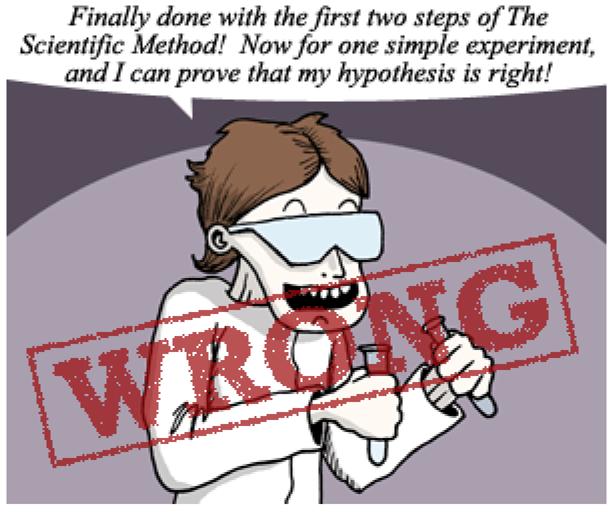
The social side of science: A human and community endeavor

The stereotypical image of a scientist is not a very social one: a geeky guy, isolated in a windowless basement lab, strictly following the rules of THE Scientific Method, until he finally makes a great discovery. No collaborators, no communication, no diversity. What's wrong with this picture? Well, several things:



1) First, as discussed in *How science works*, there is no single scientific method that can be blindly followed. The process of science is flexible and may take many possible paths.
2) Second, science is done by unique individuals—not by automated robots coldly following a routine without motivation, ambition, or creativity. Scientists are people too! Many of them care passionately about their work, and many of them are intensely creative. Their personalities, backgrounds, and goals are highly diverse.
3) And finally, science is embedded within a global scientific community. This community provides cultural norms, expectations, and accumulated knowledge, which are essential to the expansion of scientific knowledge.

In opposition to its stereotype, science much more typically works something like this: After reading up on the recent work of other scientists studying animal behavior, a scientist in Brazil gets an idea for a new bird song experiment while playing a word game with her kids. She calls a colleague in Canada to discuss the idea and to find out where she can get the recording software she will need for the experiment. She then recruits a few students and a visiting researcher from China to work on the project, and they apply for funding. After they complete the study, the team writes up the work and submits it to a journal for publication. The journal sends it out to three different scientists for review: one in Japan, one in the U.S., and one in the U.K. The reviewers like the study but suggest some changes to improve the statistical analysis. The team makes the changes and the paper is published several months later. A graduate student in France reads the paper with his lab group, emails the Brazilian researcher to learn more about her experimental procedures, and comes up with a follow-up experiment. He recruits another graduate student and a professor to work on the project with him … and so on. Compared to its stereotype, real science is more complex—but also more human.

Scientists do spend time working alone—in the field, in the lab, or at the computer—but most also collaborate on research with others. And, of course, scientists don't *just* do research. Most scientific work also involves reviewing other scientists' articles for journals, teaching, mentoring graduate students and younger scientists, speaking at conferences, and participating in scientific societies. So the job of being a scientist involves lots more than disappearing into a windowless lab and running an endless series of experiments!

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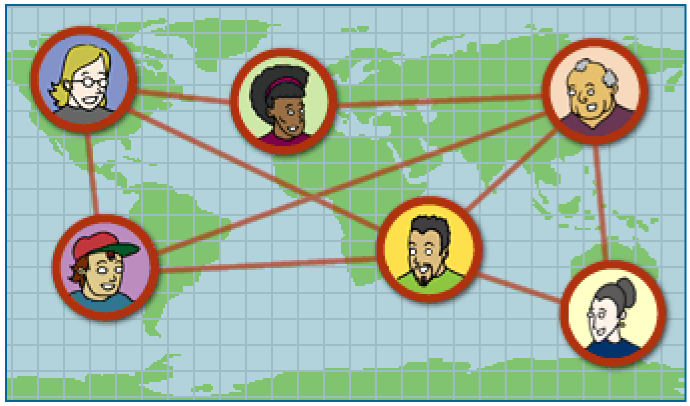
The scientific community: Diversity makes the difference



