Immersive Research Experiences in Nanotechnology—using the Research Laboratory as a Classroom

2020 SDNI-NNCI Educational Symposium | *13 September, 2020*

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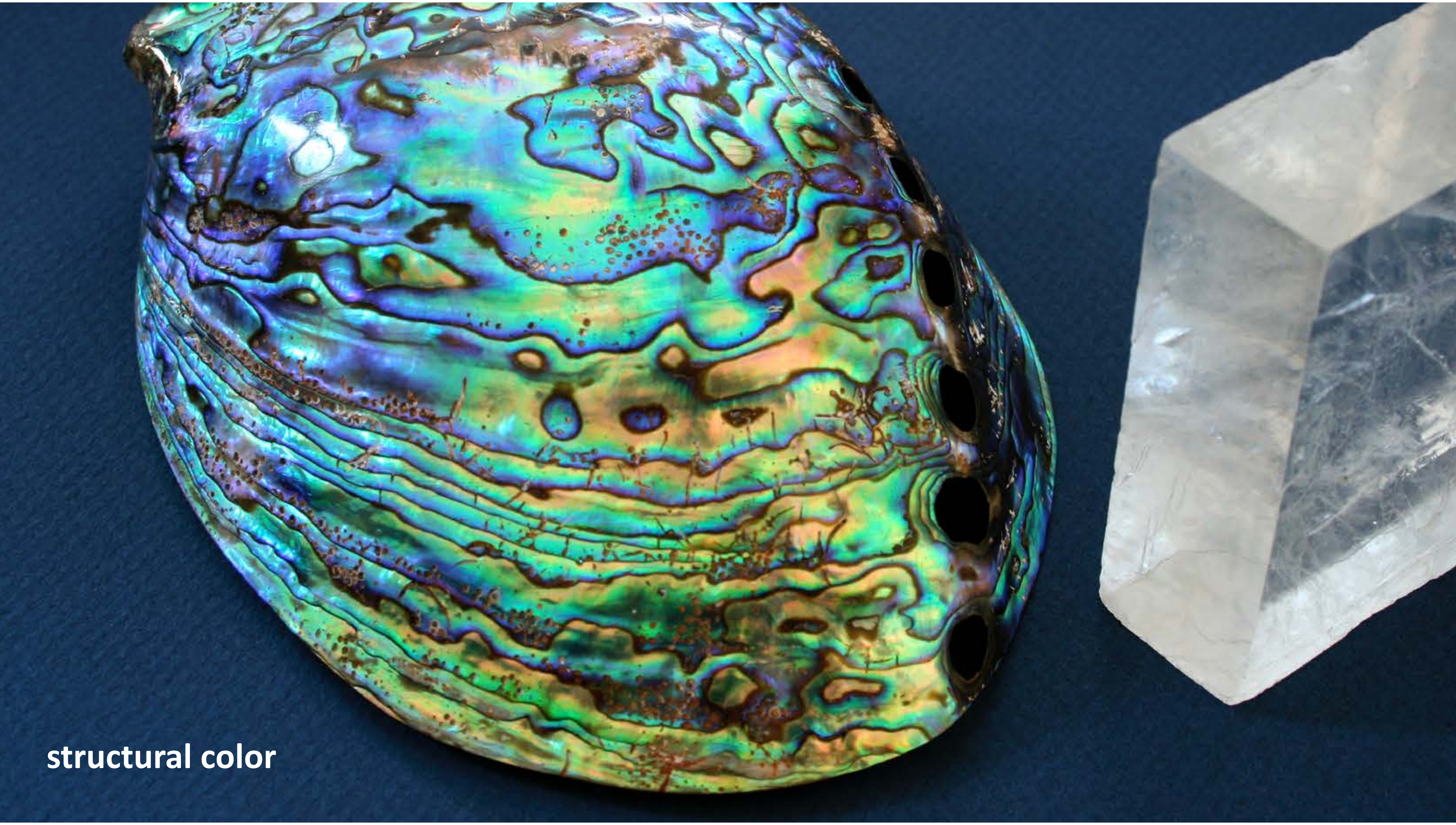
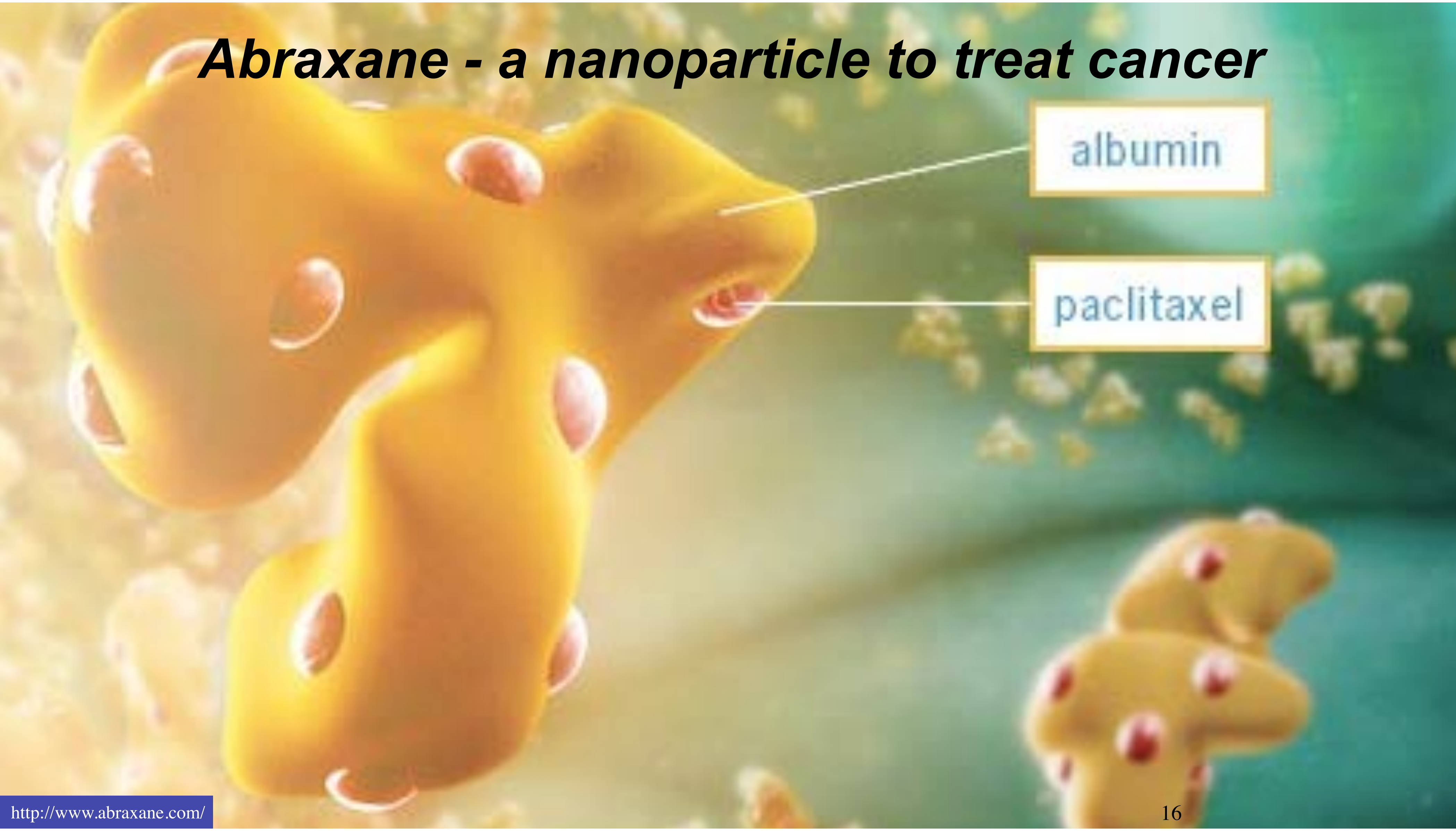
National Science Foundation
MRSEC
Materials Research Science and Engineering Centers

