Arctic center offers extreme hands-on education

From petrology to paleontology to physics, research at the world's northernmost education institute involves the Arctic and much, if not all of it, bears on climate change.

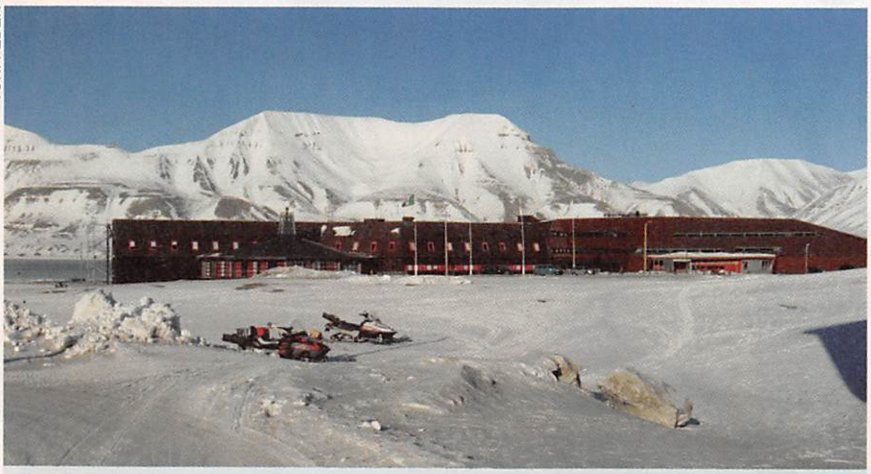
"You either love it or hate it," Steve Coulson says of Svalbard, the archipelago roughly midway between the northern tip of the Norwegian mainland and the North Pole. An arctic entomologist at the University Centre in Svalbard (UNIS), he says, "It's stunningly beautiful. And when I walk out the door, I am at my field site. There are very few places where you can do that."

Polar bears outnumber humans on Svalbard. The area is shrouded in darkness for about three months a year, and bathed in round-the-clock light for even longer. The average temperature is about −20 °C in winter and 5 °C in summer in Longyearbyen, the town at 78° N latitude where UNIS is located; three other, much smaller research and mining sites on Svalbard are also inhabited year round. Everything must be flown or shipped in. If something is not available at the single general store, people either order online or pack things in themselves; one UNIS faculty member PHYSICS TODAY spoke with during a visit this spring had just returned with a vacuum cleaner in his suitcase. The nearest town is Tromsø, a 1.5-hour flight away.

An initial batch of 23 students marked the start of UNIS in 1993, less than a year after Gudmund Hernes went into overdrive to establish the center. At the time, Hernes was Norway's minister of education and research. During an ocean expedition, he says, he "became convinced [Svalbard] was a good location for a research center. It is very interesting to captivate students with the lure of Svalbard. If you have been there once, you want to come back."

Hernes was successful in getting UNIS off the ground thanks to a confluence of political, scientific, and financial circumstances. According to a 1920 treaty, to retain sovereignty over the international territory of Svalbard, Norway must have a presence there. And its long-time activity of coal mining was on the wane. Meanwhile, international interest in the Arctic was growing because the earliest manifestations of climate change show up there. On the national front, Hernes says, "We had money for jobs. And there was an election in 1993 that we risked losing. I wanted to get [UNIS] started before a new education minister came in. We didn't lose, but I pushed forward as fast as possible."

UNIS, a government-owned company, has grown steadily ever since, and now has an annual budget of about NOK 105 million ($18 million), plus about NOK 50 million in grants. Its faculty numbers about 50, split roughly equally between full-time permanent professors and adjunct professors who spend 20% of their time there. Some 467 students from 23 countries attended courses in 2012. The focus at UNIS is education and research related to the Arctic in four broad areas: technology, biology, geology, and geophysics.


TONI FEDER

At the University Centre in Svalbard, students and researchers from around the world explore Arctic geology, biology, geophysics, and technology.

Because of the exotic location, says glaciologist Doug Benn, "a lot of scientists pass through. I see far more of my colleagues here than I would anywhere else. It's a terrific hub."