People from all over the world from all sorts of different cultures and backgrounds are a part of the scientific community. At some points in history, science *has* largely been the domain of white males, but that is simply no longer true. A glance at the authors on recent papers in top scientific journals confirms that diversity is now the norm. Rajsapan Jain, Khayrul Kabir, Joe Gilroy, Keith Mitchell, Kin-chung Wong, and Robin Hicks collaborate on high temperature magnets. Nerilie Abram, Michael Gagan, Zhengyu Liu, Wahyoe Hantoro, Malcolm McCulloch, and Bambang Suwargadion collaborate on ocean-atmosphere interactions. And Jane Carleton and her team of 64 researchers in 10 different countries around the world collaborate on the genome sequences of disease pathogens. Many of these scientists come from different societal cultures and geographic regions; however, in their research, they are all united by the global culture of science. Science is truly without borders.

Scientists from such diverse backgrounds bring many points of view to bear on scientific problems. The 24-year-old chemistry graduate student from South Africa, the 41-year-old fisheries biologist from Florida, and the 65-year-old paleontologist from Beijing probably all have quite different perspectives on the world, and science benefits from such diversity.

- **Diversity facilitates specialization.** Scientists have different strengths and different interests. Not only do people from different backgrounds choose to investigate different questions, but they may approach the same question in different ways. So, the biologist with a penchant for math, the biologist with an interest in human behavior, and the biologist who can't get enough of microscopes and lab work can all focus on their strengths. While each might choose to tackle the same topic (say, human cognition), they will do so from different angles, contributing to a more complete understanding of the topic.

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- **Diversity invigorates problem solving.** Science benefits greatly from a community that approaches problems in a variety of creative ways. A diverse community is better able to generate new research methods, explanations, and ideas, which can help science over challenging hurdles and shed new light on problems. For example, Albert Einstein approached the notions of space and time in a very different way from his contemporaries, coming up with ideas that, though unintuitive, were supported by evidence and opened up new areas of research.

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- **Diversity balances biases.** Science benefits from practitioners with diverse beliefs, backgrounds, and values to balance out the biases that might occur if science were practiced by a narrow subset of humanity. As an example, consider the ongoing scientific investigation of climate change. With such a hot-button issue, personal beliefs about the environment, the economy, business, and politics could unwittingly bias one's search for or assessment of the evidence. But science relies on a diverse community, whose personal views run the gamut: liberal to conservative, tree-hugging to business-friendly, and all sorts of combinations thereof. Scientists strive to be impartial and objective in their assessments of scientific issues, but in those occasional cases in which personal biases sneak in, they are kept in check by a diverse scientific community.

So science depends on diversity. If scientists were all the same, scientific controversy would be rare, but so would scientific progress! Despite their diversity, all of those individual scientists are part of the same scientific community and contribute to the scientific enterprise in valuable ways.

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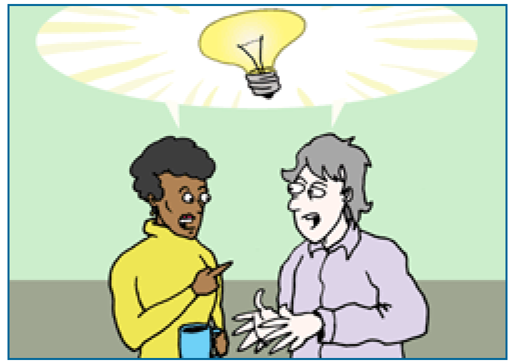
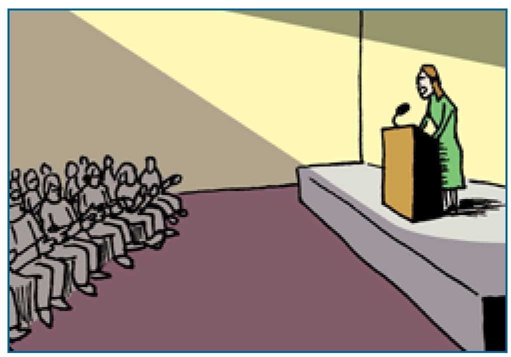
Science: A community enterprise

Most large-scale human endeavors involve a supporting community. From high schools to dairy farms, political parties to professional snowboarding competitions—they all rely on diverse communities with different members fulfilling different roles. And science is no exception. The scientific community is made up of researchers, students, lab technicians, the people who work at scientific journals, employees at funding agencies—in short, anyone who helps science govern itself and move forward.

