The California Tech

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Caltech's Incredible, Shrinking Library

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Contributing Writers

"This is just a spectacular day," beamed Thomas Rosenbaum on a bright September morning at the University of Chicago. It was 2008, and Caltech's current president, then Chicago's provost, was celebrating the groundbreaking of the university's new Joe and Rika Mansueto Library. "In my twenty-one months as provost," he declared, "this has just been a passion of mine. And how could it not be?"

Funding for the mega-library project was seeded by a $24 million dollar alumni donation won over lunch with the university's president. Now in use, the library features a glass-domed Grand Reading Room and the largest automated storage and retrieval system in North America. Five cranes flank the fifty-foot high underground shelves, fetching requested material from among the 3.5 million volumes in, on average, three minutes. "It has all the combinations of what one would like in an intellectually-oriented university," Rosenbaum noted.

In recent years, Caltech's library administration has undertaken a much less glamorous project. Like the crew of a sinking ship, they've been tearing off and throwing overboard every unnecessary cost in the struggle to stay afloat. Forced to prune the library's already small collection to stay within its $7 million annual budget, in recent years they've cut the yearly acquisition rate of books in half. Like other university libraries, the Caltech library's budget has been squeezed by rising journal costs, which now consume over fifteen times the budget for physical material.

Every two years, the librarians assemble a list of subscriptions to cut. In 2016, half a thousand were eliminated. This fall, the next sweep of titles will be selected. Available materials have not been the library's only offerings to be scaled back. Though not a cost-cutting measure, the physical size of the library system has also shrunk. The almost-entire conversion of Millikan Library to administrative offices eliminated forty percent of library space.

The diminishing physical presence of the library is accompanied by a commensurate decrease in undergraduate study space. Students sometimes find library study spaces unavailable, and are forced to seek out other places to work.

On the surface, the declining number of journal subscriptions and books entering circulation is cause for alarm, especially for researchers who rely on timely access to scientific literature. However, in engineering and the sciences, where journal articles are aggregated in a relatively small number of prominent journals, faculty are coping with the loss of journal subscriptions.

Professor Victor Tsai, a geophysicist who sits on the Faculty Library Committee, notes that the "vast majority of the stuff I want is still subscribed to by the library. This is a better situation still than when I was an undergrad [at Caltech] over a decade ago."

However, for researchers who come to Caltech from other institutions with more robust collections, the difference can be jarring. Moving from Harvard to Caltech in 2008, Professor of Chemistry Sarah Reisman found the library's journal subscriptions notably lacking. Her many complaints, she says, laughing, led to her nomination for the Faculty Library Committee. She believes that part of the problem is simply Caltech's small size: Libraries "don't scale down… well—there's a certain fixed cost to have a basic set of collections." However, she appreciates how well the library staff, led by University Librarian Kristin Antelman, has dealt with the many challenges it faces. "Kristin and her team deserve a ton of credit," she says, for "thinking very carefully about the resources we need to have on campus." Now that Reisman has adjusted to Caltech's idiosyncrasies, she says, "I've never felt that our library system has kept me from doing what I want to do, or doing it at the pace I want to do."

It is a different story, however, for humanities and social sciences faculty. HSS departments at Caltech are small and specialized. Each faculty member requires a wide variety of literature specific to her or his particular field. Recent cuts aside, "they have never been able to be supported at Caltech at the level of their research needs," Antelman notes. For these researchers, the library's current struggles have even further exacerbated a persisting problem. Their heavy use of the library and dependence on physical collections has intensified how they feel the cuts.

The funding woes experienced by the Caltech library may appear peculiar against the backdrop of the ever churning $2 billion Breakthrough Campaign. But the story is more complicated — Caltech is not as inundated with money as the campaign's glamour shots depict. Institute revenue has been flat since 2010, and library spending has been similarly stagnant.

The crux of the problem, however, is the drastically increasing cost of subscriptions to scientific journals, which Antelman estimates to have eroded over half of the library's purchasing power in the past decade. For scientists, understanding existing work is a fundamental part of research, necessitating access to journals. Research institutions are effectively hooked on journal subscriptions, allowing publishers to continually inflate prices without losing buyers. As Lindsay Cleary, the subject librarian for HSS articulates, "even if we got funding to match inflation, we would still have to face these problems anyway — just a bit later."

Further, much like cable television providers, publishers often force bundles of journals on research institutions, requiring libraries to subscribe to journals they don't want in order to get the ones they do. These companies charge libraries for the right to read articles, as well as the scientists for the right to publish the research. Despite its low profile, the scientific journal business is very profitable. Elsevier, one of the largest publishers, boasts nearly a billion annual downloads and enjoyed a 37% profit margin in 2016.

Ultimately, Antelman believes that the pain libraries are currently experiencing derives from the digitization revolution of the past decade. Publishers were able to eliminate the variable costs of printing and distributing physical journals by distributing journals online, opening the door to greater economies of scale. Taking advantage of this effect led to industry consolidation and heftier profits for the firms that survived.

Two and a half years ago, Antelman took on the task of leading the library of a premier research institution through a tumultuous time of rising costs and shifting technology. The seemingly daunting challenge was actually what drew her here, she stated in a 2014 interview. Now, she rubs her eyes as she recounts each of the library's obstacles. "People [researchers and graduate students] come from larger institutions and are surprised at how small the library collection is."

The library system has embraced a tactic of strategic withdrawal to cope with budgetary pressures. In broad metrics including books on reserve and journal subscriptions, the library has cut back and reduced its offerings. The amount dedicated to buying new books has fallen from half a million dollars annually to two hundred thousand dollars as more of the budget has been consumed by journal subscriptions.

Library hours have also been reduced to cut costs. As hours and floor space have shrunk, the library has tried to blunt the effect on students by offering more alternatives. Each service lost is often replaced by a cheaper alternative. For example, the reduction of Sherman Fairchild Library's opening hours from 24/7 to 24/5 in 2015 was accompanied by the installation of printers and computers in Winnett to maintain constant printer availability.

According to Antelman, the average cost of subscriptions has risen by 5-8% a year, reducing the Caltech Library's purchasing power. The library's concomitant reduction in journal subscriptions is accompanied by a wider embrace of DocuServe, Caltech's on-demand online document delivery service. In fact, over the past two years, use of DocuServe has doubled. However, through DocuServe, access to articles is no longer instantaneous, but is delayed until the request can be processed during the business day, about twenty-four hours on average. Rush service, which can deliver articles in less than half an hour, is also available, but at a higher cost to the library and with some restrictions for the user.

The Caltech Library's thinning of journal subscriptions coincided with their decision to make standard DocuServe free for nearly all use cases. This shifted the library's focus from maintaining items in circulation and electronic subscriptions to making resources available upon request.

But the on-demand model comes with drawbacks. Instead of being able to browse freely, professors requesting material through DocuServe are left guessing which items will be useful and worth ordering and which will be duds.

Professor J. Morgan Kousser of History and Political Science argues "there's nothing better than the ability to browse [physical copies], especially when I start to research something. We're killing our ability to do that."

