Reviews

Democratization of Systematics

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Abstract

Science, like other sectors of society, is currently in a period of rapid social and cultural change. Demands for the decolonization and democratization of research culture and scientific data are prevalent. Systematic biology, as the research community that focuses on the existentially important issue of understanding global biodiversity, and as the standard-bearer for a field deeply rooted in colonialist approaches, has a unique opportunity to develop and model a meaningful and actionable vision for systemic change. Because systematics research requires sampling and analyzing planetary biodiversity, it operates within a global arena in which undoing exclusionary norms and practices, and reimagining a new kind of science that builds knowledge collectively, is both possible and potentially hugely impactful. Because of its history, the discipline has the potential to become a powerful model of intentional transformation. Professional systematists work and conduct research across natural history museums, academic institutions, federal agencies, national laboratories, international organizations, and the private sector and they serve as leaders throughout the disciplinary ecosystem; as a result, they are well-positioned to shape cultural transformation. We highlight just one example of a change lever (peer review of proposals) to illustrate this. Beneficial outcomes of such a new era of systematics will be extensive for continued research advances in biodiversity and phylogenetics, and for critical challenges that lie at the science-society-policy intersection.

1 Introduction

Systematics research is vitally important for understanding planetary biodiversity, including its historical evolution and future sustainability. However, it is widely acknowledged that systematic biology is grounded in a long history of colonialist, exclusionary, and extractive research practices. This history has left a strong cultural signature on the discipline, but it also provides a compelling opportunity to examine the potential of a scientific discipline to radically reinvent itself in an era of profound social change. Here, we call attention to this deep history, examine the consequences of the status quo in the discipline, highlight the extensive calls for transformational change, and generally explore systemic change efforts in science and how they are accomplished.

Widespread and growing calls to decolonize, democratize and diversify science (e.g., Armenteras, 2021; Barabino, 2022; Branch & Alegria, 2018; Graves et al., 2022; Kearney et al., 2021; McGee, 2022; Tilghman et al., 2021; Trisos et al., 2021; Whitt, 2009) and, more specifically, to reform extractive and exploitive practices such as parachute science (Ashuntantang et al., 2021; Haelewaters et al., 2021; Ramírez-Castañeda et al., 2022; Stefanoudis et al., 2021), are leading to cultural change efforts across the scientific enterprise. Calls for culture change are intensifying with the growing realization of historical injustices as well as the many benefits of greater inclusion, which include a more innovative scientific enterprise (Page, 2008), a research culture that is less harmful to researchers and students, and more effective knowledge transfer between science and all sectors of the public. Here we suggest that systematics can serve as a powerful model in the context of this broader paradigm shift. Foundational to such a shift is a greater understanding and acknowledgment of the field's social history, an appreciation of the incurred costs to science and society, a strong and renewed commitment to broadly transform disciplinary culture, and an increased awareness of the power and influence that systematists hold to drive such change. Such a profound transformation requires deep innovation and vision, and this will likely be realized only with continued generational shifts and increasingly diverse leadership and representativeness in the field.

In many ways, systematics could be an ideal test case for cultural transformation in science. The discipline has a rich and complex history, and its core activities (e.g., expeditionary fieldwork, biodiversity collecting and analysis, taxonomic research, team science / internationally collaborative approaches) are particularly germane to the broader anti-colonialist and democratization agenda being promoted by many across the scientific community. By decolonizing and democratizing its community of practitioners, leaders, research culture, collecting practices, institutions, and data/infrastructure, systematics can attract untapped and diverse talent to the field, ameliorate the 'diversity-innovation paradox' (i.e., diversity is shown to enhance innovation, even though diversity of perspectives and people are not necessarily rewarded in the traditional academic system; Hofstra et al., 2020; O'Brien et al., 2020), and ensure a just and equitable foundation for future contributions to global biodiversity science. Because such reforms are aimed at abrogating deeply systemic and entrenched norms, the magnitude and complexity of the work are significant, and there are significant barriers to reform. As in all domains, attempts to modernize the field will encounter power dynamics, backlash, and gatekeeping efforts. Increasing representativeness within the discipline is a partial answer to those obstacles, and therefore broadening participation in systematics at all career levels is a foundational priority for cultural transformation. Indeed, a new generation of systematists who view the world inside and outside of science differently than previous generations is already demanding and implementing major changes.

Another challenge occurs at the systems level, where the complex feedback dynamics between components of the science system (e.g., scientific practitioners, traditional incentives for career advancement in academic science, engrained institutional norms and policies, long-established research practices, publishing criteria, funding opportunities, and peer review practices) mean that a well-aligned, systems-level change effort is necessary to realize significant progress. Here, part of the answer lies in coordinated change efforts made in alignment across the system, perhaps with the help of cross-cutting organizations such as scientific professional societies in association with experts in social change initiatives. Finally, transformational change in the discipline first requires a deep understanding and acknowledgment of the historical context in which the field developed.