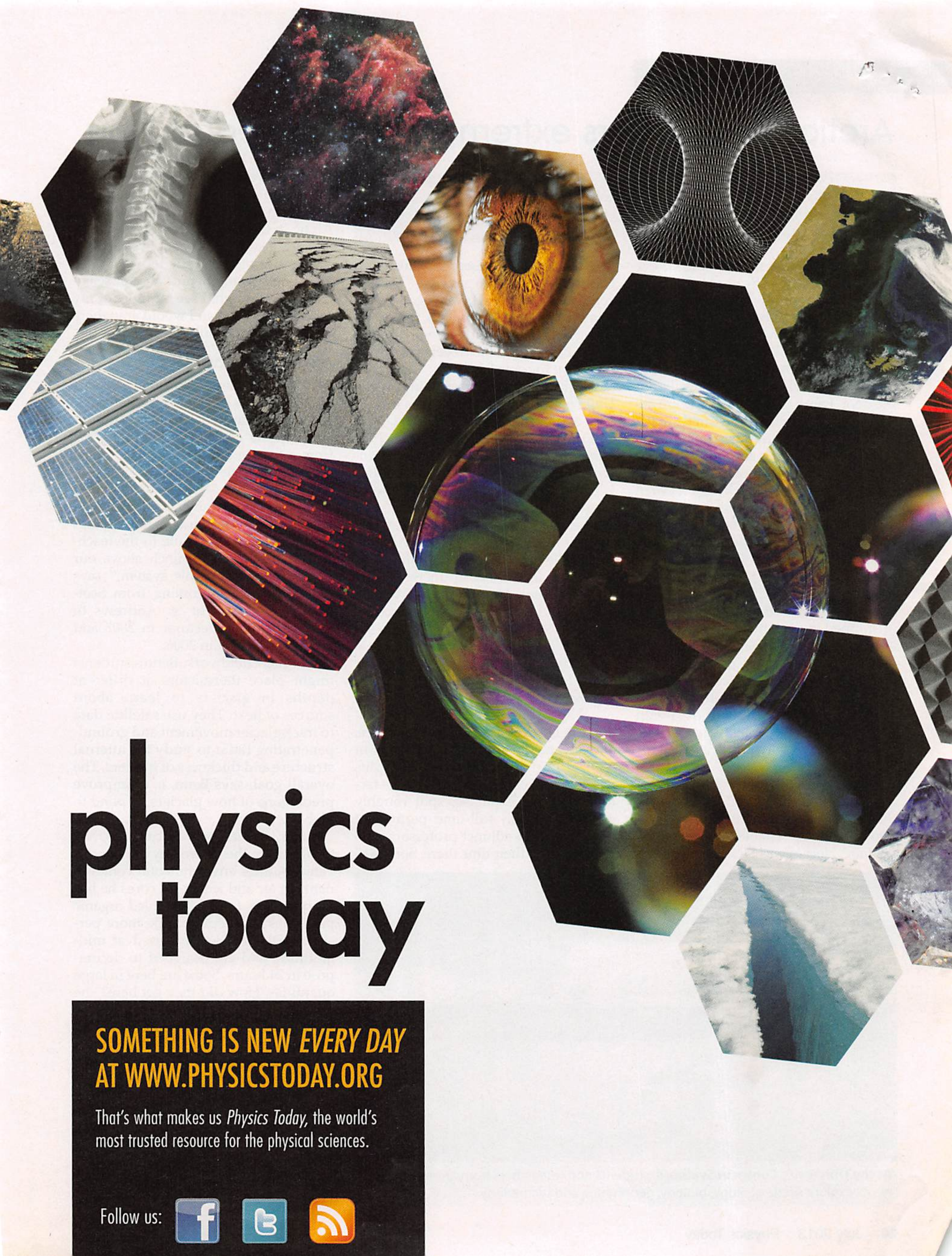
A natural laboratory

At UNIS the aim is to offer students education they can't get anywhere else. Upper-level undergraduate and graduate students come for courses lasting from a few weeks to a semester. Some stay to do their master's or PhD research, but their degrees are conferred from their home university. All courses involve fieldwork, and in most cases guest lecturers contribute to the teaching. "We can really punch above our weight because of this system," says Benn, who began coming from Scotland's University of St. Andrews to UNIS as a guest lecturer in 2003 and joined the faculty in 2006.

For their fieldwork, Benn's students might place thermistors at different depths in glaciers to learn about sources of heat. They use satellite data to track glacier movement and ground-penetrating radar to study the internal structure and thickness of glaciers. The overall goal, says Benn, is to improve predictions of how glaciers respond to global warming.

Mark Hermanson, who came to UNIS in 2009 from the University of Pennsylvania, studies environmental contaminants in air and ice. In ice cores he has found highly toxic, short-lived organic pesticides that replaced the more persistent DDT. "They are used at mid-latitudes, and are designed to decompose in 24 hours. Some are here in large quantities. How did they get here?" he asks. Another mystery is the presence of contaminants that, he says, "nobody manufactured. Could they be from a country that does not tell us? Or is some environmental process responsible?"

