McCormick

Northwestern Engineering

Mechanical Engineering

Robert R. McCormick School of
Engineering and Applied Science
Northwestern University

FALL 2013

Student Entrepreneurs

MECHANICAL ENGINEERING STUDENTS TRANSFORM IDEAS INTO BUSINESSES

Hannah Chung and Aaron Horowitz co-founded a startup to commercialize Jerry the Bear, an educational toy for children with diabetes.

When you're onto a great idea, you know it — and there's no time like the present to take action. Three McCormick mechanical engineering students have done exactly that, developing their research and side projects into promising commercial endeavors even before finishing their degree programs.

This summer, Sproutel sent out the first batch of 250 bears, available on jerrythebear.com, for $249.

Next steps for Jerry the Bear

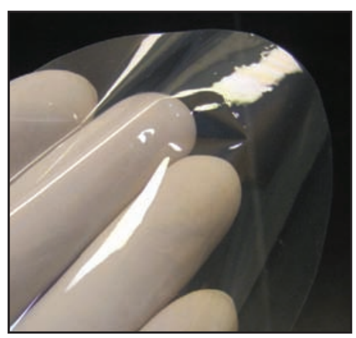
For Hannah Chung (mechanical engineering '12) and Aaron Horowitz (combined studies, mechatronics and user interaction design '12), it was involvement in the student group Design for America that launched their entrepreneurial spirit. Their creation: Jerry the Bear, a stuffed mechatronic bear that teaches diabetic children how to manage their disease.

Using voice technology and a touchscreen, Jerry tells children when his blood sugar is low, and kids can respond by checking his glucose levels and feeding him various foods. The toy is intended as a tool to reinforce the new, often overwhelming practices taught in the doctor's office. "When your child has diabetes, you might only get 30 minutes with the doctor, and the lessons you learn there have critical consequences," Horowitz said. "Behavior changes by building habits, and that's not something that happens in 30 minutes."

Since completing the 12-week Betaspring incubator program in Providence, Rhode Island, during their senior year, Chung and Horowitz's company, Sproutel, has gotten up and running. They added a new narrative element to the bear: Jerry is now an aspiring Olympic athlete who must keep his diabetes in check to reach his goals. This summer, Sproutel sent out the first batch of 250 bears, available on jerrythebear.com for $249.

New twist on a polymer

Medical innovation also sparked the interest of Erik Robinson (PhD '13, Ho). While pursuing his master's in biotechnology, Robinson became interested in Parylene-C, a biocompatible polymer that for decades had been used as a coating for medical devices to prevent the immune system from attacking them.



Erik Robinson's thin film could prevent complications during open-heart surgery.

"We saw an opportunity to make the polymer into its own device," Robinson said. He and his collaborators separated a very thin layer of the polymer from a smooth surface to make a transparent film about the thickness of a human hair. Their initial idea was to place the film near the site of a tumor to slowly release cancer-fighting drugs, but conversations with a cardiologist alerted them to another potential application.

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From the Outgoing Chair

"Our students and faculty are uniquely positioned to develop new solutions … at the intersection of mechanical engineering and life sciences."
Cate Brinson

Welcome to the ME@NU Newsletter for fall 2013. This issue highlights some of our departmental activities touching upon the life sciences. The breadth and depth of this work is amazing and really demonstrates the importance of the core discipline of mechanical engineering in many facets of global science challenges.

We see here the reach of ME expertise and techniques with application of robotics to health care, fundamental understanding of neural and motion control, new materials for drug delivery, and biomedical implants. With our hallmark interdisciplinary focus, our students and faculty are uniquely positioned to develop new solutions and understanding at the intersection of mechanical engineering and life sciences. We also see the influence of the entrepreneurial and design aspects of a McCormick education