2 Systematics in Context

A core component of systematic biology is the collection, identification, formal description, and preservation of biological material. Many of these biological collections are housed in natural history museums, which have roots in the post-Enlightenment "Great Acceleration" and stand today as iconic examples of centuries of colonialist and imperialist science (Sheets-Pyenson, 1987). The rise of natural history museums stimulated an era of even more collecting expeditions that brought (and still bring) significant samples of planetary biodiversity into a relatively small number of major museums, predominantly located in North America and Europe (Fig. 1). The tradition of engaging in collecting trips and expeditions to biodiverse areas of the planet, transporting and storing collected specimens in institutions throughout the Global North, and naming and publishing biodiversity 'discoveries' with Western eponyms and with little or no involvement or attribution from local collaborators, peoples, and/or sovereign nations, was normalized for so long (Das & Lowe, 2018; Markham, 2020; Park et al., 2023) that few questioned the practices and policies until relatively recently (e.g., Imbler, 2019; Tuhiwahi-Smith, 2021). Meanwhile, the research value of these amassed collections for studying biodiversity, climate change, global change biology, and many other scientific and societal challenges is enormous and ever-growing. Paradoxically then, the biological specimens collected and stored in natural history museums over centuries of expeditionary fieldwork are an incredibly valuable resource to science and the public, while also standing as a monument to the extractive and colonialist history of the field (Fig. 1).

The earliest and largest natural history museums relied on a global imperialist network to build their collections and displays, grow their audience, and establish their scientific credibility. Most of the collections were made by North American and European explorers and scientists, and most of the research undertaken on them today remains within the domain of North American and European scientists. Further, most natural history data remain digitally undiscoverable by a global user community (Webster et al., 2021), which represents a scientific and social inequity, as well as a failure of technology and leadership. Questions such as how best to mobilize the dark data of museum collections, how to efficiently enact the democratization of data access, which institutions will be included in these initiatives, who will lead and participate in them, and who will be permitted to use the data, demand new vision and ideas that depart significantly from the status quo. This future vision cannot be solely the purview of the current powerbrokers in the discipline (Monfils et al., 2020) but must entail a broadly democratized global effort, including all stakeholders.

Perhaps no aspect of systematics and biodiversity science is more emblematic of its colonialist history, *and* more fascinating to think about in terms of the potential to model transformational change, than the concept of the future natural history museum. Most biologists understand the immense, unique and irreplaceable value of biological collections to science and society (e.g., Hedrick et al., 2020; Nanglu et al., 2023; Raxworthy & Smith, 2021; Vogel, 2019), and it is not necessary to repeat this narrative here. What is less explored are the possibilities for radically reinventing natural history museums and other biodiversity institutions via new and diverse leadership, a new international and collaborative vision for the future, enhanced ability to serve a broader range of collections-based research uses across many more science domains, and fully democratizing access to this vast scientific infrastructure.