On the ground, there have been cosmetic changes that gently improve what the library offers at a relatively low cost. Sherman Fairchild has acquired a 3D printing lab and new furniture and will shortly add a virtual reality lab. Unlike the University of Chicago, Caltech simply does not have enough money dedicated to the library for large scale, dramatic updates. According to Antelman, the focus is instead on small, visible changes that improve the library experience but can be undertaken on a shoestring budget.

Like other facets of the library, the size of the staff has shrunk under tightening budget pressures. But as the number of staff members has decreased, the library workforce has become more technical, better educated, and on a per-person basis, better paid. There has been an emphasis on "hiring people who have both expertise in the library and expertise in the sciences," notes Cindy Weinstein, the Vice Provost.

As for the future, a new publishing model, open access, offers a glimmer of hope. Articles that are open access can be viewed by anyone, free of restriction. The open access movement is a potential counter to the oligopoly run by a handful of profitable publishing firms.

"Open access is becoming prevalent and that's generally a good thing," says Tsai, "but someone's paying." Instead of charging readers, open access journals charge authors. Even then, a 2015 study by the Max Planck Digital Library has shown that a purely open access journal system would be cheaper for both libraries and authors. Not surprisingly, the publishing firms that have benefited handsomely from the journal subscription model are reluctant to give up their perch. "Open access will be a better system if we can get there, but the transition will be challenging," admits Antelman.

Like a sand castle on the beach, the Caltech library has been slowly eroding, battered by skyrocketing costs and a stagnant budget. Instead of continuing to stockpile journals and books, the library has responded by shifting towards a more efficient, demand-based model. The staff is smaller but more technical, while the physical space has shrunk and library officers work to adapt to meet changing demands. Even as the open access movement offers a potential reprieve, broad adoption of the new model is likely a decade away, or more. In the meantime, the Caltech library will continue changing and shifting resources, striving to stay viable against the onslaught of the rising waters.

IN THIS ISSUE

Caltech Y Column

CALTECH Y

The Caltech Y Column serves to inform students of upcoming events and volunteer opportunities. The list is compiled by Katherine Guo from information given by the Caltech Y and its student leaders.

Founded by students in 1916, the Y was organized to provide extracurricular activities planned and implemented by students as an opportunity to learn leadership skills and discover themselves. The mission of today's Y remains the same—to provide opportunities that will prepare students to become engaged, responsible citizens of the world. The Y seeks to broaden students' worldviews, raise social, ethical, and cultural awareness through teamwork, community engagement, activism, and leadership. More information about the Caltech Y and its programs can be found at https://caltechy.org. The office is located at 505 S. Wilson Avenue.

Upcoming Events

Pinnacles National Park Camping Trip

October 13th - 15th | Sign up at the Caltech Y | Cost $85 due on sign up

Do you want to traverse rocky terrain to high peaks and through deep caves? Come along on a camping trip to Pinnacles National Park with the Caltech Y! Pinnacles was born from a lava field split by the San Andreas Fault, and thus supports diverse terrain and wildlife. We'll be completing a 9-mile loop around the park to High Peaks and Balconies Cave, as well as a shorter stint to Bear Gulch Reservoir. The trip departs Friday, October 13th at 1pm and returns Sunday, October 15 by 8pm. Transportation, campsites, and most meals are included. All experience levels are welcome. For more information on Pinnacles National Park, visit the National Park website at https://www.nps.gov/pinn/index.htm.

To secure your spot on this trip you must sign up and pay the fee ($85) in person at the Caltech Y (505 S. Wilson the house, just north of the Credit Union). Spaces are limited. Priority may be given to those who can share in the driving.

Kids Reading to Succeed

Saturday | October 7th | 8:30 - 11:00 AM | 500 E. Villa Street & Jackson Elementary

Kids Reading to Succeed (KRS) works with the youth of Pasadena to encourage a love ofreading and to improve literacy skills. The first hour (9:00 to 10:00) focuses on individualized and targeted reading, in which a volunteer is paired with a student who is encouraged to read aloud from a book chosen from the KRS library. Volunteers consistently ask questions of the students to gauge reading comprehension. The second hour of our program (10:00 to 11:00) is the interactive and fun presentation based on the monthly theme.

For more info and to RSVP go to http://www.kidsreadingtosucceed.org/p/get-involved.html. Eligible for Federal Work Study. Contact the Caltech Y at caltechy@caltech.edu or Kavya Sreedhar at ksreedha@caltech.edu for questions.

Caltech Y Washington DC Science Policy Trip

December 10th - 14th | Applications due, October 24th

Cost is $525 (with round-trip flight to DC and back to LA) or $325 (with one-way flight to DC - go your own way at the end) or $150 (no travel – join us in DC)

Join us for an exploration into Science Policy in the nation's capital! Our five day trip includes lodging and most meals; flights – if you choose; educational discussion sessions, and of course the opportunity to see Washington, DC landmarks like the White House, the Memorials; Smithsonian Museums; the National Archives; and the Capital. Discussion sessions include those who have played a role in setting and implementing science policy for the United States including: Academics, Lobbyists, Scientists, Politicians, and Caltech Alumni. Past figures included: Vice President Gore's Science Advisor, Science Advisor to Secretaries of State Clinton and Kerry, the Director of DARPA, the Director of the NSF, one of the Directors at the NIH, science advisors at the White House Office OSTP, and more. Don t miss this opportunity!

The Washington, DC Science Policy Trip is coordinated by the Caltech Y with generous support from the George Housner Fund. Questions and applications may be directed to caltechy@caltech.edu. Please visit: https://www.caltechy.org/programs_services/areas/dc/ for more info and applications.

Rise Tutoring Program

Monday - Thursday | 4:00 - 6:00 PM | Chandler Cafeteria

The Caltech Y Rise Program is currently accepting new tutors for the fall term. The Rise Program is an afterschool math and science tutoring program for public school students between grades 8 and 12. The program is in its twelfth year and helps students who are struggling in math or science (getting a C or below). The tutoring takes place on the Caltech campus Monday-Thursday from 4pm-6pm. Tutors work with 1-2 students and when possible work with the same student(s) throughout the year. The program is designed to help students gain greater competency in math foundations, improve skills in math and science and prepare students for college-level math and science.

Tutoring with the Rise Program is a great way to give back to the community and work with local school students to help them succeed in math and science. For more info and to apply go to https://caltechy.org/programs_services/tutoring/Resources/index.php.

Hathaway Sycamores

Every Monday | 5:45 - 8:00 PM | Highland Park

Volunteer at Hathaway Sycamores, a group that supports local underprivileged but motivated high school students. there are a variety of ages and subjects being tutored. The service trip includes about 40 minutes of travel time and 1.5 hours of tutoring. Transportation is included.

For more info and to RSVP email Elisabeth at egallmei@caltech.edu. Eligible for Federal Work Study.

Beyond the Y

Join STARS in PUSD Resource Centers

STARS (Scholars Transitioning and Realizing Success) needs volunteers for Foster Resource Centers in four Pasadena Unified School District schools to strengthen students' educational success and provide them with access to foster youth resources. The drop-in Centers are currently open one day per week for 30 to 90 minutes. Volunteers will assist by leading activities such as cooking or community building games; making presentations on careers or other topics of interest; helping students complete homework or college essays and forms; or assisting staff with College Information Days. To volunteer, contact: inbox@fostercareproject.org.

