

EDUCATION

Where Nobel winners start

List reveals undergraduate schools with most laureates.

BY TOM CLYNES

A new study ranks institutions by the proportion of their undergraduates that go on to win Nobel prizes.

Two schools dominate: École Normale Supérieure (ENS) in Paris and the California Institute of Technology (Caltech) in Pasadena. These small, elite institutions each admit fewer than 250 undergraduates per year, yet their per capita production of Nobelists outstrips some larger world-class universities by factors of hundreds.

"This is a way to identify colleges that have a history of producing major impact," says Jonathan Wai, a psychologist at Duke University in Durham, North Carolina, and a co-author of the unpublished study.

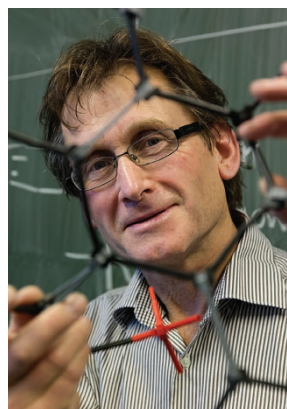
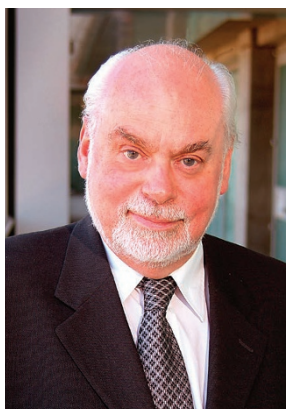
Wai and Stephen Hsu, a physicist at Michigan State University in East Lansing, examined the 81 institutions worldwide that each had at least three alumni who received a Nobel award in any of the six categories between 1901 and 2015. For a meaningful comparison, the team divided the number of Nobel laureates at a university by its estimated number of undergraduate alumni.

Many of the top Nobel-producing institutions are private, with significant financial resources. Among the more surprising high performers were several small US liberal-arts colleges, such as Swarthmore College in Pennsylvania (ranked at number 4) and Amherst College in Massachusetts (number 9).

To gauge trends over time, Wai cut the sample of 870 laureates into 20-year bands. US universities, which now make up almost half of the top 50 list, began to dominate after the Second World War. Whereas French representation in the Nobel ranks has declined over time, top-ranked ENS has remained steady in its output.

Santo Fortunato, a theoretical physicist at Indiana University Bloomington who has researched trends in Nobel prizewinners, cautions that the methodology cannot produce a highly accurate or predictive ranking. "There is a high margin of error due to the low numbers of prominent scholars," he says.

Wai and Hsu agree that there are statistical uncertainties in their rankings, owing to the small number of prizes awarded each year. The two are confident that the ENS and Caltech lead the pack, but say that statistical fluctuations could change the order of institutions placed from third to ninth, Hsu says. ■



Molecular architects: Fraser Stoddart, Bernard Feringa and Jean-Pierre Sauvage.

NANOTECHNOLOGY

Chemistry Nobel for nanomachines

Award recognizes three pioneers of molecular motors.

BY RICHARD VAN NOORDEN & DAVIDE CASTELVECCHI

Three chemists who created tiny molecular machines have won the 2016 Nobel Prize in Chemistry for their intricate designs.

Jean-Pierre Sauvage, at the University of Strasbourg in France; Fraser Stoddart, a Scottish-born chemist at Northwestern University in Evanston, Illinois; and Bernard Feringa, at the University of Groningen in the Netherlands, share the award for their work in the 1980s and 1990s, when they pioneered efforts to miniaturize motors.

"I'm a bit shocked because it was such a great surprise. And I'm so honoured," said Feringa in a telephone interview with the Nobel Committee just after the prize-winners were announced in Stockholm on 5 October.

The three have made molecular knots, shuttles, rotors, chains, pumps, axles, switches, memory devices and even a nanocar — all at the scale of molecules (see 'Nanomachines'). The nanoscale machines are yet to find application, but researchers hope that their uses could range from delivering drugs to computer memory.

"It's early days, of course," Feringa told the Nobel Committee. "But once you are able to control movement, you have a motor, you can think of all kinds of functions." He suggested that the machines could be used as tiny robots in the body to deliver drugs or detect cancerous cells; or as smart materials

that could adapt or change depending on external signals.

"I applaud the fact that — for once in chemistry — Stockholm has recognized a piece of chemistry that is fundamental in its making and being," Stoddart said at a press conference at Northwestern University, held later in the day.

