Activities report 2020 – 2021

National Center of Competence in Research Bio-Inspired Materials

Swiss National Science Foundation

BIO-INSPIRED MATERIALS
NATIONAL CENTER OF COMPETENCE IN RESEARCH

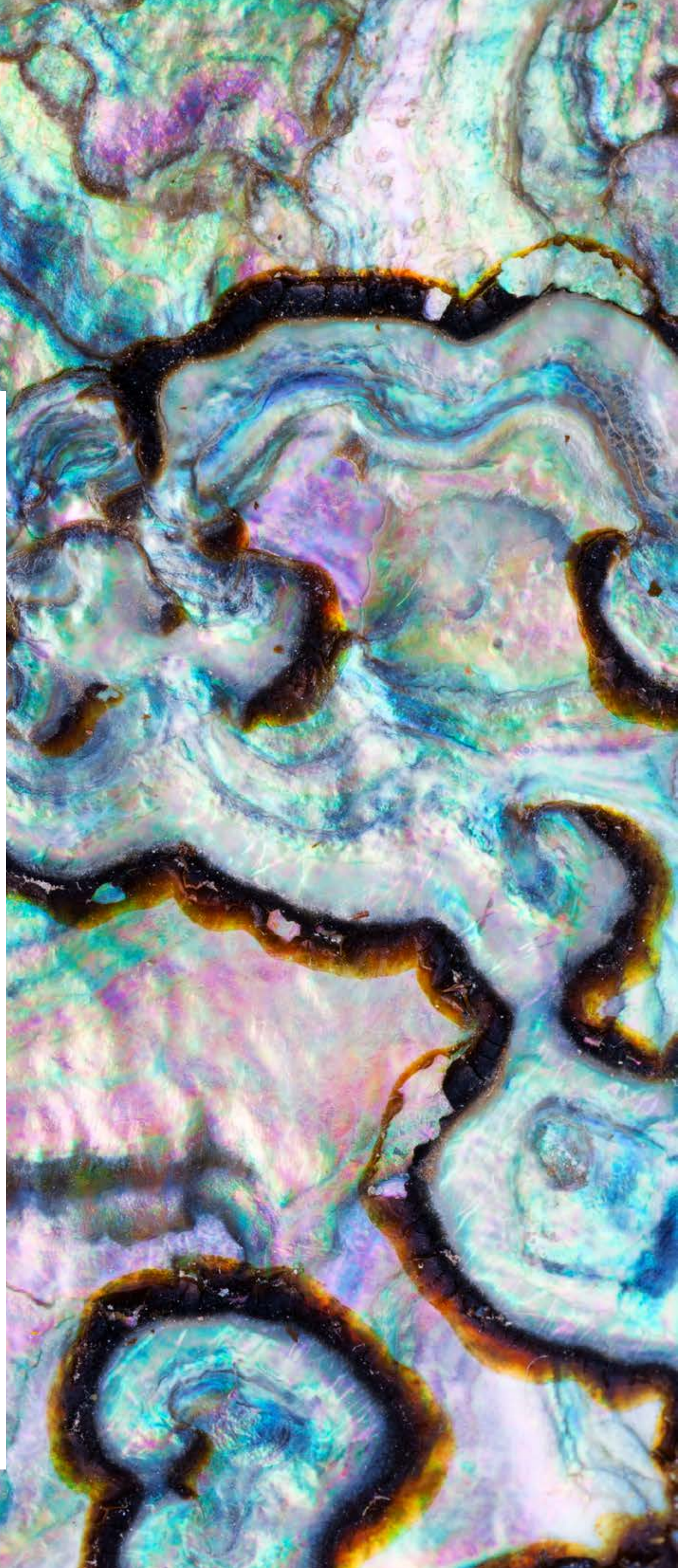
Who we are

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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Content

Message from the directors

Dear reader

Over the past year, the NCCR Bio-inspired Materials defined its strategy for the third and last funding phase, a period that brings various challenges and opportunities to the center.

In the coming years, the NCCR seeks to achieve a long-lasting impact on its home institution, the University of Fribourg, and the Swiss academic community as a whole. This objective requires a prioritization of the center's areas of intervention and is fostered by the customary reduction in the financial support by the SNSF, which expects an increased involvement of the home institution towards the stabilization of a structure that will carry the legacy of the NCCR beyond the third phase. In the face of these challenges, and with a strong support from the University of Fribourg, our NCCR succeeded in putting together a pre-proposal that focused on maintaining the high standard of the center's activities in all areas, prioritized the stabilization of key programs, and preserved what should be one of the main legacies of the NCCR, a bio-inspired materials research community linking three Swiss research institutions. The pre-proposal was refined with the feedback from the SNSF and our center's review panel, and a full proposal was recently submitted. We now look forward to start implementing the new strategy, which will guide our center from June 2022 to the expected end of the NCCR in 2026.

The last months have inevitably been also marked by the Covid pandemic, which forced us to either adapt or cancel many of the NCCR activities. This includes round tables, workshops and scientific seminars that went online, outreach activities that were cancelled, and the annual center conference, which had to be celebrated online and with a reduced program. In this turbulent context, the NCCR researchers suffered from lock-downs and delays in the delivery of scientific consumables, which led to substantial project delays and career-related stress among the young researchers. The NCCR accompanied its researchers in these difficult times addressing their needs, offering a workshop on mental health, and coordinating with the SNSF, which we would like to thank for its flexibility towards the multiple requests received from our researchers. This support was key to minimize the impact of the pandemic on their career and to make the best out of this peculiar situation.

In a different context, the NCCR celebrates the new institutional agreements signed between the Swiss Universities and some of the most important publishers in the domain of our NCCR. These agreements are key elements to achieve the SNSF's open science goals, relieve the pressure put on the researchers, and are helping our NCCR to increase the fraction of gold and green open access publications over 70 %.

We invite you to browse the present report, which collects a selection of research highlights, news, programs and general figures of our center in the last year. We wish you a good reading and invite you to follow the activities of our NCCR in the future.

Ullrich Steiner & Esther Amstad
Directors NCCR Bio-Inspired Materials

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.

At the start, our research was organized in three modules that emphasized research on mechanically responsive materials, responsive materials made by self-assembly, and the interactions of responsive materials with living cells, respectively. As hoped and expected, the boundaries between the original projects and modules have started to blur, and several new research endeavors were launched that take full advantage of the Center's interdisciplinary environment.

Light-trapping materials

Cracking the puzzle of white

The discovery that a specific type of material can reflect almost all incoming light diffusely could help to reach one of physics' holy grails and open up routes for real-world applications

Clouds, milk, bones – all have one thing in common: they're white because their constituents are sized and arranged in ways that efficiently reflect light. Now, NCCR Bio-Inspired Materials researchers showed that a specific type of material can diffusely reflect nearly all rays of incoming light – a finding that paves the way for applications in solar energy, telecommunications and light-based computing.

The work could also help to realize a phenomenon that is known to happen for all kinds of waves, but hasn't yet been observed experimentally for light. The phenomenon was described in the 1950s by late theoretical physicist and Nobel-prize winner Philip Anderson, who showed how an electron and its quantum wave can get arrested in place in a disordered medium. This so-called 'Anderson localization' was then proposed to be applicable also to light waves, and many researchers have tried to study it in disordered optical materials. "Anderson localization is a kind of holy grail in condensed matter and optical physics," says NCCR Principal Investigator Prof. Frank Scheffold of the University of Fribourg's Department of Physics.

Scheffold and Dr. Luis Froufe-Pérez, a senior researcher in Scheffold's group, teamed up with Dr. Jakub Haberko at the AGH University of Science and Technology in Krakow, Poland, to investigate Anderson localization of light in disordered hyperuniform materials. These materials, first proposed about ten years ago by a group of researchers at Princeton University, are computer-conceptualized systems with a very well-defined mathematical basis which are starting to be discovered in nature. Their structure falls between that of highly-organized crystals and that of disordered materials, Scheffold says. "It's a designer disorder," he adds.

