Reflections

Research Diversity, Disruptive Science, and Scientific Consensus

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Why is diversity important? Racial diversity is a prominent and sometimes popular goal. It has been countered by those who sense a corresponding lack of diversity of viewpoints, considering this a more important form of diversity. This paper takes a step back and looks at diversity in nature to evaluate what causes it and why it is important. Using diversity in nature as an analogue, it develops a new idea of diversity, termed "research diversity," that has intrinsic value and is needed for academic and scientific advances.

Research diversity, as used in this paper, refers to a variety of priors, methodological approaches, and objectives in a field of inquiry. It stands in contrast to concepts such as a "narrow orthodoxy" or "scientific consensus" and differs from viewpoint diversity. *Viewpoint diversity* refers to differences of opinion, and its decline in many settings has been lamented even as efforts to increase racial and ethnic diversity have expanded. Research diversity can exist with or without viewpoint diversity, and it is essential to scientific progress in ways that viewpoint diversity, though valuable, is not.

The research environment gives us a great example for identifying the sorts of bad policies that stifle diversity and lead to slower growth of knowledge, impede the

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development or refinement of ideas, and diminish resilience in the face of changing circumstances. Wu et al. (2019) report that disruptive science, and thus increases in research diversity, more often comes from small teams than large teams, something explained later in this paper. Many small teams doing similar research with different methods or priors reflect research diversity. This paper builds on the view that large teams focused on one objective do not develop new knowledge as well as small teams, although they have other uses. Thus, they do not contribute as much to the robustness, resilience, and growth that are desirable in the sciences.

This paper has four key points. The first is that diversity is evidence of a good environment, in both biology and scientific research, but it is not a framework that by itself creates this good environment. Second, diversity is needed for growth, development, and resilience. The environment for scientific research is human designed, and even the natural environment is manipulated by humans. Because of this, understanding what makes a good environment requires understanding what leads to diversity. Thus, analogues from agricultural monoculture and polyculture, or the growing of different plants in close proximity, are useful. The third point is that a good research environment is best understood in this light. Finally, the fourth point is that there exist suboptimal policies that may facilitate research but do not facilitate the growth of knowledge. Research diversity thus has intrinsic value because it reflects an environment conducive to resilient scientific advancement, and this paper highlights the institutional characteristics needed for this environment.

Diversity as an Environment for Growth

It may be conventional wisdom that diversity gives rise to a good environment, but the first point is that causation runs the other way. Biological development, with its accompanying diversity, occurs where the environment for development is most favorable. Likewise, advances in scientific research spring from an environment favorable to scientific research, which naturally produces research in many directions with different outcomes, or diversity.

Diversity at the Point of Origin in Nature

To explain the link between diversity and the environment, this section looks at the places in nature where biodiversity is greatest. From there, it evaluates the reasons for this biodiversity to explain the role of the research environment in causing research diversity. Reasons for the desirability of research diversity are the basis of this paper, but they build from this section's point that a favorable environment leads to diversity.

Biological diversity within a species is greatest at the point of origin. This observation was the basis of Ashraf and Galor's (2013) explanation of economic development as a result of the biological benefits of genetic diversity, which for humans is highest in Africa. This observation that biological diversity is greatest at the point of origins applies to more than just humans; it has been documented for numerous crops (Mujaju et al. 2010; Blake 2015; Estabrook 2015). Even nonbiological phenomena follow this pattern, which the *Oxford Companion to Food* cites as evidence that borscht, a beetroot soup, originated in Ukraine, where the greatest variety of traditional recipes is found (Davidson 1999).

The places where the aforementioned crops developed are not always where humans first intensively cultivated them. Likewise, Africa reflected a favorable environment for genetic diversity to arise, but it is not where the greatest advances in culture and human development have occurred. Institutional structures (human-designed environment) matter for economic growth and social development just like the natural environment matters for biological development, and these institutional structures historically have encouraged more growth outside Africa. Humankind's collective choices of control over the natural environment (i.e., the choice to intensively cultivate for agriculture) and cultural environment (i.e., political and economic institutions) may lead to more or less development. In the natural environment, these collective choices could lead to increased food production and more widespread balanced nutrition. In the cultural environment, they could lead to more development in the sense of knowledge or scientific advance as well as of cultural treasures (music, literature, etc.), and growth in the sense of higher material living standards.

Diversity at the Point of Scientific Discovery

Diversity reflects a favorable environment whether natural or manmade. Scientific research will develop in diverse directions when the environment is favorable. Lemley (2012) wrote that many prominent inventions frequently attributed to one groundbreaking inventor were discovered at about the same time by others, implying many concurrent efforts in a fertile environment for discovery. Lemley critiques the patent system for rewarding only one of many inventors. Diamond (2015) takes the opposite view, namely, that the patent system is just. Diamond explicitly recognizes that the patent system encourages ongoing discovery, and Lemley's work recognizes that the patent system does create a reward. The fact that multiple people have worked toward a discovery or invention, whether or not more than one of them actually invented and commercialized the finished product, indicates a fertile environment, implicit in Lemley's and Diamond's work. Concerning multiple invention, Diamond's (2019b) point is that credit should go to the person who not only solves a problem but does so in a commercially viable way. Multiple invention is a reality, but for scientific advance to benefit society more broadly, it needs widespread viability, which the patent system encourages.