UC San Diego MRSEC


structural color

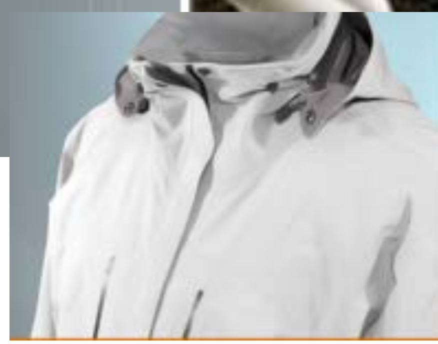
Abraxane - a nanoparticle to treat cancer



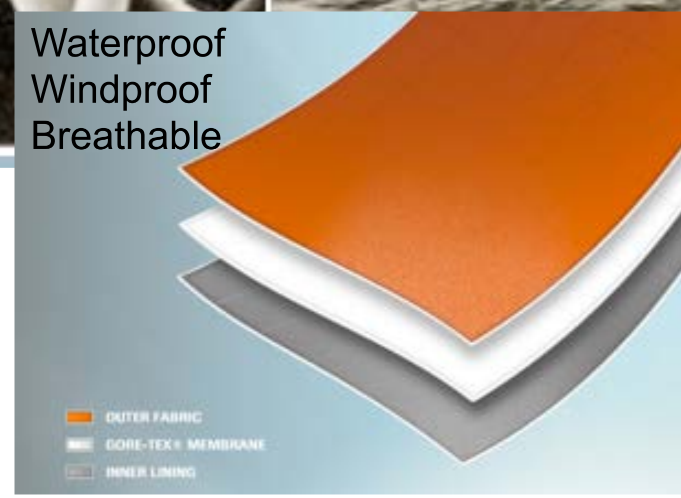
http://www.abraxane.com/

Gore-tex: one of the original nanomaterials

Invented 1985



www.gore-tex.com

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Summer School for Silicon Nanotechnology

http://sailorgroup.ucsd.edu/courses/SummerSchool/

The Summer School for Silicon Nanotechnology is an intensive, 6-week hands-on workshop involving UCSD undergraduates, high school students, graduate students, and international scholars.

Why did I start a summer school for silicon nanotechnology?

Jerry Driscoll and Ronald Ragsdale

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- That is how I started in science

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- Taking high school and undergraduate students on at random times throughout the year was a mess in terms of safety and use of my time

THE UNIVERSITY OF UTAH

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- My graduate students were embarrassing me in front of their exam committees
- Protocol drift
- I had a lot of projects with loose ends that needed tying up

Jerry Driscoll and Ronald Ragsdale

http://sailorgroup.ucsd.edu/courses/SummerSchool/index.html

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UC San Diego **Summer School for Silicon Nanotechnology:** Course materials Participants Apply Contact

Summer School for Silicon Nanotechnology

a Research Immersion in Materials Science & Engineering (RIMES) program
of the UC San Diego MRSEC, a National Science Foundation Materials Research Science and Engineering Center

Program Dates: Access to the labs is restricted due to the ongoing COVID-19 crisis. University guidelines currently restrict research and teaching activities. The current plan for phased research scale-up on the UC San Diego campus is to begin limited activities when the campus moves from Orange to the Yellow phase.

Application Deadlines: Closed for 2020. The 2021 deadlines are May 1, 2021 (for domestic applicants and for students enrolled in an affiliated UC San Diego graduate degree program). Feb 15, 2021 (for foreign applicants who will need a visa).

About the SSSiN: Begun in 2003, the Summer School for Silicon Nanotechnology (SSSiN) is an immersive six week workshop on the synthesis, properties, and applications of silicon-based nanomaterials. Affiliated with the Silicon Nanomaterials Research Laboratory run by Prof. Michael Sailor, it integrates participants from a wide variety of backgrounds and skill levels: high school students, undergraduates, graduate students, post-docs, industry researchers, and university professors. As part of the RIMSE training program of the UC San Diego MRSEC, it also serves as a "bootcamp" for selected students at the beginning of their MS or PhD degrees. Course elements include lectures, hands-on laboratory training, and a capstone "Discovery Project"- an independent research project implemented by a team of trainees under the mentorship of a current research group member.

Instructor: Prof. Michael J. Sailor

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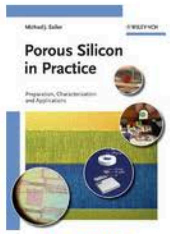
UC San Di

PROGRAM DESCRIPTION



Textbook

Lectures are held every Monday, Wednesday, and Friday from 9-11 AM. Topics include: • Introduction to porous silicon—background and overview • Semiconductor fundamentals • Etching and electrochemistry of silicon • Photoluminescent Si "Quantum Dots" • Passive optical nanostructures —photonic crystals, optical diffraction, Fabry-Perot layers and multilayers • Characterization including porosity measurements, optics, FTIR, SEM, BET, Contact Angle • Freestanding porous silicon microparticles, nanoparticles, nanowires • Chemistry of silic medical applications of silicon nanostructures, including target Metal and polymeric composites with porous silicon • Energy re and thermoelectrics • Optical biosensing, chemical sensing.

- Lectures 3 days/week
- Hands-on training assignments
- Discovery project
- Oral presentations

Hands-on laboratory training sessions are held each weekday, after the lectures. trained in preparation and characterization methods and relevant to silicon r electrochemical anodization to prepare porous silicon • stain etching • preparation of • surface chemical modification under anaerobic conditions • thermal processing • o spectroscopy (RIFTS, SLIM) • photoluminescence spectroscopy • Raman spectroscopy • infrared spectrodcopy • porosimetry (surface area, pore size, porosity measurement) • scanning electron microscopy • contact angle measurement.