Caltech Scientists Awarded 2017 Nobel Prize in Physics

WHITNEY CLAVIN
Caltech Media Relations

This article is adapted from a story that was originally published online at caltech.edu.

The 2017 Nobel Prize in Physics has been awarded to three key players in the development and ultimate success of the Laser Interferometer Gravitational-wave Observatory (LIGO). One half of the prize was awarded jointly to Caltech's Barry C. Barish, the Ronald and Maxine Linde Professor of Physics, Emeritus and Kip S. Thorne (BS '62), the Richard P. Feynman Professor of Theoretical Physics, Emeritus; and the other half was awarded to MIT's Rainer Weiss, professor of physics, emeritus.

On September 14, 2015, the National Science Foundation (NSF)-funded LIGO made the first-ever direct observation of gravitational waves—ripples in the fabric of space and time predicted by Albert Einstein 100 years earlier. The public announcement took place on February 11, 2016, in Washington, D.C. Each of the twin LIGO observatories—one in Hanford, Washington, and the other in Livingston, Louisiana—picked up the feeble signal of gravitational waves generated 1.3 billion years ago when two black holes spiraled together and collided. Two additional detections of gravitational waves, once again from merging black-hole pairs, were made on December 26, 2015, and January 4, 2017, and, on August 14, 2017, a fourth event was detected by LIGO and the European Virgo gravitational-wave detector.

The detections ushered in a new era of gravitational-wave astronomy. LIGO and Virgo provided astronomers with an entirely new set of tools with which to probe the cosmos. Previously, all astronomy observations have relied on light—which includes X-rays, radio waves, and other types of electromagnetic radiation emanating from objects in space—or on very-high-energy particles called neutrinos and cosmic rays. Now, astronomers can learn about cosmic objects through the quivers they make in space and time.

The Nobel Prize recognizes Weiss, Barish, and Thorne for their "decisive contributions to the LIGO detector and the observation of gravitational waves."

"I am delighted and honored to congratulate Kip and Barry, as well as Rai Weiss of MIT, on the award this morning of the 2017 Nobel Prize in Physics," says Caltech president Thomas F. Rosenbaum, the Sonja and William Davidow Presidential Chair and professor of physics. "The first direct observation of gravitational waves by LIGO is an extraordinary demonstration of scientific vision and persistence. Through four decades of development of exquisitely sensitive instrumentation—pushing the capacity of our imaginations—we are now able to glimpse cosmic processes that were previously undetectable. It is truly the start of a new era in astrophysics."

Thorne received the call from the Nobel committee this morning at 2:15 a.m. Pacific Daylight Time.

"The prize rightfully belongs to the hundreds of LIGO scientists and engineers who built and perfected our complex gravitational-wave interferometers, and the hundreds of LIGO and Virgo scientists who found the gravitational-wave signals in LIGO's noisy data and extracted the waves' information," Thorne says. "It is unfortunate that, due to the statutes of the Nobel Foundation, the prize has to go to no more than three people, when our marvelous discovery is the work of more than a thousand."

Barish received the call from the Nobel committee this morning at 2:45 a.m. Pacific Daylight Time.

"I am humbled and honored to receive this award," says Barish. "The detection of gravitational waves is truly a triumph of modern large-scale experimental physics. Over several decades, our teams at Caltech and MIT developed LIGO into the incredibly sensitive device that made the discovery. When the signal reached LIGO from a collision of two stellar black holes that occurred 1.3 billion years ago, the 1,000-scientist-strong LIGO Scientific Collaboration was able to both identify the candidate event within minutes and perform the detailed analysis that convincingly demonstrated that gravitational waves exist."

An Idea That Began Decades Ago

Einstein predicted in 1916 that gravitational waves would exist, but thought them too weak to ever be detected. By the 1960s, technological advances such as the laser and new insights into possible astrophysics sources made it conceivable that Einstein was wrong and that gravitational waves might actually be detectable.

The first person to build a gravitational-wave detector was Joseph Weber of the University of Maryland. Weber's detectors, built in the 1960s, used large aluminum cylinders, or bars, that would be driven to vibrate by passing gravitational waves. Other researchers elsewhere, including the late Ronald W. P. Drever at the University of Glasgow in Scotland—later a professor of physics at Caltech—soon followed Weber's lead.

When those experiments proved unsuccessful, the focus of the field began shifting to a different type of detector called a gravitational-wave interferometer, invented independently by Weiss at MIT and, in rudimentary form, by several others. In this instrument, gravitational waves stretch and squeeze space by an infinitesimal amount while widely separated mirrors hanging by wires "ride" the oscillations, moving apart and together ever so slightly. This mirror motion is measured with laser light using a technique called interferometry.

In the late 1960s, Weiss began laying conceptual foundations for these interferometers. In parallel, Thorne, along with his students and postdocs at Caltech, worked to improve the theory of gravitational waves, and estimated the details, strengths, and frequencies of the waves that would be produced by objects in our universe such as black holes, neutron stars, and supernovas.

In 1972, Thorne, with his student Bill Press (MS '71, PhD '73), published the first of many articles that would appear over the next three decades, summarizing what was known about the gravitational-wave sources and formulating a vision for gravitational-wave astronomy.

"LIGO would not exist without Kip's vision for the scientific potential of gravitational waves and his amazing gift for sharing that vision with other scientists," says Stan Whitcomb (BS '73), the chief scientist for the LIGO Laboratory at Caltech, who began working on the project in 1980.

Also in 1972, Weiss published a detailed analysis of his interferometers. He identified all of the major obstacles that could prevent the instruments from detecting gravitational waves, such as vibrations of the earth and of the mirrors, and he invented techniques to deal with each obstacle. At this stage, it became evident that large interferometers, several kilometers or more in size, might possibly prove successful—as, indeed, they ultimately did with LIGO and its 4-kilometer-long arms. Also evident was the fact that perfecting the interferometers would be exceedingly difficult: a passing gravitational wave would induce mirror motions 1,000 times smaller than a proton, and these infinitesimal changes would have to be measured. That's 100 million times smaller than an atom, and a trillion times smaller than the wavelength of the light being used in the measurement.

Triggered by Weiss's work, Drever's research group in Glasgow switched from bars to interferometers, as did a research group in Garching, Germany, led by Heinz Billing. By 1975, there were three prototype interferometers under development at MIT, Glasgow, and Garching.

A Fateful Hotel Room Discussion

At first Thorne was skeptical of Weiss's interferometer idea. "I even wrote, in a textbook, that it was not very promising," he says. But that changed when Thorne studied, in depth, Weiss's 1972 analysis. Thorne came to call it a "tour de force" and a "blueprint for the future."