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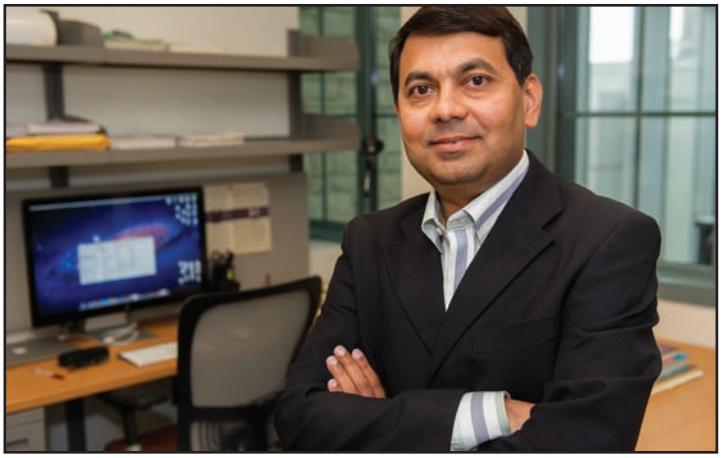
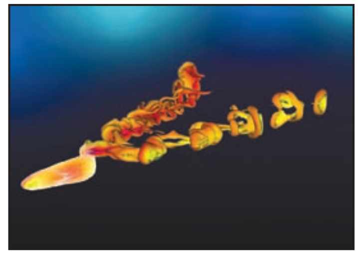
How Fish Swim: McCormick Researchers Examine Mechanical Bases for the Emergence of Undulatory Swimmers

FINDINGS COULD PROVIDE INSIGHTS IN EVOLUTIONARY BIOLOGY, NEURAL CONTROL OF MOVEMENT, BIO-INSPIRED DEVICES



Neelesh Patankar has revealed some of the mechanical properties that allow undulatory fish to move so intricately, including vorticity (shown above), the rotational velocity of the fluid in the wake of the swimming fish. (Image courtesy Namrata Patel.)



How do fish swim? It is a simple question, but there is no simple answer.

Researchers at McCormick have revealed some of the mechanical properties that allow fish to perform their complex movements. Their findings, published in June in *PLOS Computational Biology*, could provide insights in the field of evolutionary biology and lead to an understanding of the neural control of movement and development of bio-inspired underwater vehicles.

"If we could play God and create an undulatory swimmer, how stiff should its body be? At what wave frequency should its body undulate so it moves at its top speed? How does its brain control those movements?" said Neelesh Patankar, professor of mechanical engineering. "Millennia ago, undulatory swimmers like eels that had the right mechanical properties are the ones that would have survived."

The researchers used computational methods to test assumptions about the preferred evolutionary characteristics. For example, species with low muscle activation frequency and high body stiffness are the most successful; the researchers found the optimal values for each property.

"The stiffness that we predict for good swimming characteristics is, in fact, the same as the experimentally determined stiffness of undulatory swimmers with a backbone," said Amneet Bhalla, graduate student in mechanical engineering and one of the paper's authors.

"Thus, our results suggest that precursors of a backbone would have given rise to animals with the appropriate body stiffness," added Patankar. "We hypothesize that this would have been mechanically beneficial to the evolutionary emergence of swimming vertebrates."

In addition, species must be resilient to small changes in physical characteristics from one generation to the next. The researchers confirmed that the ability to swim, while dependent upon mechanical parameters, is not sensitive to minor generational changes; as long as the body stiffness is above a certain value, the ability to swim quickly is insensitive to the value of the stiffness, the researchers found.

Finally, making a connection to the neural control of movement, the researchers analyzed the curvature of its undulations to determine if it was the result of a single bending torque, or if precise bending torques were necessary at every point along its body. They learned that a simple movement pattern gives rise to the complicated-looking deformation.

"This suggests that the animal does not need precise control of its movements," Patankar said.

To make these determinations, the researchers applied a common physics concept known as "spring mass damper" — a model, applied to everything from car suspension to Slinkies, that determines movement in systems that are losing energy — to the body of the fish.

This novel approach for the first time unified the concepts of active and passive swimming — swimming in which forcing comes from within the fish (active) or from the surrounding water (passive) — by calculating the conditions necessary for the fish to swim both actively and passively.

The paper, "A Forced Damped Oscillation Framework for Undulatory Swimming Provides New Insights into How Propulsion Arises in Active and Passive Swimming," was authored by Patankar, Bhalla, and Boyce E. Griffith, assistant professor of medicine and mathematics at New York University.

The work was supported by the National Science Foundation (NSF).

