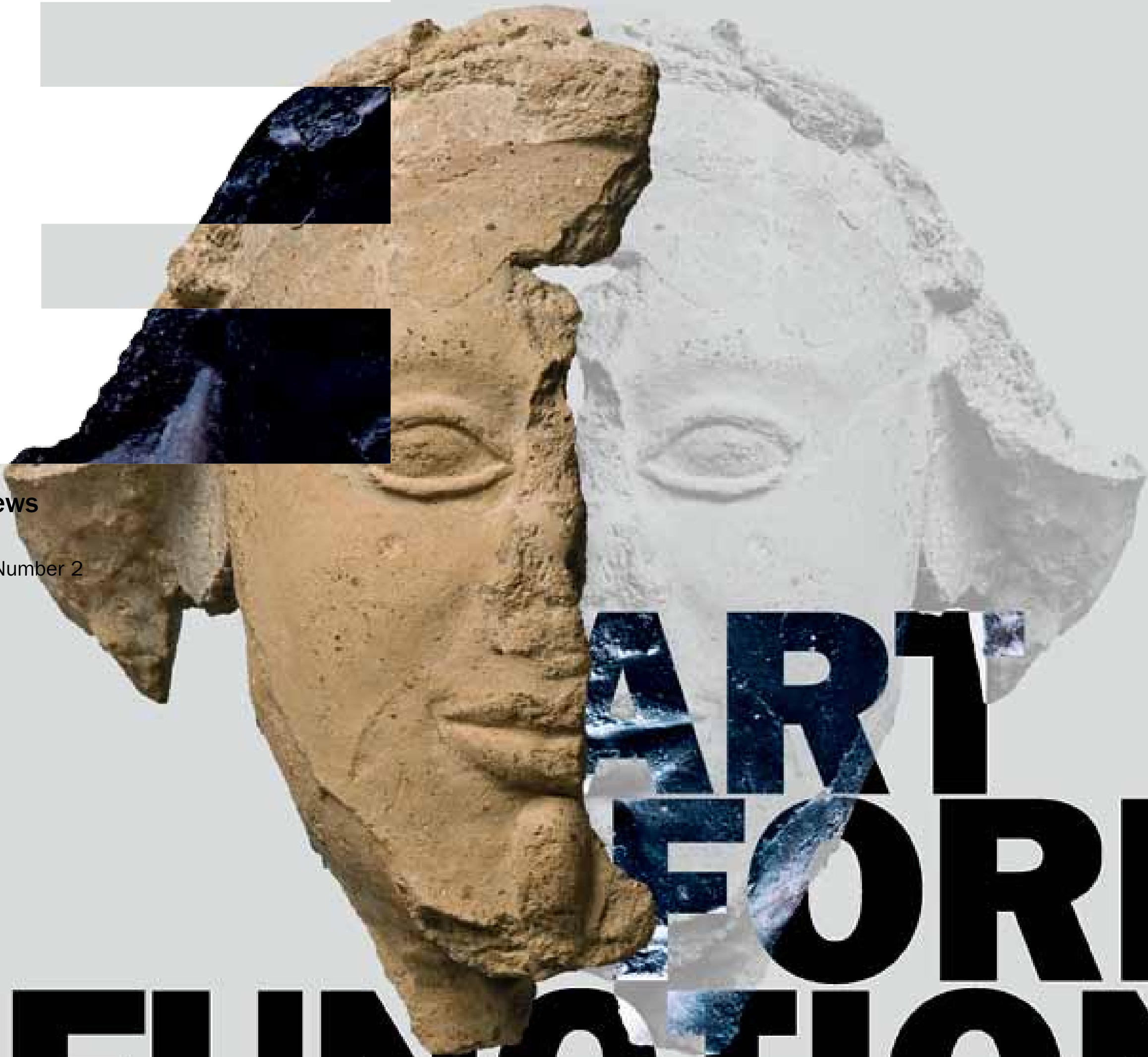

ART FORM FUNCTION

EQuad News

Winter 2013
Volume 24, Number 2

PRINCETON
School of Engineering
and Applied Science

"Principles for the Development of a Complete Mind: Study the science of art. Study the art of science. Develop your senses — especially learn how to see. Realize that everything connects to everything else."

~Leonardo da Vinci

Art and engineering: Connections that create

What does it take to solve a problem? What does it take to make something of beauty?

For the past five years, my colleagues and I have talked a lot about some big topics — energy, the environment, human health, security. These critical areas of societal need have been the focus of our fundraising efforts through Princeton University's Aspire campaign. In this issue of EQuad News, we celebrate the successful conclusion of that campaign and the tremendous advances it has put in motion. But we also are taking this opportunity to consider a topic that may seem removed from the usual problems engineers tackle: the intersection of art and engineering. It's a subject that reveals a lot about what engineering is at its best.

As Professor Mike Littman points out in his essay on page 6, engineers can be artists, artists can be engineers, or the two professions can work together in ways that yield entirely new and unexpected results. This type of interplay between seemingly disparate fields is essential in all areas of engineering. Pressing societal issues inevitably involve a mix of technological and human factors, whether it's ensuring a sustainable supply of energy or improving health around the world. In the end, creativity is the spark that expands knowledge, engages the senses and improves the human condition.

At Princeton, we deeply value the interactions that come from having a vibrant engineering school in the midst of a liberal arts institution. This collaborative, barrier-crossing spirit stays with our students long after graduation. I am proud of the great creativity and innovation our alumni bring to their endeavors and am very grateful for the support and generosity toward Princeton that they have shown in return.

Warmest regards,

H. Vincent Poor, Ph.D. '77
Dean and Michael Henry Strater
University Professor of
Electrical Engineering

EQuad News
Winter 2013
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Dean
H. Vincent Poor, Ph.D '77

Vice Dean
Pablo Debenedetti

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Peter Bogucki

Associate Dean, Graduate Affairs
Brandi Jones

Associate Dean, Development
Jane Maggard

Director of Engineering Communications
Steven Schultz

Senior New Media Editor
Teresa Riordan

Staff Writer
John Sullivan

Graphic Designer
Matilda Luk

Additional editing
Morgan Kelly

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EQuad News
C-222, EQuad
Princeton University
Princeton, NJ 08544

T 609 258 4597
F 609 258 6744
eqn@princeton.edu

www.princeton.edu/engineering/eqnews

In the Nation's Service and in the Service of All Nations

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Photos by Frank Wojciechowski

2012 Freshman class is largest ever

Princeton Engineering welcomed a record 374 freshmen in September, surpassing last year's record-setting freshman enrollment of 333.

The enrollments bring to more than 1,200 the total number of Princeton students pursuing a Bachelor of Science in Engineering, a 36 percent increase over five years. Nationally, the number of students enrolled in full-time undergraduate engineering programs grew 26 percent during the five years from 2006 to 2011.

Although it is difficult to identify a single reason for a growing interest in engineering at Princeton, Peter Bogucki, the associate dean for undergraduate affairs, said an important factor is the tight integration of the engineering school with the rest of the University.

"You are not isolated in a boutique program," Bogucki said. "Students recognize that engineering is a significant presence at Princeton."

