the brain's complex biochemistry, at least according to Damasio. "Emotions and feelings, as we know them, are related to our 'wet' biology, to our flesh," he said. "Formally you can construct them in robotic artefacts but there is no reason to believe [that] they would be the same."

In this regard, Michael Koenigs, from the Department of Psychiatry at the University of Wisconsin–Madison, USA, pointed out that humans commonly appear to balance rational and emotional factors when making judgements, creating the impression that there are distinct neural systems competing with each other. "From a psychological standpoint, in the midst of a sticky moral dilemma it can certainly feel like your mind is being pulled in two different directions," he said. "And in terms of the brain, it is very clear that certain areas are more concerned with emotion and affect, while other areas are more associated with 'cold' cognitive processes. Both systems play a role in determining morality, but at the neural level the relationship between the systems is more of an integration than a competition."

Until recently there was very little direct observation of these neurological processes at work. However, recent research based on functional magnetic resonance imaging has revealed that 'true' and 'false' statements activate different regions of the prefrontal cortex. The researchers found that people tend to use separate processes to resolve the distinctions between true and false statements, unless the answer is blindingly obvious (Marques *et al*, 2009). They concluded that people accept statements as true initially and confirm this merely by a call to memory. However, if the initial check suggests that the statement might be false, further reasoning is required to confirm the rejection. "The idea supported by this paper and others is that when the statement to verify is true—and by default we assume [that] it is—the task is to find if we have or recognize that information in our memory," explained Frederico Marques, one of the authors of the study from the University of Lisbon, Portugal. "When we do not find that information, or if we have doubts, we further process the information, more like problem solving."

Animals that are capable of MSR also possess primitive abilities to assess truth or falsehood. Magpies, for example, have to decide whether a particular individual

can be trusted to not steal food. Of course, more research is needed to provide further insight into the neurological processes involved in such assessments and to illuminate the evolutionary history of such a skill. What is established, however, is that the roots of complex social behaviour and the capacity for abstract thought—as well as ethical judgment, perhaps—can be found predominantly in the more advanced warm-blooded and social vertebrates. The capacity for morality is perhaps not, after all, uniquely human.

REFERENCES

- Gallup Jr GG (1970) Chimpanzees: self-recognition. *Science* **167**: 86–87
- Goodman M *et al* (2009) Phylogenomic analyses reveal convergent patterns of adaptive evolution in elephant and human ancestries. *Proc Natl Acad Sci USA* **106**: 20824–20829
- Marques JF, Canessa N, Cappa S (2009) Neural differences in the processing of true and false sentences: insights into the nature of

- 'truth' in language comprehension. *Cortex* **45**: 759–768
- Plotnik JM, de Waal FBM, Reiss D (2006) Self-recognition in an Asian elephant. *Proc Natl Acad Sci USA* **103**: 17053–17057
- Prior H, Schwarz A, Güntürkün O (2008) Mirror-induced behavior in the magpie (*Pica pica*): evidence of self-recognition. *PLoS Biol* **6**: e202
- Reiss D, Marino L (2001) Mirror self-recognition in the bottlenose dolphin: a case of cognitive convergence. *Proc Natl Acad Sci USA* **98**: 5937–5942
- Reiss D, McCowan B, Marino L (1997) Communicative and other cognitive characteristics of bottlenose dolphins. *Trends Cogn Sci* **1**: 2
- Sanfey AG, Rilling JK, Aronson JA, Nystrom LE, Cohen JD (2003) The neural basis of economic decision-making in the ultimatum game. *Science* **300**: 1755–1758

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Women and telomeres

Last year's Nobel Prizes for Carol Greider and Elizabeth Blackburn should be encouraging for all female scientists with children

Howard Wolinsky

Carol Greider, a molecular biologist at Johns Hopkins University (Baltimore, MD, USA), recalled that when she received a phone call from the Nobel Foundation early in October last year, she was staring down a large pile of laundry. The caller informed her that she had won the 2009 Nobel Prize in Physiology or Medicine along with Elizabeth Blackburn, her mentor and co-discoverer of the enzyme telomerase, and Jack Szostak. The Prize was not only the ultimate reward for her own achievements, but it also highlighted a research field in biology that, unlike most others, is renowned for attracting a significant number of women.