In *How science works*, we briefly summarized some of the nitty-gritty, day-to-day functions served by the scientific community. Here, we elaborate on those and discuss broader functions served by the community:



Inspiration. Community-level interactions encourage innovation and spark ideas about new lines of evidence, new applications, new questions, and alternate explanations. For example, James Watson and Francis Crick came up with a new and brilliant idea for the structure of DNA, but that idea did not come out of the blue. The idea was sparked by evidence that many other scientists (including Linus Pauling, Erwin Chargaff, Maurice Wilkins, and especially Rosalind Franklin) discovered and made available to the scientific community prior to the Watson/Crick model.



Motivation. Some people are driven by the thrill of competition—swimmers swim faster, politicians campaign harder, and students study more for college entrance exams when they know that they are competing against others. Scientists are no exception. Some scientists are motivated by the sense of competition offered by the community (e.g., rival teams racing to unlock the sequence of the human genome). Similarly, the community offers scientists the prospect of recognition from their peers. In science, achievement is usually measured, not in terms of money or titles, but in terms of respect and esteem from colleagues. The idea of uncovering a new line of evidence relating to the Big Bang is motivating in and of itself, but many scientists also appreciate the respect from other scientists that making such a discovery would engender. In science, both competition and recognition from the community encourage going out on a limb, testing a new idea, creative thinking, and plain old hard work.

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RACING FOR THE HUMAN GENOME

In the 1980s, scientists set their sights on what seemed to be a lofty, but for the first time, achievable goal: to record the DNA sequence of the three billion or so base pairs that make up the human genome. In 1990, the publicly funded Human Genome Project (HGP) began its work in earnest, using a tried and true sequencing technique that begins with a map of genetic landmarks on each chromosome. However, in 1998, that effort was challenged by a private company, Celera. Celera proposed to decode the genome using a new so-called shotgun technique that didn't require an initial landmark map—and to complete its work in just three years, four years before the HGP would complete their sequence! This competition inspired the HGP to accelerate their work and move their target completion date up to rival Celera's. In the end, this rivalry propelled both efforts forward. Both teams published their working drafts of the genome ahead of schedule in February of 2001—and when they did, the private team's paper had more than 100 authors and the HGP's had more than 1000. Talk about teamwork!

Division of labor. Science is simply too broad for an individual on his or her own to handle! Even research within a single narrow field (e.g., cellular biology) may cover an immense array of specialized topics, from the chemical details of decoding DNA to cellular communication. That specialized knowledge is divided up among different researchers, who may then share their expertise by working together. Collaborations and division of labor are increasingly important today, as our scientific understanding, techniques, and technologies expand. There's simply more to know than ever before! And as we learn more about the world, more research is performed at the intersections of different fields: chemical reactions within cellular organelles, the mathematics of protein folding, the interplay between Earth's geologic history and biological evolution, or the physics of snail locomotion. Such cross-disciplinary studies are better approached by a team of experts from different fields than by a single individual struggling to keep up-to-date with too many topics.

A cumulative knowledge base. Science builds on itself. We wouldn't have general relativity if we didn't have classical mechanics. And we wouldn't have classical mechanics if we didn't have Galileo's studies of motion and revolutionary ideas about astronomy. A similar deep history spanning hundreds of years could be given for almost any scientific idea. The scientific community provides the cumulative knowledge base on which science is built.

Scrutiny. Participating in the scientific community involves scrutinizing the work of others and allowing your own work to be similarly evaluated by your peers. This system of checks and balances verifies the quality of scientific research and assures that evidence is evaluated fairly.