New paradigms of thought have emerged from the work of multiple researchers even in areas that are not commercialized. The marginal revolution in economics came from the work of William Stanley Jevons, Carl Menger, and Léon Walras, all of whom did complementary yet distinct work. The questions that spawned their work arose during the preceding century's rapid industrialization, which provided a fertile environment for this research, and it led to diverse but complementary outcomes. In Thomas Kuhn's view, this is how science advances—one paradigm shift at a time as opposed to a linear progression, and paradigm shifts come from contesting the current paradigm, and that requires a favorable environment.

Kozlov (2023) notes the lack of "disruptive science" in recent years as fewer and fewer scientific papers lead their fields in new directions, or to more diverse techniques, goals, and outcomes. Park et al. (2023) observe the same phenomenon in both scientific papers and patents. They start with a belief that accumulated science should create conditions ripe for major advances because researchers can "stand on the shoulders of giants" to see farther than others, as Sir Isaac Newton did. Newton's advances relied on both the existing knowledge base and the environment for continued advance.

Newton was indeed a disrupter of the established views of his time. His ability to do this was due in part to his favorable circumstances, such as having a place at the Royal Society, and the political and religious climate in England. This upheaval facilitated more open inquiry than in earlier centuries or even many places on the contemporary European continent. His fight with Leibniz over primacy in the development of calculus is well remembered, yet what is often overlooked is that many earlier, small discoveries paved the way for a unified theory to emerge. The shoulders of giants were there alongside a fertile environment for both Newton and Leibniz to put calculus together and disrupt many other fields, even if their respective approaches each had some differences, or diversity, that ultimately complemented the other's.

The environment was not entirely favorable to Newton, and he may also have disrupted other areas had his circumstances differed. Moreover, much of his work was not published until after his death, although that was not his best scientific work. This delay was largely because he hesitated to publish anything he considered unfinished, and perhaps also because he didn't take kindly to criticism. He never published much of his work on alchemy and unorthodox theology because of his own fears and those of his descendants that it would tarnish his reputation. Newton's methods, which are still respected, involved thoroughly examining a subject and forming innovative opinions. Publishing unpopular research could have caused others to question his methods because he took similar approaches in his accepted works (Dry 2014). Newton's reasons for choosing what to publish show that the environment was favorable to only some of his ideas. If he had published more of his alchemy (a stigmatized practice that had been illegal), others could have evaluated and disproven it sooner, thus advancing science faster. Likewise, had the environment been unfavorable to his calculus and physics inquiries, as it was to his religion and alchemy, perhaps they too would have been stifled.

The Value of Biodiversity

The second key point of this paper is that diversity is useful for growth, development, and resilience. This section explains the value of diversity, and the dangers when diversity is lacking, in a biological setting to build an analogy to scientific research. Two terms are critical to this explanation, *monoculture* and *polyculture*. Monoculture is the practice of growing the same plant across vast areas with minimal variation, and it stands in contrast to polyculture, which involves growing different plants in the same area. Polyculture can take two forms. The first is the growing of many varieties of the same species, which reflects biodiversity, and the second is the intermingling of many different species. Both types of polyculture have important parallels in research diversity.

Two Important Reasons for Monoculture

Monoculture carries a negative connotation, but there are good reasons to practice it. These are scale, or the potential for mass production, and scope, or the maximal propagation of certain beneficial traits. Mass production with automated planting and harvesting is easiest with a monoculture. Vital as this is for feeding billions of people, growing more plants with specific desirable traits necessarily means fewer other varieties with different traits. Moreover, some seemingly undesirable varieties of crops may be lost in a monoculture, but they might contain latent positive traits that could be recognized or needed later.

Vulnerabilities of Monoculture

However, monocultures have vulnerabilities that environments of biodiversity lack. Diseases and crop failures are the most obvious vulnerabilities of a monoculture. The Irish potato famine was largely created by abusive colonial governance structures that led to the adoption of a potato monoculture. As a result, the potato blight that affected much of Europe in the 1840s and 1850s was most severe in Ireland (Fraser 2003). Inbreeding fatigue can affect many plants, and also humans, hence many cultures' prohibitions on consanguineous marriages. This vulnerability is often easily mitigated through seed production techniques involving many plants. The practice contributes little to biodiversity in general; it is the first type of polyculture, and it is more analogous to marriage within an ethnic group but not with close relatives, as opposed to across ethnic groups. Although it can prevent some plant diseases, climate issues and soil degradation are still problems.

The vulnerability of the banana monoculture has been highlighted recently. The once-ubiquitous Gros Michel cultivar of bananas succumbed to Panama disease throughout its largest growing regions, only to be replaced by the Cavendish variety. Cavendish bananas resist Panama disease, but they have other vulnerabilities. Planting more varieties of bananas close together may not solve the problem; it is more effective to plant completely different plant species alongside bananas that prevent the spread of diseases that afflict bananas, showing the need for the second type of polyculture (Viljoen et al. 2020).

The vulnerabilities of a monoculture are dynamic as well as static. Climate change may render once-productive areas unsuitable for specific cultivars, but may make them good for others. Thus, polyculture enables adaptation. This has already been recognized for crops like coffee and rice. Many cultivars exist, some of which are better suited for a warming climate, and these may be increasingly necessary in coming years (Davis et al. 2022; Sengupta 2023; Sengupta and Le Thuy 2023). Had these varieties not survived, food security for the large proportion of the world's population that depends on rice would be threatened.