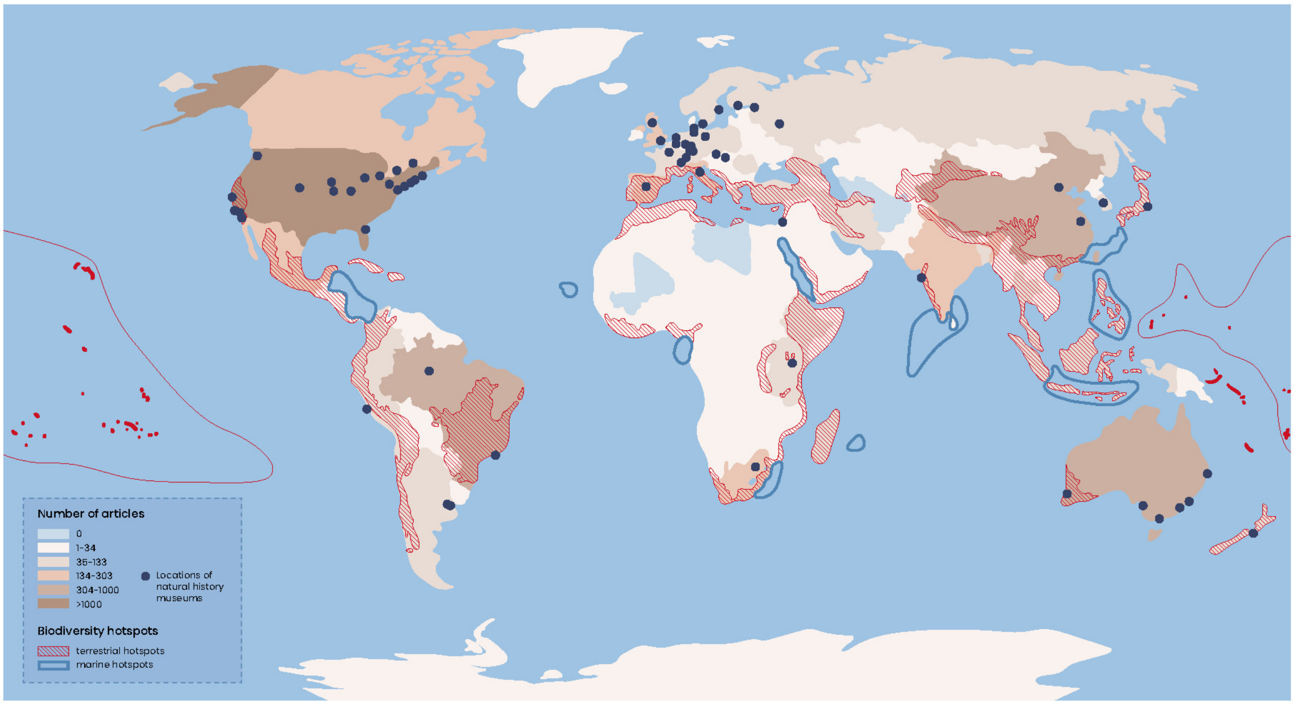

Fig. 1. The social history of biodiversity science has resulted in today's profound incongruity between the global distribution of our planet's biodiversity, the global distribution of collected biodiversity samples contained in natural history institutions, and the global distribution of publications on biodiversity conservation. Map data combined and adapted from Wilson et al. (2016); Culebras (2023); Johnson et al. (2023); and Marcer et al. (2022).

Some reform efforts are already underway, such as including the scientific contributions of Indigenous peoples,[1] providing anti-colonialist interpretations and narratives associated with exhibits,[2] repatriation or ownership-sharing of Indigenous specimens,[3] disclosing the full cultural history of the provenance of historical collections (Ashby & Machin, 2021), and increasing access to collections data (Drew et al., 2017). Many are also working towards creating learning experiences in collaboration with those communities affected by historical practices, and engaging deeply in community science approaches, both locally and internationally.[4]

Legacy approaches to biodiversity science are not limited to collecting expeditions, specimens, and natural history museums. They are visible throughout the field – for example when local collaborations are absent from competitive field-based research opportunities, when junior researchers experience toxic and/or harassing work environments during expeditions or in other domains, in species-naming practices that make new discovery claims without acknowledging longstanding local knowledge, in the narrow demographics observed in leadership positions and associated honorifics, and whenever research excludes of local knowledge experts or fails to include the scientists who provided material access and significant knowledge contributions. It is not uncommon that most research publications from formerly colonized countries are products of collaboration with scientists from Western countries, because this is often the only means of access to cover the ever-increasing costs of conducting and publishing science (Boshoff, 2009). It is also not uncommon that the role of Indigenous scientists remains largely relegated to providing access and knowledge for fieldwork opportunities rather than truly equitable intellectual collaboration (Dahdouh-Guebas et al., 2003). These longstanding cultural norms are now being challenged on all fronts: field collecting (e.g., Baker et al., 2019; Ramírez-Castañeda et al., 2022; Trisos et al., 2021), repatriation of collected specimens (e.g., Belsey, 2019; Lonetree, 2012), inclusive research collaborations [e.g., Mignolo, 2012; Quijano, 2000), open data access (e.g., Butler et al., 2023; Nagaraj et al., 2020), taxonomic approaches such as decolonizing species-naming practices (e.g., Evans, 2020; Gilman & Wright, 2020; Pennisi, 2023; Trisos et al., 2021), and challenging award names that, historically, have been narrowly conferred (e.g., Bazner et al., 2019; Pourret et al., 2021). Fundamental to all these efforts is the increas-

1 https://www.amnh.org/exhibitions/permanent/northwest-coast

2 https://www.theguardian.com/world/commentisfree/2020/mar/07/europe-museums-decolonisation-africa-empire

3 https://naturalhistory.si.edu/research/anthropology/programs/repatriation-office

4 https://www.calacademy.org/community-science; https://www.fieldmuseum.org/science/conservation/keller-science-action-center

ing acknowledgment that global biodiversity samples are both natural and cultural resources valued by many different people for many different various reasons, as well as the recognition that Global North scientists are not the sole experts in biodiversity science. Not only do multiple values of biodiversity exist, but the diverse valuers include local, Indigenous, and traditionally marginalized communities, all of whom must be included in future framing and messaging about biodiversity research and decision-making (Díaz & Malhi, 2022). But the necessary precursor to reforming these past practices is the formidable challenge of de-colonizing hearts and minds throughout the broader community by demonstrating why meaningful culture change will benefit the entire field.

