allowing for the production of customized objects.

Stereolithography, one of the most common three-dimensional printing technologies, comprising several advantages over traditional processing approaches: mass-customization, high complexity and little-to-no waste material. However, this technique has so far remained limited for the processing of functional glass structures. The NCCR researchers chose to tackle 3D printing of glass structures using conventional digital light processing (DLP) printers. This way, geometries with far greater complexities are achievable compared with commercial glass manufacturing techniques.

Stereolithography was invented in the mid-1980s as the first 3D printing technology, but due to limitations of the available material chemistries, it has only recently been established as a widespread additive manufacturing method. During the process, layers of a liquid resin are sequentially solidified through UV light exposure to form a 3D object. However, only dedicated acrylate-based resins are available for printing of transparent objects, resulting in limited thermal and chemical stability. Glass manufacturing on the other hand dates back to Egyptian times. But despite the invention of glass-blowing in the ancient world, and the recent mechanization of blowing and casting processes, glass manufacturing remains labor intensive. Even if automation and process innovations have increased the reproducibility, properties and quality of glass products, the symmetric and predominantly flat geometries achieved through these approaches remain limited compared to the intricate shapes that can be produced by glassblowers. In the context of glasses, stereolithography has the potential to reconcile the automation of the modern industrial process with even higher geometric complexity than that attained by artisan labor.

The researchers from the Complex Materials group of NCCR Principal Investigator Prof. André Studart succeeded in printing transparent glass objects with arbitrary geometric complexity by combining multicomponent glass precursors and acrylate monomers. To achieve high printing resolution, the researchers relied on the phase separation of the liquid resins. Spinodal decomposition – the mechanism through which a solution of two or more components can separate into phases with entirely different chemical compositions and physical properties – during photopolymeriza-

Far more complex glass structures can be built up with the new technique

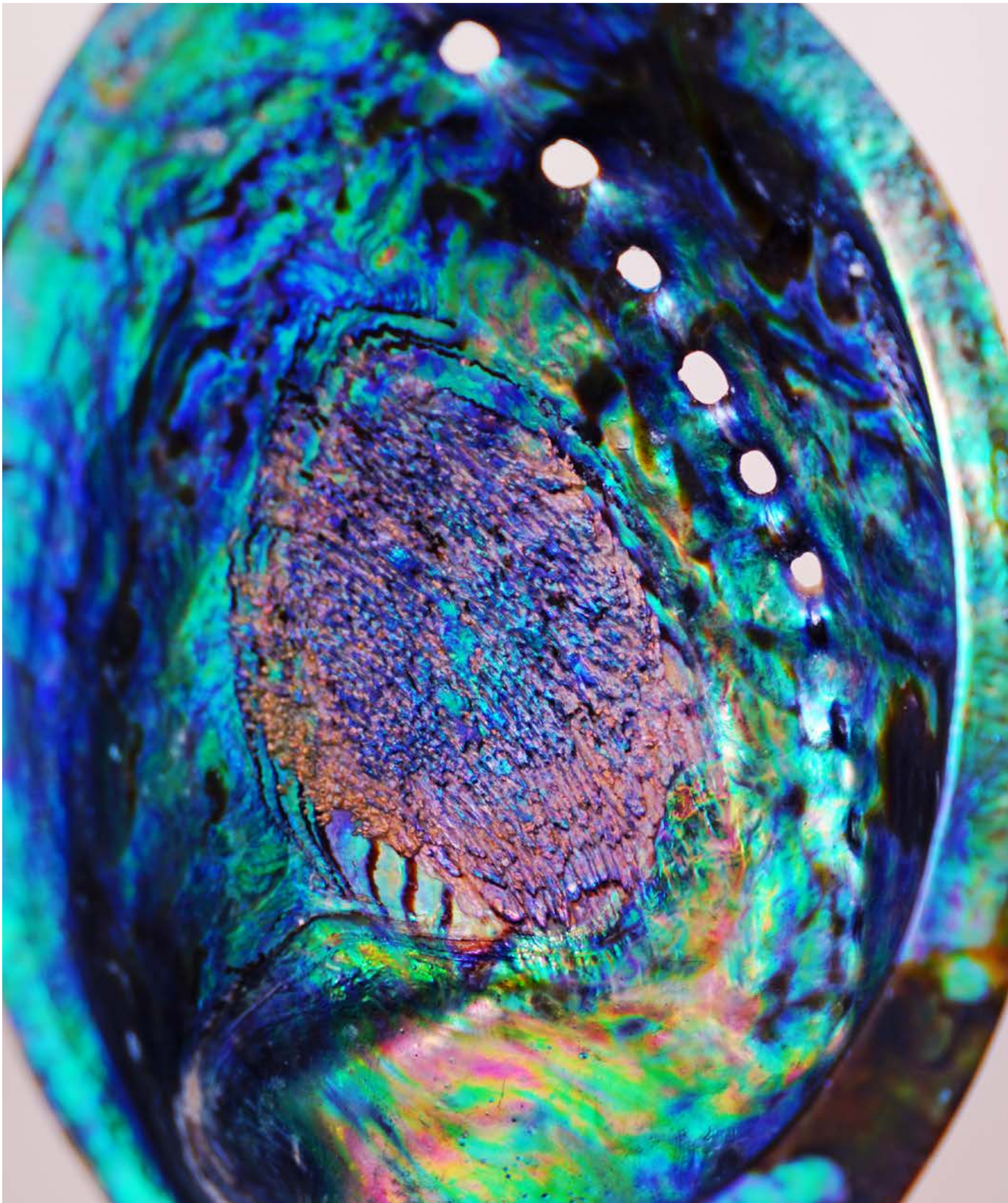
tion generates a morphology that is eventually stopped by the polymerization process. The scientists found that the phase separation enables the printing of truly complex 3D geometries through the formation of a continuous polymer network that is strong enough to withstand the mechanical stresses of the printing process. In a subsequent heating treatment, the complementary ceramic network is strengthened and its organic counterpart is burned off leaving a porous ceramic body. The final step sees the object heated at temperatures just below the melting point of glass, yielding a dense, transparent glass object. Additionally, the researchers discovered that by spatially controlling the grey-scale intensity of the digital light projection, the rate of polymerization can be also tuned on a voxel basis (the 3D equivalent of a computer screen pixel), which has an effect on the densification kinetics of the part during the final phase.

A rich variety of inorganic precursors can potentially be structured into porous or dense glasses and glass-ceramics using this additive manufacturing technique. With the high-resolution, complex geometries and locally tunable structure of the multicomponent glasses demonstrated in this work, the proposed 3D printing platform presents a step towards combining the high level of automation offered by modern digital fabrication processes with the accurate control over shape and chemistry traditionally achieved by manual labor to create glass objects.

Because readily available precursors and a commercial desktop printer and oven were used, it should be easy for the broader additive manufacturing and open source communities to adopt this new material, and digitally design and create glass components. The technology could therefore be a potential game-changer in the glass manufacturing industry by allowing small scale production of customized glass objects.

Reference

Moore, D. G.; Barbera, L.; Masania, K.; Studart, A. R. Three-dimensional printing of multicomponent glasses using phase-separating resins. Nat. Materials, 2020, 19, 212–217.



Nacre structure in abalone shells provides clues for stronger materials

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Seminars

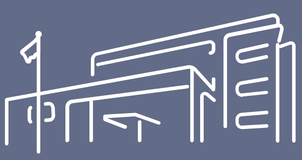
by NCCR researchers

> CHF 2.5 Mio Funds

raised by the start-ups and spin-offs

including from the the Swiss Climate Foundation, the W.A. de Vigier Foundation, Venturekick, and the ZKB Pionierpreis.

Partners



University of Fribourg (Home Institution), Federal Institutes of Technology Lausanne and Zürich

21

Research groups

of which 1 is associated

4

(inter)national conferences supported

2

industrial associates

50 % of open access publications

following the Gold or Green roads

23

undergraduate students

hosted for the NCCR's Summer Internships

Note: All figures between March 1, 2019, and February 28, 2020

Microfluidics

Simulating embryo formation with stem cells

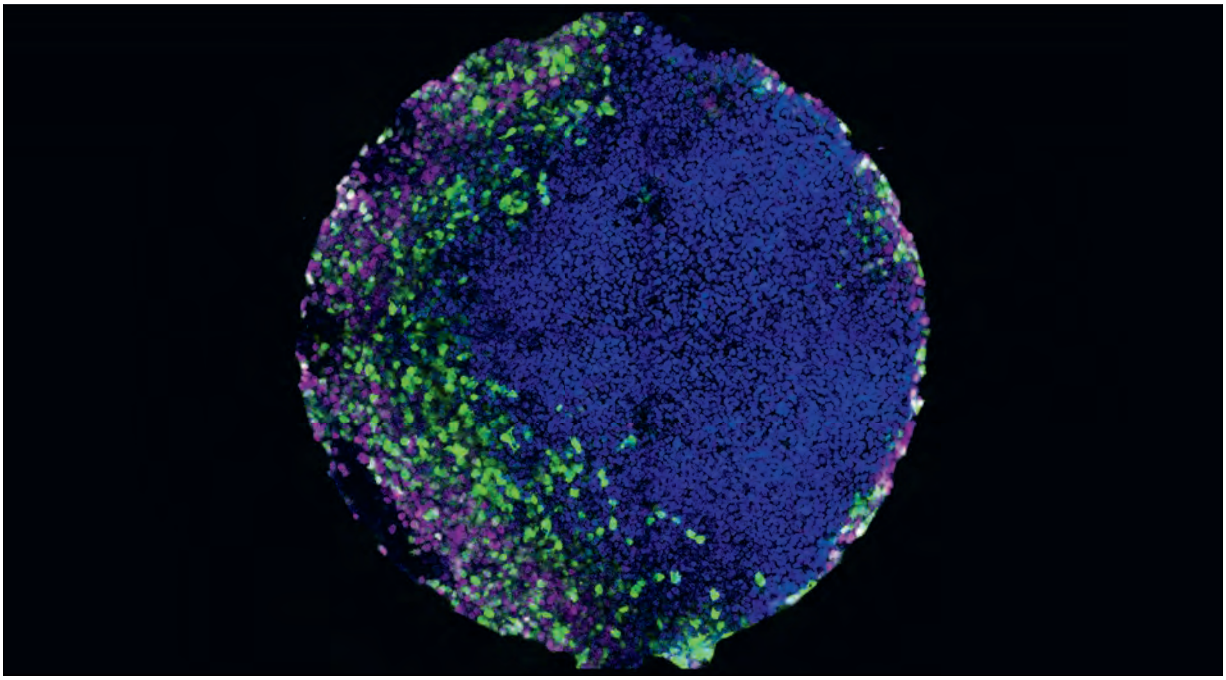
NCCR Bio-Inspired Materials researchers have used a microfluidic device to model embryonic formation with stem cells, paving the way for more controlled growth of specific human tissues in the laboratory.

