Nobel laureates are almost the same as us

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Data show that apart from their prize-winning work, the careers of Nobel laureates follow the same patterns as those of the majority of scientists.

Career patterns in different leagues

Landau's list, which the brilliant Russian physicist Lev Landau kept in his notebook, is often considered one of the most famous rankings of physicists. He ranked physicists on a logarithmic scale of achievement, grading them into 'leagues'[1]. According to Landau's classification, Isaac Newton and Albert Einstein belonged to a super league, with Newton receiving the highest rank of 0, followed by Einstein's 0.5. The first ordinary league, a rank of 1, consists of the founding fathers of quantum mechanics, such as Niels Bohr, Werner Heisenberg, Paul Dirac and Erwin Schrödinger. Landau originally graded himself a modest 2.5, which he elevated to 2 after discovering superfluidity, for which he was awarded the physics Nobel Prize in 1962. The classification continues all the way to the rank of 5 for mundane physicists, like us. In his 1988 talk My Life with Landau: Homage of a 4 1/2 to a 2, David Mermin, who with Neil Ashcroft co-authored the legendary textbook *Solid State Physics*, rated himself a "struggling 4.5".

For those who successfully advanced from class 5 or earned a Nobel Prize, or both, the impact and relevance of their work is obvious. Yet, for the remaining scientists, who like us safely retain the rank of 5, one question lingers: whether the careers of those in the 'big leagues' follow the same patterns as ours, the 'mere mortals'.

Research on scientific careers to date has suggested that the answer is, perhaps unfortunately, no. Quantitative studies of careers of Nobel laureates and ordinary scientists have revealed two important markers that seem to consistently set the Nobel laureates apart. First, literature in the field of innovation shows that the prize-winning works by Nobel laureates tend to occur early within a career[2], providing evidence of precocious minds that break through in an exceptional way. By contrast, growing evidence shows that ordinary scientific careers are determined by the random impact rule[3,4], suggesting that age and creativity are not intertwined, and the most important work in a career occurs randomly within the sequence of works. Second, there is an acclaimed tradition in the history of science that emphasizes the role of individual genius in scientific discovery. However, one of the most fundamental shifts in science over the past century is the flourishing of large teams across all areas of science[5,6]. This shift raises the question of whether Nobel laureates are unique in being solitary thinkers making guiding contributions.

Putting prize-winning work in context

Quantitative studies of Nobel laureates' careers have predominantly focused on the prize-winning work alone[2,7]. To test if there are indeed systematic differences between the careers of Nobel laureates and ordinary scientists, we studied a unique dataset of entire career histories for nearly all Nobel laureates in physics, chemistry and physiology or medicine from 1900 to 2016 (545 out of 590 laureates, 92.4%)[8]. The dataset allowed us to investigate the characteristics of their prize-winning works in the context of other works produced in the laureates' careers.

Analysis of the dataset

To test if Nobel laureates' careers follow the random impact rule, we measured the positions of the prize-winning work and most-cited work within the sequence of works produced before being awarded the Nobel Prize (51.74% of the most-cited papers were also the prize-winning papers). We find both works tend to occur early within the sequence of papers (FIG. 1a), a result supporting prior studies[2] but inconsistent with the hypothesis that scientific careers are governed by the random impact rule[3,4]. Indeed, this finding suggests that compared with ordinary scientists, Nobel laureates tend to do their best work disproportionately early in their careers, which echoes what Einstein once said: "A person who has not made his great contribution to science before the age of thirty will never do so." Yet, an intriguing result arose when we performed another test, in which we removed the prize-winning papers from the sequences of works and calculated among the remainder the position of the most-cited papers. Once the prize-winning works are removed, the timing of each of the three remaining most-cited works for Nobel laureates all follow uniform patterns (FIG. 1b).