3 The Why

The disadvantages of maintaining the legacy research culture and practices in systematics are numerous and varied. Here we focus on four of them: (i) potentially increased restrictions on access to fieldwork and other research opportunities, (ii) exacerbation of empirical and conceptual knowledge gaps in the discipline, (iii) decreased ability to translate systematics research outcomes to applications and policies that address critical societal challenges, and (iv) misalignment between the discipline and rapidly changing global biodiversity science policies.

Access to biodiversity research resources is a contentious issue and, despite global efforts, reluctance to address access, attributions, and intellectual property rights persists in some parts of the community. The Nagoya Protocol,[5] from its beginning as a concept at the Convention on Biological Diversity, is a multilateral treaty that provides a legal framework for the utilization of genetic resources, including specimens, metadata and intellectual outcomes of specimen-based research. The treaty bears significant impact on how international field research may be conducted and how biological collections may be made (Adler Miserendino et al., 2022). In reaction to past practices, such as those that led to Indigenous resources being used without attribution, research involvement, or benefit-sharing, the Nagoya Protocol arose to shift research culture towards ensuring equitable benefits. Although originally targeted at genetic resources, the protocol has broad relevance for many international science pursuits and methods by providing a general framework for ethical fieldwork conduct, collections management, and other activities. Nagoya seeks to move research workflows towards circularity and collaboration, thereby returning the resources and knowledge obtained through fieldwork to the communities that provide access, logistics, and local knowledge. Nagoya-compliant research protocols are becoming more common, but there remains much room for increased awareness, training, and involvement. There is also a persistent need to extend the underlying philosophy of the Nagoya Protocol to additional applications in the field. Institutions that employ and support biodiversity scientists should become more engaged with these evolving policies and provide training and education needed to advance compliance. This is important because international policies will continue to play a large role in what the systematics community is able to accomplish in terms of biodiversity collections and research. We urge systematists to adjust their own practices, mentoring and peer-reviewing in this regard, and to become more policy-active in this arena whenever possible.

Undemocratic practices in biodiversity science have also significantly shaped the knowledge base accumulated by biodiversity and systematics researchers. This is partly because scientists from the Global North currently hold a monopoly over global biodiversity collections and data for research purposes (Culebras et al., 2023; Wilson et al., 2016). This bias skews our knowledge of planetary biodiversity towards certain areas of the planet and towards certain kinds of biodiversity. In turn, the resulting data gaps detract from our ability to comprehensively address major scientific questions, such as the nature of biodiversity response under global change, evolutionary and phylogenetic dynamics, and the structure of the Tree of Life. For example, a large percentage of species occurrence data in the Global Biodiversity Information Facility (GBIF) are occurrences from historically well-resourced countries (Beck et al., 2014; Bowler et al., 2022; Meyer et al., 2015), though GBIF is actively and strategically working to fill these gaps.[6] The gaps derive from numerous intersecting issues, including the historical biases discussed previously in museum holdings, as well as taxonomic, geographic, ecosystem, and other collecting biases. Similarly, ninety-seven percent of fossil data (which are critical to systematics and phylogenetic biology) in a global paleontological data base derive from U.S. and western European authors (Raja et al., 2021). Incomplete and/or biased knowledge of planetary biodiversity propagates to an incomplete, and therefore inaccurate, Tree of Life. Since knowledge of phylogeny continuously evolves as we include more biodiversity in phylogenetic analyses, and since phylogenetic accuracy decreases with poor sampling (particularly when sampling is non-randomly incomplete), the unevenness of biodiversity knowledge due to historical practices is phylogenetically problematic. Dark or inaccurate areas of the Tree of Life, in turn, hinder our ability to answer important comparative questions across evolution, ecology, and conservation biology, which is a significant issue given the foundational nature of phylogeny to so many biological disciplines. In short, to obtain a comprehensive knowledge of biodiversity and phylogeny, and to use that knowledge as the basis for comparative studies and/or policy decision-making, requires ac-

5 https://learnnagoya.com

6 https://www.gbif.org/data-use/82948/prioritizing-gaps-and-biases-in-biodiversity-data

knowledging sampling biases and data gaps that are caused not only by intellectual, economic and physical constraints; they are also borne out of problematic historical practices, social inequities, and exclusionary practices in science that can now be rectified.