In 1975, Weiss invited Thorne to speak at a NASA committee meeting in Washington, D.C., about cosmology and gravitation experiments in space. Hotel rooms that summer were fully booked, so the two shared a room, where they stayed up all night talking. Thorne came away so excited by the experimental prospects that he went home and proposed creating an experimental gravity group at Caltech to work on interferometers in parallel with MIT, Glasgow, and Garching. Caltech then brought Drever on board in 1979 to lead the new experimental effort, because, as Thorne says, they knew his inventiveness would prove crucial to LIGO's success. Soon thereafter, in 1980, Caltech hired a young Chicago astrophysicist, Whitcomb, to assist in the leadership.

"What a pleasure it was to have this brilliant, budding experimental group working alongside my theory group at Caltech," says Thorne. "Those were heady days."

Together, Drever and Whitcomb led the design and construction of a 40-meter interferometer at Caltech—a prototype to test and perfect the ideas of Weiss, Drever, and others, including the teams at Glasgow and Garching.

Meanwhile, Thorne and his theory students—in collaboration with the late Vladimir Braginsky of Moscow State University, a regular Caltech visitor over three decades—were analyzing various sources of noise that the big interferometers would face, especially "quantum noise," or random fluctuations of the mirrors' positions predicted by quantum theory. They were coming up with ways to deal with those fluctuations.

In 1984, all of this parallel work came together. Caltech and MIT, with encouragement from the NSF, formed a collaboration to design and build LIGO. Rochus E. (Robbie) Vogt, Caltech's R. Stanton Avery Distinguished Service Professor and Professor of Physics, Emeritus, was recruited in 1987 as LIGO's first director. Vogt led the merging of the Caltech and MIT experimental groups; the early planning for LIGO; the writing of a proposal to NSF to fund the project; and the education of Congress about this high-risk project with a potentially exceedingly high payoff. In 1992, Congress allocated the first major funding. "NSF and Congress have backed LIGO unwaveringly ever since," says Thorne.

Scaling up LIGO

Building LIGO was a tremendous challenge—logistically and technically. To meet this challenge, Caltech and MIT later recruited, as LIGO's second director, Barry Barish, who at that time had been the leader of several very large high-energy physics projects. Barish developed the first high-energy neutrino beam experiment at Fermilab near Chicago and was one of the leaders of a large international collaboration that performed a search for magnetic monopoles—magnetic analogs of single electric charges that, if found, would help confirm the Grand Unified Theory that seeks to unify the electromagnetic, weak, and strong forces. The experiment, called MACRO (Monopole, Astrophysics and Cosmic Ray Observatory), did not find magnetic monopoles but set the most stringent limits on their existence. Barish then led the design of one of the two detectors planned for another big science project, the Superconducting Super Collider—a particle accelerator to be built in Waxahachie, Texas. The accelerator was canceled during construction in 1993, after which Barish took on the challenge of LIGO, becoming its principal investigator in 1994, and then its director in 1997.

"I always wanted to be an experimental physicist and was attracted to the idea of using continuing advances in technology to carry out fundamental science experiments that could not be done otherwise," says Barish. "LIGO is a prime example of what couldn't be done before. Although it was a very large-scale project, the challenges were very different from the way we build a bridge or carry out other large engineering projects. For LIGO, the challenge was and is how to develop and design advanced instrumentation on a large scale, even as the project evolves."

"Barish, in my opinion, is the most brilliant leader of large science projects that physics has ever seen," says Thorne.

Barish ushered LIGO through its final design stages and secured funding through NSF's National Science Board. He oversaw construction of the two LIGO facilities from 1994 to 1999, and then the installation and commissioning of the initial LIGO interferometers from 1999 to 2005. The scaling up from Caltech's 40-meter prototype to LIGO's 4-kilometer interferometers was such a huge undertaking that it was carried out in two steps. First, the team built initial interferometers, which operated from 2002 to 2010, at a sensitivity that Barish characterized as being at a level where detections were "possible." This first step demonstrated the observatory's basic concepts and solved many technical obstacles. The development and approval of the next phase of LIGO, called Advanced LIGO, was also led by Barish and then-LIGO Laboratory deputy director Gary Sanders, and was designed to be sensitive to a level at which detections were "probable." Advanced LIGO was commissioned and built between 2010 and 2015. Though Barish left LIGO in 2006 to become director of the Global Design Effort for the International Linear Collider, he would rejoin the LIGO team in 2012, in time for the project's historic discovery in 2015. After Barish left, LIGO was led by Jay Marx of Caltech, followed by current executive director, Caltech's David H. Reitze.

"LIGO had to make the change from tabletop science to a real science facility," says Whitcomb. "Barry understood what was needed, and he guided that transformation without ever losing sight of the scientific goals."

Under Barish's leadership, several key technologies were developed that ultimately led to the detection of gravitational waves. For the first phase of LIGO, now referred to as Initial LIGO, he chose to use solid-state lasers rather than the gas lasers that were more commonly in use at that time. These solid-state lasers were the basis of more powerful versions developed for Advanced

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Procrastination workshop

A 1-hour workshop offered 2 times this term:

Friday, October 13th, 4:00 - 5:00

Friday, November 3rd, 4:00 - 5:00

326 Sherman Fairchild Library

- Learn tools for coping with procrastination and work avoidance.
- Learn practical, behavioral strategies for responding differently to old habits.
- Respond differently to unhelpful thoughts like "I can just get up early and do this tomorrow."
- Optional text-based reminder system to keep the lessons fresh in the week after the workshop is over!

More information: counseling.caltech.edu

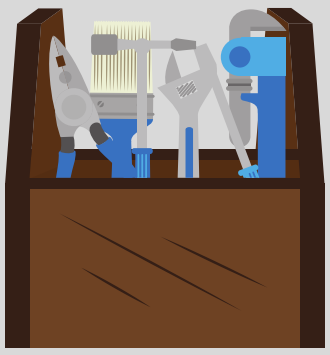
EMOTIONAL INTELLIGENCE TOOLKIT

3 modules / 2 weeks each / 1 awesome skillset

Emotional Awareness Get better at knowing what you're feeling, and see how your thoughts and feelings affect each other. **October 9th and 16th**

Open-Mindedness Learn how to be more flexible in the way you see the world! **October 23rd and 30th**

Face The Fear Learn how to hang in there with difficult situations and emotions without having to avoid them. **November 6th and 13th**