Luo Gu


High School mentor Gha Lee (center) with fellow high school students Hithaishi Paraselli and Tessa Martin (right)

The "**Discovery Project**," is an independent research project implemented by a team of 2-4 students under the mentorship of a current research group member. The research topics of the Discovery Projects harmonize with ongoing research projects in the Sailor Research Group. Many SSSiN students arrange to stay longer (up to 12 months) to complete a more extensive project, with the goal of initiating a longer-term collaboration, completing a thesis chapter, or producing a scientific publication. Many high school participants have translated their projects into California Science Fair, Lego Robotics Challenge, or Intel/Regeneron Science Talent Search competitions.

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Logistics

This is a full immersion program. The course runs weekdays from 9 am to 4 pm although there may be a few later days depending on individual projects. It is held in Pacific Hall on the UCSD campus (directions and visitor information are here). Tutorials are held every Monday, Wed 9am - 11am, which involve lecture, in-lab demonstrations, and student presentations. The remainc the laboratory working on the course experimental modules and the Discovery Projects.

Each participant must supply:

- Daily lunch (or lunch money if you want to eat at one of the UCSD eateries).
- Lab notebook (bound, numbered, lined sheets).
- Laptop computer (Mac or PC). Must contain current virus protection software.
- UCSD ID and email account
  If you don't have a UCSD ID or email account, please arrange to come in before the beginning of account.

Financial Support

There is no charge for participation in this program. However all participants must have their own support for travel, living expenses, health insurance, and any applicable visa fees (the university charges a $425 visa processing fee). There is no financial assistance available for participation in this program.

(center) with fellow high school students Hithaishi Paraselli and Tessa Martin (right)

- Lectures 3 days/week
- Hands-on training assignments
- Discovery project
- Oral presentations

- Engagement activities
- No charge

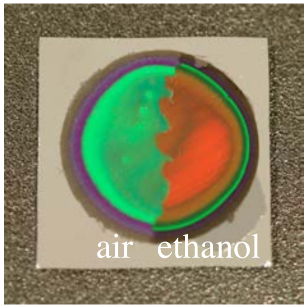
What are the main benefits for the Faculty member?

in holding a summer school in their lab

Broader Impacts: High School Student Anna Kornfeld Simpson wins the Davidson Prize for her Chemical Sniffing Robot

Michael J. Sailor (UC San Diego), DMR-Award # DMR-0806859

silicon photonic crystal



Anna's robot uses a porous silicon nanostructure to sniff out and locate an alcohol spill

Using a LEGO MINDSTORMS™ robotic kit and a chemical nanosensor she helped develop in the laboratory of NSF-funded researcher Michael J. Sailor at the University of California, San Diego, Patrick Henry High School student Anna Kornfeld Simpson designed, built, programmed, and tested a robot that was able to crawl around the floor of a building sniffing for chemical spills. For her achievement, Anna won 1st Prize in the 2009 California State Science Fair and the 2010 Davidson Prize, a $25,000 national award recognizing exceptionally gifted students. Anna worked on her project with NSF-funded graduate student Anne Ruminski.

Anna testing her robot

Anna with graduate student mentor Anne Ruminski and Prof. Sailor

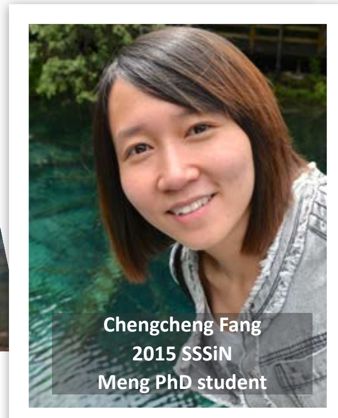
Broader Impacts: High School Student Carrie Cao wins the 2010 Intel Science Talent Search for her studies of silicon nanostructure/polymer composites

Michael J. Sailor (UC San Diego), DMR-Award # DMR-0806859

Carrie Cao, (on President Obama's left arm) wins 8th place in the 2010 Intel Science Talent Search. Carrie was a Torrey Pines high school student who began in the Sailor group in the Fall of 2008. Her award-winning project involved polymer infiltration of porous silicon matrices and was funded through Prof. Sailor's NSF DMR grant.

Sailor's Summer School for Silicon Nanotechnology involves ten local area high school students each summer. These students were hosted in Prof. Sailor's lab with support from the NSF MWN program in a 6-week program. Here four of the high school students confer on an experiment.

SUMMER SCHOOLS: TRAINING INCOMING PHD STUDENTS



LETTER

https://doi.org/10.1038/s41586-019-1481-z

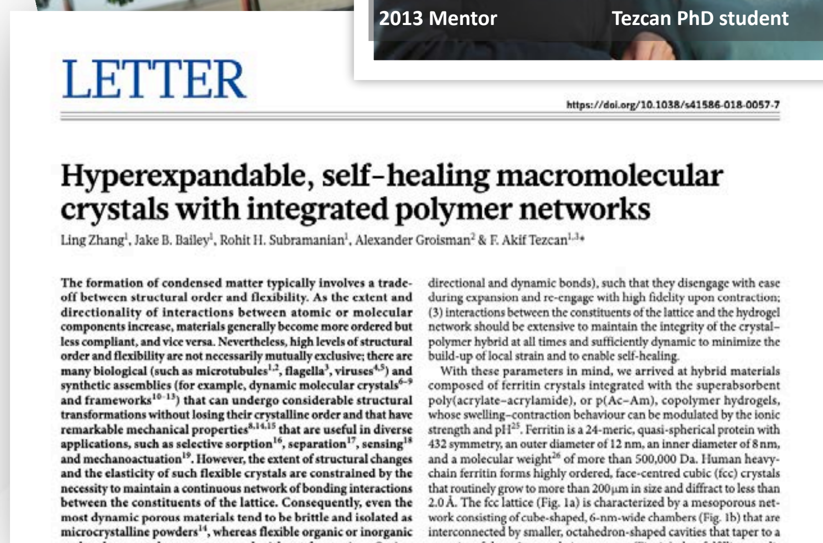
Quantifying inactive lithium in lithium metal batteries

Chengcheng Fang[1,6], Jinxing Li[2,6], Minghao Zhang[2], Yihui Zhang[1], Fan Yang[3], Jungwoo Z. Lee[2], Min-Han Lee[1], Judith Alvarado[1,4], Marshall A. Schroeder[4], Yangyuchen Yang[1], Bingyu Lu[2], Nicholas Williams[3], Miguel Ceja[2], Li Yang[5], Mei Cai[5], Jing Gu[3], Kang Xu[4], Xuefeng Wang[2] & Ying Shirley Meng[1,2]*