Acting Dean Pablo Debenedetti struck a similar theme in welcoming students during the school's orientation program. The connection between teaching and research at Princeton "is really etched into our DNA," Debenedetti said. "The result of it is that our program combines the best aspects of a research university and a liberal arts college. You will get to meet faculty members at the top of their game in both teaching and in research."

Many of the challenges society faces today, whether supplying energy or water, or the future of megacities, "are at their core technical but not exclusively technical. You can't solve these problems without dealing with the cultural aspects and without dealing with the social aspects," Debenedetti added.

"That requires a seamless integration with the social sciences and the humanities," he said. "Princeton is an ideal place for that both because of our small size and because of the very low barriers that we have, by design, for you to take courses in different departments and different programs." **–Staff**

Following introductory talks by representatives of the school's six departments on Sept. 10, freshman engineering students walked with upperclassmen to meet their faculty advisers for the first time.

Synthetic fuels could eliminate entire U.S. need for crude oil

The United States could eliminate the need for crude oil by using a combination of coal, natural gas and non-food crops to make synthetic fuel, a team of Princeton researchers has found.

Besides economic and security benefits, the plan has potential environmental advantages. Because plants absorb carbon dioxide to grow, the U.S. could cut greenhouse emissions from vehicles by as much as 50 percent by using non-food crops to create liquid fuels, the researchers said.

Synthetic fuels would be an easy fit for the transportation system because they can be used directly in automobile engines and are essentially identical to fuels refined from crude oil. That sets them apart from currently available biofuels, such as ethanol, that have to be mixed with gas or require special engines.

In a series of scholarly articles over the past year, a team led by Christodoulos Floudas, a professor of chemical and biological engineering, evaluated scenarios in which Americans could power their vehicles with synthetic fuels rather than relying on oil. Floudas' team, including graduate students Josephine Elia and Baliban, Ph.D. '12 and lecturer Vern Weekman, also analyzed the impact that synthetic fuel plants were likely to have on local areas and identified locations that would not overtax regional electric grids or water supplies.

"The goal is to produce sufficient fuel and also to cut CO_2 emissions, or the equivalent, by 50 percent," said Floudas, the Stephen C. Macaleer '63 Professor in Engineering and Applied Science. "The question was not only can it be done, but can it also be done in an economically attractive way. The answer is affirmative in both cases." **–JS**

Photo by Frank Wojciechowski

From left, Professor Christodoulos Floudas and graduate students Richard Baliban Ph.D. '12 and Josephine Elia developed a comprehensive system for optimizing the production of synthetic liquid fuels as an economical replacement for petroleum-based fuels.

Photo by Frank Wojciechowski

From left, physicist Jason Petta, electrical engineer Andrew Houck '00 and postdoctoral researcher Karl Petersson discuss their recent advance in transferring quantum information through a computing device.

Breakthrough offers new route to large-scale quantum computing

In a key step toward creating a working quantum computer, Princeton researchers have developed a method that may allow the quick and reliable transfer of quantum information throughout a computing device.

The finding, by a team led by physicist Jason Petta, could eventually allow engineers to build quantum computers consisting of millions of quantum bits, or qubits. So far, quantum researchers have only been able to manipulate small numbers of qubits, not enough for a practical machine.

"The whole game at this point in quantum computing is trying to build a larger system," said Andrew Houck '00, an assistant professor of electrical engineering who is part of the research team, which published the results Nov. 18 in the journal Nature.

To make the transfer, the researchers used a stream of microwave photons to analyze a pair of electrons trapped in a tiny cage called a quantum dot. The "spin state" of the electrons — information about how they are spinning — serves as the qubit, a basic unit of information. The microwave stream allows scientists to read that information.

In an ordinary sense, the distances involved are very small: The entire apparatus operates over a little more than a centimeter. But on the subatomic scale, they are vast. It is like coordinating the motion of a top spinning on the moon with another on the surface of the Earth.

"It's the most amazing thing," said Jake Taylor, a physicist at the National Institute of Standards and Technology, who worked on the project with the Princeton team. "You have a single electron almost completely changing the properties of an inch-long electrical system." **–JS**

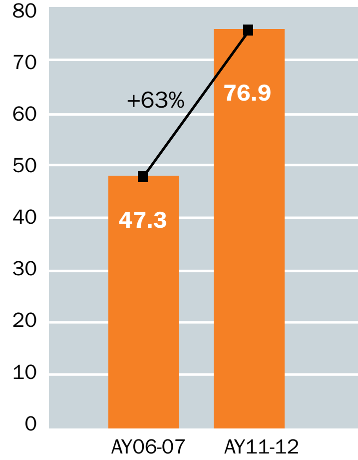
Aspire campaign helps engineers address critical societal needs

Princeton's Aspire fundraising campaign concluded June 30, 2012, having raised $327 million to support "Engineering and a Sustainable Society." The gifts established major centers for teaching and research, 10 professorships, two preceptorships, more than 175,000 square feet of new construction and more than $60 million for innovative research.

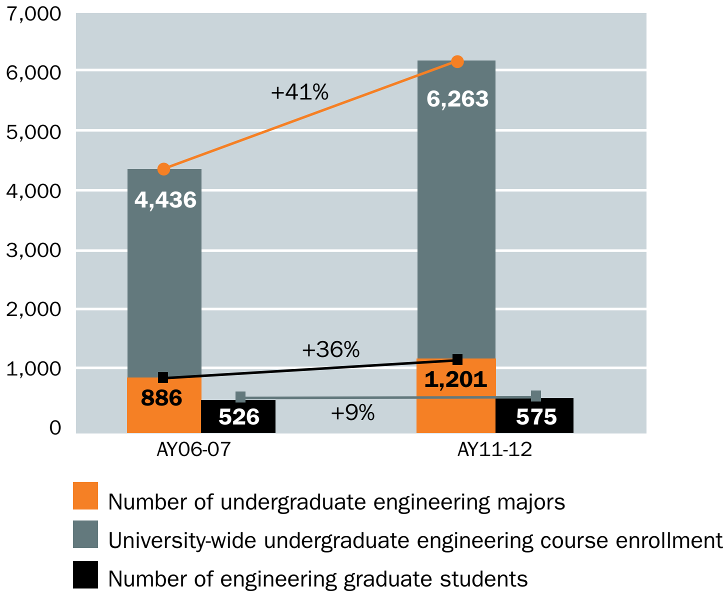
"The tremendous generosity of our alumni and friends already is accelerating work that will provide clean energy, protect the environment, improve health, and secure information and infrastructure around the world," said H. Vincent Poor, dean of engineering. "Through the Aspire campaign, we are doing more than ever to prepare all Princeton students to be leaders and to make wise use of technology. I join my colleagues in saying a heartfelt thank you to all who participated."