Another legacy of colonialism and inequity on our current state of systematics knowledge is more conceptual than empirical: neocolonialist science influences research agendas and knowledge production in quite specific ways (e.g., Trisos et al., 2021). Because the nearly exclusive access to research opportunities in biodiversity habitats, resources, and data disproportionately benefits higher-income, resource-rich institutions, the scientists at these institutions continue to disproportionately influence research agendas, knowledge production, and theory in systematic biology. Consequently, the field continues to be shaped by a dominant "Global North epistemology" that is self-validating in its disciplinary development and that privileges scientists from the Global North as the knowledge creators of biodiversity science. More generally, published hierarchies of university rankings and academic journals demonstrate that all of science remains dominated by a Global North epistemology. The increasing recognition that epistemic exclusion (i.e., of certain types of scholarship or contributions to knowledge production) disproportionately impacts and marginalizes members of underrepresented groups (Dotson, 2014; Prescod-Weinstein, 2020; Settles et al., 2022) adds even more urgency to challenging these historical norms. Decolonizing and democratizing knowledge production is an active area of advocacy for the future because intellectual decolonization is increasingly acknowledged as a barrier to the most creative research and scholarship (e.g., Nordling, 2018; Tuhiwahi-Smith, 2021; Zavala, 2016). The long-term domination of science by white, western, and/or Global North perspectives has also narrowly defined our understanding of *how to conduct* science, and sometimes manifests in a 'deficit view 'of Indigenous knowledge and a propensity to value only specific ways of pursuing discovery and knowledge. A cogent example of this from systematics is the common practice of proclaiming new species discoveries and the naming of such as honorifics after prominent Global North scientists, even though many of these 'discoveries' are often organisms and species that have been rooted in local and/or Indigenous knowledge for centuries. Many published biodiversity discoveries and descriptions are more accurately 'rediscoveries' when viewed through an anti-colonialist lens, and the 'claiming and naming' of new species is a telling example of the overall issue (Tuhiwahi-Smith, 2021).

Finally, there are societal and policy risks to maintaining the status quo in systematic biology when we consider the enormous public value for addressing the biodiversity crisis and other societal challenges. Such value can only accrue through the translation of knowledge to application – and diverse, inclusive, community-engaged science is demonstrated to be the most effective pathway for successful knowledge transfer (Curran et al., 2011). For example, conservation of biodiversity is fraught with sociopolitical dynamics, global inequities, and histories of colonizer land use that detract from effective policy adoption. Further, Indigenous peoples currently steward 80% of Earth's protected terrestrial and marine biodiversity, given that lands inhabited by Indigenous people contain 80% of the planet's remaining biodiversity (Brondizio et al., 2019; Ellis et al., 2021; Garnett et al., 2018; Nitah, 2021; World Bank, Australia, 2021; Fig 1). The 2019 global assessment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Service (IPBES) called attention to the critical role of Indigenous communities in biodiversity science and conservation, and to the strong history of careful stewardship of nature compared to the poor record of western and North American practices (Brondizio et al., 2019). Scientists have much to learn about biodiversity science and its sustainability from Indigenous peoples, who have understood, shaped and stewarded nature for thousands of years. Critically, the biodiversity crisis cannot be addressed without their knowledge, leadership, and engagement. This same perspective applies to many under-resourced local and urban communities or 'science deserts' that nevertheless harbor extensive local knowledge of biodiversity. Thus, expanding systematics with more inclusive expertise and with community-engaged science will strengthen the evidence base, trust in science, and efficacy of research findings available to communities and policymakers. Significant societal and policy impacts of systematics and biodiversity science – such as its relationship to national bioeconomy efforts,[7] environmental justice,[8] emerging diseases and public health,[9] nature-based solutions to climate change,[10] and food security[11] – will also depend on inclusive research practices and community engagement with our science.

Biodiversity-relevant policy organizations are quickly moving towards more equitable and inclusive requirements, and systematics risks misalignment with this policy

7 https://www.whitehouse.gov/briefing-room/presidential-actions/2022/09/12/executive-order-on-advancing-biotechnology-and-biomanufacturing-innovation-for-a-sustainable-safe-and-secure-american-bioeconomy/

8 https://www.whitehouse.gov/briefing-room/presidential-actions/2023/04/21/executive-order-on-revitalizing-our-nations-commitment-to-environmental-justice-for-all/

9 https://www.who.int/docs/default-source/climate-change/qa-infectiousdiseases-who.pdf?sfvrsn=3a624917_3#:~:text=The number of emerging infectious,trends are likely to continue.