Lithium metal anodes offer high theoretical capacities (3,860 milliampere-hours per gram)[1], but rechargeable batteries built with such anodes suffer from dendrite growth and low Coulombic efficiency (the ratio of charge output to charge input), preventing their commercial adoption[2,3]. The formation of inactive ('dead') lithium— which consists of both (electro)chemically formed Li^+ compounds in the solid electrolyte interphase and electrically isolated unreacted metallic Li^0 (refs [4,5])—causes capacity loss and safety hazards. Quantitatively distinguishing between Li^+ in components of the solid electrolyte interphase and unreacted metallic Li^0 has not been possible, owing to the lack of effective diagnostic tools. Optical microscopy[6], in situ environmental transmission electron microscopy[7,8], X-ray microtomography[9] and magnetic resonance imaging[10] provide a morphological perspective with little chemical information. Nuclear magnetic resonance[11], X-ray photoelectron spectroscopy[12] and cryogenic transmission electron microscopy[13,14] can distinguish between Li^+ in the solid

In our work, the pivotal difference exploited between the SEI Li^+ compounds and metallic Li^0 is their chemical reactivity: only the metallic Li^0 reacts with protic solvents (such as H_2O) and generates hydrogen gas (H_2). The solubility and reactivity of known SEI species with H_2O are listed in Extended Data Table 1. The possible presence of LiH (refs [20–22]) in inactive Li might affect the quantification of metallic Li^0 because LiH also reacts with water and produces H_2, so it was important to exclude this possibility in our results (see Methods for details). We combine H_2O titration (the step in which all metallic Li^0 is reacted) and gas chromatography (the subsequent step to quantify the H_2 generated in the reaction) into a single analytical tool, hereafter referred to as titration gas chromatography (TGC; schematic process in Extended Data Fig. 1), which is able to quantify the content of metallic Li^0 based on the reaction

$$2Li + 2H_2O \rightarrow 2LiOH + H_2\uparrow$$



LETTER

https://doi.org/10.1038/s41586-018-0057-7

Hyperexpandable, self-healing macromolecular crystals with integrated polymer networks

Ling Zhang[1], Jake B. Bailey[1], Rohit H. Subramanian[1], Alexander Groisman[2] & F. Akif Tezcan[1,3]*

The formation of condensed matter typically involves a trade-off between structural order and flexibility. As the extent and directionality of interactions between atomic or molecular components increase, materials generally become more ordered but less compliant, and vice versa. Nevertheless, high levels of structural order and flexibility are not necessarily mutually exclusive; there are many biological (such as microtubules[1,2], flagella[3], viruses[4,5]) and synthetic assemblies (for example, dynamic molecular crystals[6–9] and frameworks[10–13]) that can undergo considerable structural transformations without losing their crystalline order and that have remarkable mechanical properties[8,14,15] that are useful in diverse applications, such as selective sorption[16], separation[17], sensing[18] and mechanoactuation[19]. However, the extent of structural changes and the elasticity of such flexible crystals are constrained by the necessity to maintain a continuous network of bonding interactions between the constituents of the lattice. Consequently, even the most dynamic porous materials tend to be brittle and isolated as microcrystalline powders[14], whereas flexible organic or inorganic

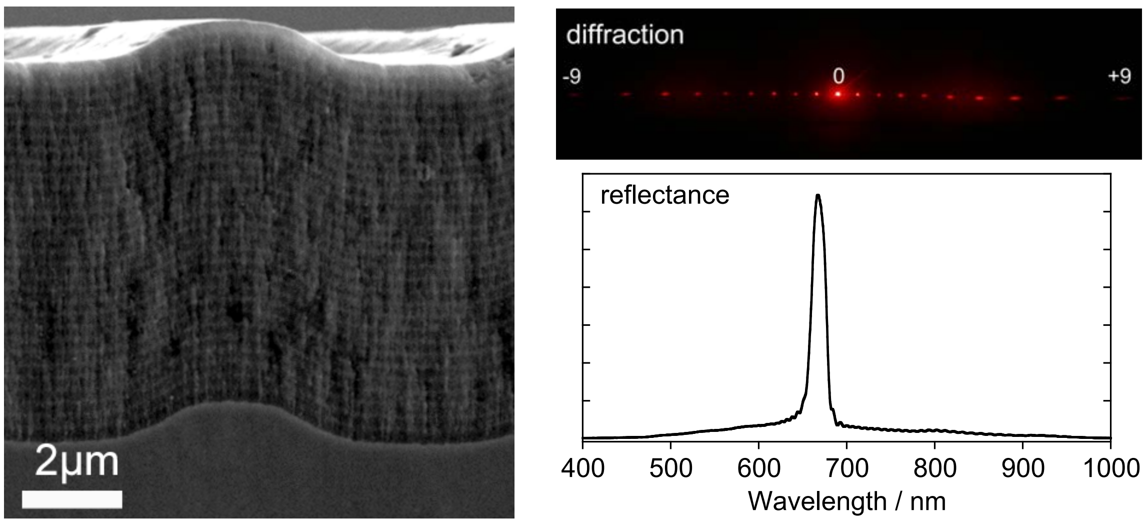
directional and dynamic bonds), such that they disengage with ease during expansion and re-engage with high fidelity upon contraction; (3) interactions between the constituents of the lattice and the hydrogel network should be extensive to maintain the integrity of the crystal–polymer hybrid at all times and sufficiently dynamic to minimize the build-up of local strain and to enable self-healing.

With these parameters in mind, we arrived at hybrid materials composed of ferritin crystals integrated with the superabsorbent poly(acrylate–acrylamide), or p(Ac–Am), copolymer hydrogels, whose swelling–contraction behaviour can be modulated by the ionic strength and pH[25]. Ferritin is a 24-meric, quasi-spherical protein with 432 symmetry, an outer diameter of 12 nm, an inner diameter of 8 nm, and a molecular weight[26] of more than 500,000 Da. Human heavy-chain ferritin forms highly ordered, face-centred cubic (fcc) crystals that routinely grow to more than 200 μm in size and diffract to less than 2.0 Å. The fcc lattice (Fig. 1a) is characterized by a mesoporous network consisting of cube-shaped, 6-nm-wide chambers (Fig. 1b) that are interconnected by smaller, octahedron-shaped cavities that taper to a

SUMMER SCHOOLS: SCOPING DISCOVERY PROJECTS

ADVANCED OPTICAL MATERIALS

Adv. Opt. Mat. **2013,** *1* (7), 510–516. DOI: 10.1002/adom.201300014



Topological control of porous silicon photonic crystals by microcontact printing

By Anne M. Ruminski, Giuseppe Barillaro, Emilie Secret, Winnie D. Huang, Andrea Potocny, Ulysse Carion, Charles Wertans, and Michael J. Sailor*

Electrochemical etching of a surface relief grating generates a conformal photonic multilayer (rugate filter). The structure displays both diffraction and an optical stop band. The three-dimensional porous structure can be removed, preserving the surface relief through at least 6 generations of electrochemical etch.