Several important outcomes of the Aspire campaign include the Andlinger Center for Energy and the Environment, the Keller Center for Innovation in Engineering Education, Sherrerd Hall and more than $60 million worth of innovation funds to support transformative research. These key areas of growth are outlined on the following two pages. For more information, visit www.princeton.edu/aspire. –Staff

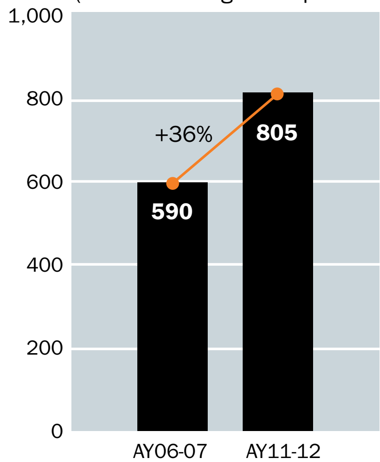
Sponsored research
(millions of dollars)



Student numbers



Space committed to engineering
(thousands of gross square feet)



Aspire Campaign

Major gifts help address societal need

Keller Center

The first gift to Aspire came from Dennis (Class of 1963) and Constance Keller to endow a bold initiative to broaden the education of engineers and to engage students from all parts of the University in a deeper understanding of technology. The Keller Center for Innovation in Engineering Education now supports many courses, extracurricular programs, internships and events that foster entrepreneurship, service and hands-on projects. One of the center's latest initiatives, called eLab, allowed four teams of students to spend 10 weeks on campus last summer building businesses they created.

Photo by Frank Wojciechowski

"One of the beautiful things about eLab was that there were so many fields represented and everyone was pursuing their dream of building a business," said Malik Jackson (above center, with white shirt with tie), a junior majoring in politics. Jackson and fellow students worked on MyGZpoints, a company that rewards students for performing well in school. The interactions with other eLab teams and the many guest speakers provided a crash course in marketing plans, presentation skills and business development. Said Jackson, "These concepts were outside my comprehension prior to eLab."

Photo by Steven Schultz

"What motivates me in my work is the bigger context of the research, namely the world's current energy challenges," said Josephine Elia (left), a graduate student who received the Andlinger Center's Maeder Graduate Fellowship. Elia works with Professor Christodoulos Floudas to design chemical and energy processes and strategic planning approaches for providing U.S. transportation fuels from non-petroleum sources. "The Maeder Graduate Fellowship is essential in enabling the work and progress of this research," Elia said. "It underscores the Andlinger Center's commitment to bridging academic contributions to real-world implementation."

Andlinger Center

In 2008, international businessman Gerhard Andlinger '52 endowed the Andlinger Center for Energy and the Environment, which supports interdisciplinary efforts to develop sustainable sources of energy and comprehensive environmental solutions. In addition to a major new laboratory, faculty positions and an active program of guest speakers and corporate affiliations, Aspire campaign gifts have created a variety of funds to support innovative research and student projects.

Sherrerd Hall

With support from the late John J.F. Sherrerd ’52 and his family, the University completed construction in 2008 of a 45,000-square-foot building bordering the green between the Engineering Quadrangle and Wallace Hall. Sherrerd Hall is home to the Department of Operations Research and Financial Engineering (ORFE) and the Center for Information Technology Policy (CITP), both of which bridge engineering and the social sciences.

Photo by Frank Wojciechowski

The design of Sherrerd Hall promotes chance conversations among disparate department members and visitors, said Jianqing Fan, chair of ORFE (left). The location also supports a continuous flow of students back and forth between ORFE and the nearby economics department and the Bendheim Center for Finance. “People bump into each other in the hallways,” Fan said, “and that makes for more effective communications.”

Photo by Frank Wojciechowski

Naveen Verma, assistant professor of electrical engineering (center), received support from the Helen Shipley Hunt Fund and the Essig-Enright Fund to work on wearable or implantable electronic chips that monitor chronic conditions in patients. The chip uses medical databases and a patient’s own data to learn patterns of signals, and alert physicians to prevent acute problems and manage disease. Conventional funding from public health and science agencies would typically support advances that fit into relatively well-understood protocols. “This technology is more ‘out there’ in terms of how it fits with and changes existing patient-care protocols,” Verma said.

“New, emergent phenomena often don’t have a natural academic home,” said Zeynep Tufekci, a visiting scholar at CITP who studies the social impacts of new technologies and is currently writing about the Arab uprisings. “CITP is a great place to do this work. It is an interdisciplinary space where you find people who are at similar intersections.”

Photo by Frank Wojciechowski

Innovation Funds

An important outcome of the Aspire campaign was the creation of innovation funds — sources of money distributed to researchers on a competitive basis for bold ideas that would be difficult or impossible to pursue using conventional grants from federal agencies. The Project X fund was created by Lynn Shostack in memory of her late husband David Gardner ’69 to support engineers who want to explore unconventional ideas and hunches, often outside their immediate areas of expertise. The Eric (Class of 1976) and Wendy Schmidt Transformative Technology Fund is open to faculty members University-wide. **E**

ART FORM FUNCTION

“The art spoke to me.”

This comment, which caused me pause when I first read it, came from a liberal arts student in an evaluation of CEE 102 “Engineering and the Modern World.” Since the 1990s, I have enjoyed co-teaching CEE 102 with Professor David Billington ’50. Billington, who recently retired, invented CEE 102 in 1985 to educate the whole campus about the major role that engineering plays in shaping our world. I was pleased by this student’s comment because it supports our belief that viewing works of art helps one to understand engineering ideas more deeply. This can be seen in paintings such as “Rolling Power” by Charles Sheeler, who masterfully captured the massive motive force produced by a high-pressure steam-driven piston. Art stimulates students’ imagination about major transformations brought about by engineering works. In class, we study the painting “Dynamism of an Automobile” by futurist Luigi Russolo as we discuss the transformation to individual mobility in America.

But there are other more important reasons to discuss art together with engineering. We observe that sometimes the engineer is the artist. Here engineering works may be efficient and economical, and at the same time be able to elicit an emotional response from the public through elegance of design. Nowhere is this more evident than in the work of bridge designers. The best of these designers are structural artists, working in a range of media — steel, stone and concrete — to create great and sometimes iconic works of engineering and public art. Such is true of the George Washington Bridge, the major work of Othmar Ammann. (This underappreciated role of the structural engineer is at the heart of CEE 262, “Structures in the Urban Environment,” a foundational course across many disciplines, which Billington created in 1974.)

We explain that sometimes artists are engineers. One great example is Samuel F.B. Morse, one of the first professors of art in America, who invented a telegraph code based on ‘dits’ and ‘dahs.’ He then managed the first full-scale test of a working telegraph system connecting Baltimore to Washington, D.C., and launched a radically new type of information network. Morse was first and foremost an artist, and then a communications engineer. His pioneering work anticipated the modern digital age where now virtually all types of information are coded as ones and zeros.

