

How science goes wrong

Scientific research has changed the world. Now it needs to change itself

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A SIMPLE idea underpins science: “trust, but verify”. Results should always be subject to challenge from experiment. That simple but powerful idea has generated a vast body of knowledge. Since its birth in the 17th century, modern science has changed the world beyond recognition, and overwhelmingly for the better.

But success can breed complacency. Modern scientists are doing too much trusting and not enough verifying—to the detriment of the whole of science, and of humanity.

Too many of the findings that fill the academic ether are the result of shoddy experiments or poor analysis (see [article](#)). A rule of thumb among biotechnology venture-capitalists is that half of published research cannot be replicated. Even that may be optimistic. Last year researchers at one biotech firm, Amgen, found they could reproduce just six of 53 “landmark” studies in cancer research. Earlier, a group at Bayer, a drug company, managed to repeat just a quarter of 67 similarly important papers. A leading computer scientist frets that three-quarters of papers in his subfield are bunk. In 2000-10 roughly 80,000 patients took part in clinical trials

based on research that was later retracted because of mistakes or improprieties.

What a load of rubbish

Even when flawed research does not put people's lives at risk—and much of it is too far from the market to do so—it squanders money and the efforts of some of the world's best minds. The opportunity costs of stymied progress are hard to quantify, but they are likely to be vast. And they could be rising.

One reason is the competitiveness of science. In the 1950s, when modern academic research took shape after its successes in the second world war, it was still a rarefied pastime. The entire club of scientists numbered a few hundred thousand. As their ranks have swelled, to 6m-7m active researchers on the latest reckoning, scientists have lost their taste for self-policing and quality control. The obligation to “publish or perish” has come to rule over academic life. Competition for jobs is cut-throat. Full professors in America earned on average \$135,000 in 2012—more than judges did. Every year six freshly minted PhDs vie for every academic post. Nowadays verification (the replication of other people's results) does little to advance a researcher's career. And without verification, dubious findings live on to mislead.

Careerism also encourages exaggeration and the cherry-picking of results. In order to safeguard their exclusivity, the leading journals impose high rejection rates: in excess of 90% of submitted manuscripts. The most striking findings have the greatest chance of making it onto the page. Little wonder that one in three researchers knows of a colleague who has pepped up a paper by, say, excluding inconvenient data from results “based on a gut feeling”. And as more research teams around the world work on a problem, the odds shorten that at least one will fall prey to an honest confusion between the sweet signal of a genuine discovery and a freak of the statistical noise. Such spurious correlations are often recorded in journals eager for startling papers. If they touch on drinking wine, going senile or letting children play video games, they may well command the front pages of newspapers, too.

Conversely, failures to prove a hypothesis are rarely even offered for publication, let alone accepted. “Negative results” now account for only 14% of published papers, down from 30% in 1990. Yet knowing what is false is as important to science as knowing what is true. The failure to report failures means that researchers waste money and effort exploring blind alleys already investigated by other scientists.

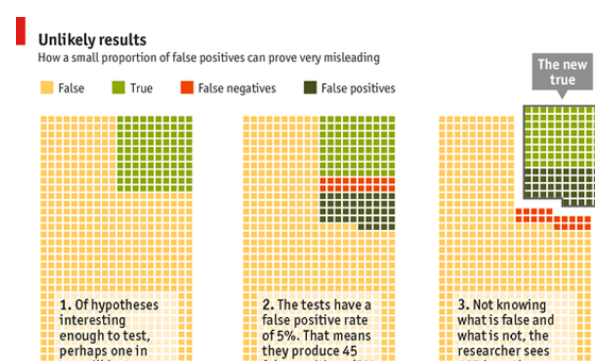
The hallowed process of peer review is not all it is cracked up to be, either. When a prominent medical journal ran research past other experts in the field, it found that most of the reviewers failed to spot mistakes it had deliberately inserted into papers, even after being told they were being tested.

If it's broke, fix it

All this makes a shaky foundation for an enterprise dedicated to discovering the truth about the world. What might be done to shore it up? One priority should be for all disciplines to follow the example of those that have done most to tighten standards. A start would be getting to grips with statistics, especially in the growing number of fields that sift through untold oodles of data looking for patterns. Geneticists have done this, and turned an early torrent of specious results from genome sequencing into a trickle of truly significant ones.

Ideally, research protocols should be registered in advance and monitored in virtual notebooks. This would curb the temptation to fiddle with the experiment's design midstream so as to make the results look more substantial than they are. (It is already meant to happen in clinical trials of drugs, but compliance is patchy.) Where possible, trial data also should be open for other researchers to inspect and test.

The most enlightened journals are already becoming less averse to humdrum papers. Some government funding agencies, including America's National Institutes of Health, which dish out \$30 billion on research each year, are working out how best to encourage replication. And growing numbers of scientists, especially young ones, understand statistics. But these trends need to go much further. Journals should allocate space for "uninteresting" work, and grant-givers should set aside money to pay for it. Peer review should be tightened—or perhaps dispensed with altogether, in favour of post-publication evaluation in the form of appended comments. That system has worked well in recent years in physics and mathematics. Lastly, policymakers should ensure that institutions using public money also respect the rules.



[Watch an animated explanation here](#)

Science still commands enormous—if sometimes bemused—respect. But its privileged status is founded on the capacity to be right most of the time and to correct its

mistakes when it gets things wrong. And it is not as if the universe is short of genuine mysteries to keep generations of scientists hard at work. The false trails laid down by shoddy research are an unforgivable barrier to understanding.

From the print edition: Leaders