

Competitive Science: Is Competition Ruining Science?

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Science has always been a competitive undertaking. Despite recognition of the benefits of cooperation and team science, reduced availability of funding and jobs has made science more competitive than ever. Here we consider the benefits of competition in providing incentives to scientists and the adverse effects of competition on resource sharing, research integrity, and creativity. The history of science shows that transformative discoveries often occur in the absence of competition, which only emerges once fields are established and goals are defined. Measures to encourage collaboration and ameliorate competition in the scientific enterprise are discussed.

Science would be ruined if (like sports) it were to put competition above everything else.

—Benoit Mandelbrot (1)

In the winner-take-all economics of science, scientists compete above all for priority, the recognition that they are the first to make a discovery (2). The “priority rule” gives scientists an incentive to share knowledge of their discoveries with the community (3) but also ensures that individuals and research teams must compete with each other. The primary currency of science is the prestige conferred by peers on the basis of one’s discoveries. Prestige in turn can lead to employment, funding, prizes, and membership in honorific societies.

It is often taken for granted that competition is beneficial for any enterprise because it provides incentives for individuals to excel. In his classic 1957 essay, the sociologist Robert K. Merton viewed competition as a favorable influence on the scientific enterprise, which promotes the rapid dissemination of research discoveries and motivates scientists (2). There are many historical examples of intense scientific rivalries. Whether one is talking about Newton and Leibniz disputing the invention of calculus, Darwin’s anxiety on learning that Russell was converging on ideas similar to his own, or Watson and Crick sparring with Pauling over the structure of DNA, the popular notion is that competition spurs scientific progress.

It has also been suggested that scientific rivalry can provide a corrective for confirmation bias, the tendency to favor evidence that supports one’s preexisting beliefs. Although scientists may be reluctant to disprove their own ideas, their rivals are unlikely to show the same restraint (4). Thus, in theory, competition may help to protect science from stagnation and dogma.

The dark side of competition. Not all historians of science have viewed competition in a uniformly favorable light. Hagstrom suggested that competition could be inefficient and wasteful because it leads to duplication of effort, although he acknowledged that competition may be stimulatory and can help to diffuse new ideas (5). While Hagstrom suggested that competition might encourage scientists to publish their results, Sullivan suggested that competition might actually lead to greater secrecy, as scientists fear being scooped by their rivals (6). McCain also observed that competition reduces the tendency of researchers to share materials, information, and methods, thus impeding scientific progress (7).

More recently, focus group discussions have confirmed that competition discourages sharing and may even lead some scientists to sabotage competitors, perform biased peer review, and engage in questionable research practices (8). Scientific leaders have decried the detrimental effect of today’s hypercompetitive environment on science (9, 10). Hypercompetition may be driving some young people away from careers in science, and this may be particularly true for young female scientists (11–13).

The author Margaret Heffernan has recently written a book called *A Bigger Prize: How We Can Do Better than the Competition*, which explores the detrimental effects of competition in all aspects of society, particularly in the business world (14). She notes that science has a tournament structure with a steep drop-off in rewards for those who do not come in first: “Even economists now concede that tournaments have perverse outcomes. These are especially costly in an activity that depends on collaboration—like science.”

A vivid real-world example of the costs of naked competition recently arose when a prominent senior scientist discouraged a younger researcher from joining the faculty at his institution (15). The young researcher received an e-mail stating that the problem was that their research interests were too similar:

I have a strong reservation about having you as a faculty colleague in the same building here at this time because of a serious overlap in research and approach. . . We briefly discussed the possibility of a collaboration. But this is complex. . . An additional drawback in logistics is about the shared resources and facilities. . . I, as Director of the Insti-

Accepted manuscript posted online 20 January 2015

Citation Fang FC, Casadevall A. 2015. Competitive science: is competition ruining science? *Infect Immun* 83:1229–1233. doi:10.1128/IAI.02939-14.

Editor: A. J. Bäumlér

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doi:10.1128/IAI.02939-14

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tute, took the major role in securing and designing rodent holding, behavior and transgenic facilities. . . I am afraid that accommodating your lab would be difficult. . . I am sorry, but I have to say to you that at present and under the present circumstances, I do not feel comfortable at all to have you here.