Indeed, the 2009 awards stood out in particular, as five women received Nobel prizes. In addition to the Prize for Greider and Blackburn, Ada E. Yonath received one in chemistry, Elinor Ostrom became the first female Prize-winner in economics, and Herta Müller won for literature (Fig 1).

Greider, the daughter of scientists, has overcome many obstacles during her career.

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She had dyslexia that placed her in remedial classes; "I thought I was stupid," she told *The New York Times* (Dreifus, 2009). Yet, by far the biggest challenge she has tackled is being a woman with children in a man's world. When she attended a press conference at Johns Hopkins to announce the Prize, she brought her children Gwendolyn and Charles with her (Fig 2). "How many men have won the Nobel in the last few years, and they have kids the same age as mine, and their kids aren't in the picture? That's a big difference, right? And that makes a statement," she said.

Marie Curie (1867–1934), the Polish–French physicist and chemist, was the first woman to win the Prize in 1903 for physics,

Fig 1 | The 2009 Nobel Laureates assembled for a photo during their visit to the Nobel Foundation on 12 December 2009. Back row, left to right: Nobel Laureates in Chemistry Ada E. Yonath and Venkatraman Ramakrishnan, Nobel Laureates in Physiology or Medicine Jack W. Szostak and Carol W. Greider, Nobel Laureate in Chemistry Thomas A. Steitz, Nobel Laureate in Physiology or Medicine Elizabeth H. Blackburn, and Nobel Laureate in Physics George E. Smith. Front row, left to right: Nobel Laureate in Physics Willard S. Boyle, Nobel Laureate in Economic Sciences Elinor Ostrom, Nobel Laureate in Literature Herta Müller, and Nobel Laureate in Economic Sciences Oliver E. Williamson. © The Nobel Foundation 2009. Photo: Orasis.

together with her husband Pierre, and again for chemistry in 1911—the only woman to twice achieve such recognition. Curie's daughter Irène Joliot-Curie (1897–1956), a French chemist, also won the Prize with her husband Frédéric in 1935. Since Curie's 1911 prize, 347 Nobel Prizes in Physiology or Medicine and Chemistry (the fields in which biologists are recognized) have been awarded, but only 14—just 4%—have gone to women, with 9 of these awarded since 1979. That is a far cry from women holding up half the sky.

Yet, despite the dominance of men in biology and the other natural sciences, telomere research has a reputation as a field dominated by women. Daniela Rhodes, a structural biologist and senior scientist at the MRC Laboratory of Molecular Biology (Cambridge, UK) recalls joining the field in 1993. “When I went to my first meeting, my world changed because I was used to being one of the few female speakers,” she said. “Most of the speakers

there were female.” She estimated that 80% of the speakers at meetings at Cold Spring Harbour Laboratory in those early days were women, while the ratio in the audience was more balanced.

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“There's nothing particularly interesting about telomeres to women,” Rhodes explained. “[The] field covers some people like me who do structural biology, to cell biology, to people interested in cancers [...] It could be any other field in biology. I think it's [a result of] having women start it and [including] other women.” Greider comes to a similar conclusion: “I really see it as a founder effect. It started with Joe

Gall, a cell biologist, [...] welcomed women to his lab at a time when the overall situation for women in science was “reasonably glum”...

Gall [who originally recruited Blackburn to work in his lab].”

Gall, a cell biologist, earned a reputation for being gender neutral while working at Yale University in the 1950s and 1960s; he welcomed women to his lab at a time when the overall situation for women in science was “reasonably glum,” as he put it. “It wasn't that women were not accepted into PhD programs. It's just that the opportunities for them afterwards were pretty slim,” he explained.