To these two categories inspired by CEE 102 — engineer as artist and artist as engineer — I add a third where engineers and artists come together — perhaps to create something entirely new, or perhaps to work in an area that shares a common interest or skill. The stories in this magazine reflect these categories. Princeton’s Streicker Bridge project (page 8) shows the work of one of the leading structural artists of our time, Christian Menn — the engineer producing art. Rebecca Fiebrink, Ph.D. ’11 (page 12) represents the artist as engineer — a flutist and computer scientist who seeks to apply machine learning to facilitate the skillful playing of musical instruments. Demonstrating the power of collaboration, mechanical and aerospace engineering professor Naomi Leonard ’85 (page 14), who orchestrates collective motion of underwater robots, and dance professor Susan Marshall, who directs collective motion of dancers, work together and advance artistic expression and engineering analysis. Civil and environmental engineering professor Sigrid Adriaenssens’ story (page 9) is one of a passion shared by artists and engineers, the ability to think and express oneself through drawing. While some pieces may not fit neatly in these classifications, it is clear that art and engineering are indeed speaking to one another in the EQuad. **E**

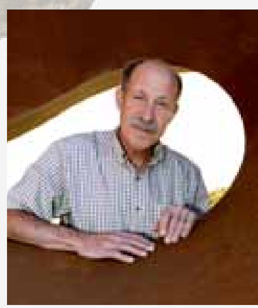


Photo by Frank Wojciechowski

Michael Littman is a professor of mechanical and aerospace engineering.

STRUCTURAL ART:
MELDING ENGINEERING AND AESTHETICS

Engineering is often seen as the most utilitarian of disciplines, a field in which aesthetics takes a back seat to function. But a group of teachers and scholars have recently begun holding annual conferences at Princeton to challenge that view. To the International Network for Structural Art, engineering has a clear aesthetic defined by elegance, efficiency and economy.

"It takes a creative spring in an engineer's mind to come up with a solution," said Maria Garlock, an associate professor of civil and environmental engineering and a leader of the group.

Photo by Frank Wojciechowski

Maria Garlock (right) teaches her course, "Tall Buildings" in 2011.

The network held its fourth annual gathering last summer. Garlock said the group was formed in 2009 by David Billington '50, then the Gordon Y.S. Wu Professor of Engineering at Princeton (now emeritus). Billington is a teacher and scholar who inspired others to appreciate the aesthetic elements of engineering. His goal was to bring together some of his former students and present colleagues to build a community of teacher-scholars for studying structural engineering as a new art form.

"He encouraged people to view works of engineering as works of art," Garlock said. "Great works of engineering — bridges, buildings, spatial structures — if designed properly are works of art."

This summer, the network published its first book, a celebration of Billington's work to advance the concept of structural engineering as an artistic discipline. Garlock and her colleagues hope to build on that legacy. Sigrid Adriaenssens, an assistant professor of civil and environmental engineering and another member of the group, said Princeton has a focus on engineering aesthetics that is nearly unique among universities, not only though teaching and research but through exhibitions of work by great engineers such as Felix Candela, Robert Maillart, Othmar Ammann, Christian Menn and Fazlur Khan.

"Many people find this interesting," she said. "Civil structures can be very efficient and also very beautiful." –JS

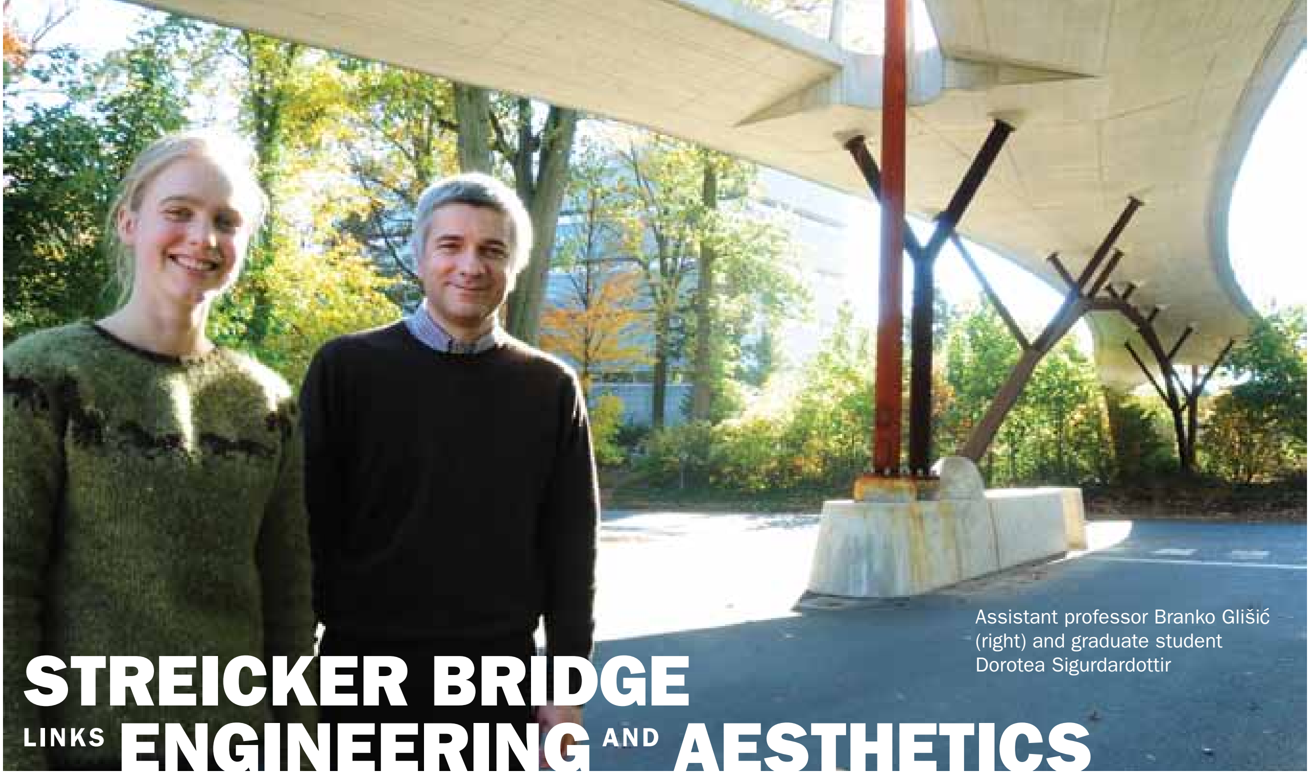
Photo by Richardo Barros

Professor Emeritus David Billington '50 has been a leading scholar and advocate of structural art as an expression of the best qualities of engineering practice and aesthetic vision.

A MODERN MOSAIC

Serguei Bagrianski (right) assembles a prototype dome to test a new type of concrete in the EQuad courtyard this fall. Bagrianski, who is pursuing a master's degree in architecture after receiving his master's in civil engineering, is testing shapes that would allow builders to use fiber-reinforced concrete to construct structural shells. If he is successful, the technique would be cheaper than using steel for domes and it would result in a segmented appearance for the shell. "It looks like a mosaic," Bagrianski said. –JS

Photo by Frank Wojciechowski



Assistant professor Branko Glišić (right) and graduate student Dorotea Sigurdardottir

Photo by Bentley Drezner

STREICKER BRIDGE LINKS ENGINEERING AND AESTHETICS

by John Sullivan

For drivers entering campus along Washington Road, the Streicker Bridge passes without much notice. A thin ribbon of concrete and steel spun over a single delicate arch, the bridge's elegant but understated design does not receive as much attention as some of the University's more recognizable monuments.

In a way, that is a tribute to the designers who worked to match the bridge to the woods and steep hills surrounding it. With bridge supports that are weathered and branched to resemble tree trunks and a deck that curves to meet the varying grades on both sides of the road, the Streicker Bridge fits perfectly into the landscape.