Soon afterward, the younger scientist took another position, and an opportunity for two researchers with common interests to work together was lost. Perhaps the senior scientist merely wanted to avoid a duplication of effort. Nevertheless, the episode had collateral costs. After an institutional committee found that the senior scientist had “behaved inappropriately,” he stepped down as the Institute Director.

A relationship between competition for funding and scientific misconduct is increasingly recognized (16), with the important caveat that most scientists are able to maintain their integrity despite difficult circumstances. Eric Poehlman, a University of Vermont researcher who served 12 months in federal prison for falsifying data, attributed his actions in part to a system “in which the amount of grants basically determined one’s self-worth. . . I was on a treadmill, and I could not get off” (17). Many scientists have noted that the “publish or perish” culture of contemporary science can foster bias in the scientific literature (18). Ioannidis explicitly states that “competition and conflicts of interest distort too many medical findings” (19). Large surveys of scientific faculty in the United States have shown a significant association between pressure to obtain external funding and soft money salary support with questionable research practices and neglectful or careless behavior (20). In a recent Belgian survey, half of scientists agreed that the competitive scientific climate led them to publish more articles, and more than half felt that publication pressure is detrimental to the validity of the scientific literature and to their relationships with fellow researchers (21).

Competition is not essential for science. History has repeatedly shown that competition is not required for seminal discoveries. Emil von Behring developed the concept of humoral immunity in his studies of the diphtheria toxin. When Shibasaburo Kitasato joined the laboratory, the two men worked together to show that protection against tetanus could be achieved in a similar fashion, and they published their results jointly (22). Similarly, Griffith’s discovery of the transforming principle of heredity and Mullis’ invention of PCR occurred in the virtual absence of competition (23, 24). We suggest that the development of such complex concepts benefited from the long intervals of time in which scientists could develop their ideas without the pressure of competition. In fact, it is not unusual for transformative scientific discoveries to be made in the absence of competition, as such events often involve serendipity and wholly unanticipated findings (25).

Even the classic examples of scientific competition may be somewhat misleading. Newton and Leibniz developed calculus independently, using different approaches, and their notorious rivalry over credit occurred only afterwards (26). Similarly, Darwin and Russell developed their theories of evolution by natural selection independently. When Russell sent a manuscript describing his ideas to Darwin, the latter hastily prepared a paper to be presented simultaneously to the Linnean Society of London, an action that in itself acknowledged the contributions of Russell. To his credit, Russell never contested the priority and greater depth and influence of Darwin’s work (27). As much as competition

might have provided an added incentive for Watson in his search to solve the structure of DNA, concern over priority is likely to have led Pauling to prematurely publish a three-stranded helical structure of DNA that proved to be embarrassingly wrong (28). The researchers’ competitive drive may also have led to some actions that were ethically questionable (29, 30). Thus, competition might at best be seen as a two-edged sword.

Competition also yielded mixed results in 1894 when Kitasato and Yersin converged on Hong Kong seeking to discover the causative agent of plague. Although Kitasato had successfully collaborated with von Behring a few years earlier, he was no longer in a collaborative mood. He reportedly paid the local authorities to deny Yersin access to the bodies of plague victims (31). In his haste to beat Yersin, Kitasato rushed an announcement of the discovery of the plague bacillus into print (32). However, his description of the bacillus was contradictory in a number of respects to subsequent publications and gave rise to a persisting controversy about whether his cultures may have been contaminated (33, 34). Yersin’s report came out 6 days later, but it is his name that is immortalized as *Yersinia pestis* (35).

And what of the argument that competition reduces the danger of confirmation bias? While it is true that competing scientists are less likely to be invested in corroborating a theory, fierce competition might actually reinforce confirmation bias by encouraging scientists to dig in their heels and defend their positions rather than lose face. Collaboration with others who do not precisely share your views might be a more effective safeguard against confirmation bias.

How competition emerges. Although transformative discoveries leading to entirely new fields can occur in the absence of competition, such discoveries typically spawn intense competition afterwards. The widespread appreciation of the importance of a new discovery can stimulate competing efforts to build upon the finding. Once goals are clearly defined, scientists recognize that achieving the goals can lead to rewards and that the first to solve the next problem will reap the greatest reward.