It's no surprise that using human embryos for biological and medical research comes with many ethical concerns. Correct though it is to proceed with caution in these matters, the fact is that much science would benefit from being able to study human biology more accurately. One solution lies in alternative tools – what scientists call in vitro models. But despite some advancements with adult tissues, when it comes to modelling the early developmental processes of the human embryo, the situation becomes more complex.

Now, NCCR Bio-Inspired Materials scientists at Lausanne's Federal Institute of Technology (EPFL), and more specifically its Laboratory of Stem Cell Bioengineering, have simulated aspects of embryo formation in vitro starting from embryonic stem cells. "A tricky problem in reliably constructing tissues outside of an organism in general is how to present key signaling molecules, also termed morphogens, to the cells in culture at the right time and dose," says NCCR Bio-Inspired Materials Principal Investigator and EPFL Prof. Matthias Lütolf, whose group led the research. "Simply exposing a collection of stem cells to a single concentration of a morphogen ends in uncontrolled morphogenesis because the cells lack important instructions."

But in a developing embryo, stem cells receive a highly dynamic range of morphogen concentrations from so-called "signaling centers". It is this gradient of morphogens that tells stem cells what type of specialized cell and tissue to become. To implement this principle, NCCR alum Dr. Andrea Manfrin developed in Lütolf's lab a method for exposing human embryonic stem cells in culture to gradients of morphogens, mimicking the real-life conditions of gastrulation – an early stage of the developing embryo where its cells begin to transform into different cell types and tissues.

The method involves growing the stem cells in a microfluidic device, which is a chip with small channels that allow the precise control of tiny amounts of fluid. The researchers grew stem cells in a culture chamber on the microfluidic chip, and were able to expose them to carefully controlled concentration gradients of various morphogens. The results were impressive: the cells developed and organized into domains of different cell types, depending on the concentration they were ex-



Human embryonic stem cells exposed to a microfluidic gradient of a morphogen, resulting in the establishment of different cell types arranged in layers

posed to, like they do in the body. In fact, the scientists report that they were able to successfully mimic aspects of gastrulation, paving the way for growing specific human tissues in the lab in a more controlled manner.

> "One of our long-term goals is to engineer organs for transplantation."
> Matthias Lutolf

"We hypothesized that engineering an artificial signaling center 'ex vivo' could allow us to steer the self-organization of a stem cell population towards a desired outcome," explains Manfrin. "This has obvious advantages for tissue and organ engineering." These advantages include new tools for drug testing and regenerative medicine. The new technique can also help scientists study processes related to developmental biology – like gastrulation – and could provide alternatives to animal experimentation in some areas of research.

"One of our long-term goals is to engineer organs for transplantation," says Lütolf, who is already working with groups at the Lausanne University Hospital and elsewhere to generate miniaturized organs ('organoids') from patient-derived cells. "We are still far from growing functional organs in a dish; but recent progress in stem cell biology and bioengineering make me optimistic that this can become a reality. The key is to better understand how cells themselves build tissues and organs in the embryo".

Reference

Manfrin, A.; Tabata, Y.; Paquet, E. R.; Vuaridel, A. R.; Rivest, F. R.; Naef, F.; Lutolf, M. P. Engineered signaling centers for the spatially controlled patterning of human pluripotent stem cells. Nat. Methods, 2019, 16, 640–648..

Cell life

Separation with no boundaries

Every living cell has a highly complex internal organization. NCCR Bio-Inspired Materials researchers at Zurich's Federal Institute of Technology (ETHZ) have been investigating the physical phenomena that determine intracellular compartmentalization.

Phase separation is a central concept of materials physics – think of the three distinct phases of water as ice, a liquid and vapor. However, as a universal physical phenomenon, it still some distance from being entirely understood. Biological phase separation, for example, relates often to intracellular compartmentalization without membranes, featuring complex compositions and elasticity. Cells need to organize a variety of biochemical reactions within their confines. Part of this conundrum is solved by compartments called organelles, which contain their own environment, have their own boundary – usually a membrane – and allow chemical reactions to take place inside. One example are mitochondria, often called the cell's power plant. Other compartments do not have a membrane though, such as the nucleoli, which produce the ribosomes that perform protein synthesis, inside the cell nucleus. How these different compartments coexist without membranes is still not entirely clear. One potential explanation is so-called liquid-liquid phase separation.

Researchers led by NCCR Principal Investigator Prof. Eric Dufresne (ETHZ) chose to study the impact of elasticity on phase separation in synthetic polymer networks. They were inspired by previous work carried out by Dufresne on non-iridescent structural color in bird feathers. Results then suggested that phase separation was responsible for the nanostructures that generated vivid hues, but how the process began and ended was unclear. Understanding this biomimetic phase separation could provide a novel route for the assembly of useful photonic structures. Past experiments have shown that elasticity can markedly impact liquid–liquid phase separation in swollen synthetic polymer networks. In a homogeneous network, droplets grow to a fixed size, controlled by the network stiffness. When the network has an anisotropic state of stress, droplets grow with scale-independent ellipsoidal shapes. Other researchers have demonstrated that in the nucleus of living cells, phase-separating domains were found for example to form preferentially in chromatin-poor regions. Chromatin's main task is to package long DNA molecules into more compact, denser structures. After drops were triggered to grow in chromatin-rich regions, they migrated toward chromatin-poor regions.

Oil and water not mixing are an example of liquid-liquid phase separation

For their study, Dufresne and his colleagues used a synthetic polymer system, where mechanical properties and chemical solubility were tuned independently to reveal the impact of network mechanics on droplet nucleation and ripening. They found that network elasticity can suppress droplet nucleation deep inside the thermodynamically immiscible region, mechanically stabilizing supersaturated mixtures. The long-term stability of droplets is strongly affected by network elasticity. They also demonstrated that in a mechanically heterogeneous network the solute moves from stiff to soft regions by diffusive transport through the dilute phase.

These phenomena suggest that living cells might regulate the localization of organelles without membranes through gradients of their mechanical properties. "We were able to show that compressive stresses in a polymer network can suppress phase separation of the solvent that swells it, stabilizing mixtures well beyond the liquid–liquid phase-separation boundary," explains Dufresne. Network stresses also drive a new form of ripening, driven by transport of solute down stiffness gradients. This elastic ripening can be much faster than conventional Ostwald ripening driven by surface tension, in which small particles shrink by releasing molecules that coalesce on larger ones.

According to Dufresne, further research is now required to quantify the heterogeneous mechanical properties of the cell interior, and the size distribution and surface tension of droplets. This will enable scientists to assess the relative contributions of surface tension and elasticity in a specific cellular context.

Reference

Rosowski, K. A.; Sai, T.; Vidal-Henriquez, E.; Zwicker, D.; Style, R. W.; Dufresne, E. R. Elastic ripening and inhibition of liquid–liquid phase separation, Nat. Phys., 2020, 16, 422 – 425.

Energy

Solar thermal gets a dopamine boost

Improving the efficiency of solar thermal heating could be improved with the use of polydopamine (PDA) nanoparticles. NCCR Bio-Inspired Materials researchers at the Adolphe Merkle Institute have applied a hybrid nanoparticle system to increase heating efficiency in solar fluid.

When it comes to solar power, photovoltaics usually garner all the attention. But sunlight is actually more frequently used to heat water. Energy is usually captured by a black absorber surface, and the heat generated is transferred to a fluid running through the panel. Two limitations to this system are the efficacy of the absorbing panel, as well as the efficiency of the heat transfer to the solar fluid. One way to overcome this is the so-called direct absorption solar collector (DASC) approach, where absorption takes place directly in the solar fluid. A variety of fluids have been proposed, starting with India ink, which contains soot particles, but also clogs and damages the collector. More efficient nanoparticle-doped fluids have also been trialed, but also fall short because of increased costs, wear and tear on installations, and issues with the disposal of potentially toxic waste.

NCCR Bio-Inspired Materials Principal Investigator Prof. Barbara Rothen-Rutishauser and her team at the Adolphe Merkle Institute chose to investigate the applicability of polydopamine. PDA is mussel-inspired material, but more importantly, can form black nanoparticles, and has extraordinary heating properties when excited with light. It could therefore be a candidate for a stable, nontoxic, and highly efficient alternative to boost solar heating. Previous research in collaboration with Prof. Vincent Ball from the University of Strasbourg, France, has shown that polydopamine can be easily modified, a characteristic the NCCR researchers used to their advantage. They synthesized hybrid PDA nanoparticles of different sizes with a capping protein, bovine serum albumin (BSA), which was used as a proof-of-concept. The heating ability of the different samples, along with food coloring containing micrometer-sized soot particles, as well as silver nanoparticles, was measured with lock-in thermography at a fixed wavelength. These results showed that that smaller hybrid nanoparticles provided the best heat transfer, although not bettering the silver nanoparticles, which have been used as solar fluids.