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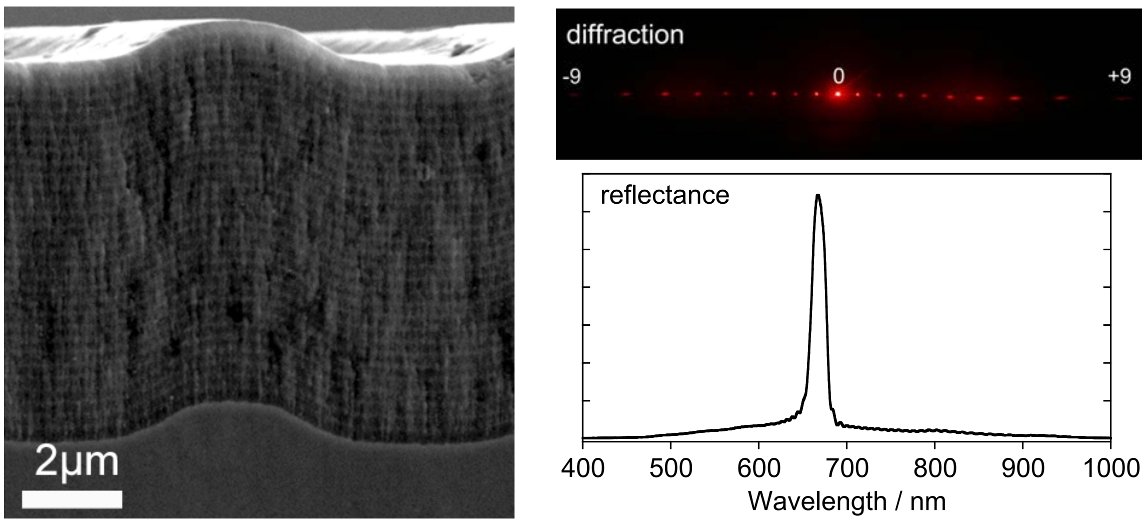

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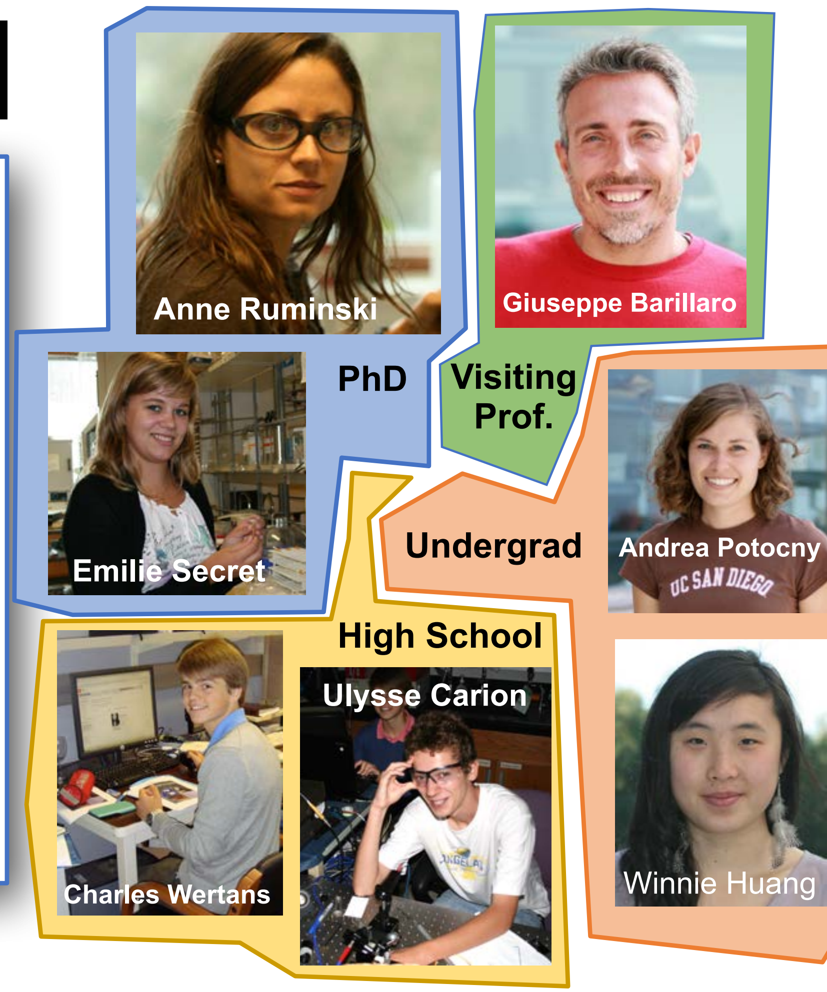

Scoping projects

video “Etching 101” on
www.youtube.com/watch?v=KpCpDq_K8Ts

Gha Young Lee >8000 views

2015 SSSiN Discovery Project:
High school student Gha Young Lee produced an instructional YouTube video "etching 101", on the preparation of porous silicon by electrochemical anodization of crystalline silicon wafers in aqueous HF:ethanol electrolytes.

Torrey Pines High School (class of 2015)
Joined the lab in November, 2012.
Participated in the 2012 and 2013 SSSiN and in 2014 as a project mentor.