An illustrative example is the discovery that heredity is transmitted by DNA. Initial speculation as to the chemical nature of genes was restricted by technological limitations of the time. Key research on the transforming principle came from a laboratory interested in understanding the relationship between different bacterial strains in the hope of developing better therapies and vaccines. DNA was thus linked to heredity, but several more years were required for enough scientists to become persuaded. At this point the race was on, with participants including Crick, Wilkins, Franklin, Chargaff, Pauling, and Watson. In the end, the race was won by Watson and Crick, who reported their findings in a landmark 1953 publication and shared the 1962 Nobel Prize with Maurice Wilkins. The elucidation of DNA’s structure led to new fields focused on replication, transcription, and translation, which in turn spawned their own goals, competitions, and prizes.

Limits of competition. It is unclear whether competition is an important incentive in science. The Nobel Prize is the most prestigious honor in science, but few laureates have had the prize in mind when they made their award-winning discoveries, and most recipients have already received ample recognition by the time Stockholm calls (36). Competition probably works best when the goals are clearly defined and a field is technologically ready. A good example is the Human Genome Project, in which competition between publicly and commercially supported teams resulted

in success years ahead of schedule (37). However, competition by itself cannot necessarily lead to progress if the goals are too ambitious, as demonstrated by the many unclaimed prizes in science and technology (38).

With the shortcomings of competition becoming more evident, its counterpart collaboration appears to be in ascendancy. The successful demonstration of the Higgs boson by research teams at CERN involving thousands of scientists working over a period of decades is an example of successful scientific teamwork. The need for diverse research approaches and transdisciplinary teams to address complex problems is increasingly recognized (39). However, a greater emphasis on “team science” will require a radical reconsideration of how scientists are organized, supported, and rewarded (40–42).

Detrimental effects of competition on creativity. By channeling research efforts along defined paths, competition may constrain the creativity required for transformative breakthroughs. Moreover, there may be an even more insidious effect of competition on scientific creativity. At its best, science is a creative process on par with art, music, and literature (43). Like creative disciplines in the humanities, science involves imagination, intuition, synthesis, and aesthetics (44). Patterns of brain activation observed by functional magnetic resonance imaging during word association tasks show similar patterns of activation in association cortex and socioaffective processing areas among artists and scientists (45). The emergence of new ideas is associated with the default mode network, or random episodic silent thought (REST), in which an individual primed by a long incubation period is allowed to performing a relaxing activity such as watching television, reading a book, taking a shower, driving, or exercising (46).

Studies by psychologists have shown that intense competition and stress can actually stifle creativity. Teresa Amabile is a psychologist on the faculty of the Harvard Business School who has been studying the social psychology of creativity for 35 years. Among her findings are that creativity is more likely to respond to intrinsic rather than extrinsic motivation and requires sufficient periods of time for ideas to incubate (47). Creativity flourishes when an individual is allowed to pursue a subject about which he or she cares passionately in an environment that feels more like play than work (48). Experimental subjects motivated by external rewards are less likely to produce creative results (49). In an article entitled *How to Kill Creativity*, Amabile describes a hypothetical work environment that is antithetical to creativity, one that relies on external financial rewards, creates relentless deadlines, and subjects any proposals to “time-consuming layers of evaluation. . . and excruciating critiques” (50)—pretty much a dead-on description of what it means to be a scientist today. Amabile notes that “when creativity is under the gun, it usually ends up getting killed” (51), and “job security appears to be extremely important in fostering creativity” (48). This underscores the fundamental difference between the positive motivation of competition and the negative “hypermotivation” that comes from the fear of loss of funding or employment faced by scientists today (52). The intensity of the stress is also an important factor; a meta-analysis of 76 experimental studies found that although mild levels of stress can stimulate creativity, high stress levels impede creative thinking (53).

Amabile has also cautioned that the detrimental effects of competition on creativity may affect men and women differently (48).

This has been borne out in subsequent studies by others. Experimental studies of groups of undergraduates and scientists in the real world have revealed important differences between how men and women tend to respond to competition. In one such study, intense competition between teams enhanced creativity in teams composed of men but impeded creativity in teams composed of women, whereas women thrived in a collaborative environment in which teams worked side by side (54). This might relate to deep-seated gender differences in cooperation and competition that have been designated the “male-warrior hypothesis” (55). The ability of women to broaden the perspective of research teams and promote collaboration has been one factor used to advocate for their greater inclusion at all levels of the scientific hierarchy (56).