The hybrid nanoparticles also proved themselves to be equal to one of the major challenges facing solar fluid doping: the degradation or

Capturing heat is the most widespread use of solar energy

aggregation of the dopant in the fluid over time. They were still stable after UV irradiation with an energy equivalent to six-and-a-half years of the sunlight reaching Switzerland, based on data from the Swiss national weather service. Heating ability itself only dropped slightly.

Taking their investigations further, the researchers built a test flow circuit including a collector. This was exposed to solar radiation in a simulator where the temperature of the collector fluid was monitored. The solar simulation replicates the entire spectrum of the sun's light, unlike lock-in thermography. Results in this case showed that the hybrids could outperform substantially the silver nanoparticle fluids. An additional benefit was that no hybrid PDA nanoparticle deposits were found in the collector in comparison to the solar fluids doped with silver nanoparticles or food coloring.

Nanoparticle-doped solar fluids face a number of challenges, not least high production costs, a certain instability, and a tendency to degrade collector components. PDA nanoparticles are well-equipped to overcome these hurdles as their main ingredients – polydopamine and BSA – are easy to obtain at a low cost. And PDA is already present in the natural environment and biocompatible at high concentrations, making it unlikely to pose any kind of hazard. Combined with their heating efficiency, these hybrid nanoparticles should be considered for future use in solar thermal applications.

Reference

Hauser, D.; Steinmetz, L.; Balog, S.; Taladriz-Blanco, P.; Septiadi, D.; Wilts, B. D.; Petri-Fink, A.; Rothen-Rutishauser, B. Polydopamine nanoparticle doped nanofluid for solar thermal energy collector efficiency increase, Adv. Sustain. Syst., 2019, 4, 1900101.

Quantum leap

Building optical antennas at the nanoscale

NCCR Bio-Inspired Materials researchers are working on the frontiers of nanophotonics, developing quantum devices known as optical antennas, which could improve the performance of solar cells or boost nanoscale LED lighting.

Antennas as such are not particularly novel. Today, while less visible than they were a few decades ago, they are found in our mobile phones, and used for example for satellite communications and in a wide variety of devices relying on the micro and radio-wave part of the electromagnetic spectrum. They can either capture waves and convert their energy into electrical signals, or take electrical signals and convert them into waves. In theory this is also possible with light, which is part of the electromagnetic spectrum.

Typically, light is commonly manipulated with lenses and mirrors. However, using these elements light cannot be focused to dimensions much smaller than the optical wavelength (~ 1 micrometer), due to the diffraction of light waves. In order to overcome this hurdle, recent research in nano-optics and plasmonics has focused on so-called optical antennas, with physicists exploring ways of translating established radio wave and microwave antenna theories into the optical frequency regime. It is hoped that such antennas could increase the efficiency of light-matter interactions in important applications, such as light-emitting devices, photovoltaics, and spectroscopy.

The purpose of these optical antennas is therefore to convert the energy of free propagating light to localized energy, and vice versa. Although this is similar to what radio and microwave antennas do, optical antennas commonly exploit the unique properties of metal nanostructures, which exhibit strong collective oscillations of their free electrons at optical frequencies an effect known as localized surface plasmons.

> "This provides us with solid ground for more sophisticated photon routing experiments."
> Guillermo Acuna

NCCR Principal Investigator Prof. Guillermo Acuna and his colleagues at the University of Fribourg have focused on fabricating optical nano-antennas, and studying their interaction with

Antennas are traditionally used to transmit radio waves

single photon emitters, including the effects of near field excitation and emission directionality. Their work calls upon the so-called DNA origami technique, developed over a decade ago by US researchers. This is based on "folding" a long single-stranded DNA sequence with the aid of shorter single-strands into a predesigned shape typically with dimensions in the hundreds of nanometers. Acuna and his team use the DNA origami as a framework where metallic nanoparticles or quantum dots for example can be precisely positioned. "This allows us to form vast numbers of theses antennas in parallel, permitting us to study fundamental interactions," explains Acuna.

The NCCR researchers have recently been investigating how DNA self-assembled optical antennas can direct the emission of single photon emitting fluorophores. The origami technique is applied to create optical antennas composed of two colloidal gold nanoparticles separated by a predefined gap. They then placed a single red fluorescent molecule in the middle of this space. By doing this, the nanoparticles act as an optical antenna that mediates the emission of the fluorophore thus manipulating its directionality.

"This work is intended to set out the basis for manipulating the emission pattern of single molecules with self-assembled optical antennas based on colloidal nanoparticles," adds Acuna. "This provides us with solid ground for more sophisticated photon routing experiments." In the longer term, this could lead to applications in fields such as sensing and super-resolution microscopy.

References

Hübner, K.; Pilo-Pais, M.; Selbach, F.; Liedl, T.; Tinnefeld, P.; Stefani, F. D.; Acuna, G. P. Directing single-molecule emission with DNA origami-assembled optical antennas, Nano Lett., 2019, 19, 6629–6634.

Grant success

Tackling major societal issues

NCCR Bio-Inspired Materials Principal Investigator, Professor Francesco Stellacci (EPFL), has been recently awarded major grants worth approximately CHF 9 million allowing him to investigate polymer recycling, and pursue efforts to develop an antiviral treatment.

Stellacci was the recipient of a prestigious ERC Advanced Grant by the European Research Council. Worth €3.35 million over five years, the grant will fund research into nature-inspired polymer recycling. His NaCRe (Nature-inspired Circular Recycling for Polymers) project is aimed at establishing a new paradigm for the recycling of plastics. The idea is to take plastics' main chemical component, polymers, and to recycle them in the same way nature does with proteins.

"Nature teaches us that it is possible to break the paradigm of recycling a material into itself", explains Stellacci. "Every time we eat, we recycle proteins into other proteins that bear no resemblance to the ones we ate."

This funding is part of the EU research and innovation program, Horizon 2020. This year's grantees will carry out their projects at universities and research centers across 20 EU Member States and associated countries. ERC competitions are open to researchers of any nationality and, in this round, which saw nearly 1,900 researchers apply, 185 scientists and scholars of 26 nationalities received funding worth a total of €450 million.

According to Stellacci, he was looking to expand his work with the NCCR. "The idea for my ERC literally came to my mind one time that I was thinking about developing a project that was profoundly bio-inspired," he adds. "I fell so much in love with the idea that now I want to make it a pillar of my research."

Last year, another NCCR Bio-Inspired Materials PI, Professor Ullrich Steiner (Adolphe Merkle Institute), was also the recipient of an ERC Advanced Grant, focusing on furthering the understanding of structural color, a project that is also closely linked to the NCCR.

Viral research

The Werner Siemens Foundation also awarded a CHF 5 million grant to Stellacci's Supramolecular Nano-Materials and Interfaces Laboratory (SuNMIL). His team, which is working on a compound that can block viral activity, hopes to make progress in developing broad-spectrum antivirals.

"I was delighted when I found out about the grant," says Stellacci. "It's even better than I

Plastic waste in one of the major environmental problems facing humanity

could've imagined. The Werner Siemens Foundation has shown itself to be very generous."

With this grant, Stellacci and his research team have been able to finance the next phase of their research on antiviral drugs. Previous work was funded by the NCCR Bio-Inspired Materials. "Our

> "We've already developed a treatment that works in vitro to block HIV, HRSV, and the dengue, Zika and herpes viruses."
> Francesco Stellacci

aim is to find a single drug that can halt the activity of several different viruses," says Stellacci. "We've already developed a treatment that works in vitro to block HIV, HRSV [human respiratory syncytial virus], and the dengue, Zika and herpes viruses. We've now added SARS-CoV-2 to our experiments. If our treatment turns out to be safe and effective, it could be used for all those diseases."

The grant will go towards covering the most expensive stage of the drug development work – clinical trials on animals and then humans. "We will be able to conduct in vivo tests of the efficacy and toxicity of our treatment," says Stellacci. "Five million francs may seem like a lot, but it will actually cover just one year of trials." If the findings are conclusive, the new drug could be available on the market in as soon as in 18 months.

Multiplier effect

Special funding has wide impact

Since its launch, the NCCR Bio-Inspired Materials has encouraged top academics to become Principal Investigators or Associate Members of the Center.

One way of achieving this goal is the "Incentive Program" for the Home Institution, the University of Fribourg, which considers materials research one of its strategic thrusts. The funding not only helps attract new talent to the university, but also provides a welcome fillip to its departments.

Competing for the hearts and minds of future professors is not always simple. The best candidates often apply for positions at different institutions at the same, and universities need to find an edge to lure the best. While some tertiary institutions can rely on strong branding and generous funders, most are not as privileged.

Fribourg won out when it hired PI Prof. Guillermo Acuna for example. However, the NCCR's incentive funding played a decisive role. "At that time, I had just accepted a full professor position in Germany. However, the incentive program clearly turned the dial in favor of Fribourg," he explains. With the money, he purchased his group a multicolor fluorescence microscope for super-resolution imaging.

"Currently, this is the piece of equipment most heavily used in my group for sample characterization," says Acuna. "I have also employed it in my lectures of Modern Optics in order to show the basic principles of fluorescence imaging. Furthermore, different groups from my department and others, for example medicine, have also used it to perform measurements."