> "If you reach Anderson localization, you have perfect reflection, and if you're close to it, you have strong reflection." Frank Scheffold

Using computer simulations, Scheffold and his colleagues found that the nano-architecture of this disordered hyperuniform material can reflect

Clouds are just one example of reflectors

nearly all incoming light diffusely. “If you reach Anderson localization, you have perfect reflection, and if you’re close to it, you have strong reflection,” Scheffold explains. The researchers discovered that under certain conditions, the material reflects more than 99.9% of light. The findings were published in the journal Nature Communications.

“If light cannot penetrate the material, then the material acts like a perfect diffuse reflector,” Scheffold explains. This means that if researchers made a channel inside the material, light could never leave the channel — this would create an optical wire in which light could be ‘channeled’ and ‘guided’ on-demand. Because photons typically move faster than electrons, hyperuniform photonic materials could serve to develop ultrafast and energy efficient optical computers and other devices, nowadays governed by electronics.

The secret behind a perfectly reflective material lies in its complex nano-geometry. The mathematically defined distribution of points can be transformed into a disordered hyperuniform network, for example, by arranging material building blocks so that every junction has four arms that connect with other junctions. This makes every part of the structure look the same on the small scale, even though the material is disordered when zooming out.

Scheffold notes that nature has evolved very sophisticated strategies to reflect light, but to reach Anderson localization, researchers have to go one step further. Confirming and observing this effect experimentally would not only lead to applications in photonics, but it could also explain fundamental physics phenomena of how light interacts with complex structural media.

Reference

Haberko, J.; Froufe-Pérez, L. S.; Scheffold, F. Transition from light diffusion to localization in three-dimensional amorphous dielectric networks near the band edge, Nat. Commun., 2020, 11, 4867.

32

Research Projects

> CHF 8 Mio Funds

raised by the start-ups and spin-offs

including venture capital as well as money awarded 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

at three universities

4

international conferences supported

2

industrial associates

73 % of open access publications

following the Gold or Green pathways

23

undergraduate students

hosted for the NCCR's Summer Internships

Note: All figures between June 1, 2020 and May 31, 2021

Shifting colors

‘Chameleon’ material could help develop better sensors

Color-changing gels that reveal subtle alterations in temperature and pH could find applications in biosensors and other biomedical uses.

Chameleons, octopuses, and cuttlefish have developed some of the animal kingdom’s most sophisticated skin, which allows them to rapidly change color to blend into the background. Inspired by the color-changing abilities of these critters, NCCR Bio-Inspired Materials researchers at the University of Fribourg have created a gel-like material that varies its hue in response to temperature and pH.

The material could be used as a drug-delivery vector or a colorimetric biosensor – among other applications. “In biology, it’s often difficult to measure alterations in pH or temperature in a very small volume, so having a material that changes in color is a big advantage,” says NCCR Principal Investigator Prof. Marco Lattuada of the University of Fribourg’s Department of Chemistry.

The ‘chameleon’ material, developed by Dr. Golnaz Isapour, a former PhD student in Lattuada’s group, is a gel-like photonic crystal. The key idea behind photonic crystals is that, depending on the exact position, size, and spacing of their components, light interacts with these materials in ways that produce different colors.

Isapour created a photonic crystal made of millions of minuscule water-swollen plastic bubbles, or hydrogel spheres, that measure several tens of micrometers in diameter. These microspheres serve as a scaffold for even smaller hydrogel nanospheres, measuring just a few hundreds of nanometers in diameter.

When temperature increases, the microspheres shrink, pushing the nanospheres closer together. This change in the spacing between nanospheres creates a shift of color that spans the entire range of the visible light spectrum — from red to green to blue. Similarly, when pH increases, the nanospheres shrink, causing the scaffolding microspheres to collapse, which ultimately results in a color change. Variations in hue happen rapidly, over several seconds or a few minutes, the researchers found.

Creating such a smart gel is no trivial task: to be able to see the different colors, the hydrogel spheres have to be packed in a precise three-dimensional arrangement, similar to that observed in opals and other crystals. “You have to make sure that these particles are able to repel each

Chameleons exhibit complex and rapid color changes during social interactions

other in such a way that they don't clump together, so that they can arrange in an ordered manner," Lattuada says. The researchers detailed the protocol to create the smart material as well as its color-changing properties in the journal ACS Applied Nano Materials.

> "In biology, it's often difficult to measure alterations in pH or temperature in a very small volume, so having a material that changes in color is a big advantage." Marco Lattuada

Lattuada notes that, with some tweaks, the 'chameleon' gel could be employed for drug delivery. He explains that when the hydrogel spheres change their size or spacing, the material expels water, just like a sponge that is squeezed. If researchers can encapsulate a drug in the gel, they could use it to release the drug into a specific tissue after a change in temperature or pH. "You can definitely encapsulate drugs as long as they don't interfere with the structure of the gel," Lattuada says. Other applications of the smart gel include colorimetric biosensors — devices that change their color when blood pH or other health indicators are altered.

Reference

Isapour, G.; Lattuada, M. Multiresponsive photonic microspheres formed by hierarchical assembly of colloidal nanogels for colorimetric sensors, ACS Appl. Nano Mater., 2021, 4, 3389–3396.

Nanocarriers

Milk digestion inspires shuttles for antimicrobial drugs

Fat-based nanocarriers change their structure in response to pH, facilitating the delivery of molecules that can kill bacteria.

As a growing number of disease-causing bacteria become resistant to antibiotics, scientists are scrambling to find new ways to prevent and treat infections. NCCR Bio-Inspired Materials researchers at the University of Fribourg have developed carriers that are just a few hundred of nanometers in size and can transport and release antimicrobial peptides – naturally occurring molecules that are increasingly being considered as useful alternatives to conventional antibiotics.

Because these nanocarriers can release antimicrobial peptides in response to changes in pH, they could be used to transport the bacteria-killing molecules to wounds and infected tissues, which typically have abnormal pH values. The mini-shuttles could also be employed to combat stomach infections without affecting the beneficial bacteria that reside in the gut. “Because the drug-delivery system is active at the low pH values of the stomach but is inactive at the higher pH values of the intestine, it will only kill the bacteria in the stomach,” says NCCR Principal Investigator Stefan Salentinig, Professor of experimental physical chemistry at the University of Fribourg.

Salentinig and his collaborators at the Swiss Federal Laboratories for Materials Science and Technology had previously shown that, as milk is digested in a lab-grown model of the human gut, it forms highly organized nanostructures. These structures could be important for transporting poorly water-soluble milk components through the digestive tract and delivering them across the gut lining. Inspired by these findings, Salentinig and his team set out to develop a drug delivery system that could protect antimicrobial peptides against breaking down in the body and release the bacteria-killing molecules in a controlled manner.

The researchers designed nanocarriers based on the assembly of a type of fatty molecule, known as DODAP, with the antimicrobial peptide LL-37, which is found in humans. At pH values of about 4.5, the fatty molecules that make up the nanocarriers form organized structures containing tiny water channels. Under these conditions, the antimicrobial peptide sits inside the nanocarriers, at the oil-water interface of the channels, the researchers found. At lower pH values, the fatty molecules form tiny sacs filled with water and

Milk digested by humans forms highly organized nanostructures

the antimicrobial peptides. Because the peptides sit within the nanocarriers, either inside the water-filled sacs or at the oil-water interface of the channels, they are protected from degradation.

Things start to change as the pH becomes higher. When it reaches values of about 6, the fatty molecules turn into emulsion droplets, like those that form when oil and vinegar are whisked together into a salad dressing. Now, the antimicrobial peptides can be released and perform their antimicrobial function. The findings were published in the Journal of Colloid and Interface Science.

The structures that the nanocarriers form as the pH changes are similar to those observed during milk digestion, Salentinig says. "By changing the pH, we can blueprint the whole range of structures that you would find during milk digestion, and then we can use them to deliver antimicrobial peptides and switch on and off their activity," he says.

Besides killing bacteria, the antimicrobial peptide LL-37 can favor cell proliferation, previous research has shown, thus promoting wound healing. Salentinig and his team developed a gel-like coating that contains the LL-37 antimicrobial peptide assembled with nanocarriers made of a food-grade fatty molecule called glycerol monooleate. In a study published in ACS Applied Bio Materials, the team tested the coating on two kind of disease-causing bacteria grown in a dish and found that it could kill both. The coating could find applications in wound pads to protect wounds and speed up healing, Salentinig says.