> "If we could play God and create an undulatory swimmer, how stiff should its body be? At what wave frequency should its body undulate so it moves at its top speed? How does its brain control those movements?"
>
> *Neelesh Patankar*

Student Entrepreneurs *continued*

Following open-heart surgery, scar tissue can cause the patient's heart to fuse to his chest cavity, causing complications. (Similar situations can occur in abdominal and gynecological surgeries.) Robinson explored how the biocompatible film could provide a barrier between the heart and chest wall. Working with two co-researchers in McCormick's Department of Biomedical Engineering, he tested the procedure on rabbits. (A paper describing the findings is expected to be published soon.)

The results have been promising. The team recently won a $5,000 Phase I E-Team Grant from the National Collegiate Inventors and Innovators Alliance and placed second in Northwestern's 2013 Applied Research Day. In April, they founded a startup, PXAD Therapeutic Film LLC. They are now pitching their technology to companies.

Welcoming a New Chair

This fall, the Department of Mechanical Engineering will see a change in leadership. After six years, Catherine Brinson, Jerome B. Cohen Professor of Mechanical Engineering, turns the position over to Kevin Lynch, professor of mechanical engineering.

Lynch joined Northwestern in 1997 and served as co-director of the Northwestern Institute on Complex Systems from 2010 to 2013. He is the creator of Introduction to Mechatronics (ME333), a course on microprocessor-controlled electromechanical systems that attracts students from several departments in McCormick. He is a former winner of the McCormick Teacher of the Year Award and the Charles Deering McCormick Professorship of Teaching Excellence. He is a member of the Neuroscience and Robotics Lab (NxR), and he frequently collaborates with the Rehabilitation Institute of Chicago on neural engineering and human-robot systems. His research in robotics is funded by the National Science Foundation, Office of Naval Research, National Institutes of Health, and others.

We asked Lynch to share more about himself and his vision for the department.

What were your initial thoughts when you were approached to be the next chair of the ME department?

Our department is fortunate to have a collegial group of outstanding researchers and educators, as well as a dedicated staff. I was excited by the opportunity to work with the faculty and staff to realize departmental priorities. Our previous chair, Cate Brinson, was a thoughtful and energetic leader, so I have big shoes to fill.

What do you see as the department's top priorities?

A major role of the chair is to provide resources to support the initiatives of the individual faculty and research groups, allowing them to focus on what they do best: research and teaching. Another role is to ensure that our students, faculty, and the department receive appropriate recognition for successes in research, teaching, outreach, and entrepreneurship. In short, we want to be great and be recognized as great. This feeds back into a strong undergraduate and graduate applicant pool, and the students are the lifeblood of the department.

Specific upcoming initiatives include a re-imagining of our curriculum to provide students with innovative course delivery, design throughout the curriculum, more open-ended learning experiences, and the chance to fail and iterate. This includes a flipped classroom model for some of our courses, where students view video lectures on their own time, allowing classroom time to be more interactive. This maximizes the added value of time spent with the professor. Some of these educational efforts require the support of dedicated teaching faculty to work with the course directors.

We will continue to expand our master's programs. This has a number of benefits, including providing closer ties with local, national, and international industry and increasing the course offerings for our undergraduate and PhD students. We are also initiating a new interdepartmental MS in Robotics (MSR) program, with first students to arrive in fall 2014.

Interdepartmental research is a hallmark of McCormick and our department, and another priority is to establish externally funded interdepartmental research centers in areas of excellence such as materials, manufacturing, energy, and robotics.

Tell us about your own research.

My research spans several areas of robotics, including robot manipulation, assist and rehabilitation robotics, and multi-agent "swarm" robot systems.

My work on robot manipulation focuses on endowing robots with advanced manipulation capabilities. Currently, most robots manipulate objects by grasping and carrying them. But if you were going to move a refrigerator, you wouldn't try to pick it up; you would slide it or pivot it about its feet. Our research focuses on automatic planning of robot manipulation employing a variety of methods, including grasping and carrying, pushing, rolling, throwing, tapping, pivoting, etc. Humans and animals use these all the time, but robots are currently much more limited. Research challenges include physics-based motion planning and high-speed control based on vision, tactile, and other feedback.

One of our current projects on assistive robotics is in collaboration with the Rehabilitation Institute of Chicago, and it focuses on restoring functional use of the arm to a person who has suffered a high spinal cord injury. The approach is based on surgically implanting stimulator electrodes that can stimulate the muscles of the chest, back, and arm, replacing the broken electrical connection with the motor cortex. This project focuses on finding the stimulation patterns needed to drive the arm along desired paths, and combining this controller with a brain-machine interface to allow the person to control the arm in a natural way.