2015-2020 Harvard undergrad
2020- Harvard Medical School

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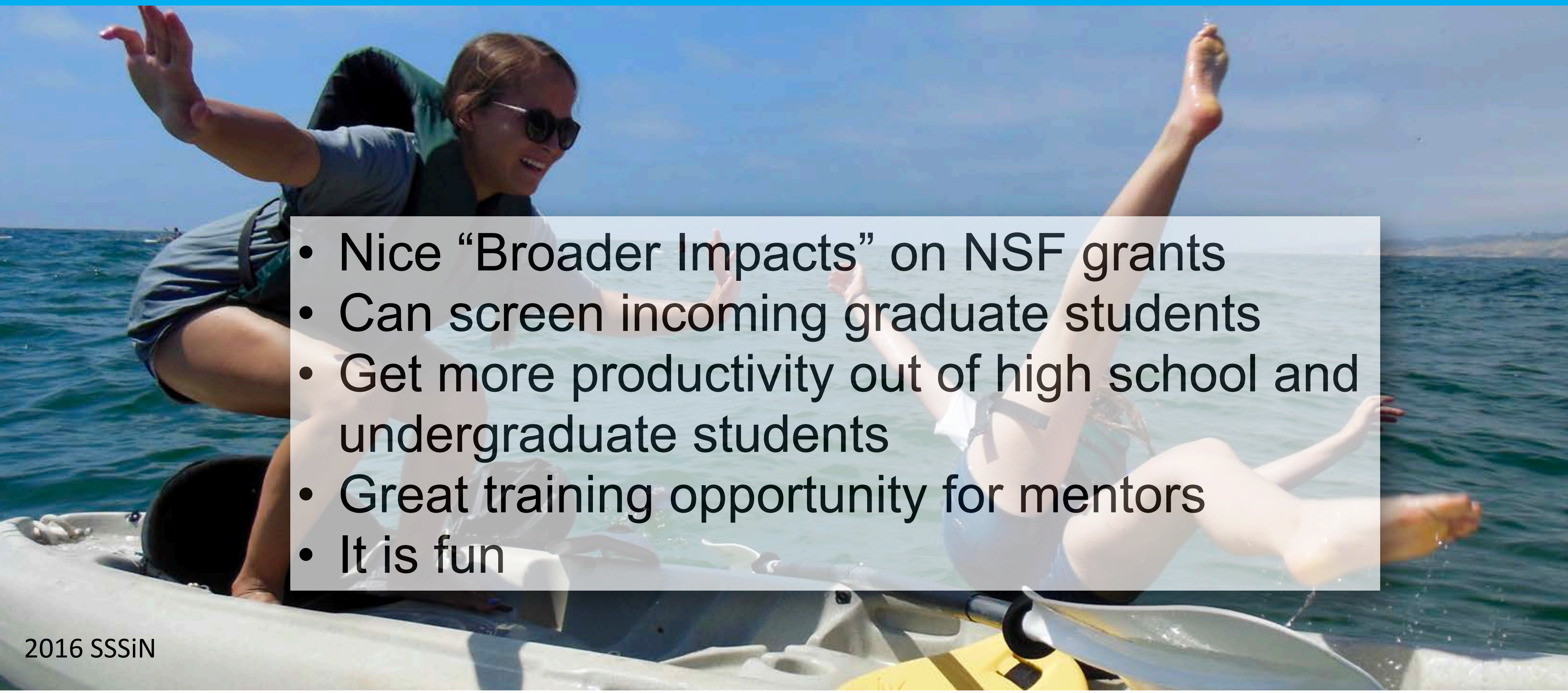

- Nice "Broader Impacts" on NSF grants
- Can screen incoming graduate students
- Get more productivity out of high school and undergraduate students
- Great training opportunity for mentors
- It is fun

UC SAN DIEGO MATERIALS RESEARCH SCIENCE AND ENGINEERING CENTER

- The Right **Team**
- The Right **Place**
- The Right **Time**

SUMMER SCHOOLS: *RESEARCH IMMERSION IN MATERIALS SCIENCE AND ENGINEERING* (RIMSE)

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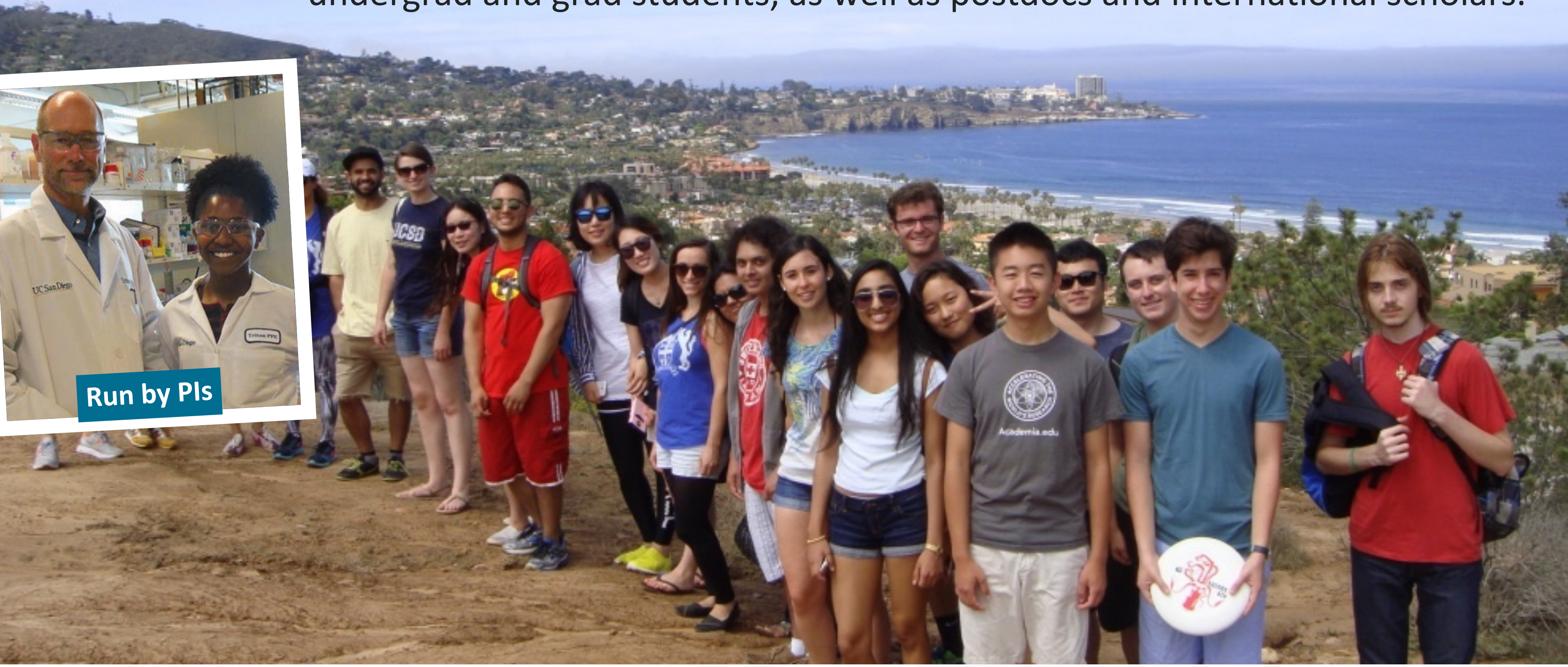