Reference

Gontsarik, M.; Yaghmur, A.; Salentinig, S. Dispersed liquid crystals as pH-adjustable antimicrobial peptide nanocarriers, J. Colloid Interface Sci., 2021, 853, 672–682.

Luminous idea

Force-responsive nanoreactors inspired by glowing plankton

Polymer-based artificial vesicles that release their load on demand could find applications in biomedicine and 3D printing.

As night falls on certain beaches around the world, the sea can glitter like stars in the sky. This 'sea sparkle' arises from single-celled organisms that have evolved to emit light at night when disturbed by movements such as a wave breaking or a fish swimming by. This natural phenomenon inspired NCCR Bio-Inspired Materials researchers to create polymer-based nanoreactors that can be switched on by shear stress, allowing the activation of chemical reactions on demand. The nanoreactors could be used for drug delivery, 3D printing and scratch-and-smell items, among other applications.

In the plankton *Noctiluca scintillans*, mechanical stimulation generates an action potential that activates proton channels in the membrane of organelles called scintillons, changing their permeability. The influx of protons then triggers a chemical reaction that produces light. NCCR Principal Investigator (PI) Prof. Nico Bruns – now at the Technical University of Darmstadt in Germany – and his colleagues set out develop mimics of scintillons made of synthetic polymers called polymersomes. "We didn't invent polymersomes, but we asked ourselves, can we switch the permeability of polymersomes by mechanical perturbation?" Bruns says.

To create such force-responsive polymersomes, the researchers turned to a second source of inspiration: DNA. The inside of the DNA double helix repels water; but when the nucleobases that join two DNA strands together unpair, the whole molecule becomes water-soluble.

Bruns and his colleagues created vesicles in which a fluid is enclosed by an outer, double-layered membrane. The membrane consists of heads made of water-loving polymer chains and tails made of water-repellent polymer chains that are linked to nucleobases. The nucleobases cluster together when paired, but after applying shear force to the vesicles, for example by aspirating them with a syringe, the nucleobases unpair, making the membrane permeable to water-soluble molecules.

Next, the team enclosed in the vesicles an enzyme that produces light and provided the substrate on the outside. "If the membrane is non-permeable for the substrate, nothing will happen, but when the membrane becomes permeable, then substrate can get into the vesicle and

Mechanical stimulation activates plankton bioluminescence

the enzyme can do its job," Bruns says. Indeed, in response to shear force, the polymersomes light up – like tiny glowing *Noctiluca scintillans*, the researchers found. "It was nice to show that we could mimic the biological role model," Bruns says.

Finally, the team used shear-responsive polymersomes to trigger a chemical reaction that transforms polymers into a gel. In this case, the force generated by mild ultrasound was enough to make the nanoreactors permeable and switch on the gelation reaction. Gel formation on demand could be used in biomedicine to create hydrogel patches that gradually release drugs. It could also be useful in 3D printing to turn liquid inks into gels only after the ink is squeezed through a nozzle.

Another possible application of polymer nanoreactors could be in scratch-and-smell items. "One could use mechanical perturbations – for example, rubbing a garment – to release a fragrance," Bruns says.

The researchers detailed the structure and the properties of the polymer nanoreactors in the journal Angewandte Chemie International Edition. The work stems from a collaborative effort between the research teams of Bruns, and NCCR Bio-Inspired Materials PIs Prof. Esther Amstad (EPFL) and Prof. Marco Lattuada (University of Fribourg). Lattuada brought fluid dynamics expertise to the project, while Amstad and her team provided a sophisticated experimental setup to prove that nanoreactors are activated by shear force, Bruns says.

The work, he adds, showcases the highly collaborative nature of the NCCR Bio-Inspired Materials. "The NCCR allowed us to collaborate with Marco, Esther and their groups with a very low level of activation energy," he says. "This merging of expertise is key for highly interdisciplinary research."

Reference

Rifaie-Graham, O.; Galensowske, N. F. B.; Dean, C.; Pollard, J.; Balog, S.; Gouveia, M. G.; Chami, M.; Vian, A.; Amstad, E.; Lattuada, M.; Bruns, N. Shear stress-responsive polymersome nanoreactors inspired by the marine bioluminescence of dinoflagellates, Angew. Chem. Int. Ed., 2020, 60, 904–909.

3D-printing

Producing stronger and tougher hydrogels

Material made of microgel grains can be 3D-printed into macroscopic objects that could advance soft robotics applications.

From the soft fibrous tissue found around our joints to the gluey threads that mussels secrete to stick to rocks, many natural materials can stretch, bend and bear weights thanks to the particular way in which they are assembled. Now, NCCR Bio-Inspired Materials researchers have developed a 3D-printing approach that mimics the assembly process of natural materials to produce stronger and tougher hydrogels. These hydrogels could find applications in soft robotics, for example for making medical tools that can better navigate the tortuous architecture of blood vessels.

Hydrogels are water-loving polymers that can absorb and retain water: they're found in everyday products such as disposable diapers as well as in several medical applications including wound dressing. Hydrogels used in biomedicine are biocompatible, but they are too weak to bear weights. On the other hand, hydrogels used in material science are stiff but also very brittle, so they can't be printed into complex shapes.

To produce hydrogels that are soft and strong at the same time, NCCR Principal Investigator Prof. Esther Amstad and her team at Lausanne's Federal Institute of Technology (EPFL) set out to develop a novel 3D-printing approach inspired by nature.

Nature produces many of its tough materials from tiny compartments filled with reagents that merge together. For example, the adhesive threads that allow marine mussels to firmly hold onto rocks in oceans are produced from compartments filled with the protein collagen. These vesicles are released on demand and self-assemble into threads in the foot of the mussel.

> "A material that can be disassembled and reassembled will be more sustainable." Esther Amstad

In contrast, researchers usually mix reagents in bulk to produce synthetic materials – like cooks combine ingredients in the kitchen. "This method is simple, cheap and easy to scale-up, but it doesn't allow us to control the local composition of the material or to process it into complex 3D shapes," says Amstad. To overcome this hurdle,

Mussels attach themselves to rocks thanks to collagen proteins they produce

her team designed hydrogels that are composed of microgel grains that assemble together. This approach has the advantage that each grain can carry different reagents, so researchers can easily vary the material's local composition.

First, the team converted a reagent-filled liquid drop into a hydrogel. They then exploited the sponge-like property of hydrogel particles to load a second reagent – a component of a glue – inside the particles. Next, the researchers concentrated the particles so that they started touching. As soon as the particles touched each other, they no longer behaved as a liquid. Instead, they became a paste that could be 3D-printed and solidified once it exited the nozzle.

Using this approach, the researchers printed different objects, including a hydrogel strip the size of an SD card that could bear a weight of one kilogram. Further tests showed that a hydrogel cylinder produced with the new approach could be compressed and crushed without breaking. "We even stood on it," Amstad says. The findings were published in the journal Advanced Functional Materials.

Stronger and tougher hydrogels could be used to make soft grippers such as prosthetic hands, for example, or tools for introducing stents in narrowed vessels to restore the blood flow. To insert stents, doctors need tools that are soft enough to navigate arteries and veins, but also stiff so that stents can be placed correctly, Amstad says.

The team is now working to produce recyclable hydrogels, she adds. "A material that can be disassembled and reassembled will be more sustainable, and has the potential to contribute to the reduction of the plastic pollution our environment currently suffers from."

References

Hirsch, M.; Charlet, A.; Amstad, E. 3D printing of strong and tough double network granular hydrogels, Adv. Funct. Mater., 2020, 31, 2005929.

145

Researchers

incl. PhD students, postdocs, senior researchers and professors

CHF 9 million

of funding including CHF 4.4 million from the SNSF

39 Nationalities

including Switzerland, Argentina Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Costa Rica, Croatia, Estonia, France, Germany, Greece, Hungary, India, Indonesia, Italy, Lebanon, Lithuania, Luxemburg, Macedonia, Netherlands, New Zealand, Peru, Portugal, Russia, Serbia, Slovakia, Slovenia, South Africa, South Korea, Spain, Taiwan, Turkey, UK, USA and Vietnam.