Monocultures can have harmful effects of their own that are independent of their vulnerabilities. Maintaining a monoculture with mechanical tilling, planting in uniform rows with tractors, and automated harvesting is harmful to the soil, thus stifling the process of natural adaptation and the development of species. As soil is treated in this way, topsoil erodes, taking away material rich in organic material that holds water and air that plants need. As soil degrades, synthetic fertilizers are needed, along with increased irrigation, creating dependency on industrial processes and exacerbating an inherent vulnerability to water shortages (Alam 2014; Crews et al. 2018; Levia et al. 2020). Abandonment of natural methods like companion planting leads to an increased need for potentially harmful pesticides and herbicides. The response has been to genetically modify crops to make them resistant to herbicides. These monocultures have done well at producing food for the world, but because they are vulnerable to exogenous circumstances and to their own harmful effects, we can do better with less monoculture on the margin.

There will always be a place for some amount of monoculture, and perhaps that place will comprise a large proportion of total agriculture because it has passed the market test and the world's population depends on it. This dependency reflects a developed, specialized economy. Dependency on monoculture can portend harm if it contains a single point of failure, such as one ubiquitous staple crop that is susceptible to disease. Just as a certain measure of dependency is good, so will there always be a place for devoting many resources to a scientific research program that has proven successful. However, increasing biodiversity and research diversity at the margin are important because they may uncover new techniques that could outperform what is presently done, or offer potential solutions to yet-unforeseen problems.

Linking Biodiversity to Research Diversity

Humans shaped nature as the potential for agriculture was recognized. This process was very different from natural, gradual change because it involved deliberate action, which can increase or decrease biodiversity. Scientific research also takes place in a human-designed environment, which determines the extent of research diversity. This section bridges the third and fourth key points, namely, that research diversity has value for reasons analogous to the value of biodiversity, and that institutional structures facilitate it. Just as the natural environment leads to biodiversity when conditions are favorable, so too does the environment for scientific research lead to research diversity.

Monoculture and Polyculture as Related to Research Diversity

Monoculture is not a natural phenomenon, but neither is agriculture more generally. Both require deliberate propagation. Like agriculture, scientific research also comes from human action, but the human-designed institutional structures can lead toward uniformity or diversity just as farmers' incentives lead them toward monoculture or polyculture. There is clearly a research monoculture when viewpoint diversity is lacking (or a scientific consensus is present), but the problem is deeper. A research monoculture, or scientific monoculture, is uniformity of priors, methodological approaches, and objectives. It may stifle work that supports the consensus view but differs in theoretical or empirical approaches.

Scientific consensus does not necessarily exist around a point of view because it is correctly understood, and correct understanding does not necessarily guarantee a scientific consensus, especially early on. Scientific consensus exists when an idea is accepted to the point that opposing views are marginalized. This sort of scientific consensus once existed around eugenics and the flat earth.

Consider the scientific consensus about anthropogenic climate change. Climate change may indeed be caused by humans, but the truth of this conclusion is independent of whether it is or is not accepted. The origin of the consensus is not in the truth of the argument, but in its acceptance. An article critical of the anthropogenic nature of climate change may not be publishable in a highly ranked journal, but the desk rejection could be more from a preference for the consensus than the editors' and referees' ability carefully to refute its arguments.

Both types of polyculture, the growing of multiple cultivars of the same crop and the growing of multiple crops together, have analogues within research diversity, and both are useful. For the first type, variation in methods and objectives within a field leads to greater variety in results and future research directions, and thus more "good options" from which to choose. For the second type, consider the possibility that one field of inquiry consistently runs into the same problem. It may be wise to see if other fields have a solution. Economics, for example, has a long history of borrowing models from other sciences, especially physics.

There are some reasons for limited research monocultures, namely scale and scope. When research shows promise, it can be valuable to have large teams intensively develop it (scale) and maximize its benefits (scope). An example is mRNA, the medical technology in some COVID-19 vaccines, which a few large teams developed quickly. Setting aside the vaccines' efficacy or lack thereof, mRNA also shows promise for curing many genetic diseases (Qin et al. 2022). These cures, however, are years down the road and will require ongoing research. This research monoculture, useful as it may be, stems from earlier discoveries that were not yet mainstream (polyculture). Stifling them would have precluded desirable medical advances that could not have been foreseen at the time. A new crop that is seemingly irrelevant may contain latent positive traits. Likewise, a research program that seems irrelevant may have unrecognized value. The great mathematician and philosopher Imre Lakatos believed that a mathematical theorem should not be considered final just because it appeared to be proven and no counterexample had been found. Further research on a seemingly irrelevant crop or an accepted mathematical theorem, or any other scientific research program, could later be valuable. Latent positive traits in a plant could be recognized in the future—or a counterexample to the theorem could disprove it, in which case the theorem may be refined or redeveloped with variations—and potentially find good use.