10 https://www.whitehouse.gov/wp-content/uploads/2022/11/Nature-Based-Solutions-Roadmap.pdf

11 https://sdg.iisd.org/commentary/guest-articles/food-system-transformation-to-boost-biodiversity-and-feed-the-planet/

evolution in the absence of its own future vision and policies for democratizing the field. The international biodiversity policy community is increasingly questioning who conducts, and who benefits from, biodiversity and conservation research, as well as who is damaged by biodiversity loss – questions that can be broadly generalized to "*Who has the right to science and its benefits*?". This latter is a question that has arguably been answered in the little-known Article 15 of the Universal Declaration of Human Rights and in the International Covenant on Economic, Social and Cultural Rights (CESCR),[12] which states that the right to benefit from scientific progress and its application applies to all peoples and, further, that all peoples have the right to contribute to scientific research. IPBES now supports a diversity of knowledge systems in biodiversity assessment and decision-making (IPBES, 2019). Similarly, the Convention on Biological Diversity's post-2020 Global Biodiversity Framework emphasizes decolonizing approaches to conserving biodiversity (Ramos, 2022). This milestone recognizes the rights and roles that Indigenous peoples and local communities play in conservation and sustainability and calls for recognition of their rights in self-determination and a collective process of learning and sharing: "Parties must align the goals and targets of the post-2020 framework with custodians' self-determined values, vision and leadership to ensure a healthy and sustainable planet for all." This perspective is highly germane to systematics, which relies on international field research, and which focuses on research issues that cannot be separated from the communities that live and work all over the world (Tengö et al., 2017). More recently, the US Office of Science and Technology Policy released a memo ahead of COP-15 (the 15th meeting of the Conference of the Parties to the UN Convention on Biological Diversity) in support of 'mainstreaming Indigenous knowledge' given that such knowledge has historically advanced conservation goals in effective ways. The more that systematists engage in democratized research practices and in the evolution of relevant science policy, the more well-positioned they will be to inform and protect future research opportunities, impact, and knowledge transfer.

The goals described above can only be pursued if the mainstream system in which systematists work can also be transformed, yet challenges remain in the conflicting incentive systems across the scientific enterprise. For example, academic culture continues to encourage and reward a narrow set of 'success criteria' – competition to discover the 'first', speed to publish, metric-chasing, sole or first author goals, high-profile publication targeting, and media metrics – despite increasing critique of these in terms of the correct cultural values for a healthy scientific enterprise. These criteria can run counter to considerations of values-based science, ethical conduct, diversity and inclusion, scientific integrity, democratization of data, and social and cultural considerations of research practices, not to mention the widely known fact that metrics do not necessarily measure research quality in any case (Muller, 2018). The central underlying question is whether we value what we can measure or reward what we value and which we choose to prioritize (e.g., Biesta, 2014). Lessons from domains outside of science are informative here, and most of them indicate that bottom-up efforts from domain practitioners are more powerful in creating change than top-down policies from leadership.

4 The How

Achieving cultural reform in systematics is a vision that requires a grounding in change theory. Change theory explains: (i) how a set of actions and interventions can lead to specific system changes and goals, (ii) who are likely to be the effective changemakers, (iii) points of influence for realizing change, (iv) potential obstacles to change, and (v) available levers to reduce those obstacles. Change theory also builds on what is already known to work well in targeted areas and then generalizes or repurposes those successes. To apply this reasoning here, we can think of the science ecosystem as containing multiple components and multiple entry points for practitioners to influence change – including hiring, promoting, mentoring, publishing, and peer-reviewing (Fig. 2). Common to all these components are the scientists themselves who serve as peer reviewers, department members, hiring committees, society members and leaders, editorial board members, and educators. Perhaps one of the most influential mechanisms for encouraging or discouraging cultural change by practitioners of science is peer review – thus, we highlight peer review here in the context of research funding as one example. We do so because intense discussion and debate of cultural issues in the field of systematics is increasingly appearing in National Science Foundation (NSF) grant proposals, reviews, panel discussions, and in other areas of interaction between NSF and the scientific community – especially from early career scientists who are challenging traditional norms.

The peer review process for proposals plays several fundamental roles: a mechanism for allocating research funding, a quality control mechanism, an assurance of scientific credibility and ethical research practices, and an enabler of strategic investments in research under limited budgets. The expertise of the scientific community underlies this process by providing expert advice on the merits of proposals, as well as constructive feedback to proposers. An extensive literature documents the strengths and weaknesses of the peer review system (e.g., Frachtenberg & McConville, 2022; Jones, 2022; Lee et al., 2012; Tomkins et al., 2017). A short summary of this literature is that peer review, while imperfect, is at the core of scientific knowledge generation (Tennant & Ross-Hellauer, 2020). But peer review is more than this because it also directly and indirectly influences