3 Grants

1 ERC Starting Grant, 1 Werner Siemens Foundation Grant, 1 EPSRC's New Horizons Grant by NCCR participants

66

Papers

including 58 original contributions and 8 reviews

1

Innosuisse project

worth CHF 0.4 million to develop a chemical reactor for nanomaterial production

Note: All figures between June 1, 2020 and May 31, 2021

In brief

Mental health workshop

To respond to the mental health challenges faced by young academics during the Covid crisis, the Center organized a special seminar in collaboration with the non-profit platform Dragonfly Mental Health to address some of these issues.

The seminar, led by Dragonfly's Dr Olga Vvedenskaya, covered topics such as how the body and mind function during global disease outbreak and subsequent isolation ; the main areas of everyday life affected

The Covid pandemic has left many academics feeling isolated away from their workplace

by the pandemic; and provided suggestions how to regain a feeling of stability. The workshop was particularly appreciated by the participants, and NCCR management is considering organizing further sessions.

Prof. Barbara Rothen-Rutishauser actively promotes the careers of female researchers

Gender equality

NCCR Bio-Inspired Materials PI and Equal Opportunities delegate Professor Barbara Rothen-Rutishauser was interviewed for Elsevier's special report "The researcher journey through a gender lens: A global examination of research participation, career progression and perceptions".

The interview covered notably Rothen-Rutishauser's realization that the academic playing field was anything but level for men and women, and that concrete actions were required to correct the gender imbalance in the sciences at least.

In her role as Faculty Delegate for the Advancement of Young Researchers and Women of the National Center of Competence in Research Bio-Inspired Materials, Rothen-Rutishauser has been instrumental in organizing roundtables for female researchers to share their experiences and get feedback and advice.

External advisory board

The first president of the NCCR's external advisory board, Prof. Marcus Textor, formerly of the Department of Materials at Zurich's Federal Institute of Technology (ETHZ), stepped down from the board in 2020.

He was replaced by Prof. Dr. Katharina Maniura, of the Materials Meet Life Department of the Swiss Federal Laboratories for Materials Testing and Research (Empa).

Prof. Dr. Katharina Maniura speciaizes in the characterization of biological responses to materials

Marie Skłodowska-Curie Fellowship

Dr. Alessandro Ianiro, an NCCR postdoctoral researcher in the Adolphe Merkle Institute BioPhysics group, was selected to become a prestigious Marie Skłodowska-Curie Fellow in 2021.

His project funded by the European Commission will focus on developing a novel class of nanocomposite materials that mimic natural muscles by combining stimuli-responsive hydrogels and colloidal liquid crystals. The hydrogels are soft and shape-compliant actuating materials like muscles, but they generally exhibit poor mechanical resistance and they expand in no specific direction. These limitations will be overcome by attaching them to the colloid particles and assembling them to make them function along a single axis. Ideally, this will lead to a novel class of soft actuators that will bring significant advancement to fields like robotics and medicine.

Dr. Alessandro Ianiro

Sparking innovation

NCCR postdoctoral researcher and group leader Dr. Stephen Schrettl (Adolphe Merkle Institute, Polymer Chemistry and Materials) was awarded a Spark grant by the Swiss National Science Foundation to investigate innovative composites that respond to external stimuli.

Examples of such innovative stimuli-responsive materials include those that adapt their mechanical properties as needed, some that signal wear and tear before a failure, or micro-capsules that release an active ingredient on demand. However, currently available capsules are incompatible with standard polymer processing methods, which constitutes a significant barrier for their use. The goal of Schrettl's project is to develop capsules that are stable enough to withstand the rigors of processing, while also performing the designated task of rupturing and releasing a cargo after integration into a polymer. The aim of the Spark program is to fund the rapid testing or development of new scientific approaches, methods, theories, standards, and ideas for applications for example.

Dr. Stephen Schrettl

PhDs

Johannes Bergmann (Steiner group, AMI) Production of bio-based surface wrinkled colloids

Aristotelis Kamtsikakis (Weder group, AMI) Leaf cuticle-inspired membranes

Subhajit Pal (Kilbinger group, UniFR) Development of Synthetic methodology for Phase Display

Sarah Raffiee (Rüegg group, UniFR) Targeting individual cancer cells by sensoresponsive nanoelements

Mirela Malekovic (Steiner group, AMI) Optics of disordered materials

Arnivan Guha (Mayer group, AMI) Energy generation using ion gradients across bio-inspired membranes

Samuel Raccio (Bruns group, AMI) Detection of malaria by atom transfer radical polymerization.

Mathias Steinacher (Amstad group, EPFL) Surface Acoustic Wave Based Spray-Dryer

Promotions

Bodo Wilts, a senior NCCR researcher and group leader at the Adolphe Merkle Institute was appointed to a professorship at the University of Salzburg, where he took up his position in October 2021. Wilts was a member of the NCCR from 2015 onwards until his appointment in Austria. He will pursue his collaboration with the Center as an Associate PI.

Two other NCCR and Adolphe Merkle Institute alumni were appointed to new positions at universities abroad. Yoshimitsu Sagara, who was an NCCR postdoctoral fellow from 2013 to 2015, was appointed as Associate Professor in the Department of Materials Science and Engineering at the Tokyo Institute of Technology, after serving for several years as an Assistant Professor at the University of Hokkaido.

Prof. Bodo Wilts

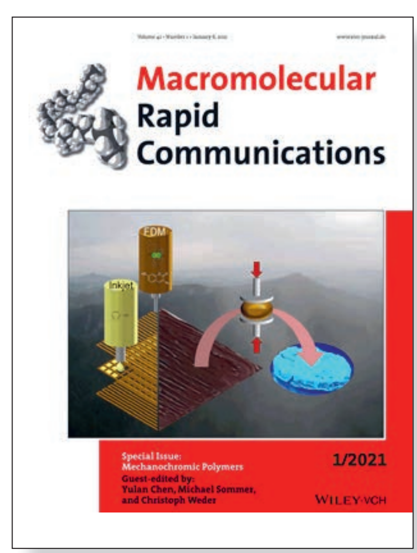
Dr. Céline Calvino

Céline Calvino, who completed her PhD in 2018, was appointed Junior Research Group leader at the University of Freiburg's Cluster of Excellence livMatS in Germany. LivMatS develops life-like materials systems inspired by nature that adapt autonomously to their environment, harvest clean energy from it, and are damage resistant. After her graduation, Calvino first joined the University of Chicago as a postdoctoral fellow.

Special issues

Two special issues of journals were edited by members of the Center. A first one for Macromolecular Rapid Communications, was guest edited by NCCR Principal Investigator Prof. Christoph Weder (AMI), and focused mechanochromic polymers.

These are macromolecular materials that change their color in response to deformation, either on account of altered absorption or reflection, as well as polymers in which other optical characteristics change upon application of mechanical force. The special issue includes several contributions from Center members. The second special issue for the open-access journal Materials was guest edited by NCCR PIs Profs. Alke Fink and Barbara Rothen-Rutishauser, as well as postdoctoral researchers Dr. Barbara Drasler and Dr. Dedy Septiadi. The issue emphasized the entire range of bio-inspired materials used in medical applications, including synthetic approaches of formulating functional systems that can be used in drug and molecule (gene) delivery, bioimaging, and biosensing, regenerative medicine, and cancer treatment.



Publication highlights

Rifaie-Graham, O.; Galensowske, N. F. B.; Dean, C.; Pollard, J.; Balog, S.; Gouveia, M. G.; Chami, M.; Vian, A.; Amstad, E.; Lattuada, M.; Bruns, N. Shear stress-responsive polymersome nanoreactors inspired by the marine bioluminescence of dinoflagellates, Angew. Chem. Int. Ed., 2020, 60, 904–909.

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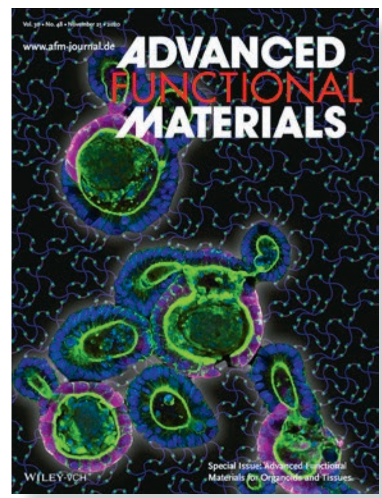


Annual Center Conference

Due to the Covid pandemic, the Annual Center Conference was held in a reduced format in 2020.

