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Optimal Team Size for Groundbreaking Scientific Research

Introduction

How many minds does it take to make a scientific breakthrough? In recent decades, the average number of authors per scientific paper has risen dramatically, sparking debate about whether bigger teams yield better science. Many **groundbreaking discoveries** in history – from Einstein's 1905 papers on relativity (single-author works) to Watson and Crick's 1953 discovery of DNA's structure (two authors) – were accomplished by very small teams. In contrast, today's research often involves sprawling collaborations: for example, the Higgs boson discovery paper listed over 2,500 coauthors, and the first detection of gravitational waves had 1,000+ authors [1]. This raises an intriguing question: **what is the optimal number of authors for truly groundbreaking scientific research?** This article explores that question through a historical perspective, descriptive statistics, and recent analyses of how team size relates to scientific impact.

Historical and Disciplinary Perspectives

A century ago, solo and duo-authored papers were the norm across most fields. In the early 20th century, fundamental advances in physics, chemistry, and mathematics were often published by one or two individuals. For instance, virtually all of Einstein's paradigm-shifting papers were authored by himself alone, and mathematicians like Ramanujan or Gödel often worked solo. In **mathematics**, even today, collaboration tends to be minimal – one study found the average number of authors in applied mathematics publications is under 2.4 [2]. Breakthroughs in math (e.g. Andrew Wiles' proof of Fermat's Last Theorem) are frequently solo efforts or involve just a couple of collaborators.

By contrast, **experimental sciences** have seen a steady march toward larger teams. Fields like high-energy **physics** and genomics sometimes require vast collaborations to achieve their goals – expensive equipment and large datasets necessitate many contributors. Physics papers now hold the records for author count (one physics paper in our sample had 2,902 authors [3] !), and astronomy/space missions similarly involve big teams. **Medicine and biology** have also embraced team science: clinical trials and large-scale studies often involve dozens of investigators across multiple centers. The *publish or perish* culture and increasing specialization have contributed to this growth. Indeed, by 2011, **89% of all publications indexed in Web of Science had more than one author** [4] , a stark change from mid-20th century when single-author papers were still common.

Rising Team Sizes: Trends and Statistics

Not only have teams grown, the trend has accelerated in recent decades. In biomedical sciences, the **mean number of authors per paper** has roughly tripled over the last half-century – rising from about **1.9 authors before 1975 to about 5.9 authors by 2015-2019** [5] . Similarly, an analysis of over 100,000 papers on PubMed Central found the **median number of authors** climbed from 3 in 2002 to 6 in 2012, remaining around 6 thereafter [6]. Strikingly, the share of single-authored papers plummeted from 33.9% of papers in 2002 to just 2.1% in 2021 [6] – in other words, solo papers went from one-third of the literature to virtually extinct in two decades. Drivers of this inflation include the growing complexity of research (requiring diverse expertise), interdisciplinary collaboration, and pressures to **"publish together or perish"** [7].