"When I think about the Streicker Bridge, I think about harmony," said Branko Glišić, an assistant professor of civil and environmental engineering who uses the bridge for research and as a teaching tool in some of his classes.

Although the bridge is matched well with its surroundings, the structure merits a longer glance, Glišić said. The 350 foot span is a masterful design, he said, light enough to do without heavy supporting piers. The deck rises 24 feet above the roadway in an elongated arch that makes the crossing easy for pedestrians. The slender steel arch that supports the deck is a funicular polygon — a curve made of straight segments — which balances the forces on the deck and allows for its thin shape.

"It is an outstanding piece of advanced engineering," Glišić said.

The bridge, funded by a gift from John Harrison Streicker, a member of the Class of 1964, fills a missing link in the pedestrian path across the southern edge of campus. The deck has an unusual shape, splitting into forks at both ends. In addition to serving a structural function — the forks provide horizontal stability for the bridge — it also serves a symbolic end by linking different scientific disciplines represented by the buildings on each side of Washington Road. The Lewis-Sigler Institute for Integrative Genomics and the (under construction) neuroscience and psychology buildings are on the west side, and the new Frick Chemistry Laboratory and Jadwin Hall, home to the physics department, are on the east.

The bridge was designed by Christian Menn, a world-renowned Swiss engineer whose bridges are typically spare and elegant. David Billington '50, a professor emeritus of civil and environmental engineering and a longtime friend of Menn's, said a great engineer never sets out to make a beautiful structure — it is inherent in the work.

"They don't say 'I am going to set out to make this an aesthetic design,' it is part of their fiber," he said. "They design it to be efficient and economic, and it will also be beautiful."

At the time he was selected to design the bridge, Menn had a long relationship with Princeton. His work had been exhibited on the campus, particularly in a major 2003 exhibition called, "The Art of Structural Design: A Swiss Legacy."

"The Streicker Bridge does not come out of the blue," Billington said.

The engineer of record for the project who oversaw the construction was Theodore Zoli, a vice president with HNTB engineering of New York and a member of the Princeton Class of 1988.

"The wonderful character of Menn's work is one of restraint," said Zoli, a 2009 MacArthur grant recipient who has completed many prominent bridge designs including the Lake Champlain Bridge and who collaborated with Menn on Boston's Zakim Bunker Hill Bridge. "He is known for not overemphasizing the opportunity, but getting the scale right."

One of the bridge's more unique features is the brown color of its supports, which match the trees in the woods on both sides of Washington Road. The color is a property of "weathering steel," which, as its name implies, allows a layer of rust to form on the outside without affecting the strength or durability of the support. Obtaining the steel was a job in itself because no foundries were making the type and quantity of steel needed for the bridge. So Zoli and project managers scoured steel yards across the country.

"We found the last cache of weathering steel in the country," Zoli said. It was a lucky find: The steel turned out to be stronger than expected.

The bridge also serves an academic function by allowing engineering students to monitor stresses and motion. During construction, Glišić oversaw the installation of 100 point sensors and a 122-foot cable sensor inside the structure. The sensors are capable of taking about 25,000 measurements per second and function like a nervous system for the bridge, Glišić said.

"The structure is not only an engineering achievement," Glišić said, "it also stimulates new discoveries both by serving as an inspiration to students and as a laboratory." **E**

DRAWING CLASSES EXTEND THE ENGINEERING MIND

Photo by Eve Aschheim

Engineering students recently spent time at Princeton's Lewis Center for the Arts taking drawing classes to better inform their work in structural engineering.

Art was not something that Bianca DiGiovanni thought she would create when she decided to pursue an engineering degree, but when the civil and environmental engineering department offered a drawing class in combination with the Lewis Center for the Arts, she decided to give it a try.

"I thought maybe I would find out I was a brilliant artist," DiGiovanni, a sophomore, said with a laugh. "I found out otherwise, but I did learn a lot."

Drawing sessions for engineering students began this year after Sigrid Adriaenssens, an assistant professor of civil and environmental engineering, reached out to visual artists Eve Aschheim and Nathan Carter at the Lewis Center, who agreed to offer drawing sessions to students in the "Mechanics of Solids" class. Adriaenssens had taken drawing as part of the engineering program as an undergraduate at the University of Bath, and she believes that drawing stimulates thinking in a different way than mathematics or language.

"When you draw, it is an extension of your mind," she said. "It is another way to generate ideas."

The drawing sessions are not required for the course, but they will probably help with the notebooks in which students are required to record their design experiences that are part of the "Mechanics of Solids" class.

"It definitely gave me more confidence in drawing," DiGiovanni said. "There has to be an aesthetic in engineering, a way to connect from the science to the application." –JS

RX FOR ART AND ARCHITECTURE

by John Sullivan

George Scherer's tours of campus are not typical. Instead of beauty, he points to deterioration, or at least the type of wear and tear that comes from years of exposure.

"My students like to tell me they always thought Princeton had such a beautiful campus — until they take my course," Scherer jokes.

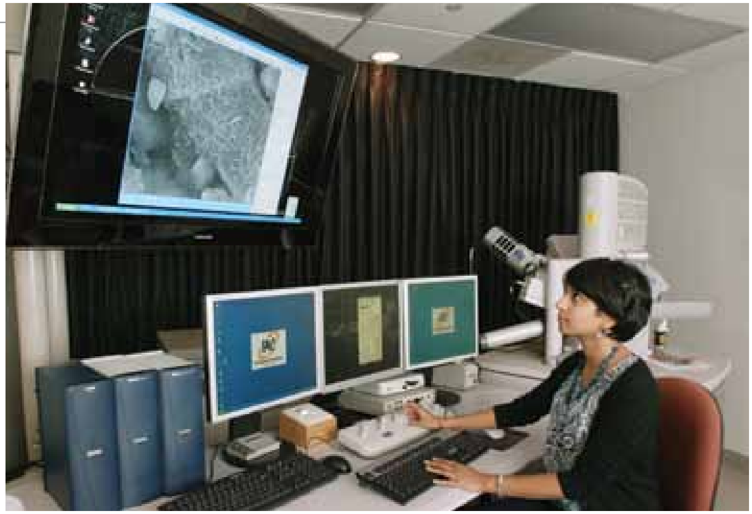
Scherer, the William L. Knapp '47 Professor of Civil Engineering, is an expert in stone: how to repair it, restore it and protect it from damage. His research group has discovered techniques to protect many materials, from brownstone to cement.

His most recent project involves the protection of marble with hydroxyapatite. Restorers apply a film of the material to the marble, where it bonds and creates a layer similar to the mineral component of human teeth. Scherer developed the compound in collaboration with Robert Cava, the Russell Wellman Moore Professor of Chemistry.

Sonia Naidu, a graduate student in chemical and biological engineering working on the project with Scherer, recently began testing hydroxyapatite in collaboration with restoration experts from the French palace Versailles, where statues had been damaged by acid rain.

"The deterioration was so extensive that a lot of statues, 100 to 200, had to be moved into a warehouse," Naidu said. "There were busts, kings, knights on horseback — and they were from all around the palace."

Olivier Rolland, an independent restorer working on the statuary at Versailles, said the tests will be observational — to see whether the treatment changes the appearance of the marble and whether it increases the resistance to damage.