The now traditional two-day meeting was cancelled in Charmey and replaced with a hybrid format, with online sessions on the first day for all NCCR members with research and management presentations, as well as two invited talks. The first one focused on ethics in publishing, given by Prof. Gianfranco Pacchioni (University of Milano Bicocca, Italy).

The second was given by Prof. Magali Lingenfelder (EPFL) on bio-inspired nanointerfaces across time and spatial scales. On the second day for the Principal Investigators met in Fribourg at the Adolphe Merkle Institute to discuss the future direction of the Center's research modules.

The ACC allowed the heads of the research groups to meet one another despite Covid restrictions on participant numbers

Celebrating female researchers

A national campaign was launched to promote academic careers for women.

To celebrate Women's Day 2021 and the 50th anniversary of women's right to vote in Switzerland, all 22 National Centers of Competence in Research across Switzerland joined forces to publish a series of videos showcasing their women researchers. As part of the #NCCRWomen campaign, the videos, aimed at women and girls of school and undergraduate age, attempted to show what daily life as a female scientist is like and make it more accessible. Each NCCR hosted a week's worth of short films on Youtube and other social media, covering a variety of research fields.

The Center featured in September, with five videos of Principal Investigators Prof. Katharina Fromm (University of Fribourg, Department of Chemistry), Prof. Barbara Rothen-Rutishauser (Adolphe Merkle Institute, NCCR Equal Opportunities Delegate), postdoctoral researcher Dr. Maria Taskova (Adolphe Merkle Institute, BioPhysics), as well as PhD students Ivana Domljanovic (University of Fribourg, Department of Oncology, Microbiology, and Immunology) and Hanna Traeger (Adolphe Merkle Institute, Polymer Chemistry & Materials).

The complete series of videos can be seen on the special #NCCRWomen Youtube channel. Further actions are now being discussed as part of the campaign.

Etienne Geoffroy (FenX) and Alessandro Ofner (Microcaps) were among the five de Vigier winners (second and third from left)

Winning startups

Two NCCR supported startups were among the five winners of the 2020 W.A. de Vigier Foundation awards, each worth CHF 100,000.

FenX and Microcaps, companies which are both based on technologies developed in the Complex Materials laboratory of NCCR Principal Investigator André Studart, where chosen from 192 submitted projects.

FenX has developed technology to turn industrial waste into high-performance insulation panels that are safe, non-flammable and have a minimal carbon footprint. Microcaps has created a system that enables precise size control of microcapsules that can be used for pharmaceuticals, fragrances, flavors and probiotics.

New specialist

The Center hired in 2020 a new specialist to complete its instrument platform team.

Dr. Jozef Adamcik worked previously at ETHZ. His expertise in atomic force microscopy has been particularly welcome as it helps compensate for the retirement of former NCCR Principal Investigator Prof. Michal Borkovec (University of Geneva) and his group's technical knowhow.

Dr. Jozef Adamcik is an AFM specialist


"A GOOD POUR"
STATE OF ART:
DESC:
- create a pipe
- multilayered
single/
one fold, overlap of the surface

Valorization

Moving from the benchtop to application

Knowledge and Technology Transfer (KTT) has been one of the NCCR Bio-Inspired Materials' core activities since its launch in 2014. With the Center nearing the end of it second phase, and preparing for its final four years, translation of research will be a benchmark when determining the NCCR's ultimate success writes the Knowledge Transfer and Innovation Manager, Dr. Eliav Haskal.

The goals for Knowledge and Technology Transfer (KTT) of the NCCR Bio-Inspired Materials are to advance scientific research while promoting and assisting the social and/or economic valorization of research results as well as training, supporting and mentoring innovation and entrepreneurship among the NCCR collaborators.

In the past eight years, a series of activities were established to develop interdisciplinary interactions on an international level, which have led to many scientific collaborations and publications. Ranging from national and international scientific conferences to workshops, seminars and an annual NCCR event, the development of a sense of community, shared curiosity and interdisciplinary skills have contributed to successful knowledge transfer and excellent journal publications.

In terms of technology transfer, where the focus lies on valorization of the NCCR's scientific research, there has been tremendous progress in many aspects, led by concrete results that are currently being realized as to their economic value, multiple company creations, and a growing spirit of entrepreneurial curiosity and willingness to learn innovation skills. Several NCCR spinoff companies have been created, already employing tens of people, and in second-round capital funding, including FenX AG, Microcaps AG and Spectroplast AG, with more still in incubation at the NCCR partner universities. Industrial research agreements with companies (which are often confidential) have been finalized and are typically always running.

Developing an ecosystem

To create an environment propitious for more innovation activities, the first challenge was to address the common academic perception that applied research, entrepreneurial and innovation activities, and collaboration with industry were "uninteresting". This could be done by introducing excellent speaker seminars from industry, showing

Innovation workshops help NCCR researchers understand how to valorize their ideas

the results of successful industrial collaborations and explaining their win-win situations, and sensitizing personnel to the challenges and benefits of entrepreneurship.

In addition, effort was invested in improving the Fribourg innovation ecosystem and align the many academic, political and industrial stakeholders. Ecosystem development had already begun at the University of Fribourg before the start of the NCCR, but the NCCR contributed with new workshops on innovation skills, sensitization to the potential of entrepreneurship as a career goal, assistance in matching research results to companies, mentoring and coaching of projects and personnel in innovation, and teaching and training.

> "Many research projects in the NCCR will also be supported for technology translation." Eliav Haskal

The goal of improving KTT in Fribourg has always been to leverage the close physical location of the five Fribourg universities (University of Fribourg, School of Management, School of Engineering, School of Health, School of Social Work) and create an interdisciplinary skill ecosystem which could assist students at any university to develop their ideas into a transferable activity. The Innovation Club Fribourg was thus created to be open to all students, and to guide them to where they could find help.

During the pandemic, many activities were curtailed – speakers moved online, workshops were abandoned and Zoom fatigue set in – yet most speaker activities continued with varying success. Contacts with companies, still usually managed face-to-face, dwindled before recovering with the introduction of new communication channels.

Translation

As Phase 3 approaches, and NCCR technology translation becomes vital to the Center's success, the KTT manager will take on a role for the Translation PhDs, in addition to the many training, coaching, teaching, and networking roles developed in the last eight years. The Translation PhDs are students whose pre-defined research projects were selected competitively as having a high potential for successful valorization, either with companies already interested in the scientific results, or as having a good chance to be spun off. The challenge to find enthusiastic researchers, and training them with innovation skills throughout their PhDs, is a long-term, prototypical experiment as to how to embed these skills into a (natural) science doctorate, which could be rolled out at the University of Fribourg beyond the NCCR's lifespan.

Finally, the many research projects in the NCCR will also be supported for technology translation. To target projects efficiently, the first step was to interview the principal investigators, to identify any potential market interest in the results, with the purpose of contacting specific companies and developing partnerships. It became clear that approximately half of the current projects could indeed result in valorizable results in the NCCR's Phase 3. These projects will be focused upon for translation, while the remaining projects will be tracked for their progress and potential. In summary, a clear path forward for ecosystem enhancement, training activities and innovation support is in place, with a focus on projects likely to succeed.

The NCCR has helped coordinate the University of Fribourg's Women In Science program

Reaching out

Calling all budding scientists

Outreach activities are important elements for the NCCR Bio-Inspired Materials, allowing the Center to increase its impact by reaching a wider public outside the scientific community.

These activities are designed for example to spark children's interest in science, encourage teenagers to pursue a scientific career, or help teachers develop teaching concepts.

The most high-profile outreach program is KidsUni, founded in 2014 by two of the NCCR's Principal Investigators, Prof. Alke Fink and Prof. Andreas Kilbinger, both affiliated with the University of Fribourg's Department of Chemistry. Since then, the popular program has expanded to include other participants from the Faculty of Science and Medicine. Organized in two sessions per year, it allows children between the ages of 10 and 13 to spend 12 afternoons discovering a variety of scientific disciplines, including geosciences, mathematics, physics, biology, computer science, as well as chemistry and nanoscience, under the guidance of the NCCR Outreach Coordinator, Dr. Sofia Martin Caba.