> "The incentive grant is definitely a crucial asset that makes the hiring processes of the University of Fribourg internationally more competitive."
> Stefan Salentinig

Associate PI Prof. Stefan Salentinig is another who has benefited from the incentive program, albeit not as part of the hiring process. The focus of the NCCR, AMI and the Chemistry Department on nanomaterials, polymers and colloids in general guided his choice to the University of Fribourg to pursue his career path in the field of physical chemistry/functional biomaterials.

"The grant was approved after the start of my professorship here," he adds. "It was an important asset that has boosted my start at the university,

Incentive grants have helped attract top talent to the University of Fribourg

and contributed significantly to further establishing my group. My research also benefitted significantly." With the funding, Salentinig was able to acquire strategic state-of-the-art research equipment for nanomaterial/interface characterization for his laboratory "The purchased equipment was crucial to our research," he says. He was also able to invest in a food material project that led to significant research output from his team.

According to Salentinig, the grant had a multiplier effect, supporting the generation of new projects and collaborations, among them a Swiss National Science Foundation project, as well as fueling industry funded collaborations with several partners in Switzerland. Overall, the funding has also contributed to projects with other departments at the university, notably helping resolve research questions in collaboration with the departments of chemistry, physics, medicine, and the Adolphe Merkle Institute.

Both professors see the program as a net positive for the NCCR's home institution. "I would consider that it has a tremendous impact on the hiring process as it strongly enhances the resources available to start your lab," say Acuna, a sentiment that Salentinig shares. "I would say that the incentive grant is definitely a crucial asset that makes the hiring processes of the University of Fribourg internationally more competitive."


250 ml

113

Researchers

Including 50 supported by the SNSF grant

CHF 8.6 million

of funding including CHF 4 million from the SNSF

35 Nationalities

including Switzerland, Argentina, Australia, Austria, Belgium, Brazil, Canada, China, Costa Rica, Croatia, France, Germany, Greece, Hungary, India, Indonesia, Iran, Italy, Kosovo, Lebanon, Lithuania, Luxembourg, Macedonia, Netherlands, New Zealand, Portugal, Russia, Slovenia, South Africa, Spain, Turkey, Ukraine, United Kingdom, United States of America, Vietnam.

13 joint publications

within the NCCR network

6

patent applications

21

Publications

in journals with an impact factor of >10 (including Nature Materials, Nature Chemistry, Nature Physics, Nature Methods, Nature Communications, Cell Stem Cell, ACS Central Science or ACS Nano)

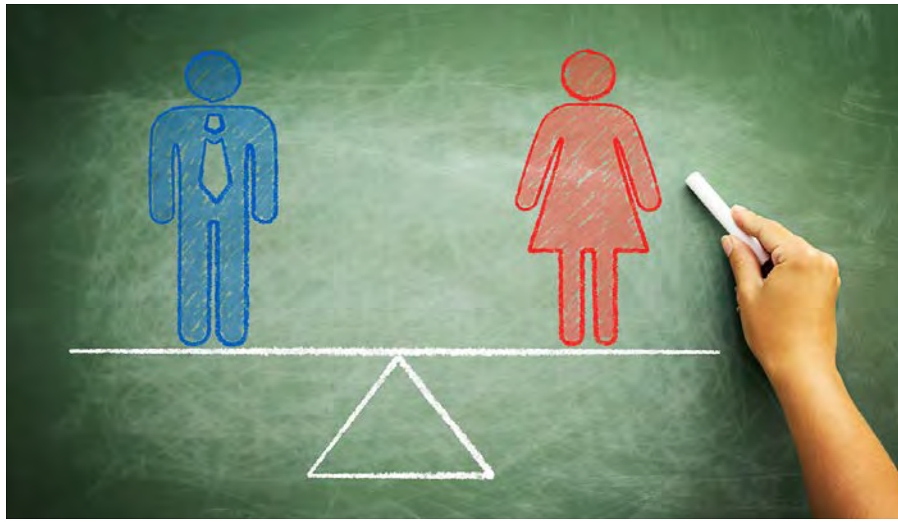
Note: All figures between March 1, 2019, and February 28, 2020

In brief

Ethical charter

The NCCR Bio-Inspired Materials introduced a new set of ethical principles, aimed at serving as a reference for decision making.

The main points include the defense of human rights, and the principle of non-discrimination. Researchers are expected to be independent, honest, and transparent, while sharing the responsibility with respect to the objects of study, the execution of the research, and the potential use of their findings. This includes carrying out, documenting, and communicating research findings according to the highest international standards of quality and ethics. The charter is available on the Center's website bioinspired-materials.ch.



Equal opportunities have been a core element in the development of the NCCR Bio-Inspired Materials

Gender equality policy

Since its launch, the NCCR Bio-Inspired Materials has strived to create a gender-balanced scientific community with an ambitious Equal Opportunities Program.

This is reflected in the new Gender Equality Policy, which reflects the commitment of the Center to offer equal opportunities to women and men. It also serves as a guideline for the NCCR's efforts to promote the integration of women at all educational levels in natural and life science disciplines to advance towards a gender-balanced academic system.

Its goals include promoting female role models and sparking the interest of female students in natural sciences from elementary school and beyond; ensuring equal career opportunities for parents; encouraging young female researchers to pursue an academic career, actively helping them to overcome existing hurdles, and supporting the career development of PhD students and postdocs; and disseminating successful measures and transfer them to the affiliated departments of the home and partner institutions .

To reach its gender equality goals, the NCCR Bio-Inspired Materials has put in place a series of measures including outreach programs for children and educational activities for high school students organized to awake their interest in natural and life sciences; scheduling meetings and seminars during normal working hours to accommodate the participation of researchers with children and families; flexible working policies are applied whenever possible; reimbursing additional childcare expenses during travel for a professional event. Other measures include round tables/workshops on topics such as negotiation skills, gender bias identification or family-work balance; sponsoring symposia at conferences that highlight female researchers as women are still underrepresented; and the Woman in Science (WINS) Fellowship.

European recognition

Two NCCR Bio-Inspired Materials post-doctoral researchers, Dr. Philip Scholten and Dr. Samet Kocabey, were awarded prestigious Marie Skłodowska-Curie Fellowships in 2020 to investigate degradable plastics and cancer biomarkers, respectively.

Scholten (Adolphe Merkle Institute) is developing degradable commodity plastics. His project will focus on novel materials based upon polymers containing metallic ions. The difficulty of recycling commodity plastics means that incineration and landfills are still the main options when dealing with this waste. Novel materials are therefore needed to help tackle these issues, and facilitate the recycling and degradation of (commodity) polymers.

Kocabey (University of Fribourg) is investigating microRNAs, which play a major role in gene regulation, as potential biomarkers for cancer diagnosis, prognosis and treatment monitoring. He plans to develop a sensitive assay system. It would allow the simultaneous detection of multiple microRNA targets from breast cancer cells and plasma by using a nanoscale folding method called DNA origami, and a state-of-art super resolution imaging technique.

Dr. Philip Scholten and Dr. Samet Kocabey

PhD awards

Two former NCCR PhD students were recognized for the results achieved in their theses.

Dr. Céline Calvino was awarded the 2019 Chorafas Prize for the best doctoral thesis in natural sciences at the University of Fribourg. Calvino completed her PhD thesis on "Mechanochromic materials based on non-covalent interactions" as a member of NCCR PI Prof. Christoph Weder's group at the Adolphe Merkle Institute. After a postdoctoral stay at the University of Chicago, Calvino is due to take up an independent position at the University of Freiburg (Germany).

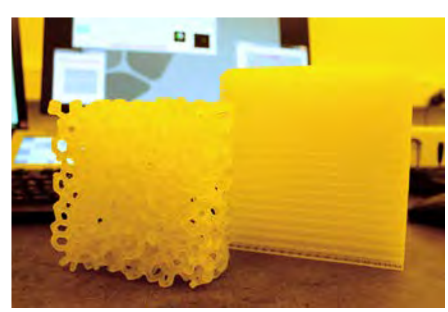
Alum Dr. Omar Rifaie Graham (Adolphe Merkle Institute, Bruns group) was awarded the University of Fribourg's prize for best experimental thesis. The award was in recognition of Rifaie Graham's PhD project "Cell inspired force and light responsive polymersome nanoreactors and polymerisation based diagnostics". His work was also influential for the NCCR supported malaria diagnostics project Hemolytics. Currently at Imperial College London, he was also awarded a prestigious Marie Skłodowska-Curie Fellowship in 2020.

Dr. Céline Calvino and Dr. Omar Rifaie Graham

Materials index

A 2019 ranking from Nature Index put the NCCR's Home Institution, the University of Fribourg among the fastest rising institutions in materials science, making it one of just two Swiss institutions in the top 50 of this list (along with the Federal Institute of Technology in Zurich), as well as one of three in Europe.

The University of Fribourg also cracked the top 200 institutions in materials science, along with NCCR partners the Federal Institutes of Technology in Lausanne (EPFL) and Zurich (ETHZ), the Federal Laboratories for Materials Science and Technology (Empa), and the Paul Scherrer Institute (PSI).



Materials research is considered a strategic domain at the University of Fribourg

The conference attracted leading natural materials' specialists

Bioinspired Materials Confe-rence 2019

The first edition of an international conference on bio-inspired materials sponsored by the NCCR was held in the southern Swiss canton of Ticino in October 2019.

The event organized by NCCR Bio-Inspired Materials Principal Investigators Prof. Esther Amstad (EPFL) and Prof. Eric Dufresne (ETHZ), NCCR staff member Dr. Stephen Schrettl (Adolphe Merkle Institute), and Dr. Silvia Vignolini of Cambridge University, focused on the fabrication and characterization of natural materials, featuring examples for the development of future bio-inspired technology. The week-long conference, with leading guest speakers from the field, provided a venue connecting research on the characterization of natural materials and investigation of their production mechanisms together with research performed on the fabrication of biomimetic materials. A second edition of this successful conference is planned for later in 2021.