We also examined the team size of the papers published by the laureates. All else being equal, at all times in

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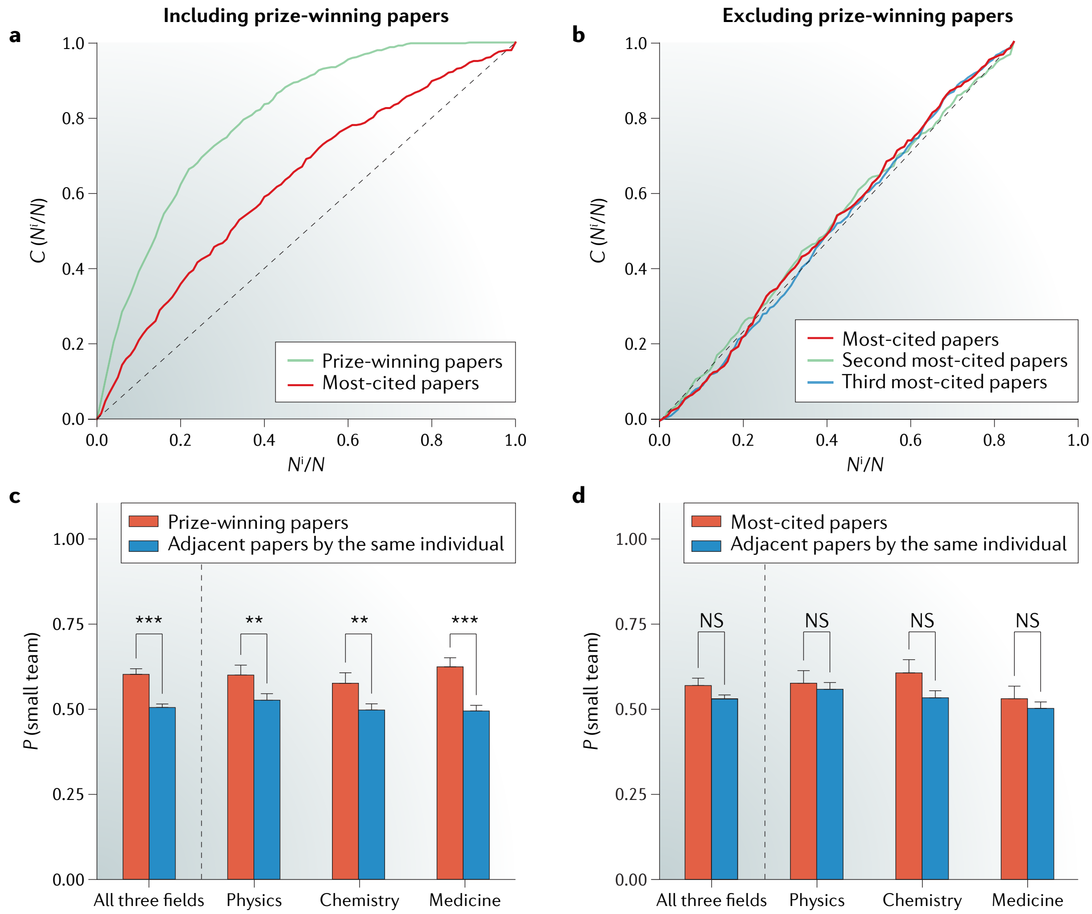

Fig. 1 | **Career patterns of Nobel laureates. a** | The cumulative distributions (*C*) of relative positions (N^i/N) of the prize-winning papers and the most-cited papers within the sequence of all papers before being awarded the Nobel prize. The dashed line indicates the predictions of the random impact rule, in which the most-cited paper occurs randomly within the sequence of papers. **b** | To eliminate potential bias in the timing of the prize-winning work, we removed prize-winning papers and calculated again the relative position of the top three most-cited papers among all the papers published before the award, finding that each of the three most-cited papers follows the random impact rule. **c** | The proportion (*P*) of small-team papers (team size of two or fewer) for all the prize-winning papers. For each prize-winning paper, we took four adjacent papers published by the same individual (two immediately before and two immediately after the prize-winning paper) and compared their proportion of small teams with that of the prize-winning papers. **d** | We removed prize-winning papers and repeated the analyses shown in panel **c** for the most-cited papers, finding no difference in the proportion of small-team papers between the most-cited papers and their adjacent papers. Error bars represent the standard errors of the mean. **, $p<0.05$; ***, $p<0.01$; NS, not significant ($p>0.1$).

