Wakey wakey

Sleeping-beauty papers offer hope that authors of uncited works are in good company.

How many of the research papers published in this week's *Nature* — or indeed any scientific journal — will go on to change the world? How many will at least make a sizable dent in their academic field, inspire future work and perhaps overturn what has gone before? Citations by other researchers are the currency of modern science, a mark of professional approval that indicates influence. But how long should one be expected to wait for them? Conventional wisdom says that the reach of a publication can be gauged by how many citations it attracts in the first five years. Which gives this week's authors until 2020 or so.

Vincent Van Gogh had no time for conventional wisdom. The artist was famously ignored in his lifetime, yet his work *L'Allee des Alyscamps* sold for US$66 million in New York earlier this month. The books of Herman Melville were out of print when he died, and 1851's *Moby-Dick* did not surface in the public consciousness until years later. Art and science are not so different. Gregor Mendel was not recognized as the father of modern genetics until decades after his experiments with peas.

Such cases sound extreme, but a study offers the presently unloved hope that delayed recognition might not be so rare after all. After analysing a database of 22 million academic papers, researchers have identified plenty of works that went for decades before they were recognized and cited as important (Q. Ke *et al. Proc. Natl Acad. Sci. USA* http://dx.doi.org/10.1073/pnas.1424329112; 2015). One paper — entitled 'Concerning adsorption in solutions' — lay undisturbed for almost a century. Its author, the German chemist Herbert Freundlich, published the work in 1906 and died in 1941. His citation spike came in 2002.

The apparent snub did little to damage his career — Freundlich went on to be widely recognized (and cited) as a pioneer of colloids research. And an initial lack of citations for a 1935 paper on quantum mechanics did not reflect the standing of its authors: physicists Boris Podolsky, Nathan Rosen and one Albert Einstein. Only in 1994 did this publication start to be cited extensively.

Scientific papers typically accrue citations steadily, peak and then decline. Those that at first lie dormant, before being discovered and enjoying a late surge, are dubbed sleeping beauties. In many cases, the awakening comes when the published research finds applications in a different field, such as when statistical methods acquire a use in biology. Some papers were ahead of their time, and described techniques that could not be exploited properly until the creation and curation of large modern databases.

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But creators of sleeping papers be warned: there is no guarantee that your prince will come. Although the latest study indicates that late-flowering papers are more common than previously thought, there remain plenty that are never cited — and never will be.

Filippo Radicchi, a researcher in complex networks at Indiana University Bloomington who worked on the study, says: "I expect, if you look at a paper that is 10 years old [and not cited] my guess is it will continue to have zero citations forever" (see *Nature* http://doi.org/4tb; 2015). He is now trying to identify the papers that wake the dormant studies from their slumber with an important citation.

Citation analysis is an increasing fact of academic life, and this study demonstrates, yet again, that the bare figures do not — and can never — show the full story. Some impact, and personal achievement, is simply difficult to measure, even during a productive career.

Herbert Freundlich achieved much in life, and more after his death. But he did not get everything he wanted. As his obituary in *Nature* noted, he was a talented but frustrated musician. "He abandoned music for chemistry," it said, "when he concluded that he would never be a great composer". There is still time, Herbert. ■

Silicon smarts

A package of articles in Nature *assesses the state of artificial-intelligence research.*

When a select band of computer scientists met at Dartmouth College in Hanover, New Hampshire, in 1956 to begin work on a field they called 'artificial intelligence', they were optimistic, to say the least. Their founding principle of developing machine intelligence was based on an assumption that human intelligence could itself be well characterized. They argued that: "Every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it."

Ask ten people to define human intelligence and you will get at least eleven answers. To a philosopher, intelligence is the absence of a lack of intelligence. To psychologists it is what intelligence tests measure.

Yet despite this fuzziness, the nature of artificial intelligence, in popular culture at least, is sharply defined: computers and robots that can think and act like a human, and that have the potential to outthink and counteract us in most situations. That is probably why many people are disappointed with what even the most advanced robots can achieve, certainly compared with the impressive abilities of even the youngest humans. In their minds, Mozart was composing and performing music at five years old whereas robots can barely fold a towel. The pre-eminence of humankind, it seems, is assured.

And yet, break down the holistic expectation of intelligence into a series of distinct (if overlapping) abilities, and the machines fare somewhat better. In a research paper on page 503, scientists define intelligence as the ability to predict the future. And they have built machines that can do it pretty well. Or at least they have built robots that can analyse the past to plan how to modify their own future behaviours if they are to continue functioning. The work's implications for the continuing survival of feeble humanity are described in a News & Views article on page 426.

Continuing the theme, a series of Comment articles starting on page 415 assesses the current state of debate over how society should respond, regulate and interact with intelligent machines. From autonomous weapons, which could be 'clever' enough to distinguish friend from foe and act accordingly, to medical diagnoses based on rapid and accurate analysis and interpretation of health-care data, these machines may not yet be classed as fully intelligent, but they are reaching a point at which they can mimic and potentially outperform specific 'intelligent' human abilities. What should be done? In the case of drones and other armed intelligent machines, decision time is looming.

Finally, a string of Review articles make up a *Nature* Insight on machine intelligence, starting on page 435. From machine-learning techniques and evolutionary computation to the design and construction of malleable robots inspired by nature, the selection offers both a primer to the uninitiated and a useful summary of the state of the art. It is all, of course, essential reading. The machines, after all, are getting smarter. We should keep up. ■

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