Equal opportunities

NCCR Bio-Inspired Materials PIs Profs. Alke Fink and Barbara Rothen-Rutishauser, along with outreach manager Dr. Sofia Martin Caba, are among the recipients of the inaugural 2019 Materials Today Agents of Change Award.

The award, worth $10,000, recognized their project aimed at boosting the professional role confidence of female scientists. Their proposal, based upon their own observations and those of other female academics, highlights that women researchers often lack this confidence as they attempt to climb the academic ladder, something that needs to be recognized as a major hurdle for career progression. Missing confidence can also engender a negative feedback loop, leading to lower publication rates, as well as decreased grant and professional successes.

Different courses of action are planned or already underway to boost the success of female researchers. These include round table discussions on the topic of professional role confidence, as well as an extended workshop on the same theme for women scientists at all levels, organized by female professionals and role models. These events should help female researchers build up a strong network in Switzerland in the materials engineering field, exchange ideas, know-how, or set up joint programs for example with the goal of addressing the aforementioned lack of "professional role confidence".

Emerging investigators

Two past and present NCCR staff members were featured in the biannual issue (2020) on emerging investigators of the journal Polymer Chemistry.

Prof. Yoan Simon and Dr Stephen Schrettl

Dr. Stephen Schrettl, group leader at the Adolphe Merkle Institute highlighted the preparation of metallosupramolecular single-chain polymeric nanoparticles and their characterization by Taylor dispersion, while Prof. Yoan Simon (University of Southern Mississippi, previously Adolphe Merkle Institute) demonstrated that learning from nature is inspirational for the photochemically driven construction of single chain nanoparticles.

High impact publications

Magrini, T.; Moser, S.; Fellner, M.; Lauria, A.; Bouville, F.: Studart, A. R. Transparent nacre-like composites toughened through mineral bridges, Adv. Funct. Mater., 2020, 30, 2002149.

Moore, D. G.; Barbera, L.; Masania, K.; Studart, A. R. Three-dimensional printing of multicomponent glasses using phase-separating resins, Nat. Mater., 2019, 19, 212–217.

Du, H.; Courregelongue, C.; Xto, J.; Bohlen, A.; Steinacher, M.; Borca, C. N.; Huthwelker, T.; Amstad, E. Additives: their influence on the humidity- and pressure-induced crystallization of amorphous CaCO3, Chem. Mater., 2020, 32, 4282–4291.

Conley, G. M.; Zhang, C.; Aebischer, P.; Harden, J. L.; Scheffold, F. Relationship between rheology and structure of interpenetrating, deforming and compressing microgels, Nat. Commun., 2019, 10, 2436.

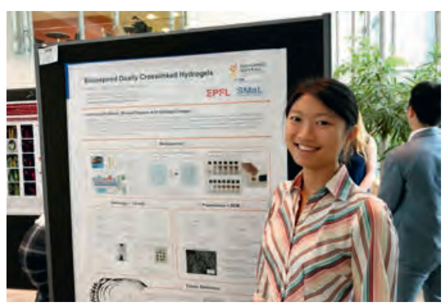
Kilchoer, C.; Abdollahi, N.; Dolan, J. A.; Abdelrahman, D.; Saba, M.; Wiesner, U.; Steiner, U.; Gunkel, I.; Wilts, B. D. Strong circular dichroism in single gyroid optical metamaterials, Adv. Opt. Mater., 2020, 6, 1902131.

Rosowski, K. A.; Sai, T.; Vidal-Henriquez, E.; Zwicker, D.; Style, R. W.; Dufresne, E. R. Elastic ripening and inhibition of liquid–liquid phase separation, Nat. Phys., 2020, 16, 422–425.

Brassard, J. A., Lutolf, M. P. Engineering stem cell self-organization to build better organoids, Cell Stem Cell, 2019, 4, 860–876.

Glushkov, E.; Archetti, A.; Stroganov, A.; Comtet, J.; Thakur, M.; Navikas, V.; Lihter, M.; Marin, J. F. G.; Babenko, V.; Hofmann, S.; Manley, S.; Radenovic, A. Waveguide-based platform for large-FOV imaging of optically active defects in 2D materials, ACS Photonics, 2019, 6, 3100–3107.

Jones, S. T.; Cagno, V.; Janecek, M.; Ortiz, D.; Gasilova, N.; Piret, J.; Gasbarri, M.; Constant, D. A.; Han, Y.; Vukovic, L.; Kral, P.; Kaiser, L.; Huang, S.; Constant, S.; Kirkegaard, K.; Boivin, G.; Stellacci, F.; Tapparel, C. Modified cyclodextrins as broad-spectrum antivirals., Sci. Adv., 2020, 6, eaax9318.



Molly Sun took part in the summer Undergraduate program in 2019

Undergraduate success

Every year, the NCCR hosts students from many countries as part of its summer research program.

The students usually spend eight to twelve weeks in Switzerland in one of the Center's partner laboratories. The impact of the program is felt quickly in some cases, more slowly in others. Molly Sun, one of the 2019 alumni, won best oral presentation at an American Chemical Society meeting in the following autumn. The University of Chicago student presented the research on bio-inspired hydrogels she carried out in PI Prof. Esther Amstad's laboratory (EPFL).

Program alum Alicia Dibble (University of Utah, 2018) was one of the authors of an article in the journal ACS Omega on improved coatings or substrates for drug delivery devices published in February 2020. Alicia worked on the project in the laboratory of NCCR PI Prof. Christoph Weder.

2018 alumn Ava LaRocca from MIT co-authored a 2020 article in Advanced Photonics Research on a novel "hyperbolic optical metamaterial", playing an important role in creating the samples underpinning this research. Ava worked in the lab of NCCR PI Prof. Ulli Steiner.

Finally, Seth Price, a 2016 alum (Durham University), was the first author of a paper in the journal Nanoscale on "Particokinetics and in vitro dose of high aspect ratio nanoparticles" (2019) in collaboration with NCCR senior scientist Sandor Balog.

Envoys program

The NCCR was able to promote equal opportunities through its network thanks to its Envoys Program.

This included notably the organization of roundtables/lunchtime discussions at the Federal Institute of Technology in Lausanne (EPFL) under the guidance of NCCR PI Prof. Esther Amstad in collaboration with the WISH Foundation. Another roundtable was organized at the Department of Physics at the University of Fribourg. Three NCCR management members (Prof. Barbara Rothen-Rutishauser, Dr. Sofia Martin Caba, and Myriam Marano) have also joined the EO commission of the Faculty of Science and Medicine there, allowing them to promote EO at the faculty level with in direct contact with the Home Institution's rectorate. The Envoys Program was launched with the goal to translate the EO culture of the Center and its most successful EO activities to the partner departments at the participating institutions.

Roundtables are a regular feature of the NCCR's equal opportunities activities

Pregnancy flexibility grant

A new action taken by the Center towards equal opportunities for women and men is the launch of the Pregnancy Flexibility Grant.

This funding scheme aims to mitigate the effects that pregnancy has on the career of female postdoctoral researchers working in potentially hazardous environments. While medically indicated leave during pregnancy is usually covered by the insurance system, and compensates for time missed after the researcher returns to work, there is no support available for future mothers who cannot carry out experimental work in laboratory settings that involve potentially hazardous substances. The NCCR Pregnancy Flexibility Grant covers this funding gap, and can be used to hire support staff to perform the work of a postdoc for the period of her pregnancy she is prevented from carrying out experimental work. One researcher has benefited so far from the grant.

PhDs

Mahshid Alizadeh (Kilbinger group, UniFR) Synthesis of model oligomers. cis-Aramide oligomers of different lengths will be prepared and incorporated into linear polymer structures.

Edward Apebende (Bruns group, AMI) Synthesis and characterization of force responsive block copolymers.

Daniel Hauser (Rothen/Fink group) Intelligent nanomaterials to reveal and to control their behavior in complex media, at the biointerface and in cells.

Phally Kong (Kilbinger group, UniFR) Synthesis of polymers with auxetic behavior.

Serhii Vasylevskyi (Fromm group, UniFR) Coordination chemistry of pyridine bis-substituted polycyclic aromatic hydrocarbones ligands with Ag (I) and Zn(II).


Telstar
LyoQuest

Equal opportunities

Fellowship helps level playing field

For the past four years, the NCCR Bio-Inspired Materials has supported equal opportunities in research through its Women in Science (WINS) Postdoctoral Fellowship. The goal of this flagship program is to attract excellent female researchers who wish to pursue a career in science.

The fellowships are awarded through an open call for project proposals, which is followed by a competitive evaluation process. The funding covers the researcher's salary, consumables and travel expenses for two years. The fellows are hosted by one of the Center's groups, and carry out their own research projects.

So far, six fellowships have been awarded since the program's launch. Dr. Yendry Corrales completed her stay in Switzerland in February 2020, taking up a staff scientist position at the National Laboratory of Nanotechnology in her native Costa Rica. "I applied for the fellowship because of the funding topic – bio-inspired materials are my main research interest," she explains. "It was also a fellowship that would allow me to develop my ideas, have the support of experienced researchers, and to work in a multidisciplinary environment." She adds that there are few centers worldwide specialized in bio-inspired materials with the cutting-edge technology the NCCR can provide.

