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Science is enforced humility

The fundamental strength of science is that it compels its practitioners to confront their own fallibility

Felisa Wolfe-Simon, whose study appeared to show bacteria could use arsenic in place of phosphorus. Despite being published in a prestigious journal, her work was strenuously critiqued. Photograph: Science

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What is the core, immutable quality of science?

It's not formal publication, it's not peer review, it's not properly citing sources. It's not "the scientific method" (whatever that means). It's not replicability. It's not even Popperian falsificationism - the approach that admits we never exactly prove things, but only establish them as very likely by repeated failed attempts to *dis*prove them.

Underlying all those things is something more fundamental. Humility.

Everyone knows it's good to be able to admit when we've been wrong about something. We all like to see that quality in others. We all like to think that we possess it ourselves - although, needless to say, in *our* case it never comes up, because we don't make mistakes. And there's the rub. It goes very, very strongly against the grain for us to admit the possibility of error in our own work. That aversion is so strong that we need to

take special measures to protect ourselves from it.

If science was merely a matter of increasing the sum of human knowledge, it would be enough for us all to note our thoughts on blogs and move on. But science that we can build on needs to be *right*. That means that when we're wrong - and we will be from time to time, unless we're doing terribly unambitious work - our wrong results need to be corrected.

It's because we're not humble by nature - because we need to have humility formally imposed on us - that we need the scaffolding provided by all those things we mentioned at the start.

Publication is important so that there's a permanent record of what we claimed to have found. It can't get lost through carelessness. It can't be changed once it has been published. We can't weasel out of an earlier mistake by claiming never to have made it.

Peer review helps to prevent us from making mistakes in those formal publications. (That applies to informal pre-submission reviews as well as the gatekeeper reviews carried out on behalf of journals.)

Citing sources allows others to check that our assumptions are well supported.

The scientific method is rather vague, and comes in many flavours, but its goal is always to keep hypothesis, experiment, results and conclusion separate, so that other scientists can clearly see what has been done, what is fact and what is opinion.

Replicability is about providing enough information to enable others to determine independently whether we've made mistakes.

Falsificationism helps prevent us from having too much faith in our own ideas, by leaving them for the community to test.

All these aspects of how proper science is executed, published and evaluated are about helping us to spot our own mistakes, giving others the opportunity to root them out, and providing a means for them to be corrected.

Scientists may not be humble people, but doing science forces us to act humbly.

These checks and balances operate all the time as science rolls on. Usually it's behind the scenes. During the publication of a recent paper that I and co-authors wrote, one of the peer reviewers - very unwelcome at the time - pointed out that the statistical section was flawed, and required us to rework it. With the benefit of hindsight, the extra work was worthwhile: it improved the final paper.

But sometimes this plays out in public. In some cases, scientists publish bad work having bypassed the review system, as with Brian Ford's absurd piece on Radio 4 claiming all dinosaurs were aquatic. The scientific community was quick to deal with such claims — by direct response to the media outlet, in online discussion, and in print. Similar nonsense about a giant artistic kraken, this time reported from the abstract of a conference talk, received similarly short shrift.

These examples are frivolous stories from my own field of palaeontology. But the same

self-corrective mechanisms apply to more important science in other fields. The most visible recent example is probably the "arsenic life" story. An article written by a team headed by a Nasa scientist made it through peer review to publication in Science, a well-respected journal. It claimed that the bacterium GFAJ-1 could grow using arsenic in place of phosphorus - a finding with possible implications for extraterrestrial life. That study was badly flawed. But rather than being blindly accepted because it was in a prestigious journal, it was strenuously critiqued: immediately on blogs, then after peer review in print - not once, but several times.

Science is not always right - very far from it. What marks it out from other fields of human endeavour is that, because of its formalised humility, it's always ready to correct itself when it makes a mistake.

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