“Very early on he was very supportive to a number of women who went on and then had their own labs and [...] many of those women [went] out in the world [to] train other women,” Greider commented. “A whole tree that then grows up that in the end there are many more women in that particular field simply because of that historical event.”

Thomas Cech, who won the Nobel Prize for Chemistry in 1989 and who worked in Gall's lab with Blackburn, agreed: “In biochemistry and metabolism, we talk about positive feedback loops. This was a positive feedback loop. Joe Gall's lab at Yale was an environment that was free of bias against women, and it was scientifically supportive.”

Gall, now 81 and working at the Carnegie Institution of Washington (Baltimore, MD, USA), is somewhat dismissive about his positive role. “It never occurred to me that I was doing anything unusual. It literally, really did not. And it's only been in the last 10 or 20 years that anyone made much of it,” he said. “If you look back, [...] my laboratory [was] very close to [half] men and [half] women.”

During the 1970s and 1980s; “[w]hen I entered graduate school,” Greider recalled, “it was a time when the number of graduate students [who] were women was about 50%. And it wasn't unusual at all.” What has changed, though, is the number of women choosing to pursue a scientific career further. According to the US National Science Foundation (Arlington, VA, USA), women received 51.8% of doctorates in the life sciences in

2006, compared with 43.8% in 1996, 34.6% in 1986, 20.7% in 1976 and 11.9% in 1966 (www.nsf.gov/statistics).

In fact, Gall suspects that biology tends to attract more women than the other sciences. "I think if you look in biology departments that you would find a higher percentage [of women] than you would in physics and chemistry," he said. "I think [...] it's hard to dissociate societal effects from specific effects, but probably fewer women are inclined to go into chemistry [or] physics. Certainly, there is no lack of women going into biology." However, the representation of women falls off at each level, from postdoc to assistant professor and tenured professor. Cech estimated that only about 20% of the biology faculty in the USA are women.

"[I]t is a leaky pipeline," Greider explained. "People exit the system. Women exit at a much higher proportion than do men. I don't see it as a [supply] pipeline issue at all, getting the trainees in, because for 25 years there have been a great number of women trainees."

"We all thought that with civil rights and affirmative action you'd open the doors and women would come in and everything would just follow. And it turned out that was not true."

Nancy Hopkins, a molecular biologist and long-time advocate on issues affecting women faculty members at the Massachusetts Institute of Technology (Cambridge, MA, USA), said that the situation in the USA has improved because of civil rights laws and affirmative action. "I was hired—almost every woman of my generation was hired—as a result of affirmative action. Without it, there wouldn't have been any women on the faculty," she said, but added that: "We all thought that with civil rights and affirmative action you'd open the doors and women would come in and everything would just follow. And it turned out that was not true."

I ndeed, in a speech at an academic conference in 2005, Harvard President Lawrence Summers said that innate differences between males and females might be one reason why fewer women than men succeeded in science and mathematics.

Fig 2 | Mother, scientist and Nobel Prize-winner: Carol Greider is greeted by her lab and her children.
© Johns Hopkins Medicine 2009. Photo: Keith Weller.

The economist, who served as Secretary of Treasury under President William Clinton, told *The Boston Globe* that "[r]esearch in behavioural genetics is showing that things people previously attributed to socialization weren't [due to socialization after all]" (Bombardieri, 2005).

Some attendees of the meeting were angered by Summers's remarks that women do not have the same 'innate ability' as men in some fields. Hopkins said she left the meeting as a protest and in "a state of shock and rage". "It isn't a question of political correctness, it's about making unscientific, unfounded and damaging comments. It's what discrimination is," she said, adding that Summers's views reflect the problems women face in moving up the ladder in academia. "To have the president of Harvard say that the second most important reason for their not being equal was really their intrinsic genetic inferiority is so shocking that no matter how many times I think back to his comments, I'm still shocked. These women were not asking to be considered better or special. They were just asking to have their gender be invisible."