With his students, Ole Jørgen Lønne tracks crustaceans, which come to the surface at night to eat, and hide in deep waters during the day. "You see this all over the planet," he says. "The question is, Why do they keep doing this [on the same 24-hour cycle during] the polar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NICK HULTON, UNIVERSITY OF EDINBURGH

To study glacier dynamics, postdoc Faezeh Nick (right), secured by PhD student Heidi Sevestre, lowers pressure and temperature sensors into a crevasse in Kronebreen, a glacier about 100 km northwest of Longyearbyen.

night and day?" Lønne also looks at macroscopic organisms that live on the underside of sea ice. "It's a unique community, because the ice melts and freezes often. It's a dynamic system." In Arctic marine biology, he says, "we have instruction outside all year."

Whereas most UNIS scientists analyze data and write papers during the dark season, that's when atmospheric physicists like Dag Lorentzen are busiest. Svalbard is the "perfect place for aurora-related space research," he says. His students use cameras and other instruments, data from satellites and sounding rockets, and the local EISCAT radar antennas (see the story on page 27) to study the atmosphere. "They learn how to set up experiments, and they do experiments they have designed themselves. It's very hands-on," Lorentzen says.

Construction and safety in a changing Arctic is another area of research at UNIS. "Svalbard is a natural laboratory," says technology department head Jan Otto Larsen. "We look at the foundations of roads, how to avoid melting the permafrost, how to build roads in glaciers, and how to predict and protect from avalanches." The leaders in studying avalanche dynamics are Norway and Switzerland, he says. "Our students go directly to good jobs."

But before heading out on a cruise to measure Arctic plankton levels, to the fjords to study uplifted rock and sedimentation, or even to the roof of the UNIS building to take UV measurements, students learn to shoot a rifle and drive a snow scooter. The safety training required of anyone staying for at least a week also includes learning what to do if a polar bear comes close, how to rescue someone who falls into cold water, how to avoid avalanches, and the like.

Political potential

Without question, the Arctic is gaining attention globally. "We are all under increased interest in the high North," says Lønne. "There is a good chance that Longyearbyen may be important for search and rescue. This will influence our [research] priorities." And climate change happening "faster here," he adds, "also opens commercial opportunities—oil and gas, transport across polar oceans, fishing." Adventure tourism, too, is on the rise; last year about 130 000 people visited Svalbard.

Hermanson, for one, thinks UNIS should contribute to the broader political and policy discussion. "We could develop knowledge about the impact of oil and gas on marine and terrestrial ecosystems. On the production and storage of oil." There is a leadership opportunity, he says. "But there is no interest. Are we relevant? No." Ole Arve Misund, the center's managing director, counters that politics is not UNIS's role. "We educate students who will have a significant role in the management of the Arctic," he says. "It's just a 20-year-old organization. By no means is the full potential reached. Depending what the Norwegian society wants for Svalbard, UNIS can increase its size and work in other fields."

The Norwegian government "uses Svalbard to showcase research. They want UNIS to excel. We get a lot of politicians [and dignitaries] here—Hillary Clinton, Ban Ki-moon, the Queen of Norway," notes Lorentzen. He says rubbing shoulders with visiting Norwegian decision makers helped raise funds to build the Kjell Henriksen Observatory on Svalbard. It is the world's largest optical observatory for auroral studies and hosts instruments from eight countries.

Some UNIS projects do have a policy connection. One is the Svalbard Integrated Arctic Earth Observing System, or SIOS, an international effort based at UNIS to coordinate Arctic data. Another is carbon dioxide sequestration. Ragnhild Rønneberg, who is on leave from the Research Council of Norway, oversees both. Svalbard relies on coal for energy, she explains. "It's a bad image for Norway," which uses mostly hydroelectric power. "We have found a place to store CO_2. The area is an uplift from the Barents Sea. We try to get the CO_2 back to the rocks, so it doesn't escape." And some research has broad, potentially political implications. For example, Larsen notes that there has not yet been an oil spill on ice—and there is no solution if one occurs. But, he says, "oil companies are eager to get ahead of the curve."

Toni Feder

Chips may replace corn for harvesting solar fuels

Researchers hunt for appropriate semiconductors and molecules to power self-contained systems that can improve on photosynthesis.