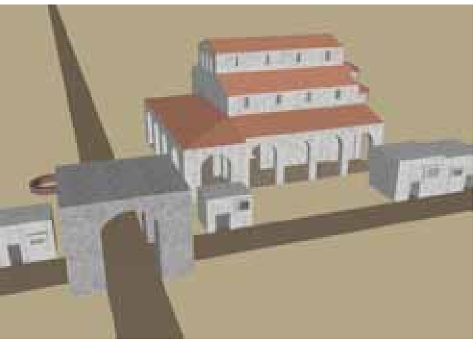


Photos by Frank Wojciechowski

Above: Graduate student Sonia Naidu examines electron microscope images of marble and its interactions with a material she helped develop to prevent environmental damage to art and architecture. Below: Professor George Scherer (foreground) points out damage to stone on the Princeton campus to Robert Flatt (at left with dark hair), a professor at the Swiss Federal Institute of Technology, and Fred Giradet, a conservator in private practice in Switzerland.

"We set the first samples with the hydroxyapatite treatment outside this year," he said. Although it is too early to report any results, he said the technique "seems one of the most promising ways to conserve calcite sculptures outdoors, especially marble sculptures." E

Head from a colossal male statue, from late sixth-century B.C.E. Cyprus, which was part of the "City of Gold" exhibition at the Princeton University Art Museum (courtesy of the Department of Antiquities, Cyprus).



Students in a joint computer science and art and archaeology class created 3-D renderings of buildings that housed the artifacts displayed in the "City of Gold" exhibition. A video of their renderings can be viewed at www.princeton.edu/engineering/art.

CITY OF GOLD

Professor of Computer Science Szymon Rusinkiewicz, an expert in 3-D graphics, has worked closely with archaeologists, first to reconstruct broken frescoes in Greece and most recently to simulate the reconstruction of entire ancient buildings in Cyprus. In the spring of 2012, Rusinkiewicz and Joanna Smith '87, a lecturer in art and archaeology, teamed up to teach a course in which students started with archaeological data and built plausible renderings of four buildings in Cyprus. The result of their work was shown as a video that accompanied the exhibition, "City of Gold: Tomb and Temple in Ancient Cyprus" at the Princeton University Art Museum, which featured artifacts from excavations led by William Childs, professor of art and archeology, emeritus. –JS

Above: Computer scientist Szymon Rusinkiewicz (front) poses with Joanna Smith '87 (to his left) of the Department of Art and Archaeology and their students. (Class photo by Henry Vega; detail of fourth-century B.C.E. pendant of Erotes courtesy of the British Museum/British Museum Images)

COAXING THE 'INHERENTLY MUSICAL'

NO DEGREE REQUIRED

Rebecca Fiebrink, Ph.D. '11, is a music teacher, although she doesn't teach students how to play instruments. Instead, Fiebrink, who is an assistant professor of computer science, teaches instruments how to play for their users.

"We are researching ways that technology has the ability to allow people who are not musically trained to express themselves musically," she said. "We are trying to offer people a way to go beyond sitting and listening and being passive consumers of music. It's making musical performance more accessible to people without requiring them to spend 30 years training to play the violin."

Fiebrink, who specializes in music technology and the interaction between humans and computers, is exploring methods to teach machines to find patterns in groups of data. Those patterns can be used to apply rules such as, "Whenever a user moves their arm in a certain way, play a C chord."

There are already programs that users can configure to transform objects into instruments. But they typically require a high degree of technical skill to set up and are fairly rigid once they are running. Fiebrink wants to produce a system that is more intuitive and accessible to a wide

PLACING THE 1970S IN THE PALM OF A HAND

The original Moog synthesizer, a staple of '70s music, had its heyday long before senior Jeffrey Snyder learned to play the keyboard, but Snyder loved that warm '70s sound.

The problem was that he found it nearly impossible to reproduce. For most musicians, the story would end there. Snyder, a computer science major, decided to build a gadget to create his own retro sound.

"Almost any computer has the ability to make these sounds," Snyder said. In fact, Moog's current line of instruments is far sleeker and more compact than their progenitors. But Snyder was looking to reduce the equipment to its simplest possible form.

"I wanted something that I could toss in my backpack," he said. "I also did not want something menu driven; I wanted something that could be used by musicians during a performance."

For his junior-year independent research, Snyder spent months working on circuit designs and programming a microprocessor. An active musician, he performs with the Princeton Rock Ensemble and the Princeton Jazz Ensemble. Snyder also used the Internet to poll dozens of keyboardists for desired features. With the help of Rebecca Fiebrink, Ph.D. '11, assistant professor of computer science, and Jeffrey O. Snyder (no relation), the music department's technical director, Snyder created the SoundBar.

About the same size as a large TV remote, SoundBar connects to a standard keyboard and allows it to faithfully recreate the sound of the '60s and '70s Snyder said he has a lot of work to do before the SoundBar is finished — the current device is a prototype. But he said there is a real value in hands-on creation both musically and scientifically.

"As a computer scientist, I wanted to study how people interact with electronic insturments," he said. "But this is also a tool I would love to use in a performance." –JS

Previous page: Computer scientist Rebecca Fiebrink, Ph.D. '11 creates software that turns ordinary objects or devices such as the hand sensor she is shown wearing into musical instruments.

range of people. The scientific goal, she said, is to explore ways to make technology more available in all fields.

"We are examining the question of how to make machine learning useful for real people," she said. "We want people to be able to interact with these algorithms without getting a degree in computer science."

Music offers a good test bed because it is something that nearly everyone has in common.

"People are inherently musical," said Fiebrink, who trained as a flutist. "It's a way to express yourself. It's fun." **–JS**

Above: Undergraduate Jeffrey Snyder at a sound studio in Princeton's Woolworth Center for Musical Studies.

ANALYZING DANCE THROUGH MATHEMATICS

As Adam Stasiw moves through a dance, he creates a pattern of movement, timing and form.

An audience can sense the meaning intuitively, but Stasiw, a computer science major, wanted to view the message of the dance through a mathematical filter. So, for his junior-year independent research, he created a computer to analyze dance (shown in photo at right).

"I took the Microsoft Kinect and used its capability for skeletal tracking and used a machine learning algorithm to watch dancers," said Stasiw, a senior who also is pursuing a certificate in theater. "By taking information about their positions and the velocity acceleration of their joints, I could come up with a way to model the dance expressively."

Stasiw used a system called Laban movement analysis as part of the computer's programming. Laban analysis, created in the early 20th century by choreographer Rudolf Laban, breaks a dance down into components of expression such as space, weight and time. Stasiw used those elements to mathematically describe the dance's range.

"The type of dance does not really matter," he said. "My training is in modern dance, so that is what I have used it for, but it would be really interesting to try it with tap or ballet."

Photos by Frank Wojciechowski

Above: Undergraduate Adam Stasiw in the dance studio at the Lewis Center for the Arts.

Stasiw used Wekinator, a machine learning language created by his project advisor, assistant professor of computer science Rebecca Fiebrink, Ph.D. '11, to create his analysis program. Right now, he is using the program to analyze dance moves, but he said it could also be used to coordinate movements and effects in a live performance.