In swarm robotics, we are inspired by the collective behaviors of animals such as birds, fish, and ants. We are developing theories to support the design of simple robots that can cooperate and communicate over wireless networks to perform complex tasks such as cleaning an oil spill or searching for survivors in a disaster area.

> "A major role of the chair is to provide resources to support the initiatives of the individual faculty and research groups, allowing them to focus on what they do best: research and teaching." *Kevin Lynch*

What are your interests outside of work?

When I was an undergrad at Princeton, I played defensive line for the football team and wrestled heavyweight. Here at Northwestern, my wife and I have season tickets for football and are regulars at wrestling matches. We have top-ranked teams in both sports. Extremely talented student-athletes from football, wrestling, and a variety of other sports have taken my classes and worked in my research lab.

I try to keep fit, primarily by cycling and weightlifting, but I'm willing to try almost anything. I have torn ligaments and tendons in my shoulders, elbows, and knees over the years, though, so I am learning to be more careful. When I have some quiet time I enjoy crossword puzzles, particularly creative and challenging variants of the usual crossword.

Department News

FACULTY

The U.S. Association for Computational Mechanics has established a medal in ***Ted Belytschko***'s honor. The Belytschko Medal will be awarded annually to a researcher with outstanding accomplishments in computational solid and structural mechanics. It is the second medal award named in his honor.

Cate Brinson was recently appointed to a National Academies committee on fuel economy.

Wei Chen published a book, *Decision-based Design: Integrating Consumer Preferences into Engineering Design* (Springer, 2012). The other two co-authors are Chris Hoyle and Henk Jan Wassenaar, her former PhD students.

Isaac Daniel received an honorary PhD from Democritus University in Greece.

Horacio Espinosa received the inaugural Sia Nemat-Nasser Medal from the Society for Experimental Mechanics.

Liz Gerber and her students at Design for America won the Ashoka U-Cordes Innovation Award for their globally relevant teaching, learning, and partnership practices in social entrepreneurship. Gerber was also selected to participate in the National Academy of Engineering 2013 Frontiers of Engineering Symposium and NSF's agenda-setting meeting on social computing.

Walter Herbst's company Herbst Produkt received a silver medal from the Edison Awards for work with Olive, a Silicon Valley home entertainment company.

Yonggang Huang has been selected to receive the ASME Drucker Medal in 2013.

Elmer Lewis is a winner of the 2013 Distinguished Alumnus Award from the Department of Nuclear, Plasma and Radiological Engineering at the University of Illinois, Champaign-Urbana.

Wing Kam Liu has been elected vice chair/2014 chair of the U.S. National Committee on Theoretical and Applied Mechanics.

Todd Murphey has been selected to participate in the Defense Science Study Group. This program selects 15 scientists every two years to focus on defense policy, defense-related research and development, and the missions of the armed forces.

Neelesh Patankar was elected a fellow of the American Physical Society.

Q. Jane Wang, along with materials science professor Yip-Wah Chung, co-edited the new, six-volume *Springer Encyclopedia of Tribology*, which was published recently.

STUDENTS/ALUMNI

PhD student ***Huanyu "Larry" Cheng*** was selected as a 2013 International Student Research Fellow of the Howard Hughes Medical Institute (HHMI), a prestigious award designed to facilitate the research training of outstanding international pre-doctoral candidates in the biomedical and related sciences.

Mark Fischer (BS'13) received the Ovid W. Eshbach Award as the McCormick graduating senior demonstrating the highest overall excellence in scholarship and leadership.

PhD students ***Julie Hui***, ***Mike Roenbeck***, and ***Rafael Soler*** received NSF Graduate Fellowships.

Alumnus ***Mert Iseri*** (BS '11) and Yuri Malina are participating in the "WSJ Startup of the Year," in an online competition sponsored by the *Wall Street Journal*. Their startup SwipeSense is currently in the top five.

PhD student ***Jacob Smith*** received a 2013 National Defense Science and Engineering Graduate (NDSEG) Fellowship.