12 https://www.ohchr.org/EN/ProfessionalInterest/Pages/CESCR.aspx

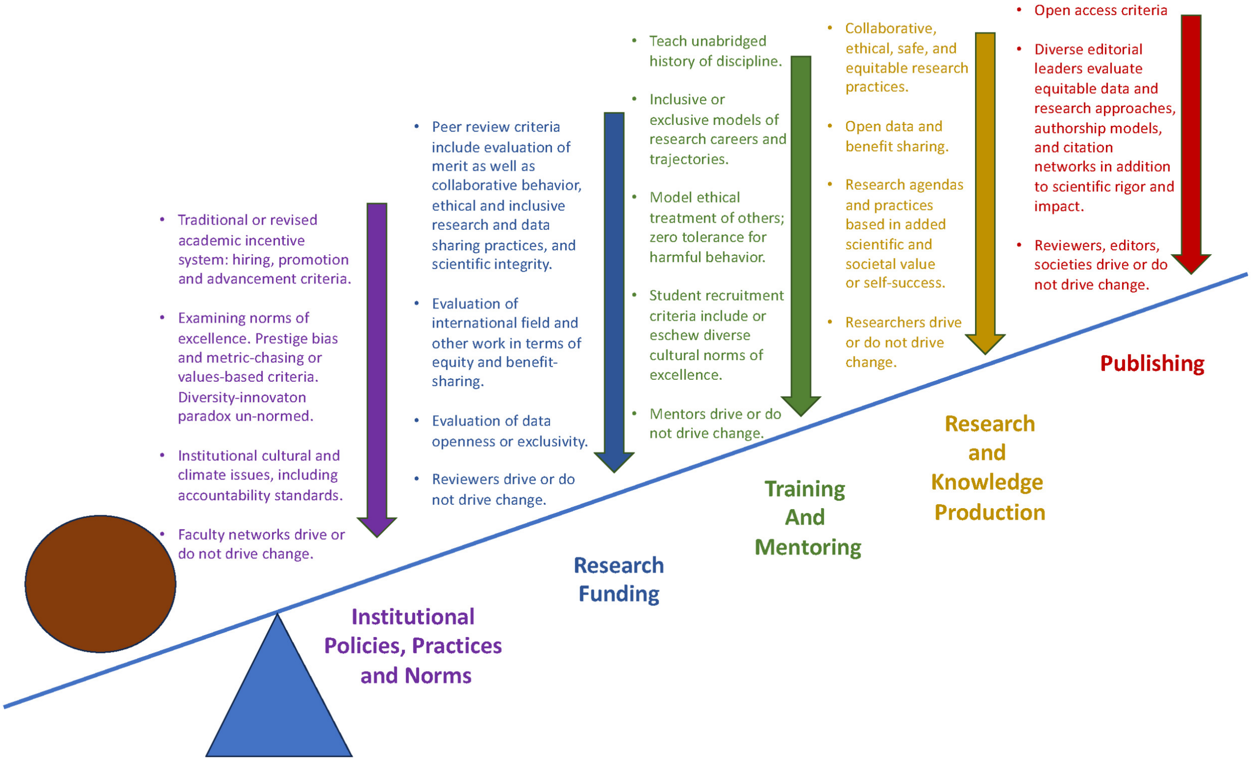

Fig. 2. Examples of some access points and levers for influencing change or stasis across some components of the science ecosystem.

and educates all involved in the review process: reviewers, co-panelists, principal investigators, program directors, institutional leaders, and others. Consequently, peer reviewers have a unique opportunity to foster or discourage disciplinary and cultural change with their colleagues and institutions. This dynamic also works in the other direction – innovative ideas and approaches (whether scientific, educational, cultural, or otherwise) within proposals influence reviewers and panelists in terms of their own future research behaviors, broader impact activities, and mentoring practices. In short, the scientific community shapes not only research directions but also helps construct the community norms via the ideas included in proposals, by the review services that they provide, and by the broader feedback and discussion that the review process engenders. At the same time, it is important to acknowledge that the composition of PI's, panelists, reviewers, and program directors influences whether these discussions arise, how they are focused, whether they are further encouraged or impeded, and the final influence that they ultimately have; these factors may be viewed as part of the power dynamics issues in change theory. Here again, the lever of influence is the community who may engage in multiple ways (including as proposers, reviewers, panelists, and rotating program directors).