Harmful Effects of a Research Monoculture

Is there any harm in a scientific consensus or research monoculture? If research that counters a commonly accepted view is not advanced, then useful research is not disseminated. Even if work critical of anthropogenic climate change contains detectable errors, it may also present new ways of looking at problems, which could inform more work in support of the anthropogenic nature of climate change. Moreover, a "consensus" view can adapt and advance better (showing development and resilience) in the face of opposition as other viewpoints are refuted rather than silenced. To draw analogies to monocultures, scientific consensus leads to vulnerabilities in the form of research gaps that are not addressed. Truly groundbreaking research can take a long time to develop into a reliable form. Disruptive research will not be done overnight, at least not with meaningful, actionable results. As an analogy, consider a hybrid plant that is bred by crossing two established varieties. It may display hybrid vigor, but it is not stable, meaning that its seeds will not produce the same plant. Producing a new stable variety takes several generations of breeding the new population. Eventually, the hybrid vigor diminishes, necessitating crossing the new strain with another.

A research monoculture can lead to a stagnation of innovation that may not be very perceptible. Mass production of agricultural products has been a godsend to the world's population, and the problems that keep food from getting where it is needed are now more political than agricultural. This mass production relies on agricultural monoculture, but this monoculture itself is a product of a research monoculture. There has been much innovation, both in equipment and the intentional development of new crop varieties, but there have been few dramatic paradigm shifts since the advent of modern farm equipment and the Green Revolution. The research monoculture has largely focused on one goal, namely, improving the agricultural monoculture, as opposed to mitigating its vulnerabilities. For example, genetically modified organisms (GMOs) are one of the prominent innovations since the Green Revolution, but the focus has been on making plants resistant to herbicides, tolerant of drought, or higher yielding, all of which improve the monoculture at the margin. Mitigating vulnerabilities could take many forms, thus requiring a research polyculture.

Farmers and agricultural researchers respond to market incentives. Monoculture is profitable, as are its marginal improvements. Societal harms from monoculture may not be severe in the near term, but changing the entire structure of production on a farm entails an upfront cost. It also means forgoing all marginal improvements to the monoculture, and as a result profits will be smaller, or at least more uncertain. For this reason, research directed toward improving the monoculture has the greatest market potential because of expected private rates of return.

The Current State of Research Monoculture

Academic success is often measured by publications in top journals as opposed to genuinely groundbreaking work, which often takes years to be valued. To paraphrase former U.S. Supreme Court Justice Robert Jackson, research is not in top journals because it is good; it is good because it is in top journals.[1]

Academic publishing involves three types of persons—editors, referees, and researchers—many of whom simultaneously work in more than one of these roles. Some journals are more highly regarded than others. The incentives for all persons involved can maintain a research monoculture. Editors, especially at prestigious journals, want to keep a good reputation, so it is risky to publish research that differs sharply in method or result from what is popular. Referees do not want to lose credibility, especially if they want to submit their own research to the journal that asked them to review, so it may be safer to recommend rejection of a paper that may either break new ground or quickly fade away. Moreover, referees who themselves write in favor of the consensus have little reason to recommend publishing opposing views. The journal system thus often reflects a "competitor's review" as opposed to peer review (Dalton 2001; Roy and Ashburn 2001). To understand this inherent bias, imagine requiring Lenovo to ask Apple to approve a new design for a laptop computer. Despite these incentives, many referees and editors are thoughtful and cooperative, so this Lenovo-Apple example is hypothetical and, although similar problems are documented in academia, they are not universal.

Park et al. (2023) believe that the lower propensity of current research to break with the past is not linked to the quality of research. Rather, it highlights a fundamental change in scientific research. Earlier disruptions are still widely accepted and cited. Even published research from large pharmaceutical companies has diminished as drug manufacturers rely more on external research (Rafols et al. 2014). Casadevall (2018) believes that, compounding this problem, the pace of biomedical innovation

1. The original quote is "We are not final because we are infallible, but we are infallible only because we are final" in Jackson's concurring opinion in *Brown v. Allen*, 344 U.S. 443, at 540.

may also be slowing, and Amiri et al. (2020) note that medical education as currently practiced does not foster creativity. This lack of innovation and disruptive research implies a research monoculture, which in turn implies a suboptimal environment for disruptive research.

The causes of this lack of research monoculture are imposed externally. As disciplines and funding became more centralized, it became harder to deviate from the prescribed direction. Likewise, pressure to adhere to mandated research protocols limits research possibilities. Medical research is far from the only field with this problem. Economics has a research monoculture that has been identified by several articles, although they do not use that term. Hoover and Svorenčík (forthcoming) point out that the American Economic Association is dominated by a few scholars at a few elite universities, and Heckman and Moktan (2018) bemoan the dominance of the top five journals and the focus of researchers on publishing articles in those journals, which are overseen by scholars at these elite universities. This dominance leads to political capture as these scholars seek to advance their own views and maintain their prestige as leaders of the monoculture.

Producing research that is truly novel and meaningful takes considerable time. Heckman and Singer (2017) encourage economists to do just this. Most economists, especially junior academics, lack such an incentive, because editors and referees tend to be very narrow in what they will accept as evidence in support of a hypothesis (Diamond 2009, 2019a, 2019b). Heckman, Singer, and Diamond correctly diagnose the problem and envision a better outcome, yet institutional structures within economics and other fields of inquiry currently prevent its realization. The current monoculture in economics, like all monocultures, has not always existed. Joseph A. Schumpeter argued that economic historians had valuable contributions to make alongside econometricians (McCraw 2007). Schumpeter's work predates the current monoculture, which started to take root with the work of his protégé Paul Samuelson.