Does cooperation work? In contrast to competition, there are many examples of the benefits of cooperation and collaboration. Empirical evidence suggests a synergy between networking of individuals in noncommercial settings. The author Steven Johnson analyzed 135 major innovations in science and technology emerging during the 19th and 20th centuries and found that 40% of these discoveries arose from networks and nonmarket settings, in comparison to 26% from networks in market settings or from individuals in nonmarket settings and just 8% from individuals working in market settings (57). The products of nonmarket networks have included such innovations as aspirin, magnetic resonance imaging, plate tectonics, atomic reactors, penicillin, and quantum mechanics. Johnson concluded the following:

Openness and connectivity may, in the end, be more valuable to innovation than purely competitive mechanisms. . . . We are often better served by connecting ideas than we are by protecting them. . . . When one looks at the innovation in nature and in culture, environments that build walls around good ideas tend to be less innovative in the long run than are open-ended environments. Good ideas may not want to be free, but they do want to connect, fuse, recombine. They want to reinvent themselves by crossing borders. They want to complete each other as much as they want to compete.

The history of science repeatedly shows that important scientific findings arise from unfettered exploration, the passion of individual scientists to understand a problem, and research environments that foster interaction. Although our current scientific enterprise could hardly be less conducive to creativity, these principles come as no surprise to scientists. When asked how to build a motivated research group, Uri Alon recommended providing young scientists with challenging problems that engage them, giving them the autonomy to seek their own solutions, and placing them in an environment in which they can readily network with others (58).

How to channel competition and foster cooperation. There remains a role for competition in science. Competition appears to work best for algorithmic tasks rather than heuristic tasks that require great creativity. Thus, defining specific goals that are technologically feasible can help to advance a field, just as Hilbert’s definition of 23 unsolved problems in 1900 helped to galvanize the attention of mathematicians.

However, most science today would benefit from a radically different structure that promotes cooperation, collaboration, and

creativity. Useful measures may include changing the criteria for professional advancement, with an emphasis on common rather than individual goals and a reduced emphasis on publication in prestigious venues (59). Unselfish scientific acts such as mentoring and making useful reagents and information available to the community should be recognized, along with more effective policing of scientists who behave selfishly. Another strategy to reduce the detrimental effects of competition is for competing groups to cooperate by publishing their findings at the same time so as to not “scoop” one another. We and others have done this on several occasions (60–72). When groups simultaneously present their findings, there are no losers, and the scientific community benefits by having immediate corroboration of a new finding. Furthermore, knowledge that their work will be published simultaneously may allow rival groups to complete their studies with greater care. Simultaneous publication requires open communication, which in itself is beneficial to science.

A major change in the economic structure of science with a renewed national investment in research and development is required to alleviate hypercompetition for grants and jobs. (Imagine the efficiency of the armed forces if only one out of every five soldiers were issued weapons and the rest were asked to spend all of their time writing applications to explain what they would do if they had one.) While it is often stated that more funding alone will not be adequate to fix science, more funding is an essential part of any effective solution. In this regard, a system that funds people instead of projects may be more rational given studies showing that this approach fosters higher-impact science (73) and that track record rather than project reviews is predictive of future researcher productivity (74, 75). A greater emphasis should be placed on open-ended investigator-initiated research and less on targeted programs. Institutions should reduce their dependence on soft money to provide researchers with more stable salary support. Larger research teams to increase numbers of senior scientist positions can enhance intragroup networking and ameliorate competition among trainees.

Scientists today must work in an environment of relentless stress, time pressure, and insecurity, factors that are counterproductive to good science. Fortunately, research in neurobiology and social psychology has provided a clear prescription. Creativity thrives on freedom and interactivity. It is time to apply these principles to reform the scientific enterprise itself.

Conclusions. As declines in funding have intensified competition among scientists, the detrimental effects of hypercompetition on creativity, efficiency, communication, collegiality, and integrity are increasingly evident. With the emergence of team science and the need for multidisciplinary approaches to challenging problems, a more cooperative and collaborative scientific culture is sorely needed. However, it is not going to be easy to make science more collaborative. We are going to have to work together.

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