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Scientific scrutiny

The scientific community provides a system of checks and balances that ensures the quality of scientific work, double-checks arguments, and makes sure that ideas are evaluated fairly. This scrutiny can serve a few different functions—from fact-checking to whistleblowing:

The community evaluates evidence and ideas. Scientists describe their work at conferences, in journal articles, and in books. By disseminating their ideas, study methods, and test results in these ways, scientists allow other community members to check their work, both by reviewing what has been done and trying to replicate all or part of it. This helps to ensure that evidence meets high standards, that all relevant lines of evidence are explored, that judgments are not based on flawed reasoning, and hence, that science moves in the direction of more and more accurate explanations. For example, in 1989, when two scientists claimed to have produced nuclear fusion at temperatures lower than was thought possible, the scientific community took a close look at their methods and results. Community members found several ways to improve the experiments and several tests that the original researchers had failed to perform. Meanwhile, other scientists got started on trying to replicate the experimental results and discovered that they could not be consistently reproduced. The scientific community ultimately found that the evidence was not compelling enough to warrant accepting the researchers' claims.

The community balances biases. Scientists are people too. They come from different backgrounds, have different personal beliefs, and favor different hypotheses and theories—and all of that can result in unintentional biases—even when scientists strive to remain objective. Luckily, the scientific community is diverse, and for every scientist who looks at a result through rose-tinted glasses, there is another who peers at it through her own blue-tinted ones. Because of the community's diversity, individual biases are balanced out and the community as a whole can evaluate scientific ideas fairly.

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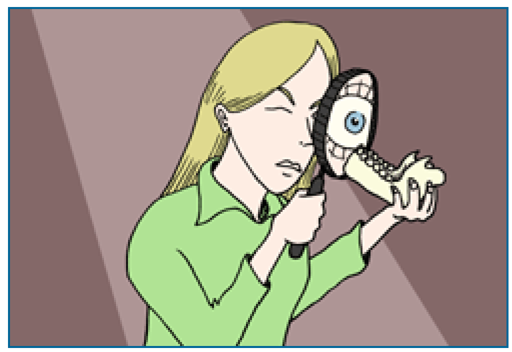
CHECKS AND BALANCES

Before the 1970s, the field of primatology was dominated by men. Male scientists observed and recorded primate behavior in the wild, male scientists developed explanations to understand those behaviors, and male scientists read and evaluated each others' work. And at that time, observations suggested that primate social life was largely controlled by males, with females playing a more passive role. But that changed when women scientists began to work in the field in the 1970s. Because of their own gender experiences, these women paid more attention to subtleties in the female primates' behavior, and revealed that female primates actually have elaborate sex lives and manipulate male behavior in many ways. So in this case, a diverse assemblage of scientists counterbalanced each others' biases, leading to a more complete and accurate understanding of primate societies.

Jeanne Altmann has studied the behaviors and social interactions of primates, primarily baboons, for more than 35 years.



The community helps identify and eliminate fraud. Though fraud is rare in science, it sometimes happens. These occasional cases of fraud are identified through the scrutiny of the scientific community. For example, a recent case in which medical researcher Jon Sudbø faked data on 900 Norwegian patients was discovered by another scientist familiar with the group of patients with whom he claimed to be working. Because they build upon the work of others, scientists take fraud very seriously. No one wants to build their own work on a shaky foundation supplied by fraudulent ideas.

Science depends on its community in many ways: from the specific (e.g., catching a mistake in an article) to the general (e.g., dividing up the enormous amount of work that keeps science moving forward). Being part of that community means meeting some expectations …

Jeanne Altmann photo courtesy of Jeanne Altmann.