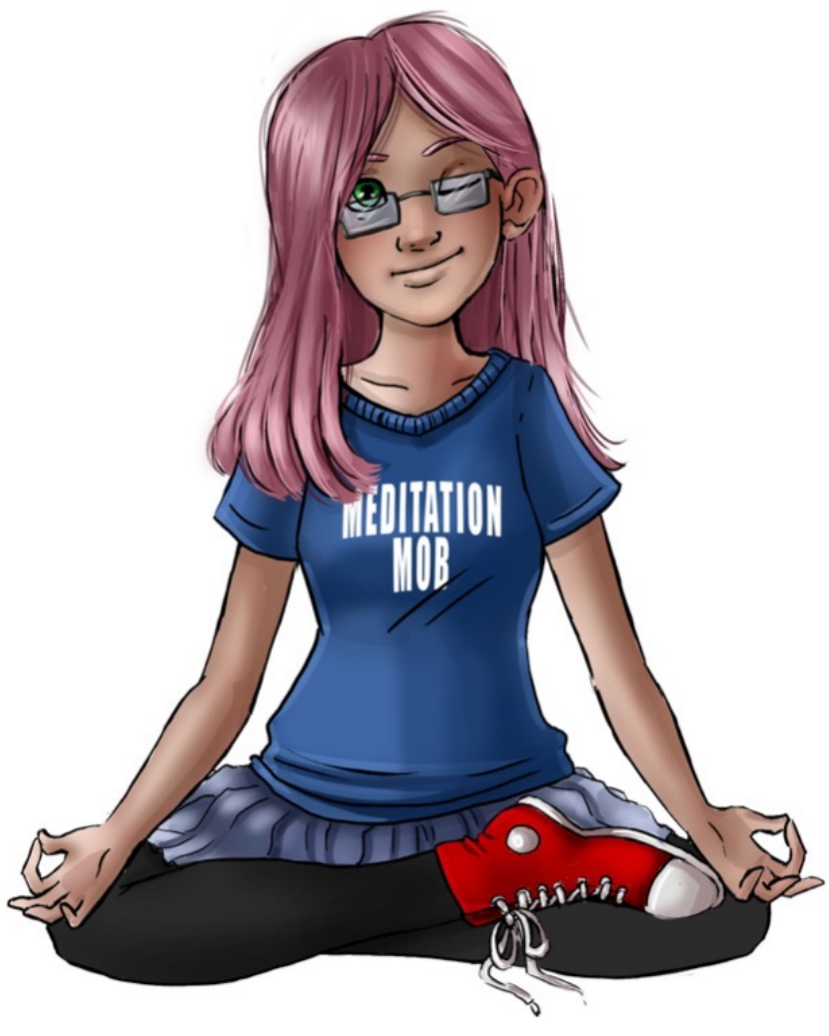
Just show up!
Mondays 4:00 - 5:00

326 Sherman Fairchild Library

counseling.caltech.edu

Join the Meditation Mob!

Tuesdays, 12:00 - 12:50



Want to learn more about mindfulness meditation? It's a great way to improve your attention and to become more grounded in the present moment.

There's no religious component. We use secular, evidence-based meditation techniques.

We meet in the study room on the **9th floor of Millikan Library.** All students are welcome, from total beginners to experienced meditators.

Mailing list and MP3 archive:
counseling.caltech.edu/students/meditation

Men and Women Trend Up in Pomona

GOCALTECH.COM
Actual Sports Content Editor

POMONA, Calif. (Oct. 14, 2017) - The Caltech men's and women's cross country teams saw personal best-times recorded up and down each lineup at Saturday's Pomona-Pitzer Invitational . Optimal racing conditions and an early start time of 7:45 a.m. paved the way for a strong day for the men's team. The Beavers bested four SCIAC schools and were fronted once again by sophomore Simon Ricci (Chicago, Ill. / Latin School of Chicago) who came in at 26:21.70 and topped his personal-best time by six seconds. Ricci's finish was good for 17th overall in a field consisting of schools inside and outside the SCIAC. Sophomore Tanner Moore (Roseville, Calif. / Oakmont) trailed Ricci by 14 seconds (26:35.73) and came within one-fifth of a second of setting a personal best for himself. He finished 23rd in the field of 137 men.

Junior Rohan Choudhury (Cupertino, Calif. / Monta Vista) took third on the team, clocking in at 27:33.75 to set another personal best. Freshmen Spencer Morgenfeld (Palo Alto, Calif. / Palo Alto) and Matthew Earney (San Diego, Calif. / Del Norte) ran in tandem for much of the race and finished fourth and fifth on the team within four seconds of each other. Earney completed the track in 27:44.43 and Morgenfeld (27:40.86) achieved a personal best. Sophomore David Fager (Miami, Fla. / Belen Jesuit Prep) finished sixth among Beavers and dropped his top time by nearly a minute (28:22.12). The biggest drop of the day came in the form of junior Michael Hashe's (Plano, Texas / Texas Acad. of Math & Science) performance. Hashe, who finished the 8K course in 30:26.09, topped his previous best time by nearly two minutes, summing up just how effective the men's team was on Saturday morning.

If those shorts were a little shorter, maybe he'd make up that last one-fifth of a second.

-gocaltech.com

"Coming into today we were pleased with how our training had progressed and were optimistic about our ability to compete well," Head Coach Ben Raphelson said. "Just about everyone stepped up with their best race of the season so far. We're confident that we can build on this going forward."

The women's team saw an equally positive result in the team results, also beating out four other SCIAC schools. Freshman Claire Hu (Palo Alto, Calif. / Henry M. Gunn) took the top spot on the women's side for a second consecutive race and clocked in at 23:20.00, good for 13th overall in a field of 158 women. Fellow freshman Molly Crotteau (Chicago, Ill. / Payton) rebounded from the SCIAC Duals to finish second again for the Beavers and 30th overall (23:58.77). Freshman Krystal Brodsky (Redmond, Wash. / Redmond) finished third among Beavers and 63rd overall (24:57.10). Sophomore Skye Reese (Concord, N.H. / Concord) finished the 6K course in 25:33.57, 30 seconds off a personal best set two weeks ago at La Mirada but finished fourth among Caltech runners for the first time in her career. Junior Melissa Gutierrez (Pico Rivera, Calif. / El Rancho) ran close behind Reese and finished just four seconds off her sophomore counterpart.

The conditions warmed up for the women's race with temperatures in the low-80s. Comparatively, the women's team finished about as expected in the context of the women's field and Raphelson believes the women's side of the program has a lot to look forward to in the coming weeks.

"We had some bad luck in a few cases in the women's race but the fact that others stepped up and helped deliver a strong team result really reflects well on this group," Raphelson said. "They're really motivated for the remainder of the season."

Raphelson and the Beavers will have two weeks to rest up and fine tune their form before competing at the SCIAC Championships on Saturday, Oct. 28.

Ravishankar Leads Women's Soccer Past La Sierra on Senior Day

GOCALTECH.COM
Actual Sports Content Editor

PASADENA (Oct. 12, 2017) – Freshman Netra Ravishankar (Fremont, Calif. / American) and the Caltech women's soccer team won for a second time this season when they took down visiting La Sierra University, 1-0, on Thursday afternoon. The Beavers had done well with controlling possession against the Golden Eagles, who entered Wednesday's nonleague clash 10-1, before Ravishankar took a pass from fellow freshman Rachel Sun (Tustin, Calif. / Beckman) and buried the ball in the back of the net from about 25 yards out. The goal came on beautiful arc that landed out of reach of the La Sierra keeper to stake the Beavers to a one-goal lead with just over 50 minutes to play in the game. Ravishankar's goal extended her scoring streak to three games, the longest in the brief history of the women's soccer program.

As impressive as the goal looked visually, the Beavers' performance was defined by their rate of play for the remainder of the game, which ultimately sealed them a second victory in the last three games.

"Our team brought the grit and determination necessary to come away with the victory," Head Coach Taylor Houck said. "It was about coming together as a group of 11, realizing what we had in front of us and a matter of wanting it bad enough to make it a reality. I thought our players did a tremendous job in tightening up as the game went on."

Skills so good, the opponents' jerseys changed.

