



Extremely small



incredibly good



What keeps Caltech at the top of the *Times Higher Education* World University Rankings? **Phil Baty** reports from Pasadena on an institution whose cultural DNA includes interdisciplinarity, minimal management and hiring only the very best

If one were to reduce the story of the California Institute of Technology to numbers, it would be difficult to know where to start.

It is 123 years old, boasts 57 recipients of the US National Medal of Science and 32 Nobel laureates among its faculty and alumni (including five on the current staff).

It is the world's number one university – and has been for the past three years of the *Times Higher Education* World University Rankings – and has just 300 professorial staff.

In short, it is tiny, and it is exceptionally good at what it does.

Ares Rosakis, chair of the Division of Engineering and Applied Science, describes Caltech as “a unique species among universities...a very interesting phenomenon”. “Very interesting” may be something of an understatement.

Caltech's neat and unassuming campus sits in a quiet residential neighbourhood in Pasadena, in the shadow of the San Gabriel Mountains.

Although it is only 15 miles away from Hollywood, the Tinseltown razzmatazz seems a world away.

But Caltech can lay claim to its own galaxy of stars. Among a long and illustrious list of former faculty is Charles Richter, inventor of the scale that quantifies the magnitude of earthquakes (handy in Southern California) and Theodore von Kármán, the first head of what is now Nasa's Jet Propulsion Laboratory. He nurtured the pioneering “rocket boys” who risked ridicule in the 1930s as

they brought space rockets from the pages of science fiction comics into the real world. The heavy hitters on the current staff include Mike Brown, the man who “killed Pluto” (when his work led to its being downgraded to a dwarf planet), and John Schwarz, who in December 2013 was named a joint winner of the \$3 million (£1.8 million) 2014 Breakthrough Prize in Fundamental Physics.

It is clear that Caltech is a special place, but how has it achieved this success? Rosakis' first answer focuses on its size.

“I always refer to this small size as being very similar to the size effect that exists in materials – there are special properties that exist when you are extremely small,” he explains in his airy office, the winter sun streaming through a bank of windows on to a chalkboard filled with mathematical formulae.

Working alongside the 300 professorial faculty are about 600 research scholars and, at the last count, 1,204 graduate students and just 977 undergraduates. The private not-for-profit university's freshman “class of 2017” consists of a mere 249 students.

While diminutive scale may be a disadvantage for some institutions, for Caltech, it is at the heart of its being, and perhaps the single most important aspect of its extraordinary global success.

Crucially, it means that Caltech is obliged to be interdisciplinary in its “mode of operation – whether we like it or not”, observes Rosakis.

“I have 77 faculty in engineering and

applied science. MIT [the Massachusetts Institute of Technology] has 490. How can I compete with an excellent place like MIT? We have to have engineers interact with all of the sciences and vice versa – it is a matter of survival. We don't have the breadth to do things in a big way unless they interact.”

If Caltech's size demands that its faculty work across traditional disciplinary boundaries to survive, it also makes such interaction exceptionally easy and natural.

While it may sound like a cliché, at Caltech exciting interdisciplinary ideas really are generated over a cup of coffee in the campus cafe, according to faculty.

Fiona Harrison, Benjamin M. Rosen professor of physics and astronomy, has worked with colleagues in aeronautical engineering, applied physics and many other disciplines.

“You run into them at the coffee shop and start a conversation, and it turns out you are both thinking about some similar technology – and so this cross-fertilisation is natural to the culture, to the fabric of the place,” she says.

“There are arguments that there are some things that you have to be big to do. But ultimately there's a feeling that there's something unique about this environment and you don't want to destroy that.”

Of course, this does mean that hard choices must be made and some areas of research will remain out of bounds in order to focus resources.

But, says Harrison, “at Caltech we have a



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saying – if the field's been around for a while then Caltech shouldn't do it, because we should be inventing the next fields”.

The interdisciplinary culture was demonstrated in late 2013 when the Division of Biology (founded in 1928 by the Nobel prize-winning geneticist Thomas Hunt Morgan) was transformed into a new Division of Biology and Biological Engineering.

The change came after what division chair Steve Mayo describes as the faculty-led “organic drift” of the Division of Engineering and Applied Science's bioengineering department into synthetic biology – looking more at manipulating biological materials.

“We felt it was better to connect that activity to biology and to emphasise the underlying biological emphasis of the engineering activity,” says Mayo, who is Bren professor of biology and chemistry.

Freed from the administrative barriers that they might face elsewhere, he adds, the researchers in his division “can interact in ways that lead to unique things happening”.

Another crucial factor in Caltech's success that is also fundamentally related to its size is its extremely selective academic recruitment strategy, Mayo suggests.

“We don't hire that many faculty each year. In many cases we have faculty searches in a particular area where it may take us several years to find the appropriate person to bring in.

“We've been extremely careful about how we hire faculty, and we are fully committed

to the success of those faculty once they are here.”