Institutional Structures for Research Diversity

Human design of the environment makes research diversity possible; human action realizes that diversity. This section develops ideas for a human-designed environment to foster desirable human action, which is the fourth key point of the paper. Drawing on research about environments that has been matched with research diversity, it explains trade-offs and evaluates needed changes to the research environment.

Collaborative teams and lone researchers both have their advantages. Singh and Fleming (2009) claim that teams have a greater likelihood of success than individuals. Cain (2012) and Klein (2013) disagree, and they point to lone researchers who may see what others not only do not see, but may even doubt. Collaborative efforts thus may not lead to the most meaningful discoveries. Singh and Fleming analyze patents, which may be sought following research with a clearly envisioned goal, which lone researchers may not have. In the case of journals with fairly narrow and well-understood criteria, many minds working on the same task may produce more publishable content (Lee et al. 2015). Seen in this light, the recent decline of solo authored papers across many fields is not surprising (Melin and Persson 1996; Lee 2000; Sutter and Kocher 2004). This metric of success—academic publications—lures more researchers into well-focused collaborative efforts to produce presumably fewer papers with more authors, which has become somewhat of a necessity as page counts have not increased at many reputable journals commensurately with the number of submitted articles, though this is not the only reason for the increase in multiple authorship (Wuchty et al. 2007; Conley 2011; Henriksen 2016). The personal experience of the author of this paper is that research that is highly unique is best done as a solo author because it is hard to build a team around the unknown, and that such research is viewed very critically by some editors and referees.

Further supporting this point, Wu et al. (2019) report that disruptive science more often comes from small teams than large teams, and a lone researcher is an extreme case of a small team. Large teams tend to have internal conservative pressures that lead only to the refinement of existing ideas. Large teams cite earlier disruptive papers, but small teams tend to cite a broader swath of papers and to bring older ideas back to the forefront, and thus they tend to be more innovative. Large teams may contain a diversity of ethnic backgrounds and even political views, but the need for consensus around the research outcome leads to temerity. Linear progression characterizes large teams, but smaller teams can lead to the paradigm shifts that Kuhn believed advance science. Wu et al. believe that a diversity of team sizes is beneficial for scientific progress, recognizing the value of both monoculture and polyculture.

Opportunity Costs and Optimal Research Diversity

Scarcity is a universal phenomenon. Time and funds eventually run out. Any effort that goes toward an ineffective earlier paradigm is effort that is not spent on a more promising topic. Conversely, continually pursuing new ideas does not leave time for them fully to develop. Diamond (2009) argues that diversity of methods is vital in the short run because we do not know a priori what will work, but there is a needed long-run effort of evaluating which methods work best. Using this paper's terminology of *scale* and *scope*, scope matters more in the short run, and scale in the long run, but ideas ought not to be scaled up unless the scope of research has been diverse enough to provide a good idea of what should be scaled. For this reason, there is a place for both radically new ideas and refinements of what has been published before. This reflects the trade-offs that Wu et al. recognize when they urge reliance on both large and small teams.

The optimal level of research diversity is hard to define. Markets solve this problem with the process of entrepreneurship, using private funds. Most new business ventures fail, and a handful succeed. Those that succeed inspire others to compete by refining the successful strategy. Consider the development of the shipping container, which revolutionized freight transportation. The idea was pioneered by Malcom McLean, an innovative trucking magnate. He understood that shipping over water was less energy intensive than over land, and he also knew that sailing a ship was not the same as transporting cargo and customers only cared about getting the delivery. Blending ideas from two industries, McLean developed the first container business. He succeeded for a while, though even his businesses fell prey to skilled competitors (Levinson 2016). Without linking the land and ocean shipping industries, either one could independently have become more efficient, but there would have been no globalized economy like what developed by the end of the twentieth century.

This anecdote about McLean and container shipping shows the value of interdisciplinary collaboration when markets can judge it. Such an approach may work in the natural sciences if results can be commercialized, but it shows less promise in the social sciences, where both researchers and funders must support it—and the profit yardstick doesn't exist. In the social sciences especially, but also in other fields, there is a need for openness to novel approaches. The optimal level of research diversity may not be quantifiable because there will be differing opinions about it, but it is much higher than what we now have.

Collaboration can be fruitful across disciplines that seem radically different. Project Cassandra was undertaken by the German Defense Ministry to predict future military and political events using fictional novels that could represent undercurrents of thought in society (Oltermann 2021). Before it was discontinued due to a lack of funding, it enjoyed some modest success. The author of this paper, an economist, coauthored a paper with a computer scientist who works in artificial intelligence programming to update the economic calculation argument of F. A. Hayek and Ludwig von Mises (Gmeiner and Harper 2022). This project highlighted new issues for AI programming as well as economic planning, showing the fertile environment for forming and answering new questions that comes from interdisciplinary collaboration.

Collective Policies and Individual Choices

Researchers who write grants or work for universities are the producers of research. Universities and grant-funding agencies, although sometimes considered producers of researchers, are actually consumers of research because they pay for it. A lack of disruptive science, which is now a recognized problem, should be viewed in light of researchers' (or producers') incentives in response to funders' (consumers') wishes. Only when those who buy research decide to demand different will the system change. This will be far from trivial, however, as it means sacrificing some prestige to pay for research that may not end up being disruptive in a good way. Cross-pollination across fields should be encouraged as a way of generating new ideas and synergizing the strengths of different fields.