-gocaltech.com

After the Beavers outshot the Golden Eagles 6-4 in the first half, the visitors came out firing in the second half and refused to go down without a fight. A solid showing from freshman goalkeeper Kali Drango (Lake Oswego, Ore. / Lake Oswego) was necessary for the Beavers in maintaining their lead. Drango totaled five saves but made her three most important stops in the second half to keep her side on top. The Golden Eagles tallied many more shots than the ones that found a path to the net, but sound play from defenders Nayla Abney (Sewell, N.J. / Deptford Township), Maquelle Tiffany (Los Alamitos, Calif. / Los Alamitos) and Gabriella Chan (Colleyville, Texas / School for the Talented and Gifted) vastly limited the visitors' attacking opportunities, particularly early to help set up the Ravishankar goal.

Meanwhile, the Beavers offense had opportunities to pad the lead. Freshman midfielder Krystin Brown (Lake Forest, Calif. / Trabuco Hills) put two shots on goal, one of which caught the bottom of the cross bar and angled down to land just in front of the goal line. Sophomore midfielder Noelle Davis (Fort Worth, Texas / Texas Acad. of Math & Science) also had two shots on goal.

Seniors Caroline Atyeo (Parkland, Fla. / Marjory Stoneman Douglas) and Gabby Tender (Bethesda, Md. / Walt Whitman) were honored for their achievements on the field and in the classroom in a pregame Senior Day ceremony.

Houck and the Beavers will travel to California Lutheran University on Monday, Oct. 16 before closing the season at home against Claremont-Mudd-Scripps Colleges on Sunday, Oct. 22.

Men's Water Polo Achieves Program-Best Ranking in CWPA Poll

GOCALTECH.COM
Actual Sports Content Editor

PASADENA (Oct. 11, 2017) – The Caltech men's water polo team opened Week 6 of the 2017 season as the 10th best team in Division III in the latest Collegiate Water Polo Association poll. It is the highest CWPA Division III ranking in the history of the program.

The Beavers' recent resume includes a SCIAC victory over Occidental College on Sept. 27th, their first since 2001, in addition to three wins at the Gary Troyer Tournament in Claremont this past weekend. It was there the Beavers knocked off out of town foes such as Penn State Behrend and Connecticut College in addition to Occidental for a second time in a non-conference game.

Even the water polo team looks shocked by this ranking.

-gocaltech.com

The Collegiate Water Polo Association is the governing body over NCAA varsity and club men's and women's water polo teams. Each poll has 10 pollsters and each pollster examine scores and rank teams in light of their results. They are charged with ranking the teams to the best of their abilities without considering their subjective feelings about the strength of a team or individual factors affecting a team's performance, such as injury or illness to specific athletes.

Head Coach Jon Bonafede and the Beavers will return to action on Saturday, Oct. 14 when they travel to Whittier College for an 11 a.m. game.

NOMINATE YOUR FAVORITE PROFESSOR FOR THE FEYNMAN TEACHING PRIZE!!!

Here's your chance to nominate your favorite professor for the 2017-18 Richard P. Feynman Prize for Excellence in Teaching! You have from now until December 15, 2017 to submit your nomination package to the Provost's Office to honor a professor who demonstrates, in the broadest sense, unusual ability, creativity, and innovation in undergraduate and graduate classroom or laboratory teaching.

The Feynman Prize is made possible through the generosity of Ione and Robert E. Paradise, with additional contributions from an anonymous local couple. Nominations for the Feynman Teaching Prize are welcome from faculty, students, postdoctoral scholars, staff, and alumni.

All professorial faculty of the Institute are eligible. The prize consists of a cash award of $3,500, matched by an equivalent raise in the annual salary of the awardee. A letter of nomination and detailed supporting material, including, but not limited to, a curriculum vitae, course syllabus or description, and supporting recommendation letters should be emailed to kkerbs@caltech.edu or directed to the Feynman Prize Selection Committee, Office of the Provost, Mail Code 206-31, at the California Institute of Technology, Pasadena, California, 91125. Nomination packages are due by December 15, 2017.

Additional information including guidelines for the prize and FAQ may be found at http://provost.caltech.edu/FeynmanTeachingPrize. Further information can also be obtained from Karen Kerbs (626-395-6039; kkerbs@caltech.edu) in the Provost's Office.

VICE PROVOST OFFICE HOURS

Vice Provost, Chief Diversity Officer, and Professor of English Cindy Weinstein holds regular office hours as an opportunity for undergraduate students, graduate students, and postdocs to meet for discussions pertaining to the Council on Undergraduate Education; Caltech accreditation; the Staff and Faculty Consultation Center; Student-Faculty Programs; the Center for Teaching, Learning and Outreach; the Caltech Diversity Center; and the Caltech Libraries.

There are four 15-minute appointments available per office hour. Sign up in the Office of the Vice Provost, Parsons-Gates room 104, ext. 6339 or by sending an email to dlewis@caltech.edu. We look forward to hearing from you!

Student Office Hours for Fall Term 2017:

10/19/17 Thursday 11:00 a.m.–12:00 p.m.
10/26/17 Thursday 10:00–11:00 a.m.
11/1/17 Wednesday 11:00 a.m.–12:00 p.m.
11/7/17 Tuesday 9:00–10:00 a.m.
11/16/17 Thursday 11:00 a.m.–12:00 p.m.
11/21/17 Tuesday 10:00–11:00 a.m.
11/27/17 Monday 10:00–11:00 a.m.

Caltech Scientists Awarded 2017 Nobel Prize in Physics

Continued from page 3

LIGO. He also oversaw the development of technologies for reducing unwanted movements in LIGO's mirrors, caused by earthquakes, passing trucks, and other ground vibrations.

"In the initial phase of LIGO, in order to isolate the detectors from the earth's motion, we used a suspension system that consisted of test-mass mirrors hung by piano wire and used a multiple-stage set of passive shock absorbers, similar to those in your car. We knew this probably would not be good enough to detect gravitational waves, so we, in the LIGO Laboratory, developed an ambitious program for Advanced LIGO that incorporated a new suspension system to stabilize the mirrors and an active seismic isolation system to sense and correct for ground motions," says Barish.

The active seismic isolation system developed for Advanced LIGO works in a similar fashion to noise-canceling headphones, except it can measure and cancel out ground vibrations coming from many directions. In conjunction with this system, a new "quieter" way to suspend LIGO's mirrors was developed with the help of the Glasgow group, which involved hanging the mirrors with a four-stage pendulum. The combination of these two advances gave LIGO a huge improvement in sensitivity to lower frequencies of gravitational waves, which was ultimately what was needed to detect the crashing of two black holes.

Barish also created the LIGO of today: a collaboration of approximately 1,200 scientists and engineers at about 100 institutions in 19 nations called the LIGO Scientific Collaboration (LSC).

"In addition to picking the right technologies and developing them, and securing funding, we needed to build a collaboration of the absolute best people possible for this almost impossible project," says Barish. "Forming an international collaboration, the LSC, enabled this. We attracted the best people from other universities and countries, creating an 'equal opportunity' collaboration, where there was no advantage to being at Caltech or MIT." The LSC conducted the scientific searches and analysis that led to the LIGO discovery.