We note that there are common misconceptions regarding the role of NSF vs. the role of the reviewer community in driving funding decisions, broader decisions about the birth and death of funding programs, and the cultural trajectory of the field. There is a tendency for the scientific community to underestimate its influence as a driver of change. While reviewers serve in an advisory capacity to the NSF, they wield significant power in many areas of decision-making. Over the last decades, the major paradigm shifts in systematics (including methodological approaches, biodiversity sampling procedures, data deposition and access standards, the types of phylogenetic data appropriate under varying conditions, the quality and scope of broader impacts, and theoretical advances) have been significantly influenced by the scientific community. In addition to its role advocating for positive change, the community may also prevent change by advocating for traditional approaches, by positively reviewing safe bets or incremental advances, or by gatekeeping the status quo. In either case, one shift we encourage is from viewing the PI/peer reviewer community as distinct from NSF to understanding that the PI/peer reviewer community is an integral part of the NSF process.

Many intellectual and cultural changes have been driven by the systematics community's interactions with the NSF. In the Systematics and Biodiversity Science program, for example, community workshops, peer review, and other modes of input have led to influential programmatic initiatives (as well as their demise) over the years – e.g., Partnerships for Enhancing Expertise in Taxonomy (PEET), Assembling the Tree of Life (AToL) and many other programs were conceived via community input. The 2008 workshop report "*Where to Next with Tree of Life?*" – developed and written by systematists and other scientists - led to the first Ideas Lab in the NSF's Biology Directorate (Assembling, Visualizing and Analyzing the Tree of Life; Collins et al., 2013), which ultimately led to the Open Tree of

Life[13] (Hinchliff et al., 2015) and other important initiatives. The systematics community also drove the conversation about the importance of digitizing museum specimens, which influenced development of the Advancing Digitization of Biodiversity Collections (ADBC[14]) program, and ultimately to the very impactful Integrated Digitized Biocollections resource (iDigBio[15]). A more general example comes from NSF synthesis centers, which were conceived to stimulate convergent and emergent research through synthesis across disciplines and communities of scientists. The scientific community communicated the need for the creation of synthesis centers in various ways (Carpenter et al., 2009; Rodrigo et al., 2013), leading to the National Center for Ecological Analysis and Synthesis (NCEAS), National Evolutionary Synthesis Center (NESCent), National Socio-Environmental Synthesis Center (SESYNC), National Institute for Mathematical and Biological Synthesis (NIMBioS), and others. These centers have produced a strong legacy of interdisciplinary research and training in emerging science areas.

The examples above illustrate the power of the community to transform the field, but we emphasize that this influence is not limited to driving intellectual change; input from the scientific community has also stimulated scientific workforce and cultural changes. Recent examples include the Mid-Career Advancement[16] program, opportunities for postbaccalaureates[17] in Biology, data management plans, harassment policies, programs for leading cultural change in biology (BIO-LEAPS[18]), and a new proposal requirement for safe and inclusive fieldwork plans.[19] Mentoring approaches, the evaluation of broader impacts, broadening participation efforts, the practices of conducting research, and the development of new diversity standards (many of which are germane to the decolonization and democratization of systematics) have all been driven from the bottom up. Thus, along with other mechanisms and points of leverage (including decisions on hiring, mentoring, collaboration practices, publishing), peer review is an example of how the culture of systematics is determined by employing the influence, values and behavior of the scientific community itself. To generalize from paradigm shifts in science (Kuhn, 1962) to broader cultural paradigm shifts, it is interesting to consider the classical Kuhnian Cycle in view of contemporary challenges to traditional norms in systematics, the phases of change, and the mechanisms by which shifts are driven.

5 Conclusion

Science, like other sectors of society, is currently in a period of rapid social and cultural change. Demands for the decolonization and democratization of research culture and scientific data are prevalent. Systematic biology has a unique opportunity to develop and model a meaningful and actionable vision for systemic change. Because systematics research requires sampling and analyzing planetary biodiversity, it operates within a global arena in which undoing exclusionary norms and practices, and reimagining a new kind of science that builds knowledge collectively, is both possible and potentially hugely impactful. Because of its history, the discipline has the potential to become a powerful model of intentional transformation. Professional systematists serve as leaders throughout the disciplinary ecosystem; as a result, they are well-positioned to shape cultural transformation. We have highlighted just one example of a lever (peer review of proposals) to illustrate this. Beneficial outcomes of such a new era of systematics will be extensive for continued research advances in biodiversity and phylogenetics, and for critical challenges that lie at the science-society-policy intersection.

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13 https://tree.opentreeoflife.org/opentree/argus/opentree13.4@ott93302

14 https://new.nsf.gov/funding/opportunities/advancing-digitization-biodiversity-collections/503559/nsf15-576/solicitation

15 https://www.idigbio.org/

16 https://beta.nsf.gov/funding/opportunities/mid-career-advancement-mca

17 https://beta.nsf.gov/funding/opportunities/research-mentoring-postbaccalaureates-biological

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