"I may end up using it in a dance thesis, but that is up in the air right now," he said. "It is definitely interesting, this method of using computer science and art." **–JS**

‘FLOCKING’ PROJECT COMBINES DANCE AND ENGINEERING

Photo by Sameer Kahn

Engineer Naomi Leonard ’85 (left) and dancer Susan Marshall (right) orchestrated a Flock Logic demonstration in 2011.

The Flock Logic dance project began after Susan Marshall, an internationally renowned choreographer, attended a 2009 lecture on groups and collective motion by Naomi Leonard ’85, a professor of mechanical and aerospace engineering.

Marshall, who had recently joined the Princeton faculty as a professor of dance, listened as Leonard explained how simple rules given to individuals can result in complex motion patterns in groups such as fish schools or bird flocks. Leonard uses the principles in her robotics work, but Marshall saw parallels to improvisational dance.

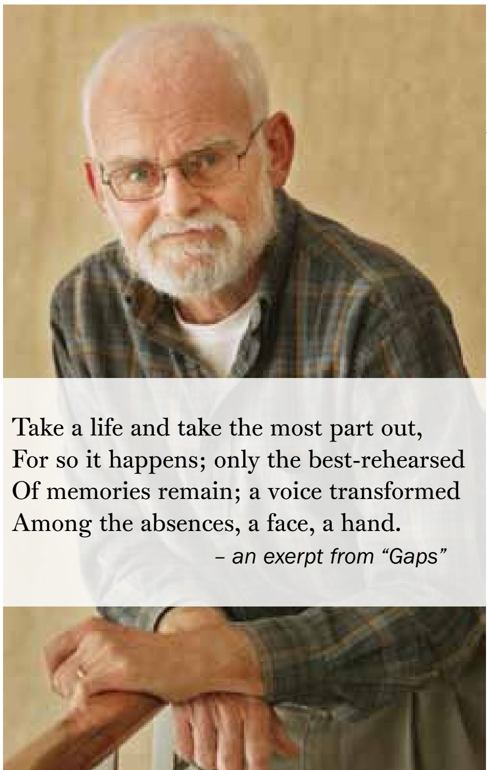
“Improvisational scores are basically a set of instructions that give dancers freedoms and limitations,” she said. “The way Naomi was talking about the rules that govern flocks and herds of animals that move collectively made me wonder where we might go with this artistically.”

Marshall and Leonard, both of whom are MacArthur Foundation grant recipients, arrived at a project in which amateurs and professional dancers would follow flocking rules.

“The project was artistic, but the approach was much like we use in engineering design,” said Leonard, the Edwin S. Wilsey Professor of Mechanical and Aerospace Engineering. “We did not set out to do engineering, but I have capitalized on our artistic explorations to address scientific questions.”

The performances occurred in 2010, but Leonard is still using the data generated from the project and recently presented a paper on the dynamics of the dancer network and its emergent motion patterns. Leonard said she would like to continue to explore feedback, interaction and dynamics at the intersection of the performing arts and engineering, with an interest in extending the approach to music as well as dance. –JS

Photo by Frank Wojciechowski



Take a life and take the most part out,
For so it happens; only the best-rehearsed
Of memories remain; a voice transformed
Among the absences, a face, a hand.

– an exerpt from “Gaps”

ART OF INCORRECT:
POETRY AND MATH SHED DETAILS TO ILLUMINATE TRUTHS

The Cantor Set is a mathematical puzzle in which segments are repeatedly removed from a line, while the number of points left remains the same.

Philip Holmes, the Eugene Higgins Professor of Mechanical and Aerospace Engineering, begins his sonnet “Gaps” with an almost arithmetical recitation of the Cantor Set that quickly expands to apply its strange perspective to the greater world.

Like much of Holmes’ poetry, “Gaps” doesn’t seek to mirror the world. It is more like a lens, allowing Holmes to focus and manipulate an interesting aspect of reality.

It’s an approach that also informs his mathematics. When Holmes builds a mathematical model, he is creating a secondary world, but one severely defined by its limits.

“A good mathematical model should be incorrect — it should be too simple,” said Holmes. “It should idealize, providing a way to pick out a few features and highlight them.”

Holmes, who has written poetry since his undergraduate years at Oxford, believes that poetry and science share an intensity of focus as a method to reveal wider truths.

“It’s a way to use few words, or equations, to tell a very big story,” he said. –JS

Left: Philip Holmes. To read more of his poetry, visit www.princeton.edu/engineering/arts.

ARTFUL ALGORITHMS

Carter Cleveland ’09, founder of Art.sy, says that as an undergraduate he was always interested in subjects such as dance and art history.

“I took many of those courses and at one point I was tempted to switch into art history to escape the huge engineering workload,” he said.

Instead, Cleveland figured out a way to combine his passion for computer science (his major) with his passion for the arts, coming up with the idea for Art.sy while sitting in his dorm room senior year.

Art.sy is a website that features all manner of art, ranging from Arabic calligraphy and African masks to Andy Warhol and Michaelangelo. The site is powered by what Cleveland calls “The Art Genome Project,” an algorithm that allows users to find new artists based on artwork they already know and like.

The concept is a close cousin to Pandora Internet radio’s “Music Genome Project.” Indeed one of Cleveland’s earliest advisers was Joe Kennedy ’81, the CEO of Pandora. Kennedy gave the keynote address at the 2009 Princeton Entrepreneurial Network conference and Carter approached him following his speech. A generation apart, the main difference between Cleveland and Kennedy seems to be that as an undergraduate majoring in electrical engineering and computer science Kennedy was dabbling not in art history but rather music theory — learning, for example, to compose his own Gregorian chants.

Cleveland’s Art.sy became hot almost the moment it hatched. In 2009, the concept (then called “Exhibytes”) took second place as well as the Audience Favorite award at TigerLaunch. It won the Rookie Award at the 2010 TechCrunch Disrupt event. And it has several million dollars in funding from top-drawer angel investors — among them Google’s Eric Schmidt ’76 and Jack Dorsey, the founder of Twitter and Square.