"The aim is to show youngsters how cool science can be, and motivate them to study it more," she explains. "The participants are usually already interested in science, so the idea is to boost that motivation. These activities also have an additional benefit for the Center postdocs and PhD students who take part, as they get to practice their supervision and communication skills, as well as be role models for the children."

> "The aim is to show youngsters how cool science can be, and motivate them to study it more." Sofia Martin Caba

Activities involving primary schoolchildren also backed by the NCCR include the Goûters scientifiques/Wissenschaft zum Zvieri, which are organized by the University of Fribourg, the NCCR's home institution, and cover both scientific and non-scientific disciplines. Others are the National Futures Day, workshops run for the Passport Vacances (holiday passport) program in Fribourg and Payerne, another within the Environnement & Jeunesse program, and for Fritime Schmitten. The NCCR is also more directly involved with school classes, either hosting groups to perform lab experiments, or going on the road to classrooms across Switzerland, both in primary schools and with teenagers in high schools and colleges to demonstrate and talk about science. The NCCR has been notably involved in the TecDays organized by the Swiss Academy of Engineering Sciences (SATW) through the participation of its Principal Investigators. The days are aimed at encouraging teenagers to take up STEM careers. Students attend three module classes from a selection of between 30 and 80 possibilities depending on the school's size. So far, more than 60,000 teenagers have attended one of the TecDays events since their launch in 2007.

Teachers have also been targeted by the Center's outreach program. High school teachers were for example invited to take part in a one-day training event, organized by the outreach coordinator and the scientific coordinator, Dr. Lucas Montero. They showed the 20 attendees how to use currently relevant topics such as plastics pollution and fake news to teach concepts such as the scientific method, and how to set up attractive lab experiments for students. The goal here was to create a multiplier effect once the teachers returned to their classrooms. Primary school teachers from canton Fribourg have also received coaching from the NCCR to help prepare for a new science curriculum.

The NCCR has also regularly participated in the biannual Swiss Science in Youth Chemistry and Materials Science Study Week, which offers high school students from the entire country the opportunity to spend a week in a laboratory to work on a short research project. The Center was the sponsor and host of the last two Study Week national closing ceremonies at the Adolphe Merkle Institute.

The NCCR's outreach and equal opportunities activities intersect at times when it comes to encouraging young women to join the ranks of science. The Center has notably helped coordinate the University of Fribourg's Women in Science (WINS) program, which hosts second year female college students over two days at the university's Faculty of Science and Medicine. The aim is to encourage these students to consider a scientific career. The program is now being expanded more than 20 years after its launch to include male students as well, while maintaining a strong focus on gender-related issues in science.

The NCCR has also taken part in more general outreach activities for the wider public. These include an exhibition co-curated by the Center at the Fribourg Natural History Museum, which was open to the public for 6 months, and included parallel group activities for visitors around the topic of bio-inspiration.

Other events including NCCR participation were the Museum Night in Fribourg where the Center presented its research activities and organizing experiments for children at the Adolphe Merkle Institute, the University of Fribourg's Explora open days, the "Going Wild" exhibitions at Zurich Zoo, or the European Heritage Days events in Zurich, in collaboration with the ETHZ Insect Collection, on the theme of colors.

"These events are important," says Martin Caba. "People are open to what we have to show,

The NCCR regularly invites primary school children to carry out science experiments in one of its laboratories

and it allows us to reach families, and get parents involved."

Finally, a collaboration with the Migros Magazine, edited by Switzerland's biggest retailer, led to the Center preparing science experiments aimed at children for publication in the weekly. After this collaboration ended, the Center brought together the other participants from the project (Espace des inventions, Lausanne; Scienscope, University of Geneva; and EPFL) to compile the best experiments and release them as a book. "Pschitt!" was published late in 2021 and is distributed for free in hard-copy format to primary schools. Its 150 pages can also be downloaded for free.

Strengthening ties

Internal collaborative projects to foster integration

The NCCR Bio-Inspired Materials has always encouraged collaborations between its different research groups. To further exchanges within the Center, a special funding mechanism was introduced for specific projects shared by different teams.

The new scheme is designed to foster collaborations within the NCCR and across its modules. These research grants support interdisciplinary projects led by at least two NCCR researchers, of which at least one must be a Principal Investigator, from different NCCR groups. The grants, worth a total of CHF 750,000, include funds to cover the salary of a postdoc, consumables, and travel expenses for a period of two years. Three initial projects were selected from seven proposals by members of the NCCR's External Advisory Board, after an international panel examined them.

The projects cover very different fields of research, stretching from the detection of circulating tumor cells, to optically manipulating objects on the colloidal scale nanoparticles via membranes for power conversion from salinity.

Detecting circulating tumor cells

Detecting circulating tumor cells (CTCs) in the blood of cancer patients is particularly significant for the early diagnosis and prognosis of disease, but also challenging due to the low numbers of CTCs in the bloodstream. NCCR Bio-Inspired Materials researchers had previously developed a DNA-based hybridization chain reaction (HCR) system as signal amplifier for CTCs. It was possible to detect a single CTC among 200 blood leukocytes, but that figure remained far below what was needed for clinical application. To overcome this shortcoming, NCCR researchers Dr. Samet Kocabey (Department of Medicine, University of Fribourg) and Prof. Guillermo Acuna (Department of Physics, University of Fribourg) teamed up to increase the sensitivity of the CTC detection system. Their solution consisted in combining the HCR method with surface-enhanced Raman scattering (SERS). Raman spectroscopy is typically used to identify molecules. In this case, it is achieved by conjugating DNA with gold nanoparticles. After initial testing on breast cancer cells, the goal is to adapt this approach to other types of cancer cells using a variety of cell surface markers.

A platform for optical micromanipulation

Optical tweezers, provide the unique capability to remotely manipulate small objects on the colloidal scale. Biology, physical chemistry, and

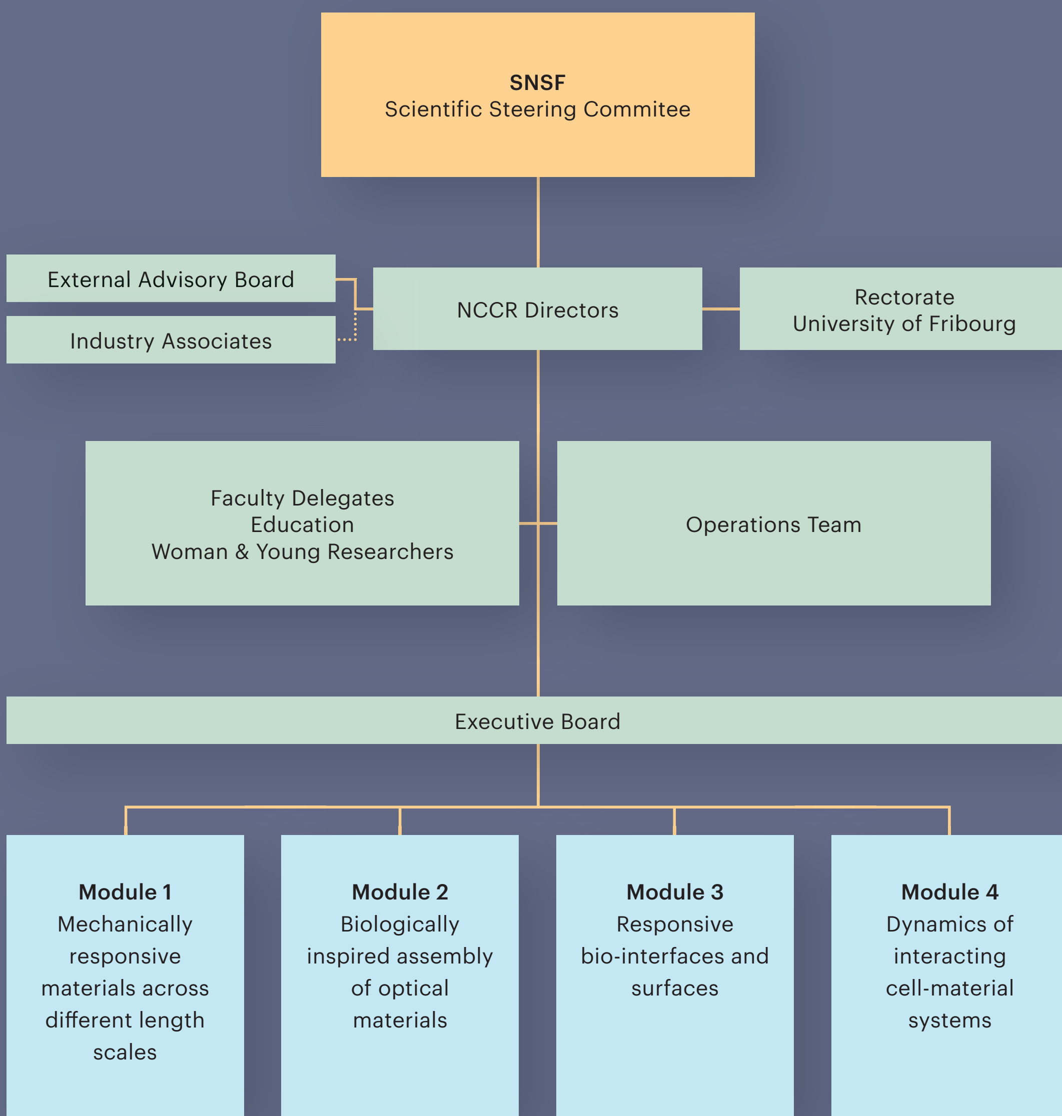
The electric eel is inspiring a new type of battery as part of a collaborative project