The agricultural monoculture exists ultimately because people buy and eat its products; when they insist on products from sustainable farms with biodiversity, which will be more expensive, farmers will produce them. Likewise, when researchers are rewarded for originality, they will produce it. Academic scientists and farmers face very different incentives largely because academic research is routed through middleman gatekeepers (editors) and is seldom consumed by the general public, but farmers and academics both respond to their respective incentives. When the incentives encourage originality, research diversity will follow.

Although the incentives differ for farmers and academics, solutions are analogous. Global markets for uniform commodities are an incentive for monoculture. If commodity markets were less monolithic and more disaggregated, regional variation in crop staples could arise. The research environment for a particular topic has become more monolithic since telecommunications technology expanded the potential pools for collaborators and coauthors in the sciences (Henriksen 2016). The number of authors per article has increased in many disciplines (Sonnenwald 2007). In the past, research collaborations were limited to academics at nearby universities; ideas could develop independently and with variation at different geographical locations. In economics, one example is the diminished distinction in the United States between the freshwater school (universities near the Great Lakes) and saltwater school (universities on the East and West Coasts). Macroeconomic research has become more similar between the two schools in recent years. Some potential solutions to this monolithic research environment include having manuscripts reviewed by researchers in geographic proximity to authors, limiting the number of coauthors, or limiting the size and sources of funding. These steps may increase research diversity only slowly at first, but they could ease the difficulties faced by small teams doing more unique work and thus lead to more variation in methods within each discipline.

In an impressive display of intellectual humility, Yang and Song (2023) determined that the rate of rotation of the earth's core has changed, yet knew that their findings may not be conclusive. Hrvoje Tkalčić, another renowned seismologist, lauded their analysis, yet said, "We use geophysical inference methods to infer the Earth's internal properties, and caution must be exercised until multi-disciplinary findings confirm our hypotheses and conceptual frameworks," and Yang and Song agreed. The question for this section of the paper is how this attitude can be rewarded.

An attitude of humility coupled with the courage to pursue bold new ideas is needed for disruptive research to make a comeback. Humility is what causes editors and referees to let disruptive research advance. Courage drives researchers to pursue an idea with an unknown, and perhaps very high, risk of not working. Diversity is greatest at the place of origin, and this reflects a fertile environment for growth and development. Research diversity will exist when the environment supports it. Such an environment will encourage some work that could be as dubious and dangerous as what was done by Trofim Lysenko in the Soviet Union. Lysenko rejected Mendelian genetics and held views that were already or soon would be discredited about spacing plants, timing the watering of plants during their life, and altering plant traits with specific treatments of seeds before germination. His skill was greatest in persuading Joseph Stalin to support him, in part because of his background as a peasant, which made him more attractive to Stalin's ruling Communists. Denouncing credible science as "bourgeois" and causing Stalin to mandate his proposed techniques while sending his opponents to labor camps, Lysenko contributed to famines that plagued the Soviet Union and China, which also adopted his methods (Reznik and Fret 2019). Though there may not be enough research diversity today, some on the fringes of plant science still believe Lysenko, and an environment of research diversity will tolerate their work (Wang and Liu 2017). This same environment will prevent people like Lysenko from stifling their opponents and will also prevent the widespread acceptance of Lysenko's techniques as they continue failing when tried in practice.

Reforming the environment to produce research diversity will occur alongside an incentive for more originality, and this shift will require changes in evaluation and compensation. As long as researchers are expected to produce peer-reviewed articles for publication, these changes may be beyond the realm of policy to effect because journal editors and paper reviewers themselves must change their evaluation criteria. For those who design policies and evaluation criteria, the goal ought to be incentivizing more creative and disruptive research, but not mandating that as an outcome. The environment will cause the diversity, but not vice versa.

Implications of Artificial Intelligence

Artificial intelligence is a rapidly developing field, and large language models (LLMs) quickly caught the public's attention during the writing of this paper. LLMs show some promise for increasing research diversity, but they could also impede it. Because LLMs are trained on existing written material, they write their output using algorithms to find words that go together from the training material. Because of this, their ability to produce novel research is limited. They do not yet follow the steps of the scientific method, nor do they have a preprogrammed research design, although it is premature to rule out such abilities in the future.

Depending on the prompts that an LLM is given, it could produce new ideas, draw connections between different fields, or propose new techniques. This requires researchers to become familiar with prompt engineering, or structuring text to lead toward LLM output of a certain type. Prompt engineering can thus aid in brainstorming new ideas. The algorithmic process that LLMs use to produce output may generate research leads that are dead ends or highly successful ideas. Discerning the difference requires extensive knowledge of the subject matter and the ability to conduct independent research, which requires human effort at the present time. Thus, the current state of artificial intelligence is such that it can assist in developing new priors, proposing new methods, and encouraging the use of methods from different fields. Its usefulness, though, depends on the environment's support for research diversity and on each individual researcher's ability to use it prudently.