While this experimental work was taking place, theorists outside Caltech, MIT, and the LIGO project were developing computer codes to simulate the massive collisions of black holes and other sources of gravitational waves that LIGO might detect. These simulations are essential to LIGO; by comparing the shapes of the waves that LIGO observes with the simulations' predicted wave shapes, LIGO scientists can figure out what produces the observed waves. In the early 2000s, Thorne became alarmed at the slow progress on simulations and so with then-Caltech physicist Lee Lindblom, he created a research group at Caltech in collaboration with a group at Cornell University led by his former student Saul Teukolsky (PhD '74), who is now jointly the Robinson Professor of Theoretical Astrophysics at Caltech and Hans A. Bethe Professor of Physics and Astrophysics at Cornell University. By 2015, this SXS (Simulating eXtreme Spacetimes) project was simulating the collisions of black holes with ease, as were several other research groups.

On September 14, 2015, just after the Advanced LIGO interferometers began their first search for gravitational waves, they captured a strong signal. Comparison with the SXS simulations revealed that the signal was from the collision of two hefty black holes 29 and 36 times more massive than the sun and located 1.3 billion light-years from Earth. The waves carried away as much energy as would be produced by annihilating three suns. After intense scrutiny of the results, the LIGO scientists announced this discovery to the world on February 11, 2016.

"I'm positively delighted that the Nobel Committee has recognized the LIGO discovery and its profound impact on the way we view the cosmos," says Reitze. "This prize rewards not just Kip, Barry, and Rai but also the large number of very smart and dedicated scientists and engineers who worked tirelessly over the past decades to make LIGO a reality."

"LIGO was a huge technical and scientific gamble," says Fiona Harrison, the Benjamin M. Rosen Professor of Physics and the Kent and Joyce Kresa Leadership Chair in Caltech's Division of Physics, Mathematics and Astronomy. "But it paid off in spades with one of the most dramatic discoveries in decades. The entire LIGO team should be celebrating today."

The 2017 Nobel Prize in Physics represents the 37th and 38th Nobel Prizes awarded to Caltech faculty and alumni. Current Caltech faculty with Nobel Prizes include: Robert Grubbs, winner of the 2005 Nobel Prize in Chemistry with Yves Chauvin and Richard R. Schrock; David Politzer, recipient of the 2004 Nobel Prize in Physics with David J. Gross and Frank Wilczek; Rudy Marcus, sole winner of the 1992 Nobel Prize in Chemistry; and David Baltimore, winner of the 1975 Nobel Prize in Physiology or Medicine, with Renato Dulbecco and Howard M. Temin.

In 2016, Drever, Thorne, and Weiss won the Kavli Prize in Astrophysics, the Shaw Prize in Astronomy, the Gruber Foundation Cosmology Prize, and the Special Breakthrough Prize in Fundamental Physics. In 2017, Barish, Thorne, and Weiss won the Princess of Asturias Award for Technical and Scientific Research and the European Physical Society's Giuseppe and Vanna Cocconi Prize.

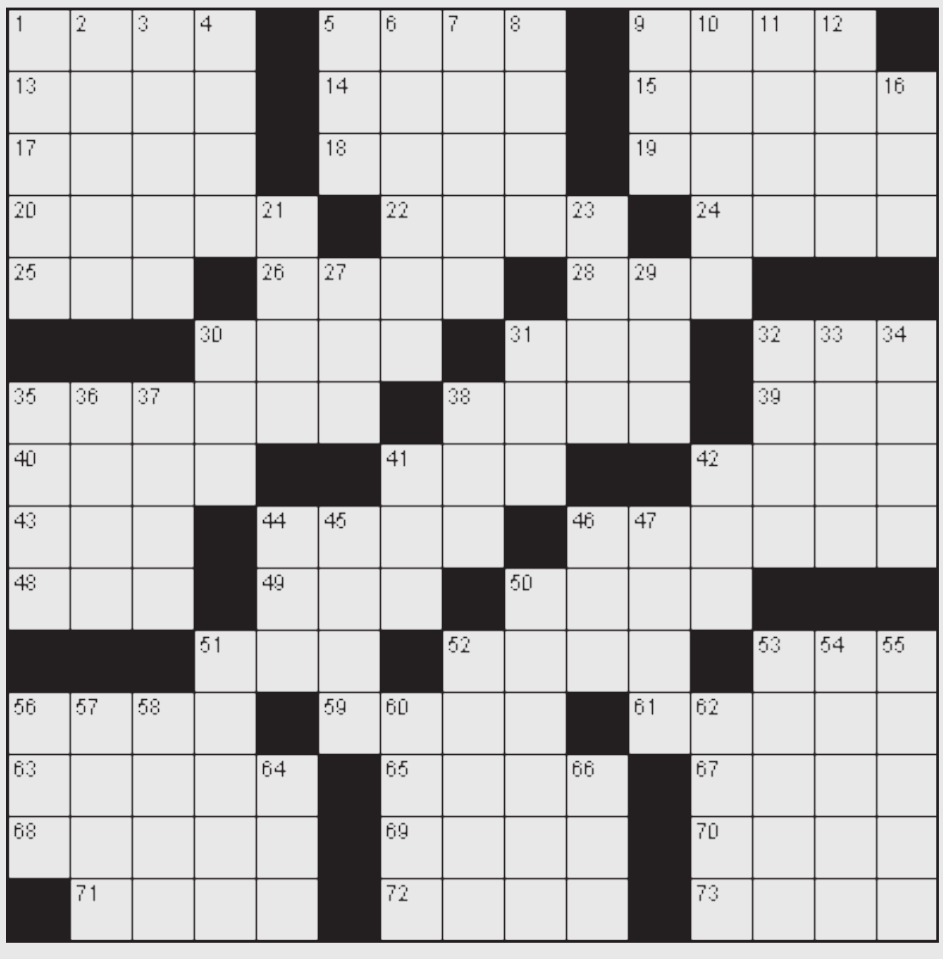
Barish was born on January 27, 1936, in Omaha, Nebraska, and spent his childhood in Los Angeles. He received his BA in physics in 1957 and his PhD in experimental particle physics in 1962, both from UC Berkeley. In 1963, he joined Caltech as a research fellow. He became an assistant professor in 1966, an associate professor in 1969, and a professor of physics in 1972. He was named the Ronald and Maxine Linde Professor of Physics in 1991 and Linde Professor, Emeritus, in 2005. He is a member of the National Academy of Sciences, and a fellow of the American Academy of Arts and Sciences, the American Association for the Advancement of Science, and the American Physical Society, the latter of which he served as president. In 2002, he received the Klopsteg Memorial Lecture Award from the American Association of Physics Teachers and, in 2016, he received the Enrico Fermi Prize from the Italian Physical Society. He won the Henry Draper Medal in 2017 with Whitcomb.