During her time with the BioNanomaterials group at the Adolphe Merkle Institute, she investigated the unique properties of the slime projected by the carnivorous velvet worm Epiperipatus biolleyi. When hunting, these worms use their antennae and chemosensory organs close to their mouths to identify their prey. Once the tiny predator has found its target, it shoots sticky white slime onto its prey to pin it down. The worm is then able to inject digestive saliva before consuming the insect. The more the prey tries to disentangle itself from the slime, the stiffer this becomes, as it hardens quickly when mechanically stimulated. The slime is originally viscous like egg yolk, and turns into a solid high-strength polymer comparable to nylon in just mere seconds. This material, however, is biodegradable, as it is composed of water, proteins, lipids, and carbohydrates. Corrales' research revealed that the slime is in fact a composite material formed by a protein matrix and vesicles containing inorganic salts. This gives it the strength of petroleum-derived

Dr. Yendry Corrales was one of the first WINS Fellowship recipients

polymers such as nylon, but with the added advantages of being protein-based and biodegradable. Typically, this natural composite could be used as a model to formulate bio-inspired biodegradable materials to replace petroleum-derived plastics such as polyester or acrylics according to Corrales.

Her project started with only a few preliminary results as a base for her investigations. She reckons though that she achieved 80 per cent of what she set out to do, and completed the main parts of the experimental work. Beyond the science, the fellowship had a wider impact, particularly in terms of career development. “Working in the AMI BioNanomaterials group allowed me to understand better the potential interconnections between biology and materials sciences,” Corrales says. “I am now a researcher at Costa Rica’s National Laboratory of Nanotechnology, but I also teach in a public university for a master’s program on medical devices. I was able to get this position due to my experience in the BioNanomaterials group.”

The fellowship also allowed Corrales to extend her scientific network related to the bio-inspired materials topic, leading to applications for further grants. A collaborative project with the AMI BioNanomaterials group on 3D hydrogel printing was recently awarded over CHF 24,000 in seed funding by Switzerland’s State Secretariat for Education, Research and Innovation. It builds on the previous velvet worm investigations, with the aim to develop a potential first application – an accessible and simple 3D printing system. In recent years, the use of hydrogels combined with 3D-printing has revolutionized the field of biomaterials, allowing for the customized fabrication of functional hydrogel scaffolds for tissue engineering, delivery systems, implants, diagnostic devices, and soft electronics. The project’s ambitious goal is to provide, for the first time, developing rural developing communities with access to customized hydrogels for their medical care requirements.

The hydrogel formulation and instrument development will be carried out in Costa Rica, while 3D-printing, nanocarrier synthesis and characterization, and development of stimuli-responsive materials will take place in Switzerland at the Adolphe Merkle Institute.

Three new fellows in 2020

Dr. Maria Taskova joined NCCR PI Prof. Michael Mayer’s group at the Adolphe Merkle Institute from the Technical University of Denmark. Her project focuses on gene therapy for human diseases. While this field is rapidly evolving, a number of issues still need to be addressed for these treatments to reach their full potential. These include the in vivo stability, specificity, and targeted intracellular delivery of the nucleic acid therapeutic. Taskova will design, synthetize and investigate advanced modified oligonucleotide therapeutics.

Dr. Kuljeet Kaur has integrated NCCR PI Prof. Harm-Anton Klok’s laboratory at EPFL from Virginia Tech (USA). Her project is aimed at quantifying the weak mechanical forces associated with swelling processes at polymer interfaces, as well as in bulk hydrogels, for a better understanding of solvent-polymer interactions at a molecular level. This knowledge should ultimately allow fine-tuning of mechanoresponsive polymeric materials properties.

Dr. Jessica Clough has joined NCCR PI Prof. Christoph Weder’s group at AMI from the Eindhoven University of Technology in the Netherlands. Her project focuses on the development of a broadly applicable, polymeric mechano-sensors capable of reporting on a wide range of deformations. The sensors take the form of spherical, photonic assemblies of colloids, combined with a mechanosensitive chemical moiety, giving “mechano-pigments” with a novel combination of mechano-responsivities that are readily dispersed in different polymeric matrices. This approach is inspired by squid skin, which uses different responsive structures to modulate its appearance.

Award-winning

Novel applications of technology reap rewards

Start-ups and application projects supported by the NCCR Bio-Inspired Materials have shown themselves to be extremely competitive in obtaining funding and recognition in their respective fields.

Fenx

CHF 200,000 from Klimastiftung Schweiz
Winner W.A. de Vigier Award 2020
Top100 Swiss Startup Award Winner 2020
2019 Forbes 30Under30 winner
2019 Swiss Technology Award Winner
Venture Kick winner
Funding from Innosuisse, BRIDGE, Gebert Rüf Stiftung, SEIF

Microcaps

Top100 Swiss Startup Award 2020
2020 Forbes 30 Under 30
Winner W.A. de Vigier Award 2020
Winner of the 2020 ZKB Pionierpreis
2nd Place at the 2019 Swiss Technology Award
VentureKick winner 2018
Funding from Innosuisse, BRIDGE, Gebert Rüf Stiftung

Spectroplast

Top 5 Winner of the 2020 Swiss Innovation Challenge
Falling Walls Winner 2020
Ranked in TOP-100 2019 Swiss Startups
2019 tct Rising Star Award (Highly Commended)
2019 Series A seed funding round closed with CHF 1.5 M
2019 Top 100 Swiss Startups of VentureLab
2019 CES ASIA Innovation Award
Invitee at World Economic Forum Davos 2019
Funding from Innosuisse, BRIDGE

Hemolytics

YPSOMED 3rd Prize winner 2019
Venture Kick 2018 Prize Winner
Funding from Innosuisse, BRIDGE, Gebert Rüf Stiftung in 2018–2020
Coaching support from SEIF and FriUp

Nanolockin

Fribourg Innovation Prize 2018
Top 10 of Venture 2018
Coaching support from FriUp
Funding from Innosuisse, BRIDGE in 2018–2020

Career funding

A stepping stone for postdoctoral researchers

How do young researchers gain an advantage in pursing an academic career? The NCCR Bio-Inspired Materials offers a number of funding programs to its members at the postdoctoral level, including the “Independence Grant”.

This funding is designed to help talented young researchers in their pursuit of an independent career. It supports activities that go beyond their work as participants of the Center, such as travel to establish new contacts, preliminary experiments, writing of independent publications, and grant writing.

One of the most recent recipients is Dr. Corey Stevens, who works in the laboratory of NCCR Principal Investigator Prof. Harm-Anton Klok at Lausanne’s Federal Institute of Technology (EPFL). When he applied for the grant, he had a number of objectives. “First and foremost was to conduct follow-up research on an initial promising result that was beyond the main research scope of my current postdoctoral activities,” Stevens explains. “The goal of the project is to identify peptides, short chains of amino acids, that can inhibit ice growth. Materials that can prevent ice growth are relatively rare, yet, they have many potential biomedical applications including the cryostorage of food, tissues, and organs. So, there is an obvious need to discover more materials that can inhibit ice growth.” Using advanced DNA sequencing and bioinformatic techniques, Stevens says he has identified additional candidate peptides, and constructed a device for quantifying their ability to inhibit ice growth.

Dr. Dedy Septiadi is another grantee. Septiadi, who works in the laboratory of NCCR PIs Profs. Alke Fink and Barbara Rothen- Rutishauser at the Adolphe Merkle Institute (University of Fribourg), says the goal of his project was to support preliminary experiments to investigate the optical properties of single biological cells in the context of a ‘’mirrorless cellular laser’’, i.e. the generation of stimulated emission from a single cell in the absence of a conventional optical cavity. “I wanted to investigate light scattering from single cells using different spectroscopy and microscopy tools,” he adds. “The idea is to provide a fundamental understanding of how single cells could support the light amplification needed to produce intracellular laser action.”

For Stevens, this type of grant makes a huge difference for postdocs like himself in terms of gaining experience and providing a first taste of independence, notably the freedom to pursue, design and fund a personal research project. It also provides a first taste of research budget man-

Corey Stevens' independence project aims to identify peptides that inhibit ice growth in food, tissues, and organs

agement. “I think managing a research budget is a critical aspect of being an independent researcher and conducting successful projects, yet, these skills are not routinely taught to graduate students and postdocs,” he points out. “As a student or postdoc, it is tempting to pursue projects and experiments regardless of the cost. However, when those costs come from your own budget, one tends to be more hesitant.”

Septiadi agrees that this initial step towards being independent is important and can lead to further funding. In his case, preliminary results helped him earn a Spark grant from Swiss National Science Foundation in 2020. This program, intended for projects that show unconventional thinking and introduce a unique approach, funds the rapid testing or development of new scientific approaches, methods, theories, standards, and ideas for applications.

He hopes the grant will also have a positive impact on his career prospects. “I have been applying for several tenure track assistant professor positions in the field of biophysics and bioengineering,” he says. “Receiving the grant itself increased the quality of my CV, and the result obtained is expected to strengthen my applications, or submissions for major grant proposals.”

Thanks to the funding, Stevens has also been busy building his own network of researchers, which he achieved by visiting campuses, giving guest lectures, and establishing collaborations that could lead to him finding an independent research position. “This project exposed me to techniques not available in my postdoctoral laboratory, but that I plan to use as an independent researcher including next-generation sequencing and bioinformatics,” he adds.