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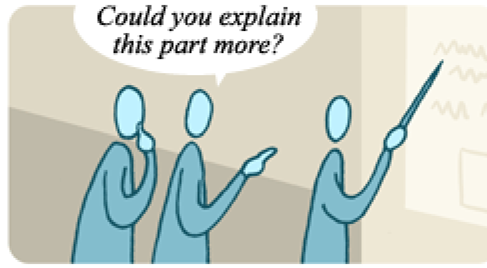
Scientific culture: Great expectations

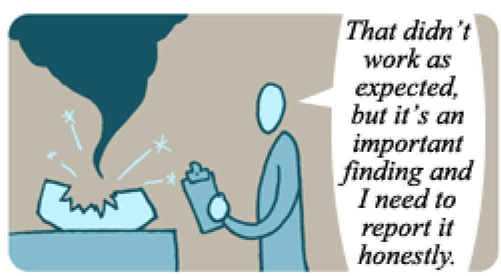
While we typically think of culture as defined by geography or ethnicity (e.g., American culture, Chinese culture), the term also applies to the practices, behaviors, and expectations of smaller groups of people—whether they're a gang of skateboarding youth or the employees of a high-powered consulting firm. Though embedded in the larger culture surrounding them, such subcultures have their own sets of unwritten rules for interacting with one another, and scientists are no exception. In science, these rules of good behavior are fairly general but are essential to maintaining the quality of scientific evidence and ideas. The scientific community expects:



Rigorous scrutiny. Imagine that you walk into a room where someone is speaking to a crowd of people. Audience members are questioning the speaker intently: "Did you consider …? But what about …? Why do you think that …?" In many communities, such intense scrutiny would signal distrust of the speaker, but in science, such scrutiny is business-as-usual. In fact, it often means that the speaker has made an important point that everyone cares enough about to question and investigate further. In science, all ideas (especially the important ones!) must stand up to rigorous scrutiny. The culture of science does not value dogma. Scrutinizing, questioning, and investigating important ideas helps ensure that only ideas supported by evidence and based on sound reasoning are accepted by the community.

IS IT REALLY ALL RELATIVE?

Albert Einstein's writings on special and general relativity presented a novel picture of the universe: time could expand and contract, space was integrated with time into the new entity space-time, and matter could theoretically be reconstituted in the form of energy. When general relativity was proposed in 1916, the ideas were strange to many and confusing to others, but definitely intriguing—especially since the theory helped make sense of previously inexplicable anomalies, like aberrations in the orbit of Mercury. Immediately afterwards and right up to today, scientists continue to scrutinize and test Einstein's ideas, not because they think that general relativity must be wrong—but because so many aspects of those ideas seem to be right!



Honesty, integrity, and objectivity. The aim of science is to uncover the real workings of the natural world, and that requires honesty. You can't get to the truth by exaggerating results, fudging numbers, selectively reporting data, or interpreting evidence in a biased way. Hence, scientists expect other scientists to act with honesty and integrity, and treat any violation of this expectation quite seriously.

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THE BEST POLICY

In science, honesty really is the best policy—even if that means publicizing a slip-up. Geoffrey Chang, a professor at the Scripps Research Institute, has made a successful career working out the physical structures of proteins used in cell membranes. His work was published in top journals and cited by other scientists many times. Then, in 2006, he found a mistake. Prompted by conflicting results from other researchers, Chang discovered that, for the past five years, he had been analyzing his data with a flawed computer program, leading to incorrect results. So what did he do? Exactly what the culture of science expected of him: he published letters retracting his previous work, offered an apology, and then started the work of reanalyzing his data in order to correct his results.

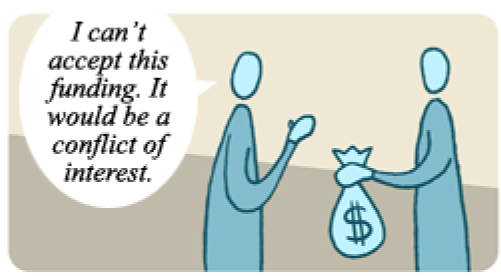
Geoffrey Chang

Credit where credit is due. In science, credit matters. A magazine or newspaper article rarely acknowledges the sources of its arguments, the books the author read, or the interviews conducted. Science, on the other hand, is scrupulous about giving credit where credit is due. Scientific research articles always provide a list of citations, crediting other scientists for ideas, techniques, and studies that were built upon by the current research. This reference system gives credit to those who deserve it, but it also creates a sort of paper trail that helps other scientists better evaluate the new study and see how it fits with previous research. By providing a list of references, an author invites other scientists to see for themselves if the ideas the author cites are supported by evidence, if the assumptions he or she makes are justified, and if the techniques described by others have been properly implemented.