soft condensed matter physics have all benefited from this development. This collaborative project between the groups of Prof. Frank Scheffold (Department of Physics, University of Fribourg), Prof. Alke Fink (Adolphe Merkle Institute), and Prof. Stefan Salentinig (Department of Chemistry, University of Fribourg) aims to design an optical micromanipulation platform building on the Scheffold group's existing know-how and integrating it into the research agendas of the other two groups. This platform, which integrates different optical microscopy techniques (bright-field, dark-field and polarized microscopy), will allow the study of colloidal phenomena on a single-particle level and particle-cell interactions. This should provide additional insights for their research on cell-nanoparticle interactions, and the design and operation of colloidal nutrient and drug delivery systems. The new platform has been used already for preliminary studies in the context of milk-inspired colloids for drug delivery, helping 'immobilize' a soft particle in solution for online imaging, as well as structural and compositional analysis.

Ion-selective membranes for power conversion from salinity gradients

The conversion of energy stored in gradients of salt concentration between sea and river water to electrical energy by reverse electrodialysis (RED) provides sustainable energy without carbon dioxide emissions. However, the charge-selective membranes used in this process have limited efficiency, due to their fragility, thickness, their incapacity to self-heal, and fouling due to the formation of biofilms. Inspired by the lipid membranes in electric eels, the groups of Prof. Michael Mayer, Prof. Christoph Weder, and Prof. Ullrich Steiner (Adolphe Merkle Institute) are now investigating ultra-thin, bilayer membranes that can be formed through the self-assembly of two different block copolymers at the interface of an aqueous two-phase system. By adding ion-selective carriers, the membrane could be either cation-selective or anion selective, opening a pathway towards bio-inspired salinity gradient batteries.

Organization Phase II



Swiss National Science Foundation

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

Who is who

Executive board

- Prof. Ullrich Steiner (AMI)
  Director
- Prof. Esther Amstad (EPFL)
  Deputy director
- Prof. André Studart (ETHZ)
  Leader Module 1
- Prof. Frank Scheffold (UniFR)
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- 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

- Prof. Guillermo Acuña
  (Department of Physics, UniFR)
- 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)
- Prof. Curzio Rüegg
  (Department of Medicine, UniFR)
- Prof. Stefan Salentinig
  (Department of Chemistry, 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)

Management

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

Research groups

Acuña group (UniFR)

- Prof. Guillermo Acuna
- German Chiarelli, Doctoral student
- Morgane Loretan, Doctoral student
- Dr. Mauricio Pilo-Pais, Postdoctoral researcher
- Dr. Lu Zhang, Postdoctoral researcher

Amstad group (EPFL)

- Prof. Esther Amstad
- Aysu Ceren Okur, Doctoral student
- Gaia de Angelis, Doctoral student
- Matteo Hirsch, Doctoral student
- Chuen-Ru Li, Doctoral student
- Lorenzo Lucherini, Doctoral student
- Mathias Steinacher, Doctoral student
- Alexandra Thoma, Doctoral student
- Tianyu Yuan, Doctoral student
- Ran Zhao, Doctoral student

Bruns group (AMI/Strathclyde)

- Prof. Nico Bruns
- Livia Bast, Doctoral student
- Micael Gouveia, Doctoral student
- Dr. Peng Liu, Postdoctoral researcher
- 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. Barbara Drasler, Postdoctoral researcher
- Dr. Begum Karakocak, Postdoctoral researcher
- Aaron Lee, Doctoral student
- Shui Ling Chu, Laboratory technician
- Dr. Fabienne Schwab, 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
- Franck Oswald, Doctoral student
- Philippe Yep, Doctoral student

Kilbinger group (UniFR)

- Prof. Andreas Kilbinger
- Angélique Molliet, Doctoral student
- Dinh Phuong Trinh Nguyen, 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

Lattuada group (UniFR)

- Prof. Marco Lattuada
- Joelle Medinger, Doctoral student

- Dr. Miroslava Nedyalkova, Senior researcher
- Jansie Smart, Doctoral student
- Lorenzo Turetta, Doctoral student

Lütolf group (EPFL)

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

Mayer group (AMI)

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

Radenovic group (EPFL)

- Prof. Aleksandra Radenovic
- Evgenii Glushkov, Doctoral student
- Simon Mayer, Doctoral student
- Helena Miljkovic, Doctoral student
- Vitautas Navikas, Doctoral student
- Arielle Planchette, Doctoral student

Rüegg group (UniFR)

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

Salentinig group (UniFR)

- Prof. Stefan Salentinig
- Rafael Freire, Doctoral student
- Dr. Mark Gontsarik, Postdoctoral researcher
- Dr. Marco Manca, Postdoctoral researcher
- Dr. Mahsa Zabara, Postdoctoral researcher

Scheffold group (UniFR)

- Prof. Frank Scheffold
- Stefan Aeby, Doctoral student
- Dr. Geoffroy Aubry, Postdoctoral researcher
- Dr. Luis Salvador Froufe Pérez, Postdoctoral researcher
- Emmanuel Gendre, Other staff
- Kalpana Manne, Doctoral student
- 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
- Viola Bauernfeind, Doctoral student
- Johannes Bergmann, Doctoral student
- Kenza Djeghdi, Doctoral student
- Dr. Andrea Dodero, Postdoctoral researcher
- Dr. Antonio Günzler, Postdoctoral 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
- Vincenzo Scaramacio, Doctoral student

Studart group (ETHZ)

- Prof. André Studart
- Dr. Ahmet Demirörs, Senior researcher
- Alessandro Dutto, Doctoral student
- Nadia Enrriquez, Doctoral student
- Dr. Anton Igorevich Kan, Postdoctoral researcher
- Julie Laurent, Doctoral student
- 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
- Dr. Jessica Clough, Postdoctoral researcher
- Dr. Sètuhn Jimaja, Postdoctoral researcher
- Aristotelis Kamtsikakis, Doctoral student
- Derek Kiebala, Doctoral student
- Franziska Marx, Doctoral student
- Anita Roulin, Laboratory technician
- Dr. Philip Scholten, Postdoctoral researcher
- Dr. Stephen Schrettl, Postdoctoral researcher
- Hanna Traeger, Doctoral student

Support staff

- Dr. Jozef Adamcik, Senior researcher (AMI)
- 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