Stevens is certainly convinced the program has a positive impact. “In the end, I aim to have my own independent research career, and I feel this grant is a first step on the journey towards realizing this goal.”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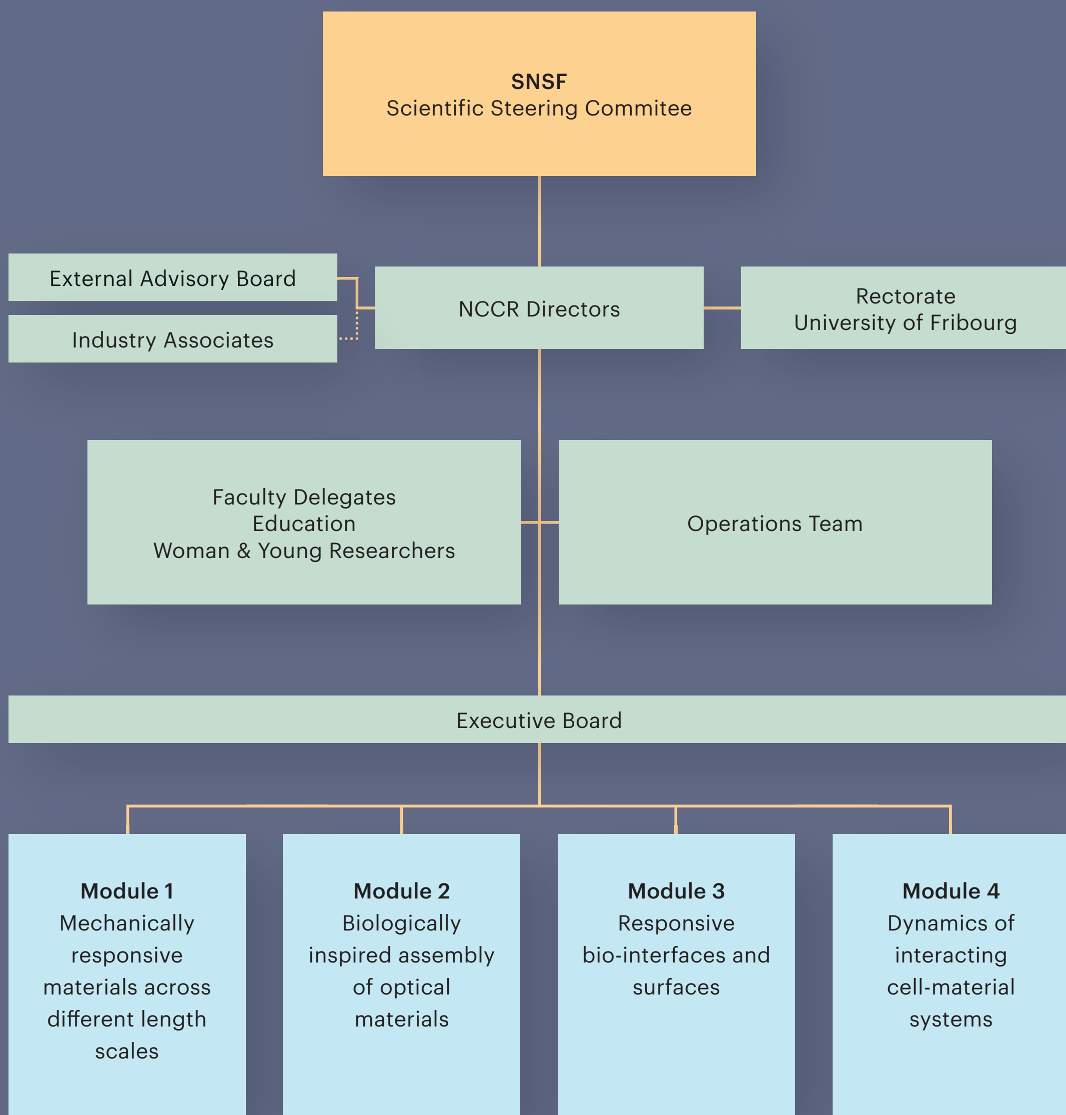
Organization Phase II



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

Who is who

Executive board

- Prof. Christoph Weder (AMI)
  Director
- 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)
  Leader Module 4
- Prof. Andreas Kilbinger (UniFR)
  Faculty Delegate for Education
- Dr. Lucas Montero
  Scientific coordinator
- Dr. Eliav Haskal
  Knowledge Transfer and Innovation manager

Principal investigators

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- Prof. Esther Amstad
  (Institute of Materials, EPFL)
- Prof. Nico Bruns
  (Adolphe Merkle Institute, UniFR/University)
- Prof. Eric Dufresne
  (Department of Materials, ETHZ)
- Prof. Alke Fink
  (Adolphe Merkle Institute, UniFR)
- Prof. Katharina Fromm
  (Department of Chemistry, UniFR)
- Prof. Andreas Kilbinger
  (Department of Chemistry, UniFR)
- Prof. Harm-Anton Klok
  (Institute of Materials, EPFL)
- Prof. Marco Lattuada
  (Department of Chemistry, UniFR)
- Prof. Matthias Lütolf
  (Institute of Bioengineering, EPFL)
- Prof. Michael Mayer
  (Adolphe Merkle Institute, UniFR)
- Prof. Aleksandra Radenovic
  (Institute of Bioengineering, EPFL)
- Prof. Barbara Rothen-Rutishauser
  (Adolphe Merkle Institute, UniFR)
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  (Department of Medicine, UniFR)
- Prof. Frank Scheffold
  (Department of Physics, UniFR)
- Prof. Ullrich Steiner
  (Adolphe Merkle Institute, UniFR)
- Prof. Francesco Stellacci
  (Institute of Materials, EPFL)
- Prof. André Studart
  (Department of Materials, ETHZ)
- Prof. Stefano Vanni
  (Department of Biology, UniFR)
- Prof. Christoph Weder
  (Adolphe Merkle Institute, UniFR)

Associate participants

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  (Department of Chemistry, UniFR)

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
- Dr. Frédéric Pont, Grant writing support

Research groups

Acuña group (UniFR)

- Prof. Guillermo Acuna,
  German Chiarelli Doctoral student
- Dr. Matthias Lakatos Senior researcher
  Morgane Loretan Doctoral student
- Dr. Mauricio Pilo-Pais, Postdoctoral researcher

Amstad group (EPFL)

- Prof. Esther Amstad
- Aysu Ceren Okur, Doctoral student
- Matteo Hirsch, Doctoral student
- Mathias Steinacher, Doctoral student
- Ran Zhao, Doctoral student

Bruns group (AMI/Strathclyde)

- Prof. Nico Bruns
- Livia Bast, Doctoral student
- Micael Gouveia, Doctoral student
- Samuel Raccio, Doctoral student
- Justus Wesseler, Doctoral student

Dufresne group (ETHZ)

- Prof. Eric Dufresne
- Dr. Robert Style, Senior researcher
- 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
- Dr. Yendry Corrales, Senior researcher
- Dr. Barbara Drasler, Postdoctoral researcher
- Dr. Christoph Geers, Senior researcher
- Dr. Begum Karakocak, Postdoctoral researcher
- Aaron Lee, Doctoral student
- Shui Ling Chu, Laboratory technician
- Dr. Dedy Septiady, Postdoctoral researcher
- Dr. Miguel Spuch-Calvar, Senior researcher
- Eva Susnik, Doctoral student
- Dr. Patricia Taladriz, Senior researcher
- Phattadon Yajan, Doctoral student

Fromm group (UniFR)

- Prof. Katharina Fromm
- Dr. Priscilla Brunetto, Senior researcher
- Emilie Jean-Pierre, Doctoral student
- Ali Kaiss, Doctoral student
- Philippe Yep, Doctoral student

Kilbinger group (UniFR)

- Prof. Andreas Kilbinger
- 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
- Dr. Kuljeet Kaur, Postdoctoral researcher
- Zhao Meng, Doctoral student
- Friederike Metze, Doctoral student
- Sabrina Sant, Doctoral student
- Dr. Corey Stevens, Postdoctoral researcher

Lütolf group (EPFL)

- Prof. Matthias Lütolf
- Dr. Nicolas Broguière, Postdoctoral researcher
- Antonius Chrisandy, Doctoral student
- Dr. Andrea Manfrin, Postdoctoral researcher
- Stefanie Boy-Röttger, Other staff
- Stefano Vianello, Doctoral student

Lattuada group (UniFR)

- Prof. Marco Lattuada
- Joelle Medinger, Doctoral student
- Jansie Smart, Doctoral student

Mayer group (AMI)

- Prof. Michael Mayer
- Dr. Louise Bryan, Postdoctoral researcher
- Jessica Dupasquier, Other staff
- Dr. Aziz Fennouri, Postdoctoral researcher
- Anirvan Guha, Doctoral student
- Dr. Alessandro Ianiro, Postdoctoral researcher
- Dr. Maria Taskova, Postdoctoral researcher

Radenovic group (EPFL)

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

Rüegg group (UniFR)

- Prof. Curzio Rüegg
- Grégory Bieler, Support staff
- Ivana Domljanovic, Doctoral student
- Dr. Samet Kocabey, Postdoctoral researcher
- Dr. Sanam Peyvandi, Postdoctoral researcher
- Dr. Manuel Rodriguez Perdigon, Postdoctoral researcher

Salentinig group (UniFR)

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- Rafael Freire, Doctoral student
- Dr. Linda Hong, Postdoctoral researcher
- Dr. Mahsa Zabara, Postdoctoral researcher

Scheffold group (UniFR)

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- Dr. Luis Salvador Froufe Pérez, Postdoctoral researcher
- Emmanuel Gendre, Other staff
- Oswald Raetzo, Other staff
- Dr. Veronique Trappe, Senior researcher
- Dr. Pavel Yazhgur, Postdoctoral researcher
- Dr. Chi Zhang, Senior researcher

Steiner group (AMI)

- Prof. Ullrich Steiner
- Johannes Bergmann, Doctoral student
- Kenza Djeghdi, Doctoral student
- Dr. Mohammadreza Ghanbari, Senior researcher
- Dr. Ilja Gunkel, Senior researcher
- Mirela Malekovic, Doctoral student
- Dr. Guillaume Moriceau, Postdoctoral researcher
- Minh Tri Nguyen, Doctoral student
- Alessandro Parisotto, Doctoral student
- Dr. Bodo Wilts, Senior researcher

Stellacci group (EPFL)