Conclusion

Diversity is good because it reflects a good environment for the growth of organisms or the expansion of knowledge, and the development of species or the refinement of ideas. When considered as an end unto itself, it can obscure or even lead to neglect of the underlying factors that cause it. Research diversity, or the use of unique approaches to research, is desirable because it leads to the expansion or growth of scientific knowledge, its refinement or development, and its practical use and resilience in the face of future challenges and changes in circumstances.

Just as a favorable natural environment leads to biodiversity, so too does a good environment for research lead to research diversity. At the present time, the environment for scientific research encourages a monoculture that refines existing ideas but is not sufficiently innovative or disruptive. To increase the amount of research diversity, interdisciplinary collaboration and the use of new approaches must be encouraged. This means changing the incentives of those who conduct research, which requires a change in the behavior of those who fund and evaluate research. Some of the value of monoculture, such as the large-scale refinement of existing ideas, will diminish, but radically new knowledge will be produced and the environment will be more resilient going forward. Without research diversity, analogues to many problems that arise from a lack of biodiversity can result, leading to stagnation in academic progress.

References

Alam, Afroz. 2014. Soil Degradation: A Challenge to Sustainable Agriculture. *International Journal of Scientific Research in Agricultural Sciences* 1 (4): 50–55.

Amiri, Mohammad, Ahmad Khosravi, Reza Chaman, Zakieh Sadeghi, and Mehdi Raei. 2020. Creativity and Its Determinants among Medical Students. *Journal of Education and Health Promotion* 9 (1): 320.

Ashraf, Quamrul, and Oded Galor. 2013. The "Out of Africa" Hypothesis, Human Genetic Diversity, and Comparative Economic Development. *American Economic Review* 103 (1): 1–46.

Blake, Michael. 2015. *Maize for the Gods: Unearthing the 9,000-Year History of Corn*. Berkeley: University of California Press.

Cain, Susan. 2012. *Quiet: The Power of Introverts in a World That Can't Stop Talking*. New York: Crown.

Casadevall, Arturo. 2018. Is the Pace of Biomedical Innovation Slowing? *Perspectives in Biology and Medicine* 61 (4): 584–93.

Conley, John P. 2011. Low Acceptance Rates, Commercial Publishing, and the Future of Scholarly Communication. *Economics Bulletin* 32 (4): A327.

Crews, Timothy E., Wim Carton, and Lennart Olsson. 2018. Is the Future of Agriculture Perennial? Imperatives and Opportunities to Reinvent Agriculture by Shifting from Annual Monocultures to Perennial Polycultures. *Global Sustainability* 1:E11.

Dalton, Rex. 2001. Peers under Pressure. *Nature* 413:102–104.

Davidson, Alan. 1999. *The Oxford Companion to Food*. Oxford: Oxford University Press.

Davis, Aaron P., Catherine Kiwuka, Aisyah Faruk, Mweru J. Walubiri, and James Kalema. 2022. The Re-emergence of Liberica Coffee as a Major Crop Plant. *Nature Plants* 8 (12): 1322–28.

Diamond, Arthur M., Jr. 2009. Fixing Ideas: How Research Is Constrained by Mandated Formalism. *Journal of Economic Methodology* 16 (2): 191–206.

———. 2015. Seeking the Patent Truth: Patents Can Provide Justice and Funding for Inventors. *The Independent Review* 19 (3): 325–55.

———. 2019a. Cross-Current, or Change in the Direction of the Mainstream? *Real-World Economics Review* 90:33–39.

———. 2019b. *Openness to Creative Destruction: Sustaining Innovative Dynamism*. New York: Oxford University Press.

Dry, Sarah. 2014. *The Newton Papers: The Strange and True Odyssey of Isaac Newton's Manuscripts*. New York: Oxford University Press.

Estabrook, Barry. 2015. Why Is This Wild, Pea-Sized Tomato So Important? *Smithsonian Magazine*, July 22, 2015. https://www.smithsonianmag.com/travel/why-wild-tiny-pimp-tomato-so-important-180955911.

Fraser, Evan D. G. 2003. Social Vulnerability and Ecological Fragility: Building Bridges between Social and Natural Sciences Using the Irish Potato Famine as a Case Study. *Conservation Ecology* 7 (2): 9.

Gmeiner, Robert J., and Mario Y. Harper. 2022. Artificial Intelligence and Economic Planning. *AI & Society*.

Heckman, James J., and Sidharth Moktan. 2018. Publishing and Promotion in Economics: The Tyranny of the Top Five. *Journal of Economic Literature* 58 (2): 419–70.

Heckman, James J., and Burton Singer. 2017. Abducting Economics. *American Economic Review* 107 (5): 298–302.

Henriksen, Dorte. 2016. The Rise of Co-authorship in the Social Sciences (1980–2013). *Scientometrics* 107:455–76.

Hoover, Kevin D., and Andre Svorenčík. Forthcoming. Who Runs the AEA? *Journal of Economic Literature*.

Klein, Gary. 2013. *Seeing What Others Don't: The Remarkable Ways We Gain Insights.* Philadelphia: Public Affairs.

Kozlov, Max. 2023. "Disruptive" Science Has Declined—and No One Knows Why. *Nature,* January 4, 2023. https://doi.org/10.1038/d41586-022-04577-5.

Lee, Wade M. 2000. Publication Trends of Doctoral Students in Three Fields from 1965–1995. *Journal of the American Society for Information Science* 51 (2): 139–44.