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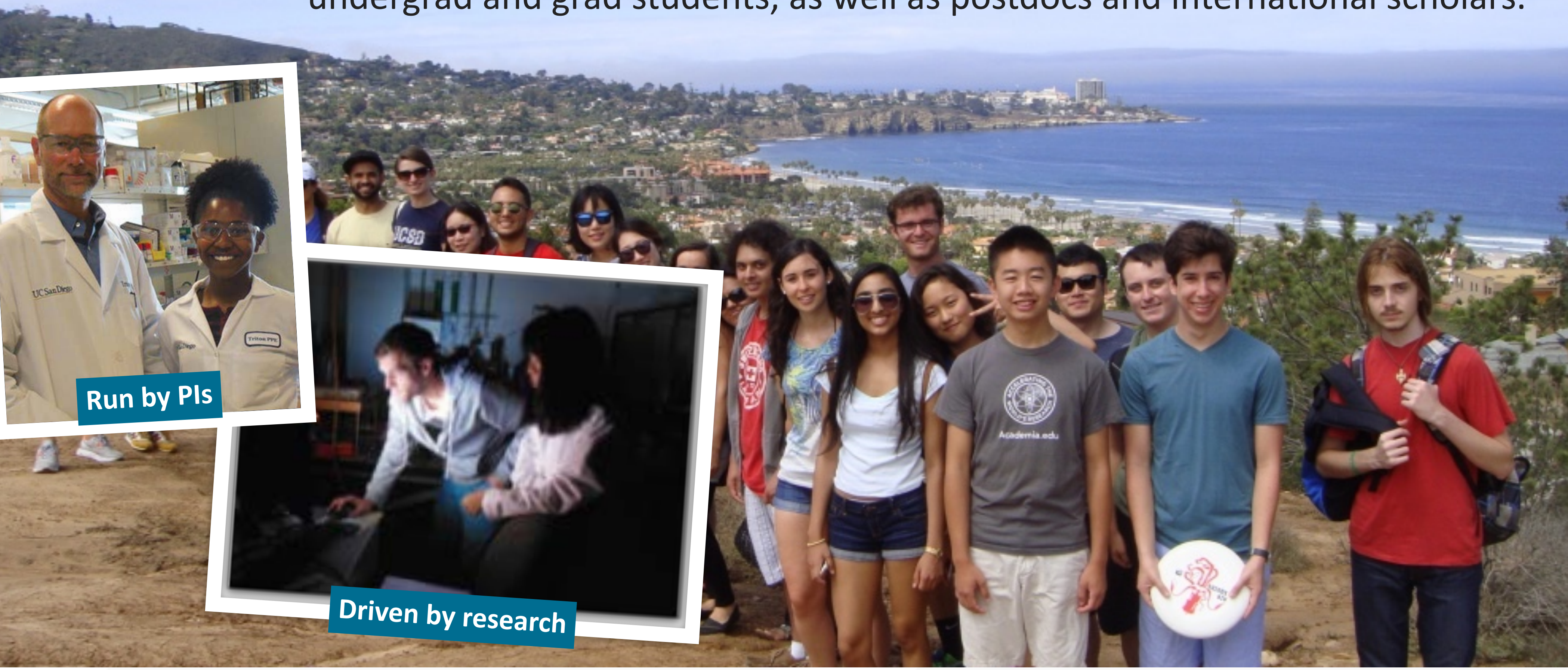

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How can a HS teacher connect students with faculty?

- Invite faculty member to give a class lecture
- Assign students to give the introduction
- Recommend the most curious students

How to connect with faculty (HS teachers)?

Build a relationship:

Dr. Sailor,

Several years ago you had one of our biotechnology students at XXX High School, YYY, as an intern in your lab. I had the opportunity to speak with you, and you indicated that if I had a good candidate for an internship I should let you know. I finally do. One of my students XXX is very bright and easygoing and very interested in nanotechnology. XXX will be attending UCSD in the Fall and would be happy to do an unpaid internship if it were in Bio engineering or nanotechnology.

I can recommend XXX highly, top 1% type of student, and very easy to work with. Please let me know if you would be interested in having him work in your lab, and the best way for him to contact you if you are able to accommodate him.

Be honest:

Hello Prof. Sailor!

I've attached a rec letter for an 11th grade student who is interested in opportunities that you may have in your group this summer. The executive summary is this: XXX is extremely persistent, kind, and eager to please, but may need a bit more guidance than other students I've sent your way. XXX is among my top third academically, but can need more time, reassurance, and guidance than some others to complete their work.

How to connect with faculty (HS Students)?

Be persistent:

Dear Professor Sailor,
How are you? Out of the several opportunities I have set up for the summer I am still most interested in participating in SSSiN.
Therefore if you could let me know any other ways for me to participate or assist in order to gain some experience, I would greatly appreciate it. In addition, since I live so close to UCSD I am readily available.
Thank you very much…

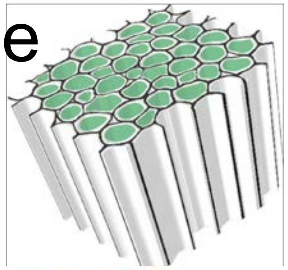
Send reminders:

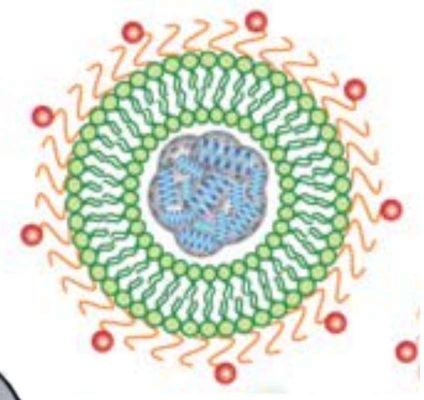
Hello Prof. Sailor!

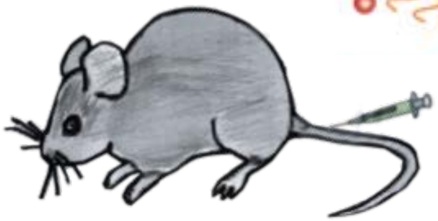
Just putting this back at the top of your inbox…

Lessons Learned: Engaging High School Students in the Research Laboratory

- Mixing hazardous materials with minors is a challenge
- Mixing trainee levels works
- Properly scope the problems
- Discovery projects, publications, tangible metrics
- Important to have cohorts
- Materials Science (and Nanotechnology) provide many visually stimulating project concepts







Questions?