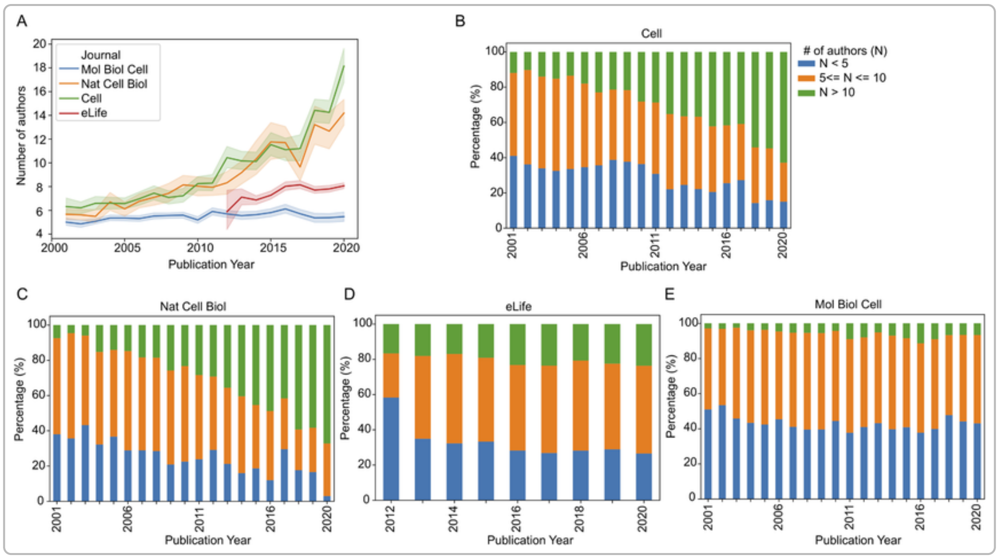

Figure: Authorship trends in select biology journals (2001–2020). High-profile journals like Cell *and* Nature Cell Biology *show a steep rise in average authors per paper (green and orange curves in panel A), nearly tripling from ~5–7 authors two decades ago to ~15–18 by 2020. Society-run journals like* Molecular Biology of the Cell *(blue curve) remained flat at ~5–7 authors on average* [8]. *Panels B–E show the distribution of team sizes: in 2020, over 60% of papers in* Cell *and* Nat Cell Biol *had >10 authors (green bars), while papers with <5 authors (blue bars) became rare (under 5–15%)* [9] [10]. *By contrast, ~40% of papers in* Mol Biol Cell *still had <5 authors* [11].

These trends span most disciplines, albeit with differences in scale. **Clinical medicine** and cutting-edge biology show especially large author lists – for example, top medical journals saw median authors per paper increase from ~8–11 in 2005 to ~11–18 by 2015 [12]. Meanwhile, fields like **mathematics and theoretical physics** remain on the other end of the spectrum, where solo or 2-3 author papers are still the norm. This divergence is well illustrated even within a single domain: as shown in the figure above, the elite biology journals now seldom publish papers with under five authors, whereas a nonprofit society journal still routinely features small-team papers. Clearly, **bigger teams have become standard in many fields** – but does bigger imply more groundbreaking?

Team Size vs. Research Impact

Intuitively, one might think **more brains = more ideas**, and indeed larger teams can tackle ambitious projects beyond the scope of any individual. There is evidence that multi-author papers tend to get more attention: for instance, multi-authored research papers receive **about 35% more citations per year on average than single-authored papers** [13] [14]. Team-authored papers are also more likely to be published in slightly higher-impact journals (each additional author correlates with a very small uptick in journal impact factor) [15]. Over the past five decades, teams have increasingly **dominated high-impact research**

output, surpassing solo researchers in producing top-cited papers in science and engineering [16] [17]. In other words, collaboration has become crucial to producing work that other scientists cite and build upon.

However, **citation count and impact are not the whole story** when it comes to groundbreaking research. Recent studies suggest a nuanced picture: while large teams excel at producing reliable, **incremental advancements** that quickly garner citations, **small teams are disproportionately responsible for disruptive, paradigm-shifting breakthroughs** [18] [19]. A comprehensive analysis of over 65 million publications, patents, and software projects from 1954–2014 found that **adding more team members tends to diminish a work's "disruptiveness"** [20]. Each additional author was associated with a *drop* in the likelihood that the paper would send its field in a new direction (as measured by a "disruption index" tracking whether future citations focus on the new work itself vs. its predecessors) [20]. In fact, across a massive dataset, **smaller teams produced "much more disruptive and innovative" research, whereas larger teams more often developed and refined existing ideas** [19].

Crucially, this pattern held even at the highest levels of achievement. **Nobel Prize–winning papers** and other landmark discoveries show the same trend: those conducted by small teams tend to be more disruptive and original in retrospect than those by larger teams [20]. Bibliometric studies of Nobel laureates likewise indicate that many laureates' key contributions were done in small groups or alone. For example, Nobelists in medicine/physiology (1969–2011 cohort) had **fewer coauthors on average than their equally accomplished peers**, and they authored more solo papers both before and after winning the prize [21]. Similarly, an analysis of "hot papers" (top 0.1% most cited papers in recent years) found that, while such papers have an average of 22 authors and often hundreds or thousands of collaborators [22], **very few Nobel laureates are among those giant collaborations** [23] [24]. This suggests that the type of work that wins Nobels has typically not been the mega-team, instantly-hot research, but more often arises from smaller-scale efforts (with the notable exception of large experimental physics projects, where prizes go to a few leaders of big teams).

Why Do Small Teams Drive Breakthroughs?