SETTING YOUR CITES

The number of citations a paper receives can help indicate how influential it was, since important research influences how other scientists think about a topic and will be cited many times in other papers. For example, the 1974 paper that originally hypothesized that chlorofluorocarbons would deplete the ozone layer has been cited more than 1700 times! Compared to many other papers published the same year (e.g., a paper on the nutritive value of coconut protein extract, which has received five citations), that's a pretty impressive statistic!

Adherence to ethical guidelines. Science is flexible and open to new ideas, but it is not an anarchic free-for-all. Many laws apply to science, and in many cases, scientists have constructed their own even more stringent guidelines in order to ensure that scientific work is of high quality, is performed in ethical ways, and benefits society. For example, scientific journals maintain an elaborate set of policies covering everything from scientists with a financial stake in their own studies, to biosecurity threats that might result from publishing an article, to the care and use of research animals, to how human participants in a study must be treated. Not abiding



Geoffrey Chang photo: Scripps Research Institute.

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by these policies makes it difficult (or impossible) to get one's research published. Funding agencies maintain a similar set of guidelines that must be followed if a scientist hopes to get research funds from that agency. And of course, scientific organizations get in on the act too. For example, the National Academies (a group of premier scientific organizations in the U.S.) assembled more than 40 scientists to draw up a set of guidelines that balance ethical concerns about embryonic stem cell research with its potential rewards. Members of the scientific community are expected to abide by such guidelines.

KEEPING TABS ON TESTING

A cancer researcher discovers a chemical that she thinks might help treat leukemia. What should her next steps be? You might imagine that recruiting leukemia patients to begin testing would be next up—but in fact, jumping into human trials at this point would violate many federal regulations and international codes. In order to protect participants, scientists have drawn up a strict set of guidelines outlining when humans can participate in experiments and how they must be treated. These guidelines, known as human subjects protocols or policies for the protection of human subjects, cover everything from how much testing a drug must undergo before it reaches human patients, to what information participants must have before entering into a test, to what sort of paperwork study participants must sign. And these regulations apply to any sort of scientific research involving human participants—whether it's testing a new drug, monitoring the effect of exercise on cholesterol levels, or just studying factors affecting the reading ability of fourth graders. Such guidelines (which vary slightly from country to country) are designed to ensure that scientific interest in the outcome of a test never outweighs risks to the well-being of human participants. So before a potential leukemia drug is ever tested on human patients, it must first be tested in both Petri dishes and animals (adhering to another set of ethical guidelines in the case of animal research) to show that the drug is safe and holds promise above and beyond other treatments currently available.

Here we've seen that the culture of science expects certain sorts of conduct from its community members. To find out what happens when a scientist doesn't meet those expectations, read on …

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The scientific community and misconduct

Some types of scientific misconduct:

- Failing to fairly scrutinize research
- Failing to be honest
- Failing to assign credit fairly
- Failing to work within ethical guidelines

On the preceding page, we saw that scientific culture entails a set of norms and practices: scrutinize ideas, be honest, give credit where credit is due, and work within the ethical guidelines of the community. So what happens when someone within the community doesn't meet those expectations? In science, not playing by the rules amounts to scientific misconduct, or at least scientific misbehavior. Serious misconduct is rare, but nevertheless, since scientists are people and have human frailties, it does happen. Perhaps a chemist is asked to review the paper of a personal friend and chooses to overlook a flaw in the research—thus, failing to fairly scrutinize the work. Perhaps a physicist performs an experiment and chooses only to report results that fit with his or her favorite hypothesis—thus, failing to be fully honest. Perhaps a biologist writes a research article but doesn't cite a previous study that inspired the work—thus, failing to assign credit fairly. Or perhaps a psychologist studies a group of students' problem-solving skills but circumvents a few guidelines about how the participants should be recruited—thus, failing to work within the ethical guidelines established by the scientific community. Such behavior works against one of science's main goals—to build accurate knowledge about how the world works in ways that are ethical and humane.