Only a handful of laboratories are currently actively engaged in making nanomachines, says Dean Astumian, who studies the theory of molecular motors at the University of Maine in Orono. But he thinks the field will get a boost from the award. "The recognition that is afforded by a Nobel prize is going to attract the best young people," he says. Astumian thinks the work will provide applications within 25 years. "There's no device that you can buy that's made out of molecular machines. But they're coming."

MOLECULAR ARCHITECTS

In 1983, Sauvage's group was the first to create molecular interlocking chains and rings — called catenanes — which were the first steps to creating the connected parts needed for molecular motors. By creating interlocking rings, Stoddart noted at his press conference, Sauvage's group effectively invented a new way to bind molecules together — a mechanical bond, rather than a chemical one. "New bonds are few and far between. They are really the blue moons," Stoddart said.

Stoddart himself, in 1991, created the first molecular shuttle: a ring-shaped molecule threaded onto an 'axle', called a rotaxane. The

L: RSC; M: UNIV. GRONINGEN; R: VINCENT KESSLER/REUTERS

ring could shunt back and forth between two sites on the axle, which was capped at each end by stoppers, and Stoddart and other chemists worked out how to control that process, using changes in acidity, light or temperature.

Since then, Stoddart's team has used similar rotaxanes to make a molecular 'lift', which can raise itself (by less than a nanometre) above a surface, and an artificial 'muscle', in which rotaxanes bend a thin sheet. The researchers have also used millions of rotaxanes to make a high-density memory device — in which the shuttles flick from an 'on' state to an 'off' state.

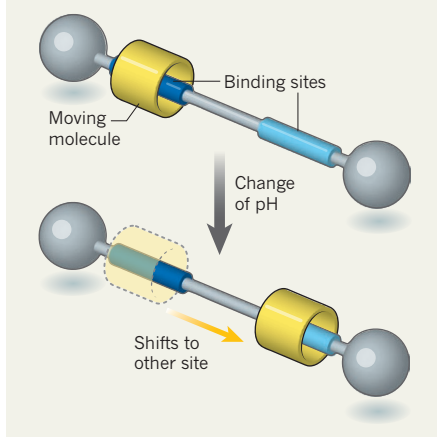
And in 1999, Feringa was the first to develop a synthetic molecular motor — a single molecule with paddle units connected by a carbon-carbon double bond. The paddles rotated, and kept on spinning, when the bond was broken with light. Feringa showed that the motors could have macroscale effects, such as rotating a glass rod sitting on top of them. Perhaps most famously, Feringa has also created a four-wheel-drive 'nanocar' out of the motors.

WIDER IMPACTS

The Nobel prizewinners' work — and other chemists' nanomachines — have also had an impact on researchers' understanding of nature, Astumian says. In particular, the artificial systems have helped to demonstrate that all chemically powered molecular

NANOMACHINES

Mechanisms the size of molecules are governed by the rules of chemistry, rather than Newtonian mechanics. An example is this switch called a rotaxane. A ring-shaped molecule is threaded onto a linear molecule and shifts between two binding sites as the acidity of the surrounding solution is altered.



machines, whether synthetic or biological, work on the same principle: they selectively harvest the random jiggles of Brownian motion, rather than push against them.

Asked by reporters at the Nobel press conference whether his machines would find a

use, Feringa likened the creators of minuscule machines to the Wright brothers, who made their maiden flight in a powered aircraft more than 100 years ago. "People were saying, why do we need a flying machine? Now we have a Boeing 747 and an Airbus. That's a little bit how I feel. The opportunities are great."

During his own press conference, Stoddart also took political swipes, both at recent UK anti-immigration rhetoric and at US Presidential candidate Donald Trump. He said that his old country, the United Kingdom, was "in a real mess because it thinks it can raise borders to people coming in". And referring to Trump's comment in his first debate with Hillary Clinton that not paying federal taxes would be "smart", Stoddart said that one-third of his Nobel earnings would go to taxes, because, he said, "I am not smart". ■

CORRECTIONS

The News story 'Ukraine embraces solar and wind power' (*Nature* **537**, 598; 2016) gave the wrong year for the annexation of the Crimean peninsula. It happened in 2014. And the News story 'Medical award for cell recycling' (*Nature* **538**, 18–19; 2016) gave the wrong affiliation for Hitoshi Nakatogawa — he is at the Tokyo Institute of Technology.

CORRECTION

The News story 'Where Nobel winners start' (*Nature* **538**, 152; 2016) wrongly said that the study assessed only four categories of the Nobel awards, in fact it looked at all six.