PhD students ***Lechun Xie*** and Qinghua Zhou were awarded a best poster award at the 2013 Annual Meeting of Society of Tribologists and Lubrication Engineers (STLE).

ME Sweeps Annual McCormick Teaching and Advising Awards

Two mechanical engineering professors have won McCormick's top teaching and advising awards for 2012-13. The 2013 Cole-Higgins Award for Excellence in Teaching was awarded to ***Neelesh Patankar***, and the Cole-Higgins Award for Excellence in Advising went to ***Todd Murphey***.

Todd Murphey

Neelesh Patankar

Patankar, whose research focuses on algorithms that simulate the complex movements of bodies immersed in fluids, was cited "for classroom experiences that are extremely engaging and very effective for making connections between applications and theory."

Murphey, who works on robotics and modeling and control of complex mechanical and biological systems, was cited "for personal interest in his advisees, covering matters ranging from course selections to career plans... and everything in between."

Each year, students nominate professors for the honor, and a committee chooses the winners. This year's awards were announced at a faculty meeting on September 24.

McCormick's First MOOC, New Video Lecture Technology

For the first time, McCormick is offering a massive open online course, or MOOC: ***Todd Murphey***'s "Everything is the Same: Modeling Engineered Systems." (MOOCs are free, online courses that attract large numbers of participants seeking to explore a new field or feed a curiosity.)

Designed for students with a background in introductory calculus, the eight-week MOOC will give students a foundation in physical modeling with topics like Newton's laws, Kirchoff's laws, and Fick's laws. (Learn more about the course at https://www.coursera.org/course/modelsystems.)

Filming for the MOOC was partially conducted in a new studio designed specifically for video instruction by ***Michael Peshkin***. Professors stand behind a special glass panel on which they can draw diagrams, and a mirrored video camera reverses the image so it appears correctly to viewers.

A lightboard developed by Michael Peshkin enables faculty to make better video lectures.

(Learn more about the "lightboard" at https://sites.google.com/site/northwesternlightboard.)

Peshkin created the studio to record his own lectures for an undergraduate course.

"The way lecturers typically make videos is by standing in front of a backdrop with slides superimposed over their shoulder," Peshkin said. "That's great if you're lecturing about a piece of art, but it doesn't work for mechanical engineering."

Mechanical Engineering Expands into Willens Engineering Life Sciences Wing

Mechanical engineering faculty and students are enjoying gleaming new facilities since the unveiling of the Willens Engineering Life Sciences Wing, a six-story, 50,000-square-foot addition for students and faculty in the life and biomedical sciences.

Made possible by a significant gift from Ronald and JoAnne Willens, the Willens Wing offers cutting-edge facilities — including offices, labs, and common space — in a modern design that integrates seamlessly with the original, 1942-construction Tech Institute.

Located on the top three floors of an addition to the northern side of Tech (between the existing B and C wings), the LEED Silver-certified Willens Wing features an airy two-story atrium, two computer-equipped conference rooms, and common areas with seating for group work and informal meetings. It is decorated with Terrazzo stairs, glass floors, and cherry millwork throughout.

The wing includes 17,000 square feet of laboratories and 8,000 square feet of offices for professors, including six mechanical engineering faculty members: J. Edward Colgate, Mitra Hartmann, Kevin Lynch, Malcolm MacIver, Todd Murphey, and Michael Peshkin.

The new space also houses biomedical engineering faculty and the Integrated Molecular Structure Education and Research Center (IMSERC). A second, 49,000-square-foot addition on the south side of Tech (between the existing F and G wings) accommodates expanding program needs of McCormick and the Weinberg College of Arts and Sciences.

Ron Willens is co-founder of the technology company Livingston Enterprises, which Lucent Technologies bought in 1997. The company made remote access equipment and software that allowed hundreds of users to dial into large corporate networks or Internet service providers. JoAnne Willens is a retired technical illustrator. Two of their sons and one granddaughter have graduated from Northwestern; another granddaughter is a current student.

From the Chair *continued*

here with fast-moving startup companies: one formed by two of our undergraduates and the other by one of our PhD students.