Several explanations have been proposed for **why smaller author groups might be optimal for groundbreaking science**. One theory is that **large teams tend to be more conservative** in research approach. A big group often works like a well-funded Hollywood sequel – aiming for a sure-hit by building on recent popular ideas ("yesterday's hits") [25]. There are practical reasons for this: with many stakeholders and resources invested, large collaborations gravitate toward established methods and questions that are likely to yield results. **Coordination and consensus** become key, which can inhibit wild leaps of creativity. In contrast, **small teams (or solo investigators) have more freedom to "do weird stuff"** [25] – they can pursue offbeat ideas or resurrect forgotten theories without needing broad approval. Indeed, data show that **small teams more often reach deep into the past literature, drawing on older or overlooked ideas**, whereas large teams focus on recent highly cited work [26]. This deeper and wider search by small groups can fertilize new paradigms. The payoff is often delayed recognition (their disruptive ideas may take time to be appreciated [27]), but ultimately these are the studies that redefine fields.

Another factor is **creative cohesion and credit**. In a small team, each scientist typically has a high degree of ownership and intellectual engagement with the project. Communication is direct and brainstorming is intimate, allowing rapid iteration of novel concepts. In larger teams, work is partitioned – which is efficient for executing complex tasks, but can lead to "siloed" thinking where no one sees the entire picture in the same depth. It's also been argued that **risk-taking is optimized in smaller groups**: a lone genius or a tight-knit duo can afford to gamble on a crazy idea (with a high chance of failure but high impact if it succeeds), whereas big labs often need steady output and may avoid risky ventures. As one researcher put it, big teams produce work “like blockbuster sequels – very reactive and low-risk,” whereas small teams are the ones that truly **“gamble” on radical new directions** [25] [28] .

It’s important to note that **large teams are by no means “bad” for science** – they are essential for certain kinds of breakthroughs. For example, confirming the existence of the Higgs boson or imaging a black hole *required* huge, collaborative efforts and specialized facilities. These are groundbreaking achievements in their own right, enabled by coordinated teamwork. However, in such cases the *conceptual* breakthrough (the theory or idea) often came from a much smaller set of minds years earlier. The **ideal scenario** for scientific progress may be an *ecosystem* where **small teams generate disruptive ideas and hypotheses, which larger teams then develop, test, or apply on a broad scale** [29] [30] . In other words, small and large collaborations play complementary roles. A flourishing research enterprise benefits from both the nimble creativity of small groups and the cumulative power of big teams to **exploit and verify** those insights.

Conclusion

Looking across scientific domains and history, the evidence suggests that the **“optimal” number of authors for groundbreaking research is on the lower end – often just one to a few dedicated individuals**. Many of the classic, paradigm-shifting discoveries were made by solo researchers or duos/trios, and modern data indicate that small teams are more likely to produce work that disrupts and redirects scientific fields [18] [19] . While large multi-author collaborations have become commonplace (and are invaluable for tackling complex problems and achieving big science feats), they tend to excel at incremental progress rather than radical innovation. The **sweet spot for novelty** seems to be a small team size that is large enough to bring in complementary skills and ideas, but **small enough to remain agile, risky, and original** – perhaps on the order of **two to four authors** in many cases.

Ultimately, “optimal team size” may depend on the nature of the scientific question. Foundational theoretical advances in fields like math or physics might emerge from the focus of a lone mind or a tight-knit duo, whereas a groundbreaking experimental result in medicine might require a slightly larger core team (plus many supporting contributors). What is clear is that bigger is not always better. **Quality and creativity do not scale linearly with team size**. As science policy makers consider how to spur more breakthrough innovation, some researchers suggest funding a diverse portfolio that includes plenty of small, independent teams – akin to a venture capitalist investing in many small startups – rather than only pouring resources into huge consortium projects [31] . History and data both indicate that if we want the next Newton, Curie, or Einstein-level discovery, we must create conditions where **small teams (and even solo scientists) can thrive alongside large collaborations**. In summary, when it comes to groundbreaking science, there is strong reason to believe that **less can be more** [18] [25] – a few great minds working in concert (or alone) are often the engine of the biggest leaps forward.

Sources: The analysis above is supported by recent “science of science” studies and bibliometric data, including Wu *et al.* (2019) in *Nature* [18] , UChicago News summary (2019) [19] [25] [20] , Wagner *et al.* (2015) on Nobel laureate collaborations [21] , and statistics from PubMed/PubMed Central analyses [5] [6] [13] , among other sources as cited throughout.

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