What if fuel could be made from sunlight, water, and atmospheric carbon dioxide? What if the intermediate step of growing, harvesting, and fermenting biomass could be eliminated and the arable land freed for food production? And what if the new fuel-making process could even reduce atmospheric CO_2? That's the goal of artificial photosynthesis (AP), currently the focus of numerous government-sponsored research projects worldwide.

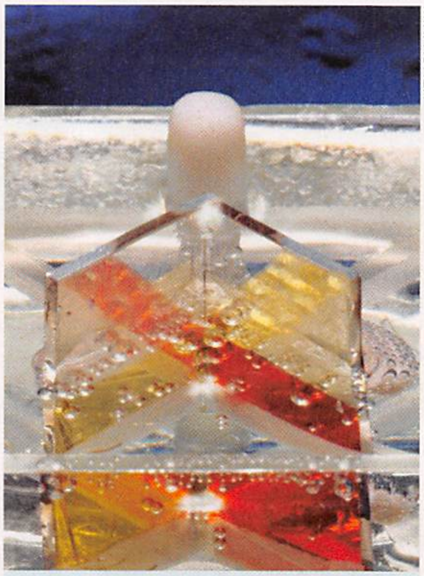
The basic principle of AP is to mimic the process that takes place in every plant leaf: splitting water with sunlight and recombining the hydrogen with carbon dioxide to make fuels. But accomplishing that at a meaningful scale without the green matter will require new materials that can efficiently perform the multiple tasks involved: light absorption, water oxidation, and hydrogen generation. And finding the right materials that can also operate under common environmental conditions has proved daunting.

"Going from a fossil-fuel society to a renewable energy society is a huge step," says Heinz Frei, a project leader at the Joint Center for Artificial Photosynthesis (JCAP) campus located at Lawrence Berkeley National Laboratory. "Biofuels we can start right away. Artificial photosynthesis needs more time because it's not an existing technology. But it's one that should get us all the way because it's not limited to arable lands." At least half the energy required by the transportation industry must come from liquid fuels, because batteries can't store enough energy to power airplanes, heavy trucks, or ships. If AP technology can reach a sunlight-to-fuel conversion efficiency of 1%—about the same as natural photosynthesis—replacing US gasoline consumption with AP would require 24 million hectares. That's roughly the area taken up by the entire US interstate highway system. At 3% efficiency, an area smaller than the Mojave Desert (about 12 million hectares) would suffice. Frei says an efficiency range of 6–8% is realistic.

Funded by the Department of Energy, JCAP is a five-year, $122 million collaboration led by Caltech. It is by far the largest of the AP partnerships. Its 120 staff members work at two campuses (Caltech and Lawrence Berkeley), with additional collaborators at SLAC, a number of US universities, and several of the 46 DOE energy frontier research centers. JCAP's goal is to make a self-contained device that can convert sunlight into fuels 10 times as efficiently as the 0.5–1% that occurs in the solar-energy-to-biomass conversion.

A two-stage process

In JCAP's conceptual two-stage cell, a light-absorbing semiconductor coated with a catalyst oxidizes water into protons and oxygen. Reducing protons to hydrogen will occur in a second semiconductor layer containing a different catalyst. Although platinum and iridium oxide will do the job, they are much too rare and expensive to be scaled up into a meaningful energy source. As JCAP's scientific director Nathan Lewis explains, the best Earth-abundant water-oxidation catalysts work by oxidizing hydroxide, plentiful only in alkaline solutions. But the best catalysts for proton reduction work most efficiently in an acidic environment. A semipermeable material capable of separating hydrogen from oxygen while allowing ions to pass to the reduction stage is a safety requirement with its own pH restrictions. "There are no membranes that can do this at pH 7," says Lewis. "If the membranes only work in acid or base, then the catalysts also need to work either in acid or in base for the system as a whole to work."



MIKI KOREN

This light-trapping structure invented at Technion–Israel Institute of Technology boosts the efficiency of ultrathin-film iron oxide material for photoelectrolytic water splitting.

Candidate materials for light absorbers also are pH limited, notes Lewis. Silicon, the most widely used light absorber for photovoltaics (PVs), dissolves in basic solutions. Other potential materials, including titanium dioxide, other metal oxides, and existing PVs, either dissolve or corrode in acid. "This is like building an airplane. Just having an engine doesn't mean the plane flies. You need wings, you've got to have avionics, got to have a fuselage, and the thing has to fly," Lewis says.

There are other, less obvious problems. Although hydrogen bubbles indi-