Jose Cruz
2013 SSSiN
2015 BS, UC San Diego
2016 Spinnaker Biosciences

UC San Diego

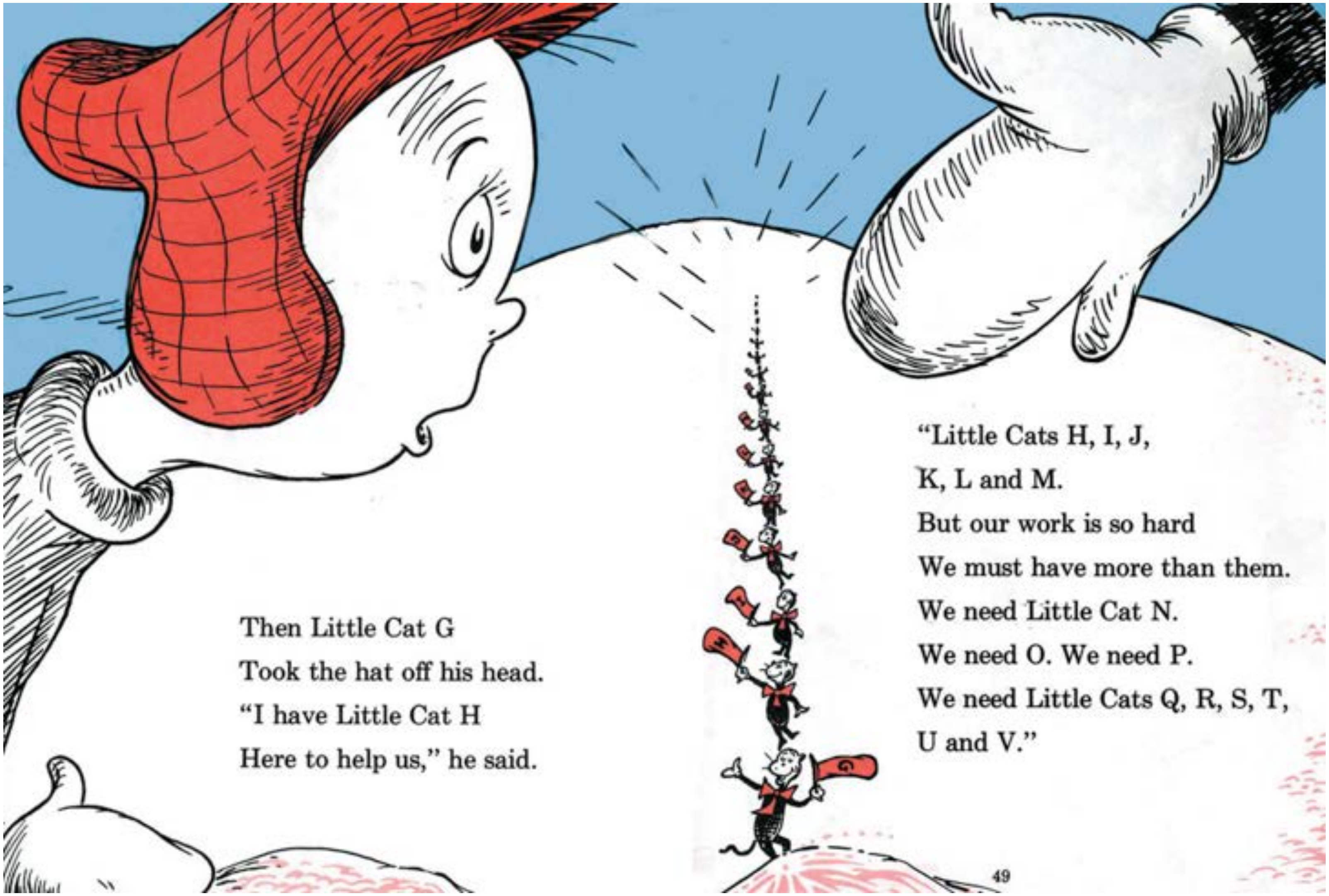
MRSEC

MATERIALS RESEARCH SCIENCE AND ENGINEERING CENTER

National Science Foundation

MRSEC

MATERIALS RESEARCH SCIENCE AND ENGINEERING CENTERS



Doctor Seuss, The Cat in the Hat Comes Back!
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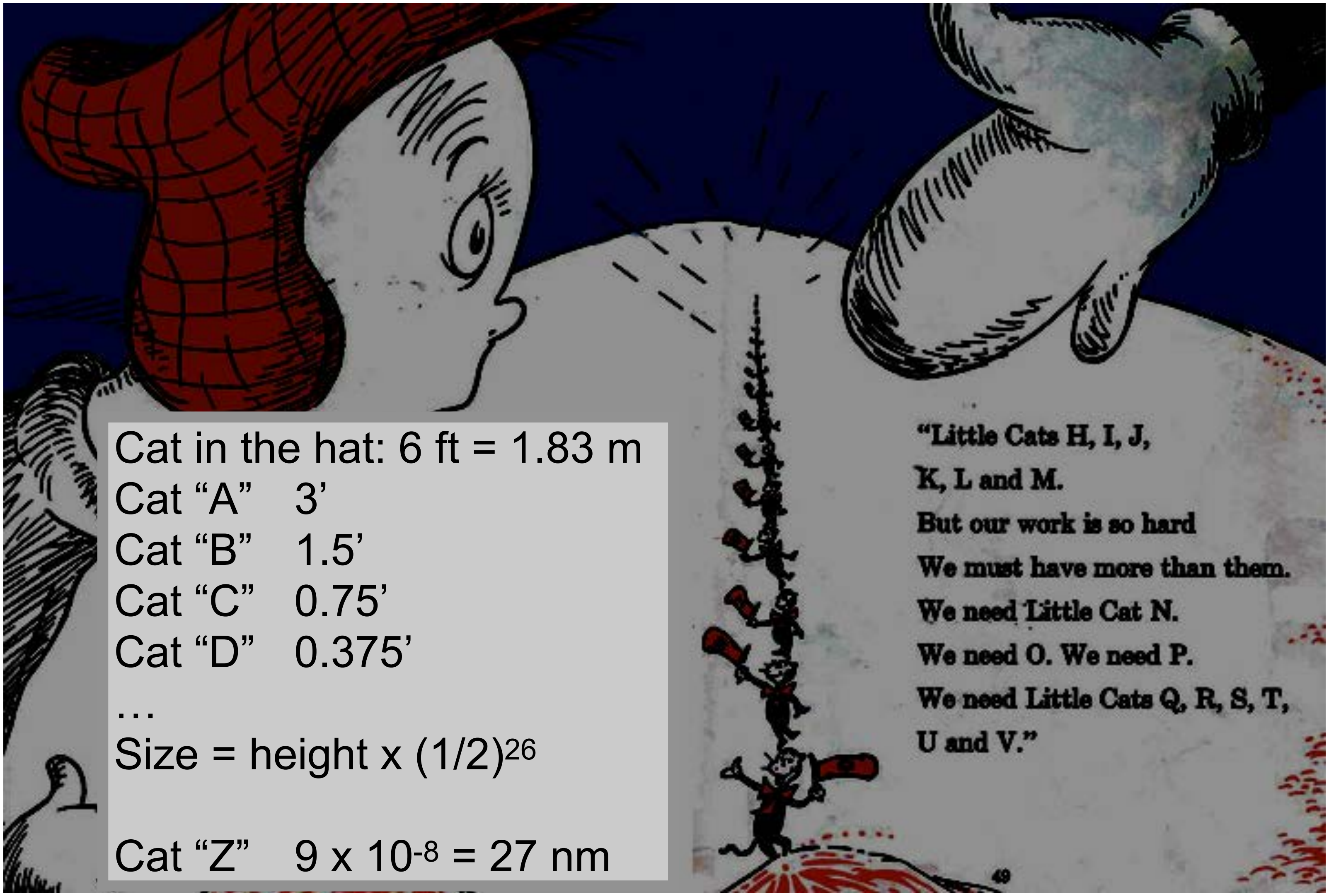

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