Thorne was born on June 1, 1940, in Logan, Utah. He received a bachelor's degree in physics from Caltech in 1962 and a PhD in physics from Princeton University in 1965. He joined Caltech as a research fellow in 1966, and joined the faculty in 1967 as an associate professor of theoretical physics. In 1970, he became a professor of theoretical physics. In 1991, he was named the Richard P. Feynman Professor of Theoretical Physics. He retired in 2009. Thorne has coauthored or authored several books, including Black Holes and Time Warps: Einstein's Outrageous Legacy, published in 1994. He served as an executive producer and science adviser for the 2014 film Interstellar. He is a member of the National Academy of Sciences, the American Physical Society, the American Academy of Arts and Sciences, and the American Philosophical Society. On October 11, 2017, Thorne will publish the textbook Modern Classical Physics, coauthored with Roger Blandford.

Crossword

Across
1. Challenge
5. Leading actor
9. Vessel
13. Paragon
14. Impulse
15. Kind of duck
17. Steals
18. Made of fermented honey and water
19. Sports stadium
20. Attempts
22. At the summit
24. Direction
25. Japanese currency
26. Officer on a commercial ship
28. Tributary of the Mississippi, ____ River
30. Inferior in strength
31. Digit
32. Nothing
35. Representation of a person
38. A ship's small boat
39. Epoch
40. Chinese currency
41. For each
42. Lure
43. Make a mistake
44. Slow pace of running
46. Pass by
48. Staining substance
49. Not in
50. Highly excited
51. Electrically charged particle
52. Air pollution
53. Pasture
56. Panache
59. Pace
61. Enchantment
63. Ocean-going vessel
65. Tied
67. Jabber
68. Subway system
69. Withered
70. Finished
71. Location
72. Large woody plant
73. Persistently annoying person

Down
1. Unclean
2. Love intensely
3. Small bird
4. Other than what is under consideration
5. Quantity of money
6. Pact
7. Impure form of quartz
8. Reconstruct
9. Large body of water
10. Employed
11. Notion
12. Writing implements
16. Rodent
21. Self-satisfied
23. Front part of a vessel
27. One, some, every or all
29. Fish
30. Wrestling hold
31. Old salt
32. Form of tide
33. Part of the eye
34. Tardy
35. Looked at
36. Frenzy
37. Taxi passenger
38. So far
41. Cooking vessel
42. Container
44. Also
45. Operates
46. Self
47. Records of messages sent or received
50. Current unit
51. Torpid
52. Cut
53. Depart
54. Fairies
55. Warning signal
56. Type of tree
57. Prevaricates
58. Not in favor of
60. Trial
62. Part of a stage setting
64. Fish eggs
66. Indicating maiden name



ASCIT Minutes

Meetings are every week in SAC 13

ASCIT Board of Directors Meeting
Minutes for 13 October 2017. Taken by Dana He.
Officers Present: Sakthi Vetrivel, Kavya Sreedhar, Rachael Morton, Sarah Crucilla, Alice Zhai, Dana He
Guests: Sarah Cai
Call to Order: 10:08 am

President's Report (Sakthi):

- Signed form for taxes.
- ASCIT retreat to beach house, date to be determined.

Officer's Reports:
V.P. of Academic Affairs (Kavya):

- Selecting freshman ARC reps this weekend.
- Launching course capture starting next week.
- A lot of course concerns regarding Ma 2, though getting better now that Nets Katz has returned.
- Add cards due today.

V.P. of Non-Academic Affairs (Rachael):

- Multi-house events will be done through ASCIT proposals instead of having a separate multi-house event fund.
- Rotation went well.

Director of Operations (Sara):

- Not in attendance.

Treasurer (Sarah):

- Still no contact person for reimbursements, so can do transfers to club or Bursar's accounts. Will talk to Tom Mannion about this.
- Sara needs to send out club funding form to schedule meetings.
- Page lent tools to Lloyd, which was broken into and the tools stolen. Request for $880 to replace tools approved.
- Members of Bechtel Committee are presenting to Board of Trustees soon regarding outcomes of focus groups.

Social Director (Alice):

- Trivia Night booked for October 19th and November 16th at Chouse.
- ASCIT movie night (Thor) will be on October 3rd.
- Could possibly get second movie night for Justice League depending on spending.
- Working on compiling a calendar of all house social events.

The California Tech

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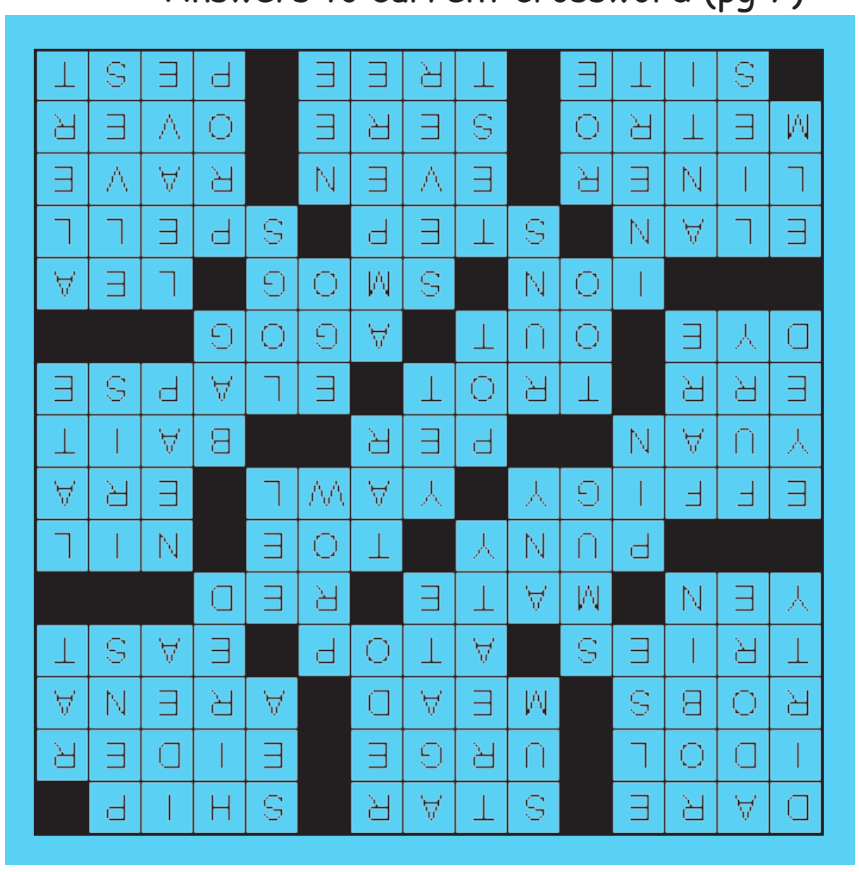
Letters and submissions are welcome; e-mail submissions to *tech@caltech.edu* as *plain-text* attachments, including the author's name, by Friday of the week before publication. *The Tech* does accept anonymous contributions *under special circumstances*. The editors reserve the right to edit and abridge all submissions for any reason. All written work remains property of its author.

The advertising deadline is 5 p.m. Friday; all advertising should be submitted electronically or as camera-ready art, but *The Tech* can also do simple typesetting and arrangement. All advertising inquiries should be directed to the business manager at *tech@caltech.edu*.

Answers to current crossword (pg 7)



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