Rosakis is much more blunt: “I cannot make mistakes when I hire. I really cannot. We have 16 faculty members in Information Science and Technology – Carnegie Mellon [University in Pittsburgh, a highly ranked research institution] has 200. If I make one hire or two hires that are wrong, I have a huge setback.

“If you ask me what is more important, to get \$100 million into my division or to hire 10 faculty members who are the best, I would say to hire those 10 faculty members.

“Our main purpose of achieving excellence is attracting the best human talent. If we have the best human talent, then the \$100 million will come, because they will be winners in writing grants, they will excite philanthropic donors to give Caltech funding and they will increase the visibility of the whole institute.”

What this means is that decision-makers at Caltech spend “an enormous amount of time making sure that we identify the best available and have the resources to attract them”, Rosakis continues.

“We take our hiring to be our first priority. We hire people and we give them everything they need to succeed. Other places would hire three or four people for the same position and let them compete. We trust that we have made a good choice, and we give them enough gold so that they cannot say that they failed [for lack of] material resources.”

Harrison, who came to Caltech as a





HONOUR BOUND: WHY CALTECH TAKES ITS STUDENTS ON TRUST

The fact that student exams at Caltech are regularly taken at home, and are never supervised, or proctored, is emblematic of a teaching environment based on an extraordinary degree of trust.

Caltech's "Honor Code" is short and simple: "No member of the Caltech community shall take unfair advantage of any other member of the

Caltech community." But as the institution points out in its undergraduate literature, this statement has far-reaching implications. "It means, for instance, that Caltech students are routinely given 24-hour access to labs, workshops, and other facilities on campus... that collaboration on homework and other assignments is not just encouraged, it's practic-

ally essential for success." And it means that students are trusted absolutely not to cheat on exams.

"The expectation is that students will follow the rules without being proctored. Proctoring is not part of the repertoire – many of the finals are take-home," says Markus Meister, Lawrence A. Hanson, Jr. professor of biology at Caltech.

Meister was himself a Caltech student 30 years ago, and he remembers the huge degree of trust placed in him and his fellow students.

"I took a lot of take-home exams – it is a challenge to complete stuff in three hours and usually you don't finish, so you draw a line and say 'this is where I got to in three hours' and then you continue. The teach-

ing fellow might only give you credit for what you did in the three hours."

Caltech boasts an intimate teaching environment – there is a student to faculty ratio of just 3:1, and undergraduates, including first-years, regularly spend their summers working in university laboratories under a fellowship scheme.

Meister believes that cheats simply cannot

prosper in an environment that includes such small-group teaching and close collaboration with colleagues because they would rapidly be exposed.

As the university says: "The Honor Code confers the power to freely choose responsible actions. Caltech students value this freedom highly and guard it fiercely, which is why the system actually works."

postdoc and joined the faculty two years later, emphasises the willingness of the institute to put faith in young researchers.

"We've all heard the 'publish or perish' mantra, but Caltech invests in young people. It said to me: 'OK, you can take a risk.'"

Harrison's risk paid off. Having developed its instrumentation, she is now principal investigator for Nasa's NuSTAR Explorer Mission (nuclear spectroscopic telescope array) – which has deployed orbiting telescopes using high-energy X-rays to study black holes. She also chaired the faculty search committee that selected Caltech's next president, physicist and current University of Chicago provost Thomas F. Rosenbaum, who will take up the post in July.

Money, of course, is also crucial, and one of the few things about Caltech that is not small in scale is its endowment – currently valued at about \$1.8 billion.

Caltech's most prominent benefactors are Gordon Moore – co-founder of the chip manufacturer Intel, who received his PhD from Caltech in 1954 – and his wife, Betty.

In 2001, they gave \$600 million (half from the couple's foundation, and half from them personally). "Moore gave a large sum, and it was a very unusual gift because he said he wanted a good fraction of it to go to innovative research – to doing the things that the government will not fund," says Harrison. "If you want to create a new field and there's no place to apply for funding, you can do it at Caltech."

But it is not just about money – attitude is also key.

"I never heard 'Well, you better just write papers', and I think that attitude really pervades at Caltech – an element of accepting risk for big pay-off," Harrison says.

"It is more important to do something that's new than just to crank out the papers. It is not about the numbers or the citation index, it's about looking beyond that and looking at what is new and truly different. Maybe that comes from a certain amount of self-confidence that the institution has. I think many places are very conscious of being judged by the outside, but Caltech doesn't have that."

This self-confidence has also allowed Caltech to resist rising pressure from governments and funders to place much more emphasis on the application of research for clear, visible economic impact, at the expense of fundamental, curiosity-driven exploration.

For a science and technology institution, it can be a delicate balance – but at Caltech the focus is resolutely blue-sky first.

Mayo explains: "No one comes to Caltech saying, 'I want to start a company.' They come because they want to benefit from the great, open, interdisciplinary environment – to do fundamental work. If they happen to have breakthroughs or discoveries with an application, then commercialisation is a side benefit."