Because it undermines science, scientists take misconduct very seriously. In response to misconduct, the scientific community may withhold esteem, job offers, and funding, effectively preventing the offender from participating in science. For example, a scientist found to have plagiarized parts of a grant application to the National Institutes of Health will likely be prevented from participating in federally funded grants for a period of time, a tough punishment for someone whose salary may be partly dependent on such grants. Some types of misconduct are even punishable by law. For example, because he faked data in funding applications and journal articles, medical researcher Eric Poehlman received a $180,000 fine, a year in prison, and a lifetime ban on receiving federal research funds!

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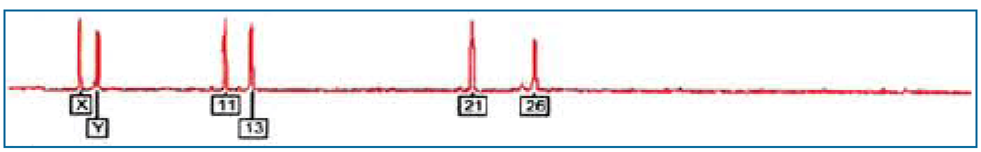
Not getting away with it

Serious and damaging cases of scientific misconduct are almost invariably found out. That's because science is designed to get at how the world really works. Any fraudulent results that paint a false picture of the world will be uncovered as science proceeds and zooms in on the true picture. For example, in the early 1900s, the influential physiologist Emil Abderhalden claimed to have shown that humans produced protective enzymes that could be used in many practical ways—foremost among them, detecting pregnancy. The only problem? Such enzymes don't actually exist—so of course, Abderhalden's fraud was eventually found out by other scientists who could not reproduce his test results and found that his pregnancy test simply didn't work.

Science's system of scrutiny, peer review, and checks and balances help accelerate the process of discovering and weeding out occasional cases of fraud. For example, the world was first clued in to Woo Suk Hwang's fraudulent claims regarding stem cells when other scientists scrutinizing his work drew attention to an anomaly: some of his data looked too good to be true. DNA fingerprint graphs purportedly representing DNA from different samples showed peaks that seemed to be exact duplicates of one another—more likely the result of image manipulation than actual DNA fingerprinting analysis. The ensuing investigation revealed that the copycat graph peaks were only the tip of the iceberg. In fact, Hwang's basic claim, that his lab had cloned human embryos and collected stem cells from them, turned out to be entirely fabricated!



A DNA fingerprinting graph from one of Woo Suk Hwang's retracted papers. Careful scrutiny of the peaks in such graphs helped identify his fraud.

Such flagrant examples of fraud can be disturbing and should lead to the indictment of offenders—but they should not lead to the indictment of science. Science has many safeguards in place to prevent fraud, and when fraud does happen, science has mechanisms for detecting it. Scientific misconduct may temporarily lead science towards incorrect conclusions, but the ongoing processes of science regularly correct such diversions.

DNA fingerprint image from Hwang, et al., "Patient-specific embryonic stem cells derived from human SCNT blastocysts," Science, June 17, 2005. Reprinted with permission from AAAS.

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Summing up the social side of science

In this section, we've seen that science is a community endeavor. Contrary to the stereotype of solitary lab work, scientists frequently interact with colleagues to collaborate on projects, review each other's work, share information, and brainstorm new ideas. In these interactions, scientists work to maintain a set of cultural norms and expectations: scrutinize ideas, be honest, give credit where credit is due, and work within the ethical guidelines of the community. The scientific community contributes to the progress of science in many different ways, from providing checks and balances to facilitating specialization—and all of those functions are furthered by a diverse scientific community. Science simply works better when lots of different sorts of people participate in it!

To see the counterpart of all this and find out how the broader community influences science, read on …

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