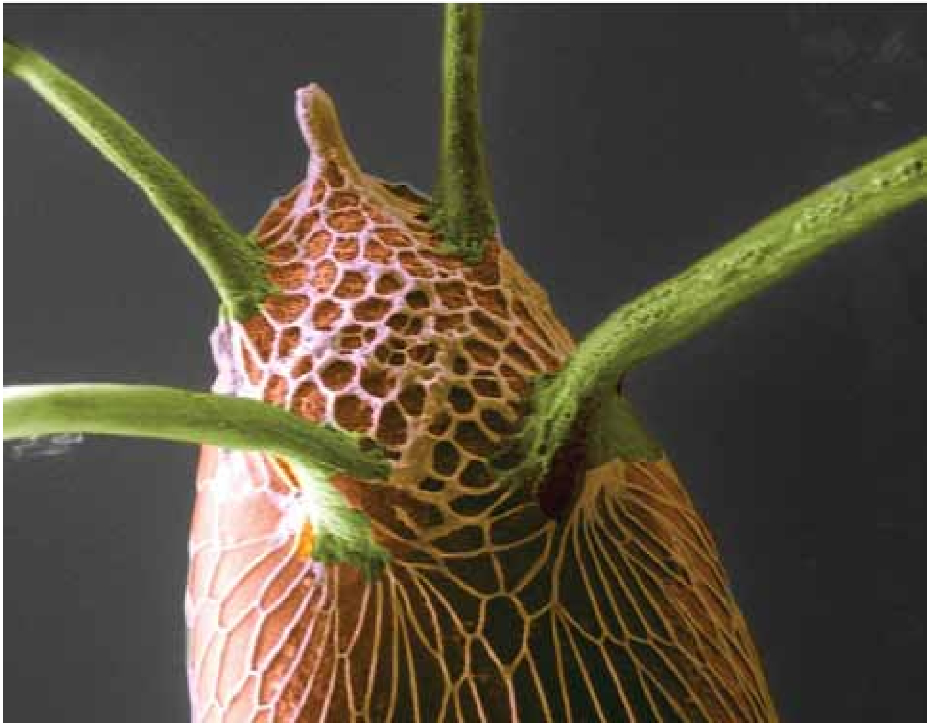
“People feel intimidated by the art scene,” says Cleveland. “This is unfortunate, because art is universal. It’s something that everyone should be able to enjoy, and we think that with the right technology, that’s possible.” **–Teresa Riordan**

Carter Cleveland ’09 in a photo by British photographer Emily Hope for Garage Magazine, which featured Cleveland’s Art.sy project.

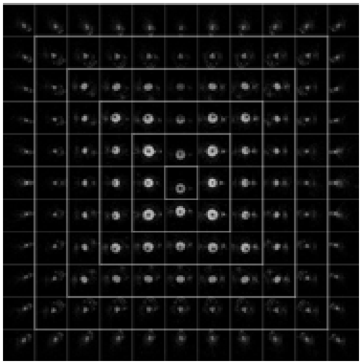
Five-year 'best of' retrospective goes on the road

A special "Princeton Art of Science" traveling show consisting of 44 images chosen from the more than 250 images exhibited during the competition's first five years opened in September at Liberty Science Center in Jersey City, N.J. The traveling show was selected by celebrated photographer and professor emeritus Emmet Gowin and Joel Smith, former curator of photography at the Princeton University Art Museum.

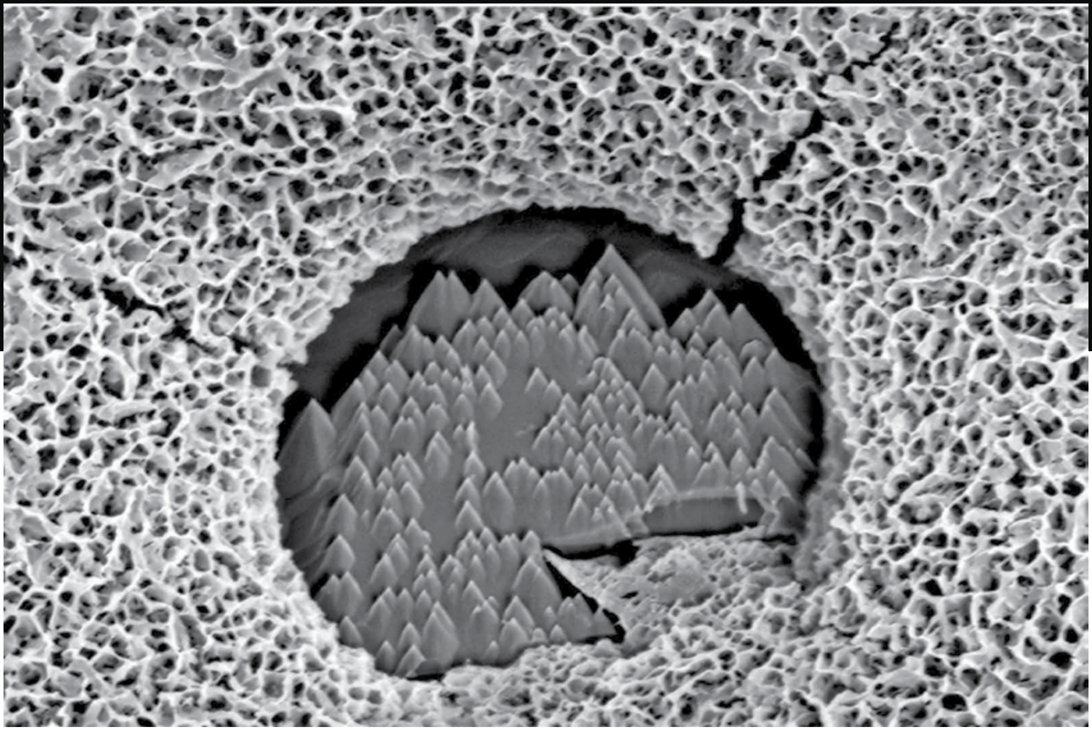
The exhibit was made possible through the generosity of the David A. Gardner '69 Fund in the Council of the Humanities and the School of Engineering and Applied Science. The exhibit will be on display at Liberty Science Center through mid-March, when it will travel to other venues.



Five-Horned Eggshell (right)
Nir Yakoby (postdoctoral researcher) and
Maria Pia Rossi (Drexel University)
Department of Chemical and Biological Engineering
This may look like a five-horned monster, but it is actually an image of a fruit-fly egg. The four green "horns" are tubes that allow the baby fly developing inside to breathe. The smaller, white horn at the top is the tube the father fly used to deposit his sperm and fertilize the egg. This particular fly is *Drosophilia virilis*, which is widely used in scientific research.



This Is a Teapot? (left)
Rafi Romero '12 (undergraduate)
Department of Computer Science
Have you ever noticed the patterns that form on a table when light shines on a wine glass? The study of this kind of phenomenon — the way parallel rays of light bend around a curved surface — is known as caustics. This image is a caustic map of the Utah teapot, a standard object used in computer graphics to test how light interacts with objects in a scene.



Secret Forest (above)
Sonia Naidu (graduate student) and
Enrico Sassoni (graduate student)
Departments of Civil and Environmental Engineering and Chemical and Biological Engineering
Acid rain causes marble monuments and sculptures to deteriorate, resulting in damage to our cultural heritage. Princeton's art conservation laboratory is experimenting with creating a surface treatment for marble made out of a mineral called apatite. Though the apatite coating is invisible to the naked eye, through a scanning electron microscope the apatite forms a forest of tiny protective crystals on top of the marble (see story, page 10).

Stirring Faces (left)
Steve Brunton, Ph.D. '12 (graduate student) and **Clancy Rowley '95** (professor)
Department of Mechanical and Aerospace Engineering
Department of Mechanical and Aerospace Engineering
These fanciful curlicues were generated by a computer to simulate the movement of a small plate through a fluid such as water or air. The "eyes" of each of the face-like pictures correspond to vortices caused by the motion of the plate through the fluid. These simulations help researchers better understand how birds and insects fly, and in turn help the researchers design smarter airborne micro-robots.

PRINCETON UNIVERSITY

School of Engineering and Applied Science
Princeton, NJ 08544-5263
www.princeton.edu/engineering

eqn@princeton.edu