"There's an unfortunate trend in the funding of science and engineering that focuses on 'what are we going to get out of this in terms of application' as opposed to 'let's enable the broad-based fundamental activity that has been demonstrated historically to lead to the kind of technological breakthroughs that become the dominant technologies in the world.'"

So although the focus is on fundamental research, Caltech is perfectly happy to allow the fruits of that labour to be exploited.

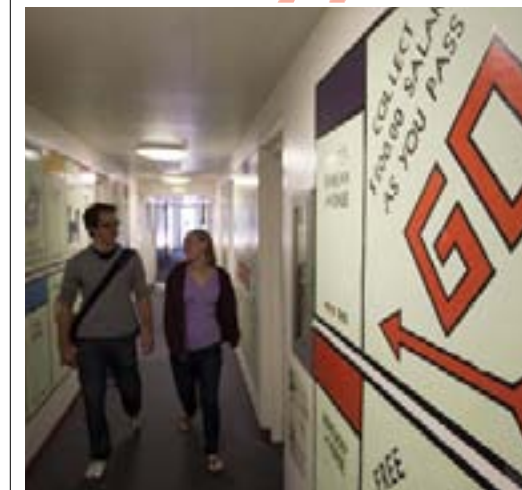
"It is often the case that breakthroughs at the basic level have profound implications for technologies that affect real people," says Mayo. "So certainly at Caltech we do not shy away from pursuing those applications."

As breakthroughs evolve into applications, Caltech is careful to create firewalls between blue-sky research and commercial activity, but it has a strong environment to facilitate technology transfer, primarily through off-campus spin-off companies.

"Caltech is very open and makes setting up such companies relatively easy compared with other academic institutions," Mayo explains. "There's an explicit attempt to make that transition as painless as possible, unlike many institutions that either have barriers put in place on purpose or have bureaucratic impediments to the transfer of technology."

The breaking-down of barriers – both disciplinary and bureaucratic – is a recurring theme, and it was central to luring Markus Meister to Caltech after 20 years at Harvard University – that, and a purpose-built, state-of-

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the-art laboratory and office with one of the best views on campus.

"The biggest difference [between Caltech and Harvard] is that this is a small institution organised in a very simple way," says Meister, who earned his PhD at Caltech in 1987 and is now Lawrence A. Hanson, Jr. professor of biology. "It is way easier to get things done than at Harvard."

Within months of his arrival in July 2012, Meister had set in motion plans for a new graduate programme in neurobiology, and recruitment for it is already under way.

"Within a few months of starting to talk about it, it was approved and in the catalogue and ready to go," he says. "Starting a new PhD programme at Harvard University would be a three-year project by the time you get all the interest-holders informed and on

your side and move obstacles out of the way.

"I have found this past year somehow a lot more effective in how I use my time. When you have a good idea and get people convinced, the step from there to actually seeing it happen is very short. Really staying lean and keeping the bureaucracy shallow is a huge value."

He marvels at the fact that at Caltech he can pick up the phone to the provost, get through and receive quick answers.

"There are fewer people involved in any given decision, and the ones who make the decisions you can actually get on the phone – and it still feels like it is driven by the faculty."

Caltech's Institute Academic Council is where many of the key decisions – faculty promotions, salaries, new hires, funding priorities – are made. It consists of the chairs of Caltech's six academic divisions and the provost and president, who meet for a full day once a month.

All senior administrators remain research-active ("you will not be respected by your faculty if you are considered an empty suit," says Rosakis) and all are closely involved in each division's activities.

The structure is simple, flat and flexible. "I would describe the boundaries between divisions as semi-permeable membranes," says Rosakis. And this prevents the development of silos. "It is one thing to be interdisciplinary intellectually and another thing to be interdisciplinary in terms of resources," he says. "Resources cross boundaries here – this is usually when people become protective – and that is very important."

The factors driving Caltech's extraordinary success thus seem quite simple: it stays deliberately small, resolutely interdisciplinary, exceptionally selective when hiring, and maintains a flat, flexible management system.

But with imitators emerging around the world, and a drive among developing nations to develop world-class institutions quickly, is it a formula that can be replicated?

"I don't think we have any real secrets," says Mayo. "The challenge would be getting this sort of system implemented somewhere else. Caltech exists in the way it does probably in many respects as a fluke of history. Its culture has evolved over decades. If you wanted to set up something new and hire several hundred faculty in order to put a new institution together, it is going to be really hard to find 300 excellent faculty who are going to work in a new environment."

Harrison concurs. "My sense is that the Caltech culture is something that you get after you've been here for a while. I've known a number of people who leave for Harvard or MIT and they end up coming back because there is something different about the culture. I don't know if you could instill it from the top down," she says.

"You can walk into your division chair's office and say 'I have this great idea' or 'I want to switch fields and here's why', and typically the attitude of the administration is to support that. In most universities the faculty think they run the place, but here it may be closer to the truth." ●