Lee, You-Na, John P. Walsh, and Jian Wang. 2015. Creativity in Scientific Teams: Unpacking Novelty and Impact. *Research Policy* 44 (3): 684–97.

Lemley, Mark A. 2012. The Myth of the Sole Inventor. *Michigan Law Review* 110 (5): 709–60.

Levia, Delphis F., Irena F. Creed, David M. Hannah, Kazuki Nanko, Elizabeth W. Boyer, Darryl E. Carlyle-Moses, Nick van de Giesen, et al. 2020. Homogenization of the Terrestrial Water Cycle. *Nature Geoscience* 13:656–58.

Levinson, Marc. 2016. *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger.* Princeton, N.J.: Princeton University Press

McCraw, Thomas K. 2007. *Prophet of Innovation: Joseph Schumpeter and Creative Destruction.* Cambridge, Mass.: Belknap Press.

Melin, Göran, and Olle Persson. 1996. Studying Research Collaboration Using Co-authorships. *Scientometrics* 36 (3): 363–77.

Mujaju, C., J. Sehic, G. Werlemark, L. Garkava-Gustavsson, M. Fatih, and H. Nybom. 2010. Genetic Diversity in Watermelon (*Citrullus lanatus*) Landraces from Zimbabwe Revealed by RAPD and SSR Markers. *Hereditas* 147 (4): 142–53.

Oltermann, Philip. 2021. "At First I Thought, This Is Crazy": The Real-Life Plan to Use Novels to Predict the Next War. *The Guardian*, June 26, 2021. https://www.theguardian.com/lifeandstyle/2021/jun/26/project-cassandra-plan-to-use-novels-to-predict-next-war.

Park, Michael, Erin Leahey, and Russell J. Funk. 2023. Papers and Patents Are Becoming Less Disruptive over Time. *Nature* 613:138–44.

Qin, Shugang, Xiaoshan Tang, Yuting Chen, Kepan Chen, Na Fan, Wen Xiao, Qian Zheng, et al. 2022. mRNA-based Therapeutics: Powerful and Versatile Tools to Combat Disease. *Signal Transduction and Targeted Therapy* 7:166.

Rafols, Ismael, Michael Hopkins, Jarno Hoekman, Josh Siepel, Alice O'Hare, Antonio Perianes-Rodriguez, and Paul Nightingale. 2014. Big Pharma, Little Science?: A Bibliometric Perspective on Big Pharma's R&D Decline *Technological Forecasting and Social Change* 81:22–38

Reznik, Semyon, and Victor Fret. 2019. The Destructive Role of Trofim Lysenko in Russian Science. *European Journal of Human Genetics* 27 (9): 1324–25.

Roy, Rustum, and James R. Ashburn. 2001. The Perils of Peer Review. *Nature* 414:393–94.

Sengupta, Somini. 2023. Hardier Brew: African Farmers Bet on Climate-Resistant Coffee. *New York Times*, April 29, 2023, A1 and A6.

Sengupta, Somini, and Tran Le Thuy. 2023. Reimagining Rice, a Crop That Feeds the World. *New York Times,* May 26, 2023, A1, A10–A11.

Singh, Jasjit, and Lee Fleming. 2009. Lone Inventors as Sources of Breakthroughs: Myth or Reality? *Management Science* 56 (1): 41–56.

Sonnenwald, Diane H. 2007. Scientific Collaboration. *Annual Review of Information Science and Technology* 41 (1): 643–81.

Sutter, Matthias, and Martin Kocher. 2004. Patterns of Co-Authorship among Economics Departments in the USA. *Applied Economics* 36 (4): 327–33.

Viljoen, Altus, Li-Jun Ma, and Augustin B. Molina. 2020. Fusarium Wilt (Panama Disease) and Monoculture in Banana Production: Resurgence of a Century-Old Disease. In *Emerging Plant Diseases and Global Food Security,* edited by Jean Beagle Ristaino and Angela Records, 159–83. St. Paul, Minn.: American Phytopathological Society.

Wang, Zhengrong, and Yongsheng Liu. 2017. Lysenko and Russian Genetics: An Alternative View. *European Journal of Human Genetics* 25 (10): 1097–98.

Wu, Lingfei, Dashun Wang, and James A. Evans. 2019. Large Teams Develop and Small Teams Disrupt Science and Technology. *Nature* 566:378–82.

Wuchty, Stefan, Benjamin F. Jones, and Brian Uzzi. 2007. The Increasing Dominance of Teams in Production of Knowledge. *Science* 316 (5827):1036–39.

Yang, Yi, and Xiaodong Song. 2023. Multidecadal Variation of the Earth's Inner-Core Rotation. *Nature Geoscience* 16:182–87. https://www.nature.com/articles/s41561-022-01112-z.

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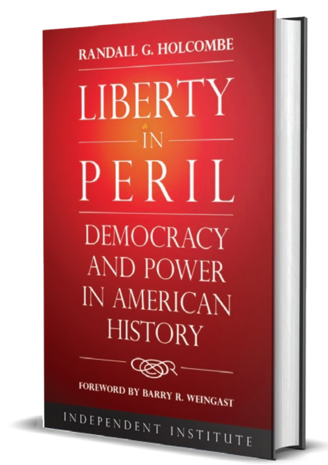

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