N onetheless, women are making inroads into academia, despite lingering prejudice and discrimination. One field of biology that counts a relatively high number of successful women

among its upper ranks is developmental biology. Christiane Nüsslein-Volhard, for example, is Director of the Max Planck Institute for Developmental Biology in Tübingen, Germany, and won the Nobel Prize for Physiology or Medicine in 1995 for her work on the development of *Drosophila* embryos. She estimated that about 30% of speakers at conferences in her field are women.

...for many women, the recent Nobel Prize for Greider [...] and Blackburn [...] therefore comes as much needed reassurance that it is possible to combine family life and a career in science

However, she also noted that women have never been the majority in her own lab owing to the social constraints of German society. She explained that in Germany, Switzerland and Austria, family issues pose barriers for many women who want to have children and advance professionally because the pressure for women to not use day care is extremely strong. As such, "[w]omen want to stay home because they want to be an ideal mother, and then at the same time they want to go to work and do an ideal job and somehow this is really very difficult," she said. "I don't know a single case where the

Fig 3 | Elizabeth Blackburn greets colleagues and the media at a reception held in Genentech Hall at UCSF Mission Bay to celebrate her award of the Nobel Prize in Physiology or Medicine. © University of California, San Francisco 2009. Photo: Susan Merrell.

husband stays at home and takes care of the kids and the household. This doesn't happen. So women are now in an unequal situation because if they want to do the job, they cannot; they don't have a chance to find someone to do the work for them. [...] The wives need wives." In response to this situation, Nüsslein-Volhard has established the CNV Foundation to financially support young women scientists with children in Germany, to help pay for assistance with household chores and child care.

Rhodes, an Italian native who grew up in Sweden, agreed with Nüsslein-Volhard's assessment of the situation for many European female scientists with children. "Some European countries are very

old-fashioned. If you look at the Protestant countries like Holland, women still do not really go out and have a career. It tends to be the man," she said. "What I find depressing is [that in] a country like Sweden where I grew up, which is a very liberated country, there has been equality between men and women for a couple of generations, and if you look at the percentage of female professors at the universities, it's still only 10%." In fact, studies both from Europe and the USA show that academic science is not a welcoming environment for women with children; less so than for childless women and fathers, who are more likely to succeed in academic research (Ledin *et al*, 2007; Martinez *et al*, 2007).

For Hopkins, her divorce at the age of 30 made a choice between children or a career unavoidable. Offered a position at MIT, she recalled that she very deliberately chose science. She said that she thought to herself: "Okay, I'm going to take the job, not have children and not even get married again because I couldn't imagine combining that career with any kind of decent family life." As such, for many women, the recent Nobel Prize for Greider, who raised two children, and Blackburn (Fig 3), who raised one, therefore comes as much needed reassurance that it is possible to combine family life and a career in science. Hopkins said the appearance of Greider and her children at the press conference sent "the message to young women that they can do it, even though very few women in my generation could do it. The ways in which some women are managing to do it are going to become the role models for the women who follow them."

REFERENCES

- Bombardieri M (2005) Summers' remarks on women draw fire. *Boston Globe* 17 Jan
- Dreifus C (2009) A conversation with Carol W. Greider: on winning a Nobel Prize in science. *New York Times* 12 Oct
- Martinez ED, Botos J, Dohoney KM, Geiman TM, Kolla SS, Olivera A, Qiu Y, Rayasam GV, Stavreva DA, Cohen-Fix O (2007) Falling off the academic bandwagon. Women are more likely to quit at the postdoc to principal investigator transition. *EMBO Rep* 8: 977–981
- Ledin A, Bornmann L, Gannon F, Wallon G (2007) A persistent problem. Traditional gender roles hold back female scientists. *EMBO Rep* 8: 982–987

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