In addition to the highlights in the articles here, the department is moving rapidly forward in the key area of education. ME has a strong belief in the power of our educational mission and has been at the center of several high-profiles online programs just starting at Northwestern. Watch for several courses by our ME faculty on Coursera this year — that you can take for free! See page 4 for more information. In addition, a highly innovative, lab-based mechatronics experience is being developed for a small-classroom online experience. With our foray into these ventures we bring part of our excellent educational experience to the world beyond NU, and we also enable new opportunities in our on-campus classrooms by connecting students with some of the traditional “lecture” material online, leaving the classroom time available for more high-impact, hands-on, interactive work.

We have also launched the Achenbach Lecture Series here at NU, with generous support from alumni, and brought the first honoree to campus in the spring: professor Ben Freund, National Academy of Science and National Academy of Engineering member and professor at the University of Illinois, Urbana-Champaign. He spoke on deformations of elastic biomembranes and met with students, junior faculty, and many colleagues. The next Achenbach Lecture will take place in spring 2014.

Finally, I leave this newsletter with my last article as chair of the department. After a wonderful six years, I am stepping down and I look forward to watching the department continue to flourish under the exciting leadership of Kevin Lynch, highlighted on page 3 of this newsletter. Please continue to stay in touch with us and stop by and visit to see our new labs and activities.

L. Cate Brinson
Jerome B. Cohen Professor of Mechanical Engineering

McCormick Freshmen Design Prosthetic Fitting Solutions for Upper-limb Amputees

For patients who have lost an arm, being fitted with a new prosthesis can be an expensive, time-consuming, and labor-intensive process.

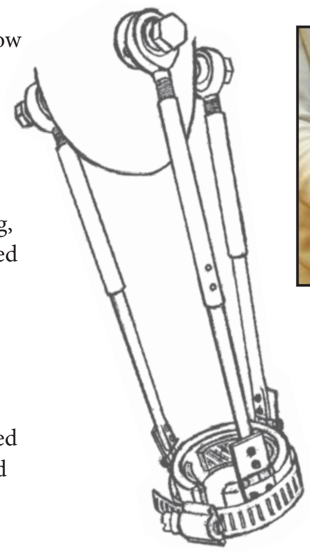
Before receiving a permanent prosthetic arm, patients are fitted with a temporary device to ensure correct size and fit. Each fitting can take three technicians as much as four hours to craft, and there's no room for adjustment; if they make an error, they must start from scratch.

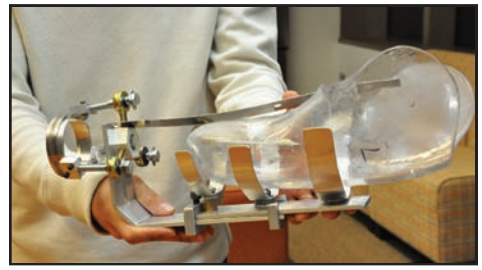
Undergraduates in McCormick's Design Thinking and Communication (DTC) course were recently given a challenge: to develop a new temporary fitting solution to connect the patient's residual limb to a prosthetic terminal device that can emulate the functions of the human hand. The new device had to require less time to customize than current methods, use less expensive materials, allow for adjustments, and allow for reuse from patient to patient.

The students spent long hours conducting background research, interviewing experts, sketching their ideas, calculating, and prototyping. They also honed their communications skills in preparation for presentations to clients and judges.

In the end, they created three prototypes: CAREFit, a design that featured two threaded telescoping aluminum tubes and two nested hemisphere-shaped wrist attachments; Triumph, a fitting that could be installed in 40 minutes, adjusted in 5 minutes, and could support 30 pounds of weight; and Pro-ARM, which featured sliding aluminum plates to allow for maximum length adjustability and a unique combination of ball joints, threaded aluminum blocks, and spring steel connectors to provide the required adjustability at the wrist.

The assignment required students to work within a number of constraints to create an adjustable, customizable, and cost-effective model that could fit with other manufacturers' permanent fittings. "This is an incredibly complex problem; just understanding the hard constraints was a challenge," said instructor David Gatchell.





Left: Triumph, created by mechanical engineering major Alex Lee with teammates Jacob Bruce, Elaine Lokken, and Ellen Zhuang; above: Pro-ARM, created by mechanical engineering majors Timothy Stead and Tessa Swanson with teammates Jonathan Kim, Hyo Joo Lee, and Jordan Pounder.

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Designer: Amy Charlson Design

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