the past century, the papers of Nobel laureates are more likely to be produced by larger teams, compared with those of ordinary scientists. Indeed, the average team size for laureates is 4.04 versus 3.25 for non-laureates (p-value ≈ 0), indicating that Nobel laureates are more collaborative than their contemporaries, contrary to the common perception of Nobel laureates as solitary thinkers. However, when we compared the team size of the prize-winning papers with those published immediately before and after by the same laureates, we uncovered a greater propensity for the prize-winning papers to be written by fewer than three authors (60.14% versus 50.41%, Chi-squared test, p-value < 10^{-5}; FIG. 1c). This observation is somewhat counterintuitive, as prize-winning papers have many more citations than those adjacent to them (Student's *t*-test, p-value ≈ 0), and highly cited papers tend to be produced by larger, not smaller, teams[5]. To test if this phenomenon is unique to prize-winning work, we repeated the same analysis for the most-cited paper after removing the prize-winning papers, and found that, somewhat surprisingly, the tendency of being written by small teams disappeared (57.17% versus 53.25%, Chi-squared test, p-value = 0.1252; FIG. 1d).

Data suggests 'lost winners'

The inconsistency between the timing of Nobel-prize-winning work and the random impact rule (FIG. 1a) suggests that career dynamics of the Nobel laureates may be fundamentally different from those of ordinary scientists. However, a possible challenge to the validity of this conclusion is a selection effect — because the Nobel Prize in science has never been awarded posthumously, those who produced ground-breaking works early on in their careers were more likely to wait long enough to be recognized[7]. Because important works in a career tend to occur in close succession[3], it is reasonable to expect that not only the prize-winning work but also other high-impact papers should appear early in the sequence of papers. However, our test of modified sequences of work indicate that apart from the prize-winning work, the timing of all other important works in the careers of Nobel laureates closely follow the random impact rule: they could be, with equal likelihood, the very first work, the last or any one in between (FIG. 1b). One implication of the selection hypothesis in light of the random impact rule is a potential population of lost winners whose deserving works were not recognized by the Nobel Prize committee simply owing to the timing of their publications, especially given the growing time lag between discovery and recognition.

Nobel-winning work comes from small teams

The statistics on team sizes behind Nobel-Prize-winning work are consistent with the finding that works produced by small teams tend to disrupt science and technology[6]. They are also consistent with Harriet Zuckerman's argument that "the future laureates were especially concerned to have the record clear for their most significant work, and particularly in their prize-winning research papers"[9], suggesting that the ubiquitous shifts toward large teams may be in tension with the fact that the Nobel Prize can only be awarded to at most three recipients for each subject each year. Nevertheless, regardless of the cause, these results demonstrate that, whereas Nobel-Prize-winning work shows an intriguing tendency toward small teams, all other works by the laureates are just as, if not more, collaborative than those by ordinary scientists.

Takeaway

The results from analysis of this dataset are remarkably consistent across the three domains we analysed. Other studies show well-documented differences across physics, chemistry and physiology or medicine. For example, the prize-winning works in physics tend to occur earlier than those in medicine[10], whereas medicine tends to have larger teams than other disciplines[6]. Yet, despite these differences, we find that the results described above hold consistently across disciplines. Indeed, we repeated our analyses for each of the three disciplines, arriving at broadly consistent conclusions.

These findings, together with other empirical evidence characterizing individual scientific careers, point to one important conclusion: apart from the prize-winning work, which may be subject to peculiarities of the Nobel, there is no known major difference that distinguishes patterns governing the careers of scientific elites from those with Landau's rank of 5. Surely it will only take one study to uncover the real mark, if any, that sets the elite apart. But until then, these results offer reasons to remain hopeful: perhaps the ranks of scientists are not fixed, and barriers to leapfrog out of rank 5 may be less insurmountable than imagined.

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Author contributions

D.W. and S.F. conceived the project; D. W. designed the experiments; J.L. and Y.Y. collected data and performed empirical analyses with help from S.F. and D.W.; all authors discussed and interpreted results; D.W., J.L. and Y.Y. wrote the manuscript; and all authors edited the manuscript.

Competing interests

The authors declare no competing interests.