- Stefan Aeby (Doctoral student, Scheffold group)
- Dr. Geoffroy Aubry (Postdoctoral researcher)
- Livia Bast (Doctoral student, Bruns group)
- Stefanie Boy-Röttger (Technician, Lütolf group)
- Dr. Louise Bryan (Postdoctoral researcher, Mayer group)
- Dr. Devanjali Dutta (Postdoctoral researcher, Lütolf group)
- Dr. Barbara Drasler (Senior researcher, Rothen group)
- Matteo Gasbarri (Doctoral student, Stellacci group)
- Simone Giaveri (Doctoral student, Stellacci group)
- Evgenii Glushkov (Doctoral student, Radenovic group)
- Dr. Anirvan Guha (Postdoctoral researcher, Mayer group)
- Dr. Alessandro Ianiro (Postdoctoral researcher, Mayer group)
- Aristotelin Kamtsikakis (Doctoral student, Weder group)
- Dr. Peng Liu (Postdoctoral researcher, Bruns group)
- Dr. Tianji Ma (Postdoctoral researcher, Mayer group)
- Tommaso Magrini (Doctoral student, Studart group)
- Simon Mayer (Doctoral student, Radenovic group)
- Subhajit Pal (Doctoral student, Kilbinger group)
- Dr. Sanam Peyvandi (Postdoctoral researcher, Rüegg group)
- Samuel Raccio (Doctoral student, Bruns group)
- Dr. Philip Scholten (Postdoctoral researcher, Weder group)
- Dr. Corey Stevens (Postdoctoral researcher, Klok group)
- Dr. Patricia Taladriz (Senior researcher, Fink group)

- Tianyu Yuan
  (Doctoral student, Amstad group)
- Dr. Mahsa Zabara
  (Postdoctoral researcher, Salentinig group)

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
- Prof. Dr. Katharina Maniura, Materials Meet Life Department, EMPA, Switzerland
- Dr. Martin Michel, Food Science and Technology Department, Nestlé Research Center, Switzerland
- Prof. Marek Urban, Department of Materials Science and Engineering, Clemson University, USA

Abbreviations:

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

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

NCCR Collaborative Projects

27. Detection of circulating tumor cells by SERS using DNA based systems as signal amplifier
28. Development of a cross-departmental platform for optical micromanipulation
29. Ion-selective membranes for power conversion from salinity gradients with unprecedented efficiency

WINS Fellowships projects

30. Responsive pigments for Pointillist mechano-sensing
31. Unified approach for intracellular delivery of multi-modified oligonucleotide sequences
32. Swelling-driven mechanical activation of polymers at interfaces and in the networks

Publications

Module 1

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Module 4

Demirörs, A. F.; Stauffer, A.; Lauener, C.; Cossu, J.; Ramakrishna, S. N.; Graaf, J. de; Alcantara, C. C. J.; Pané, S.; Spencer, N.; Studart, A. R. Magnetic propulsion of colloidal microrollers controlled by electrically modulated friction, Soft Matter, 2020, 17, 1037–1047.

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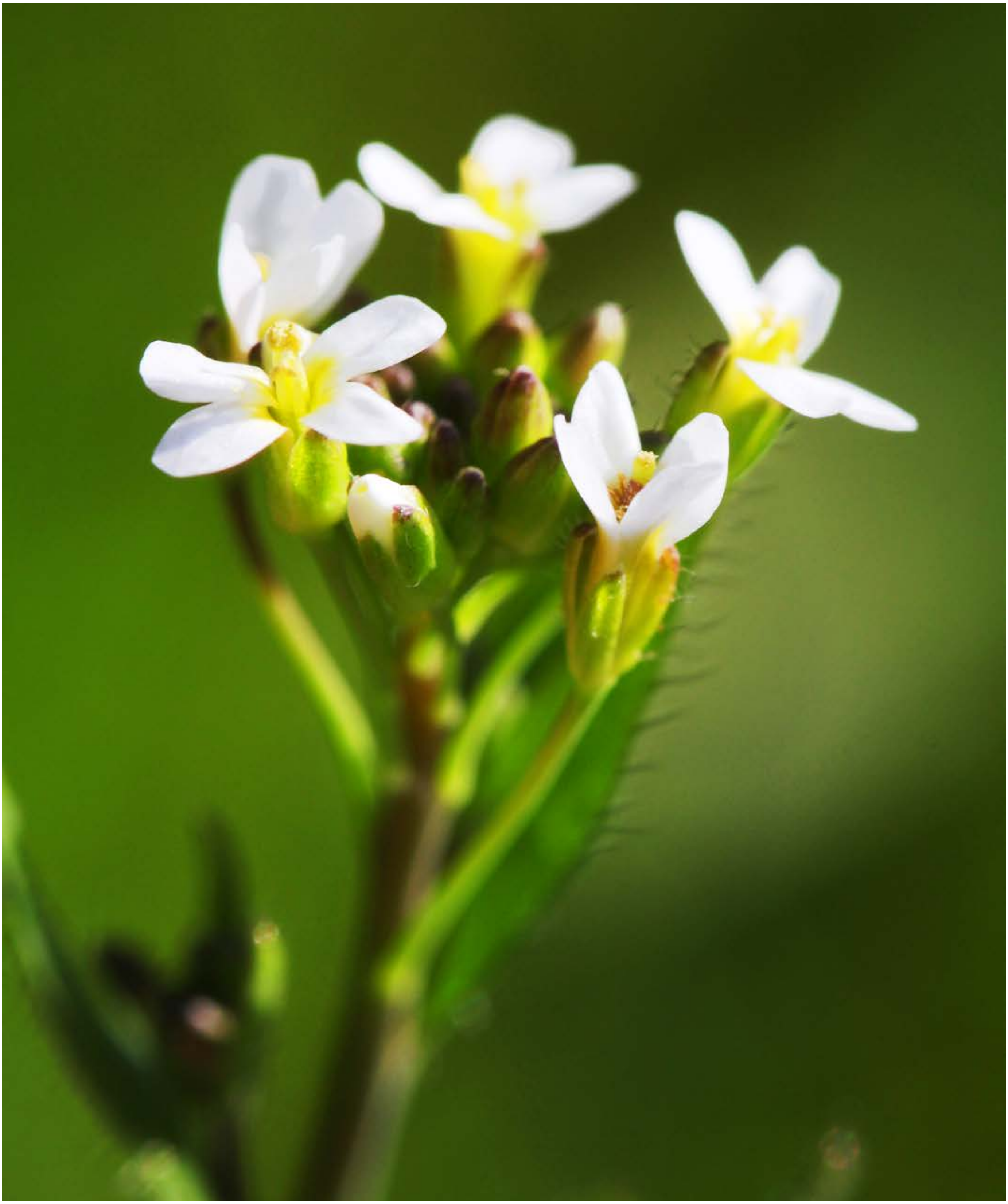

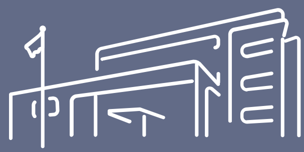

Headquarters

Adolphe Merkle Institute,
University of Fribourg

Gender balance

41% of the NCCR Ph.D. students were women

28% of the postdocs and senior researchers were women

5 round tables

and workshops on topics related to equal opportunities and personal and professional development

4 start-up companies

incorporated (Nanolockin GmbH, Spectroplast AG, Microcaps AG and FenX AG) and one additional spin-off technology (Nanofertilizer)

34 oral presentations at conferences

including 27 keynote and plenary lectures at international conferences

Over

100

children

and high school students participated in NCCR outreach activities despite the covid pandemic

8

cooperations

with external partners (6 with research institutions, 2 other)

Note: All figures between June 1, 2020 and May 31, 2021

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. Wanda Kukulski	The molecular landscape of growing human axons	University of Bern	October 29, 2020
Dr. Olga Vvedenskaya	Mental health in pandemic	DragonFly Mental Health	December 04, 2020
Prof. Albert Schenning	Bio-inspired polymer sensors and actuators	Eindhoven University of Technology, NL	January 28, 2021
Prof. Maria Helena Godinho	Hierarchical cellulose-based chiral structures	New University of Lisbon, PT	February 11, 2021

Impressum

Editorial: Ullrich Steiner / Esther Amstad / Lucas Montero / Scott Capper **Text:** Giorgia Guglielm / Scott Capper / Eliav Haskal
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BIO-INSPIRED MATERIALS
NATIONAL CENTER OF COMPETENCE IN RESEARCH

NCCR Bio-Inspired Materials
c/o Adolphe Merkle Institute
Ch. des Verdiers 4
1700 Fribourg
Switzerland

Telephone +41 26 300 92 66
E-mail: info@bioinspired-materials.ch
bioinspired-materials.ch

Swiss National Science Foundation

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