- Prof. Francesco Stellacci
- Matteo Gasbarri, Doctoral student
- Simone Gavieri, Doctoral student
- Dr. Quy Ong, Senior researcher
- Laura Roset, Julia Doctoral student

Studart group (ETHZ)

- Prof. André Studart
- Dr. Ahmet Demirörs, Senior researcher
- Dr. Etienne Jeoffroy, Postdoctoral researcher
- Tommaso Magrini, Doctoral student
- Iacoppo Mattich, 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
- Dr. Jessica Clough, Postdoctoral researcher
- Aristotelis Kamtsikakis, Doctoral student
- Derek Kiebala, Doctoral student
- Anita Roulin, Laboratory technician
- Dr. Philip Scholten, Postdoctoral researcher
- Dr. Stephen Schrettl, Postdoctoral researcher
- Hanna Traeger, Doctoral student

Support staff

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

Alumni

- Dr. Linda Hong (Postdoctoral researcher, Salentinig group)
- Dr. Matthias Lakatos (Senior researcher, Salentinig group)
- Mathias Steinacher (Doctoral student, Amstad group)
- Dr. Miguel Spuch-Calvar (Senior researcher, Fink group)
- Dr. Dedy Septiadi (Postdoctoral researcher, Fink group)
- Dr. Yendry Corrales (Senior researcher, Fink group)
- Serhii Vasylevskyi (Doctoral student, Fromm group)
- Dr. Agonist Kastrati (Postdoctoral researcher, Fromm group)
- Dr. Iris Tennie-Kramberger (Postdoctoral researcher, Kilbinger group)
- Vianello Stefano (Doctoral student, Lütolf group)
- Dr. Aziz Fennouri (Postdoctoral researcher, Mayer group)
- Michael Graf (Doctoral student, Radenovic group)
- Mattia Maceroni (Doctoral student, Rothen group)
- Dr. Maxime Bergman (Postdoctoral researcher, Scheffold group)
- Dr. Luis Froufe (Senior researcher, Scheffold group)
- Dr. Mohammadreza Ghanbari (Postdoctoral researcher, Steiner group)
- Dr. Etienne Jeoffroy (Postdoctoral researcher, Studart group)
- Dr. Patrick Rühs (Senior researcher, Studart group)

Summer students 2019

- Alain Rohrbasser (University of Fribourg)
- Alice Bedwell (University of Cambridge)
- Andrea Mael (Case Western Reserve University)
- Brian Bartlett (University of New Hampshire)
- Ceri Foster (Durham University)
- Dmitrii Nargornii (Radboud University)
- Edmund Farrell-Marcellino (University of California San Diego)
- Greta Grossman (Durham University)
- Isabel Dungworth (Durham University)
- James Murrell (Durham University)
- Johann Rapp (University of Florida)
- Jordan Furseth (University of Washington, Seattle)
- Minji Han (University College London)
- Molly Sun (University of Chicago)
- Monica Malone (Case Western Reserve University)
- Nicole Mortensen (University of Utah)
- Oliver Willis (Durham University)
- Puja Desai (Case Western Reserve University)
- Reyner Vargas (University of Costa Rica)
- Sara McBride (Virginia Polytechnic Institute and State University)
- Victoria Daramy-Williams (University of Cambridge)
- Vivian Wall (University of California Los Angeles)
- Zack Jeanrenaud (Imperial College London)

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

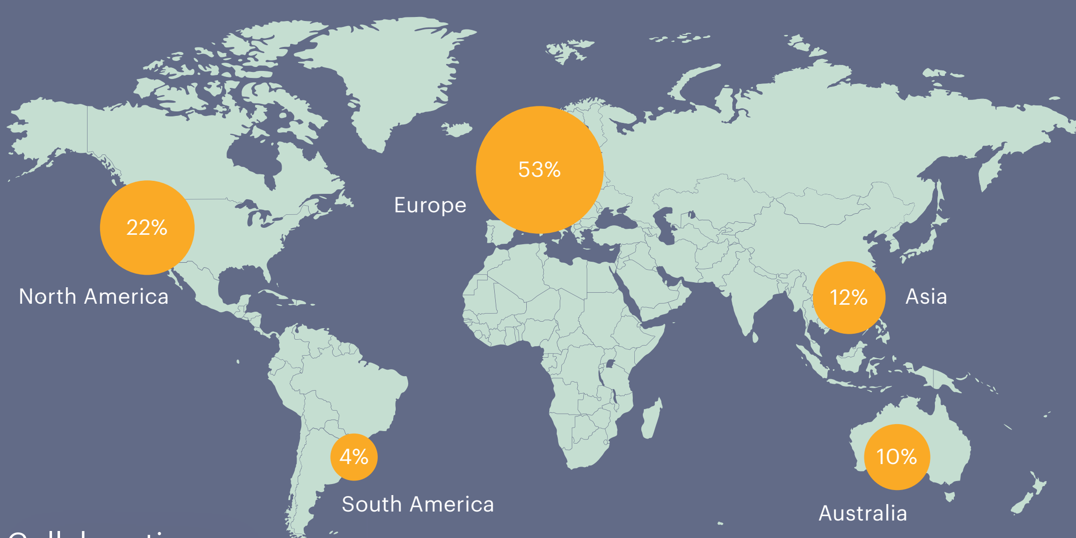
Collaborations 2019-2020

75 Scientific publications

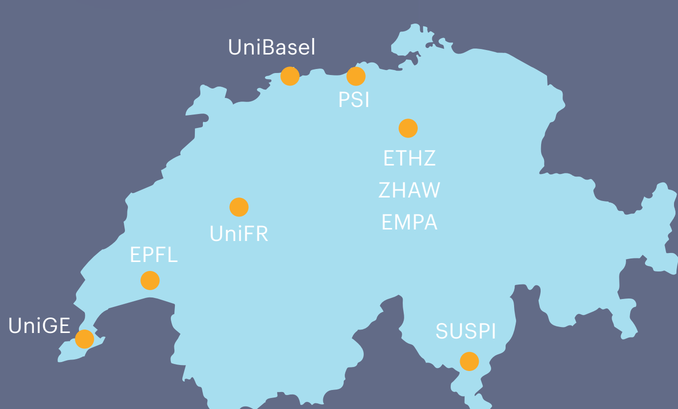
- 29 without external collaboration (39%)
- 46 with at least one external collaboration (61%)

Collaborations

- 17 Swiss collaborations
- 32 international collaborations



Collaborations with 51 international institutions



National collaborations with 8 different Swiss institutions:

- 32% ETHZ
- 16% EPFL
- 11% ZHAW
- 11% UniFR
- 11% UniGE
- 5% EMPA
- 5% PSI
- 5% SUSPI
- 5% UniBasel

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 CaCO3-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
22. 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 controlled delivery systems for organ-on-chip devices
25. Development of cargo carriers
26. Development of Tumor/Immune Cell Organoid Model

Publications

Module 1

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Module 3

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KidsUni at the University of Fribourg is just one of the outreach and education programs supported by the NCCR Bio-Inspired Materials

75

papers

including 65 research papers, 8 reviews and other literature

Gender balance

33% of the NCCR Ph.D. students were women

35% of the NCCR members were women in the reporting period. 6 seminar speakers out of 13 (46%) were women

10 round tables

(organized 4 and sponsored 6) on topics related to equal opportunities and personal and professional development

4 start-up companies

(Nanolockin GmbH, Spectroplast AG, , Microcaps AG and FenX AG) and two additional spin-off technologies (Hemolytics and Nanofertilizer)

74 oral presentations at conferences

including 51 keynote and plenary lectures at international conferences

Over

300

children

and high school students participated in NCCR outreach activities

22

cooperations

with external partners (2 with industry, 15 with research institutions, 5 Other)

Note: All figures between March 1, 2019, and February 28, 2020

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. Craig Broderson	The role of surface tension in the formation, spread, and removal of gas bubbles in the xylem of plants	Yale University, 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, USA	18 March 2019
Prof. Pupa Gilbert	Nanoscale amorphous precursors and their phase transitions in diverse biominerals	University of Wisconsin-Madison USA	18 March 2019
Prof. Helmut Cölfen	Nanocrystals as chemical building blocks Chemical and Chemomechanical	University of Konstanz, Germany	15 April 2019
Dr. Judit Horvath	Morphogenesis in Far-From-Equilibrium Systems	University of Sheffield, UK	25 April 2019
Prof. Li-Zhu Wu	Artificial photosynthesis for chemical transformation	Chinese Academy of Sciences, China	29 April 2019
Prof. Helmut Schlaad	Functional polymers from amino acids and sugar	University Potsdam, Institute of Chemistry, Germany	16 May 2019
Prof. Stefan Salentinig	Food and digestion-inspired nano-biointerfaces for drug delivery	University of Fribourg, Switzerland	6 June 2019
Prof. Gerd Schröder-Turk	What makes for a 'good' disorder: a simple mechanism that leads to hyperuniform order	Murdoch University, Perth, Australia	9 July 2019
Prof. Anja Palmans	Folded amphiphilic polymers in aqueous media: towards enzyme-like catalysis	TU Eindhoven, The Netherlands	11 July 2019
Prof. Romain Quidant	Putting nanoplasmonics to work!	ICFO – The Institute of Photonic Sciences, Castelldefels, Spain	25 September 2019
Prof. Mike Zaworotko	Crystal engineering: Then, now and next	University of Limerick, Ireland	3 October 2019
Prof. Katharina Maniura	Soft biomaterial interfaces to steer cell and tissue response	EMPA, St-Gallen, Switzerland	13 February 2020
Prof. Véronique Michaud	Tough and healable structural composite materials	EPFL, Lausanne, Switzerland	20 February 2020

Impressum

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